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Blue economy and ocean sustainable development in a globalised world: Social, political, economic and environmental issues

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Blue economy and ocean sustainable development in a globalised world: Social, political, economic and environmental issues

Topic editors

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Total factor productivity of China's marine economy: A meta-analysis

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With the rapid development of the global economy and the depletion of land resources, the ocean has gradually become a new area for human society to seek resources and space utilization. In China, the marine economy also has become an essential part of the national economy. Therefore, it is crucial to evaluate marine productivity to understand China's marine industry's input-output status and development level. We conducted a meta-analysis using 622 observations from 33 primary empirical studies to quantify the discrepancies in measurement findings and identify the influencing factors of total factor productivity (TFP) growth in the marine industry. The results indicate that: (1) In the existing literature, the mean TFP growth of China's marine economy at the provincial level is 1.002, which is lower than that at the national level (1.022); (2) The time span of the data, the estimation model, the evaluation indicator, and the journal's rank all have a significant effect on the estimation results of the marine economic TFP growth, whereas the year of publication does not affect the estimation results; (3) The TFP growth of China's marine economy peaked during the Ninth Five-Year Plan period, after which it began to decline year after year; (4) The TFP growth of the marine economy in the Yangtze River Delta region and Circum Bohai Sea region is significantly higher than that in the Pan-Pearl River Delta region; (5) Economic factors such as gross ocean product, level of opening-up, level of marine science and technology, and industrial structure all have an impact on the marine economic TFP growth. Accordingly, the following insights were obtained: In terms of marine economic development policies, we should continue to enhance the investment in marine environmental governance, strengthen the construction of marine ecological civilization, and pay attention to synergistic regional development, opening up to the outside world, scientific and technological innovation, and industrial structure optimization. In addition, the follow-up study should use long-period sample data as much as possible, pay attention to the parametric SFA model, and strip the negative environmental impact by constructing a green evaluation index system.

KEYWORDS

marine economy, total factor productivity, meta-analysis, high-quality development, China

1 Introduction

As a large country with a long coastline, China has a wealth of maritime resources and a vast ocean territory, and the Chinese government places a premium on the development of the marine economy (Gai et al., 2016; Sun et al., 2018). The 13th Five-Year Development Plan for the National Marine Economy, released in May 2017, highlighted the need to improve the quality and efficiency of marine economic development. In March 2021, the Outline of the 14th Five-Year Plan for National Economic and Social Development and Vision 2035 of the People's Republic of China proposed to establish a number of high-quality marine economic development demonstration areas and characterized marine industry clusters, illustrating China's firm resolve and staunch will to the high-quality development of the marine economy. In 2021, the National Gross Ocean Product, with a growth rate being 8.3 percent, totaled 1.41 trillion dollars which accounted for 8.0 percent of the Gross Domestic Product (The State Council of the PRC, 2022), showing that the marine economy has emerged as an essential driving force of the national economy.

However, the rapid growth of China's marine economy partly depends on the overdraft of marine resources, which belongs to the resource-intensive development model driven by an increase in factor inputs (Li et al., 2021). As China's economic development has entered a new normal, the marine economy needs to transition to an innovation-led and high-quality development mode. According to the Theory of Endogenous Growth, TFP is a proxy for an economy's long-term productivity growth or the quality of growth, and is regarded as the improvement of productivity with the exclusion of input contribution (Mahadevan, 2003). Thus, as the core of national wealth growth, especially in developing countries, TFP has emerged as a critical metric for measuring the high-quality development of the marine economy (Krugman, 1994; Johnson, 1997; Feng et al., 2019; Xia and Xu, 2020). In the above context, studying the trend and influencing factors of China's marine economic TFP growth is significant in transforming the marine economic growth pattern and achieving high-quality development of China's marine economy.

Solow (1957) first proposed the concept of TFP in his growth theory. Following this, subsequent scholars conducted substantial studies on TFP. In the estimation method of TFP, the data envelopment analysis (DEA) and the stochastic frontier analysis (SFA) are utilized by most studies (Aigner et al., 1977; Charnes et al., 1978). Previous studies mainly utilized the DEA-Malmquist model developed by Färe and Grosskopf (1992) to measure the marine economic TFP related to a specific industry or sector, such as marine aquaculture, marine fisheries, and maritime transportation (Shang et al., 1998; Jin et al., 2002; Turner et al., 2004). Later, Estache et al. (2004) measured the TFP of Mexican ports and found that the TFP estimates of ports increased significantly after the reform and opening up.

Unlike foreign scholars who focus more on the TFP of the marine industry (Mohammed and Williamson, 2004; Hassanpour et al., 2010), Chinese scholars, even if they start studying the TFP of the marine economy late, tend to measure the overall TFP of the marine economy and its regional variations (Ren et al., 2018a; Hua et al., 2021). Among them, Wang (2017) measured the TFP of the marine economy in China from 2001 to 2011, discovering that the TFP of the marine economy in coastal regions showed a declining trend to varying degrees. However, Zhu and Gai (2019) found that the growth trend of TFP in China's marine economy was stable from 2005 to 2015, except for the Guangxi Autonomous Region, which had a decline. Moreover, Zhang (2019) discovered that the average annual TFP growth rate of China's marine economy from 1998 to 2013 was 6.5 percent, with the growth rate of eastern coastal areas being relatively high.

In recent years, due to limited marine resources and unbalanced coastal development, there has been an increasing focus on the marine economic green TFP growth that considers environmental constraints (Munisamy and Arabi, 2015; Song and Ning, 2020). However, the traditional measures of TFP growth, such as the DEA-CCR and DEA-BCC models, are radial models that strictly require the input and output to change in the same proportion. Therefore, they do not embody the idea of maximizing the desirable output while minimizing the undesirable output, resulting in a certain insufficiency (Li et al., 2017). Accordingly, Chung et al. (1997) and Tone et al. (2001) developed the Malmquist-Luenberger index combined with directional distance function (DDF) and the slacks-based measure (SBM) model based on the DEA method to incorporate both desirable and undesirable output into the study of TFP. Following that, from the perspective of input, a few scholars employed the entropy method to construct a resource consumption index and used it as an input indicator to measure the green TFP growth (Sun and Song, 2019; Xiang et al., 2019). In contrast, other researchers chose to examine the marine economic green TFP growth under environmental constraints such as the amount of carbon emission and wastewater emissions from an output perspective (Kumar, 2006; Hu, 2018). Among them, Hu (2018) discovered that the estimation results of TFP growth were significantly lower after including marine wastewater emissions in the evaluation system. It is demonstrated that ignoring undesirable outputs in the analysis of TFP growth of the marine economy could lead to false conclusions and mislead policymakers.

In addition, the SFA model has also been applied to estimate the TFP of the marine economy due to the capability of distinguishing the effects of statistical noise from those of

insufficient (Managi et al., 2006; Fall et al., 2018). However, there is a significant difference in the TFP growth of China's marine economy, as obtained by Ji et al. (2017) using the SFA model and Ding et al. (2017b) using the DEA model.

A longitudinal literature review found that existing studies have made significant contributions to the study of TFP growth of the marine economy to provide an essential foundation for an in-depth understanding of the development of China's marine economy. However, few systematic analysis is carried out on the TFP growth of the marine economy. There is still a divergence in the estimation results regarding China's marine economic TFP growth reported in the current studies. Thus, what are the key determinants of the observed variations in TFP growth in the marine economy? Are they the result of varying estimation models or evaluation indicators, or are they the result of varying characteristics of published literature? Along with the estimation results in the current literature, what spatial and temporal variation characteristics does China's marine economic TFP exhibit, and what factors influence it? These questions are yet unaddressed. Therefore, this paper employs a meta-analysis to quantitatively analyze existing research findings on the TFP growth of China's marine economy to serve as a reference point for future research and relevant policy formulation.

2 Methodology

Meta-analysis is a statistical analysis that combines and integrates the results of several studies into a unified analysis (den Besten and Zwietering, 2012). It helps to find out the limitations of previous studies and explore new research directions. The main goal of a meta-analysis is to make the empirical results of specific studies comparable and suitable by controlling for the effect size (TFP growth in this case) (Angelini et al., 2022). The meta-analysis process mainly involves the selection and processing of effect quantities, the determination of heterogeneity test models, cumulative meta-analysis, and meta-regression analysis. The specific analysis process adopted is as follows:

2.1 Heterogeneity test and combination of effect size

The degree of heterogeneity of the collection of effects is one of the critical parts of a meta-analysis. Effect model selection should depend on the degree of variability among the included studies when combining effect size (Schneider et al., 2017). Two models are commonly used for the combination of effect size: the fixed-effect (FE) model and the random-effect (RE) model. The main difference between FE and RE model assumptions involves the characteristics of the studies: in the first case, studies should represent the entire population of interest, while in the second case, they should represent a random sample from a population of interest and the inference target is to extend the results from the sample to the entire population of interest (Hershey, 2021). For small heterogeneity, a fixed effect model is used, for considerable heterogeneity, a random effect model is more reliable (Egger et al., 1997). In this study, heterogeneity analysis was tested using the Q test and I^2 statistics to analyze whether there were statistically significant differences between the results of different studies. If the Q test is statistically significant or I^2 >50%, a heterogeneous distribution of effect size is assumed (Trong Ho et al., 2022).

2.2 Publication bias test

Even when conducted thoroughly, meta-analyses can be subject to publication bias—studies being less likely to be published, hence less likely to be included in a meta-analysis because the researchers and reviewers often have a preference for statistically significant results or for results that conform to prior theoretical expectations, or both (Benos and Zotou, 2014). The subsequent meta-analysis of published literature may be misleading if publication bias occurs.

Therefore, prior to the meta-analysis, this paper first used the Funnel Asymmetry Test and Precision Effect Test (FAT-PET) to determine whether there was a publication bias in the current literature. Regarding the model specification, this paper used a semi-log linear model to reduce heteroskedasticity and improve the estimation accuracy (Brander et al., 2006; Chaikumbung, 2021).

$$\ln Y_{ij} = \beta_0 + \beta_{se} SE_{ij} + \epsilon_{ij} \quad (1)$$

Where Y_{ij} denotes the i th reported TFP growth estimate of the marine economy from the j th primary study; SE_{ij} denotes the standard error of the i th reported TFP growth estimate from the j th study; β_{se} denotes the coefficient of the standard error to be estimated, which, if significant, indicates publication bias; β_0 and ϵ_{ij} denote the intercept term and random error term, respectively.

However, since the standard error of TFP growth, is rarely provided in most primary studies, we employed the inverse of the square root of the number of observations in the primary studies as a measure of the standard error with reference to the practices of relevant studies (Stanley and Rosenberger, 2009). At this point, the FAT-PET estimation model can be rewritten as follows:

$$\ln Y_{ij} = \beta_0 + \beta_{se}(1/\sqrt{N_j}) + \epsilon_{ij} \quad (2)$$

where N_j denotes the number of observations for the j th study, and the other parameters have the same meaning as in equation (1).

2.3 Meta-regression analysis

Meta-regression analysis is defined as a quantitative method used to evaluate the effect of methodological and other study-specific characteristics on published empirical estimates of some indicators (Stanley et al., 2008). This technique is no longer limited to qualitative descriptions and literature summaries compared to traditional literature surveys. Instead, it combines empirical results of existing studies based on specific criteria and uses statistical and econometric methods to conduct systematic quantitative analyses to explore the findings that are not evident in case studies but are valuable for solving new problems (Thompson and Higgins, 2002; Djokoto et al., 2020). To a certain extent, meta-regression analysis allows for the reanalysis of many studies on the same topic with specific conditions, overcoming the limitations of case studies, and allowing for the avoidance of selectivity bias and model setting bias in the original literature (Aiello and Bonanno, 2016).

The meta-regression model used in this paper is a multiple linear regression model based on the weighted least squares (WLS) method. This model can avoid the correlation between the results from primary empirical studies, which are TFP growth estimates of the marine economy in this paper (Yan et al., 2019). For the setting of model weights, this paper referred to the practice of some scholars, using the reciprocal number of observations as weights to reduce the influence of sample correlation (Salem and Mercer, 2012; Tan et al., 2020). Also, this paper transforms the observed estimates of TFP growth into a natural logarithmic form[1]. The estimation model is expressed as:

$$\ln Y_{ij} = \alpha + \sum_{k=1}^{n} \beta_k X_k + \epsilon_{ij} \tag{3}$$

In equation (3), Y_{ij} denotes the i th reported TFP growth estimate of the marine economy reported from the j th study; X_k denote the explanatory variables that summarize various characteristics of the primary studies; β_k denote the meta-regression coefficients which reflect the effect of particular study characteristics; α is the intercept term; and ϵ_{ij} is the random error term.

3 Data collection and variable selection

3.1 Data collection

The representativeness and completeness of the primary studies are the basis of meta-regression analysis (Card et al., 2010). In this study, the 11 coastal provinces, municipalities, or autonomous regions of the Chinese Mainland (excluding Hong Kong, Macao, and Taiwan) were used as the study area (Figure 1).

In order to obtain as much primary literature as possible for analysis, a comprehensive search was conducted on literature databases such as China National Knowledge Infrastructure (CNKI), Wanfang Data, Web of Science, ScienceDirect, and Google Scholar. Search keywords include "Marine Economy", "Total factor productivity", "China" and "TFP". At the same time, the literature related to the topic "Total factor productivity of China's marine economy" was also reviewed. Furthermore, secondary screening was performed for the relevant literature that was initially retrieved using the following inclusion criteria: (1) The selected literature evaluated one or two types of TFP growth in the marine economy, rather than focusing solely on a specific industry[2]; (2) The selected literature measured the TFP growth of the marine economy in coastal provinces and municipalities (or autonomous regions) or nationwide; (3) The selected literature reported quantitative research results, and the TFP growth of the marine economy estimates can be obtained directly or after simple processing; (4) The selected literature reported on the evaluation indicators, estimation models, and other information used in the estimation of TFP growth in the marine economy. Following the second screening based on the above-mentioned criteria, 33 primary studies were obtained, with 26 Chinese and 7 English literature. Table 1 presents some key characteristics of all the studies reviewed. A portion of the primary studies estimated two types of TFP growth, and all of these estimates were retained in this paper to round out the dataset. Since scholars have measured the TFP growth of China's marine economy at provincial and national levels, this paper builds two literature databases at provincial and national levels, respectively, in the subsequent analysis. Among them, 29 studies estimated TFP growth in the marine economy at the provincial level, with 408 observations; 17 studies estimated TFP growth in the marine economy at the national level, with 214 observations.

1 Since the TFP growth may be negative in the maritime economy, this study first added 1 to the TFP growth and then calculated its natural logarithm.

2 In this paper, the TFP of the marine economy is divided into traditional TFP and green TFP according to whether the non-desired output is considered in the evaluation indicators of the literature selected. And some studies estimate both types of TFP growth in the marine economy.

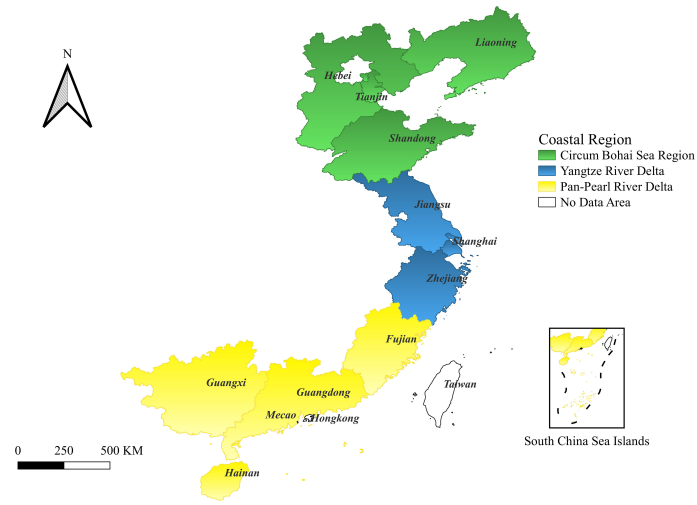

FIGURE 1
The overview and classification of China's coastal regions.

3.2 Variable selection

The TFP growth estimates of the marine economy are the effect size as well as the dependent variable of the meta-regression model in this paper, and the independent variables are the characteristic variables extracted from the corresponding primary studies. These characteristics are classified into five categories in this paper: the spatial and temporal characteristics, the estimation model characteristics, the evaluation indicator characteristics, the economic factors characteristics, and the publication characteristics.

3.2.1 Spatial and temporal characteristics

According to previous research, TFP growth tends to exhibit dynamic changes in different periods and regions (Liu et al., 2021). Therefore, this paper will explore the impact of spatial and temporal characteristics on TFP growth in the marine economy from both temporal and spatial dimensions.

At the provincial level, primary studies often examined the development status of provinces based on the average estimates of TFP growth of the marine economy over a period of time. However, the length of the time period and the year of the data used by different scholars frequently differed significantly, making it difficult to unify their time intervals of data (Li et al., 2015; Zhao et al., 2018). The length of the time period affects the amount of information contained in the data, and the year of the data reflects the TFP growth of the marine economy in a specific period. Therefore, this paper, following the practice of existing literature (Efendic et al., 2011; Ogundari, 2014), has incorporated the time span and the year of data into the model as independent variables to investigate the influence of data used in primary studies on the measurement results of TFP growth in the marine economy. In addition, this paper has divided China's coastal areas into the Circum Bohai Sea region, the Yangtze River Delta region, and the Pan-Pearl River Delta region referring to existing research and incorporating them into the model in the form of dummy variables to explore the differences in TFP growth of the marine economy in different regions (Zhang and Wang, 2021).

At the national level, the primary studies estimated the TFP growth of China's marine economy from 1998 to 2017. The years of observed TFP growth of China's marine economy estimated by primary research were incorporated into the regression model to investigate changes in TFP growth over time. Meanwhile, considering the impact of China's Five-Year Plan development policies, this paper created dummy variables corresponding to the Five-Year Plan period in which the year of estimation falls to accurately measure the change in TFP growth of China's marine economy over time.

3.2.2 Estimation model characteristics

Since different estimation models will affect the estimation results of the marine economic TFP growth (Tian and Yu, 2012). Therefore, this paper incorporated the estimation model characteristics as independent variables into the regression model. Currently, most primary studies use the traditional DEA model to estimate the TFP growth of China's marine economy, but some scholars have also used the SBM model, the DDF, and the SFA model. Therefore, This article created corresponding dummy variables to distinguish DEA, SBM, DDF, and SFA in order to investigate the effect of model differences on estimation results.

TABLE 1 Summary statistics of the primary studies used in meta-analysis.

Study number	Authors (Publication year)	Time span of data	Journal's rank	Model	Types of TFP	Number of observations
1	Zhou et al. (2013)	8	non-core	DEA	T	2
2	Ding et al. (2015)	9	core	DEA	T/G	40
3	Liu et al. (2015)	9	core	DDF	T/G	40
4	Li et al. (2015)	5	core	DEA	G	11
5	Wang (2015)	5	core	SFA	T/G	22
6	Sun et al. (2016)	9	core	DEA	T	7
7	Yuan et al. (2016)	11	core	SBM	G	21
8	Ji and Zhang (2016)	16	core	SBM	G	26
9	Du et al. (2016)	14	core	DEA	T	24
10	Ding et al. (2017a)	12	core	DEA	T/G	22
11	Wang (2017)	10	non-core	SBM	T/G	6
12	Ji et al. (2017)	9	core	SFA	T	3
13	Han et al. (2017)	11	core	DDF	T/G	22
14	Ding et al. (2017b)	11	non-core	SFA	T/G	22
15	Zhang et al. (2018)	10	non-core	SBM	T/G	24
16	Di and Liang (2018)	3	core	SBM	G	8
17	Ren et al. (2018b)	9	core	DDF	T/G	38
18	Zhao et al. (2018)	11	non-core	DDF	G	11
19	Hu (2018)	8	core	DEA	T/G	38
20	Du and Li (2018)	11	non-core	DDF	G	11
21	Cai et al. (2018)	10	non-core	DEA	T	11
22	He and Huang (2018)	10	non-core	DEA	T	4
23	Song et al. (2019)	15	core	SBM	G	1
24	Xiang et al. (2019)	8	core	DEA	T/G	40
25	Chen and Hui (2019)	9	non-core	DEA	T	20
26	Guan et al. (2019)	15	non-core	DDF	T/G	37
27	Zhang (2019)	15	core	DDF	G	11
28	Han et al. (2019)	14	core	DEA	T	14
29	Ding et al. (2019)	10	non-core	DDF	G	10
30	Wang et al. (2019)	10	core	SBM	G	9
31	Qin and Shen (2020)	14	core	SBM	G	26
32	Wang and He (2020)	7	non-core	DDF	T	19
33	Qin et al. (2021)	16	non-core	SBM	T/G	22

TFP is divided into traditional TFP (T) and green TFP (G), and if the primary research estimated both types of TFP, "T/G" is used to represent their TFP types. Regarding the journal's rank, if the journal to which the primary research belongs is included in SSCI, SCI, CSSCI, or Peking University Core, it is defined as a core journal, otherwise it is defined as a non-core journal.

3.2.3 Evaluation indicator characteristics

It has been demonstrated that the marine ecological environment imposes a significant constraint on the marine economy, and ignoring the existence of undesirable outputs may result in discrepancies in estimation results (Ye et al., 2021). Some scholars in primary studies attempt to incorporate undesirable outputs such as wastewater, carbon, and solid waste emissions into the estimation model when conducting TFP growth estimations of the marine economy. Therefore, this paper divides the evaluation indicators of TFP growth in the marine economy into traditional and green indicators based on whether the output indicators of the primary studies contain undesirable outputs and includes them as explanatory variables in the meta-regression model.

3.2.4 Publication characteristics

The characteristics of an academic journal might also account for the variation in estimated TFP growth. This study incorporated the journal's rank as an explanatory variable in the meta-regression model to investigate the influence of the journal's rank to which the primary studies belong on the TFP growth estimate findings of the marine economy. Accordingly, we divided the journal's rank into core and non-core journals based on the indexing status of the journals in which the primary studies are published. At the same time, the year of publication of the primary studies is also included in the meta-regression model because literature from different periods might reflect the views and ideas of that period.

3.2.5 Economic factor characteristics

It has been demonstrated that indicators like GDP and FDI in national economic development, as well as factors such as the level of land-based economic development and marine industry structure, can all have a significant impact on the marine economic TFP growth (Wang et al., 2021; Wei et al., 2021). As a result, variables like the gross ocean product, total imports and exports as a percentage of GDP, the number of marine research topics, and the share of marine tertiary industry in the gross ocean product are included in the meta-regression model in this paper to examine their effects on TFP growth in the marine economy.

3.3 Variable coding and descriptive statistics

3.3.1 Variable coding and descriptive statistics at the provincial level

As shown in Table 2, the average TFP growth of the marine economy in all provinces is 1.006. The average growth rate of the TFP growth of the marine economy in the coastal provinces is 0.6%. From the perspective of spatial and temporal characteristics, the average data years of the primary studies spanned 10.490 years, and the median data years were concentrated from 2006 to 2010. The estimated provinces belonging to the Circum Bohai Sea region, the Yangtze River Delta region, or the Pan-Pearl River Delta region are roughly equal. Judging from the characteristics of the estimation model, the number of primary studies using the DEA model still accounts for the majority. Still, different from the meta-analysis database at the national level, 8.8% of the literature applied the SFA model to estimate the TFP growth of the provincial marine economy. Regarding the characteristics of evaluation indicators, the green TFP growth observations are slightly higher than the traditional TFP growth observations. Regarding publication characteristics, the core journals reported more TFP growth observations of the marine economy, accounting for 66.7% of the total observations. In terms of economic factor characteristics, the total imports and exports of the provinces account for an average of 63.9% of GDP. The average proportion of the marine tertiary industry was 46.3%. In addition, considering that the volatility and magnitude differences of the raw data may affect the analysis results, this paper followed the previous research and used natural logarithms of the continuous variables when estimating the meta-regression model in order to improve the estimation accuracy of the model (Chaikumbung et al., 2016).

3.3.2 Variable coding and descriptive statistics at the national level

As shown in Table 3, the average value of TFP growth for China's marine economy is 1.036, which means that the average growth rate of TFP growth of China's overall marine economy is 3.6%, with overall positive growth[3]. In terms of time characteristics, the primary studies have estimated the TFP growth of China's marine economy from the Ninth Five-Year Plan to the Thirteenth Five-Year Plan, with the majority of studies on the Eleventh and Twelfth Five-Year Plans. In terms of estimation model characteristics, the traditional DEA model is used in most primary studies and is also used as the benchmark in this paper. The TFP growth of the green marine economy and the TFP growth of the traditional marine economy account for 61.2 percent and 38.8 percent of the total observations, respectively. Regarding publication characteristics, the observed estimates of TFP growth of the marine economy reported by core journals accounted for 80.4 percent of the total observed estimates. Among economic factor characteristics, China's average share of total imports and exports in GDP is 51.2 percent, and the average share of the marine tertiary industry is 48.0 percent. Furthermore, the logarithmic processing of the raw data is the same as described in the previous section at the provincial level.

4 Results

4.1 Combination of overall effects

As shown in Table 4, Heterogeneity analyses of both provincial level TFP growth and national level TFP growth reached very significant levels (P_Q<0.001, I^2>75%). Based on the results from heterogeneity assessment and in order to generalize the results obtained from the set of collected studies, a more restrictive random-effect model was used to combine effect sizes. In this model, each study was assigned a relative weight, which is the inverse of the sum of the sampling error and the between-study variance. At the same time, the relative weight for each study provides the basis for calculating the weighted mean corresponding to the overall effect size. The overall random-effect weighted effect

3 According to the descriptive statistics of TFP growth, the average value at the provincial level is lower than the average at the national level. This could be due to considerable differences in the volume and TFP growth of the marine economy between coastal provinces. When the TFP growth of the marine economy is estimated at the national level, the average value is assigned based on the volume of the marine economy in each province, resulting in a more objective average value. When the TFP growth of the marine economy in each province is estimated separately and the average value is calculated, each province is given the same weight, resulting in smaller volumes of the marine economy being given larger weights. In that case, the average estimates at the provincial level would be underestimated. The difference between the average provincial and national estimates has no bearing on the following empirical analysis.

TABLE 2 Results of descriptive statistics of characteristic variables that incorporate with subsequent meta-regression analysis at the provincial level.

Variables	Variable description and assignment	Mean	Std.	Obs
Dependent variable				
Provincial TFP growth	TFP growth estimates extracted from primary studies	1.006	0.101	408
Independent variable				
Time characteristics				
Data year	Midpoint of the year of the data in primary studies (2005 is set as the base year)	4.044	1.460	408
Data time span	Number of years the data used in primary studies	10.490	2.995	408
Spatial characteristics				
Circum Bohai Sea Region	1 if the estimation region is the Circum Bohai Sea region and 0 otherwise (reference)	0.353	0.478	144
Yangtze River Delta	1 if the estimation region is the Yangtze River Delta region and 0 otherwise	0.275	0.447	112
Pan-Pearl River Delta	1 If the evaluation region is the Pan-Pearl River Delta region and 0 otherwise	0.373	0.484	152
Evaluation model characteristics				
DEA	1 if the estimation model is DEA and 0 otherwise (reference)	0.436	0.497	178
DDF	1 if the estimation model is DDF and 0 otherwise	0.216	0.412	88
SBM	1 if the estimation model is SBM and 0 otherwise	0.260	0.439	106
SFA	1 if the estimation model is SFA and 0 otherwise	0.088	0.284	36
Evaluation indicator characteristics				
Traditional indicators	1 if the evaluation indicators are traditional indicators and 0 otherwise (reference)	0.478	0.500	195
Green indicators	1 if the evaluation indicators are green indicators and 0 otherwise	0.522	0.500	213
Publication characteristics				
Year of publication	Year of publication of the primary study (2013 is set as the base year)	5.463	1.727	408
Journal's rank				
Non-Core journals	1 if the primary study was published in a non-core journal and 0 otherwise (reference)	0.333	0.472	136
Core journals	1 if the primary study was published in a core journal and 0 otherwise	0.667	0.472	272
Economic factor characteristics				
Gross ocean product	Gross marine product (trillion yuan), taking the natural logarithm	2748.584	1754.648	408
Level of external openness	Total imports and exports as a share of GDP, taking the natural logarithm	0.639	0.448	408
Marine science & technology level	Number of marine science and technology topics (thousand), taking the natural logarithm	567.746	469.286	408
Marine industry structure	Share of the marine tertiary sector, taking the natural logarithm	0.463	0.068	408

Std, Standard deviation; Obs, Number of observations; In terms of economic factor characteristics, the TFP growth of the marine economy at the provincial level reported in the primary studies is mostly the mean value over the period of data utlized in the primary studies. Despite the fact that the data time span differs between studies, this paper collated and discovered that its median values are concentrated in 2006-2010. Therefore, this study assigned values to the four economic factor characteristics variables in terms of the average values of provincial GOP, total imports and exports as a percentage of provincial GDP, the number of marine research topics, and the share of marine tertiary industry in provincial GOP from 2006-2010.

size was 1.002, with the 95% confidence interval ranging from 0.972 to 1.032 at the provincial level and 1.022 at the national level, with the 95% confidence interval ranging from 0.994 to 1.051 (Figure 2). It demonstrated that TFP growth estimates of the marine economy in the selected studies are centered at 1.002 and 1.022 at the provincial and national levels, respectively.

However, the Q test and I^2 statistic are evidence for heterogeneity but cannot prove that the studies affect the overall heterogeneity. Therefore, we will continue to perform a meta-regression analysis to explore the source(s) of response heterogeneity and investigate the study characteristics' effect on the TFP growth estimates.

4.2 Results of the publication bias test

The FAT-PET was performed using ordinary least squares (OLS) and weighted least squares (WLS) in this article, and the results are shown in Table 5. When weighted least squares are used, precision may be increased due to the larger sample size used in the literature analysis with more observations. As a result, the square root of the number of TFP growth observations in the marine economy in the primary studies is used as a weight here with reference to existing studies to ensure that observations with a higher degree of research precision receive a higher weight. The test results showed that the standard error coefficients are not significant in either the provincial or national meta-analysis databases for both models, indicating that the primary studies included in this paper are free of publication bias and meet the meta-regression analysis requirements.

4.3 Results of the meta-regression analysis

In this paper, the meta-regression analysis was performed using Stata version 15.1 software, and the regression results at

TABLE 3 Results of descriptive statistics of characteristic variables that incorporate with subsequent meta-regression analysis at the national level.

Variables	Variable description and assignment	Mean	Std.	Obs
Dependent variable				
National TFP growth	TFP growth estimates extracted from primary studies	1.036	0.177	214
Independent variable				
Time Characteristics				
1996-2000	1 if the estimation year belongs to the 9th Five-Year Plan period and 0 otherwise (reference)	0.009	0.096	2
2001-2005	1 if the estimation year belongs to the 10th Five-Year Plan period and 0 otherwise	0.154	0.362	33
2006-2010	1 if the estimation year belongs to the 11th Five-Year Plan period and 0 otherwise	0.444	0.498	95
2011-2015	1 if the estimation year belongs to the 12th Five-Year Plan period and 0 otherwise	0.369	0.484	79
2016-2020	1 if the estimation year belongs to the 13th Five-Year Plan period and 0 otherwise	0.023	0.151	5
Estimation model characteristics				
DEA	1 if the estimation model is DEA and 0 otherwise (reference)	0.481	0.501	103
DDF	1 if the estimation model is DDF and 0 otherwise	0.243	0.430	52
SBM	1 if the estimation model is SBM and 0 otherwise	0.276	0.448	59
Evaluation characteristics				
Traditional indicators	1 if the evaluation indicators are traditional indicators and 0 otherwise (reference)	0.407	0.492	87
Green indicators	1 if the evaluation indicators are green indicators and 0 otherwise	0.593	0.492	127
Publication characteristics				
Year of publication	Year of publication of the primary study (2015 is set as the base year)	3.710	1.706	214
journal's rank				
Non-Core journals	1 if the primary study was published in a non-core journal and 0 otherwise (reference)	0.206	0.405	44
Core journals	1 if the primary study was published in a core journal and 0 otherwise	0.794	0.405	170
Economic factor characteristics				
Gross ocean product	Gross marine product (trillion yuan), taking the natural logarithm	26.830	10.258	214
Level of external openness	Total imports and exports as a share of GDP, taking the natural logarithm	0.512	0.086	214
Marine science and technology level	Number of marine science and technology topics (thousand), taking the natural logarithm	10.243	4.820	214
Marine industry structure	Share of the marine tertiary sector, taking the natural logarithm	0.480	0.025	214

Std, Standard deviation; Obs, Number of observations; As for the economic factor characteristics, this paper adjusts the gross ocean product of different years to a level comparable with 1998 based on the consumer price index to eliminate the influence of price factors.

theprovincial and national levels are shown in Tables 6, 7, respectively.

4.3.1 Meta-regression results at the provincial level

Spatial and temporal characteristics. Firstly, the data time span has a significant positive effect on the estimates of TFP growth at the provincial level, indicating that the longer the time period of data used in the primary studies, the higher the TFP growth in the marine economy. In addition, a longer time period of data also improves the reliability and explanatory power of the estimation results to a certain extent. Secondly, the data year in the primary studies has a significant negative effect on the marine economic TFP growth (Table 6), suggesting that the estimates decrease as the year of data extends backward. This is likely because China's marine economy is transitioning from resource intensive to environmentally friendly development, and the emphasis on development quality has resulted in a decline in TFP growth.

TABLE 4 Heterogeneity test and combination of effect size.

Item	Model	Heterogeneity test			Combination of effect size				
		Q	P_Q	I^2	ES	n	N	95% CI	
								LL	UL
Provincial TFP growth	Random effect model	4138.520	0.000**	99.9%	1.002	29	4280	0.972	1.032
National TFP growth	Random effect model	74.140	0.000**	90.4%	1.022	17	2354	0.994	1.051

ES, Overall effect size; n, Nmubers of primary studies; N, Total sample size; LL, Lower limit; UL, Upper Limit; ** indicates significance at P< 0.01.

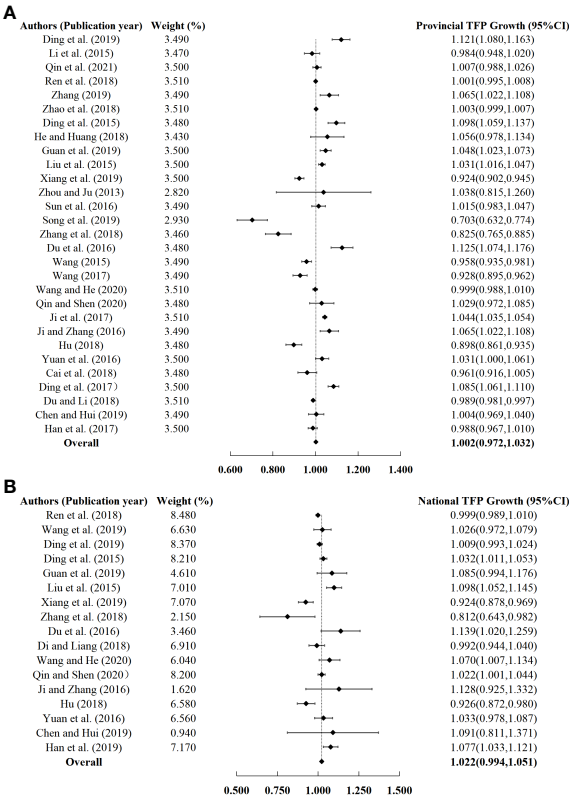

FIGURE 2
Forest plot of the weighted effect sizes and their 95% confidence intervals (CI). **(A)** Forest plot at the provincial level; **(B)** Forest plot at the national level. The solid vertical line represents a mean difference of zero or no effect. Points to the left of the line represent a reduction in final TFP growth, while points to the right of the line indicate an increase. Each diamond around the point effect represents the mean effect size for that study and reflects the relative weighting of the comparison to the overall effect size estimate. The weights that each comparison contributed are in the left-hand column. The upper and lower limit of the line connected to the diamond represents the upper and lower 95% CI for the effect size. The overall polled effect size pooled using the random effects models are indicated by the respective diamonds at the bottom.

Thirdly, the TFP growth of the marine economy in the Yangtze River Delta and Circum Bohai Sea regions is significantly higher than in the Pan-Pearl River Delta region, which may be explained by the fact that the Pan-Pearl River Delta region includes areas with a relatively weak marine economy, such as the Guangxi Zhuang Autonomous Region and Hainan Province (Figure 2).

Estimation model characteristics. First, there is no significant difference in TFP growth between the DDF and the DEA model. This could be because some studies use the DDF by selecting the evaluated unit's input and output vectors as the directional vectors, effectively equating the DDF and the radial DEA model. Second, the TFP growth of the marine economy,

TABLE 5 Results of publication bias test estimated by the OLS and WLS method.

Test variables	Indicators	Ordinary least squares	Weighted least squares
Provincial TFP growth	Constants	0.000	0.104
	Coefficient of standard error	0.001	-0.026
	R^2	0.000	0.003
	Number of observations	408.000	408.000
National TFP growth	Constants	0.085	0.037
	Coefficient of standard error	-0.228	-0.055
	R^2	0.006	0.000
	Number of observations	214.000	214.000

If the coefficient of the standard error is significant, indicating publication bias in our meta dataset.

TABLE 6 The meta-regression results at the provincial level.

Variables	Coefficient	Standard error	95% Confidence interval	
			Lower limit	Upper limit
Time Characteristics				
Data year	-0.037*	0.017	-0.070	-0.004
Data time span	0.103**	0.024	0.055	0.151
Spatial characteristics				
Pan-Pearl River Delta (reference)	——	——	——	——
Yangtze River Delta	0.032*	0.015	0.002	0.061
Circum Bohai Sea Region	0.037*	0.017	0.003	0.071
Evaluation model characteristics				
DEA (reference)	——	——	——	——
DDF	-0.004	0.016	-0.035	0.027
SBM	-0.093**	0.014	-0.121	-0.064
SFA	0.068**	0.019	0.031	0.106
Evaluation indicator characteristics				
Traditional indicators (reference)	——	——	——	——
Green indicators	-0.024*	0.011	-0.046	-0.002
Publication characteristics				
Year of publication	-0.019	0.021	-0.061	0.023
Journal's rank				
Non-Core journals (reference)	——	——	——	——
Core journals	0.023*	0.011	0.001	0.045
Economic factor characteristics				
Gross ocean product	-0.051**	0.017	-0.083	-0.018
Level of external openness	0.010	0.013	-0.015	0.034
Marine science and technology level	0.039**	0.011	0.017	0.060
Marine industry structure	0.107*	0.052	0.006	0.209
Constant term	0.082	0.119	-0.151	0.315

R^2 = 0.309; * and ** indicate significant at P< 0.05 and P< 0.01, respectively.

measured by the SFA model, is 6.8 percent higher than that measured by the DEA method. The reason could be that the non-parametric DEA model assumes no random error and thus interprets all deviations from the production frontier in the actual input-output mix as technological inefficiency, thereby underestimating TFP growth. Third, the TFP growth of the marine economy measured by the SFA model is 6.8 percent higher on average than that measured by the DEA method. Fourth, estimation results obtained by the SBM model were significantly lower than those of the DEA model. Characteristics of the SBM model could explain this. In contrast to the traditional DEA model, the SBM model can solve the problem of non-zero slack in inputs or outputs. Therefore, the SBM model has been primarily used by academics to estimate TFP growth with undesirable outputs included.

Evaluation indicator characteristics. The results of the TFP growth estimates of the marine economy using green indicators are significantly lower than those using traditional indicators. This could be because traditional evaluation indicators overlook the negative environmental consequences of marine economic development, allowing the TFP growth of the marine economy to be overestimated (Huang et al., 2022).

Publication characteristics. The year of publication does not pass the significance test, indicating that the year of publication has no significant effect on the estimation results of TFP growth in the provincial marine economy. The result also demonstrates that the TFP growth estimates in the marine economy are mature in terms of concepts and methods and that the estimation results of primary studies from various periods are highly consistent and unaffected by the publication date. In terms of the journal's rank, there are some differences between the TFP growth estimates of the marine economy in core journals and non-core journals. The coefficient of core journals is significant at the 5% level, indicating that core journals tend to get higher estimation results.

Economic factors characteristics. The gross ocean product has a negative effect on the TFP growth of the marine economy,

TABLE 7 The meta-regression results at the national level.

Variables	Coefficient	Standard error	95% Confidence interval	
			Lower limit	Upper limit
Time Characteristics				
1996-2000 (reference)	——	——	——	
2001-2005	-1.145**	0.230	-1.599	-0.691
2006-2010	-1.011**	0.246	-1.496	-0.527
2011-2015	-0.791**	0.259	-1.302	-0.280
2016-2020	-0.873**	0.289	-1.444	-0.302
Estimation model characteristics				
DEA (reference)	——	——	——	——
DDF	0.043	0.030	-0.016	0.102
SBM	0.000	0.033	-0.065	0.065
Evaluation characteristics				
Traditional indicators (reference)	——	——	——	——
Green indicators	-0.038	0.029	-0.095	0.019
Publication characteristics				
Year of publication	-0.022	0.024	-0.068	0.025
Journal's rank				
Non-Core journals (reference)	——	——	——	——
Core journals	0.013	0.029	-0.045	0.070
Economic factor characteristics				
Gross ocean product	-1.017**	0.365	-1.737	-0.297
Level of external openness	0.584**	0.217	0.155	1.013
Marine science and technology level	0.584*	0.254	0.084	1.084
Marine industry structure	3.607**	0.930	1.773	5.440
Constant term	8.996**	2.322	4.417	13.574

R^2 = 0.199; * and ** indicate significant at P< 0.05 and P< 0.01, respectively.

which is significant at the 1% level. This finding indicates that, while the marine economy has developed rapidly over the last three decades and achieved a breakthrough in total volume, the marine economic TFP growth has not improved concurrently. The result may be attributed to the current situation of excess physical factor input, insufficient scientific and technological innovation, and the deterioration of the marine environment in previous development processes. In addition, the regression coefficient for the level of openness to the outside world is insignificant. This might be due to the significant differences in the length of each province's coastline, port conditions, and marine resources, which cause the level of marine economic development in some provinces to be inconsistent with their overall stage of economic growth. The level of marine science and technology and the proportion of marine tertiary industry also significantly positively affect the improvement of the TFP growth of the provincial marine economy. For every 1% increase in the level of marine science and technology and the proportion of the marine tertiary industry, the TFP growth of the provincial marine economy will increase by 3.9% and 10.7% on average, respectively.

4.3.2 Meta-regression results at the national level

Time characteristics. The time dummy variables are significantly negative, indicating that the marine economy's TFP growth is lower in other periods than in the Ninth Five-Year Plan. This result could be explained as follows: First, the Ninth Five-Year Plan is the earliest estimation cycle and the first five-year plan following the implementation of China's socialist market economy reform, which boosted the development of China's marine economy. Second, during the Ninth Five-Year Plan, China introduced a series of policy initiatives to support the development of the marine economy formulated by the State Oceanic Administration in 1996, ushering in a new era of development for China's marine economy. Third, during the Ninth Five-Year Plan, China implemented a science and technology strategic plan to promote the sea, and made more breakthroughs in high marine technology and scientific research, which contributed to the rapid growth of TFP in China's marine economy through technological progress. Additionally, according to mean descriptive statistics, China's marine economic TFP grew at a positive rate from the Ninth to the

Thirteenth Five-Year Plans, but at a slower pace[4].

Estimation model characteristics, evaluation indicator characteristics, and publication characteristics. In contrast to the results of the meta-regression analysis at the provincial level, the regression coefficients for the estimation model characteristics variables, evaluation indicator characteristics variables, and publication characteristics variables were not significant at the national level. This is most likely because the observations at the national level were insufficient to compare the variability among the various characteristics.

Economic factor characteristics. The results of the meta-regression on gross ocean product, marine science and technology level, and marine industry structure are generally consistent with the TFP growth of the marine economy at the provincial level. The difference is that the regression coefficient for level of external openness is significantly positive at the 1% level, indicating that increasing external openness has a beneficial effect on the TFP growth of the marine economy at the national level.

5 Conclusions and discussions

This paper collected 622 observations of TFP growth for China's marine economy from 33 primary studies and used a meta-analysis to synthesize the TFP growth estimates and analyze the impacts of several related factors on the heterogeneities of TFP growth in the primary studies. Our results show that all characteristics variables of five categories can cause heterogeneities in the TFP growth of China's marine economy.

First, as suggested by the heterogeneity test results, there is significant variation among the TFP growth estimates presented in primary studies. On this basis, the overall mean TFP growth of China's marine economy over the data period is close to zero at the provincial level and about 2.2 percent at the national level. Therefore, there is still room for improvement in the TFP growth of China's marine economy.

Second, at the national level, the TFP growth of China's marine economy during the Tenth Five-Year Plan and succeeding periods was significantly lower than that of the Ninth Five-Year Plan period. Generally, the overall growth rate showed a downward trend.

Third, at the provincial level, a longer time span of data will not only significantly improve the estimation results of TFP growth in the marine economy, but also help to improve the explanatory power of the estimation results. Moreover, the TFP growth of the marine economy in the Yangtze River Delta and Circum Bohai Sea region is significantly higher than that in the Pan-Pearl River Delta region.

In addition, other characteristics variables affect the TFP growth and show differences. Regarding the estimation model characteristics, the SFA model produces higher estimation results than the traditional DEA model, whereas the SBM model tends to get lower estimation results. Regarding the evaluation indicator characteristics, the TFP growth of the marine economy estimated using green indicators will be lower than traditional indicators. About the publication characteristics, the year of publication in publication characteristics does not affect the estimation results. However, there is some variability between the estimation results of core and non-core journals. Concerning the economic factor characteristics, the improvement of the level of opening up to the outside world, the level of marine science and technology, and the optimization of the marine industry structure all positively affect the TFP growth of the marine economy. In contrast, the rise in the gross ocean product has a negative impact on TFP growth.

According to the above research conclusions, this study proposes the following recommendations for further research. First, subsequent studies should collect data and information extensively and extend the time span of sample data as much as possible to improve the explanatory power of the estimation results. Second, as the statistical data cycle continues to be extended, the provincial sample size will grow annually. Therefore, a greater focus on the parametric SFA model could produce exciting findings. Third, with the continuous extension of the statistical data cycle, the sample size at the provincial level will increase year by year, which provides more possibilities for the application of the parametric SFA model. Therefore, given the reliability of the SFA model, it should receive greater attention in future studies. Fourth, further research regarding the impact of environmental variables on the TFP of the marine economy would be worthwhile. Moreover, green evaluation index systems that can consider non-desired inputs and outputs should be applied more to fulfill the high-quality development goals.

Furthermore, the empirical results in this paper have some practical implications for policy making. First, China should actively seek new growth points for the marine economy as it transitions to a new stage of high-quality development to avoid a further decline in TFP growth. For example, the government should prioritize marine science and technology innovation and focus on marine technological progress. Second, more extraordinary efforts are required to ensure the regional growth of the marine economy. In particular, the Pan-Pearl River Delta region should fully exploit the established advantages of the Guangdong-Hong Kong-Macao Greater Bay Area to drive late-developing provinces such as Guangxi and Hainan to achieve synergistic development and shared

4 During the period from the Ninth Five-Year Plan to the Thirteenth Five-Year Plan, the average estimates of total factor productivity of China's marine economy were 1.577, 1.072, 1.025, 1.023, and 1.019, respectively.

prosperity. Third, China should further expand the degree of openness to the outside world and improve the ability to develop marine resources based on sound marine ecological civilization construction. Furthermore, it is also crucial to vigorously develop marine transportation, diversify coastal tourism and optimize the structure of the marine industry to accelerate the high-quality development of China's marine economy.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JD: Investigation, Formal analysis, Data curation, Writing – original draft, Writing – review and editing. DQ: Conceptualization, Data curation, Writing – original draft, Writing – review and editing. BY: Methodology, Formal analysis, Writing – original draft, Funding acquisition. TX: Software, Writing – original draft, Writing – review and editing, Funding acquisition, Supervision. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The blue economy's retreat from equity: A decade under global negotiation

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Heralded as a key agenda for sustainable ocean development, the blue economy has risen to such prominence over the last decade that it is near impossible to engage in the fields of ocean governance or development without encountering it. The exact nature of the blue economy's sustainable ocean development promise, however, remains stubbornly unresolved, with different actors advancing varying, at times conflicting, visions of what sustainable ocean development should look like, how it is to be achieved, and who it is to serve. Tracing the various constructions of blue economy promises over the last decade, this paper contends that the blue economy has progressively retreated from its early commitment to equitable benefit sharing, shifting instead to a deepening preoccupation with economic growth. For small island developing states (SIDS) and coastal least developed countries (LDCs) who took a leading role in embedding equitable benefit sharing within the blue economy during its early popularization, such retreat raises pressing questions over the agenda's continued suitability in advancing desired (and often much needed) sustainable development outcomes. This paper's attempt to grapple with such questions offers a timely contribution to discussions on the blue recovery and ocean-led development avenues in the wake of COVID-19.

KEYWORDS

blue economy, equity, small island developing states, equitable benefit sharing, sustainable ocean development

Introduction

Heralded as a key agenda for the achievement of sustainable ocean development, the blue economy has risen to such prominence over the last decade that it is near impossible to engage in the fields of ocean governance or development without encountering it. Broadly defined, the blue economy represents a vision for sustainable ocean development that promotes, and seeks to balance, economic growth, social inclusion and livelihoods, and the environmental sustainability of oceans and coastal areas (World Bank United Nations Department of Economic Social Affairs, 2017, p. vi). Its promise of an environmentally sustainable and socially inclusive intensification of ocean industries has attracted widespread interest from governments, civil society, commerce, intergovernmental organizations and development agencies alike—providing a central rallying point around which these diverse agents can build coalitions in their

attempts to address the interrelated challenges of degrading ocean health, climate change and seemingly ever-growing resource demands (Schutter et al., 2021).

As noted consistently throughout the literature, however, the exact nature of the blue economy's sustainable ocean development promise remains stubbornly unresolved, with different actors advancing varying, at times conflicting, visions of what sustainable ocean development should look like, how it is to be achieved, and who it is to serve (Eikeset et al., 2018; Keen et al., 2018; Garland et al., 2019; Martínez-Vázquez et al., 2021; Ayilu et al., 2022, p. 13). Silver et al. seminal study (2015) provided the first insight into these competing interpretations of the blue economy's sustainable ocean development promise, identifying four distinct discourses at the 2012 UN Conference on Sustainable Development (Rio+20) where the agenda was first introduced to global audiences. 3 years later, Voyer et al.'s (2018) analysis of international policy documents uncovered a similarly diverse body of blue economy discourses and sustainable ocean development interpretations, suggesting that little coherence had been achieved over the 6 years since Rio+20 and few conflicts resolved. As of today, the blue economy remains unsettled, with a growing crowd of agents drawing on, and arguably contorting, the agenda's promise of sustainable ocean development to align with their various interests.

Such acknowledgment of the blue economy's nebulous nature provides the basis for this paper's inquiry into the evolution of blue economy promises over the last decade. By tracing the various constructions of blue economy promises within mainstream global discourses, this paper contends that patterns can be observed in the agenda's 10-year career which, when read together, detail a narrative of retreating equity and a deepening preoccupation with economic growth. Critically, this paper understands the blue economy as a socially embedded agenda that can only be adequately analyzed and understood in the context of its various socio-historical settings (Garland et al., 2019; Bogadóttir, 2020; Fabinyi et al., 2021; Louey, 2022). This encourages an analysis of the broader socio-political ecosystems within which the blue economy and various promises have been articulated, ultimately situating it in the longer histories of sustainable development, modern geopolitics and neoliberalism.

This paper devotes particular attention to what the evolution of the blue economy promise means for the agenda's early advocates: Pacific Island nations. As the leading force behind the blue economy's introduction to global audiences at Rio+20, Pacific Island nations played a pivotal role in defining this agenda and crafting its foundational promises (Silver et al., 2015). As this paper will reveal, however, the blue economy has shifted considerably over the last decade—retaining some of the early promises that Pacific Island nations attached to the agenda while sidelining other central commitments. The final section of this paper will consider what implications such evolution in the blue economy promise presents for Pacific Island nations, and small island developing states (SIDS) more broadly. Ultimately, I urge caution in the Pacific's engagement with the contemporary blue economy, suggesting that the latest iteration of the agenda may no longer serve the interests of these ocean states, their people or ecosystems. I argue that in its current form, the blue economy no longer aligns with the region's call for environmentally responsible, socially equitable ocean development. Wrested away from the control of Pacific Islands nations and SIDS more generally, the blue economy of today appears to have been all but emptied of promises to equitable development; and has instead been recruited into the service of powerful economic interests with their ambitions of economic intensification, expansion, and growth. Under the guise of "sustainable development" it has become a project focused on "sustained development".

Turning development oceanwards and a call for equitable benefit sharing (2011–12)

The popularization of the blue economy as an agenda for sustainable ocean development can largely be credited to Pacific Island nations and their efforts, through the Pacific SIDS grouping, at the Rio+20 conference (Silver et al., 2015; Keen et al., 2018; Voyer et al., 2018). It is for this reason that this paper commences its exploration of the blue economy in the period 2011–2012[1]. Over the course of 2011 as the global development community prepared for the upcoming Rio+20, delegates of Pacific SIDS began voicing their concerns that the terrestrial focus of Rio+20's planned "Green Economy" theme risked overlooking key development opportunities and aspirations of Pacific Island and small island developing states (SIDS) (Pacific Small Island Developing States, 2011, p. 2). As large ocean states heavily dependent on oceans and coastal environments for their social, cultural and economic health, Pacific Island nations recognized the potential of a "blue economy" for elevating the profile of ocean-based development and better "ensur[ing] that issues related to the Pacific Ocean and Islands are given prominence in the Rio +20 agenda" (Secretariat of the Pacific Regional Environment Programme, 2011a, p. 4). By leveraging the blue economy concept to expand the focus of global development agents and agendas, Pacific Island nations sought to encourage a more inclusive development landscape

1 While the "blue economy" had been earlier referenced by Gunter Pauli and his Zero Emissions Research and Initiatives (ZERI) network, and by the US Senate Committee on Commerce, Science and Transport at its 2009 subcommittee hearing on "The Blue Economy: The role of the oceans in our nation's economic future" (S. HRG. 111-46), it was not until Pacific SIDS took charge of the concept in the lead up to Rio+20 that the agenda came to the widespread attention of global agents. Pacific Island nations were thus central in shaping early conceptualisations of the blue economy and, in particular, in crafting its foundational promises such that it aligned with the interests and aspirations of the Pacific Island states and of SIDS more broadly.

that more readily recognized, supported, and resourced ocean development opportunities (Pacific Small Island Developing States, 2011; Secretariat of the Pacific Regional Environment Programme, 2011a, pp. note paragraphs 17, 18; SPREP, 2011b,c). In short, the grouping sought to place ocean development on the agenda at Rio+20 and leveraged the concept of a blue economy as the vehicle through which to do this.

Throughout the 2011 preparatory period, Pacific SIDS laid the groundwork for their blue economy conceptualization through a multi-pronged and highly coordinated campaign aimed both at advocating for the agenda's inclusion at Rio+20 and socializing the concept among other actors ahead of its formal discussion at the 2012 conference. This campaign entailed the active advocacy of the blue economy concept at the second and third Rio+20 preparatory meetings (March 2011), promotion of the agenda in their Pacific SIDS submission to the draft Rio+20 outcomes document (November 2011) (Silver et al., 2015, p. 141), the convening of a Pacific Preparatory Meeting for the UN Conference on Sustainable Development to coordinate the region's position ahead of Rio+20 (July 2011), and participation at the Monaco Workshop where Pacific SIDS rallied support for the agenda among the broader SIDS coalition (November 2011). Over this period, it appears that Pacific SIDS extended two clear promises under their blue economy agenda: first, a promise of the blue economy's particular value for SIDS and coastal least developed countries (LDCs) and second, a commitment to equitable benefit sharing of marine resources, access and benefits among states.

To appreciate the strategic sophistication of Pacific SIDS' early blue economy promise, it is useful to situate this discussion within the broader context of Rio+20 campaigning and negotiation. Alongside the Pacific SIDS' blue economy campaign, the broader SIDS grouping was concurrently pushing for international recognition of SIDS as a special case (Secretariat of the Pacific Regional Environment Programme, 2011a; Komai, 2012). As part of this effort, SIDS (including Pacific SIDS) utilized Rio+20 discussions to emphasize the unique, often structural, challenges confronting SIDS in their pursuit of sustainable development—namely, that of their narrow resource base and vulnerability to climate change impacts (Secretariat of the Pacific Regional Environment Programme, 2011a). Attention to the distinct challenges confronting SIDS were thus already being brought to the fore during Rio+20 discussions, offering, I argue, a favorable environment into which Pacific SIDS' first blue economy promise could be introduced. By constructing the blue economy as an agenda of particular value for SIDS and coastal LDCs (given its explicit ocean orientation), Pacific SIDS capitalized on the congruence between special case recognition and the blue economy to garner support among the broader SIDS coalition for their blue economy campaign, ultimately strengthening their advocacy of the agenda at Rio+20. By the time of the Rio+20 conference in 2012, Pacific SIDS had secured support from the majority of their SIDS counterparts (Small Island Developing States, 2011) and successfully established the concept of a blue economy as a sustainable development agenda of particular promise for SIDS and coastal LDCs (as detailed by Silver et al., 2015). As will be further explored throughout this paper, this first promise of the blue economy has come to be one of the most enduring commitments of the blue economy across its 10-year career and while many other wealthier, larger and land dependent nations have since also adopted the agenda, recognition of the blue economy's particular value to SIDS remains central to mainstream thinking (Roberts and Ali, 2016; World Bank United Nations Department of Economic Social Affairs, 2017; United Nations Conference on Trade Development, 2020).

Despite its close relation to this first blue economy promise, the second promise to be advanced during this early period has emerged as something far more controversial: the promise to equitable benefit sharing. Considering the long history of exploitative ocean resource extraction and use by foreign agents in Pacific Island EEZ's it comes as little surprise that equitable benefit sharing of marine resources and wealth became a key promise in the Pacific SIDS conception of the blue economy. This exploitation includes, but is far from limited to: US and French nuclear testing until as recently as 1996 (Teaiwa, 1994; Jetnil-Kijiner, 2017); systemic under-compensation for fisheries licenses by deep water fishing nations—particularly in the decades preceding the Parties of Nauru Agreement (Aqorau, 2019); occasions of environmental and social fallout resulting from the establishment of multi-million dollar, foreign owned tourism resorts (consider Freesoul Real Estate Development in Fiji), and the use of Pacific waters for military war games by former and neo-colonial powers (DeLoughrey, 2019).

As noted repeatedly throughout the Rio+20 preparatory period and conference, Pacific SIDS viewed the existing structures and practices of the ocean economy as "inadequate" (Pacific Small Island Developing States, 2011, p. 2) in equitably distributing ocean benefits (Secretariat of the Pacific Regional Environment Programme, 2011a, p. 147; Silver et al., 2015). Their large ocean territories had provided considerable wealth to external agents for relatively little in return, yet, in the blue economy they saw an opportunity to drive change. In response, Pacific SIDS rooted their blue economy conceptualization to commitments to "specific targets to gain an increased share of the benefits from the utilization of our marine resource through direct participation and capacity building" (Pacific Small Island Developing States, 2011, p. 2), using the preparatory period to stress this demand.

At the Rio+20 conference itself, Pacific SIDS held steadfast to this benefit sharing commitment, with Silver et. al. observing the grouping's repeated effort to connect the blue economy with "calls for benefit sharing agreements and other governance mechanisms by which Pacific SIDS may capture more revenue from territorial marine resources" (2015, p. 147). They rallied around the concept as a means for demanding improved access to, and distribution of, the wealth harvested from their exclusive

economic zones (EEZ) and areas beyond national jurisdiction (ABNJ), and worked to embed equitable benefit sharing at the heart of their blue economy. As will be revealed over subsequent sections, this attempt to secure the promise of equitable benefit sharing as a priority of the blue economy was later overpowered as the agenda came to be embraced by the development mainstream. However, discussion of the blue economy's potential to transition toward a more equitable vision of ocean resource use, access and distribution did briefly persist into the post-Rio period as most prominently captured in the 2014 *Blue Economy Concept Paper* published by the United Nations Department of Economic and Social Affairs (UNDESA)—a document to which we shall now turn.

A juggling act: Final appeals to equity and the introduction of "decoupling" (2013–2015)

In the wake of Rio+20 the blue economy experienced a rapid uptake across the global development space, finding its way into state government policies[2], regional plans[3], intergovernmental organization programmes[4], non-governmental organization agendas[5], and the remit of the commercial sector[6]. One of the most important publications to be released during this period was UNDESA's *Blue Economy Concept Paper* (United Nations Department of Economic Social Affairs, 2014), which sought to clarify the discussions of Rio +20 and chart a path forward for the blue economy over subsequent years. While the *Concept Paper* had little success in unifying diverse blue economy visions, it marked a critical point of reference for blue economy advocates at the time and has been influential in informing subsequent blue economy visions as evident in its broad referencing by actors including the World Bank (World Bank United Nations Department of Economic Social Affairs, 2017), the Commonwealth Secretariat (Roberts and Ali, 2016), and The Energy and Resources Institute (Juneja et al., 2021). It is for this reason that the document provides a valuable point of analysis for this section, exposing both a continuation of previous blue economy promises as presented by Pacific SIDS around Rio+20 and, perhaps most critically, the introduction of a new promise of "decoupling."

Drawing heavily on the blue economy conceptualization advanced by Pacific SIDS at Rio+20, UNDESA's *Concept Paper* rearticulated both core promises made under the Pacific blue economy vision: (a) an emphasis on the agenda's particular value for SIDS and (b), a commitment to equitable benefit sharing. Moving beyond simple identification of these two promises, the *Concept Paper* actually drew the relational link between these commitments, explicitly defining the blue economy as a "sustainable development framework for developing countries addressing equity in access to, development of and the sharing of benefits from marine resources" (2014, p. 3). It thus recognized the importance of equitable benefit sharing (promise b) for the fulfillment of the blue economy's first promise to offer a development avenue of particular value for SIDS and coastal LDCs (promise a), thereby acknowledging that for a blue economy agenda to be of value for SIDS and coastal LDCs, attention to equitable benefit sharing would be paramount. Indeed, further in the paper, the "principle of equity" is described as "fundamental" to the blue economy approach and a key commitment to be upheld through the agenda's mainstreaming (2014, p. 3).

This explicit centring of equity in UNDESA's blue economy conceptualization is somewhat remarkable given the political implications of such a promise. Perhaps the framing of the publication as a concept paper (as opposed to a formal report or plan) provided the UNDESA authors with greater freedom to include equitable benefit sharing in the final document and evade pressures to water down such an expectation. Regardless, it should be noted that this *Concept Paper* contains one of the most strident assertions of the blue economy's promise to equity to yet be released by a body that does not explicitly represent the Global South. For this reason alone it provides a valuable document for blue economy observers. Yet, given the current trajectory of the blue economy, it is one that will not likely be repeated.

Seemingly in contrast to its progressive discussion of equitable benefit sharing, UNDESA's *Concept Paper* also marked the introduction of the blue economy's now notorious "decoupling" promise. Specifically, the paper stated that "at the core of the Blue Economy concept is the de-coupling of socioeconomic development from environmental degradation" (2014, p. 3). Or in other words, a promise that economic development can be pursued without compromising ecological systems and thus accelerated with minimal disturbance to the planet. While enchanting in its vision, the trouble with such promise is that it fails to confront the underlying growth imperative of contemporary ocean economies (Brent et al., 2020; Mallin and Barbesgaard, 2020). In its attempt to detach economic development from ecological impacts, the decoupling promise risks overlooking the burden that capitalist markets and contemporary societies (some more than others) place

2 Australia's *National Marine Science Plan 2015–2025: Driving the development of our blue economy* (2015); Mauritius establishes The Department of the Blue Economy (2015).

3 European Union's *Limassol Declaration* (2012); SIDS' *Abu Dhabi Declaration* (2014); the Pacific Islands Development Forum's (PIDF) Green/Blue Pacific Economies (2013).

4 UNDESA's *Blue Economy Concept Paper* (2014), the United Nations Environment Programme's (UNEP) *Blue Economy: Sharing Success Stories to Inspire Change* (2015).

5 World Wildlife Fund's (WWF) *Principles for a Sustainable Blue Economy* (2015).

6 The Economist Intelligence Unit's Blue Economy Series (2015).

on ecological systems (Ertör and Hadjimichael, 2019). This arguably facilitates the further expansion and intensification of resource extraction, rather than grappling with the need for transformative change to global consumption and distribution systems (Bond, 2019; Germond-Duret, 2022). Indeed, far from a novel approach to ocean development, the decoupling promise appears little more than a re-rehearsal of neoliberal sustainable development logics [most prominently captured in the *Brundtland Report* Brundtland, 1987] that, despite their three-decade career, have failed to discipline the development paradigm to the point that we today face the ever-deepening and compounding challenges of inequitable development, ocean degradation and climate change (Emberson-Bain, 1994; Longo et al., 2015; Wanner, 2015; McCormack, 2017; Bhagwan et al., 2020; Development Alternatives with Women for a New Era Pacific Network on Globalisation, 2020; Mallin and Barbesgaard, 2020; Germond-Duret, 2022). If these earlier neoliberal logics have fallen short in their delivery of sustainable development [often in spite of considerable resourcing (Lees, 2007)], one must question why mainstream development agents continue to insist on progressing this model? As will be explored in the following section, such questions have rarely been asked in mainstream blue economy circles, with UNDESA's decoupling promise finding favor among the agenda's key advocates and rising to prominence over subsequent years.

In the evolution of the blue economy's promise to sustainable ocean development, UNDESA's *Blue Economy Concept Paper* embodies the moment of transition from a SIDS oriented blue economy to a neoliberal regime of ocean industrialization: espousing the need for equitable benefit sharing on the one hand, while introducing the idea that ocean development can be decoupled from ecological harm on the other. The following section will detail how by 2016, substantive reference to equitable benefit sharing had all but disappeared from mainstream blue economy thinking and been replaced with more conventional visions of development *via* universal economic growth. As such, I conclude this section acknowledging 2014–2015 as one of the final periods in which the Pacific Islands' original hope for an equitable and distributive sustainable ocean development agenda was visible within the mainstream blue economy discourse.

A retreat from equity (2016–19)

By the late 2010s the blue economy had become the leading global agenda for "sustainable ocean development". Major ocean conferences were hosted with an explicit focus on the agenda[7], and voluntary commitments on the blue economy proliferated (Voyer et al., 2021). There were also expanding efforts to intertwine the blue economy concept with the UN sustainable development goal 14 (SDG14: Life below water) (Lee et al., 2020; Sea Power Centre - Australia, 2021). From the perspective of Pacific Island states, two key developments in the blue economy promise came to a head during this period; the first was a clear retreat from earlier commitments to equitable benefit sharing, and the second was the firm entrenchment of the idea of decoupling. These developments will be discussed in turn below, revealing how the mainstream uptake of the blue economy displaced core promises that Pacific SIDS had earlier worked to instill in the agenda during Rio+20.

Once a core promise of earlier blue economy conceptualisations, the commitment to equitable benefit sharing suffered a swift retreat from global discussions during the late 2010s. While blue economy advocates continued to recognize the unique value that sustainable ocean development presented for SIDS and coastal LDCs, observations suggest that this more progressive promise to distributional justice was stripped out of the agenda in, what I suggest, was an attempt to render the blue economy more palatable to larger, wealthier agents. The Commonwealth Secretariat's "Blue Economy Series" provides perhaps the starkest illustration of this retreat from equity, with *The Blue Economy and Small States* report (2016) making no mention of equitable benefit sharing despite its explicit focus on the agenda's application for SIDS and small states more broadly. Instead, the report celebrates the blue economy as "a promising avenue for economic diversification and growth" (2016, p. 5). Or, reading between the lines, an agenda wherein SIDS and small coastal states (alongside the expanding gamut of ocean actors) can grow their wealth through expanded ocean industries while posing little, if any, disruption to the established ocean economy, its powerful agents and asymmetrical resource distribution. Such approach to economic growth sidelines earlier demands of SIDS and coastal LDCs that called for a greater *share* of the wealth derived from their ocean resources—ultimately upholding a structure in which larger, wealthier agents remain unchallenged in their concentration of ocean profits. For a report designed explicitly to explore the potential of the blue economy for SIDS and small coastal states, the absence of promises of benefit sharing presents a serious watering down of the agenda's earlier ambitions.

Here it is important to mention that while calls for equitable benefit sharing were struggling for air during this period, the late 2010s did witness a rise in attention to issues of inclusivity in the blue economy discourse. This new focus on inclusion stemmed predominately from the efforts of small scale fisher organizations [e.g., ICCA Consortium, Too Big to Ignore (TBTI)], maritime workers and consortiums (e.g., Project MATES) and Global South

7 Pacific Islands Development Forum's "1st High Level Pacific Blue Economy Conference" (2017), the Our Ocean Conference added the 'Sustainable Blue Economy' as a theme (2017), the Kenyan Government in collaboration with the UNDP hosted the "Sustainable Blue Economy Conference" (2018).

coalitions [e.g., Development Alternative for a New Era (DAWN), Pacific Network on Globalisation (PANG)] who argued that livelihoods, decent employment, market access and marine tenure rights were the foundation of sustainable ocean development. Attentive to the issue of inclusivity, blue economy advocates incorporated these commitments into their discussions and program designs (see for example The World Wildlife Fund's Blue Economy Principles (2015), Europe's "Blue Generation Project", or the IIED's "Inclusive blue economy" programme).

The rise of such commitments to inclusivity, however, risk shifting attention from more transformative understandings of equitable benefit sharing. First, it is without doubt that social inclusion must be central to any framework of sustainable ocean development as without it, the agenda is left balancing precariously upon its economic and environmental pillars alone. Yet, it also appears that the rise of inclusivity has, intentionally or not, distracted from earlier equitable benefit sharing demands that more radically call for the structural transformation of global systems. As such, the blue economy finds itself caught in a trap of facilitating inclusion into inequitable systems, rather than addressing root structural disparities. Further to this, by focusing on inclusion without equity, the blue economy loads the burden of responsibility upon actors at the national level (governments, NGOs, civil society) who are expected to lead inclusivity initiatives and monitor their progress. Again, the placing of responsibility on national actors is not a negative outcome given the critical role that these actors occupy in distributing the benefits of marine development among communities. However, if not coupled with attention to global political and economic structures and their role in upholding inequitable systems these inclusivity efforts risk being merely band-aid solutions. Attention to inclusion within blue economy discourses, though important, should thus not be seen as a substitute for promises to equitable benefit sharing as first proposed by Pacific SIDS at Rio+20. After all, it is the transformative nature of the latter that first rendered the blue economy a valuable discourse for Pacific Island nations and SIDS who looked beyond inclusion to demand a redistribution of ocean wealth and access.

Turning to the promise of decoupling, the release of the World Bank and UNDESA report, *The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries* (2017), marks an key milestone in the blue economy's evolution. Like the previously discussed Commonwealth Secretariat report, this publication explicitly recognized the value that the blue economy presented to the SIDS and coastal LDCs, and in light of this, suggested a series of broad steps for these nations "to follow to make the blue economy an important vehicle to sustain economic diversification and job creation" (2017, p. ix). While the report's definition[8] of the blue economy has emerged as perhaps the most visible legacy of this publication, I contend that it's reaffirmation of the "decoupling" promise earlier introduced in the 2014 UNDESA *Concept Paper* has also powerfully shaped contemporary interpretations of the blue economy agenda.

Echoing statements earlier outlined in the 2014 *Concept Paper*, the World Bank and UNDESA report states that the blue economy "at its core it refers to the decoupling of socioeconomic development through oceans-related sectors and activities from environmental and ecological degradation" (2017, p. vi). As noted earlier, this equation advances the idea that continued economic growth remains permissible under sustainable development, with little (if any) reflection on the need for radical change in global consumption and distribution trends. Capitalism's growth imperative thus goes unconfronted, opening the way for capital's oceanward expansion to proceed unimpeded and unopposed.

Furthermore, not only does such a "decoupling" vision attempt an act of historical anomaly —proffering a counter to strongly evidenced trends over the last decade that have repeatedly shown the devastating impact that capitalism's intensification has had on social and ecological systems—but it stunningly celebrates the economy's separation from the environment as a positive achievement. Decades of scholarship and activism across a range of disciplines have challenged this assumption of ecological separatism (consider Carolyn Merchant, Donna Haraway, Teresia Teiawa, Upolu Lumā Vaai, Karl Polanyi and the degrowth movement to name a few), and numerous cultures across the world have refuted such vision for millennia. These voices have emphasized the mutual embeddedness of ecological and social systems (including economic systems) and insisted on their inalienability. The World Bank and UNDESA's reaffirmation of the decoupling promise thus serves the interests of a very specific subset of the global community (namely those who profit from the dominance of neoliberal market economics) and works to further legitimize the notion that economic development can be achieved without negative environmental consequences or a significant reduction in resource use and consumption. Today the idea of "decoupling" has developed into a core promise of the blue economy that features heavily throughout the mainstream literature (Koehring, 2020; European Commission, 2022).

Upon arrival at the 2020s, it appears that the blue economy had shifted significantly from its initial conception: losing its progressive commitment to equitable benefit sharing and hardening its orientation toward industrial interests through its promise to the notion of decoupling. These trends appear to have continued into the current decade, however, as discussed below,

8 "The "blue economy" concept seeks to promote economic growth, social inclusion and preservation or improvement of livelihoods while at the same time ensuring environmental sustainability." (2017, p. 1).

the global shock of the COVID-19 pandemic has revived an old promise of the blue economy agenda: economic recovery.

A COVID-19 recovery pathway (2020 – present)

On 31 December 2019, at the turn of the new decade, the World Health Organisation's (WHO) China Office picked up a media statement from the Wuhan Municipal Health Commission outlining cases of "viral pneumonia" in the city. 1 month later, on 30 January 2020, the WHO declared the novel coronavirus (COVID-19) as a public health emergency of international concern and within months the virus had spread across the globe. In addition to the devastating public health impact of COVID-19, the economic fallout that arose from the pandemic and associated response measures was immense and pushed many national economies to the point of crisis. Pacific Island nations and SIDS were hit particularly hard by these economic impacts as tourism, a critical sector in many of these nations, ground to a halt and the commercial fisheries sector in many cases contracted. According to the OECD, the GDP of SIDS dropped by 6.9% in 2020 compared to a 4.8% decline in other developing countries (Organisation for Economic Co-operation Development, 2021, p. 2). The impacts of COVID-19 were thus felt acutely through island nations, if not from a health perspective then almost certainly economically.

As the world started looking toward a path out of COVID-19, discussion emerged around the idea of a "blue recovery". Simply termed to convey the use of sustainable ocean development activities (i.e., the blue economy) in support of economic recovery efforts, the concept of the blue recovery has swept through ocean development circles. The blue recovery forms a central component of UNCTAD's forward work program (2020), the OECD's COVID-19 Policy Response (2021), the World Bank's PROBLUE program (2020), and even the High Level Panel for a Sustainable Ocean Economy—an organization once cautious in its engagement with the blue economy (Stuchtey et al., 2020, p. 27; Österblom et al., 2020)—has adopted the blue recovery into its agenda (Northrop et al., 2020). This is not to mention the numerous regional and national bodies that have incorporated blue recovery measures into their COVID-19 recovery plans, among which include the Pacific Islands Forum Secretariat (2021), Japan (Satoyama Initiative), the European Commission (2021), the United States' National Oceanic Atmospheric Administration (2021), and the Cortal Triangle Initiative (2021), whose members include Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands, and Timor Leste. In response to COVID-19, the blue economy has evidently been saddled with an additional promise to lead economic recovery, especially in SIDS where ocean resources are vast. However, as the following discussion will reveal, this promise is not particularly new, but rather a resurrection of one of the blue economy's initial promises.

Aspirations of economic recovery have a deep history in the evolution of the blue economy, dating back further than Rio+20 to the agenda's very early conceptualization at the 2009 U.S. Senate Committee on Commerce, Science and Transport's hearing: "The Blue Economy: The role of the oceans in our nation's economic future" (S. HRG. 111-46). Responding to the fallout of the 2008 global financial crisis, the U.S. Senate Committee presented the blue economy as "one of the main tools for rebuilding the U.S. economy" (US Senate Committee on Commerce Science Transportation, 2009, p. 1), viewing it as an agenda under which the U.S. could harness "great untapped wealth in our oceans" and create "new jobs and new business opportunities" (2009, p. 1). The hearing placed considerable emphasis on technological innovation as a central pillar for economic recovery, with speakers and senators expressing their interest in the exploration of emerging blue economy sectors, namely offshore renewable energy, marine biopharmaceuticals and marine spatial planning. In a similar fashion, the European Union developed its Blue Growth strategy (the predecessor of their present Blue Economy initiative) in the wake of the European Debt Crisis with the hope that the agenda would "[offer] new and innovative ways to help steer the EU out of its current economic crisis" (European Commission, 2012, p. 3). Emerging sectors again formed a key component of the EU's Blue Growth strategy, with the organization identifying five priority sectors—ocean energy, aquaculture, coastal tourism, marine biotechnology and seabed mining—based on their apparent "high potential for sustainable jobs and growth" (European Commission, 2012). As both the U.S. and Europe transitioned out of economic crisis, their interest in the blue economy as an expressly "recovery" oriented agenda unsurprisingly dampened and the EU, in particular, redirected their conceptualization of the blue economy as a central component of its ongoing regional maritime strategy. The return of the blue economy's recovery promise, captured in the term "blue recovery", can thus be seen as a revitalisation of an old promise, albeit with an expanded global remit. What implications the blue recovery promise poses for Pacific Island nations will be considered in the following section as part of a broader discussion about the impact that the blue economy's evolution presents for SIDS development ambitions and opportunities.

The implications of an evolving blue economy promise

As this paper has demonstrated, the blue economy has been involved in a process of considerable evolution over the last decade. Tracing the making and remaking of the agenda's promises offers a useful insight into this evolution. Nevertheless,

consideration into what these changes actually mean for the original blue economy advocates and their initial vision for the agenda should not be overlooked. This final section reflects on how the blue economy's retreat from equity, continued recognition of the agenda's unique value for SIDS and coastal LDCs, adoption of the "decoupling" vision, and re-orientation to economic recovery may impact Pacific Island communities and their ambitions for sustainable ocean development. It offers but a starting point for such discussions and it is hoped that further conversation on the blue economy's material impact may be furthered by and within the region.

One of the most disheartening trends in the blue economy's evolution has been its near absolute retreat from substantive commitments to equitable benefit distribution. Though a central promise of the Pacific SIDS' blue economy conception of 2011/2012, this commitment appears to have been watered down over the last decade to the point where its redistributive essence has effectively been usurped by the less transformative aspiration of inclusion. Under this new focus on inclusion, Pacific Island nations and SIDS more broadly are invited to participate in activities of ocean development and wealth generation yet, concerningly, are deterred from more forthright ambitions for the restructuring and/or dismantling of existing ocean economy structures that concentrate wealth in the hands of a few to the exclusion (and arguably at the expense of) the many. Existing ocean economy structures are thus broadened, not transformed; and historical power relations maintained, not confronted. I suggest that this falls short of Pacific SIDS' ambition for the blue economy to encourage a "more equitable sharing of the benefits" derived from ocean-based economies (Secretariat of the Pacific Regional Environment Programme, 2011a, p. 4) and therefore the blue economy in its current form should be approached with caution by these large ocean nations.

Indeed, the blue economy's enduring struggle to adequately acknowledge and address issues of equity within ocean development and governance has been increasingly highlighted by academic and civil society observers over recent years (Bennett et al., 2019; Cisneros-Montemayor et al., 2019; Cohen et al., 2019; Development Alternatives with Women for a New Era Pacific Network on Globalisation, 2020; Okafor-Yarwood et al., 2020; Pacific Network on Globalisation Ozeanien Dialog, 2020; Farmery et al., 2021; Pedersen, 2021; Voyer et al., 2021; Ayilu et al., 2022). Similar to this paper, these observers have suggested that issues of equity and justice continue to be overlooked in mainstream blue economy approaches, resulting in the detrimental outcomes and the further exclusion of communities distant to power. This disenfranchisement (at times dispossession) under current blue economy agendas has been documented among small scale and capture fishers (Cohen et al., 2019; Bogadóttir, 2020; Farmery et al., 2021), coastal dwelling populations (Satizábal et al., 2020; Pedersen, 2021), communities of the global south (Development Alternatives with Women for a New Era Pacific Network on Globalisation, 2020; Fache et al., 2021), and indigenous knowledge holders (Helmreich, 2007). The High-Level Panel for a Sustainable Ocean Economy has led some important discussion among global leaders about the need to prioritize equity within blue economy agendas (Österblom et al., 2020; Stuchtey et al., 2020) and have recognized "ocean equity" as one of its key areas of transformation in its Ocean Action Agenda. However, given the extent of inequity currently entrenched and perpetuated in the ocean economy (Österblom et al., 2020), further advocacy on the global stage is urgently needed. At a time where the blue economy appears to be increasingly retreating from its promise to equity, I suggest that Pacific Island nations can play a crucial role in calling for a systemic restructuring of the ocean economy while recognizing their own role in ensuring inclusive development outcomes and opportunities for their communities.

On a more positive note, continued recognition of the blue economy as a particularly valuable avenue for sustainable development among SIDS and coastal LDCs reflects an important turn in global understanding regarding the role that oceans play for the health and wellbeing of developing oceanic nations. From the position of Pacific Island nations, the blue economy's focus on sustainable ocean development enables them to direct greater attention toward the development activities and opportunities that revolve around their oceans, and subsequently, provide them with greater leverage to secure international partnerships, resourcing and support. Nevertheless, Pacific Island communities, SIDS and coastal LDCs must work carefully to control the pace, objectives and agents of this "blue acceleration" (Jouffray et al., 2021) to guard against the threat of ocean grabbing (Bennett et al., 2015). After all, a blue economy that encourages a surge in externally led and/or externally driven ocean development activities risks undermining the principle of self-determination that many developing ocean states have fought so hard to advance.

The broad embrace of the blue economy's decoupling promise presents another area of caution for Pacific Island communities, particularly with regard to its incompatibility with deeply held cultural values of socio-ecological embeddedness, respect and relations. As long noted in Pacific development debates, modern development programmes have repeatedly failed to recognize Pacific peoples' deep and reciprocal relationships with their ecosystems (Emberson-Bain, 1994; Vaai, 2019). Such programmes have instead sought to impose western assumptions of human/nature dualisms upon the Pacific, often enacting such vision through their project design. For many commentators in the region, this western understanding of human-ecosystem relations (or lack thereof) fits poorly within Pacific contexts, and for some even threatens to jeopardize and harm communities' relationship with their environment (Emberson-Bain, 1994, p. i; Vaai and Casimira, 2017). The blue economy's decoupling promise represents but the latest iteration of this western human/nature dualism, again denying the

tangled web of interactions, processes and impacts that humans share with their ecosystems. I suggest that the decoupling promise thus requires close scrutiny from Pacific communities (as well as SIDS and many coastal LDC communities) as to its compatibility with their cultural values, practices, and ontologies.

Finally, to the question of what implications the blue recovery promise poses for Pacific Island nations, three key questions appear to be of central importance for future deliberations. Firstly, the undoubted reorientation of the blue economy toward economic objectives under the blue recovery raises concern that social and environmental considerations will become sidelined as agents pursue, first and foremost, economic growth. For Pacific Island nations in particular, this undermines their original vision of the blue economy which stressed the need for environmentally responsible ocean activities, particularly in response to climate change (Pacific Small Island Developing States, 2011, p. 2; Secretariat of the Pacific Regional Environment Programme, 2011a, p. 4), and the socio-cultural importance that the ocean has long had for Pacific Islands' peoples and communities (Silver et al., 2015). Thus, there is a risk that the blue recovery will weaken the promise of *sustainable* ocean development as promoted by Pacific Island agents.

The second question raised by the blue economy's returning recovery focus concerns the issue of *which sectors* will be promoted under such reorientation. As earlier noted, Pacific Island nations have been significantly impacted by the COVID-19 pandemic, in large part (at least from an economic perspective) due to their heavy reliance on tourism and fisheries for economic revenue and employment. Unsurprisingly, discussions of economic diversification have thus become commonplace over the last 2 years as Pacific Island leaders look not only toward immediate economic recovery but also to safeguarding future prospects (Global Access Partners (GAP), 2021). Emerging sectors have drawn particular attention from Pacific Island leaders as potential avenues for diversification, including blue bonds (e.g., Fiji's sovereign Blue Bond initiative), technological innovation (Kenilorea in Global Access Partners (GAP), 2021, p. 16; The Economist, 2020), and perhaps most noteworthy: seabed mining (Cook Islands, Nauru, Tonga). The integrity of these emerging sectors as blue economy candidates, however, should be carefully considered to ensure that they meet the environmental and social objectives of the Pacific's blue economy vision. In short, economic diversification that ignores the social and environmental ramifications of newly adopted sectors not only fails to meet the sustainability baseline of the blue economy but risks undermining, and perhaps further endangering, the very promise of sustainable ocean development all together.

Thirdly, the question of *who* will lead the blue recoveries of Pacific Island nations will be a critical point of discussion over the coming years. Such a question builds on a rich history of debate that has been ongoing through the region around issues of development dependency, self-determination and self-sufficiency (Tupouniua et al., 1975). With the economic fallout of COVID-19 constraining the budgets of many Pacific Island governments, it is likely that many blue recovery activities will be undertaken by or with the support of foreign partners. To avoid the risk of overbearing or misaligned foreign involvement in ocean development projects, it will be critical for Pacific Island representatives (both political, cultural and community) to be integrally involved in blue recovery initiatives and planning—if not leading the programmes themselves. Placing Pacific Island peoples at both the center *and* head of the blue recovery will better ensure that these activities align with the ambitions, needs and interests of the region.

Conclusion

An agenda that has gained extraordinary popularity over the last decade, the blue economy has and continues to embody the aspirations and interests of its advocates in the promises that it makes about sustainable ocean development. This paper has brought to light some of the key shifts in the blue economy's promise from 2011 to present, with a particular interest in the commitments that impact Pacific Island nations. Analysis reveals a dynamic landscape of change and negotiation wherein certain promises have gained dominance and longevity (decoupling, and recognition of the blue economy's value to SIDS), others have faded into the distance due, seemingly, to their confrontation of entrenched power structures (i.e., equitable benefit sharing), and some have returned in response to somewhat cyclical contextual circumstances (i.e., economic recovery).

From the perspective of Pacific Island nations, the blue economy has, I argue, failed to retain its early promise of promoting equitable benefit sharing of ocean resources. Its uptake among the global mainstream has instead seen its agenda bend in service of interests who wish to expand ocean profits without the responsibility of sharing them. As the blue recovery accelerates in coming years, it will be critical for observers to monitor where sustainable ocean development funding and support is directed and critically, if SIDS, who rely so heavily on their ocean resources, are equitably serviced in this allocation. If this latest iteration of the blue economy fails to equitably support the recovery and development needs of SIDS then it will not only undermine current efforts to drive an equitable, inclusive and sustainable economic recovery, but also further weaken and perhaps even extinguish the value this agenda presents for SIDS.

Data availability statement

The original contributions presented in the study are included in the article/supplementary

material, further inquiries can be directed to the corresponding author.

Author contributions

PL: conceptualization, writing—original draft, and writing—review and editing.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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A multi-criteria analysis framework for conflict resolution in the case of offshore wind farm sitting: A study of England and the Netherlands offshore space

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Growing EU energy ambitions in the North Sea region are urging for an accelerated deployment of large-scale renewable energy (RE) infrastructure, with offshore wind farms (OWF) playing an essential role. However, implementing the current EU targets is limited by the competing spatial claims between existing sea uses and OWFs and uncertainties related to potential risks of interaction, creating important barriers to a swift roll-out of RE infrastructure. In tackling this issue, we are proposing a transparent and spatially explicit multi-criteria analysis tool to quantify and qualify the main risks and opportunities resulting from the interaction between OWFs and four other seas user groups (shipping, marine protected areas, fisheries and military activities). The multi-criteria analysis framework is accounting for sectoral activity specific risks of interaction with OWFs, classified through the respective available conflict resolution options, which allows for the quantification of the average conflict score (ACS) between the selected activities and OWFs. Using the resulting ACS and the geo-location of areas of interaction, we map areas of high and low conflict with OWFs and indicate management options for solving, minimizing or compensating the conflicts. Our results indicate that conflict resolution strategies in marine mammal's habitats present the highest potential for unlocking medium value OWF sites both for the Dutch case (15.8 – 28 GWs) and English case (15.94-28.3 GWs), followed by pelagic fisheries in the Dutch case (15-26.9 GWs) and passenger/cargo routes in the English case (10.9-19.4 GWs). The strategic planning of increasingly larger and more complex OWF projects will require a better understanding not only of the level of conflict with the other sea users in relation to the valuable OWF sites, but also potential management options to solve, minimize or compensate those conflicts. As an example, accessing 6.8-12.3 GWs in high value OWF sites in the Dutch EEZ will require the relocating of military flying areas with forbidden access, while technical solutions such as

"fill-in-the-gap" or relocation of lower airspace radars could unlock 10.25-18.16 GWs in the English EEZ. By avoiding high risk areas and prioritizing areas of low conflict, the bottlenecks, negative effects and inefficiencies related to space management options can be minimized, while synergies and positive effects of OWF deployment can be timely captured.

KEYWORDS

offshore wind farms, trade-offs, multi-criteria analysis, fisheries, shipping, military, nature protected areas

Introduction

The North Sea currently faces high ambitions for the deployment of offshore wind infrastructure (Government of The Netherlands, 2021a; Martínez-Gordón et al., 2022). The different North Sea countries contrast between each other regarding both installed and planned capacity for renewables offshore. For example, the total installed capacity of offshore wind in the Dutch EEZ was approx. 2.45 GWs in 2021 (Government of The Netherlands, 2021b), with a commitment towards 11.5 GWs by 2030 (Netherlands Enterprise Agency, 2022). Reaching the 2030 target will be realized in the currently designated areas for offshore wind (Government of The Netherlands, 2021b), with an approx. cumulated installed capacity of 9.6 GWs. Beyond 2030, the offshore wind deployment is subject to multiple future energy scenarios (Cleijne et al., 2020) indicating between 38 and 72 GWs of offshore wind energy (Netherlands Enterprise Agency, 2022), required to reach a climate-neutral energy system by 2050. With more ambitious OWF deployment targets, UK aims for an installed capacity of 40 GWs by 2030 (Department for Business E& IS, 2019) and between 75 (UK Department for Business Energy and Industrial Strategy [BEIS], 2020) and 108 GWs by 2050 (Aunedi et al., 2021), under different projections and energy demand scenarios. However, next to offshore wind, marine space faces increasing claims from users with different and competing interests, both from economic sectors (shipping, fisheries, oil and gas), and activities or services not tradable on economic markets (nature protected areas, military). Managing conflicts and dealing with potential trade-offs between different offshore users is, therefore, a prerequisite for reaching the EU 2050 energy goals for European marine basins.

Managing the offshore space in the EU reflects varying national political and strategic priorities (Suárez de Vivero et al., 2009), while no cross-sectoral marine basin strategy has been elaborated. Nevertheless, common objectives for the management of the marine resources can be identified in many national and EU strategies, such as sustainable economic development (EU Blue Economy (Directorate-General Maritime Affairs and Fisheries, 2020)) conservation and protection of the marine environment (EU Marine Strategy Framework Directive (European Parliament and Council, 2008)) or the realization of the renewable energy potential (Department for Environment Food and Rural Affairs, 2014a). In practice, the objectives established for using marine resources have been operationalized using management instruments, as marine spatial plans (MSP), to achieve sectoral goals and address conflicts between sectors sharing the same space (Suárez de Vivero et al., 2009). Taking as example the English case, the UK North-East Offshore Marine Plan aims at achieving, in an integrated manner, a sustainable marine economy while living within environmental limits (Marine Management Organisation, 2020). This translates into balancing different goals such as the protection and enhancement of the marine environment and mitigating climate change through offshore energy generation. Similarly, the Dutch Draft North Sea Program 2022-2027 (Government of The Netherlands, 2021a) defined 21 national interests, such as ensuring national safety, limiting climate change, maintaining and developing the main infrastructure for mobility, improving/protecting biodiversity and developing sustainable fishing.

Central to managing offshore space is the use of a Marine Spatial Plan (MSP). Normatively, a MSP aims to employ an area-based, integrated, strategic, adaptive and participatory processes (Spijkerboer, 2021), following an ecosystem-based and precautionary approach (Government, 2011) and promoting multisector management strategies that take into consideration various sectoral values (White et al., 2012). Hence, the spatial claims exerted by different sectors are managed by trying to distribute sectors among their high-value locations with the low inter-sectoral conflicts (Ehler and Douvere, 2009; White et al., 2012; Lester et al., 2013), considering principles such as freedom and safety of navigation and aviation (Dutch Central Government, 2009; Marine Management Organisation, 2020). MSPs function in the context of a legal framework, which does not allow or limits activities in the national interest designated areas (e.g. such as for the Dutch EEZ the production of sustainable energy, shipping, oil and gas extraction, defense, sand extraction) (Dutch Central Government, 2009). However,

when known risks (in particular safety) of interaction between multiple activities are low, or benefits are exceeding risks, the multi-use of space is encouraged. As a result, two main spatial allocation options for OWFs can be underlined: single-use, where only one of the sea user has priority in using the allocated site, and multi-use (Schupp et al., 2019), where OWFs and the existing sea users can jointly use an area under well-defined conditions. A single-use strategy is associated with lower risks of accidents during operation at sea, as well as lower local impacts on the marine environment due to multiple pressures (cumulative effects) (Gușatu et al., 2021). However, a single-use strategy is not always feasible within a limited offshore space.

Allocating areas offshore for the future OWF developments will require a negotiation between OWF and existing sea users, such as fisheries, nature protected areas, shipping, military, etc. Ideally, the selected locations will have a high potential for OWFs and limited to no conflict with alternative users. In reality, however, the installation of OWF turbines will come at the cost of minimizing or restricting the physical access for other activities, could result in adverse impacts on marine ecosystems (Lehmann et al., 2021) or may allow for a degree of multi-use where OWFs can be combined with other users. The exact costs and impacts will differ spatially, depending on the value an area has for each individual user. In addition, legislation under the MSP umbrella permits conflict resolution management strategies that might limit impacts: i.e. ranging from minimization/limitation of negative effects, mitigation of negative effects, to compensation or relocation, where possible (Dutch Central Government, 2009; Marine Management Organisation, 2020). Consequently, the level of conflict between the potential deployment of an OWF and alternative sea uses will depend on both its location and available resolution strategies.

In the most recent body of literature the site selection for OWFs is defined as a complex problem, which takes into account a variety of factors, from the access to wind resources and constructability of the infrastructure (in particular offshore), to environmental, social and economic factors (Gil-García et al., 2022). In order to better account for potential trade-offs between alternative OWF deployment options, a number of studies on optimal OWF site location have been focusing on combining a multi criteria decision making (MCDM) framework and GIS (geographic information systems) (Mahdy and Bahaj, 2018; Gil-García et al., 2022; Caceoğlu et al., 2022; Nagababu et al., 2022; Sánchez-Lozano et al., 2022). In particular, an entire body of literature has been focusing on the analytical hierarchy process (AHP), which implies a structured technique that compares alternatives based on weighted criteria of site selection that usually conflict with each other (Gil-García et al., 2022). Hence, most studies have so far focused on exclusion factors which would lead to a number optimal locations for locating OWFs (Loughney et al., 2021; Caceoğlu et al., 2022; Nagababu et al., 2022), or a range of options based on a suitability index (Mahdy and Bahaj, 2018). A related body of literature has been focusing on the analysis of potential pair-wise trade-offs between offshore uses and activities and the emerging offshore wind energy (White et al., 2012; Lester et al., 2013). However, most studies address the site location problem from a single-use space management option, employing a top-down approach, the multi-use of OWFs with other activities and the potential opportunities and risks attached to this management option have not yet been explored, in particular at a large spatial scale and when considering multiple overlapping offshore interests.

Opposed to these models, a more recent set of studies do consider alternative objectives by going beyond mere economic modelling and relying on a bottom-up approach to identify trade-offs by combining stakeholder engagement with GIS-based mapping tools (Gimpel et al., 2018). Nevertheless, their spatial resolution and scope remains limited (Kyvelou and Ierapetritis, 2019; Spijkerboer, 2021), while these studies also often narrow their focus on general techno-economic (fisheries (Schupp et al., 2021)) or institutional barriers (shipping (Mehdi et al., 2017; Mehdi et al., 2018)). In response to this first research gap, this study analyzes and maps the spatial distribution and intensity of conflicts between alternative sea users and OWFs, across large marine areas (country level Exclusive Economic Zone-EEZ) on a high spatial resolution (km^2) and by consideration of economic and non-economic values of OWFs and four sea user groups (fisheries, nature protected areas, military activities, shipping).

Second, most studies do not differentiate between types of activities within a sea user group. Nevertheless, there are multiple types of fisheries (such as bottom trawlers and static gears), but also different military activities, modes of shipping or protected features within nature protected areas. Those different types can have a different spatial coverage, and the exact risks and impacts posed by the development of OWFs will differ per sea user type, leading to different conflict resolution strategies at different locations. While such differences are crucial to recognize, it is also crucial to identify locations where various types of sea users may simultaneously occur in a single piece of offshore space, such as pelagic trawls and military flying areas, or sea mammals, bird's habitats and passenger routes. In response, this study does include these differences and their potential simultaneous occurrence.

Third, when looking at the North Sea basin, criteria for site selection and the balancing of spatial (sectoral) claims differs between countries, as different (mainly sectoral) policies and priorities apply. Aspects such as the size and importance of shipping lanes, the status of the protected features and protection measures for nature areas, or activities permitted within the training military zones all differ across different countries. Acknowledging these differences, which have implications on the authorization process, and therefore, the speed of deployment, this study will apply the developed method for two countries' EEZ, namely the English (East Offshore and North East Marine plans areas) and Dutch EEZ. The two cases

differ not only in the size of EEZ, but also in the offshore energy goals for 2030 (UK Department for Business Energy and Industrial Strategy [BEIS], 2020; Government of The Netherlands, 2021a). Moreover, there is a considerable contrast between the deployment pace of the two countries, which could reflect the difficulties in balancing the densely claimed space of the Dutch EEZ, as well as the degree of flexibility in dealing with conflicting spatial claims in the English EEZ.

There is a recurring need to trade national economic development for national non-economic objectives, such as ecosystem restoration, and vice versa (Confederation of European Shipmasters' Associations, 2018). This trade-off, however, is difficult to convey in clear numbers or units of measurement, due to different value measurement in the case of non-monetary trade-offs (Confederation of European Shipmasters' Associations, 2018), but also due to the absence of property rights at sea (Lester et al., 2013). As a consequence, the management of the offshore space has been, more than often, shaped by dominative power asymmetries between the offshore economic and non-economic sectors (Overlegorgaan Fysieke Leefomgeving, 2020). More recently, marine spatial plans have been developed as tools to promote a more inclusive, participatory and equitable management of the offshore space (Lombard et al., 2019). However, the MSP process has also been criticized to prioritize powerful interests, in particular OWFs, over other interests offshore, failing therefore to successfully integrate the multispectral interests offshore, from an institutional but also spatial perspective (Spijkerboer, 2021).

The overarching objective of this study is to develop and apply a multi-criteria analysis framework for quantifying, qualifying and mapping the spatial distribution of conflicts between OWFs and four sea user groups (fisheries, nature protected areas, military activities, shipping). The method and its application in our study aims to provide a robust and transparent knowledge basis for strategic spatial policy development in finding space for OWFs, potentially underpinning future standardized practices at the basin level. This is particularly relevant due to the transboundary nature of most marine activities and uses, such as shipping, marine protected areas and fishing. Moreover, making trade-offs and conflict management measures (solve/minimize/mitigate) visible could also help tackling with criticism of spatial injustice in the governance and planning of the marine area 'commons' (Ntona and Schröder, 2020).

Methods

We followed three main methodological steps for the development and application of our multi-criteria analysis framework, as we detailed in Figure 1.

Step 1. Literature review and data collection

The first step is based on conducting a literature review and data collection. The literature review will: 1) identify the sectoral

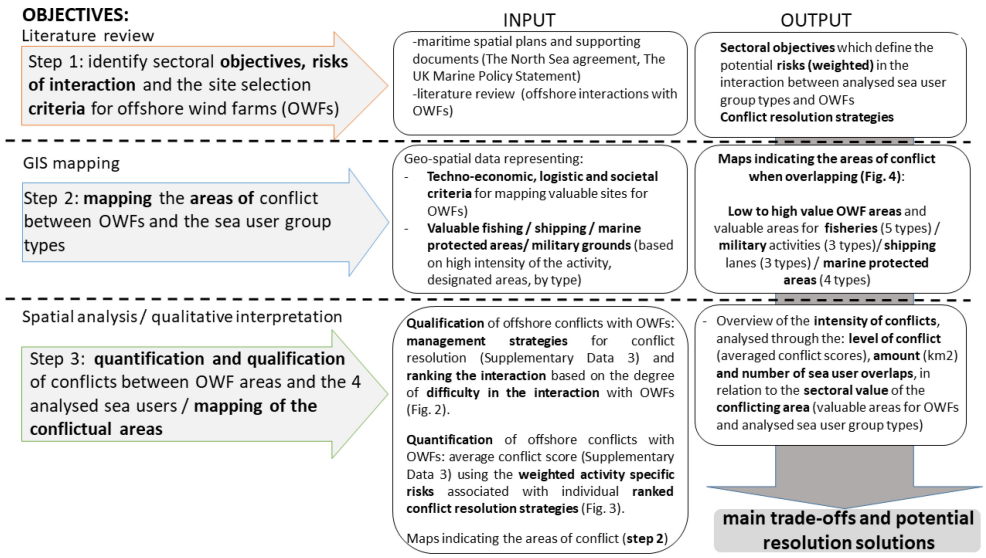

FIGURE 1
Sequence of steps for identifying trade-offs for the interactions of OWFs in the Dutch and English EEZ, with selected sea users: Fisheries (beam trawls, bottom otter trawl, bottom seine, pelagic trawls and seine, static gear), nature protected areas (seabed habitats, marine mammals habitats, birds habitats, fish habitats), shipping routes (cargo, passenger, tanker) and military activities (flying areas, shooting areas, airspace radar areas).

objectives/priorities related to all included sea user groups, 2) identify the main risks/benefits in the interaction between the different sea user types in the selected sea user groups and OWFs and 3) attach an importance weight factor to these risks to express their relative importance. Therefore, our first round of literature review was a document analysis on a country basis and international level (Supplementary Data 1) targeting the main legal setting for managing the interaction between OWFs and the other four sea users included in this study (military, shipping, fishing, nature protection areas). The method employed for this step is qualitative data analysis through two cycle coding of selected documents. For the 1st cycle coding, we used exploratory coding methods, namely provisional coding (codes: "offshore wind farms", "fisheries", "nature protected areas", "protected marine environment", "shipping", "military"). For the 2nd cycle coding we used pattern coding methods (Wicks, 2017), which enabled us to organize and group similarly coded data into a number of themes with shared characteristics (patterns). Specifically, the outcomes of this first round, in alignment with the themes that we grouped the data, are (1): the main sectoral objectives (e.g.: "access to (resources) fishing grounds", "conservation and regeneration of environmental features", "sufficient exercise space for military activities") (2), the risks involved from the interaction between OWFs sites and the selected sea user types, including the preliminary importance weights, and (3) potential benefits or synergies between different sectoral objectives (i.e., restoration of seabed habitats and protection of fish species can be achieved by forbidding fishing in OWF area, while temporary closing of OWF sites could increase fish stocks which represents a fishing sector objective). The patterns used for organizing the data are characterized by: 1) similarity (can be classified in the above mentioned categories: sectoral objectives, risks of interaction, synergies); 2) correspondence (are connected to the interaction with OWF development); 3) causation (applied in particular for risks and synergies, where codes are linked to data on effects of OWF deployment). The results reflect the international and national legal rights and obligations in the use of the sea space (e.g., safety of operation at sea) in relation to the analyzed activities.

Our second literature review round meant to help qualify and further quantify risks and benefits while also considering potential conflict resolution strategies (Figure 1). Literature targeted included: 1) scientific literature on co-location (Mehdi et al., 2017; Mehdi et al., 2018; Degraer et al., 2020; Stelzenmüller et al., 2021), risk assessments (for shipping: collision risk with vessels (Moulas et al., 2017), effects of OWFs on the shipping activity (Rawson and Rogers, 2015)), effects of OWFs on the marine environment (OWF as a protected area (Ashley et al., 2014)), fishing activity (Andrew Gill et al., 2020); 2) governmental/industry reports and guidelines on the interaction between OWFs and the analyzed activities: military (Office of the Director of Defense Research and Engineering, 2006), shipping (Maritime & Coastguard Agency, 2006), nature protected areas (Copping and Hemery, 2020) (Netherlands (Hermans et al., 2020), England (Harley et al., 2009)); 3) OWF project reports and environmental impact assessments: military (Ørsted, 2018), nature protected areas (environmental impact assessments for OWFs in the study area: Horns Rev (NL), Borselle (NL), Walney(UK), etc.). This allowed us to summarize conflict resolution and management strategies and practices for solving, minimizing or mitigating negative effects, in the interaction with OWFs. The method employed here is qualitative data analysis through two cycle coding of selected documents. For the 1st cycle coding, we used exploratory coding methods, namely provisional coding (codes: "interaction", "risk", "benefit", "effects", "gains", "losses", "impact", "recommendation", "solve", "minimize", "mitigate"). This allowed to identify recommended conflict resolution strategies for each activity specific risk identified in the first round of literature review (e.g. the negative impacts of the risk of "reduced efficiency of the air traffic control services" can be minimized through "gap-fill options using turbines as substations for air traffic control radars"- Supplementary Data 3). The second cycle coding is realized using pattern coding methods (Wicks, 2017), categorizing the data from the first cycle into two main groups representing: 1) risks of interaction with OWF infrastructure, and 2) conflict resolution options (solve, minimize, mitigate) (examples in Supplementary Data 3). The importance weight of the identified risks is reflecting the sectoral priorities and objectives underlined in policy documents (MSP document, Marine Policy statements), sectoral policy documents (Prellezo et al., 2020), technical industry reports (Ørsted, 2018) and literature review (perceived or analyzed risks). We operationalize the ranking of importance weight using: 1) the relevance towards achieving sectoral objectives, and 2) frequency of occurrence within the selected body of literature. This is detailed in Supplementary Data 3.

We further discuss the mapping of valuable sites for OWFs and the selected sea users, followed by how we used the information from this second literature review round in our third methodological step 3. It is also there where we explain how we combined the weigh factor of risk on the interaction between user groups and OWF and potential use of conflict resolution strategies in addressing these risks for identifying the intensity of offshore conflicts with OWFs.

Step 2. Spatial visualization and mapping of valuable sites and the interaction with analyzed sea users

The first part of step 2 is the mapping of the valuable OWF sites areas. We identified the initial investment costs, operation and maintenance costs, transport of electricity cost, community acceptance as essential sectoral objectives for OWF deployment and translated them into six spatial criteria with different

interval values and criteria rankings (Table 1). The sectoral objectives, spatial criteria and criteria rankings we use have been selected from the study of Deveci et al., (2020) (Deveci et al., 2020), a novel and comprehensive study involving a mixed method approach. Based on the ranking provided by Deveci et al., we selected the critical and moderate importance spatially relevant criteria for the North Sea context. For practical reasons and towards the focus of our study on the interaction with fisheries, nature protection areas, shipping and military, we excluded the following OWF criteria: proximity to landscape protection or conservation area, proximity to passage route of birds, proximity to shipping lanes, proximity to military operation area, proximity to radar and radio corridors, fishing ground proximity.

The criteria C1-C5, the criteria rankings, the interval values and their respective weights (Table 1) are used in compiling the OWF valuable sites map. This is realized using the QGIS open-source software, through a number of steps: 1) create the GIS vector layers for each criterion (e.g., the areas with water depths above -55 m, between -55 and -120 m, below – 120m), and add a separate field for the respective interval value weights; 2) convert all shapefiles in raster files for each criteria, with a spatial resolution of 1 kmx1km (Hengl, 2006); 3) apply the raster calculator using the created raster files, the interval value weight and the criteria weights, where:

cell value $=\sum_{i=1}^{5}(interval\ value\ weight\ Ci * criteria\ weight\ Ci)$, and Ci = criteria from C1 to C5.

The areas with the highest cell value are the most valuable OWF sites. We subsequently translated these values into six categories: very low value (<=0.5), low value (0.5-1), medium-low value (1-1.5), medium value (1.5-2), medium-high value (2-2.5) and high value (>=2.5). In the display of the final ACS scores (Supplementary Figures 2-5), the spatial distribution of conflictual areas (see Results Section) and space of overlap between activities per activity type (Supplementary Figure 1), we merge the first two OWF valuable sites categories, very low and low value OWFs. This is due to the fact that in the low valuable sites category there is a reduced amount of overlap with the other activities (e.g.: Supplementary Figure 1; in the English case there are 55 km^2 of overlap with fisheries, 0 km^2 of overlap with nature protected areas and nature protected areas and 4 km^2 of overlap with shipping routes).

Secondly, we exclude all other activities not considered in this study (e.g. not part of the four user groups) where OWF deployment is not possible, including their protection zones, namely cables, pipelines, oil and gas infrastructure, aggregate extraction (source: EMODnet geoportal). We also excluded the operational, authorized and under construction OWF areas (sources: Rijkswaterstaat Geoservices, The Crown Estate), and the Traffic Separation Schemes (TSS), clearways and anchorage areas (sources: Rijkswaterstaat Geoservices, Admiralty Data solutions), as permanent structures are not allowed within or in a 500 m zone surrounding these shipping routes (Dutch Central Government, 2009). A detailed explanation of the selected OWF criteria and respective interval values can be found in Supplementary Data 2. The resulting map for valuable OWF sites is illustrated in Figure 2.

TABLE 1 Explicit OWF site allocation criteria, for the calculation of valuable OWF area.

Offshore wind farm sectoral objectives	Criteria	Interval value	Interval value weights*	Criteria Rank**	Criteria weight (criteria rank/5)
Initial investment cost - **transportation** - **foundation costs**	C1. distance to ports with facilities for OWF construction	under 70 km 70 – 150 km over 150 km	1 0.66 0.33	2	0.4
	C2. water depth	above -55 m -55 to – 120 m below -120 m	1 0.66 0.33	4	0.8
Operation and maintenance	C3. distance to ports with O&M facilities	under 70 km 70 – 150 km over 150 km	1 0.66 0.33	3	0.6
Cost of electricity transportation	C4. proximity to demand areas (residential areas) -distance to the onshore grid connection (distance to shore - landing points)	under 50 km 50 – 100 km over 100 km	1 0.66 0.33	5	1
	C5. proximity to demand areas - distance to industrial clusters	under 50 km 50 – 100 km over 100 km	1 0.66 0.33	1	0.2
Community acceptance (visibility, noise pollution)	C6. distance to coastline	under 12 nautical miles (NM) from the coastline (territorial waters)	–		areas excluded from the analysis

*Based on a value scale from 1=least suitable to 3=most suitable, the interval value weights scores were obtained after division by 3.
**ranking based on the Deveci et al. (2020 study), where 1=least important, to 5=most important.

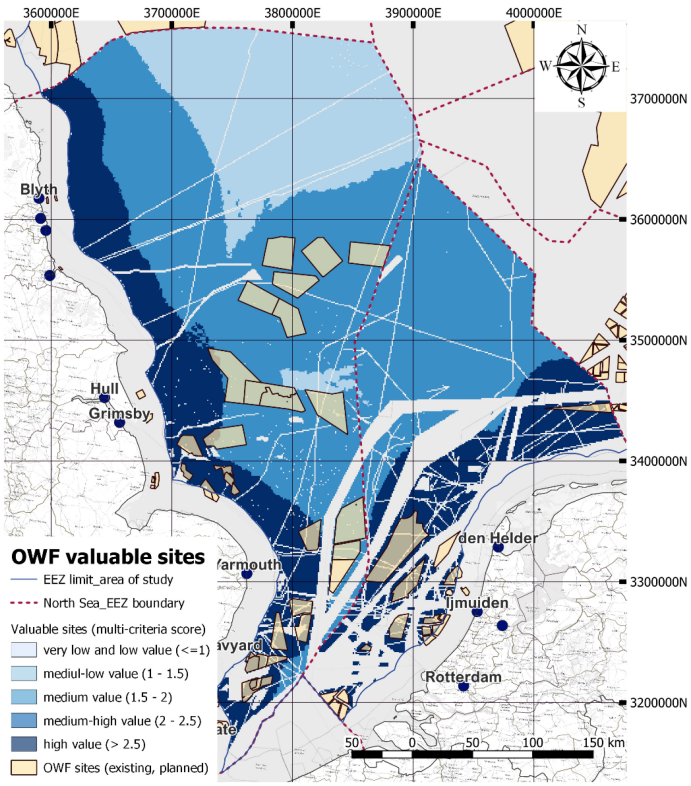

FIGURE 2
Valuable OWF sites in the Dutch and English EEZ.

Thirdly, we overlapped the OWF raster value maps (categories from very-low/low to high value) with layers (maps) illustrating the spatial distribution (presence or intensity) of the analyzed sea user groups (military areas, shipping, fisheries, marine protected areas), separated in different types for each group (Table 2). For shipping and fisheries, we only include areas with a high intensity use. Separating the sea user groups in the different types is relevant considering that different user types interact differently with OWFs (meaning they are exposed to different risks and require different conflict resolution strategies).

In compiling the raster maps to display the areas of overlap, we used the QGIS raster calculator. We assigned the raster layers representing the presence of the analyzed sea user types the value 100 and calculated the difference with the scores representing the values of the OWF areas. This allowed us to show the spatial presence of different types of sea users within each activity group (fisheries types, protected features within nature protected areas, military activities, shipping types), in all areas of very-low/low to high value/importance for OWF deployment. The results are presented as separate maps by sea user group type (Supplementary Figure 2; i.e., for shipping activity group, we display the values for cargo, passenger and tanker).

Step 3. Qualification and quantification of conflicting claims offshore (average conflict score)

The degree to which offshore activities are (in)compatible is firstly influenced by the ability of involved activities to pursue their individual objectives (e.g., accessing resources, protection of valuable features, free navigational or aviation access), when sharing the same physical offshore space (spatially and/or temporally). Secondly, based on conflict resolution theories, compatibility is influenced by the degree in which conflict management strategies are available and feasible to settle (in some cases top-down imposed) or resolve conflicts (Alexander et al., 2013). On the other hand, negative effects of the interaction can be minimized or mitigated, an approach most commonly taken in the current offshore space management strategies (Dutch Central Government, 2009; Marine Management Organisation, 2020; Government of The Netherlands, 2021a). Thirdly, next to (in) compatibility, the difficulty of addressing potential negative impacts increases with the number of overlapping activities claiming the same physical space.

TABLE 2 Geo-spatial data base for the analyzed activities with used indicators.

Sea users groups	Spatial representation and categories of sea user types (classification per country), with sources	
	Netherlands	**England**
Military activity	GIS Shapefiles representing the offshore areas claimed by military activities, represented spatially by types of designated areas at the country level for:	
	Country level Practice areas (sea bottom and surface) Shooting area Flying area Mining	Air to air refueling areas (AARA) Aerial tactics areas (ATA) Lower airspace radar service (LARS)
	sources: Rijkswaterstaat Geoservices	CAA (Civil Aviation Authority), RAF No1 Aeronautical Information Documents Unit, NATS (National Aeronautical Information Service and Peregrine Bush (geo-referencing on maps, produced by P. Bush © Copyright January 2020, https://pb-photos.com/)
Nature protected areas	Marine protected areas, with the protected features under the 4 types; -fish habitats; -marine mammal habitats; -bird habitats; -seabed habitats, represented by GIS shapefiles illustrating the designated marine protected:	
	1. Country level: Proposed areas with special ecological value **2.** North Sea basin level **(Natura 2000):** Special Areas of Conservation (SAC) Special Protection Areas (SPA)	**1.** Country level: Marine Protected Areas (MPA) Marine Conservation Zones (MCZ) **2.** North Sea basin level (Natura 2000 areas): Special Areas of Conservation (SAC) Special Protection Areas (SPA)
	sources: 1. Geo-referencing (maps collected from literature studies) 2. European Environmental Agency	1. Joint Nature Conservation Committee 2. European Environmental Agency
Shipping	Local and international shipping routes (outside IMO routes), for the 3 representative shipping types: - tankers; - passengers - cargo, represented by GIS raster files illustrating the shipping routes at country and basin level:	
	Country and basin level Route density (number of routes per square km per month) by type of shipping	**Country and basin level** Route density (number of routes per square km per month) by type of shipping
	source: EMODnet	EMODnet
Fisheries	Fishing intensity by 5 types of fishing activities: - beam trawls - bottom otter trawls - bottom seines - pelagic trawls and seines - static gear represented by GIS raster files illustrating the high fishing intensity, indicated by:	
	Basin level: Average annual fishing effort (Mw fishing hours) for vessels > 12 m with a vessel monitoring system (VMS), for the 5 fishing types	Basin level: average annual fishing effort (Mw fishing hours) for vessels > 12 m with a vessel monitoring system (VMS), for the 5 fishing types
	source: EMODnet	EMODnet

To express levels of (in)compatibility we qualify a site through a so called the average conflict score (ACS) and the number of overlapping activities. For developing an ACS, we first assign importance weights (as detailed in Methods Section 2.1.) to all risks identified in the interaction between an individual activity type and OWFs. The identified risks (Figure 3, R1-Rn, Supplementary Data 3) relate how reliant the activity is on important resources located in the area, the well-being and safety of operation, financial consequences of the interaction or, in the case of nature protected areas, impacts on the protected features (details in Supplementary Data 3). Per identified risk we subsequently assign a 'Conflict rank', which

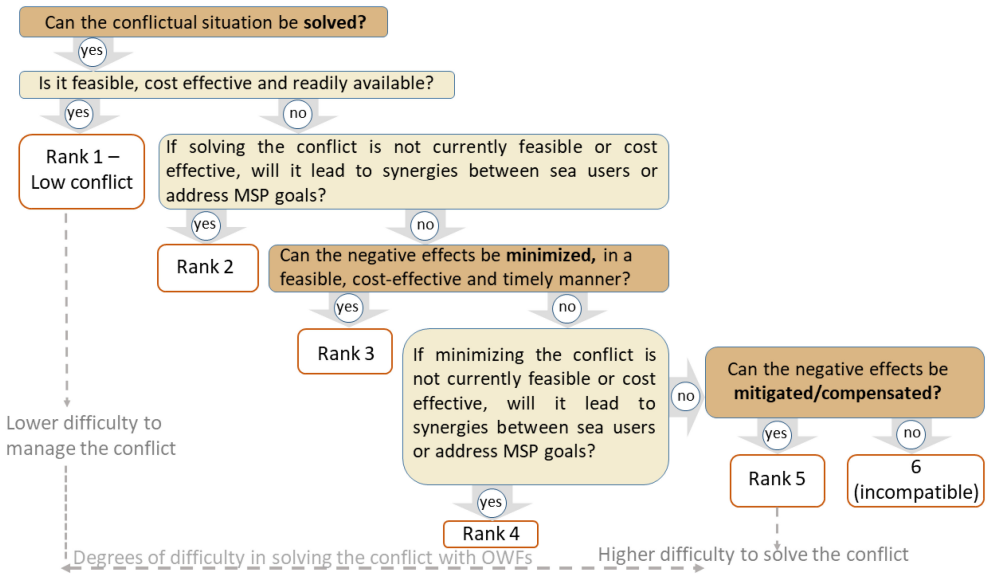

FIGURE 3
Spatial distribution (cumulated area of conflict) of conflicts (ACS) within the OWF valuable sites, for military activities sea user group types – England.

expresses the difficulty/ease of coping with the risk. We rely on three main conflict management strategies, commonly used in dealing with conflict resolution between offshore activities (Dutch Central Government, 2009; Government, 2011; Department for Environment Food and Rural Affairs, 2014a), namely 1) solving/avoiding the conflict, 2) minimizing the negative effects or 3) mitigating/compensating for the negative effects (Figure 3). For the assessment and assigning of ranks, we synthesize the techno-economic and management options for solving/minimizing/mitigating conflicts from best practices reports documenting implemented or tested options, guidelines from the policy side, management options proposed in the MSP documents, industry reports on impact assessment of OWF projects as well as scientific literature (Supplementary Data 3). If management options for solving or avoiding a risk are reliable (already implemented or successfully demonstrated), cost effective and based on readily available technologies in the short term (up to 2030), we assign the lowest Conflict Rank 1. If solving or avoiding is feasible but we have to rely on technology that is only likely to exist at a later point, or has higher costs, but demonstrates utility and necessity (create synergies between sea users that address sectoral or MSP goals), we assign Conflict Rank 2. If conflicts cannot reasonably be expected to be solved, we shift to the minimizing negative effects, implying a higher Rank. Depending on the reliability/feasibility of the management option, the implied estimated costs and the availability of involved technologies or procedures, we assign either Conflict Ranks 3 and 4. Last, if neither solving or minimizing are viable options, the requirements are that negative impacts are mitigated/compensated for, leading to Conflict Ranks 5 if this is possible and sensible and 6 if not (fully incompatible).

Calculating the ACS score on the interaction between OWF development and each individual activity type is based on multiplying the importance weight per each identified risk (R1 to Rn) regarding this interaction with the Conflict Rank related to this risk (Figure 3) and summing these together (Figure 4). This results in a final ACS for each of the distinct activity type. These final scores will be normalized for each activity type, by dividing the final activity type ACS by the highest ACS per activity type. The normalized ACS are used to spatially illustrate the areas with the different degrees of difficulty for conflict resolution. The formula used to calculate the normalized ACS score, following the sequence of steps presented in Figure 5, is therefore:

$$normalized\ Averaged\ conflict\ score\ (ACS) = \left(\sum_{i=1}^{n}(\ importance\ weight\ Risk_i * Conflict\ resolution\ rank)\right)/max\ (ACS)$$

where max (ACS) is the maximum value of the respective sea user type.

The normalized ACS scores per activity type are input for mapping the intensity of offshore conflict across the EEZs per sea user group. To better indicate the differences between the different ACS scores, they are classified on a low/medium/high scale, with low accounting for low level of conflict and high for a high level of conflict with OWFs (matrix present in Supplementary Data 4). We then assign the classified ACS scores to the raster files representing

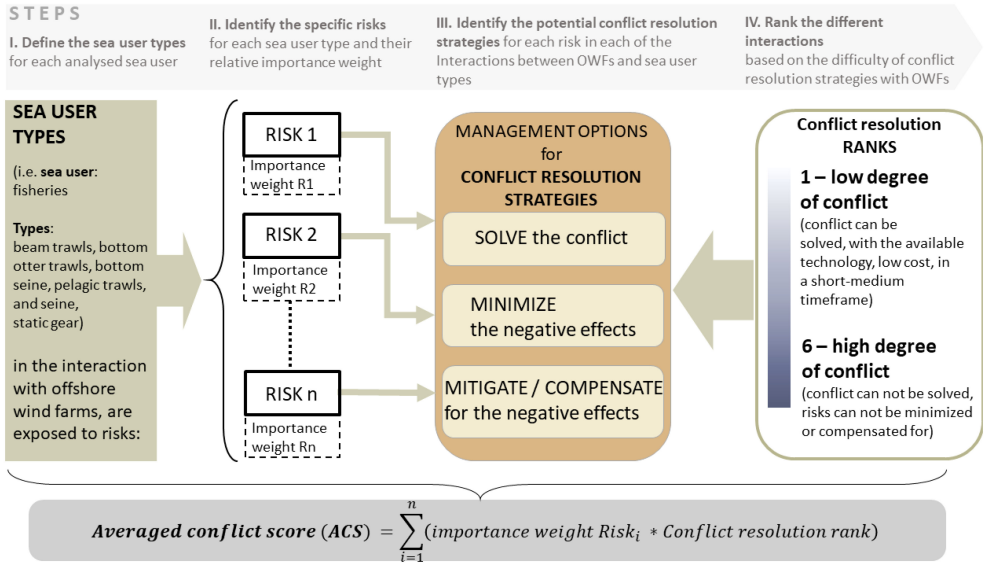

FIGURE 4
Framework of analysis to determine the conflict resolution rank (degree of conflict) for each specific identified risk of the interaction between sea user types and OWFs.

the presence of the related activity type to the six categories of OWF valuable areas (Figure 5).

$$Averaged\ conflict\ score\ (ACS) = \sum_{i=1}^{n} (importance\ weight\ Risk_i * Conflict\ resolution\ rank)$$

Per sea user group we use QGIS to identify for each cell (1 km^2): (1) the category of OWF valuable area, (2) the number of overlaps with each activity type (1 or more) and (3) the ACS score per overlap (low, medium, high). The result is a range of different intensities of conflict per cell (km^2), ranging from no conflict, limited conflict (i.e., low OWF value, overlap with 1 fisheries type

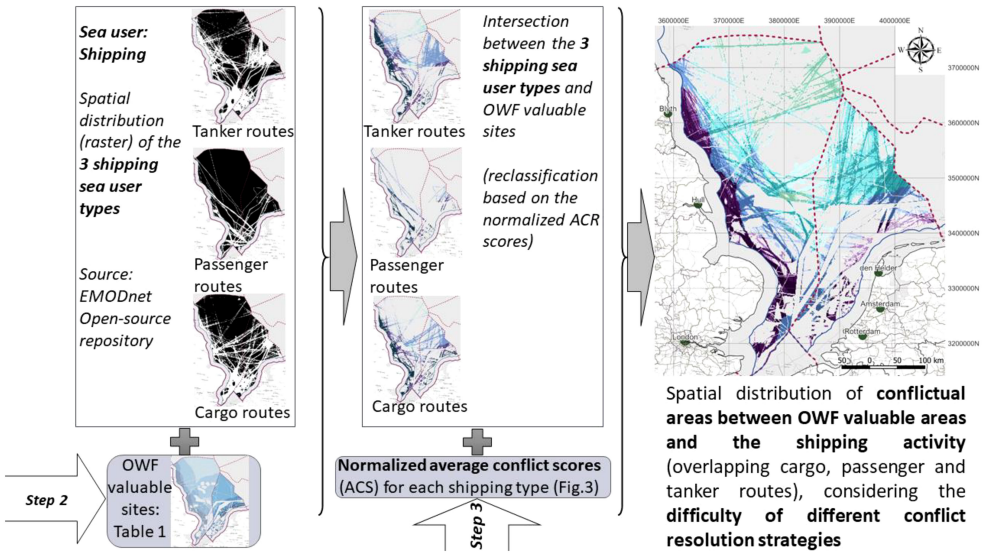

FIGURE 5
Sequence of steps to determine the average conflict resolution scores for each sea user type, based on the identified risks, conflict resolution strategies Supplementary Data 3) and respective conflict resolution ranks (Figure 4).

and a low ACR score) to high conflict (i.e., high OWF value, overlap with 4 fisheries types and high ACR score). We subsequently quantify the spatial magnitude of different intensities of offshore conflict by calculating the size of their impacted areas (km^2); i.e. resulting in tables that show per category of OWF valuable area the number of overlaps (1 or more), their related ACS scores (low, medium, high) and spatial magnitude in km^2 (Supplementary Figure 1). Apart from presenting these tables, we will also show in our results section maps that visualize the locations of each possible degree of intensity of conflict listed in these tables, for the two EEZs (Figure 5).

The pairwise assessment of interactions and conflicts offshore with OWF infrastructure offers a clear but simplified understanding of the complexity and diversity of interactions which could occur when overlapping all layers of sea users. We deliberately do not calculate intensities of conflict by combining all sea user types as we do not consider it sensible to assign weights per sea user group or simply consider these of equal importance. In addition, there is no sound academic basis to substantiate such weight factors. Nevertheless, we do spatially map possible hotspots and cold-spots of conflict when different sea user types overlap with valuable OWF sites (Figure 6).

The overlap between the different selected activity types in the four analyzed sea use groups with the five categories of OWF valuable sites resulted in 554 combinations for the English EEZ and 311 combinations for the Dutch EEZ. Using histograms (Supplementary Data 7) of the resulted ACS values of the cumulated overlaps (all sea user activity types and categories of OWF value sites), we map the cold-spots (lower 1/3 of histogram bins) and hot-spots (higher 1/3 of histogram bins) in Figure 6, to aggregate areas to be avoided (hot-spots) and areas with lower levels of conflict (cold-spots).

Results

Case studies

The case studies are the Dutch EEZ and the offshore areas corresponding to the East Offshore Marine Plan and North East Offshore Marine Plan areas within the English EEZ. The studied areas differ in size (approx. 49 997.6 km^2 vs. 99 071.8 km^2), show different degrees of intensities of use and have different offshore renewable energy targets (11.5 GWs(4) vs. approx. 29 GWs-when excluding Scottish targets (UK Department for Business Energy and Industrial Strategy [BEIS], 2020; Scottish Government, 2020) for 2030). Moreover, the two countries also differ in the speed of offshore wind farm deployment. The high number of cancelled projects (84 projects by 2018) and the substantial time delay in obtaining the approval to install and develop an OWF project of approx. 2 years (under previous regulations) (Salvador et al., 2018)

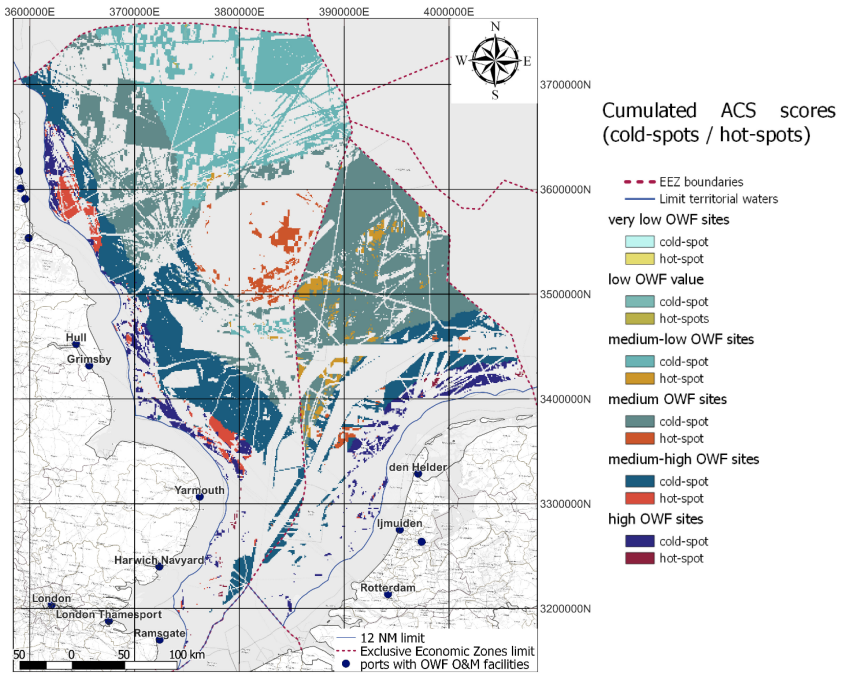

FIGURE 6
Sequence of steps to map the spatial distribution of conflictual areas by sea user, using the ACS score.

in the Dutch EEZ is partly reflecting the conflicts with other sea users, in particular fishing activities and protected marine environment features (such as migratory routes). As a result, The Netherlands is still lagging behind the other North Sea countries in reaching its offshore renewable energy targets, underlining the need for managing the offshore conflicts. As also underlined by the recent Climate Agreement (Government of the Netherlands, 2019), The Netherlands is one of the North Sea countries with high incentives to seek sustainable solutions for managing the scarce offshore space, and it has been aiming to achieve this through a cross-sectoral participation process. Recently, more innovative solutions include the "area passports", which are describing current users and potential forms of future multi-use in the area (de Koning et al., 2021).

On the other side of the spectrum, the UK (and in particular England) has the highest installed capacity in the North Sea basin of 8.1 GWs of which 7.2 GWs (fully commissioned) in the English EEZ. This has been facilitated not only by the improved clarity of the consent procedure for OWFs, by reducing the agencies involved and consents required, but also by the reduced timeline of the authorization process, with a processing time of 18 months, third fastest after Scotland and Denmark (Salvador et al., 2018). Another particular aspect which could play an important role in the high share of UK installed capacity among other North Sea countries is the high acceptance of locating OWFs in protected areas, especially in the shallow waters of the EEZ.

Furthermore, while the two countries have similar objectives and visions for the management of the offshore space, there are notable differences in the preferred spatial allocation options for the interaction between OWFs and other activities. While in the English case the multi-use option with fisheries, nature protection areas and military activities is encouraged (Andrew Gill et al., 2020; Marine Management Organisation, 2021; Ørsted, 2021), up until the current Dutch MSP2, the preferred space allocation option was single-use. The single-use strategy, however, is not always a feasible option in the highly claimed EEZs of the Netherlands and overlooks potential benefits of combining uses, where possible, such as enhancing the fish stock or contributing to the regeneration of the marine environment. Accessing the high value sites for OWFs in the Dutch and English EEZ areas (Figure 2), will require a clear understanding of the main trade-offs (risks/losses, opportunities/gains) in the offshore interactions.

OWFs- nature protected areas

Under the Marine Strategy Framework Directive (MSFD) (European Parliament and Council, 2008), the main marine environmental goals are to achieve the GES (Good Environmental Status), which implies safeguarding the marine biodiversity, the biological boundaries of commercially exploited fish species, the normal abundance and distribution of the food web, and that the seabed integrity is under acceptable limits and the human pressures are under control (Department for Environment Food and Rural Affairs, 2014b). For the North Sea countries, the sustainable economic development needs to align with measures for maintaining or restoring the GES of the marine environment, hence, limiting, protecting, conserving and recovering the losses produced by human activities (Dutch Central Government, 2009; Government, 2011; Department for Environment Food and Rural Affairs, 2014a). In achieving this, a number of Natura 2000 areas across the North Sea basin (Marine Protected Areas-MPA, Special Areas of Conservation-SAC, Special Protection Areas-SPA) have been designated with the aim to create a coherent network of protected areas at sea. In defining the risks of interaction with the OWF related activities, we use the MSFD defined qualitative descriptors for determining GES, grouped in an indicative list of characteristics, pressures and impacts (such as physical loss, interference with hydrological processes, biological disturbance) (European Parliament and Council, 2008).

As a base rule, following the precautionary principle, no activities with a risk of significant ecological effects, including the installation of OWFs, are allowed in the Natura 2000 areas of the Dutch part of the North Sea, unless no other realistic alternatives are available and there is a pressing reason of overriding public interest (Dutch Central Government, 2009) (Supplementary Data 5-Marine protected areas).The English take a more flexible approach, with planning authorities assessing both positive and negative environmental impacts of the new developments, on an area-based approach (Government, 2011). Therefore, there is flexibility of criteria used in the selection or de-selection of the protected marine areas, while cumulative impacts are assessed for the entire timeline of the proposed projects. The flexibility of the policy is aiming at increasing the resilience of the marine environment and at enabling the adaptive management to help mitigate the negative impacts on the environmental features, due to human pressure and climate change (Department for Environment Food and Rural Affairs, 2014a). Therefore, while both countries seriously constrain OWFs within nature protection areas, the English approach is increasingly aiming towards adaptive planning and area-based approach, allowing the installation of OWFs in the MPAs, SACs or SPAs.

The more flexible English approach considers synergies between different climate change actions, namely the production of renewable energy offshore and the objective of recovering the degraded maritime areas (Department for Environment Food and Rural Affairs, 2014a). There is also growing scientific evidence that the installation of structures within the marine areas may enhance the local habitat (creation of new substrate, enhancing the fish diversity and biomass) over a longer period of time (Government, 2011). In the English EEZ, the multi-use with nature protected

areas has led to the allocation of space of a large number of OWFs in already designated protected areas, where projects initiators are required to demonstrate that negative effects on the conservation objectives of marine protected areas, if occurring, were either minimized or mitigated. While more prudent, in the Dutch EEZ the "building with nature" concept has also been more recently promoted even inside ecologically valuable or vulnerable areas. Currently the Dutch see this only as an option if no other realistic alternatives are available and when negative effects will be minimized, mitigated or compensating measures will be taken (Dutch Central Government, 2009; Government of The Netherlands, 2021a).

Marine protected areas (MPAs, MCZ, SPA, SAC), have been designated for different protected features, namely seabed habitats, marine mammals, seabirds, fish species, each with specific conservation objectives (Supplementary Data 6). The interaction with the valuable OWF areas, the degree of conflict (given by the average conflict score and area of overlap) and the cumulative claims (number of overlaps) are presented in the table and maps below. The interpretation of results is facilitated through the ordinal classification of OWFs sites into 5 ranks, from very low/low (least valuable) to high (most valuable), as well as the ordinal classification of ACS scores of interaction by ranking from low (conflict with low risks that can be solved or effects minimized) to high (conflict with high risks that can be mitigated/compensated), for each interaction OWF-sea user group. The potential conflict resolution strategies are presented in Supplementary Data 3. The geo-spatial overlap between OWF valuable areas in the 5 categories and the different types of protected areas is presented in Supplementary Figure 2, and the cumulated ACS scores per grid cell are mapped in Figure 7.

Considering the results, a number of key messages should be underlined for the two EEZs, when qualifying and quantifying the pairwise interactions between the analyzed sea users and OWFs valuable sites (Supplementary Figure 2). We estimate the potential GWs to be deployed based on two densities, namely 3,6 MWs/km^2 (for a multi-use management alternative) and 6,4 MWs/km^2 (for a single-use planning management alternative). While the Dutch EEZ is nearly half the size of the English EEZ, the total area of conflict between protected areas and OWFs is 3 times smaller than in the English case. For the Dutch case, 78% of the conflict is located in medium value OWF sites, of which 46% of the interaction is taking place in habitats for marine mammal's protection, in approx. 4.361 km^2 (equivalent of 15.7-27.9 GWs). In medium-high and high value OWF sites, the main conflict occurs with bird's habitats (medium ACS), cumulating 1838 km^2 (6.6-11.8 GWs). Also relevant is the overlap with birds and seabed/fish habitats, in medium value OWF sites, accounting for 3,223.5 km^2 (11,6-20.6 GWs).

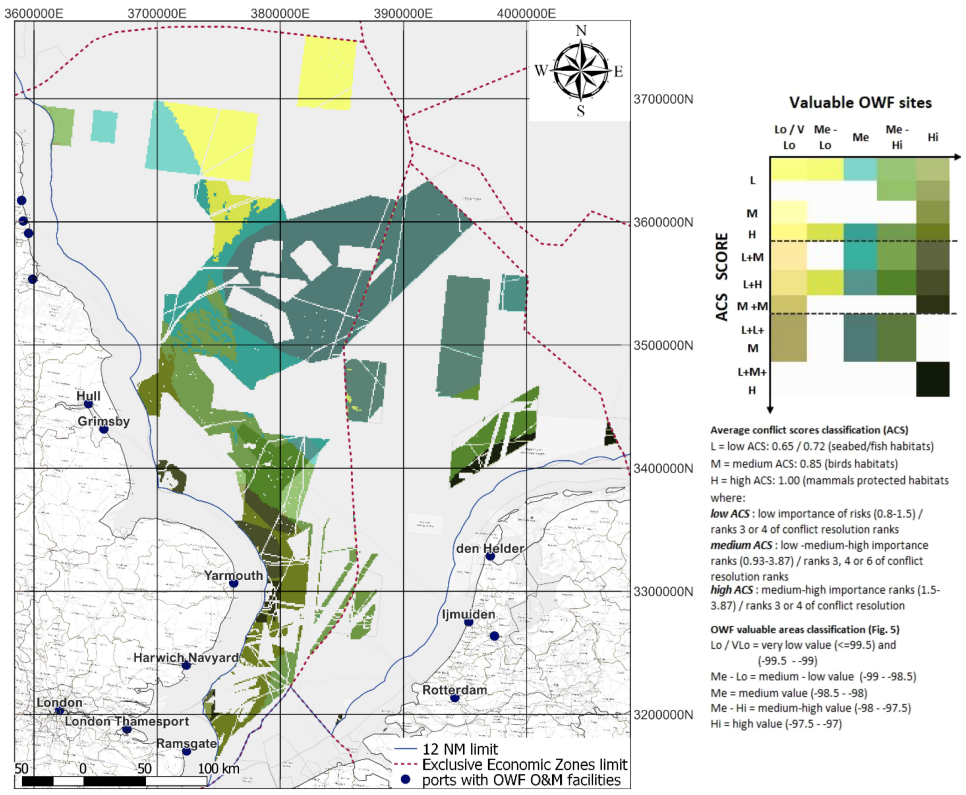

FIGURE 7
Spatial distribution (cumulated area of conflict) of conflicts (ACS) within the OWF valuable sites, for fisheries sea user group types.

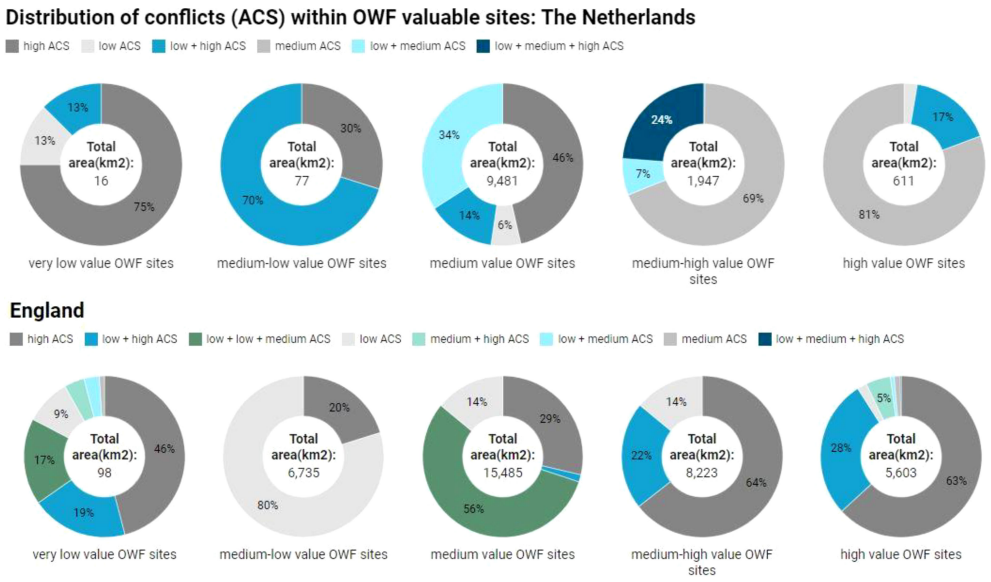

FIGURE 8
Average conflict resolution scores for the interaction between OWFs and nature protected areas.

In the English EEZ (Figure 8), the majority of the conflict is taking place in medium and medium-high value areas for OWFs, predominantly from 8,671.6 km^2 (31.2-55.5 GWs) of overlap with seabed, fish and bird habitats, and a cumulated 9,753.37 km^2 (35-62.4 GWs) in mammals' habitats. One relevant finding is the potential presented by managing the conflictual overlap with seabed/fish habitats (low ACS) in medium-low OWF value sites, which could unlock 5,388 km^2 (19.4-34.5 GWs). The alternative potential to be unlocked in areas with higher costs for the OWF sector (such as the medium value sites) at a lower environmental cost (lower ACS scores) is one of the main trade-offs which should be addressed when balancing risks and opportunities of OWF deployment.

OWFs - military activities

In both Dutch and English EEZs, the military related activities are priority activities of national interest (Dutch Central Government, 2009; Department for Environment Food and Rural Affairs, 2014a), have a role in security, and have a significant socio-economic contribution as a major employer in coastal areas (Department for Environment Food and Rural Affairs, 2014a). The main objectives of the sector are the safety of operations at sea and the sufficient areas for armed forces. As a principle, when multiple activities of national interest will be stacked in the same area, the planning approach is towards combined, efficient and safe use of space (Dutch Central Government, 2009). However, due to safety concerns of potential damage or restrictions posed by fixed installations (OWF turbines) to most military activities, the siting of OWFs is not permitted in military areas. The main concerns related to the interaction with military areas are posed by the Primary Surveillance Radars the obstacle posed by the wind turbines to low flight activities or to helicopters engaged in offshore operations (Mcpherson et al., 2019). The relocation of military activities can be considered, provided sufficient safe and feasible alternatives are available (EHD-41 defense exercise area in the Dutch EEZ2).

While the multi-use of space with permanent installations (OWFs) is not encouraged (Dutch Central Government, 2009; Department for Environment Food and Rural Affairs, 2014a), efforts are being made to limit the negative impacts of locating OWF in the range of military and aviation radars, by locating military radars on OWF turbines to fill the air gap caused by the location of OWFs (gap-fill options) (Supplementary Data 5 – Military activities). We map the interaction with the valuable OWF areas (Figure 9), the intensity of conflict per sea user group (Supplementary Figure 3) and we present the potential conflict resolution strategies to consider in each type of interaction between OWFs and military activities (Supplementary Data 3).

The military activities in the Dutch EEZ are mainly concentrated in the medium-high and high value OWF sites, at the intersection with areas reserved for flying military activities (forbidden access), over a cumulated area of 2,805.45 Km^2 (10-18 GWs) (Figure 10). While present in high value OWF areas, the military flying areas are highly incompatible with OWF related activities, the only option remaining the single use (either OWFs or military activities).

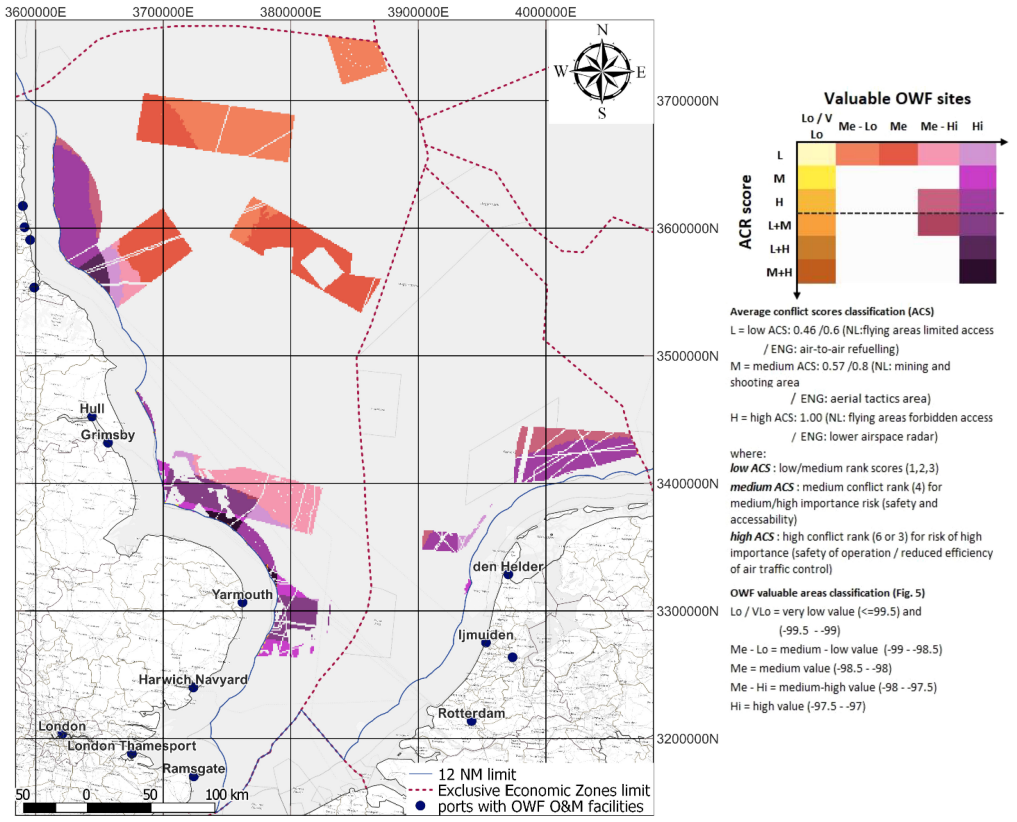

FIGURE 9
Spatial distribution (cumulated area of conflict) of conflicts (ACS) within the OWF valuable sites, for nature protection areas sea user group types.

In the English EEZ, the lowest conflict is represented by the interaction with air-to-air refueling areas, in medium-low, medium and medium-high value OWF sites. At the two extremes, in very low/low and in high value OWF sites, the degree of conflict is diversified, with the highest proportion of the conflict assigned to lower radar space, covering an area of 2,874 Km^2 (10.4-18.4 GWs). While for the Dutch case, the interaction with military flying areas is considered incompatible, in the English EEZ sustained efforts exist to tackle the negative impacts on lower radar areas with the aim to eventually balance the risks and benefits of the two activities.

OWFs- shipping routes

Shipping is another activity of national interest, with high economic value for UK and in particular for The Netherlands. Safety, accessibility and swift navigation in the designated areas and safe navigational access to ports, in particular with national strategic importance, are primary goals for the shipping sector of UK and The Netherlands (Dutch Central Government, 2009; Department for Environment Food and Rural Affairs, 2014a; Marine Management Organisation, 2020). Individual permanent structures are not allowed within the designated shipping lanes or at a distance of 500 m surrounding them, preventing OWFs in or near the recognized sea lanes of regional and international importance. UK planning documents do acknowledge the potential changes in the (mainly local) shipping activity as a result of Round 2 and 3 OWF deployment, if the safe navigation and access to ports with national strategic importance is maintained, and no adverse economic impacts on shipping occur (Department for Environment Food and Rural Affairs, 2014a; Marine Management Organisation, 2020). In contrast, new shipping lanes of economic importance for the Dutch ports are given priority over already designated OWF areas (e.g. the OWF designated area IJmuiden Ver) (Government of The Netherlands, 2021a). Therefore, both countries give a high priority to safety of navigation at sea, as well as to the economic importance of shipping activity and ports. This is highlighted by the designation of new shipping lanes in the Dutch EEZ, with an already high footprint of IMO routes (no-go for OWFs) in a highly spatially scarce EEZ.

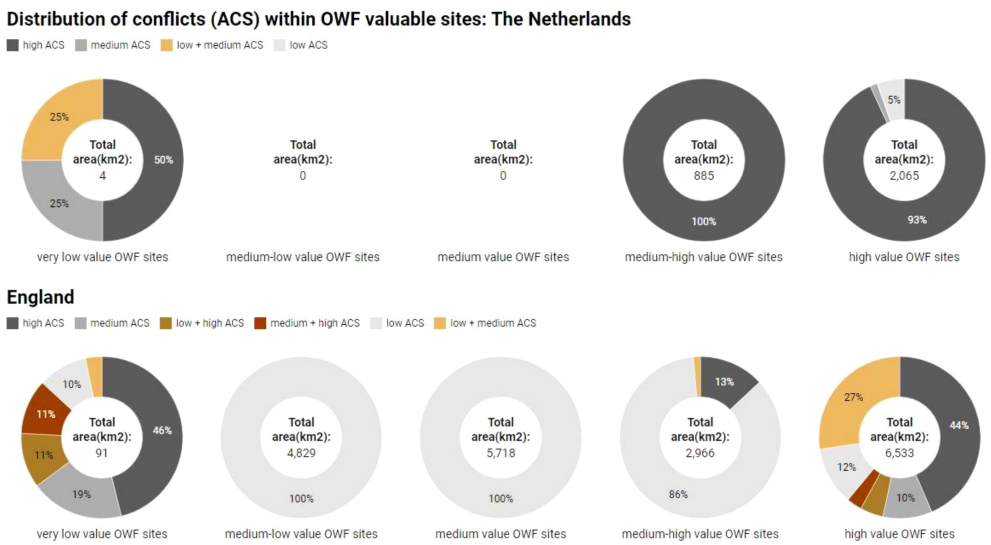

FIGURE 10
Average conflict resolution scores for the interaction between OWFs and military/aviation areas.

Despite efforts for combining activities offshore, OWFs and shipping will remain separate, due to current international regulations and guidelines for designing the shipping lanes. In consideration of local conditions (available depth of water, risk of natural hazards), the traffic density of the specific routes and vessel types may allow deviations (Confederation of European Shipmasters' Associations, 2018). In the Dutch EEZ the new policy framework allows for passage through corridors within the OWF areas, for ships under 46 meters, on a case by case approach(2). Moreover, the current standards for the safety distances from the shipping lanes to other permanently installed objects can be subject to negotiation with the shipping sector (Dutch Central Government, 2009). This approach has not been adopted by the English legislation so far.

We map the interaction with valuable OWF areas (Figure 11), the degree of conflict and the cumulative claims (number of overlaps) (Supplementary Figure 4), and present the potential conflict resolution strategies to consider in each type of interaction between OWFs and shipping types (Supplementary Data 3).

In the Dutch case, the shipping activity is highly concentrated in the medium value OWF sites, with 46% of the conflict associated with tanker shipping routes, in 6083.7 km^2 (21.9-38.9 GWs). Though having a smaller spatial impact, managing the low conflict with passenger/cargo routes could unlock 1370.3 km^2 (4.9-8.7 GWs) in high value OWF sites.

In the English case, the conflict with shipping activities is concentrated in medium value OWFs sites, in particular with tanker routes claiming 4138 km^2 (14.9-26.5 GWs, Figure 12), and in high value OWF sites, where both tanker and cargo/passenger routes cover 4674 km^2 (16.8-30 GWs). Interestingly, the management of only low conflicts (1 overlap, low ACS) with passenger/cargo routes could still unlock 10.9-19.4GWs, 3.8-6.8GWs and 2.4-4.2GWs in medium, medium-high and high OWF value sites.

OWFs- fisheries

Fishing is one of the traditional activities taking place in the North Sea basin, with an economic and socio-cultural value, linked to the identity of coastal communities (Dutch Central Government, 2009; Government, 2011). The sectoral objectives include safe access to fishing grounds (fishing resources), sustainable fishing management (keeping the stock within safe biological limits or improving the fish stock where possible) and creation of jobs at all skills levels (Government, 2011; Government of The Netherlands, 2021a). Recently, the Dutch fishing sector has been facing increasing constraints in practicing its activity due to limitation of access in Natura 2000 areas, and limited access to fishing grounds in the English waters, following Brexit. Moreover, the increased presence of OWFs has raised awareness of potential displacement of fisheries, since fisheries do not have priority over activities of national interest (such as energy production) (Dutch Central Government, 2009). Under new guidelines and agreements, both in the English and Dutch EEZ there is no strict interdiction for fishing inside the OWF. In practice, however, safety concerns of both fishing activity and damages to the wind farm (collision risks, grabbing the cables) imply that fishing activities are displaced when an area is designated for OWFs. In response, the Dutch government, through the North Sea Agreement (Overlegorgaan Fysieke

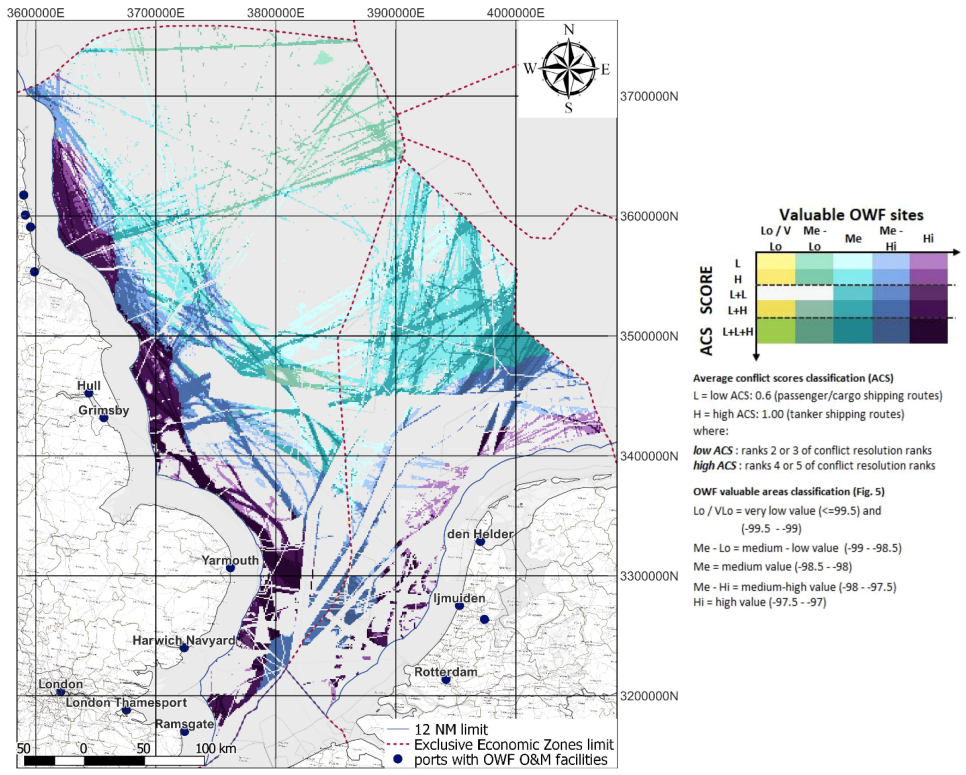

FIGURE 11
Average conflict resolution scores for the interaction between OWFs and shipping activities.

Leefomgeving, 2020), urges for the financial compensation of the fishing sector through the Transition Fund (Overlegorgaan Fysieke Leefomgeving, 2020), used primarily for the restructuring of the sector towards more sustainable fisheries (fishing gears and methods). Alternatively, the English approach is to account for impacts on the fishing activity early in the process, such as the search for viable alternatives for fishing activity, with reliable fish stock and feasible travelling possibilities to the new fishing grounds. Where negative effects on the local communities and businesses would arise, they need to be minimized or mitigated (Department for Environment Food and Rural Affairs, 2014a; Marine Management Organisation, 2020).

Multi-use of space between fisheries and OWFs is encouraged, where possible, in both the English EEZ (Government, 2011) and Dutch EEZ (except the southern part), mainly for fisheries which do not disturb the sea bottom (fixed gear – baskets) (Government of The Netherlands, 2021a). While in both cases the legal framework provides flexibility for multi-use options, no concrete guidelines and financial instruments for supporting the safe, efficient and equitable combination of the two activities exist. The co-location of the two activities, however, requires sustained efforts also from the OWF sector to ensure safety for fisherman inside the OWFs, as detailed through management strategies in Supplementary Data 3. Techno-economic solutions require better communication, knowledge exchange and working relationships between the fishermen and the OWF service vessel operators. A large body of literature is pointing at synergies between sectoral objectives, including shared facilities for operation and maintenance (e.g., commercial fishing vessels used as safety and research vessels), or developing funds to support the affected fishing communities (Orsted, 2021). Moreover, recent studies in the English and German EEZ show improvements in the local lobster (English EEZ) (Roach et al., 2018), brown crab and cod (German EEZ) (Gimpel et al., 2020) population size and characteristics within the OWFs (without fishing). This increase in local biomass may allow for the recovery of fisheries economic losses caused by the closing of the OWF, underlining the potential benefits on fish stock recovery (Roach et al., 2018; Gimpel et al., 2020).

We map the interactions with the valuable OWF areas (Figure 13), the degree of conflict (given by the area of overlap) and the cumulative claims (number of overlaps, Supplementary Figure 5) and the management options for conflict resolution (Supplementary Data 3).

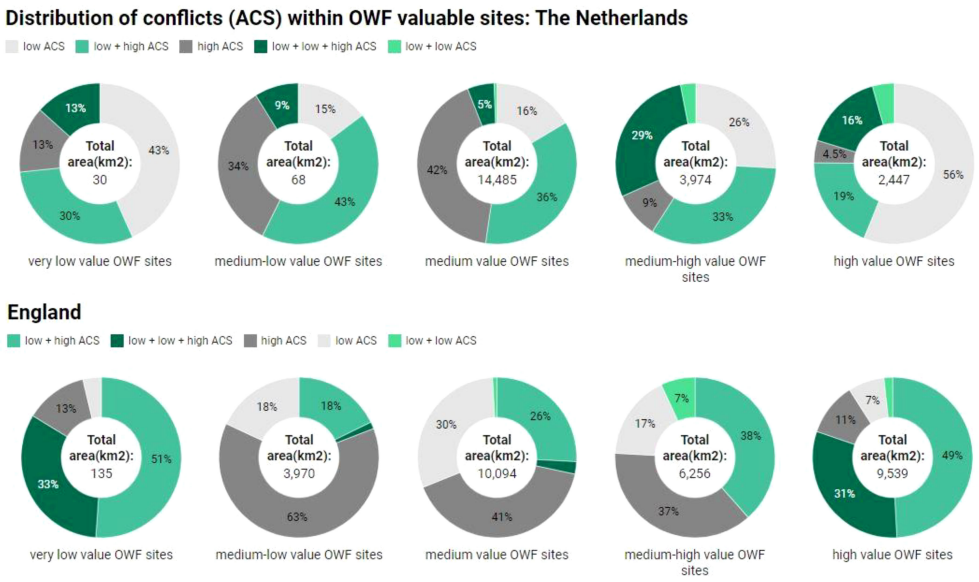

FIGURE 12
Spatial distribution (cumulated area of conflict) of conflicts (ACS) within the OWF valuable sites, for shipping activities sea user group types.

In the Dutch case, the majority of the claims occur in medium value OWF sites over 4197.6 km^2 (15-26.8 GWs), in areas of one overlap with either pelagic trawls (medium ACS) and beam trawls/bottom seine/bottom otter trawls (high ACS), and to a lesser extent in areas of two overlaps between two medium ACS and high ACS fisheries types (31806 km^2, 11.4-20.3 GWs) (Figure 14). It is important to notice the magnitude of overlap between high conflict fisheries in medium value OWF sites (33%), medium-high value OWF sites (67%) and high value OWF sites (49%), cumulating a total area of 9993,96 km^2 , 35.9-63.9 GWs.

Similarly, for the English case, the largest overlap is associated to high conflict fisheries (beam trawls/bottom seine/bottom otter trawls), accounting for 6883.3 km^2 , 24.8-44 GWs (medium OWF), 3292.2 km^2, 11.8-21GWs (medium-high OWF), 2673.2 km^2 , 9.6-17 GWs (high value OWF). Detailed tables of the resulted ACR scores, number of overlaps and area of conflict, per each OWF value site category and per country, are presented in Supplementary Figure 5.

Offshore conflicts in the planned search areas for future OWF deployments

While identifying the cold and hot spots of conflict is highly relevant for the EEZ level of strategic planning of OWFs, a discussion on the specific strategies to solve, minimize or mitigate risks can more effectively be realized at a local level. As such, we further explore the level of conflict and management strategies for the already designated areas or search areas within the English and Dutch EEZ.

Currently, the Search Areas proposed by the national governmental bodies responsible for the management of offshore activities in their respective EEZ areas, are mainly located in medium and medium-high value areas for OWFs (Figure 15). In the English EEZ case, this refers to the Offshore Wind Leasing Round 4 Characterization Areas, within biding areas 1 and 2 (The Crown Estate, 2019), while for the Dutch EEZ we consider the Search areas 1-8 proposed through the Draft North Sea Program 2022-2027(2).

The new 2030-2050 search areas for the Dutch EEZ, mapped out through the Draft North Sea Program 2022 – 2027(2), are sufficient to cover the requirements for a low energy demand of 38 GWs in 2050, resulting in an excess space equivalent to approx. 10.5 GWs. In the case of a high demand of 72 GWs in 2050, however, these proposed areas of search are still lacking approx. 23.45 GWs. Therefore, the question remains how to more efficiently use the designated areas to best balance the risks and opportunities of interaction with multiple other sea users in the low demand scenario and to identify the most suitable locations for additional areas in the high demand scenario. Using the proposed framework, we show the high level of conflict with military activities and fisheries in Search areas 2,8,4 and with nature protected areas and shipping for Search areas 6 and 7, in the Dutch EEZ (Figure 15).

For the analyzed area of the English EEZ, namely the East Offshore and North East Offshore Marine Plan areas, reaching the low 2050 targets of 75 GWs (UK Department for Business

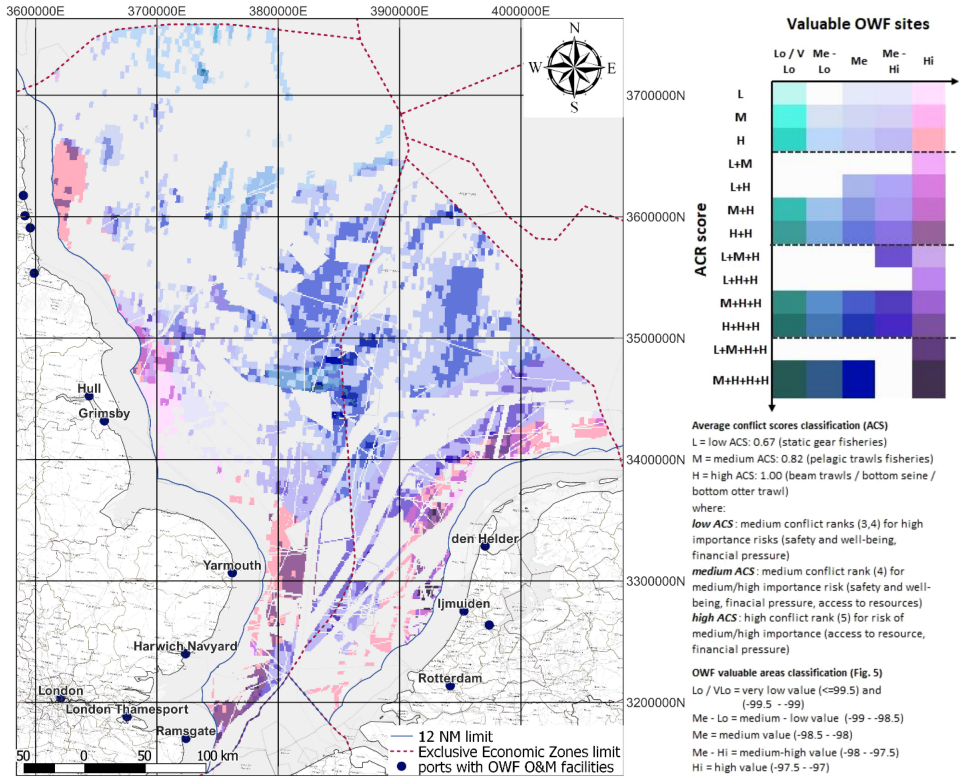

FIGURE 13
Average conflict resolution scores for the interaction between OWFs and high intensity fishing activities.

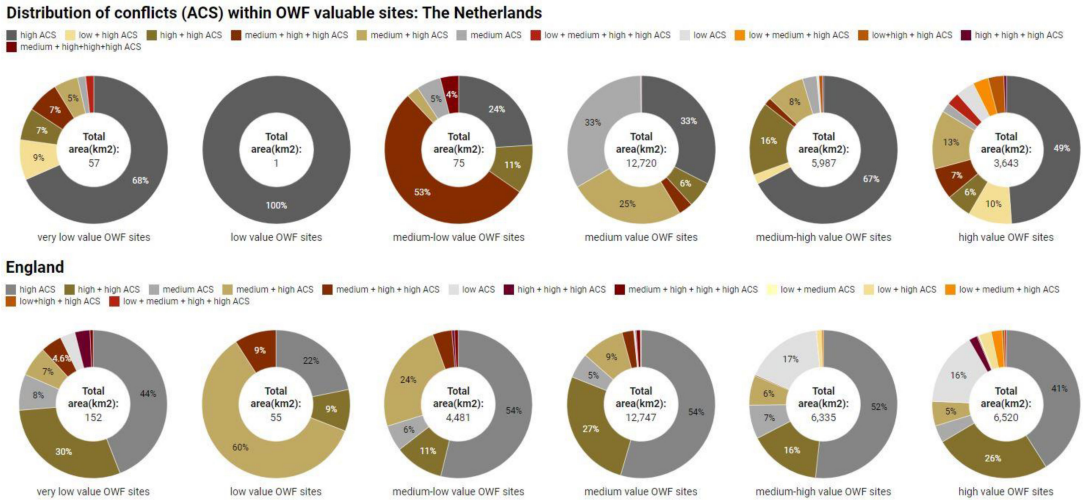

FIGURE 14
Spatial distribution (cumulated area of conflict) of conflicts (ACS) within the OWF valuable sites, for fisheries sea user group types.

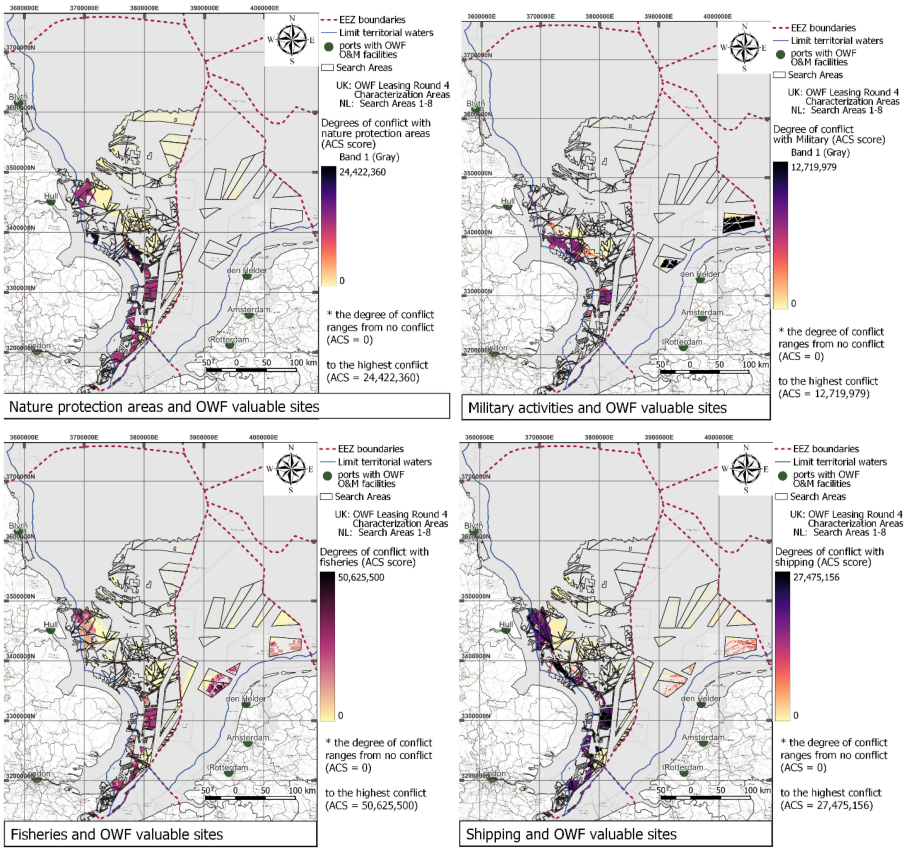

FIGURE 15
Distribution of conflict areas within the Search areas for future OWF developments, beyond 2030, by sea user.

Energy and Industrial Strategy [BEIS], 2020) or the high targets of 108 GWs (Aunedi et al., 2021) requires additional search areas for OWF deployment to accommodate an approx. capacity of 19 GWs to 37 GWs (when excluding the energy targets for Scotland, and assuming a similar trend of deployment for Wales and Northern Ireland towards 2050). This is next to the current approved and planned areas for OWFs. Accommodating the additional GWs translates into around 2.7 to 5 times more space than the currently approx. 7GWs installed.

Alternatives for the future space allocation of OWF sites

Using the proposed framework, we can distinguish between alternatives in space allocation and conflict management options, towards a more transparent and efficient balancing process between the different sectoral goals. This can contribute to the strategic planning of future OWFs in a timely manner, synchronizing the timeline of deployment with techno-economically available options to solve, minimize or mitigate potential risks of interaction. Through the proposed weighted multi-criteria framework, we distinguish between different areas in terms of: 1) difficulty to solve conflicts (higher ACS and number of spatial overlaps) and 2) the potential for OWF deployment (value of the sites for OWF development and spatial footprint in km^2 f each type of interaction).

The strategic and adaptive planning of future OWF deployment (beyond 2030) in the Dutch EEZ could be assisted by concrete maps and their related risk management options illustrating and quantifying alternatives between valuable areas of lower difficulty to access (Figure 16A)., equivalent to 8.67-15.4 GWs) and higher difficulty to access (Figure 16B., 33-59 GWs). The differences stand not only in the difficulty to access, but also in the relevance for the OWF deployment timeline, with the former located in areas closer to shore and, therefore, of immediate priority (lower investment costs in infrastructure). However, a decision in prioritizing one option over the other can also be related to the feasibility, costs and availability of the different management strategies selected for solving, minimizing or mitigating conflicts with the protected features in the two alternatives.

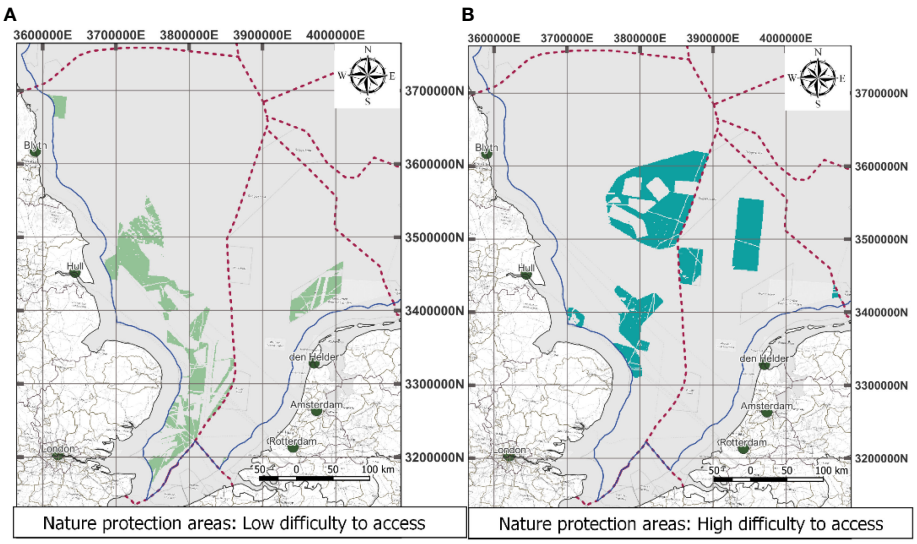

FIGURE 16
Areas of distinct focus for management strategies with nature protected sites: **(A)** low difficulty to access (low ACS/1 or 2 overlaps); and **(B)** high difficulty to access (high ACS/2 or 3 overlaps).

Similarly, for the English EEZ, using the above mentioned criteria, we distinguish between areas with lower difficulty to access (Figure 16A., equivalent of 84-149.7 GWs) and areas of higher difficulty to access (Figure 16B., 45-80 GWs). Unlocking the potential in the first category would imply mainly solving or minimizing the negative effects on mammal's habitats (in medium and medium-high valuable sites for OWFs), but also on seabed habitats and to a lesser extend fish habitats (in medium-low and medium OWF value sites). For the second case, unlocking the highest potential (12.8-22.8 GWs in medium-high and high value OWF sites) would require management options addressing effects on seabed/fish and mammal habitats.

The maps quantifying the different areas of low difficulty to access with the shipping activity (Figure 17A) reveal a dispersed pattern of interaction, concentrated in particular in the English EEZ. In those areas, solving the conflict with the passenger and cargo routes could unlock 22.4-39.8 GWs (of which 24% in medium-high and 13.7% in high value OWF areas). On the other hand, Figure 17B indicates clear concentrations of areas with a high difficulty to access (high ACS from the interaction with tanker and passenger/cargo routes), predominantly located in medium and high value OWFs, with a minimum potential for 57 GWs (Netherlands) and 85 GWs (England), under a 3.6 MWs km^2 /nsity. Nevertheless, this cumulates with requirements to manage the spatial and claims from other offshore users, such as marine protected areas, as presented in Figure 16.

For the interaction with the fishing activity, a number of key locations of low difficulty of conflict resolution (low ACS resulted from the interaction with maximum 3 fishing types) can be distinguished both in the English and Dutch EEZ (Figures 18A, B). We identified an area of 8.718 km^2 th a high level of difficulty in managing the interaction with multiple types of fishing activities within the high value OWF sites in the English EEZ. This is significantly higher compared to 1.909 km^2 f similar type of interaction within the Dutch EEZ (Figure 18C).

Main conflict resolution strategies for different types of offshore conflicts

We also identify a number of management strategies for conflict resolution between OWFs and the other existing offshore users (Supplementary Data 3). Examples of measures can rank from adapting the type of foundation to the specific conditions of protected habitats and using sound protection curtains in the installation phase, to strategic management of the OWF area with the purpose of creating a "fish sanctuary" or seabed recovery sites.

Using the ACS raster files for different sea user types, we illustrate in Figure 19 priority areas where specific conflict resolution strategies are relevant for unlocking high value OWF sites (under 50 km from shore, with a water depth over -55m), taking into account the intensity of the conflicts. Hence, Figure 19A displays areas where the priority conflict resolution measures to be considered are related to compensation of the impacted activities (beam trawls, bottom seine, bottom otter trawls) and minimization of effect by layout adaptation (to

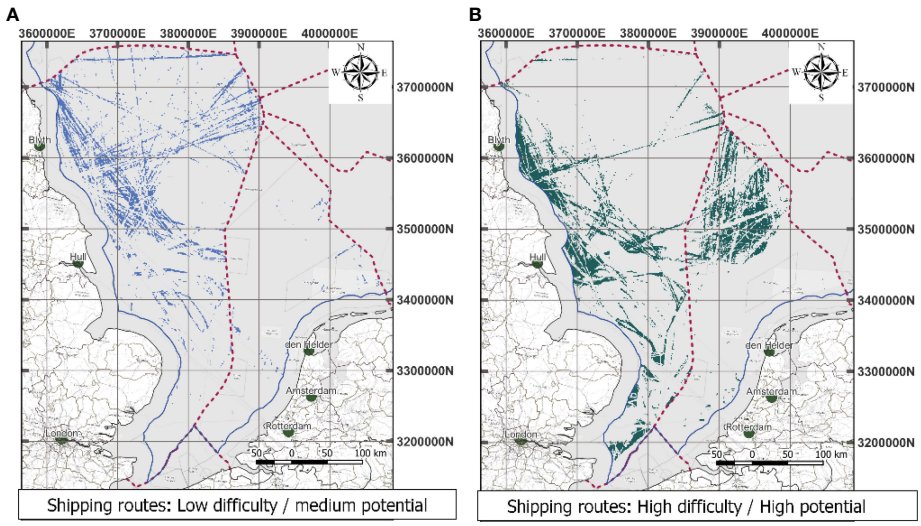

FIGURE 17
Areas of distinct focus for management strategies with shipping routes: a. low difficulty to access (low ACS from 1 or 2 overlaps)/medium potential of deployment (from 1.1 to 35GWs);b. high difficulty to access (high ACS from 2 or 3 overlaps) and high potential of deployment (from 8.4 to 67GWs).

accommodate and reduce impacts on protected habitats) while also indicating synergy with the local habitats (fish sanctuary/seabed restoration). Areas mapped in Figure 19B are indicating priority sites where measures such as layout adaptation, cable routing and turbine distancing could potentially address the conflict with pelagic trawls fisheries and static gear, over a total area of 10.522 km^2 in the Dutch EEZ and 8.160 km^2 in the English EEZ. Additionally, Figure 19C underline sites where the "passage through corridors" should be part of the management strategies in order to address the safe and smooth navigational requirements.

While for the English EEZ, the interaction with the high intensity shipping activities is distributed relatively equally in the medium and medium-high value areas for OWFs, in the Dutch EEZ those interactions take place to the highest degree in the high value OWF areas (Figure 20). This could result in two different strategies for the strategic location of future OWF large-scale deployments. For the Dutch EEZ this could entail the urge to integrate designated "passing-through" shipping corridors in the OWF layout, while for the English EEZ this could lead to a focus of the search areas further away for the busy areas close to the

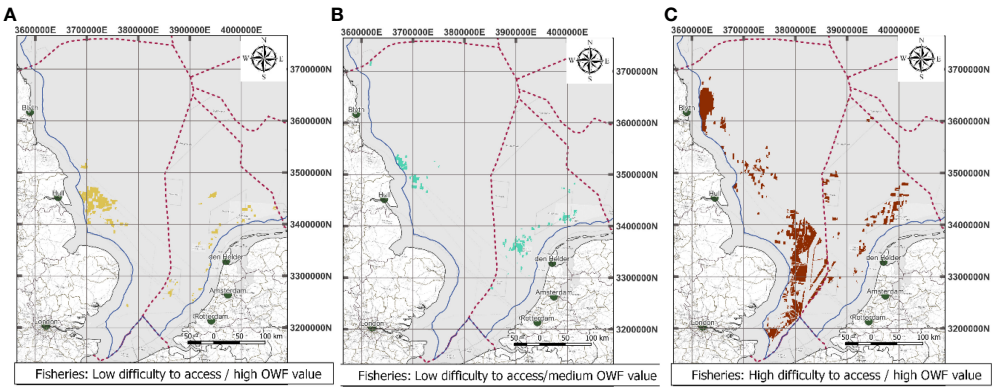

FIGURE 18
Areas of distinct focus for management strategies with fisheries: **(A)** low difficulty to access (low ACS from 1 or 2 overlaps) and high value for OWF deployment (from **(B)** low difficulty to access and medium value for OWF deployment **(C)** high difficulty to access and high value for OWF deployment.

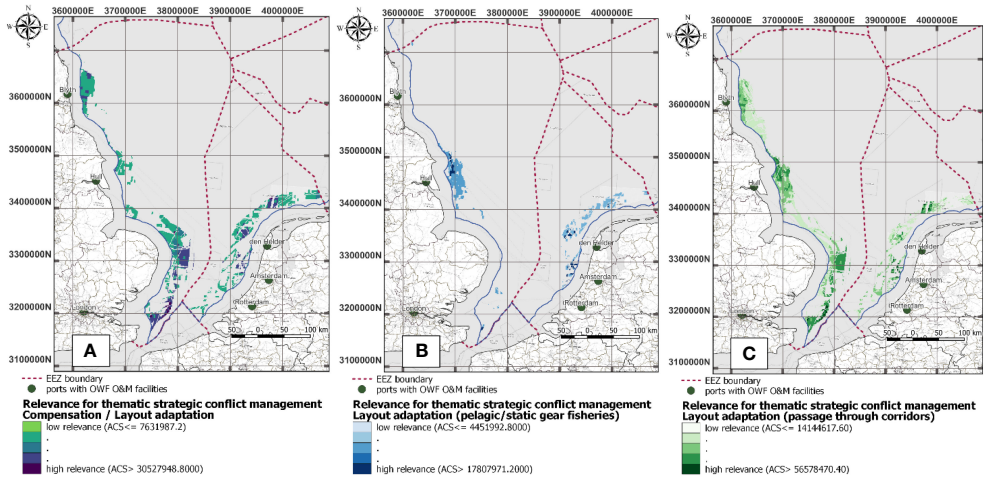

FIGURE 19
Spatial localization of priority areas (within high value OWF sites) where specific conflict resolution strategies can be relevant (based on level of conflict-ACS values and management strategies for the overlapping sea user types): **(A)** compensation (fisheries: beam trawls, bottom otter trawls, bottom seine)/layout adaptation/synergies (seabed/fish habitats); **(B)** layout adaptation/cable routing/turbine distancing (fisheries: pelagic trawls, static gears); **(C)** areas for passage through corridors (fisheries and shipping).

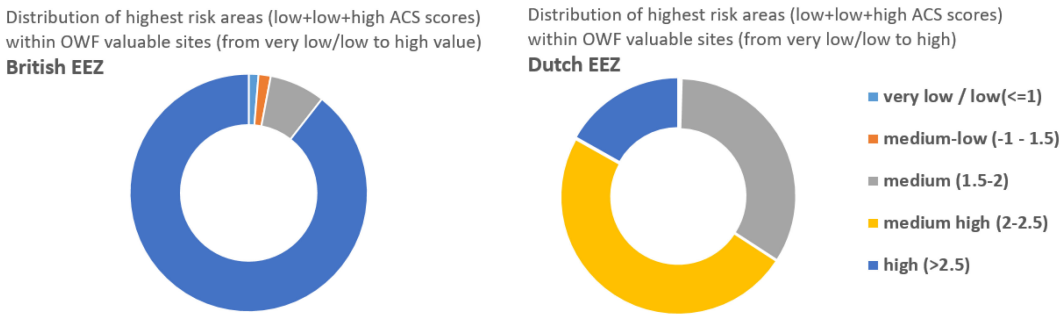

FIGURE 20
Distribution of highest risk areas for shipping activities within the OWF sites for the Dutch and English EEZ.

shore. As a consequence, for a more efficient and integrated grid, developing the energy hub in the eastern and north-eastern part of the English EEZ could prove to be a long-term preferred solution. Therefore, the proposed framework can be seen as a transparent, rigorous, knowledge-based offshore conflict management tool which can support the just and rapid deployment of the planned 212 GWs of installed OWFs (nearly 8 times 25.9 GWs installed capacity in 2021 (Wind Europe, 2021)), towards reaching the 2050 energy targets in the North Sea basin.

Discussion

The multi-criteria framework we propose in this paper may assist in MSP processes to include a more transparent and spatially detailed analysis for offshore interactions with OWF activities. Notably, by combining a spatial perspective and taking into account different sectoral objectives, the proposed framework may support MSP to promote a just and inclusive sea space management process, and to prevent delays in the authorization process towards a more rapid roll-out of RES offshore.

Unlocking valuable areas and risk management options

Using the proposed framework, we can connect risk to conflict resolution management options (addressing the precautionary principle and adaptive planning) and reduce

uncertainties by creating a tool that brings together knowledge of the cause-effect chain, to be used in decision-making. Using the ACS scores to evaluate the level of conflict with different sea user types and the spatial distribution of those conflicts within the OWF valuable sites, we can indicate which conflicts and interactions should be first addressed in order to unlock valuable sites for OWF deployment (Tables 3 and 4).

Most viable options include areas with limited conflict scores (Table 3), such as the beam trawl, bottom seine or bottom otter trawl fisheries, which would unlock 36.1-64.1 GWs in the Dutch EEZ and 55.4-99.4 GWs in the English EEZ. The management options could include not only financial compensation for reduced revenues, shared insurances for potential gear or turbine damages, but also technical solutions such as monitoring and layout adaptation. Within the nature protection area user group, the most noticeable interaction is with mammal's habitats, which covers areas equivalent to 16-28.4 GWs in the Dutch case and 52.8-93.9 GWs. However, in the Dutch case the interaction is located mainly in medium value sites for OWF deployment (99.2%) as compared to the more evenly distributed interaction for the English case (30.2%, 36%, 24% in medium, medium-high, high OWF value sites). This can lead to accelerated implementation of technical solutions (sound protection, use of gravitational foundations), particularly in the English case, in order to access the high OWF sites.

Areas much more difficult to unlock with either high ACS and multiple overlaps (or both) are presented in Table 4. Most of these types of conflicts are concentrated in areas with medium and high value for OWFs. Those are areas between 70-150 km from ports with facilities for OWF construction, O&M facilities, but also at 50-100 km from energy demand areas (urban and industrial areas), and with a water depth between -55- -120 m. Here, considering "passing through corridors" for tankers, passenger and/or cargo would unlock approx. 23.6 GWs in a multi-use scenario. On the other hand, in a single-use scenario, where shipping routes will be deviated for the location of OWFs, collaborating with the shipping industry on logistics of alternative shipping routes or compensation for longer shipping distances could unlock approx.135.6 GWs in the Dutch EEZ. This would require technical and logistic solutions such as layout adaptation for "passing through corridors", or negotiation of safety distances with the shipping industry.

The highest levels of conflict with the military activities are located for both case studies in high value OWF sites. The management of the interaction with lower radar space (fill-the-gap options, layout design to incorporate radar equipment), could unlock 11.8-20.9 GWs in the English high value sites (86.9%) for OWFs, while accessing the military areas for shooting/flying (currently forbidden access, subject to relocation) could unlock 10.1-18 GWs in medium-high (31.5%) and high (68.4%) OWF sites, in the Dutch EEZ.

The concentration of high conflicts in medium value sites for OWF deployment indicates not only the depletion of options in high value OWF sites (closer to the shore, in shallow waters), but

TABLE 3 Distribution of areas with low difficulty to unlock (low ACS and 1 or 2 overlapping interactions), with a medium or high OWF development potential (minimum 6 GWs installed capacity), within OWF valuable sites (VL-very low/L-low; ML-medium-low; M-medium; MH-medium high; H-high).

interaction by sea user type in each country		% of area overlap in each category of OWF valuable sites					area of overlap (km^2 and potential installed capacity (GWs) in 2 management options (multi-use: 3.6 MWs/; single-use: 6.4 MWs/km^2)	Cumulated ACS value
		VL/L	M-L	M	M-H	H		
NL	Shipping: passenger/cargo	0.3	0.2	49.6	21.4	28.5	4,815 (17.3 - 30.8 GWs)	0.6
	Nature protected areas: birds habitats	0.0	0.0	0.0	73.1	26.9	1,830 (6.6 - 11.7 GWs)	0.85
	Nature protected areas: mammals	0.3	0.5	99.2	0.0	0.0	4,432 (16.0 – 28.4 GWs)	1
	Fisheries: pelagic trawls	0.0	0.1	94.1	4.2	1.7	4,488 (16.2 – 28.7 GWs)	0.82
	Fisheries: beam trawl/bottom seine/ bottom otter trawl	0.4	0.2	41.3	40.3	17.8	10,016 (36.1 – 64.1 GWs)	1
ENG	Shipping: passenger/cargo	0.1	12.9	54.9	19.4	12.6	5,545 (19.9 – 35.4 GWs)	0.6
	Nature protected areas: seabed + fish habitats	0.1	61.6	24.9	13.2	0.2	8,727 (31.4 – 55.9 GWs)	1.37
	Nature protected areas: mammals	0.3	9.3	30.2	36.1	24.1	14,675 (52.8 – 93.9 GWs)	1
	Military: air-to-air refueling	0.1	34.9	41.3	18.3	5.5	13,855 (49.9 – 88.7 GWs)	0.6
	Fisheries: pelagic trawl	0.7	15.1	41.7	27.9	14.6	1,679 (6.0 – 10.8 GWs)	0.82
	Fisheries: static gear	0.2	0.0	2.1	49.5	48.2	2,172 (7.8 – 14.0 GWs)	0.67
	Fisheries: beam trawl/bottom seine/ bottom otter trawl	0.4	15.7	45.1	21.3	17.4	15,380 (55.4 – 99.4 GWs)	1

TABLE 4 Distribution of areas with high difficulty to unlock (high ACS/2 or more overlapping interactions), with a medium or high OWF development potential (minimum 6 GWs installed capacity).

	interaction by sea user type in each country	% of area overlap in each category of OWF valuable sites					area of overlap (km^2 and potential installed capacity (GWs) in 2 management options (multi-use: 3.6 MWs/; single-use: 6.4 MWs/km^2)	Cumulated ACS value
		VL	ML	M	MH	H		
NL	Shipping: passenger + cargo + tanker	0.2	0.3	33.8	49.0	16.8	2,317 (8.3 – 14.8 GWs)	2.2
	Shipping: passenger/cargo + tanker	0.1	0.4	74.0	18.8	6.6	7,008 (25.2 – 44.9 GWs)	1.6
	Military: shooting/flying area forbidden access	0.1	0.0	0.0	31.5	68.4	2,810 (10.1 – 18.0 GWs)	0.57-1
	Fisheries: beam trawl + bottom seine/bottom otter trawl	0.2	0.4	38.2	50.6	10.6	1,899 (6.8 – 12.2 GWs)	2
	Fisheries: pelagic trawl + beam trawl/bottom seine/ bottom otter trawl	0.1	0.0	76.9	11.8	11.2	4,181 (15.1 – 26.8 GWs)	1.82
ENG	Shipping: passenger + cargo + tanker	1.3	1.7	7.6	0.0	89.4	3,316 (11.9 – 21.2 GWs)	2.2
	Nature protected areas: fish+ seabed + birds habitats	0.2	0.0	99.8	0.0	0.0	8,670 (31.2 – 55.5 GWs)	2.22
	Nature protected areas: fish/seabed + mammals habitats	0.5	0.0	6.2	49.7	43.6	3,575 (12.9-22.9 GWs)	1.65 - 1.72
	Military: lower airspace radar	1.3	0.0	0.0	11.8	86.9	3,272 (11.8 – 20.9 GWs)	1
	Military: air to air refueling + aerial tactics	0.2	0.0	0.0	2.2	97.6	1,827 (6.6 – 11.7 GWs)	1.4
	Fisheries: pelagic trawl + beam trawl/bottom seine/ bottom otter trawl	0.3	35.2	38.8	13.3	11.4	3082 (11.1 – 19.9 GWs)	1.82
	Fisheries: beam trawl + bottom seine/bottom otter trawl	0.7	7.3	51.4	15.1	25.3	6571 (23.7 – 42.4 GWs)	2

also the unlocked potential for areas further from the shore, with a lower degree of conflict, in particular with shipping and military activities. Focusing on less valuable OWF sites (deeper waters, further from shore), as a result of the roll-out of technologies such as floating OWFs or the development of energy hubs, could benefit from lower levels of conflict with a lower number of sea users.

Methodological reflections

The main advantage of the method proposed is a transparent, rigorously knowledge-based and consistent framework to quantify and quality for the diverse and interlinked claims in the offshore space, taking into account sectoral objectives, reflected in both spatial and non-spatial risks and opportunities for the interaction with OWF infrastructure. We rely as inputs on an extensive literature review (scientific papers, industrial and governmental reports, environmental impact assessments, expert judgement from previous studies (Gușatu et al., 2021)), in order to identify and quantify the specific risks and management strategies for offshore interactions.

Nevertheless, our approach also has its limitations. For one, our input is derived from existing research, policies, regulations and geospatial knowledge of the presence of activities/species. Secondly, while our approach to ranking and weighing is based explicitly on existing sectoral objectives and preferences, exact ranking and weighing may well be subject to altering choices between both stakeholders and through time. Our approach, however, also allows for such changes. Both data input, assumptions and thus, assigned ranks and weights may be altered. In doing so, there is clear scope for alterations and possible improvements, for example in response to a changing legal and policy environment, differing stakeholder perspectives, but also information on the dynamic character of the analyzed activities. This may, for example, allow for input from different stakeholders, changes due to legal processes (such as the designation of new marine protected areas, changing of the status or re-drawing the boundaries of protected sites), or seasonality of activities, since the intensity or routing of fishing or shipping activity has a changing pattern in the four seasons. By involving a multitude of stakeholders and representatives of the analyzed sectors in the primary steps of the data inputs, the proposed framework could benefit from site-specific and sector-specific knowledge. More specifically, input from sector representatives could contribute in better defining the spatial location of valuable sites or routes for the four analyzed activities, but also in better defining and weighting the risks and opportunities related to the interaction with the OWF sector. Examples of potential improvements in representing

the valuable sites for the analyzed activities are: fish markets for fishing activities or preferred routes to access the valuable grounds (Holmes et al., 2020), migration routes for fish species, mammals, birds and bats, routes linking the on-land military basis and the designated military sites, etc. Finally, also limitations related to input data, such as the uneven knowledge regarding the interaction between the different sectors and OWFs (there is more research on OWF- fisheries and protected areas, than it is on OWF-shipping and military) may prompts improvements. Currently, there is a clear preference in recent scientific literature for analyzing the potential multi-use with fisheries and protected areas as compared to shipping and military activities, potentially linked to the willingness and urgency of the different sectors to mediate and collaborate towards joint solutions. Despite the noted limitations, our proposed framework offers a comprehensive approach to human activities and users of the marine space, linking ecological, socio-economic and technological consequences with spatial claims. The proposed framework of analysis can be used with different input parameters, assumptions and weights, depending on the impacts/effects of technological advancements and lessons from best practices in the interaction between offshore activities. As such, it can easily be fine-tuned to include improvements and variations following alternative perspectives and future research.

Conclusions

A first key contribution of the framework we propose is to identify valuable areas for OWFs that may be unlocked, and which risk management options may be applied in doing so. When focusing on large-scale deployments in the Netherlands, the largest potential (cumulated area of interaction and value of OWFs areas) concentrates in medium value OWF sites, where the biggest trade-offs involve OWFs and mammal habitats, tanker routes and pelagic or trawls/bottom seine/bottom otter trawls fisheries. In the English case, the spatial location of conflict is more evenly distributed across OWF value sites, with most trade-offs assigned to seabed/fish and birds' habitats in medium value OWFs, to tanker routes in medium and medium high OWF value sites, and to beam trawls/bottom seine/bottom otter trawls in medium-low through high value OWF sites.

With a lower presence in medium value OWFs, military activities are mainly claiming high value OWF sites, predominantly areas for flying in the Dutch EEZ and lower radar space zones in the English EEZ. However, with the availability of new technologies such as floating OWFs, the focus for OWF deployment might switch to currently less valuable OWFs sites (deeper waters). Also, areas further from shore might present a viable alternative for locating OWFs (north of the Dutch EEZ), as those display lower levels of conflict with other sea users.

Taking a comprehensive approach is, we argue, crucial as multiple users claiming the same space will imply a multitude of conflicting situations, each relying on different safety and operation rules, national or international laws and each prioritizing their own sectoral goals. During the authorization process, this complex interaction leads to project uncertainty and increased risk of delay or failure in implementing offshore wind projects. The proposed multi-criteria analysis framework relies on a robust knowledge basis for informing strategic spatial policy development in the allocation of space for OWFs. The robustness of the framework lies part in the input of policy considerations and stakeholder interests, also in part in the detailed spatial data and finally, in its capacity to be adapted to new knowledge or altered perspectives on interactions between sea uses and related conflict management strategies. We used our framework to quantify and qualify a number of key potential trade-offs between OWFs and four sea user groups. Moreover, through the identified solving/minimization/mitigation options, the strategic policies are provided with inputs not only on where the conflicts occur, but also how those can be dealt with. Applying this framework at a local or regional level can underpin future standardized practices, part of a timely, transparent and participatory decision-making process, in identifying and qualifying alternatives for the future OWF developments. This is of key relevance as it can provide the basis for further negotiations and discussions with various stakeholder groups that are less focused on prioritizing their own sectoral interests, but rather are interested in shared policy agreements that capture synergies and work with shared goals towards the sustainable, integrated, ecosystem-based and adaptive use of the marine resources.

The high ambitions of deploying over 212 GWs of OWFs in the North Sea basin by 2050, approx. 8 times more the 25.9 GWs installed capacity in 2021 (Wind Europe, 2021), will undoubtedly result in conflicts over the limited offshore space. The currently operational and the planned (by 2028) OWF areas are cumulating approx. 42.3 GWs and will occupy an area of approx. 9,722 km^2 The additional space to be claimed will involve multiple spatial conflicts, in particular with tanker routes, mammal habitats, military areas with forbidden access and trawler fisheries (beam, bottom seine, bottom otter) in the Dutch high, medium-high and medium value sites. Similarly, the spatial conflicts with passenger/cargo routes, mammal habitats, lower airspace radar areas, trawler fisheries (beam, bottom seine or bottom otter) will most compete with OWFs for space in the English OWF high, medium-high and medium value OWF areas. It is such knowledge that may prove crucial considering the future ahead of us. Thus, from a policy perspective, future OWF space allocation can clearly benefit from applying the proposed framework, while such an application may even challenge the suitability of the existing planned sites.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

LG, CZ, and AF conceived the ideas and designed the methodology. LG collected and performed the formal analysis of the data, realized the maps and graphs. LG wrote the first draft. LG, CZ, and AF participated in the review and formulation of the final draft. CZ and AF provided supervision. All authors contributed to project administration, edited the manuscript and gave final approval for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.959375/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Qualification and quantification of conflicts using the average conflict resolution scores (ACS), areas of overlap and number of interaction, for the interaction between OWF valuable sites and nature protected areas.

SUPPLEMENTARY FIGURE 2
Localization of analyzed sea user types within the OWF valuable sites and ACS scores of interaction with OWFs – Nature protected areas.

SUPPLEMENTARY FIGURE 3
Localization of analyzed sea user types within the OWF valuable sites and ACS scores of interaction with OWFs – Military activity areas.

SUPPLEMENTARY FIGURE 4
Localization of analyzed sea user types within the OWF valuable sites and ACS scores of interaction with OWFs – Shipping routes.

SUPPLEMENTARY FIGURE 5
Localization of analyzed sea user types within the OWF valuable sites – Fisheries.

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Global blue economy governance – A methodological approach to investigating blue economy implementation

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The proliferation of the blue economy in political discourse has gained traction in recent years, however, there remains no standardized definition. The triple bottom line goals of economic development, social equity, and environmental conservation are at the center of the blue economy vision. Yet the ambiguities surrounding the term have resulted in considerable variation in how the blue economy is implemented and what is prioritized. This paper takes a global snapshot of current approaches to national level blue economy governance. In doing so this paper provides the first global assessment of blue economy implementation approaches, through the development of a global blue economy database. Using the best available information from policy documents, media releases and other publicly available online information, we comparatively analyzed each country's governance strategy to assess the level of blue economy development in coastal states around the world. Throughout this paper we outline the novel methodological approach we took in order to develop a tool for analyzing national level blue economy implementation on the global scale. This approach will allow for ongoing and continued analysis of blue economy operationalization as the concept continues to evolve.

KEYWORDS

blue economy, governance, policy, implementation, methodology, operationalization

Introduction

The blue economy has gained traction in international and regional discourse and governance throughout the past decade (Mohanty et al., 2015; OECD, 2016; Patil et al., 2016; Mulazzani and Malorgio, 2017; Bennett et al., 2019). Despite the prominence of the term in international and national fora and programs (Bank, W2017; FAO, 2017; Nations, U, 2022a), the blue economy as a concept remains poorly defined and largely under implemented at a national level (Voyer et al., 2022). This renders the blue economy at risk of becoming a political tool rather than a tool to achieve practical objectives and advance ocean health, economic development, and social equity (Brent et al., 2020; Fabinyi et al., 2021; Louey, 2022). Given the increasing urgency of addressing the decline in ocean health, and the continued growth of ocean industries, translating high level conceptualizations of the blue economy into operational implementation and reviewing this implementation for future adaptation should be a high priority.

This paper is primarily concerned with the development of a practical assessment tool of blue economy implementation. The conceptual approach of developing a methodology to assess the extent and substance of blue economy implementation globally is grounded in the review of current literature on what should constitute a blue economy with consideration of the inclusion of triple bottom line objectives (environmental, economic, and social). This approach also recognizes the fundamental importance of governance to achieving sustainable development (Foley et al., 2020; Parlee et al., 2021; Stephenson et al., 2021), by embedding an assessment of governance arrangements within the methodological design. Governance is widely recognized as a critical component of sustainable development, and in some instances is nominated as a fourth pillar of sustainability (Foley et al., 2020; Parlee et al., 2021). Whilst governance encapsulates a broad diversity of formal and informal mechanisms aimed at enabling, supporting, or leading sustainability outcomes, in practice it remains a complex concept (Stephenson et al., 2021). For the purposes of this research, we have focused primarily on formal government interventions as a key component of governance more broadly.

Accordingly, the methodology proposes three criteria of blue economy development: evidence of policy development, integration of economic, social, and environmental dimensions of sustainable development, and assessment of the degree of implementation. We focus on enabling conditions such as governance arrangements, tools, plans, and financial mechanisms as evidence of implementation (Cisneros-Montemayor et al., 2021). Finally, we use case studies to test the effectiveness of the methodology. We also present preliminary results on the global status of blue economy implementation at the national level. The following sections outline the three criterion of blue economy development.

Policy development

One of the accepted first steps in developing and implementing a blue economy is to create governance arrangements to support it. There is no clear "standard" of blue economy governance at present (Voyer et al., 2022). However, a clear articulation of the blue economy, including the sectors which fall within it, and the development of a blue economy policy that is embedded within existing governance arrangements are important components of a blue economy in operation (Voyer et al., 2021a).

At the most fundamental level this may simply involve a national level commitment to the development of a blue economy through political statements, or through becoming signatory to regional or international commitments related to the blue economy, such as the recent ASEAN Leaders Declaration on the Blue Economy (ASEAN, 2021). Global and regional agreements, guidelines and discussions provide important drivers and context for blue economy planning at a national scale, as well as advancing efforts to harmonize blue economy efforts across international borders. For example, organizations such as WWF (2015) and UNEP (Vestergaard, 2022) have put forward high level guidelines outlining how the blue economy might be defined and implemented and there have been further calls for international guidelines or agreements (Bennett et al., 2019). However, while regional or international governance can be a driver of the operationalization of a blue economy, there are often barriers at a national level that can impact the level of meaningful implementation. Keen et al. (2018) argue that:

'External influence, often through regional and international roadmaps and policies, can help guide the development of a Blue Economy, but achieving sustainability still depends on national commitment, cultural fit, relevant capacity, and policies. A considerable degree of change and political commitment can be required to develop and implement regional policies at a national or local level'.

The translation of political statements or commitments at international forums into national level action is therefore a significant contribution towards ensuring that a blue economy is developed in a contextually sensitive way, consistent with national level priorities, culture and capacity (Voyer et al., 2021a). This might include incorporation of blue economy objectives into established policy or the development of a dedicated blue economy policy, plan, or strategy.

Integration of economic, social, and environmental dimensions of sustainable development

Despite numerous efforts to define a blue economy (Mohanty et al., 2015; Silver et al., 2015; Smith-Godfrey, 2016;

Voyer et al., 2017; Kildow, 2021; Martínez-Vázquez et al., 2021) there are ambiguities surrounding the term. This has ensured that there is considerable difference not only in the way that the blue economy is conceptualized, but in how it is implemented and what is prioritized (Voyer et al., 2018). Despite these differences, most blue economy definitions incorporate, at a minimum, a consideration of social, environmental, and economic objectives. For example, the World Bank defined the blue economy as '*the sustainable use of ocean resources for economic growth, improved livelihoods and jobs while preserving the health of the ocean*' (Bank, W, 2017). Keen et al. (2018), show that at its core the blue economy concept should '*aim to balance sustainable economic benefits with long term ocean health in a manner which is consistent with sustainable development and commitment to intra and inter-generational equity*'. Any definition or articulation of a national level blue economy approach must therefore include social, economic and environmental dimensions of sustainability at a minimum (Bennett et al., 2019). The integration of economic, social, and environmental dimensions is consistently recognized as critical to sustainable development across all UN Member states (Sachs et al., 2022) and would align blue economy governance with the UN Sustainable Development Goals (SDGs) as well as the work by the High-Level Panel for a Sustainable Ocean Economy (Stuchtey et al., 2020; Winther et al., 2020).

Whilst the blue economy has largely been accepted as a model for advancing 'triple bottom line' objectives, in practice there have been growing critiques that it is in danger of failing to adequately deliver on these objectives outside of economic development (Childs and Hicks, 2019; Cisneros-Montemayor et al., 2019; Brent et al., 2020; Cisneros-Montemayor et al., 2021). Without attention to how all three pillars of sustainability are being embedded within blue economy governance, the success of the blue economy in achieving the triple bottom line objectives will be impacted. As such objectives need to be matched with practical, time bound and funded actions or targets with accountability mechanisms such as monitoring and reporting to ensure sustainability ambitions are realized.

Implementation of the blue economy

As this paper is concerned with methodological approaches to assessing the implementation of the blue economy, it is critical to understand what implementation involves. The availability of natural capital is not a sole factor that impacts the countries' capacity to develop their blue economy, but other factors such as socio-economic conditions and governance capacity are critical (Cisneros-Montemayor et al., 2021). Strategies for implementing the blue economy across government and non-government sectors include dedicated governance structures that provide for whole-of-government institutional coordination and policy coherence, financing, monitoring, reporting and the development of operational plans for key strategic priorities such as communication, capacity building, financial accountability, stakeholder involvement and public-private partnership (Winther et al., 2020). Obtaining finance and investment in relation to activities that are relevant to ocean sectors is further evidence of implementation of a blue economy (Benzaken and Hoareau, 2021; Voyer et al., 2021a).

Current methods to assess blue economy development

At present there is no consistent and easily comparable approach to assessing the different means and approaches of blue economy development and implementation. Against such backdrop, this paper seeks to develop a method that allows us to assess the level of institutionalization and implementation of the blue economy at a national level, on a global scale. Understanding the ways in which (and the extent to which) the blue economy has been implemented at the national level and recognizing the trends for different levels implementation and operationalization is becoming increasingly important, as the concept continues to grow in popularity and the pressures on the world's oceans become increasingly apparent (IPCC, 2019). Our research contributes to this by providing a global snapshot of the 'state of play' of the real-world application of the blue economy.

Other methodological tools have been developed to assess other aspects of the blue economy. For example, Voyer et al. (2022) looked at the level of blue economy institutionalization in Commonwealth countries. Their work examined different facets of the blue economy in operation to from an understanding of governance, as well as priority sectors throughout the Commonwealth with a focus on alignment to SDGs and the Commonwealth Blue Charter. Although there is no universal definition of governance, it encompasses concepts, practices, policies, and institutions by which societal development is overseen (Rudolph et al., 2020). For this paper, the focus is on aspects of governance which enables blue economy implementation and are commonly accepted in international sustainable development contexts, including SDG 16 (transparent and accountable institutions) and SDG 17 (institutional coordination and policy coherence). Additionally, Cisneros-Montemayor et al. (2021) used available global data to quantify and map the capacity of countries to develop a blue economy. Their assessment was based on not only resource availability but also enabling conditions—namely social equity (such as human rights and gender equity), environmental sustainability, and economic viability (such as infrastructure and investment opportunity). Although similar in scope to this research, the study by Cisneros-Montemayor et al. (2021) assessed a country's capacity to establish a blue economy. Our research complements this work, by looking at what countries

have actually done in terms of establishing and implementing the blue economy.

A classification tool, *the Blue Economy Development Index*, has also been developed by Adrianto et al. (2019) to assess the level of development of the blue economy in archipelagic and island states. This tool was developed in recognition of the need to track and monitor the use of marine resources in relation to sustainability and looks at the degree of importance of the blue economy to a particular jurisdiction. In doing so it looks at ocean capital (such as the quality of the resources) and enabling factors (such as governance and technology). It also examines the degree of impact of the blue economy on each jurisdiction. This is measured through social and economic capital, which involves inclusivity and equity, and sustainable growth which focuses on the employment rate, income distribution and the ocean economy (Adrianto, 2022). A cumulative score is then given to each country based on these factors to determine the level of blue economy development. The *Blue Economy Development Index* is particularly interested in how ocean resources are being used in relation to the blue economy. The model that we put forward draws on the work done by Adrianto et al. (2019) and Cisneros-Montemayor et al. (2021), but focuses on the level of engagement, policy development and operationalization of a sustainable blue economy (that is, one incorporating social, environmental, and economic dimensions) from a governance perspective. It is intended to be a simple and practical method by which to compare and analyze national approaches on a global scale.

In the next section, we outline the methodology that we employed to develop a system of categorization by which to assess the level of global blue economy implementation. The methodological approach advances current approaches to assessing blue economy implementation and operationalization. This method was tested through its application to a global assessment of national level blue economy implementation, and further explored through detailed case studies of four national responses to the blue economy.

Method

Building on the previous analysis of blue economy development in Commonwealth countries by Voyer et al. (2022), as well as the work by Adrianto (2022) and Cisneros-Montemayor et al. (2021), we developed a methodology by which to assess and categorize the level of blue economy development at a national level. This methodology relies on two schemes: the development of a global blue economy database; and the creation of a categorization tool. An overview of our approach can be seen in Figure 1 and will be described in detail in the following sections.

Developing the Global Blue Economy Database

The Global Blue Economy Database (GBED) is a collation of country by country publicly available information that details each country's blue economy activities across a range of areas such as policy, governance, sector-based activities, international engagement, planning and finance. The first step to develop the database was to group all UN member states into five regional groups based on the classifications used by the UN Department for General Assembly and Conference Management (DGACM)

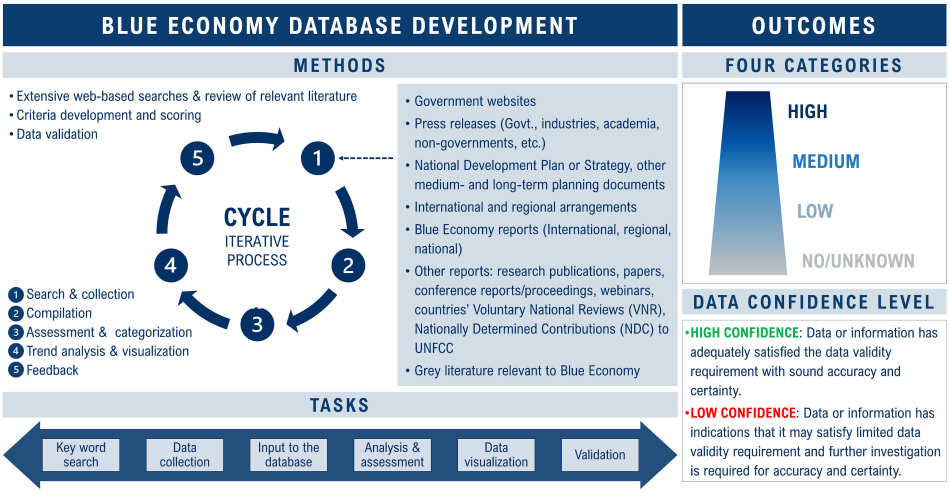


FIGURE 1
Description of the methodology.

(Nations, U, 2022b). Each state was then classified as either coastal or non-coastal. We included information on the size of the Exclusive Economic Zone (EEZ) and development status (developed, developing, least developed country), based on data from the United Nations Commission on Trade and Development (UNCTAD) (UNCTAD, 2022). This information was included as a way to identify potential trends of the Blue Economy in relation to capacity.

We then conducted a desktop review of the available web-based information to gather data on the blue economy in each of the 193 UN member states. This was initially undertaken using a key word search, which included terms such as 'blue economy' and 'blue economy policy' and related terms such as 'blue growth', 'ocean economy', 'ocean policy' 'maritime economy', 'maritime policy' 'marine economy' and 'marine policy'. The key word search was not limited to 'blue economy' as we felt that this may limit the inclusion of countries that do not explicitly use the term in relevant plans or policies. This inclusive approach to key words was chosen to reflect a range of different articulations of the blue economy concept in different countries. Data and information were included in the database if they were: a whole of government plan, policy, or strategy; incorporated clear sustainability objectives; and related to affairs relating to coasts and oceans at a national scale including land-based policies with a marine component such as an initiative to reduce marine pollution. On the other hand, the database does not consider any land-based policy in the absence of its relevancy to the ocean, for example terrestrial renewable energy; and a plan or policy that is focused on a sub national scale or developed by non-government actors, unless this was done so on behalf of, or endorsed by the national government. Using this approach, we were able to collate information on national ocean initiatives and governance relevant to their blue economy.

The web-based search also targeted publications on blue economy from a national perspective, including policy documents, official press releases and reports. For example, Blue Economy reports such as Partnerships in Environmental Management for the Seas of East Asia -National State of Oceans and Coasts - Blue Economy Growth (PEMSEA-NSOC), the World Bank Blue Economy related reports (2019-2022), and the annual EU Blue Economy Report were examined. Other relevant information that detailed or informed blue economy development also included research publications, papers, conference reports/proceedings, webinars, the Voluntary National Reviews on the Implementation of the 2030 Agenda, (VNRs), Nationally Determined Contribution to the United Nations Framework Convention on Climate Change/UNFCC (NDCs), national development plans or strategies, as well as other medium and long-term planning documents, and whenever accessible, grey literature relevant to countries' blue economy status. In the absence of specific blue economy information, these documents can provide useful information on the progress of national development relating to oceans and coasts—for example VNR reports can shed light on the implementation of SDG 14 at a national level.

Information was compiled for each country based on relevant topics which represent blue economy development and operationalization at the national level. These include specific information on the existence of a blue economy policy, plan, or strategy; institutional frameworks; financial resources; action plans; international engagement with blue economy activities; alignment of blue economy objectives to SDGs; and other examples of engagement with blue economy activities that promote accountability, transparency and coherence in sustainable financing mechanism (UNEP, 2018; Blasiak et al., 2019; Bank, W, 2021). These topics are often considered relevant for good governance, including indicators developed by the World Bank (Kaufmann et al., 2010), the OECD indicators for policy coherence (OECD, 2019), and the 11 principles for effective governance for sustainable development adopted by UN Economic and Social Council in 2018 (Committee of Experts on Public Administration, 2018).The information complied becomes illustrative of the criteria that we develop for categorization. This process of information gathering allowed us to gradually populate the GBED with adequate information that enabled us to conduct the assessment process. We adopted a 'more is more' mindset and were not restrictive in the information that we included. We worked out what information was relevant to our approach as we developed the categorization tool. Following this, we undertook a country-by-country assessment using criteria for categorization (outlined below) which allowed for the identification of the level of blue economy development in each UN Member state. Accordingly, through a process of data visualization we were able to conduct trend analysis by examining patterns of commonality and difference between countries and regions. We also held a series of workshops with the research team (the authors of this paper) to refine the objectives of the database and to develop the criteria for classification.

These steps follow an iterative process that can be repeated over time to refine, validate, and update the information in the GBED. At the time of preparing this paper, we have completed at least two cycles of database assessments and updates. This iterative approach to the methodology is effective given the rapidly changing status of blue economy development globally (Guerreiro, 2021). The open-ended nature of the methodology is an invitation to a participatory approach to developing a global database that could be further facilitated through an online platform similar to that of the SDG Dashboard (Sachs et al., 2022).

Rationale for the blue economy criteria for categorization

At the heart of this assessment process is a categorizing tool—in the form of criteria and a related scoring table—that

enables the identification and classification of the level of progress of blue economy development. Based on the scores achieved in relation to these criteria, we place each country into one of four categories: *High, Medium, Low, No/Unknown* Countries are placed into the 'unknown' classification when sufficient data or information cannot be found or is inaccessible (including when the information is not available in English). This method of categorization is not intended to provide a rigid or fixed mark on a country's blue economy development status, but it is indicative of best estimate value along a continuum of blue economy development level.

As this study is based on the availability of web-based data and information (in English) we recognize that there are limitations on the completeness, accuracy, and reliability of current information. However, we have addressed this limitation by labelling the data and information collected into two data confidence levels: high and low. When relevant information appears to be lacking or is not publicly available or available in English, we argue that it shows limited data validity and label it as low confidence. Information is classed as high confidence where it is readily available from a reputable source such as Government, the United Nations, or World Bank websites. In order for low confidence data to be classed as high confidence, further investigation to confirm the accuracy of the information would be necessary. We recognize that this is a continually evolving area, particularly in relation to governance. As such, the database and categorization tool that we have developed is the first step in creating an open-ended platform that can be updated iteratively.

The development of the criteria was a central component of this methodological approach as it was through this method that we were able to construct a way to assess the level of blue economy development in each country. To enable analysis and assessment of the countries on the global blue economy database we developed a set of criteria as shown in Figure 2.

Before explaining the scoring for each criterion, it is important to note that a Score of 0 in each of the three criteria indicates 'no or unknown' and is given to a country in a situation where there is no indication that any of the requirements listed in Criterion 1, 2 and 3 have been satisfied. In this situation a score of 0 is awarded, meaning there is an absence of evidence of blue economy development in that country. For some countries this score may be awarded as they are land-locked and as such have limited engagement with blue economy activities. This score is also awarded when information is not publicly available and therefore a conclusion cannot be reached.

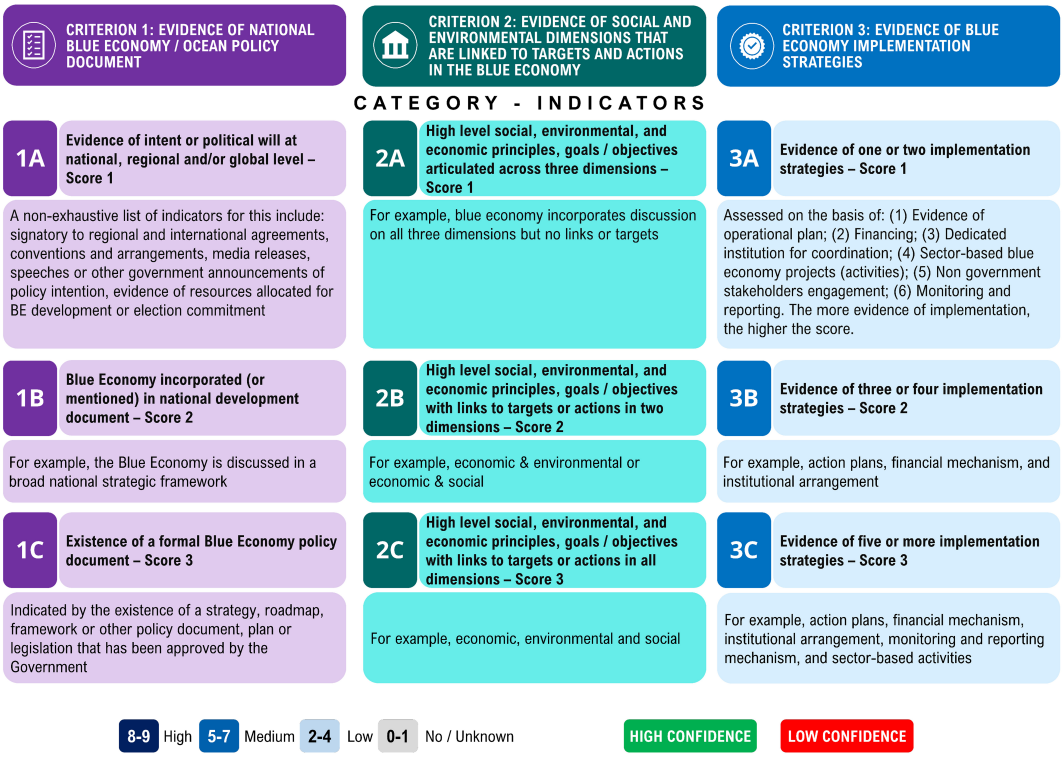


FIGURE 2
The criteria and scoring. .

Criterion 1: Evidence of National Blue Economy/Ocean Policy document

This criterion seeks to identify whether the country has a national level Blue Economy (or ocean) policy document, and the level to which such document outlines a plan of action concretely showing how the country intends to manage the development of its coastal and ocean space.

As discussed above, the existence of a policy document is an essential component of blue economy implementation (Voyer et al., 2021a). A national blue economy policy document will guide the development and conduct of programs and provide a point of reference and shared objectives for government and non-government stakeholders to prepare, plan and execute the policy into operational level activities. For the purposes of this database assessment, we did not distinguish between a blue economy policy and other commonly used integrated oceans policies, such as a National Ocean Policy. The most important consideration is whether the policy document establishes the capacity to govern and manage economic activities in the coastal and ocean space, based on the principle of sustainable development with the incorporation of social and environmental dimensions. The existence of a policy document at the national level is also useful for accountability and transparency purposes, as it places pressure on the country to monitor, evaluate and report the policy implementation. In practice, many different ocean governance tools designed to manage multiple activities in countries' coastal and ocean areas are used to achieve similar objectives related to the blue economy concept. The scoring guide for the assessment of **Criterion 1** is as follows:

* Score 1 (Category 1A – Evidence of intent or political will at national, regional and/or global level) is given to a country that indicates a political willingness or intention from government to develop a blue economy policy, plan, or strategy. This intention may be expressed at a national, regional, and/or global level. Examples of intent or political will include: government signatory in regional and international agreements, conventions and arrangements, government media releases, speeches or announcements endorsing the blue economy, or other evidence of government engagement such as election pledges, and commissioning of academic reports or policy recommendations from educational institutions and/or non-government stakeholders.
* Score 2 (Category 1B – Blue economy incorporated (or mentioned) in national development document) is given in a circumstance where the concept of a blue economy has been incorporated (or at a minimum, mentioned) in another policy document, such as a long-term, medium-term, and/or short-term national development plan or vision, or strategic framework.
* Score 3 (Category 1C – Existence of a formal blue economy policy document) is given to a country that has a formal blue economy policy document. Policy adoption is commonly an outcome of policy development or formulation processes and indicates a more mature state of implementation than Category 1A and 1B. Some clear indicators of this category are the existence of a strategy, roadmap, framework or other policy document, plan or legislation that has been approved by the national government, or at the ministerial or departmental levels of government. In many cases, the legislation includes designation of institutions or authorities with rights and responsibilities to plan, implement and evaluate the policy (Guerreiro, 2021).

Criterion 2: Evidence of social and environmental dimensions that are linked to targets and actions in the blue economy

This criterion identifies the inclusion of the three dimensions of the sustainable development (economic, environment, and social) into blue economy policy and practice.

Based on our view that the blue economy involves social and environmental goals as well as economic development goals (Bank, W, 2017; Keen et al., 2018), we deemed it important to assess each country on the *substance* of their blue economy policy, rather than simply its existence. Although many states claim to have a blue economy policy which incorporates social, environmental, and economic dimensions (consistent with the post-2015 Sustainable Development agenda from which it originates), this is not always reflected in the targets or activities actually adopted to give effect to the blue economy policy. Accordingly, we felt it appropriate to assess the evidence of social and environmental dimensions in each country's blue economy policy, by considering whether there are clearly articulated targets and actions in each dimension (Stephenson et al., 2019; Stephenson et al., 2021).

Achieving a balance between economic development, social equity and environmental sustainability should be considered a high priority, and the implementation of all three dimensions in national level policy is key to delivering a sustainable blue economy. However, there is no agreement on the scale of acceptable tradeoffs and synergies inherent in sustainable development, nor any guidance or agreed standard on measuring the optimal balance of economic, social, and environmental dimensions. In the absence of such a benchmark, minimizing potential harm to social equity and damage to environmental health would be the minimum baseline in order to ensure that social and environmental safeguards offer an appropriate check and balance mechanism

to economic development (Bank, W, 2017; UNEP, 2020). With this in mind, the scoring guide for the assessment of **Criterion 2** is as follows:

* Score 1 (Category 2A – High level social, environmental, and economic principles, goals or objectives articulated across three dimensions) is given to countries that articulate high level social, environmental, and economic principles, goals, or objectives in their national development plan. A national development plan is not necessarily a blue economy specific plan, but rather can be a general or sector-based plan that is aligned to the SDGs or other development objectives. Frequently, countries will achieve this minimum score, however without clear links to targets and actions that aim to fulfil all the triple bottom line objective goals, a higher score cannot be awarded. In the absence of clearly articulated targets and actions, these concepts remain high level.
* Score 2 (Category 2B – High level social, environmental, and economic principles, goals, or objectives with links to targets or actions in two dimensions) is given in a circumstance where social, environmental, and economic principles, goals or objectives are articulated with clear links to targets or actions in two dimensions. For example, if there is a clear indication of the absence of social equity or evidence of environmental compromises in the marine resource management or development plan then a country will not score above 2.
* Score 3 (Category 2C – High level social, environmental, and economic principles, goals or objectives with links to targets or actions in all dimensions) is given to a country that has fully incorporated social, environmental, and economic principles, goals, or objectives into their blue economy policy with clear links to targets and actions.

Criterion 3: Evidence of blue economy implementation strategies

This criterion seeks to identify actual operationalisation of the blue economy in practice. It includes primarily evidence of documented implementation plans or mechanisms to operationalise blue economy, and whenever applicable other evidence indicating the progress that has been made in blue economy related activities. For example, the blue economy has established sectors such as marine living resources, marine non-living resources, marine renewable energy (mainly offshore wind), port activities, shipbuilding and repair, maritime transport and coastal tourism in EU regions (Commission, E 2022).

Bearing in mind the enabling conditions that contribute to a country's capacity to effectively implement a sustainable blue economy (Benzaken and Hoareau, 2021; Cisneros-Montemayor et al., 2021; Voyer et al., 2021a), we take into account six components to assess the level of blue economy implementation in each country as follows:

1) Evidence of operational cross sectoral plan or action plans: national action plans, integrated ocean management plans, for example Marine Spatial Planning (MSP) or Integrated Coastal Zone Management (ICZM); other short-term, medium-term and long-term plans;
2) Existence of funding mechanisms that at minimum covers the source of fund, its value and the funding purposes;
3) Dedicated whole of government institutional structures and or mechanisms to harmonize and coordinate the implementation of the blue economy;
4) Existence of sector-based blue economy projects or activities that contributes to economic, social, and environmental goals, such as job creation and added value to national economy (Gross Value Added (GVA) and Gross Domestic Product (GDP)).
5) Evidence of non-government stakeholders' engagement in developing and operationalizing blue economy policies or plans in ocean sector activities; and
6) Monitoring and reporting mechanism that tracks progress and can provide inputs for future review and adaptation.

These considerations are related to the enabling conditions, that contribute to a country's capacity to effectively implement a sustainable blue economy (Benzaken and Hoareau, 2021; Cisneros-Montemayor et al., 2021; Voyer et al., 2021a). Regardless of the existence of an overarching national blue economy policy, some existing ocean-based governance and economic activities such as marine zoning, integrated coastal management, ecosystem based, and community-based fisheries management have already been implemented in certain countries. When these mechanisms included social and environmental dimensions they were counted as evidence towards a country's blue economy implementation, despite not being specifically labelled as 'blue economy'.

The scoring guide for the assessment of **Criterion 3** is:

* Score 1 (Category 3A – Evidence of one or two implementation strategies) is given to countries in the early stages of blue economy operationalization and where there is evidence of the employment of one or two of the components listed above. Countries with no national blue economy policy in place may fulfil this category in a circumstance where they have institutional capacity to implement blue economy activities or have sectoral based blue economic activities or have sought financing for relevant blue economy activities through

either national (state) budget, private sector, or international donors such as organizations under United Nations System and intergovernmental organisations (IGOs).

* Score 2 (Category 3B – Evidence of three or four implementation strategies) is given to countries that have evidence of a high level of blue economy operationalization by satisfying three or four components identified above. At this level, countries usually have a blue economy policy to provide overarching guidance for implementation, whether incorporated in a national development framework (Category 1B) or established as a specific blue economy policy (Category 1C).
* Score 3 (Category 3C – Evidence of 5 or more implementation strategies) is given to countries that have reached an advanced level of blue economy implementation as indicated by the presence of five or more of the components listed above. At this level, countries will have a capability to operationalize cross-sectoral economic activities based on policies or plans.

Preliminary results of pilot categorization

The current global snapshot of blue economy development throughout the 193 UN member states is shown in Figure 3. Of these countries, 10% of countries have been identified in our categorization systems as having high level blue economy development and implementation. This 10% equates to approximately 20 countries, all of which are coastal states. Most countries in this category are developed countries, however some developing countries actively promote blue economy development (such as Seychelles, Palau, and Bahamas) and they have been categorized as high development. Of the 193 states considered, 20% (or 39 countries) were categorized as medium development, which means they have made some effort to develop their Blue Economy and operationalize it, both through policy and action. Most of the states considered (70%, or 134 countries) were categorized as low development or no/unknown.

Of the 193 UN member countries, 36% (or 69 countries) have developed a blue economy policy, plan or strategy or incorporated blue economy in other planning documents (as considered in Criterion 1), but only 22% (or 43 countries) have indicated the articulation of social and environmental objectives into targets and actions in their blue economy plan (as considered in Criterion 2). However, we found evidence of blue economy operationalization (as considered in Criterion 3) in relation to 31% (or 60 countries). Based on the availability of information 24% (46 countries) were assessed with a high confidence level for the data, but 76% (147 countries) were assessed with a low data confidence level, mainly due to lack of official information on Government websites or a lack of publicly available information in English.

The chart in Figure 4 shows a breakdown of blue economy development by region. Countries from the Western Europe and Others Group lead the way on blue economy development, and many of the countries in this Group had evidence of blue economy implementation and operationalization. The analysis confirmed that land-locked countries had a low level of interest in developing a blue economy at a national level. However, our research did show that some land-locked countries have engaged with the blue economy concept and are looking to raise

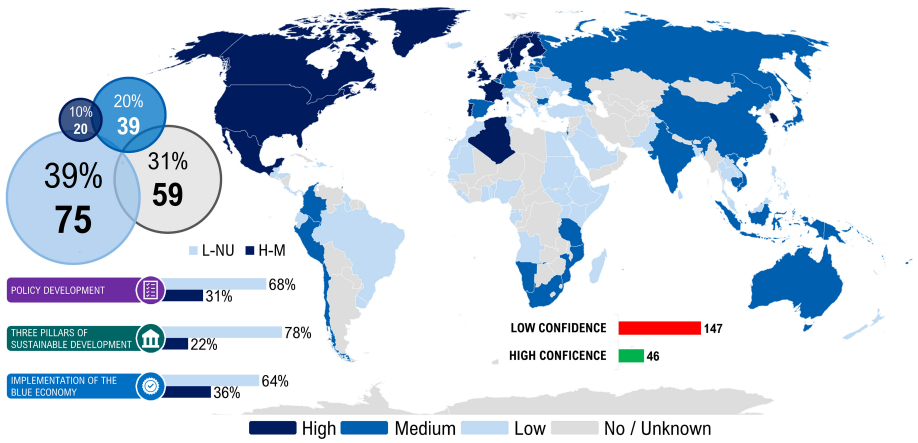
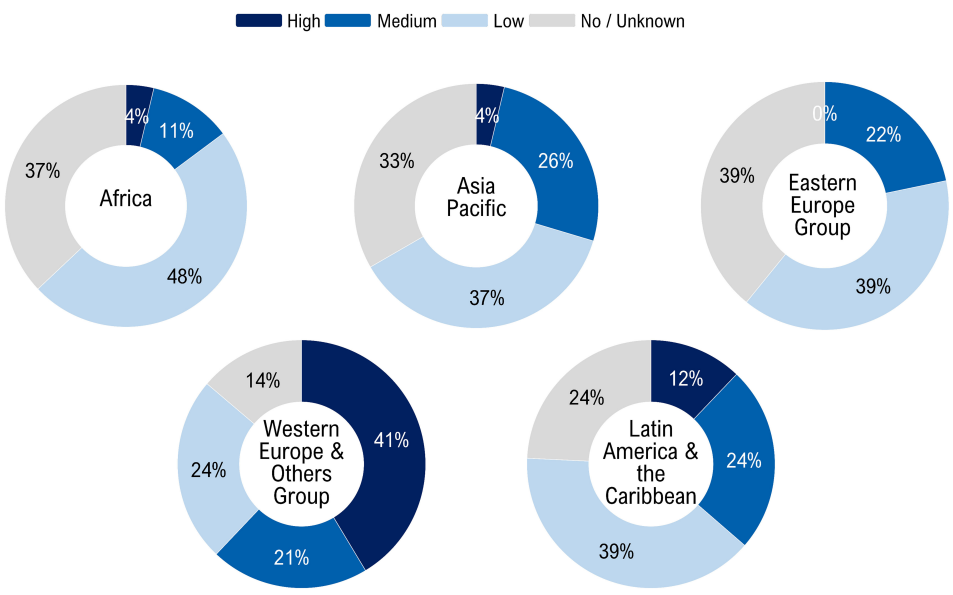


FIGURE 3
Global blue economy development overview.



Note: Western Europe & Other Group includes North America, Australia, and New Zealand.

FIGURE 4
Global blue economy development by region.

awareness of blue economy related activities or initiatives. For example, Austria is contributing to the reduction of marine plastic pollution throughout their terrestrial activities (Austria, 2020), and Mongolia has interest in global shipping registries (Administration, M. M 2018).

Classification case studies

To further investigate the efficacy of the assessment criteria, we undertook a more detailed assessment of four case studies, which consisted of assessing a sample case (country) across each level of development. Four countries were randomly chosen to represent both developed and developing economies, with a variety of maritime interests from different regions and reflecting the availability of publicly accessible information. Other than being representative of different levels of development status and different regions the choice of countries was arbitrary. The inclusion of case studies was to illustrate how the classification tool works in practice, rather than providing an in-depth analysis.

Table 1 outlines the justifications for the scores that were awarded to the four case studies. The case studies are useful in illustrating the application of this method and in testing its validity, whilst also identifying gaps that can be adjusted in the future development of the database and the categorization tool. The following sections provide an overview of each case study in order to demonstrate the application and effect of the scoring methodology.

High category - Portugal (developed economy)

Portugal is at the forefront of global advocacy in promoting sustainable development in the ocean (Government of Portugal, 2021). As a member of the High-Level Panel for a Sustainable Ocean Economy (Panel, O 2020) and the European Union (EU), Portugal has aligned its national policy to support the regional policy commitments stipulated in the EU Integrated Maritime Policy (IMP) with its subsequent blue economy policy documents (Soma et al., 2015; Katarzyna et al., 2016; Moreira and Bravo, 2019; Commission, E 2021).

At the national level, the blue economy is at the core of the Portuguese National Ocean Strategy (Portugal, G. o2014; Portugal, G. o 2021a). The adoption of Circular and Sustainable Blue Economy as Strategic Goal-2 (SG2) in Portugal's National Ocean Strategy 2021-2030 indicates a balanced approach to the blue economy that includes social inclusivity and environmental protection. It shows evidence of economic, social, and environmental dimensions that are linked to targets and actions in the blue economy. The evidence of blue economy in Portugal's National Ocean Strategy is linked to strategic goals and is in full alignment with social and

TABLE 1 Classification case studies in 4 sample countries.

Countries	CRITERION-1			CRITERION-2			CRITERION-3			Total Score	Category	Confidence Level
	1A (1)	1B (2)	1C (3)	1A (1)	1B (2)	1C (3)	1A (1)	1B (2)	1C (3)			
Portugal			3			3			3	9	High	HC
	1st, 2nd & 3rd National Ocean Strategy with Action Plan			BE Vision - sustainable ocean economy includes social and ecological targets and actions			Financing, action plan, projects, institutional arrangements (DGPM & CIAM)					
Mozambique			3	1				2		6	Medium	HC
	The Mozambique Policy and Strategy of the Sea (POLMAR) was developed in 2017 to serve several objectives including the development of a blue economy			Mozambique supports the principles of sustainable development			Plans, financial mechanism, dedicated institution, sectoral projects					
Jamaica		2		1			1			4	Low	HC
	The Green Paper on Coastal and Oceans Management for Jamaica, 2002, 'Vision 2030 National Development Plan' and member of HLP			Vision 2030 includes mention of all three dimensions			Sector-based projects					
Bosnia and Herzegovina	0	0	0	1			0	0	0	1	No/ Unknown	LC
	Unknown			Bosnia and Herzegovina supports the principles of sustainable development			Unknown					

environmental objectives. Accordingly, Portugal has been awarded the highest score (3) for Criterion 1 and 2.

To implement its blue economy, Portugal has developed an action plan that accompanies the National Ocean Strategy. The action plan includes 10 objectives with 180 concrete measures (Portugal, G. o 2021a). Portugal has dedicated institutions for ocean policy development and implementation, including blue economy related programs and activities (*Direção-Geral de Política do Mar*/DGPM within the Ministry of Maritime Affairs and the Inter-ministerial Commission for Ocean Affairs/CIAM chaired by Prime Minister as inter-agency mechanism). It has sector-based projects including renewable ocean energy, aquaculture, tourism, and marine mineral resources. Portugal has also established a financial mechanism and investment plan to support blue economy implementation. One example of this financial scheme is 'Portugal Blue' which is directed to support the economy with climate impact and sustainable development objectives (European Investment Fund, 2020). With at least five components of implementation strategies in place, Portugal satisfies the highest level of Criterion 3.

As an active proponent of the blue economy at global, regional, and national levels with adequate implementation strategies, Portugal satisfies all criteria and is categorized as **a highly developed blue economy country**.

Medium category - Mozambique (developing economy)

The overarching legal framework for the blue economy in Mozambique is the Sea Law 1996 which specifies the requirements for the use of Mozambique's jurisdiction and is implemented through the Legal Regime for the National Maritime Use or RJUEM (Mozambique, G. o 2017a). The primary policy document relevant to the blue economy is the Sea Policy or POLMAR (Mozambique, G. o2017b), which aligns with sustainable development as seen in the pillars of governance and inter-ministerial coordination, marine and coastal environment, economic development, territorial development, human capital development and international cooperation. The

Mozambique's Sea Policy makes reference to economic, social and environmental principles, objectives and strategies for implementation including a participatory marine spatial planning process (POEM) but does not have clear links to social and environmental targets and actions. Thus, Mozambique was awarded the highest score (3) for Criterion 1, but a score of only 1 for Criterion 2.

Mozambique has advanced its blue economy policy with a marine spatial plan and the establishment of a funding mechanism called ProAzul (ProAzul, 2022). However, a whole-of-government implementation plan has yet to be finalized, which would clarify strategic priorities for economic, environmental, and social objectives, the responsibilities of relevant ministries, and the enabling environment to facilitate implementation, including finance, institutional coordination and policy alignment and reporting. ProAzul has developed a Blue Economy Roadmap that identifies priorities for investment and blue financing opportunities have been canvassed with the support of the World Bank ProBlue program (Benzaken et al, 2021). The government had committed to establish a National Sea Council in 2019, but this was not supported by Cabinet. Instead, a committee of national directors of relevant Ministries has been endorsed as the mechanism for whole of government coordination. Accordingly, Mozambique was only able to score 2 in Criterion 3.

Altogether, Mozambique has made good progress in developing a legal and policy framework for a sustainable Blue Economy as well as a financing mechanism (Pro Azul). However, more information is needed in the status of institutional coordination. For these reasons, Mozambique is assessed as being in **the medium category** in their Blue Economy development.

Low category - Jamaica (developing economy)

Jamaica's policy and plan for the blue economy is associated in the National Policy on Oceans and Coastal Zone Management Policy, which was adopted and implemented in 2002 (Mattis and Edwards, 2015). The policy includes principles to protect the ocean and coastal environment and to foster sustainable management of ocean and coastal resources (NCOCZM, 2000). In 2018, Jamaica's leadership endorsed the High-Level Panel for a sustainable ocean economy's commitment to 100% sustainable management of ocean areas within a national jurisdiction (Ocean Panel, O2020). This global initiative is in full alignment with the Vision 2030 – Jamaica National Development Plan, which promotes the sustainable management and use of environmental resources (Smith, 2020). Jamaica has not, however, articulated a specific blue economy policy, but rather adopted broad principles and guidance from external sources or publications such as High Level Panel's blue papers as reference for implementation (Smith, 2020). The inclusion of Blue Economy in the National Development Plan and Jamaica's support of sustainable development principles have led Jamaica to a score 2 for Criterion 1 and a score of 1 for Criterion 2.

On the policy implementation side, an inter-ministerial council – National Council on Oceans and Coastal Zone Management (NCOCZM) – chaired by the Ministry of Foreign Affairs and Foreign Trade plays a key role in marine policy formulation in Jamaica. There is also evidence of the conduct of sector-based projects with support from international institutions, for example, the assessment and economic valuation of coastal protection services of mangroves by the University of the West Indies (UWI) that is funded by World Bank (Smith, 2020). This evidence allows for a score of 1 in Criterion 3.

Overall, given the absence of a blue economy policy and inadequate evidence of implementation, Jamaica's Blue Economy development is in **the low category.**

Unknown/no category - Bosnia and Herzegovina (developing economy)

At present, there is no evidence of national intention of blue economy or ocean policy development in Bosnia and Herzegovina (no score for the first criterion). Bosnia and Herzegovina recognizes the problems in its ocean and coastal areas, such as the negative impact of tourism, dumping of waste, and ballast water issues. The country supports the concept of sustainable development, as seen in its commitment to include SDG 14 in VNR 2019 (Herzegovina, G. O. B. A2019). Accordingly, Bosnia and Herzegovina can receive a score of 1 for Criterion 2.

Criterion 3 is not assessed in relation to Bosnia and Herzegovina situation due to the absence of English language publications on the ocean economy and a lack of knowledge about the national ocean policy or blue economy.

Overall, Bosnia and Herzegovina's Blue Economy development is categorized as **unknown/no category**.

Discussion

The categorization tool developed through this study which also used as an evaluative lens has enabled the identification of different stages of national level blue economy development on a global scale, and the preliminary identification of trends of blue economy development at the national level. The development of the criteria was a crucial component of this methodological approach as it was through this method that we were able to construct a way to make an initial assessment on the level of Blue Economy development in 193 UN member states. This

methodological approach has allowed for rapid analysis and assessment. The key preliminary findings of the assessment and subsequent categorization has provided useful insights that can support global, regional, and national efforts to optimize the development of blue economy policy and governance. This section will first outline the key preliminary findings that emerged through the application of the assessment tool. It will then go on to discuss the methodological approach that we took, through the development of the database, the criteria, and the assessment tool. In doing so we will discuss the how the tool worked in practice, the lessons learned, and how it can be used in the future.

Key preliminary findings

By investigating blue economy development globally, we were able to gain some insights into the status of blue economy development in ocean regions and different influences of regional initiatives to the blue economy development at the national level. Our preliminary analysis has shown that only 30% or 59 of the 193 UN member states could be identified as having made good progress on blue economy development. Western Europe and Other Group had the highest percentage of high development status of any region. This corroborates the findings by Voyer et al. (2021b) who found that Europe were playing dominant role in commitment to the blue economy, most likely supported by regional agreements such as the EU's Blue Growth Strategy. This paper also confirms that sub regions with a larger proportion of land-locked countries have a lower level of national blue economy development than those with more coastal states, for example, Central African, Middle East and Central Asia.

The analysis of the categorization illustrated that different countries have different approaches and priorities in institutionalizing and operationalizing the blue economy. This analysis assists in identifying broad trends and high-level comparisons across national levels governments and regions. It should be noted however that the more detailed examination of countries and the case studies point to significant nuance in the ways in which the trends are translating to national contexts. Countries may not necessarily have a blue economy policy or strategy in place but demonstrate capability and capacity in blue economy sectors; for example, Iceland which have advanced the ocean cluster concept as their blue economy implementation approach (Hansen et al., 2018). However, other countries have institutionalized the blue economy at a conceptual level and have a policy or strategy in place; but they have limited institutional and technical capacity to implement and maintain the continuity of the policy implementation in the long term, for example, Mozambique and Antigua & Barbuda. Hassanali (2022) found that the institutional arrangements of Caribbean states were largely not in a position to optimize blue economy development, thus organizational and institutional restructuring would be required to effectively develop the blue economy.

The diverse perspectives and practical application of the blue economy as policy highlights that the concept has arisen as a significant political phenomenon at national, regional, and global levels but is being adopted and implemented at national and local levels with adjustment and modifications to suit specific domestic circumstances. For example, Seychelles employs its blue economy policy as an instrument to govern the sustainable development of its ocean domain. Other countries like Papua New Guinea and Fiji choose to incorporate a blue economy section in their national ocean policy that is formulated to address specific challenges in national ocean governance. This is a common pattern of national ocean policies that were developed after 2012 when the term 'blue economy' came into use at the Rio+20 conference. Another preliminary insight gained in this research is that the incorporation of the blue economy is often as part of a broader national development framework such as a National Development Plan or Green Development Plan. This is the case for countries such as Brunei and Cambodia (National Council on Green Growth, 2013; Ministry of Finance and Economy, Brunei Darusallam, 2020).

Future development of the Global Blue Economy Database and areas for further research

In the development of this methodological approach the refinement of criteria was of critical importance. At its core, the operationalization of the Blue Economy involves policy and subsequent implementation, we also argue that it needs to incorporate the three dimensions of a sustainable Blue Economy (economic prosperity, environmental conservation, and social equity). For these reasons therefore, these pillars became an important criterion by which we assessed national level blue economy development. Finding information based on these three criteria was at times difficult. For example, identifying clear targets and actions towards the three dimensions of sustainability in national policy documents was not always a clear task. Furthermore, assessing the actual level of implementation or operationalization (rather than just what is said to have been done, or what is earmarked to be done) based on available information carried certain challenges. For these reasons, ensuring that the process is iterative is of key importance. In other words, updating the database and re-assessing countries development status as new information becomes available should be considered a crucial part of the process.

The preliminary results of the assessment and subsequent categorization has provided useful insights that can support global, regional, and national efforts to optimize the

development of blue economy policy and governance. This database can serve as a comparative and complementary tool for analytical purposes and can be used in combination with other global databases (for example, global income and development status), which would help to validate whether a country's income and development status correlate with their blue economy development progress. The trends identified in this initial assessment highlight the location of regions where blue economy development is limited—for example, in the 70% of UN member states who had low and no/unknown development in blue economy. It is fair to assume that blue economy development and implementation has not been a priority in these states. Through identifying regions with low levels of engagement this may in turn, help international donors and financial institutions to strategically direct their financial aid to areas where blue economy to date, has not been a priority. Further understanding regional and global trends and drivers on national blue economy adoption will be beneficial for decision making process and policy development in the future.

Furthermore, this database and assessment tool can be useful in fostering collaboration and cooperation between countries in developing the blue economy. The interconnectedness of the ocean and the shared barriers to effective governance ensure that collaboration and cooperation between countries and across scales should be a priority. Crossman et al, 2022 argue that '*despite the inherently transboundary and entangled nature of ocean governance issues, ocean governance continues to suffer from a lack of effective coordinating mechanisms across scales and sectors*'. Opportunities for regional cooperation at the policy development and implementation stage, mechanisms for exchanging information and blue economy experiences, and identifying capacity needs are essential components to harness international cooperation. Examples on how to integrate the three dimensions of sustainability in the blue economy should be given priority, to ensure that the blue economy does not become merely an exercise in blue growth with little consideration for social equity and the health of ocean and coastal ecosystems.

Our approach complements the work of Cisneros-Montemayor et al. (2021) and Adrianto et al. (2019) who also developed mechanisms to assess the levels of implementation of the Blue Economy. Whilst still being in its infancy, the database and categorization tool that we have developed is useful in assessing the level of blue economy implementation. The use of the three criteria was intended to provide a simple tool that provides a snapshot rather than an in-depth country-by-country analysis as is seen in the tool developed by Adrianto et al. (2019). The case studies outlined in this paper illustrate how this assessment tool works in practice. The four sample countries examined were illustrative of the varied approaches to practical application. The simplicity and practicality are beneficial in two ways: the tool can be widely used by non-technical expert analysts, and it can be customized for a more detailed assessment in the future.

Our methodological approach was reliant on publicly available information. In moving forward with blue economy governance and operationalization we suggest that countries should endeavor to ensure transparency and openness in their blue economy development. Rather than operating as individual states, recognizing the interconnectedness of the ocean and working together on integrated Blue Economy policies would instead be beneficial.

Conclusion

This paper outlined the method we employed and was intended to demonstrate how the assessment tool works in practice. It is intended that future applications of the database will facilitate data entry by a range of users and be accessible on a public platform. Future applications of this tool will be beneficial in confirming the key drivers of the blue economy. The drivers of blue economy implementation will be able to be examined more thoroughly. As the data we used was found on web-based sources, ideally it would be able to be validated by those with specific insights on a country-by-country level. The database and subsequent assessment are intended to be iterative. In this sense, we intend this tool to continue to be developed and updated. This iterative process will enable the monitoring of rapid changes in Blue Economy development.

Effectively developing, implementing, and operationalizing blue economy policies remains an international governance challenge. Our research has shown that globally, levels of blue economy governance remain low, despite the popularity of the term in international and regional political discourse. Factors contributing to this are likely to be related to the challenges of blue economy governance and ocean governance more broadly. Furthermore, Graziano et al. (2022) show that '*the Blue Economy is still conceptualized and operationalized heterogeneously, with variations not just between countries but within regions*. This statement corroborates the findings of this paper, as we identified a range of approaches to blue economy governance that reiterated the varied levels of blue economy development both regionally and globally. It is our hope that applying the methodology developed for and used in this study could help national governments to strengthen their approaches to the blue economy through the combination of national policy guidance, full incorporation of sustainability principles and effective implementation strategies.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

LW – Idea conception, methodology development, database creation, data collection, data visualization and co-writing, case study development; FC - Idea conception, methodology development, database creation, data collection and co-writing; DB - Idea conception, methodology development, case study development, editing and feedback; KA - Idea conception, methodology development, editing and feedback; CG - Idea conception, methodology development, editing and feedback; CR - Idea conception, methodology development, data collection; MV - Idea conception, methodology development, editing and feedback. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Area-based management tools to protect unique hydrothermal vents from harmful effects from deep-sea mining: A review of ongoing developments

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The deep seabed in areas beyond national jurisdiction, or what is referred to as "the Area," is the common heritage of humankind, safeguarded by mandating the International Seabed Authority (ISA) to protect the marine environment and to regulate all mining-related activities on the seabed in areas beyond national jurisdiction. So far, the ISA has 7 contracts for polymetallic sulfide (PMS) exploration. PMS deposits are located at and near deep-sea hydrothermal vents, one of the most remarkable ecosystems on Earth. Where hot and mineral rich vent fluids escape from the earth's crusts, minerals precipitate and are deposited, and unique biomass rich microbial and animal communities are thriving. Several intergovernmental organizations suggest that active vents classify as areas in need of conservation. The ISA is currently developing regional environmental plans for PMS and has set some first steps to protect active vents from mining impacts. We review the current regulatory and policy framework for deep-sea spatial management, and set it into the environmental context. We conclude that all current management measures of the ISA would not be suited to protect the marine environment from harmful mining impact. We recognize that ISA's area-based management tools are under development, and suggest that improvements can be achieved by studying and recognizing the ecological attributes of ecosystems and their connectivity, as well as governance connectivity, taking into account area-based management tools of different users in the same area.

KEYWORDS

deep-sea mining, vulnerable ecosystem, international law, International Seabed Authority, area-based management tools, connectivity, science-policy interface

Introduction

The deep sea–which is the ocean below 200 meters depth and constitutes 90% of the biosphere–represents, in scientific, technological and legal terms, a new frontier for research, development and management. On the one hand, our knowledge of the deep sea remains incomplete, and unique deep-sea ecosystems are continuously being

discovered (Amon et al., 2022). As described by Smith et al. "communities of inactive massive sulfides are mostly undescribed; the vast majority of seamounts in the ocean have never been sampled; the macrofauna and meiofauna of cobalt-rich crust deposits are practically unknown; and most of the [. . .] faunal species recently collected [. . .] are new to science" (Jones D. O. et al., 2020, p. 100; Smith et al., 2020, p. 856).

On the other hand, some entities have not only shown their interest in the rich minerals of the deep seabed and ocean floor beyond the limits of national jurisdiction also known as "the Area",[1] which are in high demand due to their use in the development of green and other technologies, such as mobile phones (IUCN, 2022), but have also communicated their readiness in engaging in their extraction. For example, on 25 June 2021 Nauru requested the International Seabed Authority (ISA) to adopt the rules necessary to facilitate the approval of plans of work for mineral exploitation in the deep seabed by July 2023 in light of its State-sponsored entity, Nauru Ocean Resources Inc, being ready to submit the necessary plans of work (Blanchard, 2021; Lyons, 2021; Willaert, 2021). This consequently triggered the urgency of completing the ISA's regulations for exploitation activities.

The potential imminent start of deep-sea mining poses undoubtable high risks to the marine environment with long-term negative consequences (Gollner et al., 2017). The impacts that mining could have on deep-sea ecosystems are also often misunderstood, and our ability to predict species and ecosystems' responses to stressors, as well as the behavior of sediment plumes, is limited (Van Dover et al., 2018; Smith et al., 2020, p. 855). Although all areas of mining interest are at risk, hydrothermal vents raise particular concerns considering the potential impacts of, for example, vent-fluid change, toxic mining plumes, as well as habitat removal and fragmentation, and associated risks of biodiversity loss of unique and endangered species (Van Dover et al., 2018). Mining may damage directly or indirectly the benthic environment of inactive and active vents, and the surrounding benthic and pelagic realm within and beyond a vent field, although it is uncertain to what extent (Van Dover, 2014; Gollner et al., 2021).

Similarly, many questions remain as to the (regulatory) framework[2] for the management of deep-sea hydrothermal vents and their protection from environmental harm. For example, many terms and concepts, as well as what they trigger in practice, are in need of clarification. Obligations–and who they bound–still need to be fleshed out. The interactions between the management of deep-seabed mining and that of other maritime activities is complex. Uncertainties and knowledge gaps, both in science and in law, therefore raise concerns as to our ability to ensure comprehensive environmental protection of unique deep-sea hydrothermal vents fields.

Mandated to organize, regulate and control all mineral-related activities in the international seabed (also known as "the Area") for the benefit of humankind as a whole (United Nations Convention on the Law of the Sea, 1982, art. 157(1) and 137(1)), the ISA has been developing, since the early 2000's, the Mining Code, a set of rules, regulations and procedures covering the prospecting, exploration and exploitation of minerals in the deep seabed (The Mining Code). While the ISA first developed regulations on the *exploration* of deep-sea minerals (The Mining Code: Exploration Regulations), the Secretary General now calls to aim to complete the *exploitation* regulations (Draft regulations on exploitation of mineral resources in the Area, 2019) before July 2023 (Status of the draft regulations on exploitation of mineral resources in the Area and proposed road map for 2022 and 2023, 2021).

The ISA's mandate also includes the effective protection of the marine environment from harmful effects that may arise from deep-sea mineral related activities (United Nations Convention on the Law of the Sea, 1982, art. 145). The operationalization of this environmental duty is being undertaken, among other things, through the development of area-based management tools (ABMTs). Broadly defined as tools or "approach[es] that [enable] the application of management measures to a specific area to achieve a desired policy outcome" (EU Commission UN Environment, 2018), ABMTs (also known as spatial management tools)[3] come in different shapes and sizes, with different mandates and purposes, and aim at achieving different policy goals.

Many studies have rendered detailed accounts of the international legal regime for deep-sea mining (Jaeckel et al., 2020), looking at it from the angle of marine environmental protection (Harrison, 2017), of the precautionary approach (Jaeckel, 2017), and of interdisciplinary research (Koschinsky et al., 2018), and they have presented how ABMTs are situated within that regime. The ISA itself has also published technical

1 Three different types of minerals, found in three different types of geographical/geological landscapes, are currently managed in the deep seabed/the Area: polymetallic nodules (on abyssal plains), cobalt-rich ferromanganese crusts (on seamounts), and polymetallic sulfides (on and around hydrothermal vents).

2 The authors use complementary yet different terms throughout the paper. Regulations/regulatory framework refers to legally and non-legally binding instruments that contain legal obligations and guidelines that shape, influence and direct actors' behaviors. Management refers mostly to measures and initiatives undertaken by an actor or entity with the objective to fulfill certain obligations. Policy refers to an array of laws, regulations, instruments, guidelines, strategies, procedure, etc. that guide decision-making. Finally, governance is used here as a more holistic concept, which encompasses regulations, policy, management, but also institutions and more broadly defined processes.

3 The terms ABMTs and spatial management tools are used interchangeably throughout the present paper.

studies and reports on various related topics, including on the design of some spatial management tools (ISA, 2017; Towards and ISA Environmental Management Strategy for the Area, 2017) and plans (Guidance to facilitate the development of Regional Environmental Management Plans (REMPs), 2019). Similarly, many publications from different domains of the natural sciences, such as marine biology, oceanography and ecology, have studied different elements/criteria that need to be considered when designing and establishing ABMTs for the deep sea (Dunn et al., 2018; Gollner et al., 2021).

The present paper reviews this body of knowledge and discusses the optimization of ABMTs to address, both at the operational and regulatory levels, the effective protection of the marine environment from harmful effects.

State of affairs

Definition of the marine environment

The term "marine environment" is not defined in the *United Nations Convention on the Law of the Sea* (UNCLOS) (United Nations Convention on the Law of the Sea, 1982) nor under its *Agreement relating to the Implementation of its Part XI* (Part XI Agreement) (Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, 1994). To understand the scope of this term in the context of deep-sea mining, one must therefore resort to the definition found under the *Draft Regulations on exploitation of mineral resources in the Area* (Draft Exploitation Regulations) (Draft regulations on exploitation of mineral resources in the Area, 2019), which refers to "the physical, chemical, geological and biological components, conditions and factors which interact and determine the productivity, state, condition and quality and *connectivity* of the marine ecosystem(s), *the waters of the seas and oceans* and the airspace above those waters, as well as the seabed and ocean floor and subsoil thereof" (emphasis added).

Thus, the legal definition addresses that the ocean is interconnected, from the surface to the seafloor and from the coasts to the high seas. For life in the ocean, there exists only one ocean with no sectoral or State boundaries. Ecological connectivity plays a critical role in healthy ocean functions, and describes the ecological linkages within and between locations and habitats, the individual organisms and the resources they require. The degree of knowledge on connectivity can ultimately determine the success or failure of area-based management (Ecological Connectivity: Implications for Ocean Governance, 2020).

Regulatory and policy framework for deep-sea spatial management

Different areas of the deep seabed fall under the scope of existing ABMTs. In order to assess their potential for the protection of active hydrothermal vents, this section first draws an overview of the nature and extent of existing ABMTs developed in the framework of the ISA, and then briefly discusses selected ABMTs from other sectors that can/could be of relevance for the protection of deep-seabed ecosystems from the impacts of mining.

ABMTs developed for polymetallic nodules under the ISA framework

As part of its mandate to control mineral-related activities and its obligation to ensure the effective protection of the marine environment from harmful effects that may arise from such activities, (United Nations Convention on the Law of the Sea, 1982, art. 145) the ISA has developed specific tools for spatial management. Three main tools are currently found in regulatory and policy instruments adopted by the ISA: areas of particular environmental interest (APEIs), which have a purely preservation aim, impact reference zones (IRZs) and preservation reference zones (PRZs), mostly intended for monitoring purposes.

Areas of particular environmental interest

APEIs are areas of the seabed closed to any mining activities, but open for marine scientific research (MSR) (Jaeckel, 2017, p. 202). For now, APEIs have only been established for polymetallic nodules in the Clarion-Clipperton Zone (CCZ) in the Pacific Ocean, through the REMP adopted for that region in 2012 (Environmental Management Plan for the Clarion-Clipperton Zone, 2011; Decision of the Council relating to an environmental management plan for the Clarion-Clipperton Zone, 2012). Nine APEIs were initially designated in the CCZ, each with a size of 400 x 400 km. This area includes a core-area of 200 x 200 km and a buffer zone of on each side 100 km to ensure that it is not affected by mining plumes from any activities immediately adjacent to an APEI (Environmental Management Plan for the Clarion-Clipperton Zone, 2011, para. 25; Lily and Roady, 2020, p. 340; Jones D. et al., 2020, p. 104). This size is "designed to be large enough to maintain minimum viable population sizes for species within the proposed mining areas *via* self-recruitment after mining has ceased" (Jones D. et al., 2020, p. 104). They have been geographically located based on knowledge on topography, particulate organic carbon flux (food for deep-sea animals), and nodule abundance (Review of the implementation of the Environmental Management Plan for the Clarion-Clipperton Zone–Report recommendations of the Legal Technical Commission, 2021, para. 22). As such, APEIs qualify as ABMTs aimed at the protection of representative habitats

and facilitation of MSR (Jaeckel, 2017, pp. 203–204; Rayfuse, 2020, p. 541). APEIs have been characterized as embodying the application of a precautionary approach (Lodge, 2017, p. 167) because they completely close the designated areas to mining activities. APEIs, however, are meant to be reviewed and can therefore be subject to modifications or eventually become completely or partially open to mining activities (Christiansen et al., 2022, p. 8).

A three-dimensional extent of APEIs' protection can be inferred from their nature: if no mining is allowed in a specific area, then both the sea floor and the superjacent waters would technically be protected from the impacts of mining. Yet, this reasoning needs to be seen in light of three elements. First, as the geographical extent of the impacts of mining are not yet fully understood, the set 100 km buffer zones may not be fully adequate. Mining impacts could reach far beyond the directly mined area, in the form of, for example, plume dispersal (Weaver et al., 2022), or noise from deep-sea mining that may span vast ocean areas (Williams et al., 2022). The buffer zones of APEIs partly but not fully take these far-reaching impacts into account, as for example noise travels far (Williams et al., 2022). Second, the species and associated functions found inside APEIs may be different from the species and functions in the designated mining areas, and thus could not prevent for example potential species extinction. Recent studies showed that many species in the CCZ have small distribution ranges (<200 km) or limited dispersal modes (Bonifàcio et al., 2020; Brix et al., 2020). Thus, species with natural distribution ranges smaller than contractor areas may face extinction risks, as they could be killed by mining but are found no-where else (also not in APEIs). A new study shows that for example APEI6 is only partially representative of the exploration areas to the south, as there are differences in community composition of microbes and animals (Jones D. O. et al., 2020). Further, the current APEIs typically have lower nodule densities than the exploration areas, and scientific evidence shows that polymetallic nodules are needed to preserve the fauna on the nodules (Vanreusel et al., 2016) and the food-webs (Stratmann et al., 2021), as many animals are dependent on nodules and cannot live without them (Cuvelier et al., 2020). Thirdly, APEIs are sectoral tools, meaning that they only offer protection from mining activities and their impacts. The protection offered by APEIs does not extend to other deep-sea activities (e.g., bottom fishing) and their impacts; consequently, APEIs do not offer multi-sectoral protection nor protection from cumulative impacts coming from different sectors.

A heated legal debate preceded the designation of APEIs in the CCZ. First, although there was initial doubt as to the legal basis upon which APEIs could be established (Lodge et al., 2014, p. 69), it was later on found that their establishment fell under the broad powers of the ISA under articles 145, 165(2)(e) and 162 UNCLOS to restrict mining activities for environmental reasons (Jaeckel, 2017, p. 203; EU Commission UN Environment, 2018). Second, the size and location of some of the initial nine APEIs were modified from original scientific advice because exploration contracts had already been granted in some of those areas (Wedding et al., 2013; Rayfuse, 2020, p. 541). These modifications were criticized: adjusting the location of APEIs to accommodate mining activities somewhat defeats the purpose of APEIs as protected areas (Jaeckel, 2017, pp. 206–208).

The CCZ REMP underwent a review of its overall implementation progress, which was published in 2021 (Environmental Management Plan for the Clarion-Clipperton Zone, 2011, paras 42 and 45; Jaeckel, 2017, p. 208; Lily and Roady, 2020, p. 340; Review of the implementation of the Environmental Management Plan for the Clarion-Clipperton Zone–Report recommendations of the Legal Technical Commission, 2021). Despite the above-mentioned criticism, the review highlighted an overall success in terms of APEI-related objectives: all management (e.g., keep under review the APEIs and determine their suitability or need for amendment) and operational objectives (e.g., protect biodiversity and ecosystems; include a wide range of habitats; avoid overlap with the current distribution of claimant and reserved areas; and provide a degree of certainty to existing and prospective contractors by laying out the location of areas closed to mining activities) were implemented (Review of the implementation of the Environmental Management Plan for the Clarion-Clipperton Zone–Report recommendations of the Legal Technical Commission, 2021, paras 10 and 15). The review recommended the establishment of additional APEIs in the CCZ, based on "the recognition of a need for improvement in representativity, replication and connectivity, which will strengthen the effectiveness of the [APEI] network" (Review of the implementation of the Environmental Management Plan for the Clarion-Clipperton Zone–Report recommendations of the Legal Technical Commission, 2021, p. 26). Four additional APEIs, one being significantly smaller than 400 x 400 km and thus not including the 100 km buffer zone as suggested in the original design for APEIs, were approved in December 2021 (Review of the implementation of the Environmental Management Plan for the Clarion-Clipperton Zone–Report recommendations of the Legal Technical Commission, 2021).

Impact and preservation reference zones

Simply put, the main purpose of reference zones (RZs) is to facilitate monitoring (Environmental Management Plan for the Clarion-Clipperton Zone, 2011, para. 41(c); ISA, 2017, pp. 9 and 13; Jones D. O. et al., 2020) and evaluate the environmental impacts of mining activities (Hao et al., 2020, p. 2; Jones D. O. et al., 2020, p. 4). Two types of RZs exist (Jaeckel, 2017, pp. 211–214; Jones D. O. et al., 2020, p. 104; Rayfuse, 2020, p. 541; Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area, 2020, pp. 35–37). First, IRZs shall lie in the area that will be mined and where impacts of mining will be assessed (Jones D. O. et al., 2020).

For their part, PRZs are areas where no mining is allowed. They should be located within a contract area and extend up to a distance "where impact can no longer be detected" (Design of Impact Reference Zones Preservation Reference Zones in Deep Sea Mining Contract Areas, 2018, p. 5), as they act mostly as monitoring control sites for IRZs (Jones D. O. et al., 2020, p. 4) and for the contract areas more generally. This might explain a suggestion that has arisen to rename PRZ as "control reference zones" (DOSI, 2019). It has been suggested that PRZs should be located close enough to mining sites, to allow the disturbed mining sites to be repopulated after activities have ceased, but they need to be large and far enough from mining sites to ensure that they are not affected by indirect effects of mining such as plumes (ISA, 2017, p. 18; Jaeckel, 2017, p. 213). Both IRZs and PRZs should be geophysically and environmentally similar to the contract areas in order to be used for monitoring the impact of activities. Yet, ensuring that adjustments can be made to these zones might be necessary in order for them to also be relevant to assess the impact of sediment plumes, about which little is currently known (Jones D. O. et al., 2020, p. 5). As these zones might also be affected by other activities (e.g., fishing), their environment, and consequently their nature as "reference" zones, could be affected. All these elements illustrate that establishing the location and size of these zones remains a challenge.

A further challenge stems from the name of PRZs, which could lead to believe that they have a preservation purpose. In fact, it has been proposed by one commentator that, because of their location closer to mining sites, "PRZs could also play important roles for conservation, for example providing connectivity as 'stepping stones' and sources for recolonization for impacted sites" (Jones D. O. et al., 2020, p. 4). The ISA Secretariat has, however, reiterated that the use of the word "preservation" should not be seen as transforming PRZs–which are in essence monitoring tools–into permanent/long term tools for conservation, a role currently fulfilled by APEIs (at least in the CCZ, potentially through other tools in other regions) (ISA, 2017, pp. 11–12 and 15).

Under the Regulations on prospecting and exploration (Regulations on Prospecting Exploration for Polymetallic Nodules in the Area, 2000; Regulations on Prospecting Exploration for Polymetallic Sulphides in the Area, 2010; Regulations on Prospecting Exploration for Cobalt-rich Ferromanganese Crusts in the Area, 2012), RZs must be included by contractors in their plans of work for exploration "if required by the Council" (Regulations on Prospecting Exploration for Polymetallic Nodules in the Area, 2000, r. 31(6); Regulations on Prospecting Exploration for Polymetallic Sulphides in the Area, 2010, r. 33(6); Regulations on Prospecting Exploration for Cobalt-rich Ferromanganese Crusts in the Area, 2012, r. 33(6)). This power given to the Council probably comes from the fact that the necessity of RZs was only envisaged for exploration activities that have the potential of creating serious environmental harm, which would happen only through exploration activities that cause disturbances on the seafloor (Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area, 2013, para. 26(d); Jaeckel, 2017, pp. 212–213)[4]. With the recent start of test mining, disturbances to the seabed became a reality; yet, the designation of RZs remains a recommendation (c.f. binding obligation) from the Legal and Technical Commission (LTC) (Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area, 2020, para. 67). Contractors such as the Federal Institute for Geosciences and Natural Resources (BGR) and Global Sea Mineral Resources (GSR) have however been following these recommendations (Environmental Impact Assessments), as a contractor who does not designate RZs is very unlikely to have reference baselines and therefore be in any position to submit an environmental impact statement (EIS). The uncertainty regarding the obligation to designate RZs, including standards and guidelines on what scientific bases they should be selected, will hopefully be clarified in the Draft Exploitation Regulations, including through the addition of a regulation on test mining, currently being negotiated (Facilitator's Revised Text : Draft regulations on exploitation of mineral resources in the Area–Parts IV VI related Annexes, 2022, r. 48bis). Annexes to the Draft Exploitation Regulations already contain a requirement for contractors to include the location of RZs, although specificities remain to be clarified (Facilitator's Revised Text : Draft regulations on exploitation of mineral resources in the Area–Parts IV VI related Annexes, 2022, p. Annex IV, para 3.1.1, and Annex VII, 2(i)).

It can be assumed that the monitoring function of RZs would target all impacts of mining activities in a specific area, meaning this could also extend to the water column. Yet, it could also be logical to conclude that the complete role and extent of RZs will depend on the way in which they are designed and designated by contractors. In fact, the designation of RZ is subject to important variations "due to differences in designation practices, as different contractors have their specific plans for surveys and long-term monitoring" (Hao et al., 2020, p. 2). A technical study published by the ISA (ISA, 2017) aimed to give some guidance to contractors in that regard; yet, according to some commentators, a clear set of harmonized "methods and steps for the designation of RZs in different environmental conditions to guide each contractor is urgently required" (Hao et al., 2020, p. 2).

4 Jaeckel observes that in the original Regulations on Prospecting and Exploration for Polymetallic Nodules, RZs were only necessary in applications for exploitation. Their necessity in applications for exploration was included in the Regulations on Prospecting and Exploration for Sulfides and Ferromanganese Crusts, and subsequently in the revised version (and now current) of the Regulations on Prospecting and Exploration for Polymetallic Nodules.

Other tools

Two other types of ABMTs[5] which interact with the deep seabed and its ecosystems, although that are not related to deep-sea mining, are also of relevance for the present discussion.

The first tool, developed in the context of deep-sea fisheries, are Vulnerable Marine Ecosystems (VMEs). This concept emerged from the need, raised in Resolutions of the United Nations General Assembly (UNGA) (Sustainable fisheries, 2004, para. 67; Sustainable fisheries, 2006, pp. 80–83), to address the adverse impacts of bottom fishing, including bottom trawling, on VMEs in areas beyond national jurisdiction (ABNJ). The UNGA indeed called upon States, through the relevant regional fisheries management organizations (RFMOs), to adopt the appropriate conservation and management measures to "protect vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals, from destructive fishing practices, recognizing the immense importance and value of deep sea ecosystems and the biodiversity they contain," in line with the precautionary and ecosystem approaches (Sustainable fisheries, 2004, p. 67; Sustainable fisheries, 2006, p. 80).

A couple of years later, the Food and Agriculture Organization, as part of its International Guidelines for the Management of Deep-sea Fisheries in the High Seas, provided a list of characteristics to identify VMEs and assess significant adverse impacts (International Guidelines for the Management of Deep-sea Fisheries in the High Seas, 2009, para. 42)[6]. The Guidelines also elaborate on the way flag States and RFMOs should conduct the assessments to "establish if deep-sea fishing activities are likely to produce significant adverse impacts in a given area" (International Guidelines for the Management of Deep-sea Fisheries in the High Seas, 2009, para. 47), as well as ways to ensure enforcement and compliance (International Guidelines for the Management of Deep-sea Fisheries in the High Seas, 2009, paras 54 and following).

VME identifications are intended to lead to the adoption of conservation and management measures by RFMOs. For example, the North-East Atlantic Fisheries Commission (NEAFC) has adopted recommendations that include, among other measures (Recommendation 19 2014: Protection of VMEs in NEAFC Regulatory Areas, as Amended by Recommendation 09:2015 and Recommendation 10:2018, 2018, art. 3), area closures for the protection of VMEs, which also cover parts of the northern Mid-Atlantic Ridge (nMAR) (Recommendation 19 2014: Protection of VMEs in NEAFC Regulatory Areas, as Amended by Recommendation 09:2015 and Recommendation 10:2018, 2018, art. 5), as well as a strict procedure for engaging in exploratory bottom fisheries outside area closures (Recommendation 19 2014: Protection of VMEs in NEAFC Regulatory Areas, as Amended by Recommendation 09:2015 and Recommendation 10:2018, 2018, arts. 6–7). The recommendations also contain rules to abide by if fishing vessels encounter evidence of VMEs. These include the necessity to cease fishing and move away from the VME-evidenced location, as well as quantify the catch of VME indicators, which could later on be used to establish a temporary closure (Recommendation 19 2014: Protection of VMEs in NEAFC Regulatory Areas, as Amended by Recommendation 09:2015 and Recommendation 10:2018, 2018, art. 8).

Similarly to APEIs, VMEs are sectoral tools, offering protection only from bottom-fishing activities and their impacts. However, they are also of relevance for the management of deep-sea mining activities, as their identification criteria could be relied upon to assess what sites could be characterized as sites/areas in need of protection/precaution under the draft nMAR REMP (Gollner et al., 2021). This also calls for the strengthening of a multi-sectoral dialogue, questions further discussed below.

The second tool, developed in the context of the Convention on Biological Diversity (CBD), is the Ecologically and Biologically Significant Areas (EBSAs) process. The EBSA process "is a global scientific and technical process" (Diz et al., 2017, p. 8) that aims to identify and collect information about specific areas of the ocean having special importance for ecological and biological processes (Workshop "Protecting deep seabed ecosystems under the future Agreement on the Conservation Sustainable Use of BBNJ by the ISA–Perspectives of Government, Civil Society, Stakeholders, and Law and Science", 2021; EBSA). This identification process uses a set

5 The International Maritime Organization (IMO) has also created ABMTs in the form of Particularly Sensitive Sea Areas (PSSAs), areas "that needs special protection through action by IMO because of its significance for recognized ecological or socio-economic or scientific attributes where such attributes may be vulnerable to damage by international shipping activities" (Revised Guidelines for the Identification Designation of Particularly Sensitive Sea Areas, 2006, pt. Annex, para 1.2) Despite (1) the similarities between the PSAAs identification criteria and the ones described below for VMEs and EBSAs, and (2) the relevance of PSSAs for the broader discussion on ABMTs, the present paper does not address PSSAs as none has so far been declared in ABNJ (De Santo, 2018, p. 35) nor are the existing PSSAs found in current areas of interest for deep-sea mining activities.

6 The criteria are:

1) uniqueness or rarity, i.e. "contains rare species whose loss could not be compensated for by similar areas or ecosystems";

2) functional significance of the habitat, i.e. "that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks"; 3) fragility, i.e. "highly susceptible to degradation by anthropogenic activities";

4) life-history traits of component species that make recovery difficult, i.e. species that have, e.g., "low growth rates, late age of maturity, low or unpredictable recruitment; or long-lived"; and

5) structural complexity, i.e. "complex physical structures [where] ecological processes are usually highly dependent on these structured systems."

of seven criteria, which present many similarities with the VME criteria[7]. The assessment of EBSA criteria also contains a strong interaction with the way one defines and assesses the scope of serious harm to the marine environment (Levin et al., 2016a; Mengerink, 2018). In fact, such assessment relies on a combination between the extent, duration/frequency, intensity/magnitude and probability of harm, the vulnerability of the site, and cumulative effects (Workshop "Protecting deep seabed ecosystems under the future Agreement on the Conservation Sustainable Use of BBNJ by the ISA–Perspectives of Government, Civil Society, Stakeholders, and Law and Science", 2021).

An EBSA designation can then support the need for a management measure in the area, such as marine protected areas or other effective area-based conservation measures. Yet, contrary to VMEs, which are *intended* to lead to the adoption of conservation and management measures to protect vulnerable marine ecosystems, no similar intention can be derived from an EBSA designation. Management measures flow from other international obligations (e.g., art. 194(5) UNCLOS), while the EBSA designation simply acts as a scientific and technical basis for the establishment of such measures. The two are however linked to some extent: as explained by Diz et al. (2017), the "modification of described areas can have implications when the EBSA description has been used as a basis for the implementation of management measures pursuant to other international legally binding obligations" (Diz et al., 2017, p. 8).

This difference between an EBSA designation and the establishment of conservation and management measures can be illustrated by the case of the Lost City hydrothermal vent. Located on the nMAR, the Lost City, along with many other sites in the area, was identified as an EBSA in 2014 (Report of the North-West Atlantic Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas, 2014, pp. 107–122). The site was also "recognized in the world heritage reports for its potential outstanding universal value in the high seas" (Gollner et al., 2021, p. 9). Yet, a deep-seabed mining exploration contract was granted to Poland in 2018 for that area, "based on a recommendation of the ISA's [LTC], which did not specify any particular environmental concerns" (Christiansen et al., 2022, p. 9). Commentators have heavily criticized this decision, mentioning that this situation stemmed from the fact that non-use values (e.g., natural beauty or aesthetic importance), which, along with the seven EBSA criteria, strongly characterizes the Lost City, are not taken into consideration in ISA assessment procedures before granting exploration contracts (Workshop "Protecting deep seabed ecosystems under the future Agreement on the Conservation Sustainable Use of BBNJ by the ISA–Perspectives of Government, Civil Society, Stakeholders, and Law and Science", 2021). It remains to be seen whether the Lost City and other EBSAs on the nMAR will become protected through measures in the newly developed draft nMAR REMP.

EBSA criteria certainly consider connectivity between species and their habitats, as well as the importance of this connectivity for overarching natural processes. Consequently, they are powerful justification tools upon which to rely to establish management measures. Whether this connectivity is replicated at the regulatory and management levels, however, seems to remain the result of a compromise between scientific evidence and other considerations (which, to some extent, reminds us of the case of some CCZ APEIs which had been modified from initial scientific evidence to accommodate exploration licenses already authorized).

Development of ABMTs for the regional environmental management plan for the northern mid-Atlantic ridge

Ecological considerations for ABMTs to protect active vent ecosystems

Three exploration contracts for polymetallic sulfides are issued along the nMAR, and four in the Indian Ocean. In these contract areas, some of the most of pristine and remarkable ecosystems on Earth are located: hydrothermal vents (Figure 1).

Deep-sea hydrothermal vent fields are unique ecosystems, where so-called chemoautothroph microbes gain their energy from chemicals from the vent fluids as opposed to sunlight, and create abundant food for a unique fauna. Globally, the vent ecosystem is a rare habitat, covering only an estimated area of 50 square kilometers, and meeting all scientific rationales for protection (Van Dover et al., 2018; Gollner et al., 2021). The small but unique and biomass rich deep-sea vent ecosystems are found patchily distributed in an otherwise typically food-depleted deep sea, where food mostly originates from the biomass produced *via* sunlight and photosynthesis in the ocean surface waters (Smith et al., 2008). In the past seen as isolated oases in the deep sea, recent evidence suggests that vents influence their surrounding areas: there are large transition zones harboring a mixture of vent fauna, as well as species from the surrounding deep sea that are utilizing the resources generated at these sites (Gollner et al., 2015; Levin et al., 2016b; Georgieva et al., 2020; Haalboom et al., 2020; Klunder et al.,

7 The criteria are:
1) uniqueness or rarity;
2) special importance for life history stages of species;
3) importance for threatened, endangered or declining species and/or habitats;
4) vulnerability, fragility, sensitivity, or slow recovery;
5) biological productivity.
6) biological diversity.
7) naturalness.

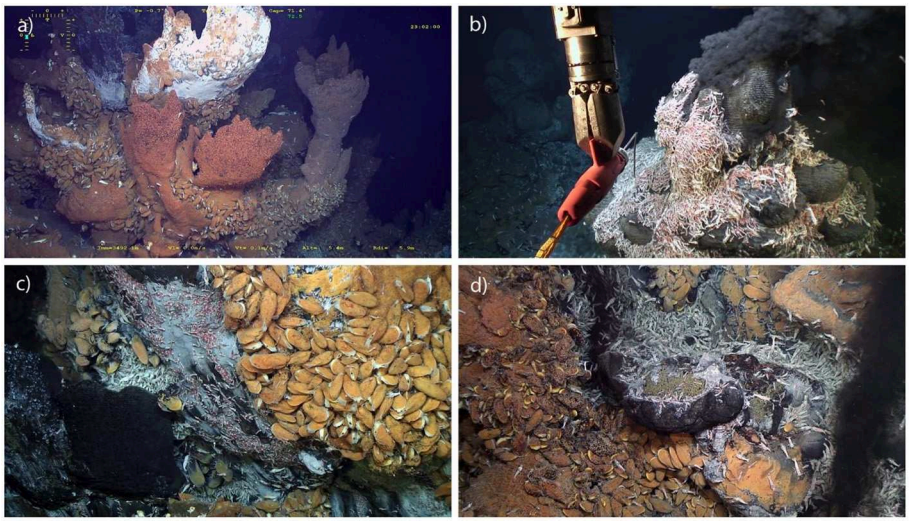

FIGURE 1
Snake Pit vent field in 3350–3500 meters depth at the northern Mid-Atlantic Ridge. Pictures show the structural diversity of mineral deposits [for example active black smoker in **(b)**] and endemic animals which rely on the energy of the vent fluids: **(a)** mussel assemblages, **(b)** shrimp swarms, **(c)** juvenile shrimp swarms and mussels, **(d)** gastropods surrounded by shrimp and mussels. BICOSE 2014 cruise copyright Ifremer. Video of **(a,b,d)** is available at https://doi.org/10.17882/74349. Figure replicated from Gollner et al. (2021).

2020; Cordes et al., 2021; Roohi et al., 2022). To identify the three-dimensional transition zone and thus the management measures to protect active vents, the physical, chemical and biological links need to be measured.

There is a high need for environmental researchers to work on characterizing the transition of the physical habitat, communities and ecosystem functions. For example, they should explore questions such as "are there species overlaps between active vent and surrounding areas?" or "what is the origin of food source?" or "what is the productivity and how does it change?" or "where are the subsurface channel that may connect vent fluids to inactive vents?" (Cordes et al., 2021). The ultimate goals are to determine the three-dimensional sphere of vent influence at each vent field, and to suggest methods for baseline surveys so that the full geographical scope of a vent is covered. The definition of the vent transition zones may be further linked to any network criteria, i.e., with regard to connectivity between vent fields, that is typically achieved *via* particle (such as animal larvae) transport with the natural vent plume and ocean currents from one vent field to the other (Adams et al., 2012; Van Dover et al., 2012; Mullineaux et al., 2018).

Potential ABMTs under the ISA framework for polymetallic sulfide deposits

In accordance with the Council's decision to "develop REMPs in priority regions where exploration activities take place" (Preliminary strategy for the development of regional environmental management plans for the Area, 2018; Implementation of the Authority's strategy for the development of regional environmental management plans for the Area, 2019), an LTC working group developed a draft REMP for the nMAR (Draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits, 2022). The draft was published in April 2022 and remained open for stakeholder consultations until early June 2022. The LTC circulated a revised version of the REMP in early October 2022 (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022).

The ABMTs included in the REMP are largely inspired by–or even replicate–suggestions made at expert workshops held in 2018 in Szezin, Poland (Workshop for Developing a Framework for REMPs for Polymetallic Sulphide Deposits in Mid-Ocean Ridges, 2018), 2019 in Evora, Portugal (Report of the Workshop on the Regional Environmental Management Plan for the Area of the Northern Mid-Atlantic Ridge, 2019), and 2020 online (Report of the Workshop on the Development of a Regional Environmental Management Plan for the Area of the Northern Mid-Atlantic Ridge with a Focus on Polymetallic Sulphide Deposits, 2020). It is also worth noting that the

> REMP does not include ABMTs identified through the application of network criteria such as representativity and connectivity. It is noted that further work will be needed on the application of such criteria.

> (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022 para. 33).

Network criteria, discussed in a 2018 study (Dunn et al., 2018) have therefore not been taken up in the draft (Christiansen et al., 2022, p. 9) nor the revised version. This lacuna is of significance for our discussion, as connectivity is also assessed through network criteria (Dunn et al., 2018, pp. 4 and 9).

Three types of area-based management measures are presented in the nMAR REMP: areas and sites in need of protection (AINPs and SINPs, or S/AINPs), as well as sites and areas in need of precaution (S/A Precaution). The REMP identifies 3 AINPs, 11 SINPS and 12 S/A Precaution (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, paras 40, 45 and 49). This means that these sites or areas have been identified as requiring the level of protection or precaution established by each tool.

AINPs are "large-scale areas of ecological importance due to their uniqueness and/or biodiversity" (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 37), aiming to protect ecosystem features at the regional scale (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 38). The management measures for such areas are (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 39):

- Protection from direct and indirect impacts of mining;
- Protection as an integrated system; and
- Zoning system, including a core zone of full protection, buffer zones, and possibly other zones where some compatible activities could be allowed.

SINPs are "fine-scale sites described on an individual basis," aiming to manage activities that would have serious harmful effects (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 41). Management measures include (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 43):

- Protection from direct and indirect impacts of mining (contractors will have to provide sufficient information to prove this protection);
- Delineation and description, by contractors guided by the LTC, of SINPs falling within their contract areas; and
- Zoning system (similar as under AINPs).

Finally, S/A Precaution are either fine-scale sites or large-scale areas having "been predicted to have features that may give the site/area important conservation value" (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 46). The REMP spells out a procedure for 'upgrading' an S/A Precaution to a S/AINP or for removing the S/A Precaution status (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 47). The REMP finally calls upon contractors planning to undertake exploitation activities to apply a precautionary approach, and to not start such activities in an S/A Precaution until their status is assessed (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 48).

Discussion

Outstanding questions impacting on the readiness of the nMAR REMP

Although S/AINPs and S/A Precaution, and the REMP more generally, were acknowledged for making good progress and for representing a good basis upon which to develop further work, they fall short of "clarity regarding obligations, roles, and responsibilities" (USA Comments–Stakeholder consultation on the draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge with a focus on polymetallic sulphide deposits, 2022; Pew Charitable Trusts–Stakeholder consultation on the draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge with a focus on polymetallic sulphide deposits, 2022; Germany–Stakeholder consultation on the draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge with a focus on polymetallic sulphide deposits, 2022, para. 2; DOSI–Stakeholder consultation on the draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge with a focus on polymetallic sulphide deposits, 2022; Italian delegation–Stakeholder consultation on the draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge with a focus on polymetallic sulphide deposits, 2022). Similar concerns were reiterated by

members of the Council, non-members and observers at the third part of the Council's 27th session in November 2022. These deficits trigger an important number of questions, especially when trying to understand the function of ABMTs and their foreseen implementation[8]. A selected number of questions are discussed below.

1) Identification/establishment/implementation

The identification of S/AINPs relies on similar criteria (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, sec. Annex IV). However, it is unclear whether the processes for their establishment are similar. It is also not clear who establishes the S/AINPs once the conditions are identified (e.g., it seems to be the contractors to some extent for the SINPs, and it is not specified for AINPs). Should there be a standardized process led by the LTC, in consultation with the scientific community, or by a scientific committee[9]? By giving too much leeway to contractors, we could have a similar situation as with RZs, which, left in the hands of contractors, could lead to great disparities in terms of measures. It is furthermore not always clear how and by whom the management measures are going to be implemented and enforced, i.e., by the ISA, the sponsoring State, or the contractor.

2) AINPs vs. APEIs

It is unclear what differentiates an AINP from an APEI. Is it because different scientific criteria exist to identify them? Is it because, as the nMAR is very different from the CCZ, we use another concept to highlight this distinction? The authors recognize that REMPs have a regional role and must represent the particularities of a specific region, but, as the ISA also has a global mandate, using similar tools and vocabulary could help streamline the obligations that the ISA has toward all regional environments. Furthermore, are legal obligations stemming from an AINP designation different from an APEI designation? Both tools seem to lead to similar obligations as an APEI is an area closed to mining activities (Environmental Management Plan for the Clarion-Clipperton Zone, 2011, para. 39(a)) while AINPs "will be protected from direct or indirect impacts" of mining; yet, the different terminology could lead to concluding otherwise.

3) How do AINPs, SINPs and S/A Precaution interact and/or relate to one another?

Could a certain number of SINPs lead to the creation of AINPs? Further, activities seem to be allowed in S/A Precaution, at least to some extent, as the REMP requires "[c]ontractors planning to undertake exploitation activities in the S/A Precaution [to] apply a precautionary approach" and "not start exploitation activities until [their] status is assessed" (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 48). It is however unclear what this entails. Does this mean that the management measures established for S/AINPs, especially the protection from direct and indirect impacts of mining, should be applied to S/A Precaution until their status is assessed? We also question through what other methods the precautionary approach could be applied in this situation.

4) The need to fully respect the rights and obligations of contractors when applying management measures for SINPs

The draft REMP originally mentioned that management measures for SINPs must fully respect the rights and obligations of contractors in the existing contracts for exploration (Draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits, 2022 para. 40). Although this phrasing has been removed in the revised text, we believe that its previous inclusion warrants a short discussion. What would have this respect entailed for the protection of the marine environment? Could this full respect for the rights and obligations of contractors have been interpreted as giving priority to those rights and obligations over management measures and, consequently, the protection of the marine environment? It is difficult to understand the meaning and impact of these words, as the need to "fully respect" is not found under UNCLOS nor the Part XI Agreement. Aligning the wording of the REMP with terminology used under UNCLOS and the Part XI Agreement could provide clarification. For example, the use of due regard, which ensures a balancing exercise, could entail, e.g., that the management measure of a SINP do not block exploitation activities in other parts of the contract area. Similarly, the idea of "full cooperation," which is used with regards to the transfer of technology (Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, 1994, sec. Annex, Section 5, para 1(b)), could be replicated to ensure

8 Some of the questions discussed in the text are inspired by the questions found in the submission by Pew Charitable Trusts. Other questions stem from reflections and observations made by the researchers in the project, which have in part been reflected in the submission by DOSI.

9 A standardized process has been suggested by Germany, the Netherlands and Costa Rica (Procedure for the development, 2020).

cooperative actions from all relevant parties, including the contractor. Overall, such alignment with existing terminology should be ensured throughout the text of the REMP to warrant that the protection of the marine environment does not come in second place.

5) (The absence of) network criteria

If network criteria have not yet been established, does this mean the adoption of the REMP can still go ahead? A new regulation in the Draft Exploitation Regulations suggests that a REMP should be adopted before an application for a plan of work can be considered (Facilitator's Revised Text : Draft regulations on exploitation of mineral resources in the Area–Parts IV VI related Annexes, 2022, r. 44bis(3)). Does this mean that an application for a plan of work could be considered based on an adopted REMP that does not include network criteria? The management measures for AINPs indicate that "each of them will be protected as an integrated system" (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, para. 39b)). Is this a stepping stone to later on build a system at the network level, or, on the contrary, an inhibitor of a network, as each AINP is to be considered as a system in itself?

6) (The absence of) the size of SINPs

The draft nMAR REMP lists 11 SINPs, covering the known active vent fields. However, at the time of writing, the draft REMP only gives, single point coordinates, and the actual delineation of the sites is left to contractors (Draft regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits, 2022, para. 40(b)). The revised text does not seem to provide more guidance on the size or extent of SINPs (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, paras 43 and Annex II). Considering the ecology of hydrothermal vents it is of upmost importance to robustly determine the three-dimensional sphere of vent influence at each vent field and to protect this space. Otherwise, the goal to protect unique vents is programmed to fail. Cooperation between scientists and contractors will be crucial, as the scientific field of studying and understanding the sphere of vent influence is just developing. Ecological connections between vents and the surrounding areas need to be unraveled and translated to ABMTs, including SINPs.

All these questions highlight the work that remains to be done to clarify the nature, role and impact of the suggested ABMTs in the nMAR REMP. The revised version of the REMP was circulated by the LTC prior to the third part of the Council's 27th session in November 2022, with the hope that it would be adopted during that session. However, on 11 November 2022, the Council, although acknowledging the progress made, considered that the document needed to be developed further before it is ready for adoption. It therefore remains to be seen in which direction the discussions on the nMAR REMP will go in upcoming sessions of the Council, also in light of the discussions on the *Guidance to facilitate the development of regional environmental management plans*, which aim to provide "a standardized approach for the development, approval and review of [REMPs] in the Area, including a template with indicative elements" (Guidance to facilitate the development of regional environmental management plans, 2022).

Beyond ecological connectivity: connectivity among international instruments, institutions and processes

One way to ensure that legal/regulatory instruments and sectoral measures address ecological connectivity is to connect different regulatory and policy components of oceans conservation and management so that they do not stand alone. The ISA has, to some extent, developed partnerships with other entities mandated with the regulation of activities at sea. For example, the ISA entered into an Agreement of Cooperation with the International Maritime Organization, which aims to increase consultations on matters of common interests to ensure maximum coordination and exchange of information in fields of common interest (Agreement of Cooperation between the International Maritime Organization (IMO) and the International Seabed Authority (ISA), 2016, paras 1–2). The ISA has however not joined the Collective Arrangement for the North-East Atlantic that among other goals, seeks "cross-sectoral practical implementation of [...] conservation objectives" in selected areas in ABNJs (Christiansen et al., 2022, p. 7), to which only NEAFC and OSPAR are currently parties (Collective arrangement between competent international organisations on cooperation coordination regarding selected areas in areas beyond national jurisdiction in the North-East Atlantic, 2014). Joining such Arrangement could be beneficial to coordinate different sectoral objectives and measures, in order to give a cross-sectoral and cross-zonal (i.e., deep seabed and water column) coverage of hydrothermal vents and other relevant features, especially considering that the region is under exploration contracts (Exploration Contracts). As the creation of collaborations with other entities is listed as one of the strategic objectives of the ISA in its 2019-2023 Strategic Plan (Strategic Plan of the International Seabed Authority for the Period 2019–2023, 2018, sec. Direction 1.2), the ISA may actively seek to formalize partnerships with entities operating in the same regions.

When addressing issues of spatial management in ABNJ, one cannot ignore the negotiations currently underway to develop an

Implementing Agreement under UNCLOS for the conservation and sustainable use of marine biodiversity beyond national jurisdiction (BBNJ process). Many overlaps exist between this process and the work of the ISA, not only geographically (the BBNJ process covers all ABNJ, including the Area), but also in its subject-matter. The BBNJ process indeed generally aims to improve coordination and cooperation among different uses, institutions and measures in ABNJ, and, more specifically, one of the four core issue-areas covered by the process are ABMTs (International legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation sustainable use of marine biological diversity of areas beyond national jurisdiction, 2017, para. 2).

How, then, could we take advantage of these concurrent developments to strengthen mechanisms in each process, but also connectivity between processes and their spatial management measures (including ABMTs)? A recent study focuses on ways to strengthen "governance integration and the development of a coherent and collaborative interplay between" the BBNJ process and ISA instruments (Christiansen et al., 2022), suggesting that connectivity in governance can be truly operationalized through an ecosystem approach to management (EAM) (Christiansen et al., 2022, p. 2–3). EAM targets natural dynamics and connectivity through a cross-sectoral and long-term vision, the consideration of cumulative impacts and effects, adaptive management, and stakeholder involvement (Long et al., 2015; Christiansen et al., 2022, p. 4).

A challenge however, often raised by delegates in both the BBNJ process and the ISA fora, is to implement an EAM in practice. One option, the study suggests, is to explore how REMPs could be used as vehicles to operationalize an EAM, which would help align REMPs with BBNJ objectives and measures. Different policy recommendations are made to that effect (Christiansen et al., 2022, p. 17), three of which are of direct relevance to shape new and/or strengthening existing ABMTs in a way that addresses ecological connectivity.

First, ambitious principles and goals could direct coordination between objectives and processes (Christiansen et al., 2022, p. 12). In the specific context of the ISA, developing strategic environmental goals and objectives (SEGOs), complemented by clear targets and indicators, has been identified as necessary to properly assess "progress toward meeting those objectives" (Tunnicliffe et al., 2020, p. 7; Singh, 2021, p. 3). General objectives and/or guiding principles for marine environmental protection and management are found in the ISA Draft Exploitation Regulations (Facilitator's Revised Text : Draft regulations on exploitation of mineral resources in the Area–Parts IV VI related Annexes, 2022, r. 44), in the CCZ REMP (Environmental Management Plan for the Clarion-Clipperton Zone, 2011, para. 13), in the nMAR REMP (Regional environmental management plan for the Area of the northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphide deposits–Issued by the Legal Technical Commission, 2022, paras 12–13), and in the BBNJ draft text, both for the agreement as a whole and for ABMTs more specifically (Further revised draft text of an agreement under the United Nations Convention on the Law of the Sea on the conservation sustainable use of marine biological diversity of areas beyond national jurisdiction, 2022, arts. 5, 14 and 17(1)(a)). These are good stepping stones, but the necessary SEGOs would have more ambitions and a "higher purpose" for all initiatives linked to the conservation and management of the marine environment. SEGOs could also help align deep-sea mining environmental efforts subject to art. 145 UNCLOS with other processes which have similar goals, including the BBNJ process (Workshop "Protecting deep seabed ecosystems under the future Agreement on the Conservation Sustainable Use of BBNJ by the ISA–Perspectives of Government, Civil Society, Stakeholders, and Law and Science", 2021). ABMTs could be designed in order to fulfill these goals, embedded in a cross-sectoral and cross-zonal strategy.

Second, REMPs, and management tools included therein, should always respect–and even align with–existing identifications and designations, e.g., VMEs and EBSAs. One step further would be to ensure that the designation of ABMTs by the ISA also relies on the same/similar criteria as the one used for VMEs and/or EBSAs, which are also used as "indicative criteria for identification of" ABMTs found in Annex I of the draft BBNJ text (Further revised draft text of an agreement under the United Nations Convention on the Law of the Sea on the conservation sustainable use of marine biological diversity of areas beyond national jurisdiction, 2022). This "alignment" exercise could moreover complement the standardized approach to the development of REMPs suggested by Germany, the Netherlands and Costa Rica in their joint 2020 submission (Procedure for the development, 2020).

Finally, pursuing an EAM to guide the design of "connectivity-friendly" ABMTs would reiterate the importance of stakeholder involvement. Hosting a consultation with stakeholders following the publication of the draft nMAR REMP is one positive way forward; yet, it is unsure whether stakeholder input will be sought on revised versions of the draft. Stakeholder engagement is necessary at all stages of the process, and it would furthermore be a way to warrant the consideration of conflicting oceans uses and interests that might impact on the effectiveness of a sector-specific ABMT (Christiansen et al., 2022, p. 7).

As the regulatory framework for the protection and management of different areas and resources of the oceans remains fragmented (and, as the BBNJ negotiations have shown, this division is strongly protected by existing institutions, who often fiercely guard their respective mandate), the policy suggestions discussed above are ways to find synergies among instruments, institutions and processes. Facilitating this type of connectivity therefore contributes to embedding the highest possible environmental standards in ISA regulation and practice (Hydrothermal vent fields: Protecting deep seabed hydrothermal vent fields through area-based management tools).

Conclusion

ABMTs developed by the ISA can only partly cover connectivity between the deep seabed and the water column. This flows from the definition of "marine environment" found under the Draft Exploitation Regulations, as well as the role of the different tools, which aim to protect from and/or monitor the *impacts* of deep-seabed mining, which are likely to also occur in the water column. However, uncertainties with regards to the exact nature and scope of existing tools limit a full understanding of their functioning. There is a clear need to identify the ecological transition zones of vents, so that the sphere of vent influence can be determined in practice and thus a three-dimensional space that would need protection can be assigned. Furthermore, the impossibility for sectoral organizations to develop truly cross-sectoral tools restricts the full three-dimensional potential of current spatial management. The ISA will therefore need to continue its work to ensure that the environmental protection pillar of its mandate is truly fulfilled.

As part of their overarching objective to translate ecological connectivity into regulatory mechanisms, researchers and decision-makers might have to delve into broader and more holistic governance mechanisms and processes, in order to reflect the necessary connectivity that also exist between international instruments, institutions and processes. Exploring alternative and complementary types of governance, such as polycentricity (Gjerde and Yadav, 2021; Dalaker, 2022), a "governance that is characterized by multi-scale governing authorities, institutions, and bodies rather than a centralized governing body" (Ostrom, 2010; Dalaker, 2022, p. 37), is also necessary.

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Conflict of interest

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An evolutionary game study of environmental regulation strategies for marine ecological governance in China

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The choice of environmental regulation strategies for marine ecological pollution governance is vital for China's promotion of collaborative marine ecological management. First, based on the assumption of limited rationality, we established a three-party evolutionary game model of China's central government, local governments, and marine enterprises from the perspective of environmental policy to explore the dynamic evolution process of the game strategies of the three participants and the stability of the system equilibrium point. Second, we used numerical simulations to investigate how the incentive- and penalty-based policies of central and local governments have different effects on local governments and marine enterprises, respectively. Finally, we introduced a reputation loss model of public participation to explore the game strategy choices of the three parties under public participation. The finding reveal that (1) Local governments are more sensitive to the central government's punishment policies than marine enterprises are. (2) Increasing the punishment of local governments on enterprises can simultaneously enhance the willingness of enterprises to govern and the willingness of local governments to implement. Moreover, the local governments policy of punishing enterprises was more direct and effective than that of the central government. (3) Although local governments subsidies for marine enterprises can increase their probability of governing marine ecology, they can also decrease local governments' willingness to implement. Finally, (4) Public participation can quickly promote the active governance of marine enterprises. Accordingly, the suggestions are proposed to maintain China's marine ecological security, e.g., the central government should focus on urging local governments to strictly implement marine environmental protection policies; local governments should take the lead in supervising and guiding marine enterprises; and all levels of government need to take measures to promote public participation in marine ecological governance.

KEYWORDS

marine ecological governance, environmental regulation strategy, evolutionary game, numerical simulation, public participation

1 Introduction

At the end of the 20th century, China planned to vigorously develop its marine economy and incorporate the development and utilization of marine resources into its national development strategy (Mallory, 2015; Winther and Su, 2020; Li et al., 2020; An et al., 2022). However, China's marine ecology problems have become more acute as marine resource consumption and the acceleration of urbanization and industrialization have increased in coastal areas, resulting in highly adverse consequences for human survival (Manzoor et al., 2018; Kelly et al., 2019; Chen and Zheng, 2020; Haas et al., 2022). To reverse this crisis, the Chinese government has gradually adjusted its strategic policy from vigorously developing the marine economy to constructing a marine ecological civilization, including measures for combating marine pollution, restoring marine ecosystems, and protecting marine biodiversity. Overall, China's marine ecological management system has achieved positive results. The information disclosed in the 2018 and 2019 China Marine Ecological Environment Status Bulletins indicates that China's marine ecological quality is generally stable. However, some areas still have problems, such as increased marine ecological pollution (Gao et al., 2022b), reduced biodiversity (Xu et al., 2012), declining fishery resources (Yuan et al., 2022), and frequent natural disasters and emergencies (Chen et al., 2017). Ecological fragility and high resource loads have become the norm. Environmental regulation plays a vital role in promoting marine ecological protection (Wright, 2014; Kelly et al., 2019; Chen and Qian, 2020; Liu and Chen, 2022). China's environmental regulatory policies are often formulated by the central government and implemented by local governments. However, local governments often neglect central government policies and tweak enterprise supervision due to high implementation costs or to pursue local economies (Rosenberg, 2009; Chang et al., 2013; Li et al., 2020). Local governments thus form non-cooperative game relationships with the central government. Therefore, choosing a reasonable environmental regulation policy and forming an idealized cooperative game model of "central government guidance, local government promotion, and marine enterprise implementation" has become a key issue in China's marine ecological governance.

As an important element of government social regulation (Niu et al., 2017; Nielsen et al., 2019; Eghbali et al., 2022), the implementation of environmental regulation inevitably involves the interests and strategic choices of multiple co-regulatory actors. The behavioral strategies of subjects with limited rational co-regulation are optimized chiefly through repeated trial and error and learning imitation to reach a stable state (Weibull, 1997; Sotomayor et al., 2020; Wang et al., 2022). This indicates that environmental regulation issues are suitable for evolutionary game analysis. Through the continuous efforts of scholars, many research results have been achieved regarding the evolutionary games of environmental co-regulation subjects. These can be divided into the following four types.

(1) The game of environmental behavior between central and local governments.

Marine ecological management is closely related to government structure. China's central government gives local governments the authority to manage the environment, which constitutes a typical principal–agent relationship. Nevertheless, local governments often neglect to protect the ecological environment in order to win promotional tournaments based on GDP assessments. Yu and Wang (2013) created a Stackelberg model to simulate central and local government solutions regarding afforestation projects and showed that, while the central government tries to maximize eco-efficiency, local governments tend to reduce their administrative budgets due to budget constraints. Kolk and Tsang (2017) explored the strategic choices of central and local governments regarding automotive companies and their sustainability using a mathematical model. The results showed that the central government favored small cars for the sake of environmental development sustainability, whereas local governments focused more on large cars to pursue municipal development. Teichmann et al. (2020) took the environmental game as their starting point and analyzed central government measures taken to combat corruption in local governments. The results showed that excessive government subsidies increased the risk of public official misappropriation and that compliance bonuses may be an effective way to eliminate corruption. Sun et al. (2021) analyzed the key factors in environmental strategy choice between central and local governments based on evolutionary game theory. They pointed out that the choice of environmental behavior for central and local governments depends on a comparison between costs and benefits in governance. Zhu et al. (2022) explored the influence of relevant factors on environmental strategies between central and local governments, finding that there is no evolutionary equilibrium strategy for China but that incentive policies can help the central government guide local governments in choosing environmental strategies in the short term.

(2) The game of environmental behavior among local governments

To develop the local economy, compete for mobile resources, and obtain public support, local governments will launch a political game, which will ultimately affect regional environmental development. In research on Vietnam, Clausen et al. (2011) found that local governments focusing on the game of economic growth would ignore environmental problems, which would ultimately affect the sustainable development of the whole country. Driscoll (2018) proposed that the fierce political game is an antidote for obtaining social sponsorships but also aggravates social tension and instability because, when the two major political parties compete closely for local elections, local governments pay more attention to environmental

development in order to win the trust of the people. Meckling and Nahm (2019) affirmed the positive impact of the British political game on green development. They found that local governments use political signals to promote green technology change and enable states to communicate green policies to producers and consumers. In other words, when a local government issues green policies, other local governments may follow closely to seize a competitive advantage. Some scholars argue that games among local governments may cause environmental damage. Jin et al. (2020) analyzed the impact of environmental gaming behavior between governments across regions on local green total factor productivity based on a panel dataset of 278 prefecture-level cities in China.

(3) The game of environmental behavior between local governments and enterprises

Enterprises are key players in pollution emissions and are the main drivers of local economic growth. Therefore, it is important to study the strategic interaction behavior between the government and enterprises in ecological governance. Fairchild (2008) studied the game between governments and enterprises in environmental pollution regulation, using mathematical modeling to analyze the strategic interactions of the participating actors. The results show that enterprises' motivations for ecological governance are closely related to investment costs. By applying cooperative game theory, Meibodi et al. (2015) analyzed how the Iranian and Iraqi governments combat enterprises that generate dust. The results show that cooperation between governments can effectively reduce government supervision costs and improve the government's net revenue. Cai et al. (2016) studied the behavior of the government and two competing firms using an evolutionary game and performed a simulation analysis. The results indicate that the standard penalty strategy has the best suppression effect on environmental pollution, whereas the dynamic penalty strategy can stabilize the fluctuation of the evolutionary game process. Nielsen et al. (2019) studied how government policies affect the strategic choices of enterprises. The results show that, under government incentive measures, it is beneficial for enterprises to establish sustainable development as a goal, increase green investment, and foster environmental improvement. Eghbali et al. (2022) argue that government intervention affects green behavior among enterprises. They find that the government's static intervention reduces the maturity of green startups and improves their innovation level, ultimately reducing their willingness to cooperate with technological enterprises. When the government intervenes dynamically, cooperation between technology companies and green startups is more desirable.

(4) The behavioral game of multiple interests of multiple subjects in environmental governance

Realistic environmental regulation is a complex system of interactions among multiple subjects. Studying the game between only two parties will lead to incomplete research results. Studying the game between multiple subjects can effectively address current research gaps. Based on game theory, Barari et al. (2012) discuss how to establish coordination among manufacturers, retailers, and customers to evaluate their strategies for triggering green practices. The results show that manufacturers can invest in green activities and pass on the cost of greening to customers; retailers then have to invest the maximum marketing cost to emphasize the green dimension to offset the price increase. Bašič et al. (2015) analyzed the environmental behavior game of governments, enterprises, and other subjects to mitigate climate change. They argued that the uncertainty of environmental governance will make all subjects inclined to win-win cooperation. At the same time, they also found that only coordinated actions by multiple participants could effectively reduce greenhouse gas emissions. Xiao et al. (2019) developed an evolutionary game model of collaborative innovation involving multiple actors, including governments, enterprises, financial institutions, and research institutions. They found that complementarity in the resources and capabilities of multiple actors is a crucial factor in forming collaborative innovation alliances and an essential source of additional benefits for innovation actors. Gao et al. (2022b) analyzed the tripartite game mechanism comprising government, marine enterprises, and the public under a new media background. The results showed that a fair new media environment would positively affect marine ecological governance.

In summary, the literature offers many interesting research results regarding the strategic evolution game of environmental co-regulation subjects, but it has several shortcomings. First, the literature describes the regulatory strategies of the central government as either supervision or non-supervision. However, due to China's strong emphasis on marine ecological governance, the central government ignores the fact that marine ecology is inconsistent with reality. Second, most scholars study only the central government, local governments, or the public as the game's leading players. Few scholars have put the central government, local governments, and enterprises into the same game framework and simultaneously considered the impact of public participation on the evolutionary game. Third, most studies only examine whether the regulatory policy has a positive or negative impact on each governance subject in environmental regulation, and ignore whether there are differences between each impact. As China's marine ecological protection policy is improving, studying the effects of different regulatory policies on the same subject and those of the same regulatory policy on different subjects can provide a theoretical basis for using environmental regulatory policies more reasonably.

This study makes several important contributions to the literature. First, considering that the central government's regulatory behavior may range between full supervision and no supervision, this study introduces a degree variable into the strategic choice of the central government. Second, we construct

a dynamic evolutionary game model for the central government, local governments, and marine enterprises. We then introduce the reputation loss model of public participation to explore its impact on the players' strategy. Finally, we set the game variables according to the environmental regulation policies implemented in China. We also use MATLAB to change the parameters to explore the differences between punitive-based and incentive-based environmental regulation policies. Finally, this study provides a theoretical basis and policy reference for the efficient management of marine ecology.

The remainder of this paper is organized as follows. Section 2 constructs and solves the evolutionary game model of marine ecological governance and analyzes the evolutionary stable point (ESS) based on the life cycle theory of circular economy. Section 3 introduces the influence of the parameter changes in the relevant policy variables on the ESS through numerical simulation. Finally, Section 4 summarizes and concludes the study.

2 Methodology

2.1 Model assumptions

Given the actual situation of China's marine ecological governance regulation policy, this study proposes the following seven model hypotheses (model parameters and descriptions are expressed as shown in Table 1).

Hypothesis 1: The central government (CG) is participant 1, local governments (LGs) are participant 2, and marine enterprises (MEs) are participant 3. All three parties are finite rational participants, and the strategy choice is stabilized over time using the optimal strategy.

Hypothesis 2: Some scholars divide the central government's strategy simply into supervision and non-supervision (Eghbali et al., 2022). However, the central government, as the main leader of the country's development, cannot completely ignore the pollution behavior of enterprises (Chen et al., 2021). Therefore, we improved the strategy space selection for the central government and set the strategy space of CG as "strict supervision" and "weak supervision"; the proportion of strict supervision is x, and the proportion of weak supervision is 1 - x, $x \in [0,1]$. The strategy space of the LGs is "positive implementation" and "negative implementation"; the proportion of those who choose positive implementation is y, and the proportion of those who choose negative implementation is 1 - y, $y \in [0,1]$. The strategy space of MEs is "positive governance" and "negative governance"; the proportion of those who choose positive governance is z, and the proportion of those who choose negative governance is1 - z, $z \in [0,1]$.

Hypothesis 3: The cost of central government regulation is affected by regulation intensity (Sun et al., 2021; Gao et al., 2022a). However, some scholars simply set the regulatory cost as a fixed value (Du et al., 2022) and do not consider the dynamic effect on cost of regulatory intensity. Therefore, we use r to

TABLE 1 Model parameters and expression meanings.

Players	Parameter	Description
Central government	r	CG's supervision efforts
	C_1	Cost of strict supervision by CG
	S	CG subsidies to LGs and MEs
	m	Influence coefficient of local marine ecological governance level on national marine ecological governance level
Local governments	q	Rate of subsidies transferred from CG to MEs by LGs
	C_2	Costs incurred by LGs when positively implementing marine ecological governance policies
	E	Net environmental benefits generated by LGs when MEs are positively governed (compared to negatively governed)
	P_1	Penalties suffered by CG when LGs do not implement marine ecological management policies, but also the benefits of CG
	i	Share of LGs in CG's and LGs' taxes
Marine enterprises	R	Additional benefits of positive governance (compared to negative governance) for MEs
	C_3	Costs paid by MEs when positively governing marine ecology
	P_2	Penalties of LGs for MEs' negative governance
	P_3	Penalties of CG for MEs' negative governance
	α	Probability of negative ME governance being discovered by CG
	T_1	Lower environmental taxes levied when MEs govern actively
	T_2	Higher environmental taxes levied when MEs govern negatively

denote the CG's supervision intensity, $r \in (0,1]$. When the CG chooses the strict supervision strategy $r = 1$, the supervision cost is C_1. When the CG chooses the weak supervision strategy, $0< r< 1$ will generate a supervision cost rC_1. The introduction of r considers the CG's strategic choice more comprehensively and improves the assumptions of previous scholars regarding the cost of setting up CG supervision.

Hypothesis 4: When LGs choose a positive implementation strategy, it incurs an enforcement planning cost C_2. Moreover, strict enforcement by LGs will force MEs to choose active governance and improve the LGs' environmental performance (Fan et al., 2021). E is the net environmental benefit generated by LGs when the MEs are positively governed compared to when they are negatively governed; when LGs choose negative implementation strategies, they are penalized by the CG, including *via* economic and political penalties, denoted as P_1 ; and the level of local marine ecological governance indirectly affects the governance effectiveness of CG, with m denoting the influence coefficient of local marine ecological governance level on the national marine ecological governance level, $0< m< 1$.

Hypothesis 5: The enhanced benefits of positive ME governance (compared to negative ME governance) are R, and the additional cost of management is C_3; when MEs choose negative governance, they are penalized by LGs, expressed as P_2. According to China's Marine Inspection Regulations, the CG has established a National Marine Inspection Committee to guide, coordinate, and monitor the national marine ecological situation. We thus assume that there is an α $(0 \le \alpha \le 1)$ probability that the pollution behavior of MEs will be discovered and punished by the CG; the penalty amount is denoted as P_3. While Jiang and Li (2021) assume that MEs will definitely be punished by the CG when they display pollution behavior, this study considers a certain probability of being penalized given China's actual policy, which improves upon the previous assumptions in the literature.

Hypothesis 6: To better promote marine ecological governance, the government (including the CG and LGs) will adopt a series of incentive and penalty policies, including financial subsidies, fund allocation, environmental taxation, and tax sharing policies. (a) Regarding the financial subsidy policy, the "Marine Ecological Protection and Restoration Funds Management Measures" issued by the Chinese Ministry of Finance state that the CG will provide, through general public budget arrangements, a dedicated transfer fund to support marine ecological governance and protection, which is important for ecological security and has a wide range of ecological benefits. We assume that S is the transfer payment amount of the CG, which can effectively reduce the implementation costs of LGs and the governance costs of MEs. (b) Regarding fund allocation policy, this concerns the proportion of LGs that have the right to decide on the allocation of funds to MEs. Reiling et al. (2021) stated that LGs may transfer all or part of their funds to enterprises. Therefore, the distribution ratio in this study is q $0 \le q \le 1$. (c) Regarding environmental protection tax policy, the "Marine Engineering Environmental Protection Tax" issued by the State Administration of Taxation of China and the State Oceanic Administration of China mandates that the government shall determine the taxable amount of an enterprise by multiplying the number of its pollution equivalents by the specific tax amount, and the amount of pollution generated when the enterprise is positively governed must be smaller than that when it is negatively governed. Therefore, T_1 and T_2 represent the environmental taxes levied on the positive and negative governance of MEs, respectively; thus $T_1< T_2$. (d) The tax-sharing policy addresses the CG's and LGs' financial rights, and the core is the division of tax revenues (Buettner et al., 2011). We assume that i represents the share of LGs in the taxes; thus $0 \le i \le 1$. When the CG raises the share of LGs in environmental taxes, it can encourage LGs to take the initiative to implement policies related to marine ecological governance and strengthen marine ecological regulation.

2.2 Payment matrix construction

According to the above conditional assumptions of the evolutionary game and the reality of marine ecological governance, we constructed the payment matrix of the tripartite evolutionary game among the CG, LGs, and MEs, as shown in Table 2.

2.3 Evolutionary stabilization strategy solution based on replicated dynamic equations

In marine ecological governance, the CG, LGs, and MEs influence each other and jointly determine the evolution of the game. According to the "economic man" assumption, the strategy choice of all types of subjects is based on the maximization of their own interests. Therefore, the expected benefits of participating subjects are analyzed with the help of a payment matrix, and then the system's single-population evolutionary stabilization strategy is formed by solving the replicated dynamic equation.

2.3.1 Replication dynamic equation of CG's "strict supervision" behavior and its equilibrium point

Suppose that U_1^1 represents the expected payoff of the CG if they are strictly supervised, and U_1^2 represents the expected payoff of the CG if they are weakly supervised. $\overline{U_1}$ represents the average expected payoff of the CG. U_1^1, U_1^2, and $\overline{U_1}$ can be written as

TABLE 2 Three-party subject game payment matrix.

		Local governments	Marine enterprises	
			positive governance (z)	negative governance (1-z)
Central government				
	Strict supervision (x)	positive implementation (y)	-C_1-S+mE+(1-i)T_1, -C_2+iT_1+(1-q)S+E, -C_3+qS+R-T_1	(1-i)T_2-S-C_1, -C_2+iT_2-S+P_2 -T_2-P_2
		negative implementation (1-y)	-qS-C_1+mE+T_1+P_1, E-P_1, -C_3+R+qS-T_1	-C_1+P_1+αP_3+T_2, -P_1, -T_2-αP_3
	weak supervision (1-x)	positive implementation (y)	-rC_1+mE-S+(1-i)T_1, -C_2+E+(1-q)S+iT_1 -C_3+R+qs-T_1	-rC_1+(1-i)T_2-S, -C_2+iT_2+S+P_2 -T_2-P_2
		negative implementation (1-y)	-rC_1+mE+rT_1+rP_1-(1+rq-r)S, E-rP_1+(1-q)(1-r)S -C_3+R+qS-rT_1	-rC_1+rP_1+raP_3+rT_2-(1-r)S (1-r)(1-q)S-rP_1 -raP_3+(1-r)qS-rT_2

$$\begin{cases} U_1^1 = yz[-S - C_1 + mE + (1-i)T_1] + y(1-z)[(1-i)T_2 - S - C_1] + (1-y)z(-qS - C_1 + mE + T_1 + P_1) + \\ \quad (1-y)(1-z)(-C_1 + P_1 + \alpha P_3 + T_2) \\ U_1^2 = yz[-rC_1 + mE - S + (1-i)T_1] + y(1-z)[-rC_1 + (1-i)T_2 - S] + (1-y)z[-rC_1 + mE + rT_1 + rP_1 - \\ \quad (1 + rq - r)S] + (1-y)(1-z)[-rC_1 + rP_1 + r\alpha P_3 + rT_2 - (1-r)S] \\ \overline{U_1} = xU_1^1 + (1-x)U_1^2 \end{cases}$$

Then, according to evolutionary game theory, the replicator dynamics of the CG adopting the "strict supervision" strategy can be written as

$$F(x) = x(1-x)[(1-r)(-C_1 + T_2 + S + P_1 + \alpha P_3) - y(1-r)(S + P_1 + \alpha P_3 + T_2) - z(1-y)(1-r)(qS + T_2 - T_1 + \alpha P_3)]$$

Make $F(x) = \frac{dx}{dt} = 0$; the obtained solution may be the equilibrium point of the evolution process.

When $z \neq z^* = \frac{(1-r)(-C_1+T_2+S+P_1+\alpha P_3)-y(1-r)(S+P_1+\alpha P_3+T_2)}{(1-y)(1-r)(qS+T_2-T_1+\alpha P_3)}$, we obtain x=0 and x=1 as the two possible equilibria of $F(x)$. According to the stability theory of the replica dynamic equation, it can be concluded that, when $\frac{dF(x)}{dx} < 0$, this point is ESS.

We can obtain the following formula by taking the derivative of $F(x)$:

$$\frac{dF(x)}{dx} = (1-2x)[(1-r)(-C_1 + T_2 + S + P_1 + \alpha P_3) - y(1-r)(S + P_1 + \alpha P_3 + T_2) - z(1-y)(1-r)(qS + T_2 - T_1 + \alpha P_3)]$$

When $z = z^* = \frac{(1-r)(-C_1+T_2+S+P_1+\alpha P_3)-y(1-r)(S+P_1+\alpha P_3+T_2)}{(1-y)(1-r)(qS+T_2-T_1+\alpha P_3)}$, then $F(x)\equiv 0$, indicating that all points on the x-axis are in a steady state, and implying that the CG's strategy choice does not change with time at this point.

When $0<z<\frac{(1-r)(-C_1+T_2+S+P_1+\alpha P_3)-y(1-r)(S+P_1+\alpha P_3+T_2)}{(1-y)(1-r)(qS+T_2-T_1+\alpha P_3)}$, then $\frac{dF(x)}{dx}_{x=1} < 0$, $\frac{dF(x)}{dx}_{x=0} > 0$, Therefore, x=1 is the equilibrium point for the evolution of the CG's behavior. That means that, if MEs tend to opt for negative governance, then the probability of the CG's "strict supervision" strategy will approach 1.

When $\frac{(1-r)(-C_1+T_2+S+P_1+\alpha P_3)-y(1-r)(S+P_1+\alpha P_3+T_2)}{(1-y)(1-r)(qS+T_2-T_1+\alpha P_3)} < z < 1$, then $\frac{dF(x)}{dx}_{x=0} < 0$, $\frac{dF(x)}{dx}_{x=1} > 0$, Therefore, x=0 is the equilibrium point for the evolution of the CG's behavior. That is to say, if MEs tend to opt for positive governance, then the probability of the CG's "strict supervision" strategy will approach 0.

2.3.2 Replication dynamic equation of LGs' "positive implementation" behavior and its equilibrium point

Suppose that U_2^1 represents the expected payoff of the LGs if they are positively implemented and U_2^2 represents the expected payoff of the LGs if they are negatively implemented. $\overline{U_2}$ represents the average expected payoff of the LGs. U_2^1, U_2^2, and $\overline{U_2}$ can be written as

$$\begin{cases} U_2^1 = xz[-C_2 + iT_1 + (1-q)S + E] + x(1-z)(-C_2 + iT_2 + S + P_2) + (1-x)z[-C_2 + E + (1-q)S + iT_1] \\ \quad +(1-x)(1-z)(-C_2 + iT_2 + S + P_2) \\ U_2^2 = xz(E - P_1) + x(1-z)(-P_1) + (1-x)z[E - rP_1 + (1-q)(1-r)S] + (1-x)(1-z) \\ \quad [(1-r)(1-q)S - rP_1] \\ \overline{U_2} = yU_2^1 + (1-y)U_2^2 \end{cases}$$

Then, according to evolutionary game theory, the replicator dynamics of the LGs that adopt the "positive implementation" strategy can be written as

$$F(y) = y(1-y)\{-C_2 + iT_2 + P_2 + rP_1 + (r + q - rq)S + z[i(T_1 - T_2) - qS - P_2] + x(1-r)[P_1 + (1-q)S]\}$$

Make $F(y) = \frac{dy}{dt} = 0$; the obtained solution may be the equilibrium point of the evolution process.

When $x \neq x^* = \frac{C_2-iT_2-P_2-rP_1-(r+q-rq)S-z[i(T_1-T_2)-qS-P_2]}{(1-r)[P_1+(1-q)S]}$, we obtain y=0 and y=1 as the two possible equilibria of $F(y)$. According to the stability theory of the replica dynamic equation it can be concluded that, when $\frac{dF(y)}{dy} < 0$, this point is ESS.

We can obtain the following formula by taking the derivative of $F(y)$:

$$\frac{dF(y)}{dy} = (1-2y)\{-C_2 + iT_2 + P_2 + rP_1 + (r + q - rq)S + z[i(T_1 - T_2) - qS - P_2] + x(1-r)[P_1 + (1-q)S]\}$$

When $x = x^* = \frac{C_2-iT_2-P_2-rP_1-(r+q-rq)S-z[i(T_1-T_2)-qS-P_2]}{(1-r)[P_1+(1-q)S]}$, then $F(y)\equiv 0$, indicating that all points on the y-axis are in a steady

state, and implying that the LGs' strategy choice does not change with time at this point.

When $0<x<\frac{C_2-iT_2-P_2-rP_1-(r+q-rq)S-z[i(T_1-T_2)-qS-P_2]}{(1-r)[P_1+(1-q)S]}$, then $\frac{dF(y)}{dy}_{y=0}<0$, $\frac{dF(y)}{dy}_{y=1}>0$, Therefore, y=0 is the equilibrium point for the evolution of LGs' behavior. This indicates that, if the CG tends to select the "lax supervision" strategy, the probability of the LGs choosing the "positive implement" strategy will approach 0.

When $\frac{C_2-iT_2-P_2-rP_1-(r+q-rq)()-z[i(T_1-T_2)-qS-P_2]}{(1-r)[P_1+(1-q)S]}<x<1$, then $\frac{dF(y)}{dy}_{y=1}<0$, $\frac{dF(y)}{dy}_{y=0}>0$, Therefore, y=1 is the equilibrium point for the evolution of LGs' behavior. This implies that, if the CG tends to select the "strict supervision" strategy, the probability of the LGs choosing the "positive implement" strategy will approach 1.

2.3.3 Replication dynamic equation of MEs' "positive governance" behavior and its equilibrium point

Suppose that U_3^1 represents the expected payoff of the MEs if they govern positively and U_3^2 represents the expected payoff of the MEs if they govern negatively. $\overline{U_3}$ represents the average expected payoff of the MEs. U_3^1, U_3^2, and $\overline{U_3}$ can be written as

$$\begin{cases} U_3^1 = xy(-C_3+qS+R-T_1)+x(1-y)(-C_3+R+qS-T_1)+(1-x)y(-C_3+R+qS-T_1) \\ \quad +(1-x)(1-y)[-C_3+R+qS-rT_1] \\ U_3^2 = xy(-T_2-P_2)+x(1-y)(-T_2-\alpha P_3)+(1-x)y(-T_2-P_2)+(1-x)(1-y)\ [-r\alpha P_3+(1-r)qS-rT_2] \\ \overline{U_3} = zU_3^1+(1-z)U_3^2 \end{cases}$$

Then, according to evolutionary game theory, the replicator dynamics of the MEs adopting the "positive governance" strategy can be written as

$$\begin{aligned} F(z) = z(1-z)\ &-C_3+R+r(qS-T_1+T_2+\alpha P_3) \\ &+y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3] \\ &+x(1-r)(qS+T_2-T_1+\alpha P_3)-xy(1-r)(qS+T_2-T_1+\alpha P_3)\} \end{aligned}$$

Make $F(z)=\frac{dz}{dt}=0$; the obtained solution may be the equilibrium point of the evolution process.

When $x=x^*=\frac{C_3-R-r(qS-T_1+T_2+\alpha P_3)-y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3]}{(1-r)(qS+T_2-T_1+\alpha P_3)-y(1-r)(qS+T_2-T_1+\alpha P_3)}$, then $F(z)\equiv 0$, indicating that all points on the z-axis are in a steady state, and implying that the MEs' strategy choice does not change with time at this point.

When $x\neq\frac{C_3-R-r(qS-T_1+T_2+\alpha P_3)-y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3]}{(1-r)(qS+T_2-T_1+\alpha P_3)-y(1-r)(qS+T_2-T_1+\alpha P_3)}$, we obtain z=0 and z=1 as the two possible equilibria of $F(z)$. According to the stability theory of the replica dynamic equation it can be concluded that, when $\frac{dF(z)}{dz}<0$, this point is ESS.

We can obtain the following formula by taking the derivative of $F(z)$:

$$\begin{aligned} \frac{dF(z)}{dz} = (1-2z)\ &-C_3+R+r(qS-T_1+T_2+\alpha P_3)+y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3]+ \\ &x(1-r)(qS+T_2-T_1+\alpha P_3)-xy(1-r)(qS+T_2-T_1+\alpha P_3)\} \end{aligned}$$

When $0<x<\frac{C_3-R-r(qS-T_1+T_2+\alpha P_3)-y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3]}{(1-r)(qS+T_2-T_1+\alpha P_3)-y(1-r)(qS+T_2-T_1+\alpha P_3)}$, then $\frac{dF(z)}{dz}_{z=0}<0$, $\frac{dF(z)}{dz}_{z=1}>0$; therefore, z=0 is the equilibrium point for the evolution of MEs' behavior. This indicates that, if the CG tends to select the "lax supervision" strategy, then the probability of the MEs choosing the positive governance strategy approaches 0.

When $\frac{C_3-R-r(qS-T_1+T_2+\alpha P_3)-y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3]}{(1-r)(qS+T_2-T_1+\alpha P_3)-y(1-r)(qS+T_2-T_1+\alpha P_3)}<x<1$, then $\frac{dF(z)}{dz}_{z=1}<0$, $\frac{dF(z)}{dz}_{z=0}>0$; therefore, z=1 is the equilibrium point for the evolution of MEs' behavior. This implies that, if the CG tends to select the "strict supervision" strategy, then the probability of the MEs choosing the positive governance strategy approaches 1.

2.4 Stability analysis of ESS in tripartite evolutionary game

Based on the above analysis, the three-dimensional dynamical system of the evolutionary game can be written as

$$\begin{cases} F(x) = x(1-x)[(1-r)(-C_1+T_2+S+P_1+\alpha P_3)-y(1-r)(S+P_1+\alpha P_3+T_2) \\ F(y) = y(1-y)\{-C_2+iT+P_2+rP_1+\alpha P_3)+(r+q-rq)S+z[i(T_1-T_2)-qs-P_2] \\ \quad +x(1-r)[P_1+(1-q)S]\} \\ F(z) = z(1-z)\{-C_3+R+r(qS-T_1+T_2+\alpha P_3)+y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3] \\ \quad +x(1-r)(qS+T_2-T_1+\alpha P_3)-xy(1-r)(qS+T_2-T_1+\alpha P_3) \end{cases}$$

The ESSs of the system can be obtained as $F(x)=F(y)=F(z)=0$. In the three-party evolutionary game, we need only discuss the following ESSs: $E_1(0,0,0)$, E_2 (1,0,0), $E_3(0,1,0)$, E_4 (0,0,1), $E_5(1,1,0)$, E_6 (1,0,1), $E_7(0,1,1)$ and E_8 (1,1,1) (Bjornerstedt and Weibull, 1994). According to Lyapunov stability theory, the asymptotic stability of a system at the equilibrium point can be determined using the eigenvalue of the Jacobian matrix. When the eigenvalue is less than zero, the equilibrium point is the ESS. Thus, we can obtain the eigenvalue expression of the corresponding Jacobian matrix by replacing the aforementioned eight points in the Jacobian matrix (see Table 3). Because $(1-r)C_2>0$ always holds, E_5 (1,1,0) and E_8 (1,1,1) can only be unstable points. Therefore, we only need to discuss the remaining six equilibrium points. The stability conditions for the remaining six points are listed in Table 4.

From the stability conditions of the above six equilibrium points, it can be seen that the difference between the benefits and costs determines the strategy choice of the three subjects. Based on the life cycle theory of the circular economy (Piila et al., 2022), the marine ecological governance process is divided into three stages: the initial, development, and maturity stages. The equilibrium points of different stages are then analyzed.

In the initial stage, the CG neglected marine ecological protection because it paid more attention to the marine economic dividends generated by the use of marine resources, resulting in a lack of systematic and relevant marine ecological governance policies (Xu, 2018). LGs tend to implement marine environmental policies negatively because they lack the constraints of relevant laws and policies, wish to avoid the high cost of implementation, and attach more importance to

TABLE 3 ESS and eigenvalues of the dynamic system.

ESS	Eigenvalue		
	λ_1	λ_2	λ_3
(0, 0, 0)	$(1-r)(-C_1+T_2+S+P_1+\alpha P_3)$	$-C_2+iT_2+P_2+rP_1+(r+q-rq)S$	$-C_3+R+r(qS-T_1+T_2+\alpha P_3)$
(0, 0, 1)	$(1-r)(-C_1+P_1+T_1+S-qS)$	$-C_2+iT_1+r(P_1+S-qS)$	$C_3-R-r(qS-T_1+T_2+\alpha P_3)$
(0, 1, 0)	$-(1-r)C_1$	$C_2-iT_2-P_2-rP_1-(r+q-rq)S$	$-C_3+R+P_2+T_2-T_1+qS$
(1, 0, 0)	$-(1-r)(-C_1+T_2+S+P_1+\alpha P_3)$	$-C_2+iT_2+P_1+P_2+S$	$-C_3+R+qS+T_2-T_1+\alpha P_3$
(1, 0, 1)	$-(1-r)(-C_1+T_1+S+P_1-qS)$	$-C_2+iT_1+P_1+(1-q)S$	$C_3-R-qS-T_2+T_1-\alpha P_3$
(1, 1, 0)	$(1-r)C_1$	$C_2-iT_2-P_1-P_2-S$	$-C_3+R+T_2-T_1+qS+P_2$
(0, 1, 1)	$-(1-r)C_1$	$C_2-iT_1-r(P_1+S-qS)$	$C_3-R-P_2-T_2+T_1-qS$
(1, 1, 1)	$(1-r)C_1$	$C_2-iT_1-P_1-(1-q)S$	$C_3-R-T_2+T_1-qS-P_2$

TABLE 4 Stability conditions of equilibrium points in the evolutionary game.

ESS	Stability condition
(0, 0, 0)	$(1-r)(-C_1+T_2+S+P_1+\alpha P_3)<0$; $-C_2+iT_2+P_2+rP_1+(r+q-rq)S<0$; $-C_3+R+r(qS-T_1+T_2+\alpha P_3)<0$
(0, 0, 1)	$(1-r)(-C_1+P_1+T_1+S-qS)<0$; $-C_2+iT_1+r(P+S-qS)<0$; $C_3-R-r(qS-T_1+T_2+\alpha P_3)<0$
(0, 1, 0)	$C_2-iT_2-P_2-rP_1-(r+q-rq)S<0$ $-C_3+R+P_2+T_2-T_1+qS<0$
(1, 0, 0)	$-(1-r)(-C_1+T_2+S+P_1+\alpha P_3)<0$; $-C_2+iT_2+P_1+P_2+S<0$; $-C_3+R+qS+T_2-T_1+\alpha P_3<0$
(1, 0, 1)	$-(1-r)(-C_1+T_1+S+P_1-qS)<0$; $-C_2+iT_1+P_1+(1-q)S<0$;$C_3-R-qS-T_2+T_1-\alpha P_3<0$
(0, 1, 1)	$C_2-iT_1-r(P_1+S-qS)<0$; $C_3-R-P_2-T_2+T_1-qS<0$

the economic development of their territories. MEs consider economic interest as their primary goal and lack government constraints, so they continue to expand the scale of production for short-term gain, ignoring the discharge of pollutants into the sea and using marine resources crudely (Saldaña-Ruiz et al., 2022). Therefore, this phase corresponds to the equilibrium point $E_1(0,0,0)$. From Table 4, the following three conditions must be met for the point to be stable: ① $(1-r)(-C_1+T_2+S+P_1+\alpha P_3)<0$;② $-C_2+iT_2+P_2+rP_1+(r+q-rq)S<0$;③ $-C_3+R+r(qS-T_1+T_2+\alpha P_3)<0$. The following array 1 is assigned to satisfy the stability condition in the initial stage: C_1=21,C_2=18,C_3=20, r=q=m=i=0.5,S=5,T_1=1,T_2=2,P_1=10,P_2=5,P_3=6,R=10,α=0.1,E=6 . Array 1 was randomly started from different initial policy combinations in the range [0,1] and evolved 50 times over time, as shown in Figure 1.

In the development stage, Marine ecological governance is becoming more complex (Brodie Rudolph et al., 2020). As the LGs' and MEs' consumption of marine resources progresses, marine ecological problems are slowly increasing and becoming more complex and challenging to solve. Therefore, marine ecological problems have become an important policy issue for the CG. The CG's focus has shifted from marine economic development to a moderate development of marine resources and marine ecological protection. Relevant policies and regulations have gradually been improved to address the contradiction between marine economic development and marine ecological protection. As the policies and regulations are still being perfected, the constraints on LGs are limited, and they still choose to ignore marine ecological management for the sake of territorial economic development and performance assessment, while indulging the marine pollution of the MEs. Meanwhile, the MEs still disregard marine ecology to maximize profits. Therefore, this stage corresponds to the equilibrium point $E_2(1,0,0)$. From Table 4, the following three conditions must be met for the point to be stable: ① $-(1-r)(-C_1+T_2+S+P_1+\alpha P_3)<0$;② $-C_2+iT_2+P_1+P_2+S<0$;③ $-C_3+R+qS+T_2-T_1+\alpha P_3<0$. The following array 2 is assigned to satisfy the stability condition in the initial stage: C_1=18,C_2=24,C_3=19,r=q=m=i=0.5,S=6,T_1=2, T_2=3,P_1=10,P_2=5,P_3=6,R=10,α=0.1,E=6 . The systematic evolution path of Array 2 is shown in Figure 2.

In the mature stage, the CG is paying increasing attention to marine ecological issues to ensure the sustainable development of marine ecology. Therefore, marine ecological regulation policies have been deepened and improved in order to induce LGs to perform their duties; these improvements include the CG's environmental tax, fiscal subsidy, fund allocation, and environmental tax sharing policies. The LGs, as "proxy regime operators," will gradually respond to the CG's initiative by adjusting and strengthening their supervision from a political perspective to restrain the marine ecological hazards of the MEs. When the LGs are actively implementing and the MEs are actively governed, the CG will gradually withdraw from supervision to reduce unnecessary financial expenditures. Therefore, the equilibrium point corresponding to this stage is

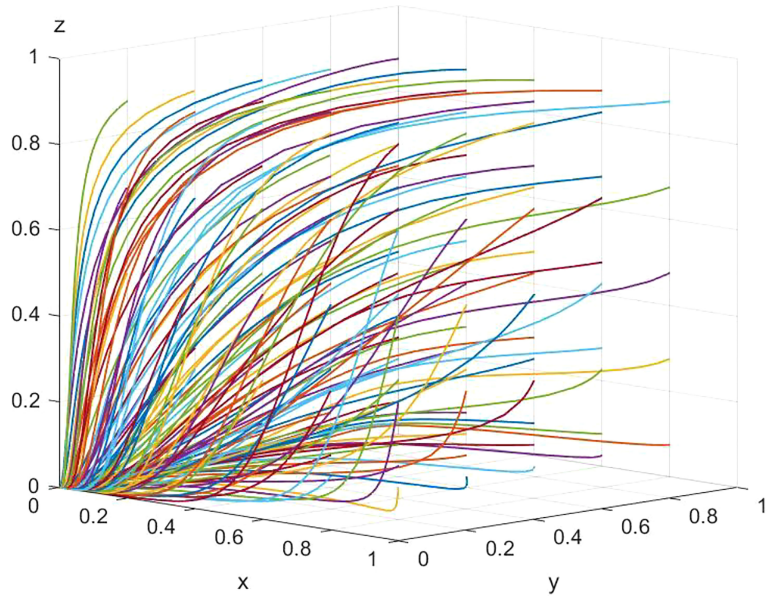


FIGURE 1
Initial stage evolutionary path.

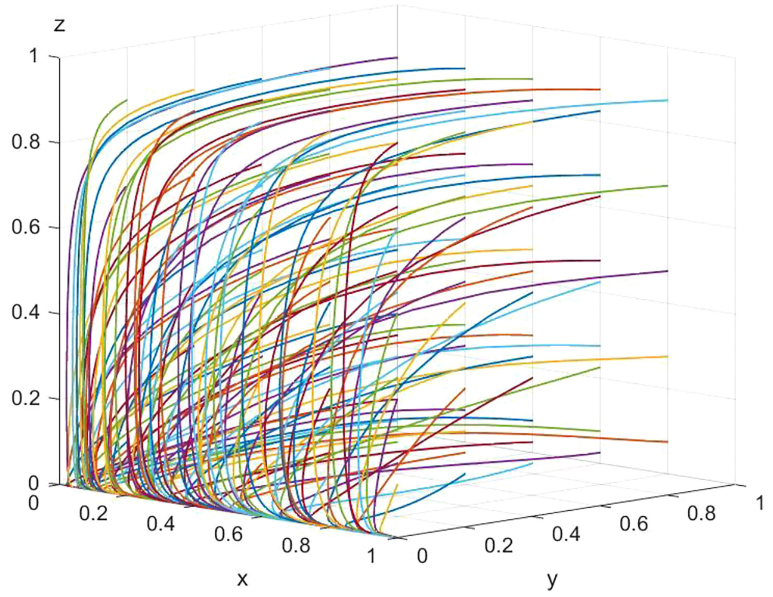


FIGURE 2
Development stage evolutionary path.

$E_7(0,1,1)$, which is the ideal stage for a marine ecological management strategy. From Table 4, the following three conditions must be met for the point to be stable: ① $C_2-iT_1-r(P_1+S-qS)<0$; ② $C_3-R-P_2-T_2+T_1-qS<0$. Assignment of Array 3 to satisfy the stability condition of the maturity stage: C_1=12, C_2=8,C_3=10,r=q=m=i=0.5,S=8,T_1=2,T_2=4,P_1=14,P_2=7,P_3=8, R=5,α=0.1,E=6 .The systematic evolutionary path of Array 3 is shown in Figure 3.

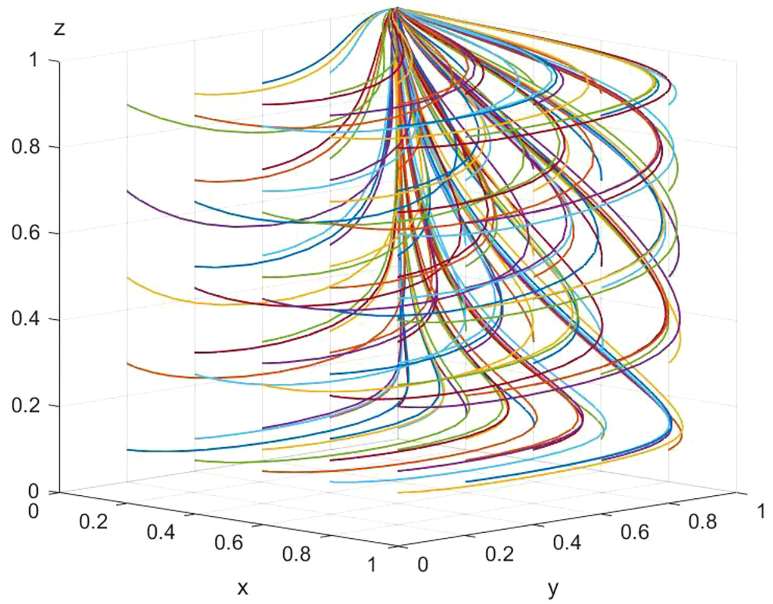


FIGURE 3
Mature stage evolutionary path.

3 Simulation analysis

3.1 Initial strategy simulation analysis

To reflect how these policy changes affect the game players, we use MATLAB to simulate the ideal stage, $E_7(0,1,1)$. As LGs have a geographical advantage (Adewumi, 2021), their governance cost is lower than the CG's supervision cost. By contrast, MEs, as the main subject of marine ecological governance, have governance costs that are higher than the LGs' costs of policy implementation. Once the MEs' violations are discovered by the CG, the CG's penalties become heavier than the LGs'. Therefore, Array 3 satisfied this condition. The willingness to govern marine ecology increased for the MEs, LGs, and the CG, in that order. Drawing on Fan et al. (2022), this study sets the initial probabilities of marine ecology governance by MEs, active implementation by LGs, and strict supervision by CG at 0.3, 0.5, and 0.8, respectively. The results obtained from the initial simulations are shown in Figure 4.

3.2 Simulation analysis of parameter changes

The choices of the three game players may be influenced by many regulatory strategies, including fiscal subsidy policies, environmental tax policies, fund allocation policies, penalty policies, and ecological tax-sharing policies. Therefore, this section examines the impact of various regulatory strategies on the evolutionary game of the tripartite subject. To facilitate the analysis, the CG's incentive is to generate higher financial subsidies, higher fines, and a reduced LG share of tax revenue as a punitive measure. For LGs, reducing their share in the allocation of government and corporate funds is an incentive for MEs, while imposing higher environmental taxes and increasing fines on MEs are penalties.

3.2.1 Impact of CG's incentives on evolution

When the remaining parameters are unchanged, we increase the CG's financial subsidies. This study changes the value of S, fluctuating upward by 50% (S is assigned to 12 and 16, respectively), and the evolutionary path is shown in (2) and (3) in Figure 5. Comparing (1), (2), and (3) in Figure 5, we see that the evolutionary trend of LGs changes very little as subsidies increase, while MEs converge faster. This happens because MEs seek to maximize their economic interests. The MEs are more sensitive to the CG's incentives than the LGs are. Specifically, MEs can use CG subsidies for green technology innovation, shift from old to new dynamics, reduce the cost of marine ecological governance, improve economic efficiency, gain social prestige, and create an endogenous incentive to govern marine ecology. Therefore, the more subsidies MEs receive, the faster they evolve to govern marine ecology, and the stronger their willingness to do so.

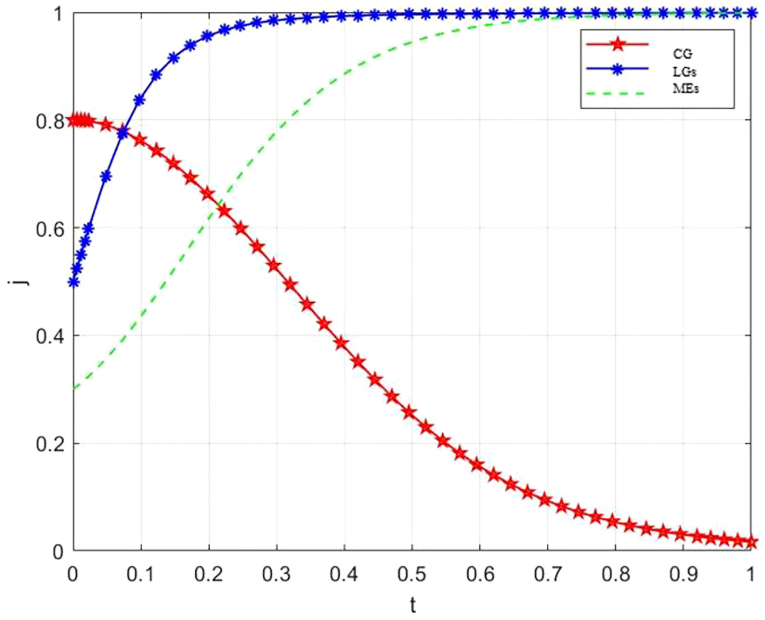


FIGURE 4
Three-way evolution with initial parameters.

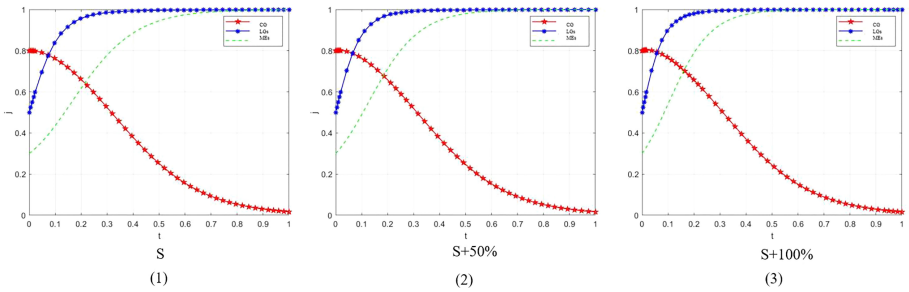


FIGURE 5
The impact of CG' incentives on the evolution.

3.2.2 Impact of CG's penalties on evolution

With the remaining parameters unchanged, when the CG inspects more frequently, sets higher fines, and reduces the tax share of LGs, we obtain P_1 , P_3 , and α , which fluctuate upwards by 50% (P_1 is assigned 21 and 28 respectively; P_3 is assigned 12 and 16 respectively; α is assigned 0.15 and 0.2 respectively), while i fluctuates downward by 50% (i) is assigned 0.25 and 0). The evolutionary path is shown in (2) and (3) in Figure 6. Comparing (1), (2), and (3) in Figure 6 reveals that, as the CG imposes stricter penalties, LGs can quickly reach a steady state of a strict implementation of marine environmental policies; however, this has not been effective in driving MEs to a state of active governance more quickly. The root cause of this fact is that the long-standing pressure-based system in China has made the behavioral logic of LGs fall more in line with the will of the CG. When the CG raises penalties for marine ecological governance, it conveys more precise political intentions to LGs, leading them to actively implement the CG's decisions. In addition, the CG, as the macro-control authority, always has limited human, material, and financial resources to invest in the direct supervision of regional ecological governance. Thus, MEs are more likely to evade accountability and punishment by the CG. As a result, LGs are more sensitive to penalties imposed by the CG than MEs are. The higher the penalties imposed by the CG and the greater the pressure exerted, the faster the LGs evolve towards an active implementation strategy.

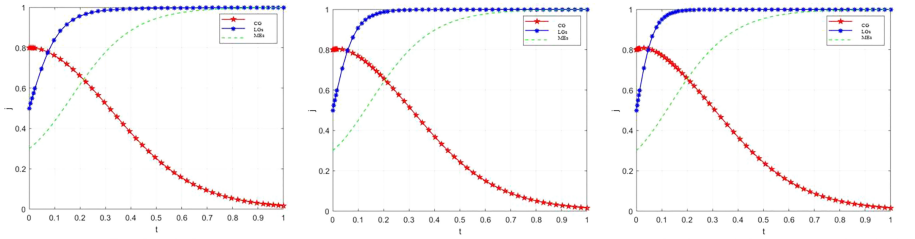


FIGURE 6
The impact of CG' penalties on the evolution.

3.2.3 Impact of LGs' incentives on evolution

When the remaining parameters remain unchanged, we increase the LGs' subsidies to MEs. q is the range of subsidies allocated to MEs by the CG as a percentage of LGs. The LGs can flexibly adjust q to encourage MEs to take responsibility for marine ecology management. When the number of subsidies allocated by the CG is determined, the subsidies that MEs can receive from the LGs are affected only by the allocation ratio q. In this section, we change the value of q fluctuating upward by 50% (assigned to 0.75 and 1), and the evolutionary path is shown in Figure 7. Comparing this to the results shown in Figure 5, we see that the more the proportion of subsidies allocated to MEs increases, the more active MEs will be in governing marine ecology, and the more the rate of "positive governance" will decrease. This happens because LGs have increased their subsidies to MEs, and the internal funding of LGs will decrease. The high supervision cost has led to a small decrease in the frequency of LGs' supervision. By contrast, MEs are the direct beneficiaries of the increased subsidies from LGs. Adequate subsidies incentivize MEs to improve production techniques, implement lean management, transform production methods, optimize business processes, and achieve an intensive use of marine resources. Therefore, when LGs' subsidies to MEs increase, the willingness to apply "positive governance" increases, but the "strict supervision" willingness of LGs decreases.

3.2.4 Impact of LGs' penalties on evolution

When the remaining parameters remain unchanged, we assume that LGs adopt a stricter environmental tax policy with a heavier ecological tax and higher penalty amount. The values of T_1 and P_2 fluctuate upward by 50% (T_1 is assigned to 10.5 and 14, respectively; P_2 is assigned to 3 and 4, respectively), and its evolutionary path is shown in (2) and (3) in Figure 8. Comparing this to the results shown in Figure 5, we see that, as the penalties increase, the curve trend of CG changes little, whereas both LGs and MEs can reach a steady state more quickly. Compared with the results shown in Figure 6 (regarding how the CG's penalties affect the evolution), the LGs' penalties are more likely to force MEs to govern marine ecology than the CG's. The LGs, as the implementers of marine environmental governance policies, have geographical and information advantages over the CG in their jurisdictions. Thus, LGs are more sensitive to marine resource waste, direct discharge into the sea, and negative governance by MEs seeking to maximize profits. MEs are more likely to be negligent about marine ecology, and the opportunity cost of "negative governance" becomes higher. The fines paid by MEs also cover the cost of LG supervision. Therefore, when faced with LG supervision, MEs are more willing to engage in positive governance. At the same time, the fines paid by MEs increase the LGs' willingness to supervise strictly. In summary, LGs are more effective than the CG

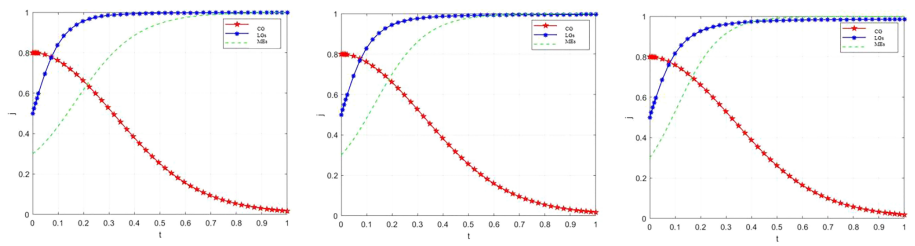
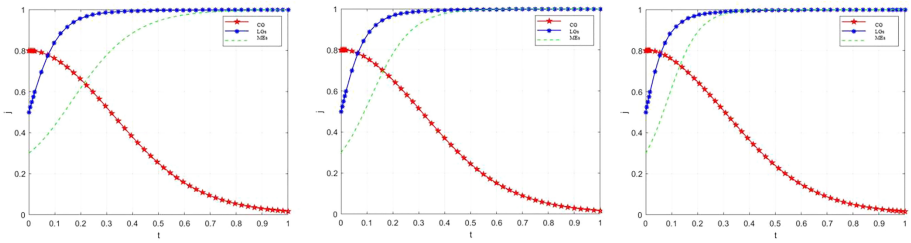


FIGURE 7
The impact of LGs' incentives on the evolution.



P_2、 T_1 (1) $P_2+50\%$、 $T_1+50\%$ (2) $P_2+100\%$、 $T_1+100\%$ (3)

FIGURE 8
The impact of LGs' penalties on the evolution.

in restraining the negative governance of MEs. The stronger the penalties imposed by the CG, the higher the probability that sea-related enterprises and local governments will be inclined to actively govern marine ecology.

3.3 Impact of public participation on evolution

In the protection and governance of marine ecology, public participation can compensate for the lack of government supervision, which is an essential factor influencing ecological governance and the efficiency of pollution control (Gao et al., 2022b). Many countries have adopted public participation to complement their environmental governance. In Japan, the Basic Law for the Environment, enacted in the 1990s, clearly stipulates that citizens have the right to participate in marine ecological governance and the disposal of marine litter, which implies the rights to information, supervision, and consultation. The public's right to ecological information disclosure is guaranteed by law. Denmark was the first country in the world to establish an environmental protection department and enact the Environmental Protection Act, under which the Ministry of Energy and the Environmental Protection Agency were given authority to develop a series of explicit and detailed environmental regulations setting out how the public can participate in marine ecological governance. The United States passed the Freedom of Information Act in 1967, which gave citizens the right to access government information and provided institutional safeguards for public participation in environmental governance. The US National Environmental Policy Act Implementation Regulations, promulgated under the National Environmental Policy Act, stipulate that the public must be fully consulted and supervised throughout the preparation of an environmental impact statement. The Environmental Protection Law of the People's Republic of China was officially implemented in 2015. It not only established a system that allowed the public to access ecological information and participate in ecological protection, but also affirmed the importance of public participation in ecological protection. Therefore, it is necessary to consider the impact of public involvement in marine ecological governance. First, for MEs, negative governance can bring negative externalities to the coastal public. This would lead the public to give the ME a poor rating, resulting in a loss of reputation and operating earnings. This loss is denoted as L_1. Second, for LGs, amid improvements in information disclosure, inaction will cause dissatisfaction among the coastal public, leading to a decline in their credibility; this is denoted as L_2. Finally, for the CG, the public will also have a poor impression of its lax supervision, causing the CG to suffer a loss of credibility; this is denoted as $(1-r)L_3$.

The dynamic replication equation for the tripartite subject was adjusted after the introduction of public participation. The changed replication dynamic equations are as follows:

$$\begin{cases} F(x)_1 = x(1-x)[(1-r)(-C_1+T_2+S+P_1+\alpha P_3+L_3)-y(1-r)(S+P_1+\alpha P_3+T_2+L_3)+ \\ z(1-y)(1-r)(qS+T_2-T_1+\alpha P_3+L_3) \\ F(y)_1 = y(1-y)\{-C_2+iT_2+P_2+rP_1+L_2+(r+q-rq)S+z[i(T_1-T_2)-qs-P_2-L_2]+ \\ x(1-r)[P_1+(1-q)S] \\ F(z)_1 = z(1-z)\{-C_3+R+L_1+r(qS-T_1+T_2+\alpha P_3)+y[(1-r)(T_2-T_1+qS)+P_2-r\alpha P_3]+ \\ x(1-r)(qS+T_2-T_1+\alpha P_3)-xy(1-r)(qS+T_2-T_1+\alpha P_3) \end{cases}$$

In the stability analysis of equilibrium points in a three-party evolutionary game, we must discuss eight particular equilibrium points and one mixed-strategy equilibrium point (Bjornerstedt and Weibull, 1994). The characteristic expressions of the Jacobian matrix are then obtained by substituting each of the eight special equilibrium points into the Jacobian matrix. Because $(1-r)C_2>0$ is constant, only the stability of the six equilibria in Table 5 must be discussed under the stability conditions. In particular, this study focuses on the ideal evolutionary equilibrium point $E_7(0,1,1)$, with no public participation, and the ideal evolutionary equilibrium point $E_7^{'}(0,1,1)$, with public participation. From $E_7^{'}(0,1,1)$ in Table 5, it can be seen that, in the presence of public participation, the MEs' governance strategies are influenced by public evaluations, in addition to the cost of governance, benefits of positive governance, government subsidies, penalties for negative governance, and environmental taxes. |In Figure 9, the MEs in (2)

TABLE 5 Stability conditions for the equilibrium point under public participation.

equilibrium point	Stability conditions
(0, 0, 0)	$(1-r)(-C_1+T_2+S+P_1+\alpha P_3+L_3)<0$; $-C_2+iT_2+P_2+rP_1+L_2+(r+q-rq)S<0$; $-C_3+R+L_1+r(qS-T_1+T_2+\alpha P_3)<0$
(0, 0, 1)	$(1-r)(-C_1+P_1+T_1+S-qS)<0$; $-C_2+iT_1+r(P+S-qS)<0$; $C_3-R-L_1-r(qS-T_1+T_2+\alpha P_3)<0$
(0, 1, 0)	$C_2-iT_2-P_2-rP_1-L_2-(r+q-rq)S<0$; $-C_3+R+L_1+P_2+T_2-T_1+qS<0$
(1, 0, 0)	$-(1-r)(-C_1+T_2+S+P_1+\alpha P_3+L_3)<0$; $-C_2+iT_2+P_1+P_2+S+L_2<0$; $-C_3+R+L_1+qS+T_2-T_1+\alpha P_3<0$
(1, 0, 1)	$-(1-r)(-C_1+T_1+S+P_1-qS)<0$; $-C_2+iT_1+P_1+(1-q)S<0$;$C_3-R-qS-T_2-L_1+T_1-\alpha P_3<0$
(0, 1, 1)	$C_2-iT_1-r(P_1+S-qS)<0$; $C_3-R-P_2-T_2-L_1+T_1-qS<0$

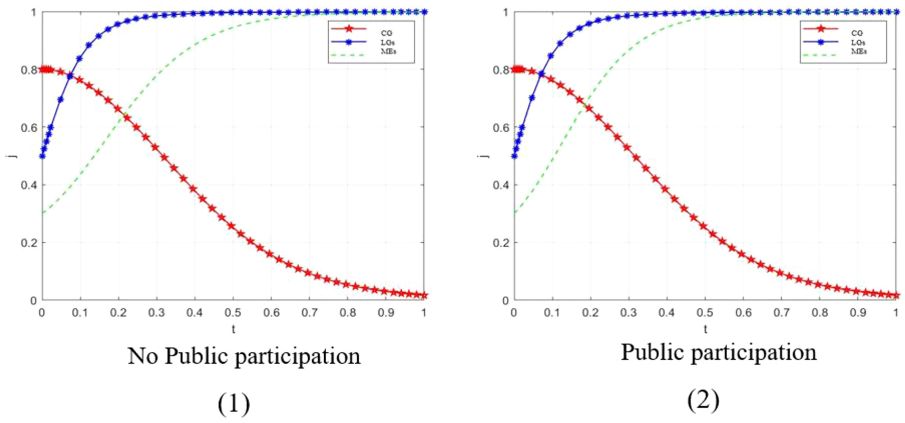


FIGURE 9
The impact of public participation on the evolution.

can evolve to positive governance at a rate much faster than the rate of those in (1). This shows that public participation can accelerate the MEs' adoption of eco-friendly behavior. The ideal situation of strict CG supervision, positive LG implementation, and positive ME governance will soon be realized.

4 Results and discussion

4.1 Results

Based on evolutionary game theory, this study focuses on the problem of marine ecological governance and constructs a three-party evolutionary game model composed of the CG, LGs, and MEs. Moreover, based on the life cycle theory of circular economy, the evolution strategy of the three subjects is sorted out. Then this paper use MATLAB to analyze the influence of policy factors and public participation on the strategic selections of game subjects in the optimal evolutionary stability point. The study draws the following conclusions. (1) CG's penalties have limited effect in pushing MEs to govern marine ecology. In addition, we also find that LGs are more sensitive to CG's penalties. Through policy pressure, CG can effectively guide LGs to strictly implement marine ecological environmental protection policies. (2) Compared with CG, LGs are more direct and effective in punishing MEs to govern marine ecology. In this regard, if the government wants MEs to govern marine ecology positively, LGs need to implement marine ecology policies strictly, increase penalties for non-compliant MEs and enhance the deterrent effect themselves. In reality, many countries have issued a series of environmental laws and regulations to urge subordinate departments to restrict the pollution behavior of enterprises, and have achieved certain results. For example, China's Environmental Protection Inspection Plan and "Environmental Storm" activities, Japan's Environmental Strategy, France's Environmental Charter and the United States' "National Environmental Policy Act", etc. (3) LGs' subsidies are effective in supporting MEs to govern marine ecology, increasing the endogenous motivation for positive governance. However, this crowds out funds for LGs to implement marine ecological policies, leading to a decline in LGs' willingness to do so. (4) With the deterioration of global environment and the improvement of public environmental awareness, polluting enterprises are facing more and more pressure to improve environmental protection (Zhao et al., 2022). Quesnel and Ajami (2017) showed that the public's influence is huge and can directly affect the behavior of the government and enterprises. This paper confirms this view. We find that coastal public participation facilitates the strategy selection of MEs to positively govern marine ecology. Thus, the ideal situation of CG's strict

supervision, LGs' positive implementation, and MEs' positive governance will be realized soon.

4.2 Discussion

The research results of this paper may have the following three contributions compared with previous relevant studies: First, previous studies only verified whether the existing marine ecological governance policies have a positive or negative impact on relevant stakeholders (Innes et al., 2015; Song et al., 2020). Few studies compare the differences in impacts. This paper is based on the actual implementation of China's marine ecological governance policies, it compares the effects of different regulatory policies on the same subject and the same regulatory policy on different subjects, which helps the Chinese government to implement marine regulatory policies more efficiently. Second, previous research on marine environmental regulation policies mainly focused on the practice of regulation policies (Matheson, 2019; Roll et al., 2022), lacking relevant theoretical research. This paper explores the actual implementation of China's marine environmental regulation policies using evolutionary game method, which helps to make up for the lack of theoretical research. Third, the previous research subjects of marine environmental regulation policies mainly focused on the CG or LGs (Willis et al., 2018; Song et al., 2022). This paper also considered the CG, LGs, MEs and the public, which is not only helpful to understand the complex relationship between different stakeholders in marine ecological governance, Moreover, it can provide a more comprehensive theoretical basis for the formulation of relevant environmental regulation policies in China.

Based on the above conclusions, this study proposes the following suggestions. (1) The CG should focus its supervision on LGs and gradually establish systems that can ensure the normalization of the supervision process. As a pressure-based accountability mechanism, the CG's ecological willingness can be conveyed to LGs more quickly. Specifically, when marine ecological performance is included in the annual appraisal system of LGs, it can punish government personnel for failing to implement CG policies, urge LGs to implement marine environmental policies strictly, and induce LGs to govern and protect marine ecology. (2) Moreover, LGs should actively take responsibility for marine ecological governance, give full play to their geographical and informational advantages, and strengthen ME supervision and guidance. LGs should provide subsidies to MEs that display positive governance to support them in green technology innovation. In addition to financial subsidies, MEs can seek financial support through equity financing, industrial funds, and bond financing. LGs should also raise the environmental tax rate and increase the penalties on non-compliant MEs to reduce their violations. This will induce enterprises to reduce their emissions, promote intensive production, and ultimately produce a shift from "pollution first and then treatment" to "treatment at source." (3) In addition, the government should establish a system of public participation for marine ecological governance. Although the public is a victim of environmental pollution, they have little awareness of their responsibility to participate in marine ecological governance. First, the government should stimulate the public's awareness of their responsibility to participate in marine ecological governance through awareness raising and training campaigns. Second, the government should improve the incentive mechanism for public complaints and reports about marine ecological problems. Finally, the government could reduce the cost of public participation by establishing public monitoring platforms, hotlines, and litigation channels.

This study resets the central government's strategic choice behavior based on the actual situation in China and makes a breakthrough by integrating multiple marine ecological governance stakeholders into a unified analytical framework. However, it has several limitations. The study is based on relatively idealistic assumptions, wherein the central government, local governments, marine enterprises, and the public are assumed to be independent stakeholders. Moreover, the vertical partners of marine enterprises are not considered. In future studies, we intend to consider a more complex reality by building a more practical model, and thus generate deeper insights.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

LG: conceptualization, writing, review, and editing; AY: conceptualization, writing original draft, methodology, software; QY: writing original draft, methodology, reviewing, and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Good governance for sustainable blue economy in small islands: Lessons learned from the Seychelles experience

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The blue economy has emerged as an influential global concept. It is commonly understood to relate to the development of the ocean in a manner which also addresses concerns about ocean health in the face of increasing demands on ocean resources, marine pollution, and climate change. While the blue economy holds potential to act as an integrating policy framework for the sustainable development of the ocean, to date, there are limited examples of implementation in practice to test the usefulness of the concept. Based on a typology of "good governance" adapted from existing global typologies, we investigated the role of blue economy governance in enabling integration. We used a mixed methods approach to explore the experience of Seychelles, a blue economy early adopter, combining policy and institutional analysis, semistructured interviews with key actors and partners, and country fieldwork. Our analysis shows that from its inception, Seychelles' vision of blue economy was a transformative model of development based on the protection and sustainable use of ocean resources for the benefit of Seychellois, consistent with the SDGs. Thanks to early political leadership and international engagement, the adoption of the blue economy concept was successful in raising awareness of the ocean health and its connection to people and the economy, and in establishing the basis of a national blue economy "architecture," which helped secure innovative finance for implementation. Transitioning to implementation, several governance challenges emerged, which included maintaining high-level political momentum, stakeholder engagement, and institutional coordination and capacity. While some governance barriers to effective integration may be unique to Seychelles, some are common to SIDS, and others are found in a range of governance settings. Seychelles international visibility has brought high expectations, not always commensurate with local aspirations, capabilities, and jurisdictional responsibilities. Bridging the gap between global expectations and local realities will require support for locally driven institutional reforms, which take account of issues of scale, culture, and capacity.

KEYWORDS

blue economy, Sustainable Development Goals, Seychelles, SIDS, good governance, policy coherence, institutional coordination, institutional reform

Introduction

The blue economy has emerged as an influential concept at the 2012 Rio+20 United Conference on Sustainable Development, redefining the role of the coastal and marine space in sustainable development. It has brought to the fore concerns about ocean health in the face of increasing demands on ocean renewable and non-renewable resources, marine pollution, and climate change. The ocean is increasingly being advocated as a development space by developing and developed nations, in particular for Small Islands Developing States (SIDS), and there has been a rapid proliferation of international and national blue economy initiatives (Roberts and Ali, 2016; Patil et al., 2016b; World Bank, 2017; Okafor-Yarwood et al., 2020; Stuchtey et al., 2020).

Despite efforts at defining a blue economy, it remains a contested and evolving concept as evidenced by ongoing debates among scholars and policymakers around issues of governance, sustainability, equity, and ocean privatization, a reflection of the broad range of blue economy actors, their values, and objectives (Bennett et al., 2015, 2019; Silver et al., 2015; Campbell et al., 2016; Ehlers, 2016; Barbesgaard, 2018; Bennett, 2018; Voyer et al., 2018; Jouffray et al., 2020). Working definitions are available, which can provide some guidance on developing and implementing a blue economy in practice. For example, the World Bank defined the blue economy as "*the sustainable use of ocean resources for economic growth, improved livelihoods and jobs while preserving the health of the ocean*" (World Bank, 2017). The OECD defines the ocean economy as "*the sum of the economic activities of ocean based industries together with the assets, goods and services provided by the marine environment*" (OECD, 2016, p. 17). Importantly, most definitions seek to balance economic social and environmental objectives, consistent with the Sustainable Development Goals (SDGs) (Keen et al., 2018; Benzaken and Hoareau, 2021).

A review of regional blue economy initiatives including the EU new approach for a sustainable blue economy (2021), the African Union Blue Economy Strategy (2019), the Commonwealth Blue Charter "Shared Ocean, Shared Values" (2021), the High Level Ocean Panel for a Sustainable Ocean Economy, and the ASEAN Declaration on Blue Economy (2021) provide some insights into how blue economy has been enacted to date. It shows that although those initiatives vary in scope and scale, they share some common features including the recognition of the ocean as a driver for national and regional sustainable development and innovation, as well as key principles or objectives such as ocean health, sustainability, equity, and resilience. In addition, they recognize the critical role of enabling conditions, such as governance to achieve the multiple objectives of a blue economy (Roberts and Ali, 2016; OECD, 2019, 2020a; Cisneros-Montemayor et al., 2021).

The rapid growth in the popularity and political capital of the concept has drawn attention to its potential capacity to help drive a more integrated approach to ocean governance (Winther et al., 2020). Considering a blue economy approach as an integrating policy framework for the sustainable development of the ocean requires contextualizing the blue economy within broader ocean governance frameworks, namely, the United Nations Convention on the Law of the Sea (UNCLOS) and related agreements and the 2030 Sustainable Development Agenda and Goals (SGDs). Although these frameworks are applied through different modalities (rule-based and goal-based, respectively), they share a common mandate of a "holistic" and "indivisible" approach to the sustainable development of the ocean. However, they face implementation challenges when it comes to cross-sectoral integration and effective consideration of economic social and environmental dimensions of sustainable development. Given this context, a sustainable blue economy approach could provide a practical policy space for integration, building on the respective strengths of both systems and operationalizing SDG 16 (effective accountable and inclusive institutions) and SDG 17 (policy coherence) to achieve integrated sustainable development outcomes consistent with international law (Blanc, 2015; Stafford-Smith et al., 2016; Singh et al., 2018).

To date, there are few examples of national adoption of the blue economy as a transformational approach for the sustainable development of the ocean. A recent analysis of how blue economy has been enacted and governed across Commonwealth countries shows an array of plans and policies at different stages of development and implementation and institutional arrangements (Voyer et al., 2022). This review found that in practice, the blue economy may succeed if a more integrated approach to sectoral management is developed; however, there was less evidence that it was successful in driving integration of social, economic, and environmental objectives, with particularly limited engagement with equity objectives across many countries. This suggests the blue economy may not be fulfilling its potential for driving a truly integrated policy framework yet.

This study seeks to explore in depth the merit of the blue economy as an integrating policy setting for the sustainable development of the ocean, in particular the role of governance in enabling integration, through an in-depth examination of the experience of Seychelles, a blue economy early adopter and a global leader in blue economy implementation. Using Seychelles as a case study, we explored the following:

- The extent to which the adoption of the blue economy has provided a national pathway for the sustainable development of the ocean domain, consistent with the SDGs and UNCLOS.
- The extent to which blue economy governance arrangements have enabled effective integration of economic, social, and environmental dimensions of sustainability and cross-sectoral policy coherence

consistent with SDG 16 and SDG 17 and principles of good governance for sustainable development.

The following sections will introduce the analytical framework we developed, based on the principles of "good governance" in order to explore these research objectives, before introducing Seychelles as the case study area.

Identifying "good governance" principles

As shown by Cisneros-Montemayor et al. (2021), the ability of any country to transition to a sustainable and equitable blue economy and to benefit from goods and services from its ocean resources depends more on enabling conditions such as socioeconomic and governance factors than on resource availability. This leads to questions as to what type of governance arrangements are best suited to given socioeconomic, environmental, and governance settings. Many countries around the world are currently considering the most appropriate governance arrangements for their context, including whether to strengthen existing governance arrangements or establish new ones.

Although governance is seen as a key enabler to transition toward a sustainable and equitable blue economy, there is no unified definition of governance. It broadly understood to include *concepts, practices, and institutions by which societal development is overseen* (Rudolph et al., 2020, p. 2). Governance is understood to be a *system of values, policies, and institutions by which a society manages its economic, political, and social affairs through interactions within and among the state, civil society, and private sector* (UNDP EU, 2004, p. 3). Bennett and Satterfield (2018) defined governance as "*institutions, structures and processes that determine who makes the decisions, how and for whom the decisions are made, whether how and what actions are taken and by whom and to what effect* (Bennett and Satterfield, 2018, p. 2).

A number of governance theories and models have been developed to describe and explain structural configurations an processes of decision-making to achieve desired outcomes such as conservation, livelihoods, or sustainable development, each with a unique strength and application to a particular situation or scale of decision-making (Partelow et al., 2020; Rudolph et al., 2020). For the purpose of this study, we identify good governance as a possible model as our research primarily focuses on government effectiveness. Good governance as a model originates from development scholarship in response to "*the disjunct between aid and sustainable development and concerns related to issues of corruption*" and is based on the premise that "*successful governance is dependent upon good institutions*" (Stojanovic and Gee, 2020, p. 5). It is based on ideas of legitimacy, accountability, performance fairness, and direction, which are relevant to government functions. We also selected this approach as it provides a practical articulation of what constitutes good governance, which is commonly accepted and understood by practitioners working in international development contexts. We conducted a review of a range of international relevant and influential "good governance" indicators. These included the World Bank Worldwide Governance Indicators (WGI) (Kaufmann et al., 2010), the UN principles of effective governance for sustainable development (United Nations Economic Social Council, 2018), SDG 16 and SDG 17 targets, and OECD indicators for policy coherence for sustainable development (OECD, 2019). In order to tailor our analysis to be specifically relevant in the context of a sustainable blue economy and how it can guide countries aiming to transition to a sustainable and equitable blue economy, we compiled a list of relevant governance indicators (Table 1).

The analytical framework focused on the dimensions of good governance related to the effective whole of government policy development and implementation. For example, the analytical framework includes political leadership and stability dimensions but investigates neither democratic processes *per se* nor the control of corruption, which are important dimensions of the World Bank Worldwide Governance Indicators (WGI) as a multilateral development bank.

Seychelles blue economy as a case study

The concept of blue economy has been particularly attractive to Small Island Developing States (SIDS), as an opportunity to sustainably develop their marine resources to generate much needed income and employment, diversify their economy, reduce their energy and food dependency, overcome their climate and economic vulnerabilities, and protect their unique and often globally significant biodiversity assets (Roberts and Ali, 2016; Patil et al., 2016a; World Bank United Nations Department of Economic Social Affairs, 2017; World Bank, 2017; Voyer et al., 2020; Benzaken and Hoareau, 2021).

Seychelles has been a strong advocate of the blue economy concept in international fora since 2010 and is one of the few countries that is implementing a blue economy agenda (Voyer et al., 2022). The Seychelles experience provides an opportunity to explore in depth the merit of the blue economy as a policy setting for the sustainable development of the ocean, including the role of governance in enabling integration and add to the existing scholarship on blue economy in Seychelles (Bueger and Wivel, 2018; Techera, 2018; Schutter and Hicks, 2019; Bhim, 2020; Schutter et al., 2021; Bramley et al., 2022). Although lessons learned from the Seychelles experience cannot be generalized, they can nonetheless provide important insights into both successes and challenges and contribute to a blue economy community of practice, as well as inform global blue economy policy and academic discourses and policy settings.

TABLE 1 Dimensions of good governance adapted from the UN principles of effective governance for sustainable development (United Nations Economic Social Council, 2018) SDG 16 and SDG 17 (2015), WB Good Governance Indicators (WGI), and OECD indicators for policy coherence (2019).

Governance dimension	Description	Sources
Political leadership/commitment/ stability	Extent to which leadership drives blue economy as an integrated Framework	OECD 1 (2019) SDG 16 UNDESA 2018
Policy coherence	Extent to which blue economy is reflected/ mainstreamed in national and sectoral policies	OECD (2019) SDG 17.14 WB WGI
Whole of government policy making/policy coordination	Extent to which institutional mechanisms facilitate a coordinated approach to BE policy development and implementation	UNDESA 2018 SDG 16 WB WGI
Effectiveness/competence/Institutional capacity	The extent to which institutions are mandated and able to perform their functions	UNDEDESA (2018) SDG16 WB WGI
Partnerships	The extent to which national and international partnerships drive and facilitate BE implementation	SDG17.6, SDG17.9
Transparency and accountability	The extent to which access to information and Mechanisms for monitoring and reporting on implementation are in place and functioning	UNDESA 2018 SDG 16.6, 16.10 WB WGI
Equity and inclusiveness	Extent to which stakeholders are engaged in decision-making and BE implementation and benefit sharing	WB WGI SDG16.7 (OECD)

Seychelles is in the Western Indian Ocean just south of the Equator. It has an exclusive economic zone (EEZ) of 1.35 million km^2, a land area of just 454 km^2, and has a population of around 96 000, mainly concentrated on three main islands. Seychelles had a gross national income (GNI) per capita of US$16 870 (2019), which ranks it as a high-income country. The two main pillars of Seychelles' prosperity are tourism and fisheries, both being ocean-based activities. In addition, Seychelles has one of the highest fish consumption per capita (circa 65 kg per annum) (Republic of Seychelles, 2013). Seychelles' unique island and marine environment is of global significance with one marine UNESCO World Heritage Site, the Aldabra Atoll, which is famous for its endemic population of giant tortoises and is rich marine life.

Due to its geography and socioeconomic characteristics, Seychelles' prosperity directly and indirectly depends on its coastal and marine environments; hence, there is critical importance of a well-articulated blue economy strategy to inform national development in a way that respects its marine ecological integrity. The adoption of a blue economy concept has been an opportunity to take stock and rethink the development model, starting from the new reality of being a high-income country since 2015, and looking to the coastal and ocean as a "development space" (Benzaken and Hoareau, 2021). The high-income status meant ineligibility to official development assistance (ODA) and rethinking how to finance development and blue economy and exploring innovative finance mechanisms and new partnerships.

Seychelles initiated a national blue economy strategy in 2012, establishing a blue economy department and a *Blue Economy Research Institute as early as 2015, which led to the adoption of a Blue Economy Strategic Policy framework and Roadmap (2018–2030)* in 2018, hereafter referred to as the blue *economy roadmap*. Seychelles has achieved international visibility, thanks to a successful debt swap for conservation and climate change adaptation in 2015 and the issuing of the first blue bond for transitioning to sustainable fisheries in 2018 both of which contributing to the implementation of *Seychelles blue economy roadmap* (Republic of Seychelles, 2018; World Bank, 2018).

Materials and methods

The research used a mixed methods case study approach (Patton et al., 2002), combining an analysis of government documents, 21 semistructured interviews with key actors selected for their role in the blue economy (2021), and country data collected by the lead author as an independent advisor to the government for the development of the Seychelles blue economy strategy over a 2-year period (2016–2018).

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TABLE 2 Sample description.

Category of respondents	Numbers	Notes and recording sent	Feedback received
Government senior officials	9	Yes (8) one sent written comments	1
Politicians (former and present administration)	4	Yes (3) one sent written comments	2
Independent institutions	3	Yes	No
International partners	I bilateral	Yes	1
	2 NGOs		
	2 Multilateral		
Total	21	20	4
Decline/no response*	3		
Total contacted	24		

*1 decline (local NGO), 2 did not respond (private sector representative and independent expert).

The desktop analysis was used to identify early trends, approach, and drivers, which informed the development and led to adoption of the blue economy roadmap. It involved the analysis of government policy documents, reports, and meetings minutes related to the development of the blue economy in Seychelles since it was first conceptualized, with particular attention to institutional arrangements for policy coordination and policy coherence. It also explored the extent to which blue economy objectives and strategic priorities had been "mainstreamed" in national development and selected "blue" sector-based strategies.

In-depth semistructured interviews (n21) were conducted with key actors selected for their role in the blue economy, including government (9), politicians (4), non-government institutions (3), and international partners organizations (5), and were administered remotely due to COVID-19, over a period of 2 months (June to July 2021) (Table 2).

The interview protocol investigated the following broad topics:

1. The impact of the blue economy as an agent of change,
2. The effectiveness of the blue economy as a strategic policy framework, and
3. The extent to which governance arrangements had facilitated integration of economic, environmental, and social considerations and policy coherence.

The design of questionnaires and analysis of interviews used two main approaches: the first approach was adapted from the most significant change qualitative methodology used in program evaluation studies (Dart and Davies, 2003). The value of this approach is the focus on perceived change (usually through story telling), rather than objective measures of change, based on meeting predetermined objectives and goals. In the context of this research, it was elicited by asking participants to reflect on their perception of the most significant change (positive or negative) that they believe occurred in response to the blue economy development in Seychelles and to highlight what they thought were successes/benefits and challenges. This approach provided a way to perform a more in-depth analysis of the role of governance in blue economy development. The second approach applied the good governance typology outlined in Table 1 to assess the effectiveness of blue economy governance arrangements. Table 3 details how each governance dimension was considered using the data collected.

Interviews were transcribed and sent to participants for accuracy and for additional information. Responses were first entered into an Excel spreadsheet to get an overall sense of the spread of the responses to both most significant change and governance effectiveness questions. The aim was to identify the range, rather than the frequency, of any specific theme, in part to respect the anonymity of respondents, some of whom have a high profile in the small community in which they work and live, and in part because of the small sample size. Responses to the most significant change questions were categorized as drivers, positive/successes, and challenges/gaps as per the questions. The spreadsheet was then reexamined in order to draw the major themes and compare and contrast ideas, concepts, and perceptions. Responses to the governance questions were coded according to the predetermined coding framework of good governance described in Section 1.1 and then categorized as positive/successes or challenges. Quotes to illustrate findings against each theme are included in Tables 5, 6.

The analyses of the interviews and the desktop review were complemented by the lead author in country information and knowledge obtained over a 2-year period. The lead author as recruited by the Commonwealth Secretariat as an ocean governance advisor at the request of the government of Seychelles to assist in the development of the Seychelles blue economy roadmap and all aspects of blue economy implementation nationally and internationally. Trusted relationships established over that period and ever since were critical to the understanding of the Seychelles context, government structures, processes, and knowledge of the blue economy policy development; access to blue

TABLE 3 Dimensions of good governance and methods engaged to explore each dimension.

Governance dimension	Description	Methods
Political leadership/commitment/stability	Extent to which leadership drives blue economy as an integrated Framework	Interviews/advisor
Policy coherence	Extent to which blue economy is reflected/mainstreamed in national and sectoral policies	Policy analysis/Interviews
Whole of government policy making/policy coordination	Extent to which institutional mechanisms facilitate a coordinated approach to BE policy development and implementation	Institutional analysis/ interviews/advisor
Effectiveness/competence/institutional capacity	The extent to which institutions are mandated and able to perform their functions	Interviews/advisor
Partnerships	The extent to which national and international partnerships drive and facilitate BE implementation	Interviews/advisor
Transparency and accountability	The extent to which access to information and Mechanisms for monitoring and reporting on implementation are in place and functioning	Policy analysis/interviews/advisor
Equity and inclusiveness	Extent to which stakeholders are engaged in decision-making and BE implementation and benefit sharing	Institutional analysis/Interviews/advisor

economy-related documents, reports, and notes; and identify willing participants to interviews. The contribution of the advisor helped validate and contextualized the results of both the desktop policy analysis and the results of the interviews.

The triangulation of those three data sources allowed for robust insights into the blue economy as a transformative pathway for the sustainable development of the ocean and the role of good governance in facilitating effective integration of social, economic, and environmental dimensions toward a sustainable and inclusive blue economy.

Results

Genesis of blue economy

The analysis of available published and unpublished government documents shows that as early as 2012, the government of Seychelles acknowledged the cross-sectoral nature of the blue economy concept and established an inter-ministerial committee initially to coordinate Seychelles co-hosting of the 2014 Blue Economy Summit in Abu Dhabi, United Arab Emirates (UAE). The Abu Dhabi Declaration adopted the blue economy concept as one that emphasized conservation and sustainable management of the ocean and complemented the green economy (United Nations, 2014). It informed the UN Third Conference on SIDS (September 2014, Samoa). The Seychelles blue economy was conceptualized in the context of sustainable development in the government's documents and used to position Seychelles with international partners (Nevill, 2014). In his foreword to the *Blue Economy Seychelles' vision for a blue horizon* (2014), Former President Michel elaborates on Seychelles blue economy vision: "*Sustainability in the context of blue economy is all about our ability to use our oceanic space as opportunities for development….protected areas that improved biodiversity conservation, climate change adaptation and provide increased food security*" (Agrippine et al., 2014, p. 12). There was an acknowledgment at the time that there was a need to clarify the status of a blue economy portfolio and mandate in the context of existing national development strategies and governance, specifically in relation to the Sustainable Development Strategy (SSDS, 2012-2020) (Republic of Seychelles, 2012) and the National Development Strategy (NDS) (Republic of Seychelles, 2015).

A National Stakeholder Consultation Forum (December 2014) was the first step toward building an inclusive process for the development of a blue economy strategy. The Forum brought together national and international participants to explore the opportunities a blue economy could bring to Seychelles (e.g., fisheries value adding, biotechnology, renewable energy, aquaculture, tourism, oil and gas, and infrastructure). Issues emerging from the forum included the importance of the knowledge of the marine environment, the need for an operational definition of blue economy for Seychelles, the importance of maximizing the value of existing products, building technical and professional capacity of Seychellois, creating an enabling environment to support local Seychellois entrepreneurs, and strong governance to drive blue economy implementation across government backed with adequate funding (Republic of Seychelles, 2014).

With the support of international partners, and in particular the Commonwealth Secretariat, an inter-ministerial group on blue economy, a Blue Economy Officials technical working

group and a Commonwealth Advisor team were established to oversee the development of a blue economy roadmap, as part of a process to integrating the blue economy concept into the country's policies and strategic frameworks. A meeting of senior officials and Commonwealth advisors held in London laid down the foundations of a blue economy roadmap (Commonwealth, 2015). In 2015, a blue economy department was established to coordinate the government agenda including the development of a blue economy roadmap. At the request of the government, a dedicated Commonwealth expert, hosted into the blue economy department, was appointed for 2 years (2016–2018) to progress the development of Seychelles blue economy roadmap.

The Seychelles blue economy strategic policy and roadmap (2018–2030)

The Seychelles Strategic Policy Framework and Roadmap (2018–2030), hereafter the blue economy roadmap, was adopted in 2018 (Republic of Seychelles, 2019a). Informed by international blue economy policies and existing Seychelles development policies, and in particular Seychelles Sustainable Development Strategy (2012–2020), it was initiated by a whole of cabinet ministerial retreat in 2016 (Republic of Seychelles, 2016). The retreat report pointed out that "*the transition to a blue economy model would require the following: Valuing the ocean as a development space, and focusing on sustainability; Changing the business model across government—mainstreaming a blue economy vision and approach in development planning; Developing a culture of shared responsibility across government; Investing wisely in strategic priority areas for action (e.g., over 5, 10, 15 years); Creating the enabling environment to make this transition happen (capacity, finance, knowledge/tools and innovation); Maximizing international/regional opportunities; Focusing on results and measuring success; and Maintaining international leadership*" (Republic of Seychelles, 2014, p. 4). Following cabinet consideration of the report and decision to proceed with the roadmap, a whole of government consultation process and analysis of the status of blue sector policies were undertaken to ensure the roadmap was evidence-based, targeted, and achievable, yet proposing strategic opportunities for a transition to a sustainable blue economy (advisor notes). Despite proposals for a broad-based stakeholder consultation, consultation was primarily focused on government stakeholders, with some input from local experts, civil society, and international organizations (advisor notes).

The vision of the blue economy roadmap "*To develop a blue economy as a means of realizing the nation's development potential through innovation and knowledge-based approaches, being mindful of the need to conserve the integrity of the Seychelles marine environment and heritage for present and future generations*" (Republic of Seychelles, 2019a) is based on principles of efficiency, innovation, equity, sustainability, resilience, transparency, inclusiveness, accountability, and good governance. It articulates Seychelles "blue economy brand" as a unique comparative advantage based on its sustainability credentials, builds on Seychelles national and international legal and policy frameworks and flagship initiatives such as a marine spatial planning and innovative finance, and puts forward a prioritized agenda for action and investment to 2030 under four pillars, namely, *creating wealth*, *sharing prosperity*, *securing healthy and resilient ecosystems*, and *strengthening the enabling environment* to achieve the leaders' early vision of a sustainable and equitable blue economy. Under each pillar, 2030 objectives and strategic opportunities were identified to inform sector-based planning and development. Due to time constraints, roles, and responsibilities as well as costings were postponed post-adoption by the cabinet in 2018. Importantly, the *blue economy roadmap* is closely aligned with the Sustainable Development Agenda and Goals, which the government signed up to in 2015 and aims to provide an integrated policy and reporting framework for the sustainable development of the ocean (Table 4).

Progress on the implementation of the *blue economy roadmap* since adoption includes the development of a 5-year *Blue Economy Action Plan* (2019) with the support of UN Economic Commission for Africa (UNECA) (Republic of Seychelles UN Economic Council for Africa, 2019). The action plan focuses on the key implementation priorities of communication, whole of government coordination, establishing a blue economy satellite account, and advancing strategic projects including carbon neutrality, marine litter, maritime security, and regional integration (Benzaken and Hoareau, 2021).

Blue economy as an agent of change: Change, drivers, successes, and challenges

Table 5 summarizes the thematic analysis of interviews, in relation to what interview participants identified as the most significant change (positive or negative) from the development of the blue economy agenda in Seychelles. They fell under the following themes: international engagement; awareness of ocean as a development space and socioeconomic opportunities; the realization of the linkages between ocean sustainability and livelihoods; the availability of finance; the awareness of threats to Seychelles coastal and ocean environments including overfishing, pollution, and climate change; the establishment of dedicated blue economy institutions; and an increased focus on whole of ocean planning and management. There was significant overlap in responses between most significant change,

TABLE 4 Alignment of *Seychelles blue economy roadmap* with the SDGs.

Blue economy strategic priorities	Description	SDG
Creating sustainable wealth	Sustainability of existing sectors (fisheries, tourism and ports) and diversification through value chains and sustainability branding; Exploring feasibility of emerging sectors (mariculture, renewable energy, oil and gas, ICT, Biotechnology, trade)	SDG 7, 8, 9, 11, 12, 14
Sharing prosperity and food security	Local Production systems and markets; healthy lifestyles Access to quality education and Skill development, professional training and job opportunities Local private sector development and entrepreneurship	SDG 2, 3, 4, 10
Securing healthy and productive oceans	Natural capital accounting Protection of natural assets; ocean/coastal risks reduction (coastal development, marine pollution, ocean acidification) Blue economy/Climate resilience (adaptation andmitigation)	SDG 6, 13, 14, 15
Strengthening the enabling environment	Integrated coastal and marine planning; R&D& innovation; knowledge management; financing, maritime security; partnerships; international and regional cooperation and advocacy;	SDG 14, SDG 17
Blue governance	Legislative reform, whole of government institutional coordination; policy coherence; stakeholder participation; ocean stewardship; transparency and accountability; blue accounting; monitoring and reporting.	SDG 16, 17

successes/benefits (positive change), and challenges and gaps (negative change).

When asked about the key drivers of blue economy development in Seychelles, responses ranged from high-level political leadership, strong international partnerships, dedicated blue economy institutions for blue economy implementation, attractive development and livelihood opportunities, access to private capital through innovative finance, and availability of new marine knowledge and expertise for integrated ocean planning.

Global policy drivers such as the SDGs placed Seychelles (and other SIDS) at the forefront of the blue economy and ocean sustainability with high expectations for proof of concept at the national level. The nexus among high-level leadership, international engagement, strong international partnerships, a willingness to engage in innovative approaches, and the availability of new marine knowledge was seen as instrumental in facilitating access to finance and expertise for ocean planning as well as the establishment of blue economy institutions for the whole of government implementation.

The completion of the debt swap for Conservation and Climate Adaptation (2015) and the establishment of the Seychelles Conservation and Climate change Adaptation (SeyCCAT) to administer the proceeds and the issuance of the Seychelles Blue Bond for transitioning to sustainable artisanal fisheries (2018) allowed the completion of the Seychelles Marine Spatial Plan and the designation of 30% of the EEZ as marine-protected areas and importantly the availability of ongoing local finance in the form of grants for local conservation projects and loans for sustainable fisheries and diversification. These were the most cited successes arising from implementing a blue economy agenda.

The establishment of blue economy structures including the blue economy department, the Blue Economic Research Institute, and the adoption of the Seychelles Blue Economy Strategic Policy framework and Roadmap (2018–2030) were seen as key drivers providing the basic "*architecture*" necessary for the implementation of a whole of the government blue economy agenda. The development of the blue economy 5-year implementation plan (2019) in partnership with UN Economic Council for Africa (UNECA) and the development of the Blue Economy Research Institute marine research capability in partnership with international organizations were important steps in progressing the implementation of the blue economy roadmap.

The availability of sustainable development and livelihood opportunities the ocean space offered through diversification of existing sectors such as tourism and fisheries as well as the recent adoption of the aquaculture regulations and financial support for the development of a local biotechnology sector (African Development Bank *Blue Economy Micro-Small Medium Enterprises Technical Assistance* project 2020) were also cited as key drivers for implementation.

Transitioning to implementation, several challenges were identified, ranging from the country dependency on a small number of economic activities, energy, and food imports

TABLE 5 Exploring blue economy as an agent of change: drivers, successes, and challenges.

Most significant change	Drivers	Successes/benefits	Implementation challenges/gaps	Example quote
International engagement/leadership (regional/global)	High level Political will and vision International agenda (SDGs, Blue Charter) High expectations	International accountability Seychelles as African Union blue economy champion Profile at the UN in NYC	Maintaining momentum across political changes and continuity of high-level Ministerial leadership	"With the new administration, initially there was no political will, now blue economy is acknowledged as an important policy for Seychelles and the new Minister for Fisheries and Blue Economy is very active in supporting diversification and value adding of marine resources" (senior official-1) "On the issue of visibility and expectations, it is not just about good stories but also challenges and teething problems. We are a large ocean state, however, when it comes to implementation, we are still a SIDS with limited resources and capacity to match and we need financing and technical support. Blue economy is like a building a ship as you are sailing it" (Politician-10)
	Strong international partnerships (finance/research andinnovation)		Dependence on external expertise	"The blue bond was an international first. It demonstrated that SIDS can think outside the box" (Senior official-5)
Finance	Access to finance- Investor confidence Capital markets interest in investing in sustainability	Blue bond and debt swap negotiated and establishment of SeyCCAT Long term financing flow	ODA eligibility, Cost of finance Meeting commitments post COVID Mixed results in disbursing of funds in particular Blue Bond loans BE Financing gap still Investment strategy needed	"Investors are frustrated at the slow pace of implementation even if they are happy about the [bluebond] initiative" (international-14) "SeyCCAT is a transparent mechanism for attracting and delivering finance for ocean, maintaining international relationships, building awareness and providing and enabling environment" (Senior official-23)
BE Governance and institutions [blue Economy Department, Blue Economy Research Institute, and the independent Seychelles Conservation and Climate Adaptation Trust (SeyCCAT)]	BE Department as focal point for whole of government blue economy implementation	Blue economy policy approved by Cabinet Opportunity to develop a Blue economy research agenda Implementation Plan Socioeconomic and ecological assessment (UNECA)—BE Contribution to GDP. BE project database Youth mobilization on blue economy	Whole of government/Policy coordination constrained by Authority and clarity of mandate of the Blue Economy Department following successive government restructure, Overcoming silos. Lack of whole of government ministerial oversight and formalized collaboration mechanisms between BE institutions Institutional capacity—IT technology infrastructure and training Communicating blue economy and sustainability to stakeholders. empowering local communities; lacking. Stakeholder	"The Blue Economy Department looks at projects under the banner of blue economy, rather than looking at its core functions such as coordination and communication" (International-15) "The establishment of the Blue Economy Department has provided a national focal point for ocean related matters including the development of the Blue Economy Roadmap" (senior official 23) "There is not enough collaboration between institutions. It is slow moving. Without sufficient coordination, slow can be paralysis" (International-14)

(Continued)

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TABLE 5 (Continued)

Most significant change	Drivers	Successes/benefits	Implementation challenges/gaps	Example quote
Awareness of ocean as development space and sustainability	Attractiveness of ocean resources (fisheries and tourism) Socioeconomic opportunities through Diversification (eg fisheries value chains) Increased research for sustainable development	Aquaculture regulations, biotechnology, Seychelles "blue brand" Linking conservation to economic development Focus on sustainability	Regulating/negotiating access to ocean resources for local benefits COVID 19- dependence on tourism revenue Slow uptake of local business opportunities Mainstreaming sustainability, innovation and resilience thinking in ocean sectors, local business, and financial institutions Sustainability of extractive industries and fisheries	"Without the element of sustainability brought about by the blue economy our economic potential would have been severely limited" (Politician-7) "The pandemic has shown that relying on tourism solely for government revenue was a vulnerability. Blue economy offers opportunities for diversification including biotechnology and the use of marine products such as seaweeds" (Senior official-1)
Linkages between ocean health, livelihoods and job opportunities			Communication, Education, and Skill development /local entrepreneurship/incubators Transitioning to sustainable small-scale fisheries Communicating blue economy and sustainability to stakeholders and empowering local communities	"There is still confusion about what blue economy means at stakeholder and government levels" "We have a clear direction for our pursuit of economic diversification and the attainment of socio-economic opportunities" (Senior official-2) There are weak linkages between science and policy… there is a lack of understanding of the process of research and development which brings benefits. Linking "*knowledge people and profit*" (independent-19
the awareness of threats to Seychelles coastal and ocean environments and focus on whole of ocean development approach and Ocean sustainability	Improved knowledge of the marine environment and threats (overfishing, marine pollution, climate change)	Marine spatial Plan and 30% of EEZ designated as MPAs Youth mobilization on coastal and ocean protection and marine pollution Ocean and climate: Blue carbon initiatives/Blue Economy in Seychelles Secretariat (2021) Regional infrastructure for maritime security Seychelles contribution.	Ocean Authority for MSP implementation on pause, access to finance for MSP/MPA management Maritime surveillance capacity and Compliance and enforcement lacking	The MSP process has provided traction to the blue economy implementation. The commitment to meet 30% of EEZ as MPAs through Seychelles debt restructure combines debt reduction and a sustainable development approach to the ocean, which is consistent with our national objectives" (Senior official 23) "Maritime security is not yet well-addressed. Monitoring Compliance and Surveillance capability is lacking including for the JMA"(Senior official 23)

Themes from interview responses.

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and the impacts of external factors such as COVID-19, illustrating the vulnerability of Seychelles as a SIDS to the governance and institutional challenges for implementing a whole of government blue economy agenda. These institutional challenges ranged from the loss of political momentum, high-level strategic oversight, barriers to effective coordination across government (including a lack of clarity regarding the mandate of the blue economy department following successive government restructures), and a lack of formalized collaborative mechanisms across government and between blue economy institutions. Other challenges raised included access to financial resources for implementation commensurate with the needs and the slow local uptake of blue economy opportunities. Communicating the concept of blue economy and sustainability across government and blue economy stakeholders was cited as ongoing challenge, which would require a change in local mindsets toward sustainability, and skills and capacity to improve uptake of blue economy opportunities.

Effectiveness of blue economy governance arrangements

A combination of a desktop analysis of policy and institutional arrangements, interviews, and information collected by the advisor over a 2-year period was used to analyze the effectiveness of blue economy governance arrangements for the whole of government blue economy implementation. A summary of main themes is outlined in Table 6 and described in detail in the following sections, grouped according to the typology of good governance.

Leadership and political stability

As highlighted in the previous section, political leadership and commitment were seen as essential to ensuring effective blue economy integration across government sectors. At the same time, maintaining momentum over time and across political changes were seen as a key challenge to ensure the longevity of blue economy as national policy for the development of the ocean. Some respondents mentioned efforts at cross-party communication to ensure blue economy remained a key component of Seychelles sustainable development landscape. International expectations on delivering outcomes were seen both as an opportunity and a challenge, according to some respondents, as other countries were now sharing international leadership in the blue economy space and hence perceived as competition for access to resources. Finally, COVID-19 compounded those impacts as tourism revenue dropped and health priorities took center stage. However, COVID-19 was also seen as an opportunity to promote a blue recovery, understood as *supporting a recovery that addresses most critical structural challenges of SIDS, enhancing the resilience and sustainability of existing key economic sectors, and fostering economic diversification by unlocking new, more resilient, and sustainable development opportunities that can attract private investments and mobilize domestic resources (OECD, 2021).*

Policy coherence and institutional coordination

The desktop analysis of available policy documents and reports was used to investigate the extent to which the blue economy was mainstreamed in national development and relevant blue economy sectoral policies. This included a review of the institutional arrangements under those policies, including blue economy institutional arrangements. The thematic analysis of interviews on the effectiveness of blue economy institutional coordination complemented the findings of the desktop policy and institutional analysis and highlighted the successes and challenges facing the transition from sustainable blue economy development to implementation and reporting.

The comparative analysis of the *blue economy roadmap* and the *National Development Vision (2019-2033*) and the *5-year National Development Strategy (NDS, 2019-2023)* shows that although developed through separate ministries and processes, they shared a similar vision, principles of sustainability, resilience, and equity and include strategic economic, social, environmental, and enabling objectives. The NDS is organized around the six pillars (good governance, people at the center of development, social cohesion, innovative economy, economic transformation, environmental sustainability, and resilience), which are closely aligned with the four strategic pillars of the blue economy roadmap, as described in Table 3. The NSD implementation strategies place a strong emphasis on good governance and government effectiveness, strengthening public sector service delivery and behavior change, transparency, and accountability and strengthening financial management and resource mobilization. These strategies, which reflect the mandate of the Ministry of Finance, Trade and Economic Planning, are acknowledged as essential enablers in the *blue economy roadmap*. The *blue economy roadmap* includes additional ocean-focused cross-cutting, enabling activities such as integrated coastal and ocean planning, marine research and innovation, maritime security and safety, regional cooperation, and international advocacy (Supplementary Table 1).

The analysis of the extent to which the vision and strategic priorities of the *blue economy roadmap* were mainstreaming in the new *Fisheries Policy* (2019), the *Tourism Master Plan* (2019–2023), and the *Nationally Determined Contributions* (Secretariat, 2021) to the Paris Agreement shows similar trends. Although the *Tourism Master Plan* does not refer to blue economy or the *blue economy roadmap* (nor the *National Development Strategy*) *per se*, the vision, objectives, and priority actions are nonetheless broadly aligned with many of strategic opportunities identified in the *blue economy roadmap* for this sector. The Fisheries Policy (2019) did

TABLE 6 A summary of key governance themes from interviews.

Governance indicator	Successes/benefits	Challenges	Example quotes
Political commitment	Early High-level political commitment	Maintain momentum/high level political leadership, BE advocacy (national/international)	See above
BE whole of government coordination and processes	BE architecture: high level BE ministerial Council and Stakeholder Forum BE department coordinating institution in Ministry of Finance; University based Blue Economy Research Institute; Independent Seychelles Conservation and climate change adaptation Trust to disburse grants for marine conservation, climate resilience MSP/blue economy implementation Consultative Marine spatial planning of Seychelles EEZ completed (2020)	High level ministerial BE oversight Stakeholder Forum and MSP regulatory Authority on hold Representation on Stakeholder forum (eg private sector and NGOs) Move of BE department to Vice president office and Ministry of fisheries—Clarity of coordination mandate and authority of Blue Economy department (eg coordination and or projects focus) Overcoming public sector silo culture BE research agenda and finance to drive marine/blue economy research (*knowledge, people, profit*)	"The Blue Economy governance has been scrapped. The Blue Economy Department is not able to coordinate across government and stakeholders" (Senior official-4) "Instead informal and good relationships between officials" (Independent,-20). "The Blue Economy Department has no Authority to deliver or influence delivery, wrong institutional mechanism" (International-13) "Blue economy has lost its place and importance as an overarching framework for the sustainable development of the ocean in the policy and institutional landscape with loss of institutional memory" (International-20) "The Blue Economy Forum does not have enough private sector representation" (independent-20) "Collaboration across silos and budgets is difficult, agreement in principle but no consensus on roles and responsibilities" (Senior official 23)
Effectiveness/ Institutional capacity	Improved M&E Communication and legal capacities in BE department Public sector restructure to reduce duplication of roles and expenditure and performance-based service delivery	Strategic thinking/leadership needed. Improved coordination competencies needed. Reliance on expat technical capacity; better use of qualified young professionals; career paths. Staff turnover	Capacity is not an issue, there are many qualified young people" (Politician-8) "Right people for the right jobs. A public service commission should advertise interview and select public servants on merit. They should not be appointed by the President" (NGO-18) "The mindset in the government. It is a very hierarchical Top down approach, not bottom up as yet with resistance to change, It is a challenge" (Senior Official-4) "The Seychelles public sector was out of control under the previous administration with too many parastatal bodies with significant overlap and duplication. The new administration is streamlining the public sector" (international-15)
Policy coherence	Blue economy Strategic policy framework and roadmap (2019–2030) adopted in 2018 and implementation Plan (2019)	Slow progress in implementing the roadmap/implementation plan Perception that BE is taking other ministries' responsibilities Mainstreaming BE in the national economic framework (balancing economic environmental social and cultural goals) eg National mainstreaming in development Vision 2033 and 5 year strategy (2019-2023) and sectoral policies.	"Significant alignment with other overarching national strategy such as the NDS" (Senior official 5) "A challenge is the increasing more intense competition for limited resources, there are instances whereby sectoral strategies take precedence over assigned responsibilities in the Roadmap" Blue economy is not mainstreamed in economic planning. It is considered an aspiration it, should have been the center point, not an add on" (Senior official-2)

(Continued)

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TABLE 6 (Continued)

Governance indicator	Successes/benefits	Challenges	Example quotes
		Improving coordination across sectors and budgets	
Equity and inclusiveness, communication and Stakeholder engagement	Successful Youth mobilization around blue economy and marine conservation Stakeholder engagement in MSP. Improved BE visibility (social media, national press)	High level stakeholder platform for advice to government on BE implementation- representation of private sector and NGOs lacking Lack of an BE integrated communication strategy with consistent messages and customized to government/non-government stakeholder; BE communication not just BE institutions responsibility Improving coordination of comm activities across BE institutions and sectors A hoc educational activities No community engagement yet	"The blue economy concept is not understood. It operates as a top-down approach. Stakeholders are leaving the process" (Independent 20) "There is No platform for dialogue (Senior Official-4) "Younger generation takes a more holistic view of the ocean, BE is a pathway to a blue society, which includes social and cultural aspects, not just economy" (Politician 10) We need to accelerate the availability of information; more work is needed to understand information needs and accessibility" (senior official-5) "BE, SBS, SeyCCAT all have awareness programs. We need to improve our working with other bodies" (senior official-5)
Transparency and accountability	BE M&E framework in development Ministry of finance implementation of Results based Management framework with PPBB focal point in each ministry Satellite accounts for tourism and fisheries Seychelles first report to the Fisheries Transparency Initiative Global office in Seychelles	Independent review of BE implementation across sectors needed. Effective Platform for coordinating M&E processes across government and non-government needed Accessibility and availability of BE information constrained by internet access, effective whole of government information systems	"There are no mechanisms for monitoring and reporting progress that I am aware of" (independent-12) "The focus now is being placed on the M&E framework. It brings together 22 implementers to coordinate actions" (senior official 2)
Partnerships	Seychelles high international/regional profile/leadership/advocacy on BE and oceans Access to networks of partners and investors for oceans and BE implementation and climate resilience	New platforms and actors on blue economy ocean and climate for international attention COVID and climate change has shifted the global narrative and reshaping the BE narrative	"International partnerships are key to MSP implementation to attract expertise, build technical capacity and benefit from lessons from abroad which would be applicable to Seychelles" (International-12) "For ocean, development and climate change are one of the same in SIDS as they are interconnected" (politician-10)
	Effective partnerships with international organizations on finance, research and marine protected areas (investor confidence) Seychelles as African Union Blue economy Champion Mainstreaming of Seychelles/SIDs in international agendas through coalition (eg AOSIS) Willingness to partner and innovate, partners' access to Seychelles high level decision-making, good governance, good place to work	Discontinuity between global advocacy and national implementation Managing expectations if not translated into practice Transforming global opportunities into national capacity and benefits Improved partner/donor coordination COVID/Climate change and changing priorities Difficulty of engaging government on long-term commercially successful projects.	"International interest in financing blue economy has been good for Seychelles including the private sector" "There is limited donor harmonization despite the requirement for it. . . . a Government roundtable might be an option" (International-14) "Successful advocacy more than implementing. Talk to talk but not walk the talk" (International-17) "Lots of positive, but too much talk about BE globally and not enough about making it work at home" (International 17) "Experience across the world shows that political will and good counterparts in government ready to commit and follow through are essential" (International-14)

refer to the *National Vision 2033*, the *National Development Strategy 2019–2023*, and the *blue economy roadmap* in its preamble and was also found broadly aligned with strategic opportunities identified in the *blue economy roadmap*. Both policies shared common features including the diversification and sustainability of their sector as well as the need to ensure economic benefits flow to local people, through access to training and education, and entrepreneurship, which is consistent with the *blue economy roadmap* strategic priorities of creating sustainable wealth, sharing prosperity and social equity. The Nationally Determined Contribution (Secretariat, 2021), which is targeted to achieve the commitments of the country to the Paris Agreement, identified blue economy as a major strategy to achieve climate adaptation and mitigation targets (Supplementary Table 2).

The review of the institutional landscape under the policies analyzed before shows a multiplicity of implementation structures, each with their own mandate and stakeholder engagement. The extent to which these processes interacted was not clear, although interview participants indicated that cross-membership was common (Supplementary Table 3). As mentioned by one respondent, the planned review of the NDS in 2022 and the mid-term review of the *blue economy roadmap* may be an opportunity to foster closer alignment and greater synergies, as well as improved institutional coordination and harmonization of stakeholder engagement and communication.

In contrast to the desktop analysis, feedback from interviews on policy coherence and coordination revealed more critical perspectives on the mainstream of blue economy in the government policy landscape. Some respondents indicated that the blue economy was originally designed as the template for a national development policy and economic planning, given the dependance of the country on the ocean for prosperity. Others considered the blue economy to be aspirational and no longer a relevant, integrated framework for the sustainable development of the ocean. A lack of mainstreaming the *blue economy roadmap* objectives in national development strategies and sectoral policies was widely reported by the participants and attributed in part to the move of the blue economy portfolio from the Ministry of Finance Trade and Economic Planning, following successive government restructures.

It was also attributed to the perceived inability of the blue economy department to effectively coordinate a blue economy agenda across government actors. Expectations were that policy alignment was the responsibility of the blue economy department parent ministry, now the Ministry of Fisheries and Blue Economy, not a shared commitment. The latest government restructure, while elevating blue economy to the ministerial level, nonetheless sent the message that the blue economy was about fisheries, rather than a whole of the government development framework for the ocean. Some respondents suggested going back to the original vision of the blue economy and the establishment of Ministry of Blue Economy as a central coordinating mechanism with the authority to better integrate social, economic, and environmental goals and architectures. Others suggested an Ocean Ministry, ministerial committee, and stakeholder committee under the Office of the President and vetted by the parliament. Some respondents saw the need for continuity and a long-term blue economy plan as essential to attract investment. The disconnection between the policy analysis and interview responses seems to indicate the challengesto transitioning from policy to implementation, the critical role of the effective whole of government coordinating mechanisms, and the need to generate ownership and a sense of common responsibility for implementation.

Governance arrangements for whole of government blue economy coordination

The institutional analysis showed that besides the blue economy department, which has been functioning since 2016 under various parent ministries, dedicated institutional arrangements for whole of government coordination and stakeholder engagement have been either slow to establish or short lived (Supplementary Table 3). Proposals for institutional arrangements for the development and implementation of the *blue economy roadmap* were not fully supported by the cabinet in 2016 and again in 2018. Eventually, the government established a Blue Economy Ministerial Council in 2019 chaired by the Vice President, to provide strategic leadership and oversight, and a Multi-Stakeholder Forum as a platform for dialogue and advice to the Ministerial Council on cross-sectoral implementation of blue economy, which were abolished in 2020 following the change of government, creating a governance gap. Three independent bodies, the Seychelles Blue Economy Research Institute hosted at the University of Seychelles, the independent Seychelles Conservation and Climate change Adaptation Trust (SeyCCAT) established under legislation, and a proposed Seychelles Ocean Authority as the regulatory body, to implement the MSP complete the institutional architecture for blue economy implementation.

The desktop analysis and feedback from interviews of blue economy institutions for whole of government coordination raised issues of duplication, relationships to other mechanisms, collaboration between blue economy institutions, and lack of continuity of high-level oversight and meaningful participation of stakeholders. In the absence of high-level whole of government oversight and directions, the blue economy department has been the focus of criticism of whole of government coordination. The Seychelles Conservation and Climate Adaption Trust, which was established as an independent board under legislation to administer the proceeds of the debt swap for conservation and climate adaptation,

was seen as a successful governance model with a board consisting of government, private sector, and civil society and a *de facto* avenue for stakeholder engagement and support through the disbursement of grants for local projects (Supplementary Table 3).

Effectiveness and institutional capacity

Interviews showed that the capacity of the blue economy department, as the primary mechanism for coordination, had improved in aligning and prioritizing blue economy strategic actions across government stakeholders, developing a blue economy project database development, monitoring and evaluation, and media and communication. Its ability to effectively coordinate across government sectors with other blue economy institutions was however constrained by weak mechanisms for the whole of government coordination processes, leading to duplication and competition for resources and reinforcing silos. Some respondents criticized undue reliance on external technical expertise and insufficient use of qualified young professionals, pointing to deeper public sector systemic issues. The need to build capacity, and retain and better use existing local professional expertise within government and non-government sectors was seen as essential to reduce dependency on international expertise. Career paths and mobility were mentioned as possible strategies. The latest restructure of the public sector was welcomed by some respondents as they considered that it would reduce duplication and public expenditure and improve overall effectiveness of service delivery. It was seen as a positive step toward reducing the multiplicity of agencies and bodies established over time under previous administrations as their functions repatriated under the relevant ministries. There were also concerns that the blue economy department made *ad hoc* and short-term decisions, rather than decisions supported by long-term strategic planning. Some respondents mentioned the recent move toward a "results-based management" framework and performance-based service delivery reforms across government sectors supported by the World Bank as a positive step to address some of those issues.

Equity and inclusiveness

Both the *blue economy roadmap* and *implementation plan* place a strong emphasis on social equity as a key to their vision and objectives. Although stakeholder engagement was meant to be an essential feature of institutional arrangements for the development and implementation of Seychelles blue economy, implementation showed mixed results. The respondents noted success in a strong youth mobilization around blue economy and marine conservation including initiatives such as SIDS Youth Aims Hub (SYAH) blue economy internship program first supported by the UK government and then by the private sector. Overall, despite some early stakeholder engagement in the design of a blue economy roadmap and the inclusive blue economy vision and social objectives, there was limited reference in interviews to non-government stakeholders' engagement besides SeyCCAT and the MSP process led by the Ministry of Environment, Energy and Climate Change (MEECC) with the technical support of the Nature Conservancy.

This may be a bias of the mainly government affiliation of interviewees, but some mentioned a failure of effective stakeholder engagement. A communication strategy was initially developed as part of the development of the blue economy roadmap, but its implementation was limited (advisor notes). One of the challenges identified by the respondents was uncoordinated blue economy communication and stakeholder engagement across government ministries, which sent confusing messages about the blue economy. Some respondents nonetheless acknowledged the recent improved blue economy profile in the national press and social media. Others noted the increasing *de facto* role of the SeyCCAT in blue economy communication and engagement through the financing of local community blue economy projects. The Blue Economy Multi Stakeholder Forum, proposed as early as 2016 (advisor notes), as a platform for an inclusive blue economy dialogue, was established in 2019 but did not live up to expectations with limited private sector, civil society, and community representation. At the time of writing, there is no knowledge of formalized mechanisms for stakeholder participation in blue economy implementation. The lack of clear and consistent messages around the blue economy and ongoing stakeholder engagement over time were major impediments to its wide acceptability within government and by the community and the persistence of the view that blue economy was only serving the political agenda of the day. This is not helped by the fact that the blue economy roadmap document and 5-year implementation plan have yet to be made widely available (advisor notes). In the absence of such critical information, misconceptions arise and trust in government is eroded (OECD, 2020b).

Transparency and accountability

The respondents cited the implementation of macro-economic reforms post-Global Financing Crisis (2008) following the defaulting on debt payments, as the trigger for introducing market approaches of a largely centralized economy and the introduction of the mechanisms for accountability in the public sector, including the establishment of the National Bureau of Statistics. The implementation of results-based management across government sectors supported by the World Bank, and the establishment of satellite accounts for fisheries (2022) and tourism (2021) were seen as important improvements in accountability of government blue economy financial flows, although accountability of non-government financial flows was yet to be developed. The piloting of a

blue economy valuation toolkit (BEVTK) as part of a broader UNECA Africa initiative showed progress on assessing blue economy economic performance but with challenges to establish useful social indicators for assessing social objectives of blue economy (Laing, 2020, 2021). The respondents reported the blue economy department was developing a blue economy monitoring and evaluation framework, which has yet to be made publicly available. Finally, Seychelles membership to the Extractive Industries Transparency Initiative (EITI) and the Fisheries Transparency Initiative (FiTI), both of which were multi-stakeholder-driven, were also cited as models of transparency and accountability the government was engaged in. Challenges raised by the respondents included accessibility of blue economy information constrained by internet availability and effective coordination of government information systems and data platforms. Attempts at developing whole of government management systems was seen as an issue of digital communication technology and services (e.g., e-government) as much as an issue of strategic leadership and coordination across knowledge-based institutions and government budgeting and reporting processes.

Partnerships and collaborations

The respondents consistently referred to partnerships with international organizations to secure access to finance, expertise, policy advice, and research collaborations for blue economy implementation as positive developments. Examples included partnerships between the Ministry of Environment, Energy and Climate Change and the Blue Economy Research Institute in marine research and conservation. Some of the success factors identified by international partners were Seychelles unique geography and natural assets, the willingness to partner and innovate, access to Seychelles high-level decision-making, good governance, and an overall good place to work. Seychelles partnerships with the Nature Conservancy and the World Bank, which help secure debt-based finance for the development of the marine spatial plan; the designation of 30% of its EEZ as protected areas; and the transition to sustainable fisheries were seen as successful partnerships. Some respondents, however, indicated that the availability of finance to date was far from covering the costs of blue economy implementation and that the initial quantum of finance requested by the government was not granted and ultimately at the discretion of global investors. Concern was expressed by local respondents of the volatility of international attention, and the challenges to transforming global attention into lasting local capacity and benefits. Some respondents expressed the need for better donor harmonization and regional cooperation to pool resources and influence in the context of transboundary fisheries management, capacity building, and climate change policies.

Discussion

The purpose of the research was to investigate the extent to which the blue economy had provided a pathway for the sustainable development of the ocean, and the extent to which blue economy governance arrangements had enabled effective integration of economic social and environmental dimensions of sustainable development, consistent with SDG16 and 17 and the principles of good governance.

Overall, the research, despite a relatively homogenous sample, shows a patchwork of perspectives, at time contradictory, particularly in the area of governance. The results show that blue economy indeed had provided some of the enabling conditions necessary toward sustainable development of the ocean, as evidenced by the *Seychelles blue economy roadmap*, the institutionalization of blue economy within government, and the perception that blue economy had led to important achievements and local benefits. However, it has also revealed numerous implementation challenges from continuity in leadership to those related to the effectiveness governance arrangements, policy coherence, and communication across government and non-government stakeholders. There was criticism of current arrangements or lack of them, but few solutions were advanced by participants.

Seychelles has been heralded as an international success story in the implementation of a blue economy, thanks to its international advocacy and innovative financing for marine conservation and sustainable fisheries. The international attention it has received is a credit to its leadership and willingness to partner and innovate in a challenging and contested global policy space. The investigation of how international attention has been translated into practical national outcomes presents a much more nuanced picture. The research shows a combination of achievements and challenges across all good governance dimensions. The results can be broadly summarized as follows:

Key achievements

- Strong political will, international leadership, and successful partnerships on innovative finance for high-profile blue economy projects such as Seychelles Marine Spatial Plan, the designation of 30% of the EEZ as MPAs, and the establishment of Seychelles Conservation and Climate Change Adaptation Trust as innovative governance.
- The adoption of a *blue economy roadmap* and *implementation plan* setting out a vision, principles, and social economic, environmental, and enabling objectives and priorities for action aligned with the SDGs as well as the establishment of blue economy structures including a blue economy department and a blue economy research institute and the SeyCCAT as the basic architecture for implementing an integrated blue economy agenda.

- Progress on implementation of sector-based blue economy policies and development of networking systems for blue economy financial accountability across government stakeholders.

Governance challenges

- Maintaining a high-level political momentum across political changes, leading to some marginalization of blue economy as a national integrated policy framework for the sustainable development of the ocean.
- A lack of continuity and clear mandates of blue economy structures and processes for the whole of government coordination and communication, combined with a limited public sector capacity and efficiency as major impediments for implementing a long-term coherent blue economy agenda across government and non-government sectors.
- Weak avenues for stakeholder participation in decision-making and access to authoritative consistent blue economy policy information as impediments to a national shared vision, commitment, and active engagement in blue economy implementation.
- Barriers to effective whole of government tracking mechanisms of blue economy implementation including financial flows across both government and non-government stakeholders.

Implementing a sustainable and equitable blue economy agenda is a long-term project, which requires learning from and building on successes and developing strategies to address challenges. In the next section, we discuss reconciling global expectations and local realities and propose strategies to convert challenges into opportunities through institutional reform; acknowledging the political nature of blue economy and building a national consensus; learning from local governance innovations and strengthening institutions; and investing in public sector capacity and expertise.

Reconciling global expectations and local realities

Seychelles has achieved high international leadership and diplomatic influence in blue economy and ocean governance, responding to global demands for innovative blue economy models (Bueger and Wivel, 2018). The adoption of the *blue economy roadmap* and *5-year implementation plan*, and early establishment of dedicated institutions and successful projects such as the Marine Spatial Plan and MPA designation are significant milestones. International visibility has however come with high expectations, not necessarily tuned to local aspirations nor commensurate with capabilities and jurisdictional responsibilities.

Reconciling global expectations of Seychelles as a successful model for blue economy with local realities were evidenced in the challenges experienced in establishing the functioning whole of government processes and meaningful stakeholder participation, which would allow for the effective implementation of the blue economy as an integrated framework for the sustainable and inclusive blue economy. Changes in political leadership over time led to a decline in support for blue economy as a national priority and in turn has weakened the whole of government processes and reinforced a view that the blue economy was serving an international agenda and was taking over existing ministerial responsibilities. The shift of the blue economy portfolio across several ministries further undermined its relevance of as a national policy framework and the legitimacy of structures and processes for coordination.

The challenges to establishing long-term well-designed mechanisms for the whole of government implementation of blue economy, which would allow for inter-ministerial collaborations and reduce potentially conflicting policy objectives, could be attributed to a lack of shared understanding and clarity about the blue economy concept and roles of ministries in the implementation of the *blue economy roadmap* (Barbe, 2020) as much as symptoms of broader systemic public sector issues. Some of the systemic barriers may be unique to Seychelles, some common to SIDS, and others found in a range of governance settings. Seychelles shares many of the characteristics of small islands, including a relatively large public sector (as % of population) because of diseconomies of scale in the provision of public goods and services. As a major employer, it is strongly personalized and vulnerable to conflicts of interest, political interference, clientism, and nepotism. In addition, a limited pool of expertise and recruitment through social, family, or political connections, rather than merit, hinder institutional reform to overcome entrenched public sector silo mindsets (Everest-Phillips and Henry, 2018). In addition, Seychelles historical legacy of a centralized one-party system for an extended period continues to influence both the structure and functioning of the public sector and perceptions of th egovernment (Bhim, 2020; Schutter et al., 2021). Communication and decision-making still follow a largely hierarchical approach with limited delegation of decision-making and formalized structures and processes for inclusive decision-making and collaboration across ministries and recruitment processes (Barbe, 2020).

Turning challenges into opportunities

As the most important instrument of the state, it is essential to improve how the public service functions to achieve lasting

development outcomes. Public sector institutions (as distinct from structures) include policies, markets, and legal frameworks, as well as informal norms and code of conducts that drive government decision-making, the behavior of public sector workers, resource allocation, and the exercise of power within a state bureaucracy (North, 1990). Public sector governance reform requires institutional reforms to improve performance and generate greater commitment, capacity, efficiency, and integrity to achieve development objectives (Joshi and Carter, 2015). To be effective, institutional reforms need to work within the local political context and be based on a common understanding and framing of the issues at stake. They should also acknowledge the pervasive nature of informal institutions, build on existing capacity, and value incremental adaptive reform, which can generate learnings and momentum for change (Joshi and Carter, 2015). With a new administration willing to tackle some of the systemic issues of the public sector, there is an opportunity for the government to re-energize its approach to the blue economy as a whole of government inclusive of national policy, provided governance gaps presented before are attended to.

The negative perceptions of the effectiveness of the institutional arrangements for coordination as lacking authority and competence and the marginalization of the *blue economy roadmap* in core ministerial responsibilities did not necessarily question the underlying public sector systemic issues at play. The decline in support for blue economy can be explained by the political and institutional culture in which policymaking and coherence are embedded, combined with a lack of available incentives and perceived benefits/costs for inter-ministerial collaborations, which are at the core of an integrated approach. Policy coherence challenges for sustainable development and by extension the blue economy may be magnified in small island governance settings; however, barriers to effective integration across government stakeholders can be found in a range of government settings. A case study of SDG implementation in the Netherlands shows that policy coherence across SDGs implemented as a technical coordination process ignores the basic fact that the trade-offs between SDGs are political and require negotiation, a fact conveniently left to states to implement (Yunita et al., 2022). Furthermore, an analysis of government officials' perceptions of policy coherence in the implementation of the Post-2015 Development Agenda in Mexico shows that despite attention to policy coherence in global policy research, national implementation beyond high-level policy commitments is difficult to achieve in practice. The research found preference for coherence as an overall benefit to society; however, a combination of political culture, organizational structures, and budget processes, which are essentially hierarchical are not conducive to inter-ministerial collaborations. The latter requires additional time, resources, and commitment, all of them borne by the public sector, with costs that are not acknowledged and quantified, and hence not accounted for (Moure et al., 2021).

Guidelines for operationalizing policy coherence for development propose a participative methodology of policymaking, engaging a plurality of government and non-government actors based on information exchange and transparency, which can identify mechanisms that reinforce or undermine collaborations for integrated sustainable development outcomes and propose solutions, applicable in the context of blue economy (Koff et al., 2020). This is consistent with approaches to institutional change and governance in the context of aid for development, which argues that effective institutional reform starts with country ownership and context-specific existing governance structures and processes, rather than international best practice as conditionality, despite acknowledging the important role of external actors to help overcome domestic political support for change (Booth, 2011).

As an integrated framework for the sustainable development of the ocean, blue economy needs to encompass a broad range of values, activities, users, and needs, and hence the importance of avenues for dialogue and engagement of both government and non-government stakeholders. Although interviews did not include non-government participants, a key governance challenge identified was weak arrangements for meaningful stakeholder engagement, despite social equity and inclusiveness being one of the four pillars of the *blue economy roadmap*.

Research conducted in Seychelles on perceptions of the blue economy concept among policymakers, practitioners, and resource users engaged in the Marine Spatial Planning process (Schutter and Hicks, 2019) shows that the international discourse on blue economy advocating a triple bottom line conflicted with local realities, whereby this dominant vision was driven by the government's need to maintain international visibility and influence. This overshadowed local views and tensions between stakeholder perspectives, leading to "*depolitization*" of a shared vision. There was however a local desire to shape both process and outcome, despite potential trade-offs and incompatibilities between different interpretations of the blue economy among stakeholders. As noted by the authors, this may not be specific to Seychelles and indeed be a characteristic of the blue economy policy space more broadly. Other research on stakeholder values in Seychelles shows a strong link among blue economy, sustainability, quality of life, access to education and skills, and livelihood opportunities (Bramley et al., 2022). Accounting for those values requires a greater focus on inclusive governance (Rudolph et al., 2020) based on a long-term shared vision of blue economy and prosperity, valuing local empowerment and solutions including facilitating local private sector engagement and entrepreneurship (Benzaken and Hoareau, 2021).

Bridging the gap between global expectations and local realities requires support for locally driven institutional

reforms, which take account of issues of scale, culture, and capacity. Options to consider range from re-energizing a national consensus for blue economy, learning from governance innovation, to developing strategies for strengthening the whole of government mechanisms for coordination and stakeholder engagement, investing in public sector capabilities and rethinking approaches to international partnerships.

Acknowledging the political nature of blue economy: Building consensus

As current research suggests (Booth, 2011; Joshi and Carter, 2015; Koff et al., 2020), acknowledging and understanding the political context and local policy and institutional landscape in which a blue economy is developed and implemented could be a useful first step. Such an approach would require high-level whole of government leadership and champions across the political spectrum within and outside the government. It could take the form of a series of multi-stakeholder conversations, where different perspectives and needs can be shared, a common understanding and vision of blue economy validated, models for coordination and responsibilities discussed, and processes that undermine or facilitate collaborations across government and non-government and local incentives for collaborations identified. The *blue economy roadmap* was designed to provide common goals and strategic opportunities for sector-based implementation, not to replace them, highlighting the importance of an implementation plan that sets priority actions, articulates roles and responsibilities across government and non-government sectors, and includes an investment plan and tracking mechanism, some of which are underway. A review of the implementation of the *blue economy roadmap* to date, which highlights some of the achievements and challenges, may provide a useful background for such conversations (Benzaken and Hoareau, 2021).

Learning from local governance innovations and strengthening existing institutions

Seychelles has a history of innovation that can be brought to bear. Earlier public sector reforms post the 2008 Global financing Crisis and the implementation of results-based management supported by the World Bank and the International Monetary Fund have significantly improved transparency and accountability, brought prosperity, and allowed Seychelles to become a high-income country, despite a relatively low government effectiveness score compared with similar economies and a persistent inequality (Republic of Seychelles, 2019b). Governance innovation enabled by the Seychelle's Blue Economy agenda included the Seychelles Conservation and Climate Adaptation Trust. The trust was established under legislation and functions as a grant manager under an independent board comprising government, private sector, and civil society. The SeyCCAT mandate is to manage the proceeds of the Seychelles Debt Swap for conservation and climate adaption and part of the Seychelles Blue Bond. This includes meeting loan repayment obligations to investors, capitalization of the trust, and establishing transparent and competitive grants for local blue economy projects. Consequently, it has become a *de facto* place to go for blue economy information and participation in blue economy.

Lessons learned from the SeyCCAT as a delivery model is its independence from the government and hence political interference in resource allocation and a demonstration of the value of transparency and accountability in generating trust in institutions. Such a governance model, driven by the need for the debt swap financial accountability, has yet to be successfully replicated, despite similar model for blue economy governance proposed under the *blue economy roadmap* (Republic of Seychelles, 2019a) and a proposed for a Seychelles Ocean Authority. The role of The Nature Conservation (TNC), the NGO which purchased the Seychelles debt and sits on the SeyCCAT Board, has attracted some criticism as potentially infringing on sovereign decision-making (Schutter and Hicks, 2019; Standing, 2022). However, as suggested by one respondent, pragmatism and trade-off between attracting financial resources and some loss of sovereignty for the period of the loan could be a calculated risk in the context of the high cost of finance.

There might be other examples of successful governance innovations both in the government and non-government sectors in different policy spaces to learn from worth exploring either in Seychelles or in other SIDS, however these were not investigated in this research. The analysis of policy coherence in Timor Leste for example shows the value of identifying and strengthening existing influential policy hubs and coordination mechanisms, as opposed to establishing new ones as an effective way of addressing policy and governance gaps (Voyer et al., 2020). Consideration of non-government governance innovations could add value and provide models, which the government could consider as part of a broader blue economy "governance ecosystem." Such approaches would require greater flexibility within the government governance system and, as suggested by Joshi and Carter (2015), could generate learnings and momentum for change.

Investing in public sector capacity and expertise

Building public sector capacity is a long-term investment. Lessons learned from a range of case studies of public sector reforms in the Pacific and the Indian Ocean SIDS (Ismail, 2019) found that there is limited evidence of the effectiveness of public sector reforms or capacity building initiatives in SIDS, in particular reforms aimed at downsizing the public sector (Hassal, 2018). Most SIDS, including Seychelles, invest considerable financial and human resources relative to GDP

in order to deliver public services to their small populations. Successful reforms such as the Seychelles e-government reform can be attributed to a combination of political will, executive leadership and partnership between the government, the development of partner and the service provider, high level of literacy, and political stability. This reinforces the role of international partnerships in supporting locally driven governance solutions (Commonwealth Secretariat 2016).

The challenges associated with building and retaining local expertise and skills, as raised in interviews, included making better use of qualified young professionals, not necessarily in a position of influence in the decision-making process. A combination of competitive recruiting processes and the availability of career paths could lead to reduced dependence on international expertise, which is locally negatively perceived (Schutter and Hicks, 2019; Stefanoudis et al., 2021). Public sector professional skills development based on an assessment of local needs would also be helpful.

Conclusion

In this study, we investigated the role of blue economy as an agent of change and good governance as enabling blue economy as an integrating policy framework, using the Seychelles experience. Our analysis shows a combination of successes and governance challenges for implementing blue economy as an integrated policy framework, some unique to Seychelles, others common in islands, and others also found in other governance settings. Seychelles international leadership, while acknowledged as an essential driver and contributor to blue economy development, has exerted considerable pressure and expectations on the government capabilities not commensurate with its jurisdictional responsibilities. Reconciling global expectations with local realities highlighted several governance challenges. These included maintaining political momentum and a strategic focus; effective communication and stakeholder engagement; policy coherence and institutional coordination; and addressing issues of legitimacy, public sector culture, and technical and human capacity. Options for institutional reform could consider re-energizing blue economy as a national policy framework through consensus building among government and non-government stakeholders, learning from governance innovations, identifying and strengthening local governance solutions for effective institutional coordination and integration, and strengthening local public sector capacity and expertise to build momentum for change across government sectors and beyond.

Lessons learned from the Seychelles experience provide insights, which can be shared with other islands wishing to implement a blue economy agenda, mindful that the Seychelles experience, while common with many SIDS, nonetheless is unique to its political, economic, social, cultural, environmental, and governance settings. It also provides some ground truth of international development policy and academic blue economy narratives and highlight the importance of practice and the needs to balance global objectives and governance standards with local needs for improving local governance outcomes. International partners should focus on supporting institutional reforms, which reflect priorities and capacity needs and customize good governance models to local governance issues and solutions.

Good governance for blue economy development could be summarized as follows:

- Ongoing high-level political leadership and commitment to long-term implementation.
- A national conversation that builds ownership and collective action.
- A blue economy policy that articulates a national vision and priorities, reflects national socioeconomic and environmental circumstances, provides a long-term strategic policy setting, and is embedded in the national development policy landscape.
- A legal framework and institutional arrangements that builds on existing structures and processes, has legitimacy and authority to facilitate a whole of government implementation, creates incentives for collaboration, is inclusive, and learns from tested innovative governance models domestically or elsewhere.
- Institutional reform that enhances government performance, build capacity, and accountability.
- Adaptive mechanisms that encourage creativity, innovation and flexibility, and the use of new knowledge and opportunities, including those which arise from international engagement and partnerships.

Limitations of the research

The mixed methods and case study approach used in this research were unique in that it combined longitudinal data sources and in-depth insights through the advisor, not usually available to external researchers, and empirical analytical methods. The choice of the most significant change and good governance model was well-fitted to explore the Seychelles blue economy experience. Primarily focused on government, the results unsurprisingly showed consistency on the importance of blue economy to Seychelles long-term prosperity, and much was made of successes to date, with most of the conflicting perspectives related to implementation and in particular governance. As the research design was purposely focused on a government perspective, the impacts of blue economy as transformative policy beyond the realms of government operations were not investigated. Specifically, the perspectives and contributions of actors such as civil society and the private

sector were not thoroughly investigated, despite their key role in blue economy implementation. Furthermore, the contribution of other critical enabling factors, in particular finance and the role of the private sector, has yet to be analyzed.

To conclude, as one respondent said, "*blue economy is like building a ship while it is sailing*," and hence, it is a work in progress.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee, University of Wollongong. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

DB as the lead author, conceptualized, designed, and conducted the research, wrote and reviewed the manuscript, and prepared the manuscript for submission. MV reviewed the manuscript and provided constructive comments on the first and second drafts. AP reviewed the manuscript and provided constructive comments on the first draft. QH reviewed the final draft of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpos.2022.1040318/full#supplementary-material

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The role of marine and diving authorities in workforce development in the blue economy

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Island governments have made decent work and social protection their highest policy priority, aiming to link them to the so-called blue economy sectors such as fisheries. The development of small-scale commercial fishing is primarily driven by transnational fisheries trade and depends on dive fisher labour force facing issues with deficits in decent work, health and safety, and safety at sea provisions. Given the macro-policy priorities for decent work in the transition of small island developing states (SIDS) to blue economy, this paper examines the development interventions in small-scale commercial fisheries trade that have exacerbated unsafe marine working conditions of dive fishers. Despite significant investments in developing commercial fisheries trade, the mismatch between macro-level decisions and micro-level labour needs has hardly been explored *via* the blue economy and sustainable development goal interlinkages. This study used a qualitative research approach to examine the unsafe working conditions of dive fishers and examined why dive-related accidents and fatalities occur in commercial fisheries in the first place. A systematic approach in the analysis of diving accidents helps the study to, firstly, highlight the gaps between macro policy and practice at the national and global levels. Secondly, the approach helps explore the need for a coherent approach to policy integration that bridges the gap between the macro and operational levels of small-scale fisheries labour force. The study analyses the International Labour Organization's decent work instruments with SIDS sustainable development priorities for fisheries workforce and points out that governments must be responsible at the macro level for managing accidents at sea and building a safe diving workforce through competent marine and diving authorities.

KEYWORDS

SIDS, dive fishers, dive accidents, SAMOA pathway, competent marine authorities, safety at sea, blue economy, SDGS

Introduction

The commercial small-scale fisheries trade has become a central part of blue economic development plans of small island developing states (UNOC, 2017). Development in the small-scale fisheries sector is interdependent on the underwater workforce—for example, dive fishers whose diving-specific occupational needs are often hidden or under-regarded (Nisa et al., 2022). For years, tropical island nations have taken note of the significant economic contribution of diving fishers to national development in the context of trade in wildlife fishery products, much of which is transnational. Bolatagici (2016) highlighted this in the case of Fiji's small-scale fisheries sector, which since 2000 has built up a pearl export industry worth about US$13 million per year that is dependent on the dive fisher labour force. Barclay et al. (2019) added that the dive fishers' contribution to the beche-de-mer trade from the Pacific Islands to Asian seafood markets was US$25.5 million in 2016. Island fisheries trade, such as the export of live fish and corals from Pacific Island states and aquaculture production for the aquarium industry, is worth US$200 million per year and is dependent on the diving labour force (Gillett et al., 2020). The development of the lobster fisheries trade in the Bahamas relies on the dive fisher labour force accounting for an economic contribution of US$75–90 million, which accounts for 40% of the islands' total exports and 60% of total fisheries landings, as highlighted by the World Wild Life (WWF, 2018).

Despite their economic contribution, the development approaches of small-scale commercial fisheries have many shortcomings in integrating decent work policy guidance, as outlined in the 2015 Voluntary Guidelines for Securing Sustainable Small-scale Fisheries. Policy failures undermining diver-specific labour needs are leading to an increase in fatal and non-fatal dive accidents, placing an overall burden on the health sector (Bassett, 2019; Marschke et al., 2020; FAO, 2022). The lack of integration of the International Labour Organization (ILO) decent work and social protection policy framework at the bottom of the fisheries product supply chain concerning the dive fisher labour force has arguably led to hundreds of diver occupational accidents. Luthfi and Isdianto (2019); Marschke et al. (2020) and Bassett (2019) have extensively discussed dive fish occupational accidents, such as decompression accidents leading to total paralysis, permanent neurological disabilities, and fatalities. In their legal study, Sloan and Tuivanualevu (2017) unveiled indigenous dive fish worker fatalities in the case of Fiji's beche-de-mer trade which lacks labour protection, exacerbating the burden on the health sector and coastal communities. A recent intergovernmental study by the FAO (2022) has also demonstrated policy-level gaps and current challenges in tackling unacceptable form of work of dive fisher labour force in nine countries in the wider Caribbean region.

The economic importance of the islands' coastal commercial fisheries trade in national development, which is highly dependent on the underwater workforce, justifies an urgent need for a policy framework based on ILO decent work. Since 2000, the ILO occupational profile for dive fishers has detailed the risks to divers in their work environment and outlined preventive measures and core labour standards where workers aim to produce goods for the market (ILO, 2000). However, the development of the fisheries trade in small island developing states (SIDS), which itself is dependent on the dive fisher labour force, has failed to interlink and cooperate with labour institutions as the islands transition from locally managed fisheries to developing their small-scale fisheries trade products. An example is the Marine Stewardship Certification (MSC) applied to the Bahamian lobster fisheries trade. This certification development process, in partnership with the government, lacks investments in labour force development and occupational health and safety where the WWF (2018) reported that approximately 9,000 dive fishers are involved in fisheries operations. With such demand-led development, island policymakers continue to face the dilemma of international development portfolios that focus only on economic outcomes while ignoring interlinked or cross-sectoral policy objectives such as workforce, safety at sea, and technological development [see islands' decent work policy challenges discussed at intergovernmental levels in ILO (2014a) and Le Manach et al. (2020)].

Given island governments' policy-level labour concerns relating to dive fishers' occupational fatalities in the commercial fisheries trade, how can SIDS governments prepare labour and social protection policies for dive fishers when they persistently face difficulty in accessing diver training needs, such as underwater technology, engineering, and maritime safety-support? In a recent publication, Nisa et al. (2022) discussed the challenges SIDS government policymakers face in getting access to dive industry-specific skills and training strategies and cooperating development partners. Based on the interlinked problems mentioned above, this paper identifies policy gaps that hinder labour and social protection and skills building for dive fishers in Fiji Islands beche-de-mer and the Bahamas lobster fishery development projects. This study adopts the concept of decent work for the fisheries sector as discussed by Garcia Lozano et al. (2022), which considers a wide range of labour concerns in fisheries from income and working hours to social security, occupational health and safety, and collective bargaining.

Building on this definition, this study aligns the concept with the range of labour concerns of dive fishers with the ILO's SDG decent work targets adopted by governments, which are discussed in more detail in Section 2.2. The study uses a methodological approach tailored to the diving industry's safe working environment to bridge human and organisational factors in understanding why unsafe working events and failures keep happening and where the gaps are between practices within fisheries operations and national trade policy. The findings of this study provide a policy framework based on the ILO decent work programme as the main driver for change for governments to improve the working conditions of

small-scale fishers through the SDG 8 targets interlinked with 14.b —explicitly negotiated for small-scale fishers. In doing so, it identifies a strategic pathway and practical macro-policy response for SIDS in creating decent work in the case of dive fishers by outlining the interactions between SDG 14.7 and SDG 14.b at all levels of development cooperation. This study aims at decision-makers and development partners to stimulate further discussions between island governments and ILO decent work programmes on eliminating unacceptable forms of work in diving.

Theoretical framework and methods

This section outlines the theoretical framework, material, and methods that link the main phases of the study: the working practices of dive fishers and the policy directions for integrating dive fisher labour and safety into the blue economy and SDGs.

Theoretical framework

In order to understand how to eliminate unsafe working conditions (sustainable development goal, SDG 8.7), the human and technical factors involved in maritime accidents must be viewed through the lens of the risk management and safety framework established by the competent authorities (ILO, 2019a). Leveson (2011) detailed how to engineer a safer world in industries using system approaches. This study adopts the need for integrating human, technical, and safe engineering factors in fishing operations and occupations to link macro-level decision-making frameworks to reduce the unacceptably high number of injuries and fatalities in commercial fishing (Chen et al., 2013; Holliday and Anrooy, 2021). In the case of diving operations, its safety domains reside in the high-risk maritime, navy, and aviation disciplines, where safety and risk management are studied and advanced to the workforce's needs (Smart, 2017a; Shreeves et al., 2018; Lock, 2019). Given the risks involved in marine and fishing jobs as well as the need for competent authorities in accident analysis in high-risk working conditions, the labour needs of occupational divers must be studied from the domain of the diving and scuba industry safety and risk management (Jeff, 1993; Wilks, 2015; Burman et al., 2019; Lock, 2019).

Diving for work occurs in a complex socio-technical compressed air system (Lock, 2011; Wilks, 2015; Smart, 2017; Lock, 2019), which has been incorporated into the occupational needs of ILO dive fishers (ILO, 2000). Lock (2019) introduced a system-based causality model to study why diving accidents happen in the first place, and this is a recent methodological advancement on the accident causation framework in the field of dive safety and risk management. This study used the systemic accident causation analysis framework outlined by Lock (2019) to the selected case of unsafe working conditions of island divers: linking diver skill and knowledge application with technical and safe scuba engineering factors with health and safety at sea and underwater operations. Emphasis is placed on the interactions between the main system components and the technical, human, organizational, and management factors that need to be considered at the policy level.

Materials and methods

The study adopts the definition of fishery development projects from Basurto et al. (2017: 34-37) and Hamilton et al. (2021: 6), where aid development is interlinked with economic production and trade agreements undertaken by governments. A qualitative case study research design, guided by Yin (2018), is used to understand the inadequacies and gaps between policy and practice in the case of unsafe working conditions of the dive fisher labour force under government-approved commercial fishery trade projects. Garcia Lozano et al. (2022) suggested the need for qualitative case study approaches to examine unsafe working conditions and fatal and non-fatal accidents in developing countries.

Step 1 of this study investigated the reported unsafe working conditions and fatal and non-fatal accidents of the dive fisher labour force in two small-scale commercial fisheries for trade development projects in islands. The development projects are as follows:

1. the beche-de-mer trade of the Fijian government: Project development endorsed under the The Fijian Government (2015), Ministry of Industry, Trade and Tourism and
2. the lobster trade of the Bahamas government: Project development endorsed under the Ministry of Fisheries [see the Affirmation Given to Management of Bahamian Spiny Lobster Fishery in The Government of The Bahamas (2018) and the lobster fisheries improvement project document (MRAG, 2015)].

The fishery development projects as case studies 1 and 2 are purposely selected to understand technical, human, organizational, and management factors underpinning labour force working conditions and policy-level gaps. The study of fatal and non-fatal accidents in these cases adopted Leveson (2011) and Lock (2019) approach that recognises the attributes of human factors in diving and a systemic analysis combining the diagnosis of multi-layered causes of accidents, such as organisational influences, unsafe supervision, and the preconditions for unsafe factors in the constantly reported accidents among divers. Data coding followed the thematic qualitative analysis process used in similar risk and safety management studies in marine operations (Chen et al., 2013).

ILO dive fisher occupational profile content analysis was applied alongside the SDG 8 targets as shown in Box 1. The ILO decent work and the SDG 8 targets (8.7, 8.8, 8.5, 8.3, 8.2, and

Box 1: Classification of SDG 8 targets adopted from the International Labour Organization decent work program and grouped for the dive fisher labour force.

- SDG 8.7 urges the government to take immediate and effective means to abolish, control, and limit unsafe working conditions, such as in fishing sectors.
- SDG 8.8 urges decision-makers to protect labour rights and promote safe and secure working environments for all workers, including those in precarious employment.
- Indicator 8.8.1: monitors workplace safety that measures the frequency rates of fatal and non-fatal occupational injuries.
- SDG 8.5 is a target for governments to achieve productive employment and decent work for all by 2030.
- Indicator 8.5.1: focusing on themes concerning the future of work and earnings by occupation.
- SDG 8.3 urges decision-makers to promote development-oriented policies that support decent work creation and growth of micro-, small-, and medium-sized enterprises, including access to financial services.
- SDG 8.2 urges decision-makers to achieve higher productivity through diversification, technological upgrading, and innovation, focusing on high-value-added and labour-intensive sectors.
- SDG 8. a: It urges wealthier nations to increase aid for trade-related technical assistance for a just transition for developing countries which can be considered a way to address economic means of implementation and systemic means.

8.a), as shown in Box 1, were grouped based on their policy level impact on the dive fisher labour force.

Step 2 involved linking step 1 data (obtained through thematic qualitative analysis) with the factors at the macro-policy level (the targets of SDG 8 in Box 1), guided by a similar study conducted by Zhang et al. (2016), interlinking technological, policy, and managerial development interventions. Integrative content analysis was applied to connect the textual coding and findings from the cases studied with the ILO SDG 8 policy instruments. The analysis of policy instrument documents *via* content analysis was guided by the methodology adopted by Neuendorf (2017) to gain qualitative data sets to link with the SDG 8 targets. Within the policy domain, this study searched ILO resolutions and recommendations on decent work from the last 12 years (2003–2015) for the terms "inshore fishing", "divers", "occupational classification", "divers' safety and health", "dive fisher", "labour standards", "islands", "fishing occupation", "decent work", and "fisheries workers". From this search, this study narrowed the search to examine five ILO policy instruments as listed in Table 1. The contextual-level policy framing of this study was guided *via* SDG interlinkage analysis as applied by Weitz et al. (2015) and integrated policy-making from a similar work of Elder et al. (2016: 12-16) and Tosun et al. (2019), linking SDGs across sectors by Stafford-Smith et al. (2017). The study adopts the definition of SDG interlinkages as follows: actions taken to achieve progress on one goal may reinforce each other or potentially hinder the achievement of other goals; hence, any time progress on one goal or target leads to positive or negative externalities on another. The relationship between them is called an interlinkage (IAEG-SDGs, 2019).

Results

Fishery development—Fiji

Barclay et al. (2019) pointed out that trade in beche-de-mer (BDM) from the Pacific Islands was worth US$25.5 million in 2016. The question, however, is whether this income contributes positively to the government's ability to build up a labour force or whether this trade exploits labour. The dive fishers labour force is at the bottom of the supply chain for BDM trade and has existed for over a century, along with other high-value coral reef-linked trades (Teh et al., 2009). As on land, the customary reef fishing areas in the Fiji Islands context are managed and owned by indigenous Fijians in their respective traditional fishing areas (*qoliqoli*) and leadership groupings (*yavusa* and *vanua*) (Veitayaki, 1998). Under these governance and social leadership systems (*qoliqoli* ownership), indigenous dive fishers have customary fishing rights and have critical powers in the commercial use of local marine resources (Veitayaki, 1998; Kitolelei and Sato, 2016; Rohe et al., 2017). Dive fishers are still customary rights holders and have unique and exclusive access rights to their traditional fishing grounds (Rohe et al., 2017; Ferguson et al., 2022). They are also recognised in national and regional coastal fishery policy (Gourlie et al., 2018). Fijian BDM development for the local market and international trade is a commercial activity whereby indigenous divers play a national economic role; therefore, their workforce should not be classed as subsistence diving activity (Pakoa et al., 2013). Purcell et al. (2017) and Barclay et al. (2019) outlined the BDM value chain organisation structure in which the safety at sea and social protection schemes of diving and boating operations of the labour force remain under-discussed, keeping the workforce development costs hidden.

Economic feasibility studies on the prospectus of global commercial trade demand for coral reef-linked trade products, including BDM (Lal, 2004; Lal and Cerelala, 2005), have highlighted where the product will be harvested *via* divers who face social–technological challenges. During the preliminary period of the trade, shifts from freediving to compressed air diving without training impacted the labour force and contributed to diving-related disability accidents and fatalities of Fijian dive fishers (Lal, 2004; Lal and Cerelala, 2005). National-level decision-makers within trade agreements initially assumed that dive fishers working on BDM harvests

TABLE 1 List of policy-level instruments and thematic data set studied.

Year	Name of policy tools and instruments applied to cases 1 and 2	International Labour Organization (ILO) policy thematic provisions for sustainable development goal (SDG) interlinkages.
2012	ILO—International Classification of Occupation—diver–indigenous fisherman (ILO, 2000)	Supports occupational hazards that divers and indigenous fishers are exposed to when working underwater Defines who is an indigenous diver. A worker whose main job is to hunt or gather marine products underwater Outlines what is dangerous about diving for work in terms of marine accidents and physical, chemical, and biological hazards Outlines several preventive measures with reference to added specialized information on diving-related health and safety research to be followed
2014	FAO: The Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the context of food security and poverty eradication (FAO, 2015)	Section 6 of SSF, Articles 6.1 to 6.14, agreed on provisions on social development, employment, and decent work and called for states and intergovernmental cooperation between the ILO, FAO, and IMO to address human rights, unfair working conditions, and advance fisheries labour and safety at sea
2015	Integrated nature of the SDGs (Le Blanc, 2015; Liu et al., 2015)	Agenda 2030 supplies an integrated policy framework for rural economy and indigenous communities
2016	ILO—resolution concerning decent work in the global supply chain	ILO resolution: decent work in the global supply chain, including seafood and fisheries. Ensuring that economic development and decent work go hand in hand
2017	C188 Work in Fishing Convention 2007 (ILO, 2007) in force	Islands positioning labour standards in their coastal and artisanal fisheries *via* island led C188 interpretation: recalling the making of the convention *via* Conditions of work in the fishing sector. A comprehensive standard (a convention supplemented by a recommendation) on work in the fishing sector (ILO, 2004b). From informal to co-adventures to formal workers? ILOs work in fishing convention, 2007 (Mathew, 2010)

would need less technical support with large, open marine work areas of the reef flat (Lal, 2004). However, since Fiji became a hotspot for BDM exports, with stocks declining in other parts of Southeast Asia (Teh et al., 2009), the diving workload has increased. O'Regan (2015) outlined the divers' working hours and workload underwater and highlighted misassumptions at management and policy levels on sea cucumber harvest concerning the underwater workforce.

In 2013, 108 life-threatening diving accidents were reported concerning the dive fisher labour force, while the number of fatalities that later occurred from the accidents remain unrecorded and under-discussed (Pakoa et al., 2013). At the same time, workloads increased as dive fishers in geographically remote areas looked to cover quota-based trade systems through cash payments, leading to competition. The market prices for BDM across species (averaging US$15–385 kg) appear to have primarily increased six- to 12-fold over the past decade (Purcell, 2014) for average export prices of large-sized BDM from Fiji. As export quotas increased, the recruitment of unskilled divers to work in the reef-linked fishery trade increased, and equipping of the labour force with diving gears and scuba operations got transferred to third parties, mainly Asian export companies (Pakoa et al., 2013). In 2015, the direct costs of diving accidents and fatalities in the case of the indigenous Fijian dive fishers labour force for BDM trade were quantified alongside the economic returns from BDM [see Purcell et al. (2017)] and other reef-linked fisheries such as Fijian grouper fish harvested by dive fishers (Sadovy de Mitcheson et al., 2018).

Mangubhai et al. (2017) used cost–benefit analysis in the case of dive fishers' compressed air-related accidents alongside the supply chain of BDM, as outlined by Purcell et al. (2017), to inform policy-level decision-makers on the diver accident management cost. The annual cost of treating the decompression accidents of 50 divers averaged to about FJ$515,000 per year, whereas the cost to the Fijian village was estimated to be much higher at FJ$5.8 million for the same period (Mangubhai et al., 2017). Sloan and Tuivanualevu (2017) outlined the legal challenges of the dive fishers' labour force involving the fatalities of 12 dive fishers within a year in Fiji who were working to meet the increased sea cucumber harvest demands. This legal analysis unveiled preconditions for unsafe policy decisions, such as the lack of investments in safety at sea boating and diving technology capabilities that underpin the diver workforce's health and safety. The preconditions include the diver labour force renting diving equipment from third-party suppliers who often do not meet safety accreditation in overall diving operation systems (Sloan and Tuivanualevu, 2017).

Based on the proliferation in value chain studies and economic projections of BDM [see the work of Purcell (2014) and Purcell et al. (2017)], BDM exporters now face competition requiring a highly skilled commercial diver labour force. However, government foundation and functional safety at sea provisions continue to lack operational ability in many islands' government development plans. The government of Fiji highlighted in the 2018 FAO Global Review of Safety at Sea (Remolà and Gudmundsson, 2018) that 95% of marine casualties involve the small-scale commercial fisher labour force. Fiji's fisheries sector lack adequate investments in safety at sea capabilities within fisheries and marine environmental sustainability projects (Remolà and Gudmundsson, 2018). The lack of basic safety at sea capabilities at the government level highlights

how, for dive fishers, the core systems to support human safety at sea are missing or under-regarded in development cooperation (Sloan and Tuivanualevu, 2017; Remolà and Gudmundsson, 2018).

Fishery development—Bahamas

Bahamas is the largest producer and exporter of lobster among Caribbean SIDS (FAO, 2017). In the Bahamas, diver-harvested lobster is worth US$75–90 million and accounts for 40% of the islands' total exports and 60% of total fishery landings (WWF, 2018; Thomas Travaille et al., 2019). The Bahamian lobster trade is governed under the regional cooperation mechanism, namely: (1) Regulation for the Regional Management of the Caribbean Lobster Fishery and (2) St. George's Declaration, adopted by fishery ministers in 2015 under the Caribbean Regional Fisheries Mechanism (St. George's Declaration, 2015; WECAFC, 2018). As a regional policy instrument, under the 2015 St. George's Declaration, island leaders called for the correct procedural use of scuba diving and compressed air systems for lobster harvest alongside the preamble supporting the well-being of the fishers employed or involved. While island governments established a mechanism to address dive fishers' labour dimensions concerning compressed air systems, has this need been adequately supported for improvement at the macro-policy level with their trading and supply chain partners?

On the back of the regional fisheries governance in 2019, the Bahamas government became the first island country within the SIDS grouping to be certified by the Marine Stewardship Council (MSC) for lobster trade. The certification status and timelines of the Bahamian lobster fishery and the country profile are available on the MSC website (see https://fisheries.msc.org/en/fisheries/the-bahamas-spiny-lobster-fishery/). The 10-year assessment process leading to the MSC certification is discussed by Thomas Travaille et al. (2019), with a focus on the environmental sustainability of the lobster. With the certification, the exported Bahamian lobster are now eligible to carry the MSC blue fish label, giving product promotion by being sourced through higher environmental standards (WWF, 2018). Le Manach et al. (2020) outlined how policymakers increasingly recognise MSC without fully understanding its weaknesses. From the perspective of the safety of the ILO workforce, both the government and the MSC partners opted for divers, relying on diving with scuba and other pressurised air systems and disregarding the cross-sectoral policy objectives for workforce development, safety at sea, and during diving operations [see the government report on the lobster fishery improvement project MRAG (2015) and the report of MSC (Gascoigne et al., 2018) on the unit of certification, where the dive fisher labour force and use of compressed air diving for fisheries trade and products is registered].

The Bahamas diver-operated lobster fishery employs some 9,000 divers (WWF, 2018), where the divers' labour dimension and technical elements are primarily disregarded for upgrading and investments. Dive fishers' health and safety-related studies have been conducted in the region, particularly concerning the dive fisher labour force who are at risk under compressed air diving associated with the lobster trade, parallel to Bahamas MSC development-driven fisheries—for example, fatal diving accidents in lobster fisheries, as reviewed by González (2018) and Orr and Douglas (2007) at the Divers Alert Network (DAN), highlighted the urgent need for dive professionals to unpack dive safety surveillance in maritime and public policy [see the diver alert network on harvesting divers at risk along the expanded global supply chains and fishery products that exacerbate diving accidents (https://dan.org/alert-diver/article/harvesting-divers-at-risk/)].

The Bahamian dive fisher labour force also faces added tasks during lobster harvest in combating venom lionfish, an invasive species placing an ecological and economic threat to the region (Green et al., 2012; Marschke et al., 2020). More than 1,000 kg of lionfish are caught as bycatch in the lobster harvest each year, and fishers must handle them carefully to avoid any disability accidents (Harris et al., 2020). Dive fishers primarily remove invasive lionfish *via* scuba and compressed air systems (Pitt and Trott, 2015; Harris et al., 2020). Diving for lobster for trade and, at the same time, tackling lionfish show how species-by-species development-driven fisheries weaken the overall holistic view of the workforce's health and safety needs. The technical diving work needed by Bahamian fishers (lobster and lionfish hunting) places high demands on a diver—in this case, dive fishers' occupational needs and technical knowledge base as listed in ILO (2000), which is undermined by private investments.

The Bahamas has been out of the World Trade Organization (Knowles et al., 2019). The government's MSC certification of the Bahamian lobster trade is a pathway to facilitate access to foreign markets, which is hindered by border tariffs to the United States and the European Union (Government of the Bahamas, 2018). In the months since the Bahamas government announced its market access advancements in lobster trade development, diving for lobster has intensified. It is important to note that the lobster trade has been described as a red–gold rush in the region since 2012 (Monnereau, 2012; Kaplan-Hallam et al., 2017). In the case of a lack of scuba diving operational investment, small-scale dive fishers working under informal labour conditions to meet the lobster trade are placed in working conditions with multiple safety at sea deficiencies. The Royal Bahamas Defence force has drawn policy attention to the fact that the small fishing vessels on which divers work are not designed or engineered for safe diving operations, making divers vulnerable to dive accidents like gas poisoning (Tribune, 2021). The Bahamian media and public have expressed concerns about fatal and non-fatal diving accidents in the lobster trade (Divernet, 2021; Tribune, 2021). The Bahamian government partnership with MSC lacks evidence in investments that help governments prioritise ILO diver occupational, scuba diving engineering, and fishers occupational health and safety needs.

Such organisational influences disregard the allocation and building of islands nations' fisher labour force equipment and facilities. For policy-level intervention, McConney et al. (2017) extensively discussed co-management and fishery trade challenges compounded by an inadequate enabling environment for island countries. A recent study by the FAO (2022) outlined unresolved macro-policy gaps on dive fishers' health and safety in the wider Caribbean involving the ILO, regional fishery bodies, and member states.

Call for competent marine and diving industry authorities and professionals

Smith and Basurto (2019) highlighted how value chain studies can become misleading representations for policymakers in developing states as opposed to the fully capitalist industrial fisheries in developed nations. Decker Sparks et al., (2022) outlined evidence of how voluntary and non-governmental organisations that had promised to improve ILO decent working conditions largely failed by widening the inequality gap between the producing and buying county. Only quantifying the monetary values of island diver-harvested fishery products, such as studies by Purcell et al. (2017) on BDM and Spalding et al. (2017) on reef-linked fisheries, has presented island government investors in the fisheries sector with reasons to over-prioritise single economic outcomes. Under fishery trade and product-driven demand projects, such as World Bank projects concerning Fish to 2020 as discussed by Delgado et al. (2003) and Fish to 2030 initiatives (World Bank, 2013), fishery trade deals lack evidence under island development cooperation intersectoral partnerships with competent marine and diving authorities. The analysis of dive fisher labour force practices in Sections 3.1 and 3.2 demonstrates the demand for a competent dive accident causation methodological framework and the need for authorities to guide the labour force needs at policy level, as argued by Lock (2019). Holliday and Anrooy (2021) extended the need for competent authorities within the UN systems to guide macro-policy-level needs in managing fishery accidents.

Bavinck et al. (2012) and Monnereau (2012) discussed job satisfaction, physical safety, and mental pressure on divers. Bavinck et al. (2012); Huchim-lara et al. (2015), and Monnereau (2012) have long highlighted marginalisation. In the case of the Jamaican dive fisher labour force, inequalities and worse forms of labour conditions have been discussed by Marschke et al. (2020), and governance and management have been discussed by Finkbeiner et al. (2017). While academic research has discussed the ILO occupational guidelines for divers in the fishery sector, discussions on the relevant authorities, such as the Navy and Coast Guard, and diving industry professionals for hyperbaric medicine and diving safety officers are missing. Decker Sparks et al. (2022) further unveiled how development inventions keep fishing labour as a job within the informal category, where labour violations in the seafood business remain an under-discussed policy subject. Barclay et al. (2019) and Marschke and Vandergeest (2016) highlighted how development in fishery projects aimed to meet globalised trade has failed to address the inequalities in technology access and infrastructure. Mohammed et al. (2018) and Natuva (2021) argued that a lack of intersectoral cooperation has meant that, to date, marine strategy and communication and technological advancement have undermined the primary layer of health and safety as well as social protection and marine accident prevention. In the marine accident case highlighted in Section 3, it is evident that island governments' single economic bottom-line-focused decisions in the fishery sector continue to disregard intersectoral cooperation with competent marine authorities to protect the marine and diving workforce.

Such policy-level decision-making trends in islands highlight the unsafe working conditions of dive fishers set by the flawed governance systems and organisational influences. Barclay et al. (2019) unveiled concerns of the BDM supply chain in low-income contexts, raising multiple concerns of the overall governing systems, a problem requiring the application of integrated solutions. Both development cases show that island governments' new tasks at the macro-policy level require positioning the SDGs for commercial small-scale fishery development. One is to align the SDG 8.7 target that calls for competent authorities to take immediate and effective means to abolish, control, and limit unsafe working conditions unpinning any kind of labour force (IAEG-SDGs, 2019) across the value chain.

This study also notes several violations of dive safety standards highlighted by competent diving authorities occurring in the profitable seafood supply chain, placing a heavy burden on dive medical, health, and social sector professionals. Studies of accidents and fatalities by Shreeves et al. (2018) and Buzzacott et al. (2017) reported dive safety violations by other industries and sectors, where the chain of poor decisions of one sector negatively affects other sectors and industries. Orr and Douglas (2007) examined diver labour standards, certifications, accident reporting on fatalities, and violations of safe diving. Organisational decisions on single economic bottom-line development trigger unsafe acts and conditions that are precursors to the dive accidents and incidents studied in Sections 3.1 and 3.2. A just diving safety culture and the application of human and organisational factors to diving fatalities and accidents is a high priority for the diving community at all levels, involving various organisational and industrial development levels (Lock, 2011; Lock, 2019). Morgera and Nakamura (2021) shed light on the fishers' undermining of social justice and human rights within the UN Declaration on the Rights of Peasants and other people working in rural areas. The development projects analysed in Section 3 highlight the need for policymakers to urgently create an enabling environment that is inclusive of competent marine, labour, and diving safety and security

authorities at the macro level in preparing their dive fisher labour force within the blue economy.

Discussion: Understanding the policy systems: Macro-level policy barriers to SIDS development

Tackling inequalities of the ocean workforce has moved to the forefront of global policy debates. Consensus has been reached between developed and developing states that everyone should have equal access to opportunities and no one should be left behind (Chasek et al., 2016), which is a fundamental guiding principle of the 2030 Agenda for Sustainable Development (UN, 2015). ILO (2014a) and ILO (2014b) consultations with island governments discussed policy responses for decent work and social justice in Pacific and Caribbean SIDS (see consultations reports ILO, 2014a and ILO, 2014b). Island governments and ILO intergovernmental processes built the momentum for island nations to establish sustainable, inclusive, and equitable economic development with decent work as their highest policy priority in the SIDS Accelerated Modalities for Action, referred to as the SAMOA pathway (UNGA, 2014). Through the SAMOA pathway, SIDS has brought an integrated approach to policy-making to the forefront of policy debates in the UN, where they remain a case for sustainable development (see https://sustainabledevelopment.un.org/sids/samoareview).

However, at the macro-policy level, SIDS continue to face multiple political barriers within the global ocean governance regimes where politics direct decisions on the global fisheries trade as discussed by Avelino et al. (2016), Patterson et al. (2017), and Blythe et al. (2021). Nisa et al. (2022) discussed this in the case of SIDS leadership at the 2017 Oceans Conference, which advocated for SDG 8 and SDG 14 interlinkages within the blue economy. However, ILO decent work governance remains isolated from many decisions within the UN ocean governance structures and institutions (Rudolph et al., 2020). Political discussions have failed to bridge the divide for the integration of ILO decent work with the targets of SDG 8 within blue economic investments and SDG 14 (UNDESA, 2017). The international ocean governance regime across the UN's plethora of organisations is challenged by too little consensus and cooperation between international agreements (Heinrich Böll Foundation Schleswig-Holstein et al., 2017). Hence, the road maps through which ministers of labour, maritime safety security, and fisheries will bridge the decent work agenda under their blue economy remain politically under-discussed and invested in UNDESA (2017). Moreover, a severe institutional structural problem at the macro-policy level hinders SIDS in meeting their first policy priority—decent work creation and socially inclusive blue economy development (Caribbean Development Development, 2018).

SIDS policy priorities *via* blue economy and SDGs

SIDS have endorsed the ILO's decent work goals (SDG 8) as the highest policy priority in the SAMOA pathway at the macro level, and, in practice, the implementation of SDG 8 targets (8.7, 8.8, 8.5, 8.3, and 8.2) has to be a shared goal between island governments and their development partners (ILO, 2019b). Against this backdrop, the first necessary step is to establish a policy framework that positions the SDGs that address the needs of SIDS' underwater workforce development in preparation for their blue economy. The original concept of the blue economy came from the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. UNCTAD (2014) extended this discussion in relation to a multilateral fishery policy for SIDS. The relationship between the SIDS' blue economy and the SDGs is further discussed by Nisa et al. (2022) and Natuva (2021) concerning maritime security and marine safety at sea.

As part of SDG 14, target 14.7 is a political agreement that calls on the intergovernmental process to increase pathways in the sustainable use of marine resources to obtain increased economic benefits in the case of the SIDS (United Nations, 2015). While Le Blanc (2015) provided a political mapping of SDG 14.7 linked with SDG 8, a conceptual policy framework at the macro level has been lacking in the SDG framework for integrated policy-making in the case of islands' small-scale fisheries labour force. Nisa et al. (2022) made timely contributions *via* a macro-level policy framework based on the ILO decent work domain (SDG 8) as the primary driver of islands to bring practical changes to their underwater workforce for SDG 14, including for dive fishers. In Figure 1, the arrows show the relationships, *i.e.*, the interlinkages and interdependencies, where actions to achieve one SDG target is interdependent on another and, if not linked, can hinder the achievement of the other targets and the overall goal. If the high-level SDGs for SIDS are to be successful, more attention needs to be paid to linking SDG 8 targets with SDG 14.7 and SDG 14.b in the case of small-scale commercial dive fishers—for example, the targets of SDG 8, such as 8.8, urges island decision-makers to promote safe and secure working environments, including those in precarious employment, by placing reporting requirements for occupational fatal and non-fatal accidents (indicator 8.8.1). SDG 8.5 is a target for governments to achieve productive employment and decent work for all by 2030. Figure 1 provides a starting point for macro-level policy discussion where island governments have the most influence and opportunity to shape an integrated plan for the sustainable development of their underwater workforce and promote policy coherence through investment in the blue economy.

In Figure 1, SIDS macro positions are derived from a content analysis of the SIDS Accelerated Modalities of Action (SAMOA) Pathway, Resolution Adopted by the General Assembly on/14 November 2014 (A/RES/69/15, 2014), in correlation with SDG 14 targets, as outlined in Table 2.

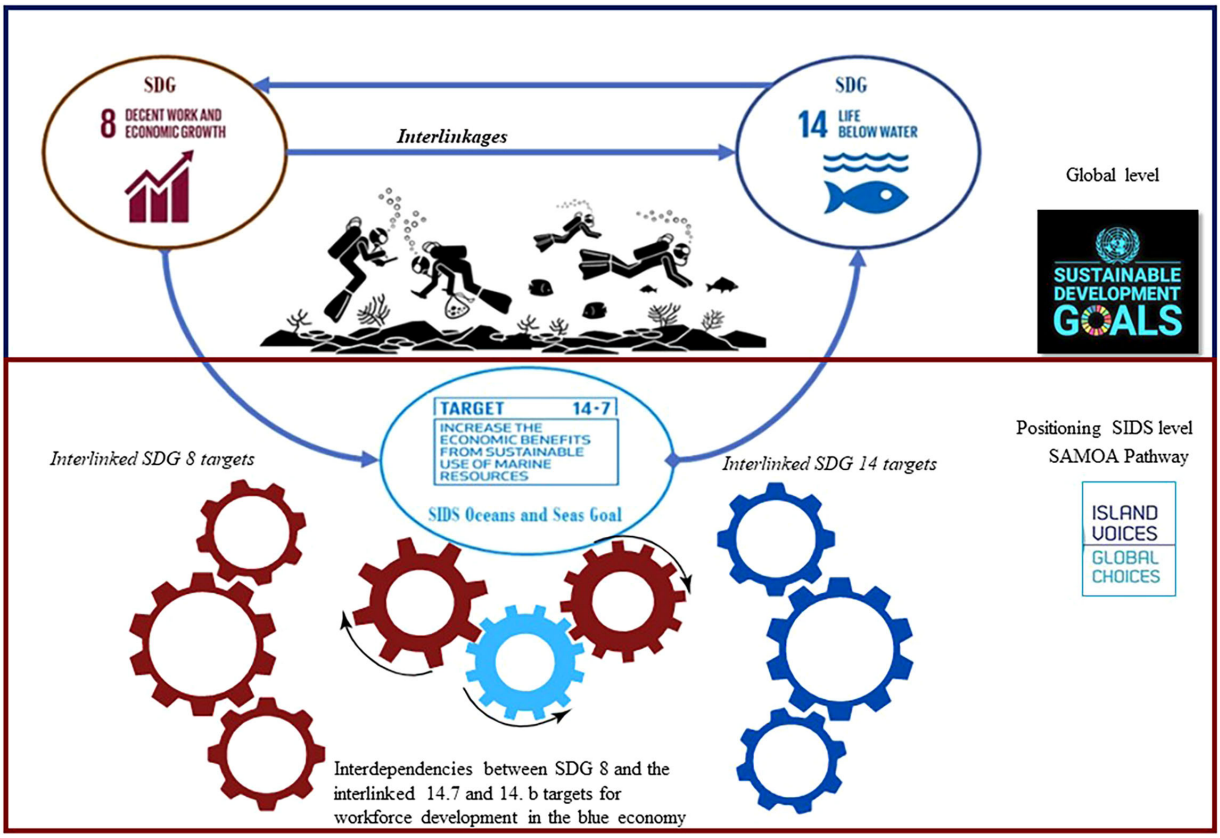

FIGURE 1
Three-tier level sustainable development goal interlinkages for decision-makers at the global, small island developing states (SIDS), and island government levels for dive fisher workforce development in the blue economy. The SIDS level *via* the SIDS Accelerated Modalities of Action pathway demonstrates their policy priority and interdependencies between ILO SDG 8 targets, 14.7 and 14.b. Expanded from Nisa et al. (2022) *via* systems thinking and systems integration advocated by Liu et al. (2015).

Positioning ILO policy instruments with blue economy and SDG interlinkages

With increasing human rights violations, as well as safety standards and labour exploitation at all levels, island policymakers need to prioritise SDG targets for small-scale commercial fishers that allow governments to minimise such negative impacts. In a recent study, Sparks et al. (2022) offered an in-depth analysis of ILO labour standards, market-based certifications, and relevant instruments for a labour-oriented human rights strategy for fishery supply chains. As dive fishers are workers under development in fisheries for trade, their workforce development needs and labour provisions across the value chain need to be mapped under SDGs. The state is responsible for executing such principal standards to ensure fishers' rights as per the law are not clouded (Syed et al., 2021). This section discusses the new labour guidelines for fishing: ILO Work in Fishing Convention (number C188) integrated with ILO diver occupational profile. To ensure that the landmark convention (C188) is positioned as a helpful policy guiding tool to a wide range of decision-makers across the fishery trade value chain, this study creates awareness of C188 by holistically examining a range of policy tools and instruments, as listed in Table 1, over the timeline of the initiation of different tools. Nisa et al. (2022) and Natuva (2021) argued that the island-led blue economy and interlinked SDG targets should be explored holistically for new policy purposes—for example, SDG 8.5 is a target for governments to achieve productive employment and decent work for all by 2030, and Natuva (2021) extended this discussion with public sector reforms.

It is critical to note that, after years of complex negotiations and multiple pushbacks and disagreements within global labour and ocean governance networks (ILO, 2004; Mathew, 2010), the new labour instrument C188 was agreed upon by member states in June 2007. In 2017, the new labour standard for fishing progressively entered into force after its 10th ratification[1] (ILO,

1 https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_535063/lang–en/index.htm

TABLE 2 Macro-level policy analysis of SIDS oceans and seas goal and correlating SDG 14 negotiate text highlighting SDG 14.7 and 14.b policy positionality holistically across island governmental tasks.

SAMOA Pathway Text: SIDS Positions			
Para 58 a- p Para 58. SIDS Accelerated Modalities of Action (SAMOA) Pathway, Resolution Adopted by the General Assembly on/ 14 November 2014 (A/RES/69/15, 2014)		**Corresponding SDG 14 targets**	
a	Sustainably use the oceans, seas and their resources by supporting research and the implementation of strategies on coastal zone management and ecosystem-based management.	**14.7**	Sustainable use of marine resources, including through sustainable management of fisheries, aquaculture, and tourism.
b	Engage in national and regional efforts to sustainably develop the ocean resources of small island developing states and generate increasing *returns for their peoples*.	**14.7**	Increase the economic benefits to small island developing states and least developed countries from the sustainable use of marine resources.
c	Protection of regional seas	14.2	Sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience and acting for their restoration to achieve healthy and productive oceans
d	Mitigate marine pollution	14.1	Prevent and significantly reduce marine pollution of all kinds, from land-based activities, including marine debris and nutrient pollution
e	To undertake urgent action to protect coral reefs and other vulnerable marine ecosystems through the development and implementation of comprehensive and integrated approaches for managing and enhancing their resilience to withstand pressures.	14.2	Sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience and acting for their restoration to achieve healthy and productive oceans.
f	Marine scientific research	14.a	Increase scientific knowledge, develop research capacity and transfer marine technology.
g	To enhance and implement the monitoring, control and surveillance of fishing vessels to effectively prevent, deter and eliminate illegal, unreported and unregulated fishing, including through institutional capacity-building at the appropriate levels.	14.a	Transfer marine technology to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries,
h	**To support the sustainable development of small-scale fisheries, improved mechanisms for resource assessment and management *and enhanced facilities for fisheries workers*, as well as initiatives that add value to outputs from small-scale fisheries and to enhance access.**	**14.b**	**Provide access for small-scale artisanal fishers to marine resources and markets**
i	Reform fishery subsidies	14.6	Prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, and eliminate subsidies that contribute to illegal, unreported and unregulated fishing
j	Protection of the Underwater Cultural Heritage		No correlating targets
k	Promote the conservation, sustainable use and management of straddling and highly migratory fish stocks, including through measures that benefit small island developing states	14.4	Effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans,
l	Enhance the capacity to use their fisheries resources and develop fisheries-related industries, enabling them to maximise benefits from their fisheries resources and ensure that the burden of conservation and management of ocean resources is not disproportionately transferred to small island developing states;	14.7	By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism
m	Cooperation of the international community in implementing shared responsibilities under regional fisheries management organisations		No correlating targets
n	Mitigate ocean acidification	14.3	Minimise and address the impacts of ocean acidification
o	To protect 10 per cent of coastal and marine areas	14.5	By 2020, conserve at least 10 per cent of coastal and marine areas
P	To prevent toxic waste disposal	14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, from land-based activities, including marine debris and nutrient pollution

2016). Sparks et al. (2022) and Lozano et al. (2022b) provided substantive elements and indicators of decent work (SDG 8) developed by the ILO under C188.

C188 presents an agreement for the first time that includes all commercial fishing operations and their access to principal labour standards and decent working conditions in the globalised economy (Mathew, 2010; ILO, 2017). Additionally C188 puts forth labour dimensions, such as occupational health and safety, accident prevention, and social protection, within the scope of all commercial fishing operations (Fadzil, 2013). ILO country profiles on occupational health and safety provide the policy foundation for ILO divers' and indigenous fishers' occupational needs within the economic role of the divers (ILO, 2000). An earlier work of Dunford et al. (2002) and Gold et al. (2000) on diving-specific

labour dimensions and the social protection of divers of Thailand and Australia served as the basis for the ILO Committee's decisions on the primary occupation standards for dive fishers. Nisa et al. (2022) positioned health and safety for diving occupations within SDGs at the global level, and this study extends ILO labour instruments that position dive fishers' occupations in national development. In Figure 1, the ILO diver occupation profile is extended to the policy level to advance the SDG impacts and, in Table 3, articles 31–33 of C-188, sets the drivers and policy levers for a series of labour provisions and actions in the context of island fishery development projects, interdependent on the dive fishers' labour force.

C188, alongside Figure 1, also allows policy dialogues to discuss the bottlenecks and chart steps to eliminate, control, and eradicate worse forms of labour and unsafe working conditions (SDG 8.7) in the case of island divers. Cases that are reporting systemic occurrences of occupational fatalities and disability accidents of dive fishers due to the weakening of ILO labour dimensions and macro-level policy failure need urgent policy innovation at all levels (Marschke and Vandergeest, 2016; Nisa et al., 2022).

Macro policy safeguards for dive fishers in the global supply chain *via* SDG interlinkages and applications

Sparks et al. (2022) outlined the relevant ILO policy tools targeted at seafood supply chain actors to take responsibility for implementing principles of C188, mapping SDG impacts across the supply chain and geographies as essential. This study takes the principal provisions of the convention (C188) and links it with the ILO resolution concerning decent work (SDG 8) in the global supply chain (ILO, 2016), which includes the fish trade. Unless policymakers specifically address the inequalities that have deepened in island dive fishery development, there is a real danger that the piecework approach to diver health and safety will not end the worst forms of labour (SDG 8.7). Nisa et al. (2022) argued that opportunities in realising the interdependencies between SDGs, as in Figure 1, require relevant labour and trade partners and institutions to agree on abolishing unsafe and non-decent work impacting SDG 14. Therefore, island governments must ensure that their trading and industry partners at all levels are mandated to control and eradicate the worst forms of labour and unsafe working conditions (SDG 8.7). The principal provisions of the convention (C188) are likely to have a more significant impact on SIDS fishers when viewed comprehensively with the blue economy and SDG interlinkages that connect safeguards in the supply chain. Cammarano et al. (2022) and Montiel et al. (2021) contextualised the SDGs in supply chains and transnational trade. A policy framework based on decent work must be the main driver for the global supply chain (ILO, 2016), and Figure 1 provides a starting point for decision-makers in the case of island dive fisher labour force building under the blue economy. *Via* Figure 1, SDG 8.8 provides provisions for governments to seek investments in promoting a safe and secure working environment interlinked with small-scale fishery development, global supply chains, and economic productivity (SDG 14. b).

SIDS SDG positions in decent work creation for island dive fishers

UN top-down approaches make policy shifts difficult for SIDS-limited institutional capacity (Zitoun et al., 2020). Due to the continued lack of cooperation and consensus on many international agreements, the sector silo situation continues between fisheries and labour (Morrison et al., 2020; Gibbs et al., 2021). Moreover, this is apparent in the FAO setting SDG indicators for target SDG 14.7 in measuring its success. Indicator 14.7.1 is set around three inputs: GDP, value added in fisheries, and the biological sustainability of fish stocks (FAO, 2020). Additionally, under the business-as-usual approach to the implementation of SDG target 14.b, promoted under the guidance of Pacific island countries by the FAO (FAO, 2021), there is a disregard for the call for SDG integration, such as SDG 8 on labour and social protection for small-scale fishers. The FAO positions in addressing SDG 14.7 and 14.b are described as what Elder and Olsen (2019) and Fukuda-Parr and McNeill (2019) outlined as the politics in setting and measuring SDGs and being the custodian agency for SDG 14.7.

Behind this politics, island policymakers must be mindful of the role of the SAMOA pathway in bringing the need of policy integration to the forefront (UNDESA, 2019) and in localising the SDGs as per national needs, as shown in this paper in Section 4.1. The SAMOA pathway calls for an integrated approach in strengthening the fisher labour force to go hand in hand with a policy priority of an inclusive, fair, and more comprehensive economic need with decent work for all (UN-DESA, 2018; Zitoun et al., 2020). SDG 14.7, pointed out by Blanc et al. (2017), is a new politically negotiated text for SIDS in Agenda 2030. Therefore, the SIDS's political positionality in their fishery sector reforms will be critical to ensuring that the UN agencies adhere to the integrated nature of the SDGs in the islands' blue economy policy designs. Figure 1 provides that prompt position between global and SIDS levels and priority SDGs in the case of dive fishers in order for island policymakers to start preparing their future blue economy development-oriented policies driven by decent jobs and safety at sea (SDG 8.3).

Conclusion

Fishery development case studies illustrate that decades after the development of ILO occupation of dive fishers' guidance for policy purposes, the basic decent work provisions for building

TABLE 3 International Labour Organization policy instruments in the case of small-scale dive fisher labour, occupational health and safety, and social protection.

Type of decent work and labour policy instruments	Application of provisions from articles 31–33 with ILO diver occupation profile
C 188—policy tool and its application alongside other international agreements **SDG 8 targets** **SDG 8.8 urges decision-makers to protect labour rights and promote safe and secure working environments for all workers, including those in precarious employment:** **Indicators that monitor workplace safety involve measuring the frequency rates of fatal and non-fatal occupational injuries[2] (indicator 8.8.1)**	• Fishing vessels and operations must be adequately and efficiently equipped to meet safety at sea • Sets minimum requirements for occupational safety and health • Emphasizes the need for medical care on fishing vessels • Ensures that fishers receive help from social security provisions • Sets a minimum age for working on fishing vessels • All fishers must undergo regular medical examinations to confirm their health condition to work in fishing operations

the workforce have continued to be weakened at the macro policy level. Tackling unacceptable forms of work in fisheries including indigenous labour force is urgent for island governments in fisheries trade. There is a need to raise the ILO's occupational profile for divers ILO (2000) and inter agency cooperation with competent marine authorities for dive accident prevention and in tackling unacceptable forms of work. SIDS, or large ocean states as the pioneering blue economy nations prefer to call them Hawke (2017), are at a critical juncture for an institutional framework that breaks policy silos in the fisheries sector (Caribbean Development Development, 2018). Figure 1 shows the pathways for island policymakers to overcome the policy fragmentation caused by a lack of consensus at the global and regional levels for small-scale fishery workforce development in transnational fisheries product supply. Whole-of-government approaches are needed to get the ILO decent work programme adopted as a driver for sustainable development and blue economy (UNDESA, 2017; UNOC, 2017). By linking the blue economy and SDGs, policymakers can develop more coherence between ministries of labour, fisheries, maritime security, and other relevant marine agencies of their blue economy, as Nisa et al. (2022) argued. Lee et al. (2020) have outlined other SDG linkages with the blue economy.

Under the 2030 Agenda, the ILO also has mandated enforcement and competent authorities to urgently eliminate, monitor, and eradicate poorer forms of work and unsafe working conditions (SDG 8.7). This study creates awareness on the workforce labour instrument—the Work in Fishing Convention, 2007 (no. 188)—that needs to be promoted at the island government level to protect workers from non-decent work. The findings of this study demonstrate possible synergies *via* ILO standards for dive fisher occupations and the convention (C188) in significantly improving policy preparation between the targets of SDG 8 and SDG 14.b. Figure 1 firstly bridges the gap and secondly capitalises on the synergies between the ILO, C188, and the decent work targets of SDG 8, 14.7, and 14.b to safeguard and build a workforce that is fit for the purpose of addressing their needs for the blue economy. Only through such interlinked policy cooperation and coordination can the blue economy concept that focuses on decent job creation, social inclusion, innovation, and the promotion of small actors and businesses, as envisaged in SDG 8.3, be operationalised. The blue economy and SDGs open this policy-level dialogue for a new coordination mechanism amongst policymakers and competent marine organisation, labour force institutions, industries, and maritime security as highlighted by Natuva (2021) and Voyer et al. (2018). Furthermore the blue economy business model aims to break the old business patterns and transform island economies into more competitive players in global markets (Saavedra and Alleng, 2020). The blue economy is in line with Elkington's (1998) "triple bottom line" business concept of sustainability, which aims to achieve environmental sustainability, change old economic patterns, and improve social justice and the lives of island communities. While SIDS continue to lead the way in promoting the blue economy, SIDS-led industry and interdisciplinary research on supply chains and transnational trade, as well as public sector reforms, are limited. This study contributes to SIDS' evidence-based policy research and advances these limitations for island governments pioneering the blue economy and needing island-led marine strategies.

Author contributions

The Author contributed to the conceptualization, research, writing of the original draft, visualization, and analysis and interpretation of the data for this paper. The author confirms being the sole contributor of this work and has approved it for publication.

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2 https://sdg.tracking-progress.org/indicator/8-8-1-fatal-occupational-injuries/

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Diversity, equity, and inclusion in the Blue Economy: Why they matter and how do we achieve them?

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The Blue Economy (BE) has captured the attention of diverse interests to the ocean and there is rising concern about making it more equitable and inclusive. As it currently stands, diversity, social equity, and inclusion considerations have not been foregrounded in the discourse surrounding the BE and are continuously overlooked and undervalued. This paper reviews the ongoing social inequalities in the BE and distribution of benefits and costs across different groups in society. It also explores why equity matters, and how it can be achieved. Mirroring the call for under-represented or marginalized social groups to receive a fair share of the returns, which may be more than they have received to date. Our analysis shows that between 1988 and 2017, a Germany–based company has registered about 39% of all known marine genetic resources, while three companies in Asia control 30% of the market share of seafood sector in 2018. These findings show high consolidation of the ocean space by top corporations. Therefore, this paper argues that the exclusion of equity considerations within the BE investments can undermine ocean-based activities such as marine wildlife conservation initiatives that may disrupt the ocean sustainability agenda.

KEYWORDS

Blue Economy, ocean sustainable development, sustainable Blue Economy, gender, diversity, equity, inclusion

1. Introduction

There is widespread recognition that the ocean is a global common, where transboundary and commercial use of ocean activities such as fishing (e.g., Sumaila et al., 2020), cruise tourism, shipping, and fossil fuel extraction accelerates. In this study, we see the Blue Economy (BE) as equity–focused but we frequently utilize the term interchangeably with ocean economy, which refers to ocean–dependent economic activities. Increasingly, academics and policy makers perceive the "BE or Ocean Economy" to be a useful concept to help conserve the seas and oceans (Lee et al., 2020). Yet the BE is vastly inequitable where corporate and national consolidation of resources are stark and pervasive. Globally, about 82 percent of fishing activity is

carried out by just 25 countries, while 97 percent of marine genetic resources have been patented by companies domiciled in just 10 rich countries (Blasiak et al., 2018; Österblom et al., 2020). In turn, the largest 100 companies, referred to as the "Ocean 100," collectively generate 60 percent of gross revenues. In a recent study, Virdin et al. (2021) found that only ten companies account for 45% of the gross revenues of each of the eight major ocean industries (i.e., fish processing, tourism, shipping, port infrastructure & services). Vessels from ten rich nations, including Korea, Japan, and Spain, take 71% of fishing catches from the high seas (Sumaila et al., 2015; Sala et al., 2018). This magnitude of aggregation in the ocean economy offers opportunities as well as poses risks to securing equity in the use of the global ocean. Mounting evidence demonstrates that the BE is inequitably used (Bennett et al., 2019; Österblom et al., 2020; BCCIC, 2021; Cisneros-Montemayor et al., 2021). Besides, recent proof from the fishing sector globally reveals how unrestrained development led to human-rights abuses, including food security and inadequate access to fisheries by local communities (Tickler et al., 2018; Singleton et al., 2019).

A BE aims at setting up environmentally sustainable, socially equitable, and economically viable ocean industry. However, what is not yet known is the role of Diversity, Equity and Inclusion (DEI) in the growth of the BE. DEI alongside economic development and environmental sustainability is recognized as central to a sustainable BE, and sustainable development more broadly (Cisneros-Montemayor et al., 2019). Until now, despite its importance, DEI have been largely overlooked in BE policies, discourses, and activities (Österblom et al., 2020; Bennett et al., 2021). In part, this may be due to limited understanding and the lack of guidance on what DEI means in practice, and how DEI goals and objectives might be institutionalized. This paper seeks to address these challenges by providing practical suggestions on why DEI matter, and how it can be achieved in BE governance. Although DEI touches all groups, this paper focuses primarily on women, otherwise systemically disadvantaged groups, racialized minorities with poor employment prospects, and inadequate infrastructure, and those at risk of suffering from environmental degradation and unsustainable BE development. However, it must be noted that this is not a "one size fits all approach," rather, this paper is meant to offer a flexible approach that can be adapted to fit the context in which it is being applied. It aims to provide high level guidance to assist in ensuring DEI are thoroughly and comprehensively considered within BE governance.

2. Understanding the origin and discourses of BE terminology

The 2012 Rio + 20 conference first raised the idea of a BE and the need to stimulate "blue growth," particularly for small island developing countries (SIDS) with significant maritime and coastlines areas. Martínez-Vázquez et al. (2021) offer an extensive review of the Ocean Economy, Marine Economy, Blue Growth, BE, and Maritime Economy, and where the authors investigated various definitions of the terms used by authors. Given the growth potential of oceans, many Small Islands Developing States (SIDS) and coastal countries such as Mauritius and Seychelles have been strong advocates of BE, feature environmental sustainability and social equity in their vision (Cervigni and Scandizzo, 2017; Bennett et al., 2019, 2021). However, the lack of a generally accepted definition of what a BE is, what it incorporates, and what equitable and sustainable means has resulted in different organizations, actors, and industries around the world have defined it to encompass a wide variety of goals and motivations (Silver et al., 2015; Sumaila et al., 2021).

The concepts of circular, green, and BE share the same philosophy, which is to shift the existing economic practices in the direction of a more sustainable one. While the red economy is based on an unbalanced production system and inconsiderate consumption habits that do not place the natural environment at the center of industrial activities (Genovese et al., 2017). This is driving increasing attention to the sustainability of the marine *agri–sea–food* system. The growing demand for seafood products necessitates the expansion of the BE (Naylor et al., 2021) while minimizing detrimental ecological and social consequences (Issifu et al., 2022). To date, the economy has been redder than ever. The result is terrible and the impact on the environment is far from benign. As we move toward a less red economy, the seafood industry should become more sustainable. Achieving such a strategic goal of sustainable management will enable fishers to establish a bluer consumption system based on ocean–friendly practices, such as zero plastic policies. In addition, achieving DEI in the BE sector is linked to achieving DEI in the other sectors. The greener BE sector promotes green energy use, recycling and more inclusive profits. Implementing DEI is pivotal not only to the success of BE but also to the green and circular economies. For example, in the pursuit of cutting greenhouse gas emissions, the BE can contribute to this goal by assisting with carbon mitigation in ocean-related industries and infrastructure. Examples include smart ports that use data analytics to improve performance and economic competitiveness, for a review see Battino and del Mar Muñoz Leonisio (2022). In this regard, it must be recognized that the green and blue economies are centered on natural resources. Their successful implementation can be facilitated by the principle of the circular economy, as it will contribute to the efficient use of resources while stimulating and calling for innovative improvements that build better livelihoods for all fishers.

Green economy and BE have been subject to various definitions but those currently being adopted by development partners, civil society, and international organizations have a lot in common. Green economy strategies tend to focus largely

on terrestrial sectors such as energy, agriculture, and forestry (Silver et al., 2015) in order to improve human wellbeing and social equity, while drastically minimizing ecological scarcities and environmental risks (UNEP, 2011). Scholars and other groups in society argue that the terrestrial focus of the "green economy" did not adequately address the needs of frontline coastal communities who rely heavily on coastal resources for their jobs and livelihoods (Louey, 2022). This has led some to call for BE—an alternative way of recognizing the interconnected nature of the ocean to livelihoods, and the economy with a focus on the equitable use and distribution of marine resources (Cisneros-Montemayor et al., 2021, 2022). According to the European Commission, the BE involves all ocean related economic ventures which covers a wide range of interwoven including both emerging and established sectors (The Economist, 2015). The BE is seen as a rallying cry for the sustainable utilization of ocean resources for development, enhanced sustenance, and employment while conserving the health of ocean ecosystem (World Bank, 2017).

WWF adds that BE denotes any economic venture in the ocean sector, whether renewable or not, while for others, it encompasses everything from the historic fishing industry to tourism and shore side attractions like beaches to emerging industries such as marine biotech and wind energy and simply aims to use the ocean and its assets for sustainable economic growth (WWF, 2015; Sumaila et al., 2021). Yet, the notion progressed further at the BE conference in Abu Dhabi in 2014, where representatives of the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization discussed the BE as a device to accelerate development in SIDS (SDG Knowledge Platform, 2014). Just as the green growth and green economy was once on the frontier of investment and development planning, its maritime-based equivalent has captured the imagination of the African Union, the European Union, Commonwealth Secretariat, policymakers, Organization for Economic Co-operation and Development (OECD), the United Nations, development finance organizations (such as the World Bank), and Non-Governmental Organizations (NGOs) alike.

However, global interest has focus on the ocean as a source of wealth was sparked by the seminal publication "The Ocean Economy in 2030" by the OECD (2016). They focus on the term "ocean economy" than the "BE" (see also Sumaila et al., 2021). In advancing the idea of a sustainable BE, all activities in the ocean, including the extraction of non-living resources, exploiting living resources, and the creation of new resources within the ocean must be done in a sustainable manner. How to stimulate economic growth in ocean nations or areas may be understood to many, but it is not clear how to make the BE more equitable and inclusive and under what policies and pathway is it most likely to develop.

We argue that central to the BE is DEI. As alluded to in Section 2 of this paper, these terms are often used interchangeably. The term diversity can denote the presence of differences within a given context, such as an organization. It refers to groups rather than individuals. These may denote a wide characteristic, such as religion, race, gender, and sexual orientation. Although diversity is used more within a group context, the hiring of person can bring additional diversity to an organization or a group. The term equity involves a world in which all peoples can attain their potentials while contributing to the general good; they do not just only survive but flourish. The goal for promoting equity is to move beyond historical and systemic barriers that limit access in order to achieve greater fairness of outcomes. To comprehend how social justice or equity is, and is not, addressed in ocean planning, you first have to pay attention to the complex nature of equity. The four dimensions of equity include: procedural, distributional, recognition and contextual (Wells et al., 2021). Procedural equity involves participation in governance and inclusion in decision making whereas distributional equity involves the fair distribution of benefits and minimization of burdens (Österblom et al., 2020; Hicks et al., 2022). Recognition equity incorporates the recognition and respect of diverse knowledge systems, values, and social norms (Bennett et al., 2019). It also involves recognizing the diversity of ocean actors and their rights. The fourth dimension is contextual equity, which highlights the fact that to understand what is equitable requires understanding the context and history of specific places and the context specific situations that people face (Alexander et al., 2021; Cisneros-Montemayor et al., 2022). Contextual equity therefore denotes the broad socio-economic and cultural contexts, including aspect of the past and present that influence the capacity of an actor to participate in decision–making, ensure fair distribution, and gain recognition. For example, ethnicity, power dynamics, age, gender, and education should play a role (Wells et al., 2021). Inclusion on the other hand, relates to specific actions taken to leverage the unique strengths of all peoples. The goal is to ensure that individuals feel welcomed, valued, and supported with their environment. Inclusions therefore goes beyond ensuring representation. It captures the level of participation and empowerment individuals have within a given setting. We establish from the literature that inclusion is not necessarily an output of diversity, in others words, inclusion is not a natural consequence of diversity or promoting diversity would not necessarily result in inclusion. The focus of DEI efforts will vary depending on the sector of the BE and the type of organizational culture. For example, while some organizations tend to pay more attention to individual characteristics such as gender, gender identity, age, race, sexual orientation, disability, and religion, other organizations may place emphasis on diversity of thought or cognitive diversity.

Globally, nations are looking to transition to a "green" economy with low–carbon technologies, socially inclusive and resource efficient governance systems (KPMG, 2021). The green agenda is central to achieving over-arching broader social equity

ambition outlined in the 2030 United Nations Agenda for Sustainable Development. Green economy demonstrated gains in job quality especially ocean-related jobs, promoted social inclusion and reductions in poverty (ILO and International Institute for Labour Studies, 2012). For these reasons, incorporating DEI in the "green" component of the "blue" transition will not only facilitate a more equitable sustainable ocean economy but will also lead to thriving ecosystems, communities and individuals.

3. Existing social inequities in the BE

The BE is already a powerful economic engine for most countries in the world today. The OECD projects that the ocean economy will likely expand faster than the world economy from 2010 to 2030, contributing to general expectations of an unmatched period of blue growth (Jouffray et al., 2020). Specifically, it is estimated that the BE will contribute about $100 billion per year to the economies of coastal and island nations. Oceans and coasts are expected to add $25 billion worth of ecosystem services through economic activities such as nutrient cycling, coastal protection and carbon dioxide absorption by 2025. A final example of the high expectations from the ocean economy is that it is expected to expand three times faster than Australia's total gross domestic product over the next 10 years (Coffin, 2015).

However, the ocean economy is fraught with a suite of social inequities and inequalities. Anecdotal evidence shows existing marginalized groups such as indigenous peoples, women, small scale fishers, low–income earners, otherwise systemically disadvantaged groups, racialized minorities, coastal communities, and remote populations with poor employment and infrastructure at risk of environmental degradation and unsustainable development. Black Americans and Black Canadians and Indigenous peoples are disproportionately more likely to live near industrial areas and are exposed to higher levels of toxins than other citizens (Bullard, 2007), both through the environment and through consumption of fish (Cisneros-Montemayor et al., 2016; Stackelberg et al., 2017). Fisheries with predominantly Black and Indigenous fishers are threatened more by climate change resulting high impact and anxiety among Black, Indigenous, and People of Color (BIPOC) generally (American Fisheries Society, 2015).

Historically, indigenous communities are inherent rights-holders to marine areas and resources and have managed these areas sustainably over millennia in keeping with their own laws and customs (BCCIC, 2021). Yet indigenous peoples have been ignored from decision-making pertaining to the ocean because indigenous rights were shortchanged and marginalized when European settlers colonized North America and imposed their own legal systems (BCCIC, 2021). According to BCCIC (2021), the Canadian government dismantled Indigenous traditional governance systems and imposed strict regulations on the lives of Indigenous peoples through treaties and statutes such as the Fisheries Act (1868) and The Indian Act (1876). A considerable amount of literature argues for a different approach, where power dynamics and social inequities must be addressed first given that they are at the root of both unsustainable use of natural resources and inequitable distributions of economic gains (Bennett et al., 2019; Cisneros-Montemayor et al., 2022). The legacies of inequitable power dynamics caused by colonial legislation are still in effect today. For example, in 2018, about 70% of families in the Nunavut, and the Inuvialuit Settlement Region of the Northwest Territories of Canada faced food insecurity (BCCIC, 2021). These inequities are a result of final decision–making authority associated with natural resource management and economic development activities that occur on unceded or Treaty Indigenous lands and waters is legally held by Crown governments. In some cases, whole communities were forced to relocate further North where hunting and fishing opportunities were scant compared to their home territories (BCCIC, 2021). Food insecurity remains a source of social injustice and a key social driver of health, including jobs, education, income, racism, and gender. This places people who are part of historically marginalized groups at higher risk of food insecurity, including sexual orientations and gender identities known as 2SLGBTQ+ groups. In the same vein, in Africa, Namibia's colonial era saw significant exploitation of the country's minerals likewise the overutilization of the country's fish stocks under both the German colonialization and South African apartheid rules (Sumaila and Vasconcello, 2000). Carver (2020) observed historically disenfranchised voices and the lack of local ownership in Namibia due to the continued dominance of white elites in the ocean economy.

The industrialization and subsequent privatization of ocean resources has resulted in the dominance and consolidation of a small group of transnational corporations (TNCs), hence a few companies control a huge market share of the total output or sales of marine products or service (Gereffi, 2014; Folke et al., 2019). Although transnational in operations, the site of the headquarters of the transnationals corporations (TNCs) can give indications of the geographic distribution of benefits from the ocean economy. Selig et al. (2019) mapped the degree of human dependence on marine ecosystems based on the magnitude of the benefit, susceptibility of people to a loss of that benefit, and the availability of alternatives, and found the top 5 countries (Indonesia, Nigeria, Philippines, Vietnam, and Myanmar) with the high proportion of their populations with high dependence in term of nutrition, economic, and coastal protection. Sadly, none of the headquarters of the TNCs is located in any of the top 5 countries with the highest numbers of people with high dependence on marine ecosystem. The United States, Saudi Arabia, China, Norway, the United Kingdom, France, and Iran, South Korea, the Netherlands, Brazil, and Mexico are among

the TNCs countries with the largest share of the gross revenues generated (Virdin et al., 2021). The United States has close to 12%, Saudi Arabia and China 8%, respectively, Norway has 7%, France 6%, the United Kingdom 5%, and Iran, South Korea, the Netherlands, Mexico, and Brazil (4% each). Saudi Arabia, Iran, Brazil, Mexico, and the United States collectively host the largest offshore oil and gas TNCs. Also, China, South Korea, and Italy host the largest maritime construction and equipment companies (Virdin et al., 2021). Huge amounts of consolidation in the ocean economy pose danger to attaining globally shared goals for sustainability by contributing to inadequate access to ocean resources (Sumaila et al., 2015; Österblom et al., 2020).

Globally, women depend on the ocean for livelihood, coastal protection and food (Selig et al., 2019; Harper et al., 2020). Although close to 85 percent of the workforce in the sector are women, they are not accounted for in fisheries management positions (Harper et al., 2018), hence policies tend to undermine their livelihoods (WWF, 2012). The exclusion of women from decision-making about ocean can increase their vulnerability and affect their rights and wellbeing (Selig et al., 2019; Harper et al., 2020). To ensure the inclusion of women and other vulnerable groups, local communities should not be ignored from decision-making relating to ocean development and management. These challenges often emanating from social conventions restrain the purchasing power of women to secure better equipment and boats to explore new fishing grounds. In recent years, the term "ocean grabbing" has become a great source of concern since they affect the rights and livelihoods of vulnerable coastal peoples and small–scale fishers. "Ocean–grabbing"—constitutes shrouded access agreements that hurt small–scale fishers, incursions into protected waters, unreported catch, and the diversion of resources away from local communities (Bennett et al., 2015).

4. Why the need for DEI in BE?

Several studies have highlighted the business case for diversity and inclusion, companies or entities that focus on diversity and inclusion, and add equity, repeatedly outperform those that do not, with regards to profits, innovation, creativity, reputation, and productivity (e.g., Bourke and Dillon, 2018; Dixon-Fyle et al., 2020). Other potential benefits of DEI in BE context include provision of alternative livelihoods, revitalization of coastal economies, improved food security and well–being and ensuring fair socio-economic policies (OECD, 2016; Michel, 2017). In addition, blue foods are less affordable where gender inequality is higher (Hicks et al., 2022). DEI offers suggestions as to how to better achieve sustainable results, including economic viability (Schuhbauer and Sumaila, 2016) and environmental integrity (Pauly et al., 2002). By looking at DEI approaches, we can ensure a fair distribution of benefits over a longer term, such that ocean resources are conserved and delivered for future generations (Sumaila and Walters, 2005; Cisneros-Montemayor et al., 2021; Sumaila, 2022). A recent study by Cletus et al. (2018) reported that while diversity in the workplace fosters the acquisition of many professional skills, such as critical thinking and problem solving, it also helps with the improvement of productivity, organizational attractiveness and talent retention. Equity issues merit upfront attention and when they are overlooked, they can have effect on how well other objectives are attained. Figure 1 presents the relationship between DEI and BE in a conceptual framework.

For example, ocean planning in California was unsuccessful when equity issues were overlooked, however, this was resolved by the Marine Life Protection Act (MLPA) process in the state. The use of a top-down approach during the initial phase of the planning failed to involve stakeholder groups, this made the process unsuccessful. However, in the third phase of the initiative, planners engaged various stakeholders, encouraged participation and gave voice to the affected members, and the planning led to a network of MPAs along the whole California coast (De Santo and Yaffee, 2021). On Mafia Island, Tanzania, the lack of consultation with the local community of fishers before the established of an MPA by NGO almost ruined the conservation effort (Sumaila et al., 2000). Other good examples of situation where the introduction of equity consideration in ocean planning are in the development of Individual Transferable Quotas (ITQ) for bad-performing fisheries. Decisions about how to apportion quotas when the ITQs are first set up, and the rules concerning how quotas can be consolidated after the system is established can have profound outcomes for fishery performances (De Santo and Yaffee, 2021). In many Pacific Island states, inclusion is critical in the implementation of ocean governance because of poor ocean management owing to the lack of gender-disaggregated ocean data (Michalena et al., 2020). Michalena et al. highlight the relevance of Pacific women's knowledge of Pacific Ocean ecosystems as it differs from that of other groups. We argue that a broad–based and concerted approach that includes civic institutions, academics, industry partners, and individual change agents can enhance the recruitment, retention and integration of underrepresented and marginalized people into the BE by facilitating focused strategies across the entire mentoring system. Especially, a number of positive factors have been demonstrated to foster increased minority engagement throughout mentoring approaches such as (1) active support for training and skills development programs for new and existing workers in the various sectors of BE, including specific programs for under–represented groups and Indigenous peoples (Fisheries and Oceans Canada, 2022); (2) making available role models or having mentors (Indigenous Guardian Program); (3) participation in afterschool and summer learning DEI–related subjects such as gender equity, equitable distribution of benefits, intergenerational equity, and recognizing Indigenous rights holders and their distinctive role in the BE.

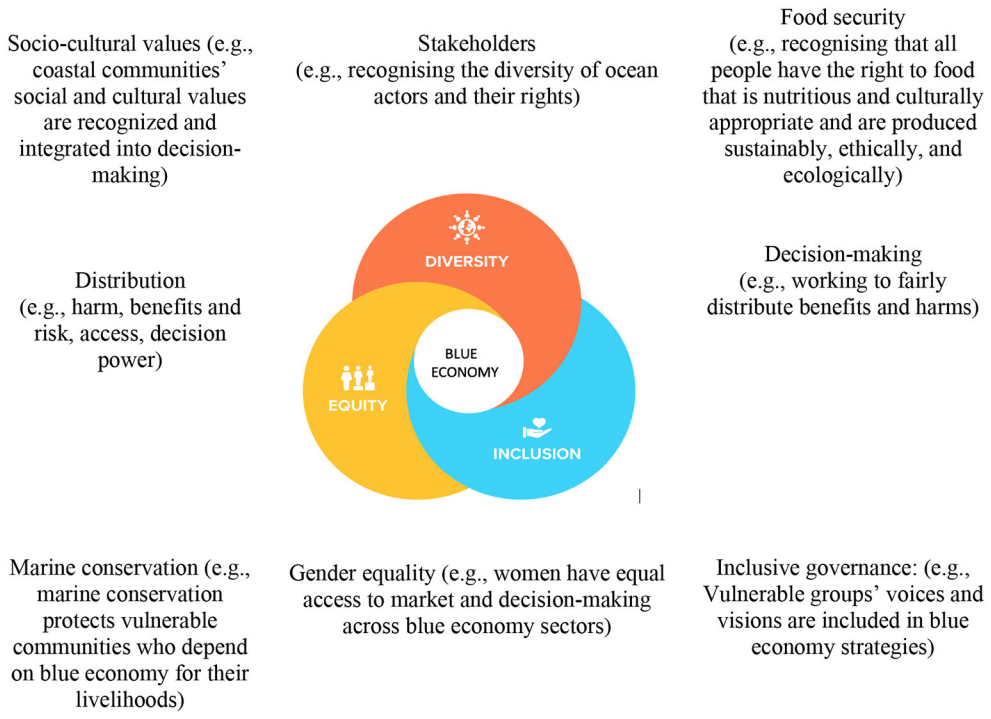

FIGURE 1
A conceptual diagram of the relationship between the BE and diversity equity and inclusion.

5. International and national-level legal and regulatory actions

The UN Convention on the Law of the Sea's (UNCLOS) core mandate involves setting a legal framework to regulate all marine and maritime activities such as the conservation and sustainable use of marine biodiversity in the areas beyond a nation's Exclusive Economic Zone (EEZ), where no single nation claims sole ownership and management. In 2017, UNCLOS has also established a new resolution 72/249 (United Nations, 2018), which seeks to integrate the common heritage of mankind, inter-generational equity and benefit sharing as legally binding instruments to protect, preserve and conserve marine biological diversity in the high seas, i.e., areas beyond the EEZs of coastal countries. This new ongoing treaty seeks to address issues of ocean equity and ensure equitable access to marine resources for land–locked, developing and geographically disadvantaged nations. We found that between 1988 and 2017, one company based in Germany has registered about 39% of all known marine genetic resources, while three Asia–based companies control 30% of the market share of seafood sector in 2018 (see Supplementary material) raising questions about the principle of common heritage of mankind to marine genetic resources. To paraphrase Arvid Pardo's, man's penetration of the deep ocean could be a unique opportunity to lay solid foundations for a share future prosperity for all (Tladi, 2014). In addition, as developing nations and small island developing states face legal and technical capacity restrictions and have been marginalized in some international negotiations (Blasiak et al., 2016, 2017), raising concerns about equity in the setting of negotiations is important to increasing ocean equity. Capacity-building for marginalized communities in turn enhances greater equity (Österblom et al., 2020).

Most Governments and NGOs around the world are relentlessly pursuing legislation to make corporate bodies and stakeholders deliver social benefits to all peoples. Many nations have crafted national legislation to address DEI, for instance, in Canada the Canadian Business Corporation Act mandates federally distributing companies and corporations to reveal information on four designated groups i.e., women; persons with disabilities; aboriginal peoples; and members of visible minorities. Besides the UN new resolution 72/249, regional and national legislation, universities, and financial regulators are also introducing disclosure rules around DEI. Table 1 presents an overview of national level legal and regulatory actions. We see from the Table that the California Corporations Code, as modified by Assembly Bill 979 requires companies and corporations to hire at least one person from a marginalized community on its board of directors by the end of 2021.

TABLE 1 DEI indicators embedded in legal and regulatory development.

Country	Actions/acts	Summary
Canada	The Impact Assessment Act (Bill C−69)	○ This act outlines consideration of issues of diversity, equity and inclusion. The Act transforms existing inequalities and unequal power relations in communities
Chile	Chilean Labor Code (Law No.21, 275)	○ Corporations must: 1. Maintain at least 1 employee, with specific knowledge that promote the labor inclusion of people with disabilities. 2. Promote internal policies on matters of inclusion3. Annually inform those policies through a communication to the Labor Board. 4. Develop and implement annual training programs for an effective labor inclusion. 5. Consider the rules on equal opportunities and social inclusion of people with disabilities from law No. 20,422 in all activities outside workdays
Finland	Non–discrimination Act 1325/2014	○ The aim of the Act is the promotion of equality, the prevention of discrimination and improving the protection provided by law to discriminated groups
Iceland	Act on Equal Status and Equal Rights Irrespective of Gender, No. 150/2020	○ This Act seeks at setting up and maintaining equal status and equal opportunities for people. It encourages gender equality in all aspects of society. All people shall have equal right and opportunities to derive material benefit from their own economic activities and to develop their skills irrespective of gender
Portugal	Social Balance Law 7/2009 (Article 31)	○ Equal working conditions where the employees have the right to equal remuneration for work of equal value. Moreover, no differences in job description and remuneration shall be based on objective criteria, common to men and women
South Africa	Broad–based Black Economic Empowerment Act	○ The Act was introduced with the goal to establish a legislative framework for the promotion of black economic empowerment vis: 1. Ownership (Direct Empowerment), 2. Management Control (Indirect Empowerment), 3. Enterprise Development 4. Skills Development and 5. Socio-Economic Development
Spain	Organic Law 3/2007 for the effective equality of women and men	○ The Act established new legislative measures concerning violence against women in relation to sexual harassment in the workplace, gender violence, and the right to asylum and refugee status for foreign women
United Kingdom	The UK Gender Pay Gap Reporting Act	○ All voluntary-sector employers and private entities with 250 or more workers are required to disclose data on their gender pay gap
US, State of California	California Corporations Code, as modified by Assembly Bill 979	○ By this Bill, companies are required to hire at least one person from a marginalized groups on its board of directors by the end of 2021

6. More DEI in BE would help deliver the UN sustainable development goals

Decolonisation of development and the need for transformative change to challenge racial, gendered, colonial, and capital biases in global economic frameworks is high on the development agenda (Sultana, 2022). The Sustainable Development Goals (SDGs) highlights the importance of inclusivity as a strong framework for assessing progress regrading the performance of the sustainable BE. It addresses the multi-dimensional inequalities associated with development in the area of gender, age, and ethnicity without exacerbating or perpetuating existing inequalities (Gupta and Vegelin, 2016). Giving the intersections between the social SDGs and SDG 14, pursuing Goals 1 (eradicating poverty), 2 (eradicating hunger), 5 (gender equality), and 7 (clean energy) are all relevant to inclusive outcomes, likewise SDG 14, which is on the oceans (Singh et al., 2018). Ocean based renewable energy is fast-growing and, on the path, to becoming a key source of energy for the world (IOC–UNESCO, 2021). It is important to consider how these marine energy sources might contribute to a sustainable and equitable ocean economy. By embracing the concept of equity in the BE, the marine energy sector can make transformative contributions to coastal communities. The reverse would lead to development that is socially and/or ecologically harmful and exacerbates inequalities. There are also positive interactions between SDG 7 and other SDGs, including those that promote strengthening infrastructure and economic wellbeing through innovation. We also found that adopting DEI considerations in BE means that harnessing the power of the ocean is done in ways that address the varied resources, diverse needs and concerns of local communities. This understanding allows us to both widen the opportunities for marine energy developers, and it also encourages the sector to engage in equitable and sustainable development as a foundation of renewable ocean energy for in a BE. Table 2 provides an

TABLE 2 Ocean–related SDGs are pivotal to accomplishing the DEI practices needed to power the BE.

Ocean related sustainable development goal (SDG)	DEI practices needed to power BE development
SDG 2: End hunger, achieve food security, and improved nutrition	Achieve food security within marginalized communities by supporting the economic development of new aquaculture species in sustainable domestic and global food production—so that coastal communities and historically underserved people have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy lifestyle
SDG 3: Ensure healthy lives and promote wellbeing for all people	Strengthen access to clean water and develop new inclusive social protection systems in underserved communities. Support investments in health, and fiscal strategies that ensure a healthier, sustainable BE
SDG 5: Gender equality	Achieve gender equality and empower all women and girls involved in small-scale fisheries. Design policies and program incentives to increase gender equity. Prioritize the socio-economic wellbeing of women and girls by promoting equity in the labor market
SDG 7: Ensure access to affordable and clean energy for all	Create strong energy-equity metrics, incorporating voices from historically underserved communities in the creation of energy systems and technologies and advancing equitable distribution of energy at scale to address underrepresented communities
SDG 9: Foster innovation by building resilient infrastructure, and promote inclusive and sustainable industrialization	Build resilient and modern marine infrastructure, including live storage tanks, ports, and seafood processing plants. Resolve systemic inequities for historically underserved communities by collaborating with indigenous peoples and other minorities to ensure consistent decision making
SDG 11: Make cities and communities inclusive, safe and sustainable	Leaving no one behind requires more investment to reduce coastal slum dwellers and make cities more resilient to climate change impacts and maintain coastal environmental health. Support actions to challenge discrimination, stereotypes, and promote inclusive and equal opportunity in housing.
SDG 12: Ensure sustainable consumption and production patterns	Support the elimination of waste streams that enter marine ecosystems through the superior design of products, materials, and systems. Respect and recognize the legitimate expectation of future generations and fosters equitable interventions that allow for inclusion in decision-making processes, and strengthens equity with transparency to empower racialized and minorities communities
SDG 13: Take urgent and uniform global action to address climate change and its impacts	Ensure global climate plan to get to net-zero through the international commitments to ocean health. Increase actions to protect, restore, and rebuild aquatic resources and marine ecosystems, including wild fish stocks. Protect and support the resilience of frontline coastal economies and livelihoods, and provide alternative livelihoods, for those disproportionately affected by climate change
SDG 14: Life below water	Protecting the needs of the present people without "compromising the ability" of the ocean to meet the needs of the future generations. Specifically, intergenerational equity needs to be considered to make BE equitable and sustainable
SDG 16: Peace, justice, and strong institutions	Provide access to justice for coastal and minorities communities by means of accountable and inclusive institutions at all levels. Bring the unique knowledge of indigenous peoples and other diverse voices in decision making
SDG 17: Strengthen the global partnership for sustainable development	Facilitate global cooperation in implementing effective capacity-building in small island developing countries (SIDS) and other developing economies to support national plans to implement ocean-related sustainable development goals

overview of how Ocean–related SDGs are pivotal to facilitating the DEI practices needed to power the BE. For instances, we observed that SDG 7: Ensure access to affordable and clean energy for all people may improve BE through creating strong energy-equity metrics, incorporating voices from historically underserved communities in the creation of energy systems and technologies, and advancing equitable distribution of energy at scale to address underrepresented communities. We propose transformative actions for DEI (Table 3).

7. Conclusion

The oceans have the potential to significantly contribute to decreasing global malnutrition and hunger (Srinivasan et al., 2010; Hicks et al., 2019) and with a lower carbon footprint, which would help decrease the contribution of the food systems to global warming (Béné et al., 2015; Farmery et al., 2020; Sumaila and Tai, 2020). Huge potentials can be achieved within a BE that enhances benefits alongside the fair and sustainable use of ocean resources. But, the current trend of the BE focusing on output and only profit is leading to the over-consolidation of BE narratives by private corporations' interests, to the neglect of marginalized voices calling for equitable distribution of ocean resources. Solving inequities present in the BE is important by ensuring that the voices of under-represented groups and people of different genders and backgrounds are heard alongside with all others. In this paper, we assessed how renewable ocean energy could contribute to an equitable BE. We began our analysis by providing a comprehensive analysis of the terminology involved in this study, and then discussed the rationale for DEI and the reason why everyone should be at least concerned, if not involved in ensuring DEI in the BE. As mentioned, the assessment of current inequalities represents a big missing piece of the DEI puzzle. What does it take to make the BE equitable?

TABLE 3 Recommendations for advancing DEI in BE.

Diversity actions
○ Recruitment of Indigenous and racialized individuals into senior positions or creating new positions for Indigenous and racialized peoples within the BE will foster relationships with minorities partners, support cultural safety initiatives and ultimately, work toward building sustainable BE ○ Incentivize increased diversity in training, education and sectors
○ Recognize that there are no one-size-fits-all" solutions and the diversity of stakeholders in the BE has to be taken into account
○ Ensure that Gender Based Analyses are culturally relevant and enforceable across all BE programs, policies, and legislation
○ The current BE is over-consolidated among a small group of corporations. We must put people ahead of profit in development of the BE
Equity actions
○ Food security: Ocean development projects respect local communities need to fish as food
○ Benefits sharing: Ensure that economic benefits from ocean industries are fairly distributed to local communities
○ Develop and enhance existing equity data collection, reporting, compilation, and analyses
○ Fisheries Management: Ensure that small scale fishers' livelihoods are protected, and that they have access to decision-making in ocean development
Inclusion actions
○ Inclusive governance: Include marginalized groups' voices and visions in ocean strategies and governance ○ Inclusive science: To make science more just and inclusive, open source is the answer to speeding up innovation–not patents and paywalls
○ Leave no-one behind: Advance the participation of indigenous people and under-represented population
○ Develop inclusion tools: Factors such as age, income, gender, ability, and ethnicity and measuring inclusion must be taken into account in developing the BE
○ Raise awareness of BE opportunities and connect marginalized populations and racialized minorities with these opportunities

We argued that indigenous communities and all coastal states need to be treated fairly. Also, we highlight the existing inequalities and inequities due to inadequate DEI practices in the BE. We conclude that BE activities should work toward achieving SDG14, while concurrently working to meet the other ocean–related SDGs. The current study established the potential benefits derived from renewable ocean energy needs to be considered in regional contexts to ensure equitable and sustainable developments. For example, marine energy could have synergistic benefits with SDG 6: Clean water and sanitation. We suggest recommendations with specific DEI actions. Finally, we incorporate DEI Practices needed to power BE development within the context of ocean-related SDGs.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpos.2022.1067481/full#supplementary-material

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Ocean defenders and human rights

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Two pressing and overlapping marine policy issues are related to human rights in the ocean and the situation of ocean defenders. Human rights issues and violations are on the rise in the ocean due to the ongoing, rapid and unchecked escalation of anthropogenic activities in marine and coastal environments, which increasingly undermine the fundamental, civil and political, economic, social, cultural or environmental rights of individuals and groups. In this context, it is essential to recognize, support and safeguard the individuals, groups or communities who are mobilizing, advocating or taking action to protect the marine environment, coastal and oceanic territories, and associated human rights from existential threats. Yet, these 'ocean defenders' often face marginalization, intimidation, criminalization, threats, violence and murders. The failure to protect the human rights of coastal populations and ocean defenders needs to be urgently rectified by states, the private sector and civil society. We identify six specific areas of urgent action to protect human rights in and related to marine and coastal environments and to support and safeguard ocean defenders.

KEYWORDS

ocean defenders, environmental defenders, human rights, environmental human rights, ocean governance, environmental justice, blue economy, ocean economy

Human rights and the ocean

Human rights are a foundational norm and global standard for a just society that values human well-being for all people. *The Universal Declaration on Human Rights* (UDHR), which was adopted by the United Nations General Assembly in 1948, explicitly recognized a set of fundamental rights (e.g., life, liberty and security of the person, freedom from slavery and torture, freedom from discrimination, freedom of movement,

property, nationality), civil and political rights (e.g., freedom of thought, religion, opinion, expression, association, and peaceful assembly), as well as economic, social and cultural rights (e.g., health, education, housing, adequate standard of living, freedom from hunger) (United Nations, 1948). The declaration was founded on the idea that human rights are universal, egalitarian, inalienable and inherent to the dignity of all individuals. The adoption and ratification of the International Covenant on Civil and Political Rights (ICCPR) and the International Covenant on Economic, Social and Cultural Rights (ICESCR) and its two *Optional Protocols* make the rights contained in the UDHR binding on states (United Nations, 1966a; United Nations, 1966b). Parties to the Covenants assume obligations to respect, protect, and fulfill human rights. Additionally, the UDHR, ICCPR and ICESCR (collectively known as the International Bill of Human Rights) provide broadly accepted guidance even for states that are not parties to these agreements.

International human rights law is also comprised of other treaties, declarations, resolutions, guidelines and principles (with varied levels of legal status and clout) that have advanced the understanding and implementation of human rights. For example, additional international treaties [e.g., the International Convention on the Elimination of All Forms of Racial Discrimination, the Convention on the Elimination of All Forms of Discrimination Against Women, the Convention on the Rights of the Child, and the Convention on the Rights of Persons with Disabilities (United Nations, 1969; United Nations, 1979; United Nations, 1989; United Nations, 2006)] articulate how ethnic, religious, and minority groups, women, children, and persons with disabilities, require specific protection from discrimination. The *United Nations Declaration on the Rights of Indigenous Peoples* (UNDRIP) clarifies how to interpret international human rights obligations with specific regard to the distinctive cultures and connections to places of Indigenous Peoples (United Nations, 2007). The *United Nations Declaration on the Rights of Peasants* further clarifies that tenure and access are inherent to the dignity, livelihoods, food security and cultures (i.e., human rights) of Indigenous Peoples, small-scale fishers, and other traditional communities who have historically occupied and relied on an area or resources (United Nations, 2007; FAO, 2012; FAO, 2015; UN Human Rights Council, 2018; Morgera and Nakamura, 2022). International and regional agreements - including the Aarhus Convention on *Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters* (Aarhus Convention) and the *Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean* (Escazú Agreement) - recognize everyone's right to information, participation in decisions and access to justice pertaining to the environment (UNECE, 1998; United Nations, 2018). Most recently, the United Nations General Assembly adopted a resolution recognizing the human right to a clean, healthy, and sustainable environment (United Nations, 2022) – which can be understood as encompassing the right to clean air, safe and sufficient water, healthy and sustainable food, healthy ecosystems and biodiversity, safe climate, and non-toxic environment, as well as environmental information, participation and justice (Knox, 2018b; Boyd and Orellana, 2022). Taken together, the body of international human rights law clarifies the legal obligations of states, and the responsibility of business enterprises and other organizations to respect the human rights, including the environmental human rights (Knox, 2018a; United Nations, 2022), of individuals and groups. Numerous additional guidelines and sets of principles - such as the *Voluntary Guidelines on the Responsible Governance of Tenure*, *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries*, *Voluntary Principles on Security and Human Rights*, *UN Guiding Principles on Business and Human Rights* and the *Framework Principles on Human Rights and the Environment* (Secretariat for the Voluntary Principles on Security and Human Rights, 2000; UN Human Rights Office of the High Commissioner, 2011; FAO, 2012; FAO, 2015; Knox, 2018b) - provide additional guidance to states, businesses, and other organizations on meeting their human rights obligations and responsibilities.

Due to their universality, international human rights norms, agreements and related obligations are applicable in the oceans, just as on land. All coastal and ocean-dependent populations are thus entitled to human rights - with certain groups being entitled to specific protections due to their status as Indigenous Peoples or small-scale fishers (FAO, 2015; Morgera and Nakamura 2022). Yet, human rights issues and violations are on the rise in the ocean due to the ongoing, rapid and unchecked escalation of human activities in marine and coastal environments (Jouffray et al., 2020; Bennett et al., 2021). Local populations and small-scale fishers are often marginalized from and lack a voice in ocean governance and environmental decisions that will impact their lives and rights (Cohen et al., 2019). Past and ongoing ocean economy developments have physically displaced coastal populations and traditional livelihoods, undermined security of local tenure and access to resources, and produced pollution and toxic wastes (Barbesgaard, 2016; Bennett et al., 2021; Blue Economy Tribunal, 2021). The effects of marine pollution, coastal habitat destruction, overfishing, and climate change have all undermined the human rights of coastal and ocean-dependent populations to a clean, healthy and sustainable environment (Landrigan et al., 2020; Ertör, 2021; United Nations, 2022; Bennett et al., 2023). These environmental issues in the ocean can also have impacts on other fundamental human rights – including the right to life, livelihoods, food, as well as social and cultural rights (United Nations, 2022; Xanthaki, 2022).

While these human rights impacts are increasingly being identified, much remains to be done to raise awareness and build capacity to protect human rights in marine and coastal

environments. One urgent area of concern is related to the situation facing ocean defenders - individuals, groups or communities who mobilize, advocate or take action to protect the marine environment, their coastal and oceanic territories, and associated human rights against existential threats (Bennett et al., 2022). These 'environmental defenders' or 'environmental human rights defenders' are entitled to all the rights, freedoms and protections set out in the *UN Declaration on the Right and Responsibility of Individuals, Groups and Organs of Society to Promote and Protect Universally Recognized Human Rights and Fundamental Freedom*s (Declaration on Human Rights Defenders) (United Nations, 1998). Yet, there is evidence that ocean defenders are being marginalized, harassed, criminalized, threatened, attacked and murdered for their efforts (Forst, 2016; Bennett et al., 2022). In this paper, we aim to highlight the role of 'ocean defenders' in protecting against violations of human rights, discuss the threats that ocean defenders are facing, and explore actions that should be taken by states and corporate actors to recognize, respect and protect human rights in and related to marine and coastal environments and to support and safeguard ocean defenders.

The role of ocean defenders in protecting human rights

Individuals, groups and communities are mobilizing and taking action to protect the marine environment, their coastal and oceanic territories, and associated human rights against existential threats all over the world (Bennett et al., 2022). The Environmental Justice Atlas, for example, documents 766 mobilizations of fisher people against oil, renewable energy, tourism, mining, fisheries, aquaculture, and water infrastructure developments that pollute the environment, undermine fisheries, and threaten livelihoods (EJAtlas, 2021; Ertör, 2021). Broader coalitions of small-scale fisher people (e.g., World Forum of Fisher Peoples, International Collective in Support of Fishworkers) have been particularly active in advocating for the rights of small-scale fishers at regional and global scales (Mills, 2021). Civil society groups within or broader coalitions of coastal communities around the world have organized resistance efforts against various forms of development that are undermining local tenure, resource access, resource productivity, livelihood sustainability and culture. This includes, for instance, initiatives by coastal communities to hold out against coastal tourism development in India (Routledge, 2001), iron sand and gravel mining in Indonesia (EJAtlas, 2017), industrial waste-water disposal in China (Lu and Chan, 2016), or mangrove deforestation for charcoal production and coastal development in Thailand (Kongkeaw et al., 2019). In Chile, various local community groups have coalesced to protest against the severe health impacts associated with acute pollution of air, coastal lands, waterways, and fisheries in several 'sacrifice zones' associated with highly industrialized areas in Quintero-Puchuncaví Bay, Coronel Bay, and Hualpén-Talcahuano Bay (Valenzuela-Fuentes et al., 2021). Pacific Islanders have been actively involved in resistance efforts against the inevitability and impacts of climate change - for example, the Pacific Climate Warriors have taken action both at home and abroad (e.g., employed campaigns and assembled flotillas of canoes and kayaks) to resist the idea that they are helpless and that their islands and cultures are sinking (McNamara and Farbotko, 2017; Fair, 2020; Ledderucci, 2021). Many Indigenous Peoples continue to have to advocate for both their fishing rights and traditional territories. In Canada, Indigenous groups have been fighting court battles for the return of their constitutionally protected traditional fishing rights for decades - and have engaged in various forms of social mobilization, protest, occupations and civil disobedience to fisheries policies and management plans that do not recognize, respect and protect those rights (Jones et al., 2017; von der Porten et al., 2019; Andrews et al., 2022). Women are often at the forefront of local actions to defend the ocean. For example, women dependent on mangroves in Ecuador resisted the rapid expansion of shrimp aquaculture and the privatization of customary community mangrove areas (Veuthey and Gerber, 2012) and women-led groups in South Africa have been recognized for their efforts to prevent the construction of nuclear plants near Cape Town (BBC, 2018).

This small set of examples of coastal populations who are active in the defense of their rights provides a few insights into ocean defenders. First, there are many different local groups who are active in the defense of the marine and coastal environment. This includes individuals and collectives of coastal communities, local citizens groups, small-scale fishers, Indigenous Peoples, women and youth. We recognize that many other non-local individuals and organizations (e.g., researchers, philanthropic organizations, non-governmental organizations) and broader social movements can support the efforts of local ocean defenders; however, it is local actors, their organizations, and communities who have historical rights and tenure to coastal areas, who continue to depend on marine resources for sustenance and cultural continuity, and who are rightful custodians of the oceans (Capistrano and Charles, 2012; Vierros et al., 2020; Fischer et al., 2022). They have the most to lose, and the most to gain, from activities that undermine human rights and from taking actions to protect the ocean. Second, ocean defenders are active in all regions of the world (Ertör, 2021; Bennett et al., 2022). Due to the rapid acceleration of growth of the ocean economy and the global scope of environmental injustice issues in the ocean – human rights issues are becoming more prominent around the ocean (Bennett et al., 2021; Bennett et al., 2023). Third, ocean

defenders are mobilizing against different activities that are infringing upon their rights - including activities in the sea (e.g., aquaculture development, overfishing, deep sea mining, energy development, etc.), on coastal lands (e.g., tourism development, port infrastructure, oil refineries, desalination plants, etc.), and in the intertidal margins (e.g., blue carbon initiatives, mariculture, etc.). Fourth, ocean defenders are seeking to protect against threats to a range of different rights – including their right to have a voice in environmental decisions, the security of their tenure and access to areas and resources, their rights to a healthy ocean environment, as well as their rights to traditional livelihoods and cultural connections to the ocean. Finally, ocean defenders are engaging in numerous types of actions to oppose and resist threats to their rights – including public protests and demonstrations, research and documentation, awareness and communications campaigns, creation of organizations and networks for collective action, formation of and alliances with social movements, legal and policy interventions, monitoring and enforcement activities, and corporate activism (Table 1). While the United Nations definition of environmental human rights defenders requires that they must be peaceful (Forst, 2016), we recognize the complex realities facing those who may find themselves in hostile and violent contexts, where some acts of resistance used by those who seek to defend their marine territories, environment and rights can be destructive (e.g., destruction of fishing gear, sabotage of boats, and damage to harmful or polluting infrastructure), highly confrontational, or even violent.

The triple threat facing ocean defenders

Ocean defenders are often experiencing a triple threat. First, coastal populations are facing threats from anthropogenic activities that are undermining their human rights – the threats and related human rights issues are also changing, mounting, converging and cumulative. Ocean development is growing exponentially due to increasing global demand for marine resources - and there is also a marked shift in the types of development activities that are occurring in the ocean away from fisheries and shipping and towards a much broader suite of activities including aquaculture, energy development, and deep sea mining (Jouffray et al., 2020). The increased scale and scope of ocean developments likely means that environmental and human rights issues in the marine and coastal environment will also escalate without adequate precautions and safeguards (Bennett et al., 2021). As multiple anthropogenic activities overlap, threats to environmental health and human rights will also converge in some places where multiple development activities occur simultaneously - as is the case in so-called "sacrifice zones" (Valenzuela-Fuentes et al., 2021). Multiple environmental issues and human rights violations may also accumulate - if, for example, one development is excluding and displacing a local fishing community while at the same time industrial fisheries are undermining fish populations required for local livelihoods or food security. Coastal populations are also among the most

TABLE 1 Examples of activities and actions by ocean defenders to mobilize, oppose and resist threats to their rights.

Activity	Details
Public protests and demonstrations	Public demonstrations and other forms of public dissent (e.g., marches, gatherings, artistic displays, blockades, occupation of public campaigns, strikes or walkouts) to express opposition and call for the attention of authorities and the public to an issue.
Research and documentation	Conducting research to document impacts from the perspective of affected communities (e.g., community-based environmental impact assessment), and to collect evidence for legal processes (e.g., photos, testimonies).
Awareness and communication campaigns	Engaging in public awareness efforts to communicate in various formats (e.g., media, reports, videos, online maps, databases) for different audiences.
Creating organizations and networks for collective action	Creation of local, national and transnational organizations or networks to gain visibility, influence, and protection, including through 'allyship' with other organizations (e.g., unions, human rights organizations, international environmental NGOs, International Organizations).
Legal and policy interventions	Actions seeking to assert legal claims or seek remedy for illegal actions (e.g., court-cases), influence policy (e.g., advocacy), or transform decision-making institutions and processes (e.g., participation in meetings, organization of alternative meetings).
Monitoring and enforcement	On the ground efforts seeking to identify (e.g., patrols), and stop harmful actors or activities or actors (e.g., enforcement, communication with authorities, blockades).
Corporate activism	Actions to try to change corporate activities (e.g., vocal participation in public consultation processes), influence corporate decision making (e.g., official complaints, petitions, shareholder activism and resolutions), or undermine corporate profits (e.g., boycotts).
Formation of and joining social movements	Forming or joining broader alliances under social movements (e.g., World Forum of Fisher People) or with other social actors (e.g., small-scale fishers together with peasants, farmers and Indigenous Peoples in *La Via Campesina*) whose strategic interests align. These alliances put pressure on international organizations (e.g., UN, IUCN, World Bank) to support their human rights, tenure rights, food security and sovereignty.

disproportionately affected by 'loss and damage' resulting from the effects of climate change, including coastal erosion, storm surges, and sea level rise (Dorkenoo et al., 2022), as well as the permanent loss of land and ocean territories and associated ecosystems, livelihoods, and cultural heritage (Fry, 2022).

Second, ocean defenders are frequently from groups already subject to historical and continued structural marginalization and exclusion from decision-making. This includes small-scale fishers, Indigenous Peoples, Peoples of Colour, women and youth - whose level of marginalization and vulnerability is shaped by persistent economic, political, and social structural inequalities. Structurally induced socio-economic marginalization and high levels of resource dependence for livelihoods and food security produces a situation whereby certain groups are more exposed, susceptible and vulnerable to the effects of environmental injustices such as climate change, fisheries decline, or marine pollution (Bennett et al., 2023). Groups who are at greater risk of environmental harm include women, children, older persons, persons living in poverty, members of Indigenous groups, persons with disabilities, ethnic and racial minorities, and displaced persons (Knox, 2018b). Inadequate recognition and consideration of rights is a persistent problem for many groups - including Indigenous Peoples and small-scale fishers (Knox, 2017; Morgera and Nakamura, 2022). Persistent discrimination (including racism and sexism) means that racialized and gendered impacts of coastal development are often ignored and made worse for these groups. For example, women's gleaning activities or use of mangroves are often sidelined in environmental deliberations and thus their livelihoods and subsistence activities are disproportionately impacted by environmental decisions and policies (Walker and Robinson, 2009; Cormier-Salem, 2017). Indeed, the specific human rights challenges of women in small-scale fishing communities are routinely under examined (Golo and Erinosho, 2023). Environmentally destructive and polluting coastal development projects have often been situated near Black and Indigenous communities (Castleden et al., 2017; Waldron, 2021). More attention needs to be paid to racial discrimination in relation to the ocean: this is exemplified by the recent UN report on racial discrimination, environmental crisis and climate justice (Tendayi Achiume, 2022), which did not include any reference to ocean-related instances. Historical and continued exclusion, combined with inadequate information sharing and ineffective participation, increases the likelihood that the voices, needs, livelihoods, tenure, and access rights of different marginalized groups are not being taken into account in decisions relating to potential future development projects (Forst, 2016; Knox, 2018b; Menton and Le Billon, 2021). Furthermore, it is an uphill battle for many marginalized groups to access justice - due to barriers caused by lack of recognition, power and knowledge imbalances, and lack of access to financial resources (Forst, 2016; Knox, 2018b).

Third, ocean defenders might also be experiencing intimidation, repression, threats, violent assaults and murders for taking a stand against activities that undermine their human and environmental human rights. There has been a staggering amount of documentation about the dramatic increase in issues facing and number of attacks against environmental defenders in the terrestrial realm (Knox, 2017; Menton and Le Billon, 2021; Front Line Defenders, 2022; Global Witness, 2022). Past efforts have shown that environmental and human rights defenders can be subject to intimidation and repression in various forms - such as surveillance, damage to property, smear campaigns, delegitimization, criminalization, arrests, imprisonment, threats, violence, physical attacks, and assassinations (Forst, 2016; Knox, 2017; Menton and Le Billon, 2021; Front Line Defenders, 2022). Of particular concern, environmental and land defenders are the group of human rights defenders that has experienced the most murders: in 2021, 69% of the 358 killings of human rights defenders were of defenders of the environment and Indigenous land rights (Front Line Defenders, 2022). While private sector interests (e.g., corporations, businesses, wealthy individuals) may be the perpetrators or drivers of these actions, governments are often complicit in the violation of the rights of environmental defenders to assemble, organize, express their opinions, and seek to protect their rights. Governments might, for example, shift the narrative and label defenders as "enemies of the state" or "terrorists", employ the law to restrict, criminalize or persecute the activities of environmental defenders, use police or military units to carry out repression or assassinations, and allow impunity for violations of human rights to continue (Knox, 2017).

There is evidence that similar issues have been experienced by ocean defenders. For example, in Honduras in 1995, Jeanette Kawas-Fernandes was killed for her work to protect a 40 kilometer area of the coast that was also important for development projects (Inter-American Court of Human Rights, 2009; Tanner, 2011). Environmental activist Jorge Varela - who was awarded the Goldman Environmental Prize in 1999 for his campaign against mangrove destruction due to shrimp farming in Honduras - received multiple death threats and two members of his NGO (CODDEFFAGOLF) were killed (Goldman Prize, 2022). In Costa Rica in 2013, Jairo Mora Sandoval was threatened, then later beaten and shot in front of international volunteers, for protecting a sea turtle nesting beach from illegal poaching (The Tico Times, 2016; Knox, 2017). Following protests from local women's and small-scale fishing groups after a mass intoxication event at the 'sacrifice zone' associated with the Ventanas Industrial Complex in the Quintero-Puchuncavi region of Chile, the fisher folk leader Alejandro Castro died under highly suspicious circumstances (Macarena, 2018; Manuschevich and Meynen, 2018; EJAtlas, 2019). In the Philippines, at least eight fisherfolk leaders and members have been killed between 2017-2021 (PAMALAKAYA, 2021b). This includes the murders of Ariel and Chai Evangelista - who had long been actively opposing coastal land use conversion - during a raid by police and military forces in 2021 during which 9 activists were assassinated and 6

others arrested (PAMALAKAYA, 2021a). Multiple Indigenous leaders associated with the Defense Committee of Indigenous Peoples (CODEDI) have been jailed, attacked and killed in the Oaxaca region of Mexico due to their activism against displacement by the construction of luxury hotels for coastal tourism and beach privatization (Talledos Sánchez, 2012; EJAtlas, 2022). These examples are just the "tip of the iceberg": we do not know the true scale and geographic distribution of the repression, violence, and murders being experienced by ocean defenders due to a historial lack of attention to the marine and coastal environment in efforts to document the plight of environmental defenders (Bennett et al., 2022). What is more, these assassinations of ocean defenders often occur after these individuals and groups have already been subject to surveillance, campaigns to delegitimize their efforts, arrests and imprisonment, and threats against them and their families.

Protecting human rights in the ocean and safeguarding ocean defenders

Despite these increasing threats to human rights in, related to and dependent on marine and coastal environments and the worrisome plight of ocean defenders, these issues remain relatively "out of sight and out of mind" for international policy, non-governmental, academic and philanthropic organizations. We urge greater scrutiny of these overlapping issues through the lens of human rights. Below, we discuss six specific areas that require urgent attention by states to comply with existing international human rights law, as well as for the private sector and civil society to meet their legal and moral obligations to respect and protect human rights in, related to and dependent on marine and coastal environments, including by recognizing, supporting and safeguarding ocean defenders (Table 2).

First, national governments must strengthen mechanisms that advance human rights - including by addressing ocean governance gaps to enable the proactive identification and prevention of environmental and human rights issues that are being produced by ocean development activities. According to their obligations under the International Bill of Human Rights (UDHR, ICESCR, and ICCPR), states have a responsibility to create strong legislative, effective accountability, and independent legal mechanisms to promote, respect, protect and fulfill universally recognized human rights and fundamental freedoms (United Nations, 1998). With regards to protection of human rights to a clean, healthy, and sustainable environment (which includes the ocean), states should: a) establish laws, policies and institutions that contribute to substantive, non-retrogressive and non-discriminatory protection of the marine environment; b) ensure that there is effective monitoring, investigation, and enforcement of environmental and human rights standards; and c) provide access to justice and effective remedies (e.g., judicial, legislative, administrative, or other effective grievance mechanisms) for violations of human rights and environmental laws (Knox, 2018b; United Nations, 2022). Laws and policies on the protection of the marine environment from ocean development activities should focus on preventive and precautionary measures to proactively reduce environmental harms and human rights impacts (Boyd and Orellana, 2022). Conducting environmental and socio-cultural impact assessments, as well as ongoing monitoring, is essential to raise red flags for government decision-makers related to potential environmental and human rights issues in fisheries and other sectors of the ocean economy (Nakamura et al., 2022). At the same time, purposeful, negligent, or accidental infringements on human rights arising from the ocean economy (e.g., violent dispossession,

TABLE 2 Urgent areas of action to protect human rights in and related to the ocean and to safeguard ocean defenders.

Urgent areas of action to protect human rights in and related to the ocean and to safeguard ocean defenders
1. States must fulfill their obligation through strengthening legislative, accountability, and legal mechanisms to respect, protect, and fulfill human rights and addressing ocean governance gaps to enable the identification, prevention and remediation of environmental and human rights issues in the ocean economy.
2. Businesses operating in the ocean economy must embrace their responsibility to respect human rights according to international law, through articulating clear policies, implementing due diligence procedures, establishing processes to prevent harms, creating grievance mechanisms, and providing access to effective remedies where abuses have occurred.
3. States and businesses should pay greater attention to procedural rights - including the right to participation, information, and access to justice - in ocean policy-making and management decisions related to ocean development, especially for vulnerable or marginalized groups.
4. States and the private sector need to increase recognition, improve protection of the specific rights of Indigenous Peoples, small-scale fishers, and other traditional coastal populations due to their distinctive connection to and dependence on the ocean.
5. States, the private sector, and civil society organizations must recognize, support, respect and safeguard the rights and fundamental freedoms of the individuals, groups, and communities (i.e., "ocean defenders", "environmental defenders") who are working to protect the marine and coastal environment and their human rights.
6. Non-governmental, academic, media, legal and philanthropic organizations supporting the work of ocean defenders should recognize, respect, center and promote their political autonomy, agency, and agenda.

fisheries declines impacting livelihoods, marine pollution impacts on health, among others) cannot be allowed to proceed with impunity, and perpetrators must be held to account (Knox, 2018b; Boyd and Orellana, 2022). In line with the *Framework Principles on Human Rights and the Environment* (Knox, 2018b) and the underlying human right of freedom from discrimination recognized in UDHR, ICCPR & ICESCR, states also have a specific duty to protect historically disadvantaged, vulnerable or at risk groups from discrimination and harm to the marine environment (Knox, 2018b; Boyd and Orellana, 2022). Finally, states have a responsibility to protect against human rights abuses by third parties - and thus should provide guidance to businesses, ensure they are aware of their obligations, and have laws requiring mandatory human rights and environmental human rights due diligence by companies including those working nationally and those domiciled in states but working elsewhere (UN Human Rights Office of the High Commissioner, 2011; Knox, 2018b). The question of private foreign investors, with growing interest in the ocean economy, requires particular attention by governments due to the protection afforded by international investment law (Cotula and Berger, 2020). On the whole, the substantive environmental issues and human rights violations in the ocean are not an isolated set of issues, but rather a global pattern that is being perpetuated by lax regulation, oversight, enforcement, and failure to act on international commitments and obligations in many countries. These gaps in ocean governance need to be addressed to protect the environment and the human rights of coastal and ocean-dependent populations.

Second, businesses have a responsibility to protect and respect human rights according to international law, and provide access to effective remedies where abuses have occurred (UN Human Rights Office of the High Commissioner, 2011; Knox, 2018b; Boyd and Orellana, 2022). Extractive industries in the ocean economy should consider human rights responsibilities set out in the *Voluntary Principles on Security and Human Rights, UN Guiding Principles on Business and Human Rights*, and the ocean-specific guidance provided under the *United Nations Global Compact*, and the *Sustainable Ocean Principles* (Secretariat for the Voluntary Principles on Security and Human Rights, 2000; UN Human Rights Office of the High Commissioner, 2011; UN Global Compact, 2021; UN Global Compact, 2022). Specific responsibilities and recommendations for businesses include: establishing and communicating an explicit policy commitment, clear expectations, and procedures regarding human rights; carrying out ongoing due diligence processes to identify and assess adverse impacts on human rights, as well as integrating and acting on this information through preventing and mitigating possible harms, and accounting for and communicating how they address impacts on human rights; and, providing or cooperating on grievance mechanisms and clear processes to remedy adverse impacts (UN Human Rights Office of the High Commissioner, 2011). Non-judicial grievance mechanisms might be established by businesses or industry associations - but they must be legitimate, accessible, predictable, equitable, transparent, rights-compatible, and embody continuous learning (UN Human Rights Office of the High Commissioner, 2011). International financial institutions - e.g., World Bank, regional development banks - are often complicit, and display surprising gaps between human rights commitments and application on the ground (Forst, 2016). Financial institutions investing in the ocean economy need to adopt and implement zero tolerance environmental and social safeguards to ensure their investments are not contributing to human rights abuses in the ocean.

Third, greater attention is needed to procedural rights in ocean policy-making and decisions related to development. Procedural rights - including the right to participation, information, and access to justice - are foundational for the proactive protection of substantive human rights and environmental human rights (Knox, 2018b; Boyd and Orellana, 2022). These obligations align with the provisions of the *Aarhus Convention* and the 'Escazú Agreement' (UNECE, 1998; United Nations, 2018). Participation needs to move beyond coercive or "rubber-stamping" consultation processes towards active involvement and genuine participation of potentially affected groups, which requires removing structural inequalities through providing adequate capacity and funding, culturally appropriate and accessible processes, as well as effective facilitation to ensure all voices are heard (Le Billon and Middeldorp, 2021). Free, prior and informed consent (FPIC) is a further requirement for groups whose rights might be affected (United Nations, 2007; FAO, 2015). Access to information is linked to the right to seek, obtain and impart information (Forst, 2016), enables effective participation and is a precursor to FPIC. Comprehensive information regarding the environmental and social impact of ocean development initiatives should be required by law, rigorously collected, transparently communicated, openly discussed and deliberated on (UNECE, 1998; UN Human Rights Office of the High Commissioner, 2011). All parties must have access to justice - an independent, rigorous, free or inexpensive, and accessible review procedure in a court of law or other impartial body established through law (UNECE, 1998). Power inequalities cut across all phases of participation and decision-making; as a result, additional steps may be required for women, rural or marginalized populations, and Indigenous peoples.

Fourth, there is a need for increased state and private sector recognition of, respect for and protection of the rights of Indigenous Peoples, small-scale fishers, and other traditional coastal and ocean-dependent populations. These groups of rights-holders require heightened levels of protection due to their historical discrimination and distinctive relationships with specific coastal or marine areas and resources (United Nations, 2007; FAO, 2015; Morgera and Nakamura, 2022). Specifically, states have a duty to protect the rights of these groups from the

potential impacts of marine policies or ocean development activities due to their connection to and susceptibility to impacts on their traditional territories, environments and associated human rights. For example, tenure and access rights are central to the realization of human rights to food, livelihoods, housing, rural development, and human dignity for coastal and small-scale fishing communities (FAO, 2012; FAO, 2015; Morgera and Nakamura, 2022). Therefore, there is a need to ensure that small-scale and artisanal fishers have adequate, secure, and culturally appropriate tenure and access rights to marine and fishery resources, to fishing areas, and to adjacent coastal lands (FAO, 2015). Recognizing and respecting the rights of Indigenous Peoples and traditional communities obligates states and businesses to: recognize lands, territories and resources owned, occupied and used by communities; consult and obtain free, prior and informed consent prior to approving development initiatives that impact the aforementioned; identify and not arbitrarily displace access and tenure rights; respect and integrate traditional knowledge and practices into decisions; and fairly and equitably share benefits from the use of those territories and resources (ILO, 1989; United Nations, 2007). Moreover, there is a need for greater recognition of and awareness of how the rights of Indigenous Peoples and small-scale fishers extend into the ocean - and apply both to oceanic territories and marine resources. Business, international financial institutions, and non-governmental organizations working in the marine environment should be expected to respect these international human rights standards in their conduct.

Fifth, the rights of the individuals, groups, and communities who are working to defend the marine and coastal environment and human rights must be recognized, supported and safeguarded, even if they do not self-identify as 'environmental human rights defenders', 'environmental defenders' or 'ocean defenders' (Knox, 2018b). When the preventative measures such as those mentioned above do not succeed, all people must have the right to assert and advocate for their universal human rights, including environmental human rights, and fundamental freedoms (United Nations, 1998; Knox, 2017; Boyd and Orellana, 2022). States have an obligation and businesses, financial institutions and civil society organizations have a responsibility to support and protect those who are defending human rights and freedoms from violations by both state and non-state actors (Forst, 2016). In general, state protections should be in place to ensure freedom of expression, association, assembly, and peaceful protest (United Nations, 1998; Knox, 2017). Specifically, states must: adopt and implement laws that protect human rights defenders; publicly recognize the societal contributions of human rights defenders and ensure their efforts are not criminalized or stigmatized; develop effective programmes for protection and early warning; provide appropriate training for law enforcement officials; ensure prompt and impartial investigation of threats and violations; prosecute alleged perpetrators; and provide for effective remedies for violations (Sekaggya, 2011; Sekaggya, 2013; Forst, 2016; Knox, 2018b). Similarly, actions to support and safeguard environmental defenders include creating an enabling and safe environment for and actively protecting them (Khanna and Le Billon, 2021). Not only should ocean defenders be able to operate without threats, harassment, intimidation and violence, their work should be publicly recognized and encouraged (Knox, 2018b). Ocean defenders must be allowed to communicate with international bodies, including the media, to access funding, and to access effective remedies and reparations (Knox, 2017). Collective security measures by ocean defenders' communities must be recognized and respected by the state and corporations (Orellana, 2020). To protect the safety of ocean defenders, governments must provide accessible, independent and impartial mechanisms and bodies (e.g., national human rights tribunals or commissions) for environmental human rights defenders whose rights are being threatened or violated to register complaints and report grievances (Forst, 2016). Investigations should be prompt, independent and impartial - and results made public (Forst, 2016; Knox, 2017). Importantly, perpetrators of crimes against ocean defenders - from harrassment to threats and murders - must be brought to justice and punished; otherwise, impunity appears to beget a vicious cycle of corruption where these types of heinous and unconscionable actions continue in certain countries and geographical contexts (Le Billon and Lujala, 2020; Front Line Defenders, 2022; Global Witness, 2022).

Finally, a foundational aspect of protecting the rights of ocean defenders is to recognize, respect, center and support their political autonomy, agency and agenda. Coalitions of different organizations - including non-governmental, academic, media, legal and philanthropic organizations - can play a role in supporting the agenda and work of ocean defenders through documenting their rights, raising their profile, advocating for and helping set up strategies for their own protection, supporting individual and collective capacity building efforts, accessing legal and financial resources, facilitating access to media, creating safe digital and physical spaces, and helping to create collaborative platforms and networks for sharing and learning (Forst, 2016; Knox, 2017; ALLIED, 2021). However, these coalitions and organizations should be cautious to take direction from ocean defenders on how to best support their actions and agenda, and not produce further risks with interventions implemented from outside (Forst, 2016; Knox, 2017; ALLIED, 2021).

Conclusion

Rapid unchecked growth of human activities in the ocean is producing numerous human rights issues around the globe. In the face of these substantive threats, ocean defenders are

advocating for and trying to protect their human rights, including their right to a clean, healthy and sustainable ocean. For their efforts, ocean defenders are often facing further marginalization, criminalization, threats, violence and even murder. The situation facing ocean defenders represents a dual failure of governments, the private sector and civil society. Under international law, states have obligations to protect the fundamental and inalienable human rights of all people who are connected to and depend on the ocean. The private sector and civil society organizations also have a responsibility to respect human rights, including environmental human rights related to the marine and coastal environment. Furthermore, individuals and communities must have the right to organize, advocate and peacefully protest for the protection of the ocean environment and against violations of human rights in the ocean. Yet, we still do not have a complete picture of how these issues are unfolding in relation to the oceans. Moreover, greater attention is needed globally to understanding, increasing the visibility and profile of, and preventing or remedying human rights issues related to the ocean and the plight of ocean defenders. Ocean defenders are doing the critical work of advancing a vision of a just and sustainable ocean.

Author contributions

NB: Funding acquisition, Conceptualization, Investigation and analysis, Writing - original draft; RL: Investigation and analysis, Writing - review & editing; PLB: Funding acquisition, Investigation and analysis, Writing - review & editing; IE: Investigation and analysis, Writing - review & editing; EM: Investigation and analysis, Writing - review & editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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Active hydrothermal vent ecosystems in the Indian Ocean are in need of protection

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Deep-sea hydrothermal vent fields are among the most pristine and remarkable ecosystems on Earth. They are fueled by microbial chemosynthesis, harbor unique life and can be sources of precipitated mineral deposits. As the global demand for mineral resources rises, vent fields have been investigated for polymetallic sulfides (PMS) and biological resources. The International Seabed Authority (ISA) has issued 7 contracts for PMS exploration, including 4 licenses for vent fields in the Indian Ocean. Here, we provide a summary of the available ecological knowledge of Indian vent communities and we assess their vulnerability, sensitivity, ecological and biological significance. We combine and apply scientific criteria for Vulnerable Marine Ecosystems (VMEs) by FAO, Particular Sensitive Sea Areas (PSSAs) by IMO, and Ecologically or Biologically Significant Areas (EBSAs) by CBD. Our scientific assessment shows that all active vent fields in the Indian Ocean appear to meet all scientific criteria for protection, and both the high degree of uniqueness and fragility of these ecosystems stand out.

KEYWORDS

hydrothermal vent fields, Indian Ocean, deep-sea mining, vulnerable marine ecosystems (VMEs), ecologically or biologically significant areas (EBSAs), particularly sensitive sea areas (PSSAs), International Union for Conservation of Nature (IUCN)

1 Introduction

1.1 Ecology of hydrothermal vent ecosystems

Deep-sea hydrothermal vent ecosystems are exceptional habitats teeming with exotic life. Like oases in the desert, they are small but immensely productive hotspots on the otherwise barren seafloor. These dynamic ecosystems are located in geologically and tectonically active areas of the ocean, such as mid-ocean ridges, back-arc basins, and submarine volcanic arcs (Hannington et al., 2005; Beaulieu et al., 2013; Gollner et al., 2017). The release of geothermally heated fluid from the ocean crust supports chemosynthetic microbial communities that use reduced compounds from the vent fluids as energy to fix carbon

and produce organic compounds that sustain high growth of fauna. A vent field usually covers multiple active or (temporarily) inactive vent sites with a shared subsurface circulation (Jamieson and Gartman, 2020). When hydrothermal fluids come into contact with the cool ocean water, polymetallic sulfide deposits (PMS) are formed as minerals from the fluid precipitate (von Damm, 1995; Hannington et al., 2005). Differences in geophysical settings, fluid chemistry, and fluxes in vent flow lead to high spatial and temporal variations of geochemical and physical nature in vent fields (Lutz and Kennish, 1993).

Hydrothermal activity creates a mosaic of microhabitats with distinct faunal zonations along the physicochemical gradient (Marsh et al., 2012; Watanabe and Beedessee, 2015; Copley et al., 2016; Galkin, 2016). Chemoautotrophic microbes form the basis of the food web, supporting dense aggregations of chemosynthetic macrofauna and primary and secondary consumers (Grassle, 1987). Vent species are physiologically well adapted to the unstable and extreme vent environment, such as to rapid and intense temperature shifts, a low pH, low oxygen concentrations, and high heavy metal exposure (Minic et al., 2006; Ramirez-Llodra et al., 2007). High growth rates, high biomass, and low faunal diversity are typical for vent assemblages (Grassle, 1985). The vast majority of taxa are vent-obligate (endemic), and communities drastically change when hydrothermal discharging ceases (van Dover, 2001; Gollner et al., 2020).

The ecosystem description of a "hydrothermal vent" can be as broad as the description "forest" (Thaler and Amon, 2019). Forests range from tropical to boreal, and vent systems are as diverse in their chemical, geological, and physical properties. Although every vent field is unique, distinct biogeographic provinces do exist, which are characterized by their dominant species and overall community structure (Mullineaux et al., 2018). The Indian Ocean has been considered to be one of these biogeographic provinces (Moalic et al., 2012).

The Indian Ocean has four mid-ocean ridges with intermediate to ultraslow spreading rates (Moalic et al., 2012; Rogers et al., 2012). Kairei on the Central Indian Ridge was the first vent field discovered in this province at the beginning of the 21st century (Hashimoto et al., 2001). Since then, another 12 active vent fields have been discovered in the region (Figure 1). The Indian Ocean has been hypothesized as an ecological corridor between Atlantic and Pacific vent populations, with a closer relation to the West Pacific metacommunity (van Dover, 2001; Watanabe and Beedessee, 2015). The mussel *Bathymodiolus marisindicus* and shrimp *Rimicaris kairei* are two dominant species that closely resemble their Atlantic counterparts (Hashimoto, 2001; Watabe and Hashimoto, 2002). Other common fauna are bythograeid crabs, neolepas barnacles, alviniconcha snails, and actinostlid anemones, all reminiscent of the West Pacific. However, several species are unique to the Indian Ocean communities such as most notably the scaly-foot snail *Chrysomallon squamiferum* (Warén et al., 2003; Chen et al., 2014).

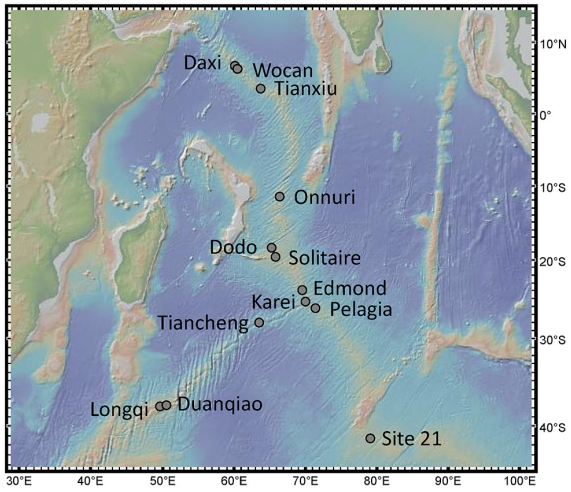

FIGURE 1
Location of the 13 active confirmed hydrothermal vent fields in the Indian ocean. Map created with GeoMapApp.

1.2 Exploration of polymetallic sulfide deposits and governance

Since the first discovery of a hydrothermal ecosystem in 1977, nearly 700 vents have been reported globally (Wang et al., 2021).

The interest for deep-sea mining has accelerated accordingly due to an increased metal demand (Wedding et al., 2015). At vent fields, mineral resources are found in the form of polymetallic sulfide (PMS) deposits, which are also known as seafloor massive sulfides (SMS) (Levin et al., 2016b). The International Seabed Authority (ISA) is in charge of regulating all mining-related activities in the Areas Beyond National Jurisdiction (the *Area*) under the United Nations Convention on the Law of the Sea (UNCLOS)[1]. The ISA has the obligation to ensure that human activities in the international seabed are carried out for the benefit of humankind as a whole and to protect the marine environment from harmful impacts caused by resource extraction activities[2]. At present, the ISA has issued three licenses for PMS exploration on the northern Mid-Atlantic Ridge and four licenses on the Indian mid-ocean ridges[3]. The four contractors are the German Federal Institute for Geosciences and Natural Resources (BGR), the China Ocean Mineral Resources Research and Development Association (COMRA), the Ministry of Earth Sciences from the Government of India, and the Government of the Republic of Korea. Each contract area covers 10,000 km^2 of which 75% will be relinquished. The contract areas of COMRA are on the South-West Indian Ridge, of the Government of India on the South-West Indian and the Central Indian Ridge, of BGR on the Central and South-East Indian ridge, and of The Government of the Republic of Korea on the Central Indian Ridge. Currently, 8 from the 13 confirmed active vent fields in the Indian Ocean (Longqi, Duanqiao, Tiancheng, Onnuri, Dodo, Kairei, Edmond, and Pelagia) are within those contract areas (Perez et al., 2021).

1 https://www.isa.org.jm/about-isa.

2 https://www.isa.org.jm/.

3 https://isa.org.jm/index.php/minerals/exploration-areas.

Mining activities may disturb vent ecosystems in an unprecedented manner on spatial and temporal scales (Gollner et al., 2017). Vent ecosystems on slow and ultraslow spreading ridges, such as those in the Indian Ocean, tend to be more stable and their biological communities are less exposed to natural disturbance events such as major volcanic eruptions than ones on fast spreading ridges (Gollner et al., 2017; van Dover et al., 2018). No disturbance experiments have been performed to mimic mining at vent ecosystems in the *Area*, but it is expected that mining would have severe consequences. Direct mining impacts may include removal of substrate and fauna, causing habitat loss, habitat fragmentation, and habitat modification, leading to loss of biodiversity at all levels: genetic, species, functional, and habitat (Levin et al., 2016b). Other direct mining impacts include light, sound, and electromagnetic exposure from mining equipment (Chen et al., 2021b) as well as changes in vent fluid flow (Kawagucci et al., 2013). Mining plumes can also create indirect mining impacts such as increased heavy metal load or high turbidities following sediment resuspension (Weaver et al., 2022). While it is expected that harm will be done to vent communities dependent on PMS as substrate, the ramifications extend beyond the local sphere (Levin et al., 2016a). Low recolonization of fauna in the vicinity of vents has been previously observed after a disturbance, likely due to lower resilience of those species (Gollner et al., 2015). In a wider region surrounding the vent, resuspension of potentially toxic sediment and returning plumes from the surface operational ship could affect both benthic and pelagic life.

The International Seabed Authority has been developing Regional Environmental Management Plans (REMP) for PMS at the northern Mid Atlantic Ridge (nMAR) and is planning to develop REMP for the Indian Ocean. A draft for the nMAR REMP has been released for stakeholder consultation on the 19th April 2022 (Lee, 2020), whilst a first workshop focusing on scientific issues related to REMP development in the Indian Ocean Region (IOR) has been co-organized by ISA, COMRA and Hong Kong University of Science and Technology.

In this study, we evaluate whether the confirmed active vent fields at the Indian mid-ocean ridges meet scientific criteria for protection from anthropogenic impacts, through a comprehensive review of the scientific literature, and a comparison of available baseline information of each vent field against criteria developed by the Food and Agricultural Organization (FAO) for Vulnerable Marine Ecosystems (VMEs), the Convention on Biological Diversity (CBD) for Ecologically or Biologically Significant Areas (EBSAs), and the International Maritime Organization (IMO) for Particularly Sensitive Sea Areas (PSSAs), following the same procedure as described in Gollner et al. (2021) for active vents fields under mineral exploration at the nMAR. All active vent fields of the IOR appear to be vulnerable and significant ecosystems.

2 Methods

In this study, we assessed 13 vent fields with confirmed activity from the Indian mid-ocean ridges from the Carlsberg Ridge (CR) to the Central Indian Ridge (CIR), the South-East Indian Ridge (SEIR), and the South-West Indian Ridge (SWIR): Daxi, Wocan, Tianxiu, Onnuri, Dodo, Solitaire, Edmond, Kairei, Pelagia, Tiancheng, Duanqiao, Longqi, and Site 21 (Figure 1).

The search engines Google Scholar and Scopus were used to collect scientific literature in November and December 2021, and June 2022, using English key words for our searches, which limited our search solely to publications in English. The following key words were used: "hydrothermal activity", "hydrothermal field", "vent fauna", "vent-endemic biota", "Indian Ocean", "Indian mid-ocean ridge", "deep-sea mining", "polymetallic sulfide", "mineral extraction", "resilience", the names of all Indian mid-ocean ridges, and individual vent fields. Additional literature used in this review was found through the references of initially selected articles. Furthermore, the search engine Ecosia was used to acquire general information from organizations such as the ISA, FAO, CBD, IMO, and IUCN, and to gain access to their online documents.

We first review the main ecological findings and shortly discuss i) the discovery and exploration of the vent field, ii) the geochemical setting, and then focus on iii) the biological composition. Regarding vent biodiversity, we focused on macro- and megafauna.

Scientific criteria for identifying hydrothermal ecosystems in the Indian Ocean in need of protection follow the determination as used in "Application of scientific criteria for identifying hydrothermal ecosystems in need of protection" for nMAR vents to evaluate ecosystem vulnerability and significance by Gollner et al. (2021) (Appendix 1). Criteria include 1) uniqueness and rarity, 2) functional significance, 3) fragility, 4) life-history traits of component species that make recovery difficult, 5) structural complexity, 6) biological diversity, 7) biological productivity, 8) naturalness, and 9) ecosystem services. The criteria have been derived from the guidelines for identifying VMEs from the FAO (FAO, 2009), EBSAs from the CBD (CBD, 2009), and PSSAs from the IMO (IMO, 2005). One PSSA criterion (social, cultural and economic criteria: Social or economic dependency, human dependency, cultural heritage) was not included in the scoring, but rather an Ecosystem Services criterion was proposed as a more relevant addition (Gollner et al., 2021). There is a precedent for applying ecosystem services in a deep-sea context, which entails supporting, provisioning, regulating, and cultural services (Earth Economics, 2015; Levin et al., 2016a; Le et al., 2017; van Dover et al., 2018; Turner et al., 2019; Orcutt et al., 2020).

Based on the literature review, both vent-specific and general information on 12 vents is used to determine if each vent field meets the scientific criteria for protection. For vent "Site 21", there are only 2 references available – one on detection of plume anomaly and another on the collection of vent-endemic *Neolepas* barnacles with a dredge (Watanabe et al., 2018). Although these findings indicate that Site 21 shall be a confirmed active vent, we decided to exclude it in our assessment because of the lack of visual observation which complicates the scientific analyses of many criteria.

3 Results

3.1 Review of main ecological findings of IOR vent fields

An overview of different geochemical and biological characteristics for each vent field is listed in Table 1. The 13 active vents in the Indian Ocean occur across a depth range of ~2000 meters (from 1732 to 3690) along ~48° from the Northern to the Southern hemisphere, spanning four mid-ocean ridges.

TABLE 1 Selected attributes of 12 active vent fields in the Indian Ocean, based on the literature used in this review.

ATTRIBUTE	CR			CIR					SEIR	SWIR		
	Daxi	Wocan	Tianxiu	Onnuri	Dodo	Solitaire	Edmond	Kairei	Pelagia	Tiancheng	Longqi	Duanqiao
Latitude	6°48′N	6°22′N	3°39'N	11°25'S	18°20'S	19°33'S	23°53'S	25°19'S	26°09'S	27°57'S	37°47'S	37°39'S
Longitude	60°18'E	60°31'E	63°45'E	66°25'E	65°28'E	65°50'E	69°36'E	70°02'E	71°26'E	63°32'E	49°39'E	50°24'E
Depth (m)	3450	2973-3105	3500	1990-2170	2745	2606	3290-3320	2415-2460	3680-3690	2682-2729	2755	1732
Host Rock	Basalt	Basalt	Serpentized harzburgite	Peridotite, grabbro	Fresh basalt	Basalt	Basalt	Basalt serpentized troctolite	n.d.	Basalt	Basalt	Basalt
Mineral	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide	Sulfide
Tmax (°C)	273°C	358°C	"high"	242°C	356°C	307°C	382°C	369°C	368°C	"high"	379°C	277°C
pHmin	n.d.	n.d.	n.d.	n.d.	3.3	4.4	3.1	3.3	3.2	n.d.	3.6	n.d.
[H2S]max	n.d.	n.d.	n.d.	n.d.	2.80	4.75	4.81	6.06	n.d.	n.d.	n.d.	n.d.
[CH4]max	n.d.	n.d.	"high"	n.d.	0.025	0.043	0.22	0.20	n.d.	n.d.	0.41	n.d.
[H2]max	n.d.	n.d.	n.d.	n.d.	2.2	0.43	0.12	8.5	n.d.	n.d.	0.21	n.d.
Taxa presence												
Alvinoconcha spp. snail	Absent	Dominant	Dominant	Dominant	Absent	Present	Present	Present	Dominant	Present	Absent	Absent
Chrysomallon squamiferum snail	Absent	Present	Absent	Present	Absent	Present	Absent	Present	Present	Dominant	Dominant	Present
Bathymodiolus marisindicus/septemdierum mussel	Absent	Present	Present	Dominant	Absent	Present	Absent	Dominant	Present	Dominant	Dominant	Dominant
Neolepas marisindica barnacle	Absent	Present	Present	Present	Absent	Present	Absent	Present	Present	Dominant	Dominant	Present
Rimicaris kairei shrimp	Dominant	Dominant	Dominant	Present	Dominant	Dominant	Dominant	Dominant	Dominant	Absent	Present	Absent
Mirocaris indica shrimp	Present	Present	Present	Present	Absent	Present	Present	Present	Present	Present	Present	Absent
Austinograea spp. crab	Present	Present	Present	Present	Dominant	Present	Present	Present	Dominant	Dominant	Absent	Absent
IUCN (critically) endangered or vulnerable species	Absent	Present	Present	Present	Absent	Present	Present	Present	Present	Present	Present	Present

[]: concentration in mmol kg^{-1}, end-member fluid; n.d.: no data.

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3.1.1 Vent fields of the Carlsberg Ridge

The CR, which is also referred to as the North-West Indian Ridge or the northern section of the CIR, is a divergent tectonic plate boundary between the Somalic plate and the Indian plate. It borders the CIR in the south and the Owen Transform Fault in the north and has a slow spreading rate of 22 - 32 mm per year (Ray et al., 2012). Daxi, Wocan, and Tianxiu active vent fields were found on the CR over the last 10 years. In total, 34 species have been recorded in these three vent fields (Zhou et al., 2022). The benthic communities in Tianxiu and Daxi fields appear to be subsets of those in Wocan, with a high genetic connectivity among the three vents (Zhou et al., 2022). It was suggested that biological communities in the CR vents form a separate province from those in the CIR and SWIR, based on differences in faunal composition and clear genetic clustering of species among these ridges (Zhou et al., 2022). Although the CR shares some community characteristics with the CIR, the prominent presence of polychaetes sets the CR metacommunity apart (Zhou et al., 2022). Interestingly, 2 polychaete species found on the CR have been grouped into clades with their East Pacific congeners, elucidating a direct biogeographic linkage between the CR and distant East Pacific metapopulation (Zhou et al., 2019).

3.1.1.1 Daxi (6°48′N, 60°10′E, 3450m)

The basalt-hosted Daxi vent field was discovered during the Dayang (DY33) cruise of COMRA in 2015 (Wang et al., 2021). Three mounts are located in this vent field and at least one of them accommodates clusters of active black smokers at the top (Wang et al., 2021). Eight chimney complexes ranging from several to more than 10 meters were seen, some discharged their fluids vigorously and others slowly (Wang et al., 2021).

The vent community at Daxi consisted of 15 recognized megafaunal species which are a subset of the community at Wocan (Zhou et al., 2022), and was dominated by alvinocaridid shrimps, polychaetes, and crabs (Wang et al., 2021). The shrimp *Rimicaris kairei* was very dominant nearby hydrothermal activity while actinostlid anemones were common at the periphery. The alvinellid worm *Paralvinella mira* was endemic in the Daxi and Wocan vent fields, with lower abundances at Daxi (Han et al., 2021). The alvinellid strongly resembles 2 species, *P. hessleri* and an unnamed species *Paralvinella* sp. ZMBN, from the West Pacific (Han et al., 2021). *Austinograea rodriguezensis* crabs, *Munidopsis* lobsters, and shrimps resembling *Mirocaris indica* were also present at Daxi, while other typical Indian vent species, such as *Chrysomallon squamiferum* scaly-foot snails, *Alviniconcha marisindica* hairy snails, *Bathymodiolus marisindicus* mussels, and *Neolepas marisindica* stalked barnacles, were absent (Wang et al., 2021). A recently described novel neolepetopsid limpet, *Neolepetopsis prismatica* and a potentially new *Desbruyeresia* species were found so far exclusively in this vent field (Chen et al., 2021c; Zhou et al., 2022).

3.1.1.2 Wocan (6°22′N, 60°31′E, 2973-3105m)

Wocan was the first vent field discovered on the CR during the COMRA's DY28 cruise with the Research Vessel (RV) *Zhukezhen* in 2013 (Wang et al., 2017). TV-sled and TV-grab observations revealed the existence of two vent sites: Wocan-1 (~450 x 400 m) and ~1.7km to the northwest Wocan-2 (~200 x 400 m) (Qiu et al., 2021). During the COMRA's DY38 cruise in 2017, a cluster of 17 active black smokers in Wocan-1 and a low-temperature diffuse flow area at Wocan-2 were confirmed (Qiu et al., 2021). Inactive (collapsed) chimneys, hydrothermal sediments, and sulfide talus were also found at Wocan-1 (Qiu et al., 2021).

Around the active vents, many vent-endemic species were discovered, including alvinocaridid shrimps, bythograeid crabs, actinostlid anemones, bathymodiolin mussels, and alviniconcha snails (Qiu et al., 2021). A potentially new shrimp species from the genus *Rimicaris* was recovered from Wocan (Zhou et al., 2022). The annelid *Amphisamytha wocanensis* was also found solely at Wocan, which surprisingly fell into a clade with species from the East Pacific (Zhou et al., 2019). A third polychaete observed at Wocan was the alvinellid worm *Paralvinella mira*, which was associated with *Alviniconcha* and *C. squamiferum* snails at at this vent field (Han et al., 2021). Strikingly, *P. mira* and *Hesiolyra heteropoda* were highly abundant and form an alvinellid-/hesionid-polychaete worm dominated assemblage unique to the Indian Ocean (Han et al., 2021).

3.1.1.3 Tianxiu (3°7′N, 63°8′E, 3500m)

The ultramafic-hosted Tianxiu was also discovered during the COMRA's DY33 cruise in 2015 with a TV-sled and TV-grab (Chen et al., 2020). Black smoker chimney complexes, low-temperature diffuse vents, inactive massive sulfides, and hydrothermal sediments all occurred at Tianxiu (Zhou et al., 2022). A total of 12 megafaunal species were reported from the Tianxiu field, including *Alviniconcha marisindica* snails, *Neolepas marisindica* barnacles, *Bathymodiolus marisindicus* mussels, and a new crab species *Austinograea* sp. CR, and all of them were also found in the Wocan field (Zhou et al., 2022).

3.1.2 Vent fields of the Central Indian Ridge

Vent fields of the CIR are the most comprehensively studied among all the vents reported on the Indian mid-ocean ridges. The CIR borders the CR in the north and meets the SEIR and the SWIR at its most southern point in the Rodriguez Triple Junction (RTJ). The CIR has an average full spreading rate of 48 mm per year, which is moderate to slow spreading (Kumagai et al., 2008; Perez et al., 2021). To date, five active vent fields have been reported, including Onnuri, Dodo, Solitaire, Edmond, and Kairei (Hashimoto et al., 2001; van Dover et al., 2001; Tamaki, 2010; Nakamura et al., 2012; Ryu et al., 2019).

CIR vent communities show an immense diversity, including different morphotypes of *Chrysomallon squamiferum*. This scaly-foot snail hosts endosymbiotic sulphur-oxidizing bacteria (SOB) in its esophageal gland, which is rather unique among molluscs (Goffredi et al., 2004). Other characteristic CIR species are *Rimicaris kairei, Mirocaris indica*, and *Bathymodiolus marisindicus*, which are endemic to the Indian Ocean (Hashimoto et al., 2001; Watabe and Hashimoto, 2002; Komai et al., 2006). Furthermore, the vent-endemic polychaetes were discovered at Solitaire on the CIR (Nakamura et al., 2012). The copepod family Dirivultidae is the most species rich invertebrate family found in vent fields, yet members from this family have been hardly recorded at four Indian vent fields, three of which are located on the CIR (Gollner et al., 2010; Gollner et al., 2016; Lee et al., 2020; Sun et al., 2020). Onnuri, Solitaire, and Kairei

clearly emerge as extraordinary ecosystems, considering the exceptional diversity reported so far in these vent fields. Edmonds community seems to be a subset of Kairei's and may comprise source populations of both *R. kairei* and *Alviniconcha* sp. hairy snails on the CIR (Beedessee et al., 2013). Dodo is a relatively young vent field, which may explain its relatively low colonization by vent-endemic species (Nakamura et al., 2012). It was recently suggested that the CIR together with the northern SWIR (Tiancheng) forms a separate province from the CR and southern SWIR, with multiple vent sites that are of equal importance to the species pool (Zhou et al., 2022).

3.1.2.1 Onnuri (11°24'S, 66°25'E, 1990-2170m)

The Onnuri vent field was first explored with a TV-grab during a cruise on the RV *ISABU* from the Korean Institute of Ocean Science and Technology (KIOST) in 2018 (Kim and Lee, 2020). The field is ultramafic-hosted and was thought to have diffusive, clear, and low-temperature fluids from cracks in the seafloor (Kim and Lee, 2020; Kim et al., 2020). However, high temperatures were recorded during a re-visit to Onnuri (Suh et al., 2022).

During the first expedition scientists identified 21 macrofauna taxa and 65 nematodes, which were mainly distributed around cracks in the seafloor from which the hydrothermal fluids were emitted (Kim et al., 2020). Onnuri was visually dominated by three species of bathymodiolus mussels, *Bathymodiolus marisindicus, Bathymodiolus* sp.1, and *Gigantidas vrijenhoeki* as well as *Neolepas marisindica* barnacles (Jang et al., 2020; Kim et al., 2020). *G. vrijenhoeki* was associated with the scale worm *Branchipolynoe onnuriensis*, and both species were found exclusively at Onnuri (Jang et al., 2020). As the only member of the genus *Gigantidas* in the Indian Ocean, the *Gigantidas* mussel in Onnuri field is genetically closely related to two *Gigantidas* species from cold seeps in the Western Pacific (Jang et al., 2020; Ryu et al., 2021). This mussel species carries unique sulfur- and methane-oxidizing symbionts that differ in composition and are phylogenetically distinct from the symbionts of *B. marisindicus* at Onnuri (Jang et al., 2020). Besides *B. onnuriensis* and *G. vrijenhoeki* and their symbionts, many other organisms are only known from Onnuri. For example, Onnuri was the second Indian vent field from which copepods were retrieved so far, and the first with distinct species described alongside Solitaire (van Dover et al., 2001; Lee et al., 2020). This included a copepod species from the distant East Pacific, *Aphotopontius limatulus*, but also the novel species *Stygopontius spinifer* and *Aphotopontius kiost* which were found at Solitaire and Onnuri (Kim and Lee, 2020; Lee et al., 2020). Moreover, *Munidopsis lauensis, Smacigastes pumila, Alvinocaris markensis*, *Paralepetopsis ferrugivora*, *Lepetodirilus* sp. C, *Nereis* sp., and *Branchipolynoe seepensis* were absent at other Indian vent fields (Kim et al., 2020; Hwang et al., 2022). Three other taxa were known only from one other Indian vent field, *Archinome* sp. from Edmond (CIR), *Branchipolynoe* sp. from Kairei (CIR), and *Hesiolyra cf. bergi* from Longqi field (SWIR) (Kim et al., 2020). Besides the exceptional diversity of rare species, many taxa typical for Indian vents, including *Alvinocaris* shrimps, *Mirocaris* shrimps, *Austinograea* crabs, *Munidopsis* crabs, *Chrysomallon* snails, and *Alviniconcha* snails were present (Jang et al., 2020). Based on 16 retrieved taxa, seven trophic guilds, and four trophic levels have been recognized in the food web structure of Onnuri (Suh et al., 2022).

3.1.2.2 Dodo (18°20'S, 65°17'E, 2745m)

Dodo was visited during the cruise YK 09-13 on the RV *Yokosuka* of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in 2009, following the detection of plume anomalies in 2006 (Kawagucci et al., 2008; Nakamura et al., 2012). The vent field is located amid the Dodo Great Lava Plain, which is a flat stretch of seafloor covered with sheet flow lava (Nakamura et al., 2012; Nakamura and Takai, 2015). Black smoker chimneys in a diameter of 15 meters were observed to emit hydrothermal fluids in 2009, but discharging was not observed in 2013 (Nakamura et al., 2012; Kawagucci et al., 2016). The system was hosted by fresh basalt and there were three main chimneys (Kawagucci et al., 2016).

Few vent megafauna species were found at Dodo, making this community emaciated in comparison to the communities of other CIR vents (Nakamura et al., 2012). However, sparsely distributed *A. rodriguezensis* crabs, patches of *R. kairei* shrimps on chimneys, some *Marianactis* sea anemones, lepetodrilid limpets and provannid snails were observed (Nakamura et al., 2012). The hydrothermal activity is suspected to be very young, which may explain the low biomass and faunal diversity (Nakamura et al., 2012). Microbial populations, however, were very abundant at Dodo (Kawagucci et al., 2016). The microbial density was several orders of magnitude higher than that at the neighboring Solitaire field and also significantly higher than those previously observed (Kawagucci et al., 2016).

3.1.2.3 Solitaire (19°33'S, 65°51'E, 2606m)

Like Dodo, the basalt-hosted Solitaire was explored during the JAMSTEC cruise YK 09-13 in 2009 after plume anomalies were detected in 2006 (Kawagucci et al., 2008; Nakamura et al., 2012). Hydrothermal fluids were emitted from a larger area (~50 x 50 m) than that of Dodo but the size was comparable to Kairei and Edmond (Nakamura et al., 2012). Three main chimneys of more than 5 m in height with mounds at their bases were present on top of talus, and extensive diffuse flows occurred from the permeable and thick talus throughout the field (Nakamura et al., 2012).

The lush vent community at Solitaire is rich in genetic, morphologic, and species diversity (Beedessee et al., 2013; Watanabe et al., 2018). For example, Solitaire was the first vent field outside of the Pacific where alvinellid polychaetes were found. Apart from Wocan, it remains the only field from which alvinellid worms have been described (Nakamura et al., 2012; Han et al., 2021). The alvinellid worms co-occurred with the *C. squamiferum* scaly-foot snail (Han et al., 2021). The white "Solitaire type" scaly-foot snail differed from the Kairei and Longqi morphotypes since they lack iron sulfide on their sclerites and shell, because Solitaire's vent fluids were iron-depleted (Nakamura et al., 2012). The scaly-foot snails and alviniconcha hairy snails at Kairei live near low-temperature fluids, whereas they were present at chimneys emitting high-temperature diffuse fluids at Solitaire (Nakamura et al., 2012). Other typical endemic vent species of Solitaire community include *R. kairei*, *M. indica*, *Bathymodiolus* mussels with lepetodrillid limpets attached, phymorhynchus gastropods, undescribed scale worms, and *Neolepas marisindica* and *Eochionellasmus* sp. barnacles (Nakamura et al., 2012; Watanabe et al., 2018). Noteworthy were the two cohorts of different sized *A. rodriguezensis* crabs at Solitaire, as they could be the source population of these bythograeid species for the CIR (Beedessee et al., 2013). The presence of copepods was another special feature of

this Indian vent community, as copepod species were previously described for only one other Indian vent field (Lee et al., 2020). The East Pacific *Aphotopontius limatulus* was shared by Solitaire and Onnuri, as well as the novel *A. muricatus* and *Stygiopontius spinifer* (Lee et al., 2020). However, the novel *Benthoxynus constrictus*, *S. horridus* and *S. geminus* were exclusively found at Solitaire (Lee et al., 2020). The first sessile barnacle of the family Chionelasmatidae outside of the Pacific was also found at Solitaire, and this novel species *Eochionelasmus coreana* has only been recorded here (Chan et al., 2020). Furthermore, the rare deep-sea snail *Desbruyeresia marisindica* was unique to Solitaire and Kairei (Watanabe and Beedessee, 2015). Other deep-sea taxa occasionally observed outside of the venting area included *Macrourid* fish, *Marianactis* anemones, *Munidopsis* squat lobsters and sea cucumbers (Nakamura et al., 2012).

3.1.2.4 Edmond (23°53'S, 69°36'E, 3290-3320m)

The basalt-hosted Edmond was the second active Indian vent discovered during the Voyage 162-13 with the RV *Knorr* and the Remotely Operated Vehicle (ROV) *Jason* in 2001 (van Dover et al., 2001). The vent field of 100 x 90 m is located in an area with cross-cutting ridge-crest structures reminiscent of the Trans-Atlantic Geotraverse (TAG) field on the nMAR (van Dover et al., 2001). Old, disaggregated sulfides, massive sulfide talus, and orange-brown iron-oxyhydroxide sediments are characteristic of Edmond, while chimney formations and venting styles varied greatly (van Dover et al., 2001).

Edmond supported a dense vent community with thousands of *R. kairei* shrimps swarming the black smokers and marianactis anemones dominating the vent periphery (van Dover et al., 2001). *R. kairei* populations between Edmond and Kairei sites showed no genetic differentiation and the former was suggested to provide the larval supply for other CIR vents since that population had the broadest size distribution (Beedessee et al., 2013). Edmond is also regarded as the source population of *Alviniconcha* sp. 3 snails (Beedessee et al., 2013). *A. rodriguezensis* crabs, *Mirocaris indica* shrimps, *branchinotogluma* scale worms, and *phymorhynchus* snails were also prevalent at Edmond (van Dover et al., 2001; Komai et al., 2006). The neolepetopsid limpet *Eulepetopsis crystallina* collected from the Edmond vent field was recently described (Chen et al., 2021c). Additionally, chemolithoautotrophic and heterotrophic bacteria not known to other vents have been isolated from Kairei and Edmond sulfides (van Dover et al., 2001).

3.1.2.5 Kairei (25°19'S, 70°02'E, 2415-2460m)

Kairei was the first active vent field discovered in the Indian Ocean during a JAMSTEC cruise with the RV *Hakuho Maru* and ROV *Kaiko* in 2000 and is one of the most visited vent fields (Hashimoto et al., 2001; van Dover et al., 2001; Komai et al., 2006). The hydrothermal activity covered an area of 40 x 80 m containing at least seven active vent sites with massive PMS deposits, including individual black smokers of more than10 m in height (Hashimoto et al., 2001; Han et al., 2018).

Kairei is characterized by a high biomass and high diversity with thousands of *R. kairei* shrimps living in the hydrothermally active zone and marianactis anemones occurring in the vent periphery, which is similar to those in Edmond. *R. kairei* shrimps partially feed on sulfide-oxidizing filamentous episymbionts in their branchial chambers, which were found to be the dominant primary producers in the Kairei community (van Dover et al., 2001; van Dover, 2002). Underneath the blanket of shrimps, bathymodiolus mussels, alviniconcha hairy snails and scaly-foot snails (*C. squamiferum*) formed clusters of hundreds of individuals (van Dover et al., 2001; van Dover, 2002). The scaly-foot snail was discovered in Kairei vent field and occurred only at Monju site (Nakamura et al., 2012). During the second excursion to Kairei, 36 invertebrate taxa were identified, with one-third of those species being found in the Pacific but many taxa belonged to new genera (van Dover et al., 2001). The recorded taxa include neolepas barnacles, actinostolid actinians, lepetodrilus limpets, bathymodiolus mussels, mirocaris shrimps, munidopsis lobsters, and many more (Hashimoto et al., 2001; van Dover et al., 2001; Watanabe and Beedessee, 2015). Further undescribed copepods, the new neolepetopsid limpet *Eulepetopsis crystalline*, and the new amphinomid polychaete *Amphisamytha marisindica* were collected at Kairei, all of which were found in a very limited number of Indian vent fields (van Dover et al., 2001; Zhou et al., 2019; Chen et al., 2021c). Furthermore, the lobster *Munidopsis laticorpus* and the snail *Iphinopsis boucheti* are unique to Kairei; and the snails *Bruceiella wareni* and *Desbruyeresia marisindica* are known only from Kairei, Wocan, and Solitaire (Cubelio et al., 2007; Watanabe and Beedessee, 2015; Zhou et al., 2022).

3.1.3 Vent fields of the South-East Indian Ridge

With a uniform spreading rate of 69 - 75 mm per year, the SEIR separates the Indo-Australian and Antarctic plates (Sempéré and Cochran, 1997) and meets the CIR at its most northwestern point in the RTJ and the Macquarie Triple Junction in the far east of the Pacific Ocean (Sempéré and Cochran, 1997). The SEIR is perhaps the less studied region of the Indian Ocean, with only two active vent fields reported so far.

3.1.3.1 Pelagia (26°1'S, 71°3'E, 3659m)

Pelagia was discovered during the INDEX 2014 cruise with the RV *Pelagia* by the German Federal Institute for Geosciences and Natural Resources (BGR) (BGR, 2015), and thereafter visited during the BGR INDEX 2016 cruise with the RV *Pourquoi pas?* and ROV *VICTOR 6000* (Han et al., 2018).

Consistent with other vents, strong faunal zonation was recorded at Pelagia. One study examining merely a single chimney complex recorded 17 megafauna taxa, which occurred in 4 zones of proximity to the hydrothermal activity (Gerdes et al., 2019). Common Indian species found at Pelagia were the snail *C. squamiferum*, the shrimps *M. indica* and *Alvinocaris solitaire*, and the stalked barnacle *N. marisindica* (Gerdes et al., 2019). The hairy snails *Alviniconcha marisindica* and the crab *A. rodriguezenis* were highly abundant nearest to black smoker fluids, followed by the shrimp *R. kairei* and thereafter the mussel *B. marisindicus* (Gerdes et al., 2019). Note that the bathymodiolin species *B. septemdierum* and *B. marisindicus* cannot be distinguished based on the mCOI marker gene (Breusing et al., 2015). The community at Pelagia resembled those of other CIR vent fields, with newly described holothurian species (*Chiridota hydrothermoca* sp. *inc*) (Smirnov et al., 2000; Gerdes et al., 2021) and fish species (*Pachycara angeloi*) (Thiel et al., 2021), which were

reported from other CIR vents as Chiridotidae and Zoarcidae (Gerdes et al., 2019). Additionally, rare microbial strains were found at Pelagia and Kairei that distinctly differed from other mid-ocean ridge samples (Han et al., 2018). They were sampled at both active venting zones and inactive areas, with much larger proportions of novel operational taxonomic units than at chimneys in most other vent ecosystems (Han et al., 2018). Such rare species are likely dormant until better conditions for growth arrive and may be responsible for large element turnovers that affect large-scale biogeochemical cycling (Han et al., 2018).

3.1.3.2 Site 21 (41°15′S, 79°06′E)

Plume anomalies were detected at Site 21 near the Amsterdam-St. Paul Plateau, and a vent-associated barnacle belonging to the genus *Neolepas* was retrieved by dredge (Scheirer et al., 1998). However, no further publications have confirmed the activity of Site 21.

3.1.4 Vent fields of the South-West Indian Ridge

The SWIR is the second most slow spreading ridge in the world with an ultraslow spreading rate of ~15 mm per year (Patriat et al., 1997). Meeting the other Indian Ridges in the RTJ, the SWIR is a tectonic plate boundary between the Antarctic and African plate (Patriat et al., 1997). Three active vent fields from the SWIR have so far been reported, namely Tiancheng, Longqi, and Duanqiao.

The SWIR comprises of two separate clusters, the south-western Longqi and Duanqiao and the north-eastern Tiancheng (Sun et al., 2020). This appears to be the case for both community composition and genetic divergence since the *C. squamiferum* population of Longqi shows low connectivity to the CIR populations (Sun et al., 2020; Zhou et al., 2022). Tiancheng however showed a striking similarity to CIR vent communities, and transform faults on the SWIR possibly form a powerful barrier to gene flow among SWIR vents (Sun et al., 2020). Geological or hydrodynamic barriers thus could be a more important determinant of connectivity between these vent communities than ridge characteristics such as spreading rate. The Longqi and Duanqiao populations share community components with the CIR, the MAR, and the East Scotia Ridge, and have been suggested to be a separate province (Zhou et al., 2018; Reid et al., 2020; Zhou et al., 2022). The northern SWIR vent Tiancheng would be part of the CIR-nSWIR province (Zhou et al., 2022). Only four species so far occur at all the three fields: the mussels *B. marisindicus*, the scale worms *B. longqiensis*, the barnacles *N. marisindica*, and the scaly-foot snail *C. squamiferum* (Zhou et al., 2018; Sun et al., 2020). An interesting feature of all SWIR vents is the absence of alvinocarid shrimp dominance, which is typical for most CIR vents. Instead, mussels were highly abundant throughout the SWIR, even though there is a large bathymetric range between these vents (1732 - 2760m) (Zhou et al., 2018).

3.1.4.1 Tiancheng (27°57′S, 63°32′E, 2682-2729m)

The basalt-hosted Tiancheng vent field lies in the most northeastern section of the SWIR on the slope of the Tiancheng seamount (Chen et al., 2018; Fang and Wang, 2021). Three vent sites have been found, of which two diffuse flow areas and one high-temperature black smoker area (Sun et al., 2020).

An initial report identified 11 taxa at Tiancheng early on when only the diffuse TC-1 vent site was known (Zhou et al., 2018), with dense aggregations of the mussel *Bathymodiolus marisindicus* in the center, actinostolid anemones in the periphery, and the presence of bythograeid crabs *Phymorhynchus* snails, *Mirocaris* shrimps, *Phymorhynchus* sp.“Tiancheng” snails, *Neolepas marisindica* barnacles, *Polynoidae* polychaetes, and *Ophiidae* fish (Zhou et al., 2018). However, a following visit to TC-2 and Tianchang recorded 12 additional taxa, including a distinct new morphotype of the snail *C. squamiferum* and the snail *Desbruyeresia* cf. *marisindica* (Sun et al., 2020). The “Tiancheng type” scaly-foot snail was dominant here and had reddish-brown zinc sulfide deposits on its dirty white scales and a brown shell (Sun et al., 2020). Some taxa that are uncommon in the Indian Ocean were recorded at Tiancheng, including undescribed copepods from the family Dirivultidae, the sea cucumber *Chiridota*, and the polychaete *Ophryotrocha* (Sun et al., 2020). Interestingly, Tiancheng’s vent community was more similar to the CIR vent fields and had low connectivity to other SWIR vent fields (Zhou et al., 2018; Sun et al., 2020). Species that were reported for CIR vents but not at the other SIWR vents include the limpet *Eulepetopsis crystallina*, crab *A. rodriguezenis*, and mussel *B. marisindicus* (Sun et al., 2020; Chen et al., 2021c).

3.1.4.2 Longqi (37°47′S, 49°39′E, 2755m)

Longqi was the first active vent field discovered on an ultraslow mid-ocean ridge worldwide, and is by far the most explored vent field on the SWIR (Tao et al., 2012; Zhou et al., 2018). The basalt-hosted field has three vent sites that extend laterally over ~1000 m (Tao et al., 2012; Zhou et al., 2018). The first vent site was identified during the COMRA DY19 cruise in 2007 and two other vent sites were explored during the COMRA DY20 cruise in 2008/2009 (Tao et al., 2012). Temperature of discharging fluids was over 300°C but diffuse venting of clear fluids was also observed (Copley et al., 2016).

Longqi harbors a stunning vent community of about ~35 identified taxa to date with a unique biodiversity and a complex zonation pattern (Zhou et al., 2018; Zhou et al., 2019; Chen et al., 2021a; Chen et al., 2021c), including the scaly-foot snail *C. squamiferum*, alvinocaridid shrimps *R. kairei* and *M. indica*, stalked barnacle *N. marisindica*, and mussel *B. marisindica* (Zhou et al., 2018). At Longqi, dense shrimp aggregations occurred only in small quantities (Zhou et al., 2018). A lack of suitable substrate might have prevented the dominance of *R. kairei* at Longqi, since high-temperature fluids were only released from chimney summits (Zhou et al., 2018). Dominant species were, in distance from the venting, the scaly-foot snails *C. squamiferum*, peltospirid snails *Lepetodrilus* sp. “SWIR” and *Gigantopelta aegis*, mussel *B. marisindica*, and barnacle *N. marisindica* (Copley et al., 2016). The black *C. squamiferum* Longqi population was highly connected to the nearby Duanqiao population but exhibited low connectivity to the CIR populations (Chen et al., 2015; Zhou et al., 2018; Sun et al., 2020). Three polychaetes of the same genus occurred at Longqi: *Amphisamytha marisindica* which likely has an ancestor in the East Pacific, and *Amphisamytha collaris* and *Amphisamytha* sp. Longqi which were closely related to a Southwest Pacific species (Zhou et al., 2019). To date, at least 12 species have been recorded only in this vent field: the peltospirid snails *Dracogyra subfuscus*, *Lirapex politus* and *Lirapex felix, Phymorhynchus* sp. “SWIR”, the lobster *Munidopsis* sp. “SWIR”, the limpet *Neolepetopsis ardua*, and the polychaetes *Ophryotrocha jiaolongi*, *Amphisamytha collaris*, *Amphisamytha* sp.

Longqi, Polynoidae sp. 2, Polynoidae n. gen. n. sp. "655", and *Laonice* sp. "Longqi" (Chen et al., 2017b; Zhang et al., 2017; Zhou et al., 2018; Zhou et al., 2019; Chen et al., 2021a; Chen et al., 2021c). The peltospirid snail *Gigantopelta aegis*, scale worm *Peinaleopolynoe* sp. "Dragon", limpet *Lepetodrilus* sp. "SWIR", and yeti crab *Kiwa* sp. "SWIR" occur only in one other vent field, the neighboring Duanqiao (Zhou et al., 2018). A unique feature of Longqi is the co-occurrence of five peltospirids snails, all within the same assemblage (Chen et al., 2021a).

3.1.4.3 Duanqiao (37°39'S, 50°24'E, 1732m)

The basalt-hosted Duanqiao vent field was discovered during the COMRA DY20 cruise (Tao et al., 2014). It was first believed to be an inactive field, until weak fluid emissions from a large sulfide edifice were observed with a TV-grab during the COMRA DY34 cruise in 2015 (Zhou et al., 2018). While only diffuse venting was observed from the manned submersible *Shenhaiyongshi*, high fluid temperatures were recorded during the same 2018/2019 cruise with the RV *Tansuoyihao* (Liao et al., 2019).

Duanqiao is less studied than the other two SWIR vents. However, 13 taxa were collected during the DY35 cruise (Zhou et al., 2018). Duanqiao shared ten of those taxa with Longqi, including the novel species *Gigantopelta aegis* snails, *Lepetodrilus* sp. "SWIR" limpets, and *Peinaleopolynoe* sp. "Dragon" scale worms that were so far not found at other vent fields (Zhou et al., 2018). *B. marisindicus* mussels and *Neolepas marisindica* barnacles were the most abundant species in both the Duanqiao and Longqi vent fields (Sun et al., 2020). At first glance, Duanqiao appeared to be a subset of the neighboring Lonqi, yet multiple species were recorded at Duanqiao but not Longqi, including the gastropod *Desbruyeresia* sp. "SWIR" and the sea spiders *Sericosura bamberi*, *S. heteroscala*, and *S. duanqiaoensis*, of which the latter was a newly discovered species (Wang et al., 2018; Zhou et al., 2018). The scaly-foot snail *C. squamiferum* population at Duanqiao also differed from those in other vent fields, with a black shell and white sclerites (Zhou et al., 2018). This "Duanqiao type" snail showed very low genetic divergence from Longqi, and the morphotype is the result of Duanqiao's distinct chemical environment (Zhou et al., 2018).

3.2 Generic and field-by field characteristics of active vent fields on the Indian Ocean ridges applicable to VME, EBSA, and PSSA criteria (Appendix 3)

By their very nature, vent fields globally, including those on the Indian Ocean Ridges, share fundamental ecological characteristics relevant to each of the 9 criteria assessed (Gollner et al., 2021). Criteria that are met by all vent fields include 1) Uniqueness and rarity, 2) Functional significance, 3) Fragility, 4) Life history traits of component species that makes recovery difficult, 5) Structural complexity, 6) Biological productivity, 7) Biological diversity, 8) Naturalness, and 9) Ecosystem services (Appendix 1, Appendix 2). Our scientific assessment of 12 vents fields on the Indian Ocean Ridges shows that all vent fields meet all scientific criteria for protection (Table 2 and Figure 2). A detailed field-by field analyses is also given in Appendix 3.

The Indian Ocean vent fields are unique and rare as they host small, island-like vent ecosystems with distinctive biotic and abiotic features (Han et al., 2018; Wang et al., 2018; Kim et al., 2020; Chen et al., 2021a; Han et al., 2021) (Table 1). Autotrophic microorganisms use chemosynthesis to fix carbon, as animal symbionts (e.g. *Alvinichona* or *Bathymodiolus* foundation species), bacterial mats or free-living cells (Dick, 2019). All active vents are of functional significance, as they support primary production by microorganisms, serve as discrete feeding area, and are essential for the growth, survival, reproduction, and persistence of vent-endemic species (van Dover, 2001; Mullineaux et al., 2018). The juveniles and adults of vent-endemic (vent-obligate) taxa are adapted to the extreme chemical and physical conditions of the vent habitat and thrive in these specialized (unique) ecosystems. Many animal species and microbial strains found in the Indian Ocean are endemic to this specific region, or even restricted to a single vent field (Han et al., 2018; Dick, 2019). Structural habitat complexity and local chemical gradients create niches that expand biodiversity on a genetic, morphological, functional, and species level (van Dover, 2001; Dick, 2019)

Various Indian vent-endemic species so far have only been found in a single vent field, like the limpet *Neolepetopsis prismatica*, the sessile barnacle *Eochionelasmus coreana*, and the sea spider *Sericosura duanqiaoensis* (Wang et al., 2018; Chan et al., 2020; Chen et al., 2021c). Even when a species is present at multiple vents, local fluid composition may influence phenological expression (Minic et al., 2006; Ramirez-Llodra et al., 2007). For instance, there are at least 5 different morphotypes of the scaly-foot snail *C. squamiferum* due to the different chemical profiles of Solitaire, Kairei, Tiancheng, Longqi, and Duanqiao vent fluids. Furthermore, all Indian vents sustain rich microbial communities that are mostly shaped by local geochemical circumstances, often with a large variability between vent sites from a single field (Dick, 2019). Symbiotic species, such as *Crysomallon squamiferum* and the mussel *Gigantidas vrijenhoeki*, are associated with novel microbial strains (Goffredi et al., 2004; Jang et al., 2020). Novel chemolithoautotrophic and heterotrophic microbes were isolated from sulfides, sediments, and plumes of the Indian vent fields (van Dover et al., 2001; Ding et al., 2017; Hu et al., 2020).

Many benthic species rely on pelagic larval stages to maintain population and genetic connectivity (Mullineaux et al., 2018; Chapman et al., 2019). There are many uncertainties surrounding recruitment relating to reproduction, larval development, larval dispersal, and settlement (Perez et al., 2021). However, some Indian-endemic species are thought to have low dispersal abilities due to negatively buoyant larvae or eggs, including the peltospirid snails *Chrysomallon squamiferum*, *Gigantopelta aegis*, *Dracogyra subfuscus*, and *Lirapex politus* (CR) (Chen et al., 2014), or the crab *Kiwa* sp. "SWIR" (Reid et al., 2020). Habitat degradation and fragmentation due to anthropogenic disturbance may lead to local loss of biodiversity (Pardini et al., 2017; van Dover et al., 2017; Niner et al., 2018) and ecosystem services (Le et al., 2017).

Currently, 11 vent species found in the Indian Ocean are on red list of the IUCN[4], including the vulnerable mussel *Bathymodiolus*

4 https://www.iucnredlist.org/search

TABLE 2 Application of the scientific criteria for identifying hydrothermal ecosystems in need of protection at 12 Indian vent fields, based on the literature used in this review. Criteria definition follows Gollner et al. (2021) (see Appendix 1, 2).

Criterion	Subcriteria	Active vent fields known from the Indian mid-ocean ridges											
		Daxi	Wocan	Tianxiu	Onnuri	Dodo	Solitaire	Edmond	Kairei	Pelagia	Tiancheng	Longqi	Duanqiao
1. Uniqueness or rarity	1.1 habitats that contain endemic species	+	+	+	+	+	+	+	+	+	+	+	+
	1.2 habitats of rare, threatened or endangered species; only in discrete areas	+	+	+	+	+	+	+	+	+	+	+	+
	1.3 nurseries or discrete feeding, breeding or spawning areas	+	+	+	+	+	+	+	+	+	+	+	+
	1.4 unique or unusual biotic or abiotic features (chemical, physical, geological)	+	+	+	+	+	+	+	+	+	+	+	+
2. Functional significance	2.1 for survival, function (e.g. feeding), spawning/reproduction, or recovery of species	+	+	+	+	+	+	+	+	+	+	+	+
	2.2 for particular life history stages (e.g. nursery grounds or rearing areas, migratory routes for fish, reptiles, birds, mammals, invertebrates)	+	+	+	+	+	+	+	+	+	+	+	+
	2.3 for rare, threatened, or endangered marine species	+	+	+	+	+	+	+	+	+	+	+	+
3. Fragility	3.1 An area that contains a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events)	+	+	+	+	+	+	+	+	+	+	+	+
4. Life history	4.1 slow growth rates	-	-	-	-	-	-	-	-	-	-	-	-
	4.2 late age of maturity	-	-	-	-	-	-	-	-	-	-	-	-
	4.3 low or unpredictable recruitment	+	+	+	+	+	+	+	+	+	+	+	+
	4.4 long-lived species	=	=	=	=	=	=	=	=	=	=	=	=
5. Structural complexity	5.1 complex physical structures created by biotic and abiotic features	+	+	+	+	+	+	+	+	+	+	+	+
	5.2 ecological processes are dependent on these structured physical systems	+	+	+	+	+	+	+	+	+	+	+	+
6. Biological diversity	6.1 An area that contains comparatively higher diversity of ecosystems (including high diversity associated to complex structures), habitats, communities, or species, or has higher genetic diversity	+	+	+	+	+	+	+	+	+	+	+	+

(Continued)

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TABLE 2 Continued

Criterion	Subcriteria	Active vent fields known from the Indian mid-ocean ridges											
		Daxi	Wocan	Tianxiu	Onnuri	Dodo	Solitaire	Edmond	Kairei	Pelagia	Tiancheng	Longqi	Duanqiao
7. Biological productivity	7.1 An area that has a particularly high rate of natural biological production. Such productivity is the net result of biological and physical processes which result in an increase in biomass	+	+	+	+	+	+	+	+	+	+	+	+
8. Naturalness	8.1 An area with a comparatively higher degree of naturalness as a result of lack of or low level human-induced disturbance or degradation	+	+	+	+	+	+	+	+	+	+	+	+
9. Ecosystem services	9.1 provisioning services, such as food, materials and energy, which are directly used by people (including marine genetic resources and bioprospecting, bioinspired materials, bioinspired processes)	+	+	+	+	+	+	+	+	+	+	+	+
	9.2 regulating services, that cover the way ecosystems regulate other environmental media or processes (including climate regulation, biological pump and carbon sequestration)	+	+	+	+	+	+	+	+	+	+	+	+
	9.3 cultural services that are related to the cultural or spiritual needs of people. These incluse spiritual services, aesthetic services, recreation, education (e.g. an area that offers an exceptional oppurtunity to demonstrate particular natural phenomena), and science (e.g. a research area that provides suitable baseline monitoring conditions because it is in near natural condition)	+	+	+	+	+	+	+	+	+	+	+	+
	9.4 supporting services, such as ecosystem processes and functions that underpin the other three types of services (including primary production, nutrient cycling)	+	+	+	+	+	+	+	+	+	+	+	+

Color codes for level of relevance for each criterion: Green (+): high, Yellow (=): medium, Red (-): low. Details of the scientific evidence supporting each score are provided in Appendix 3.

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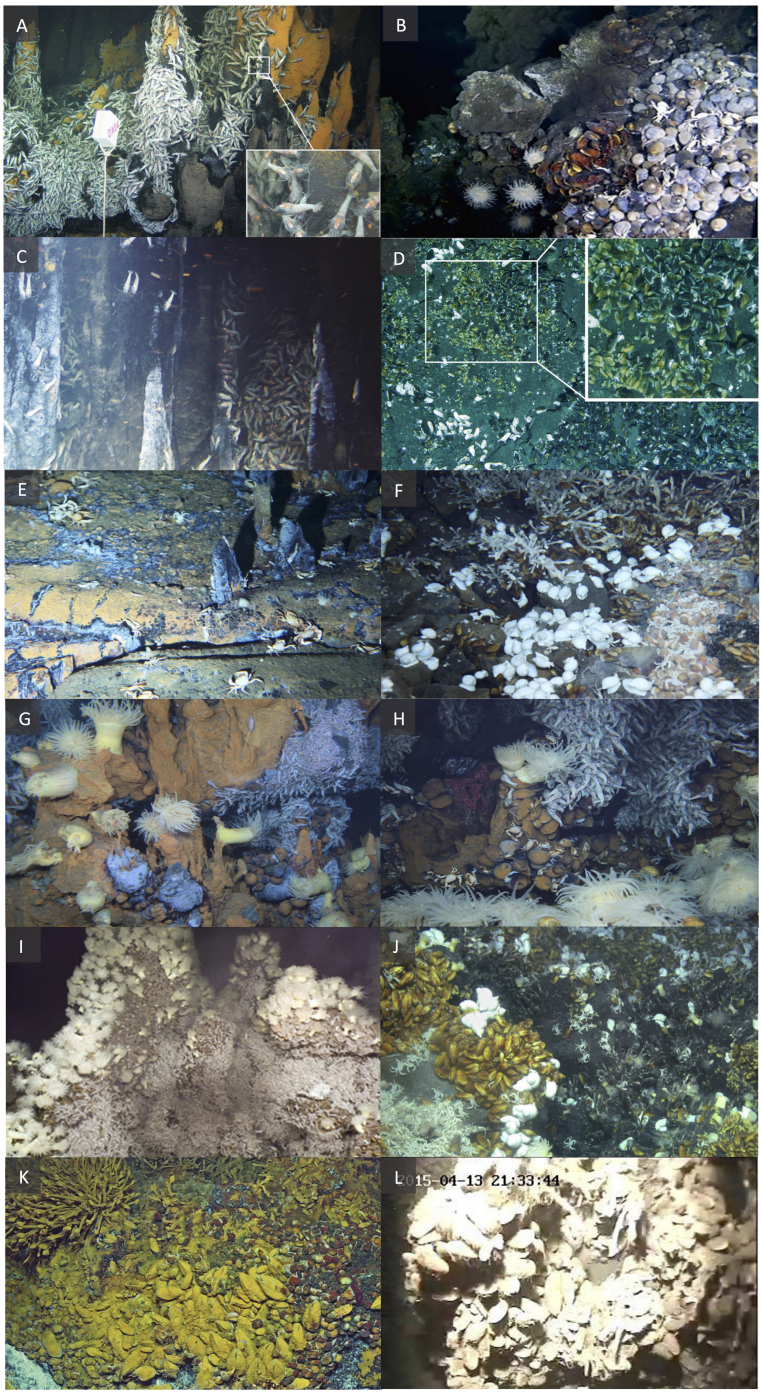

FIGURE 2
A selection of ecological features for each active Indian hydrothermal vent. **(A)** Extensive swarms of alvinocaridid shrimps at Daxi. **(B)** Snails, mussels, crabs, shrimps, and anemones near a black smoker at Wocan. **(C)** Alvinocaridid shrimp swarming on massive sulfide structures at Tianxiu. **(D)** Dominant mussel species *Bathymodiolus marisindicus* (yellow brown) and *Gigantidas vrijenhoeki* (dark brown) at Onnuri. **(E)** Sparsely distributed anemones and bythograeid crabs at Dodo. **(F)** Diffuse flow vent assemblage with mussels, different snails and barnacles at Solitaire. **(G)** Dense alvinocaridid shrimp aggregations surrounded by snails and anemones at Edmond. **(H)** High densities of shrimps, snails, crabs and anemones at Kairei. **(I)** Layered shrimp, mussel and anemone aggregations on a chimney structure at Pelagia. **J**) Mussel beds with patches of snails, crabs and shrimps at Tiancheng. **(K)** Tiamat chimney dominated by peltospirid snails, alongside dense mussel and barnacle colonies at Longqi. L) Mussel dominance at Duanqiao. Image credits; **(A)** Wang et al., 2021 rightslink # 5441960651432); **(B)** Qiu et al., 2021 (rightslink # 5441961199302); **C**) Zhou et al., 2022 (CC BY); **(D)** Jang et al., 2020 (rightslink # 5441970372620); **(E, F, G, H)** Beedessee et al., 2013 (CC BY); **(I)** Gerdes et al., 2019 (CC BY); **(J)** Sun et al., 2020 (CC BY); **(K)** Chen et al., 2021a. (rightslink # 5443111350852); **(L)** image from powerpoint presentation by Dr C.B. Soon at ISA workshop in Poland in 2018 (photo courtesy of COMRA).

marisindicus (VU), the endangered snails *Alviniconcha marisindica*, *Chrysomallon squamiferum*, *Debruyeresia marisindica*, and endangered mussel *Bathymodiolus septemdierum* (EN), as well as the critically endangered snails *Gigantopelta aegis*, *Iphinopsis boucheti*, *Dracogyra subfuscus*, *Lirapex politus*, *Bruceiella wareni*, and the mussel *Gigantidas vrijenhoeki* (CR). The first three species are characteristic members of the Indian vent metacommunities, as are the bythograeid crab *Austinograea rodriguezensis*, the stalked

barnacle *Neolepas marisindica*, and the alvinocaridid shrimps *Rimicaris kairei* and *Mirocaris indica*. Although these species are common, they are absent at some vent fields (Table 1).

To date, vent fields in the Indian Ocean remain among the most pristine ecosystems on Earth as they have been visited by scientists only in recent years (Menini and van Dover, 2019; Gollner et al., 2021). Moreover, these ecosystems have an outstanding potential to contribute genetic resources and inspire biomedical, biotechnological and commercial applications (Harden-Davies, 2017; Adam et al., 2020; Orcutt et al., 2020). For instance, the 'armor design' of *C. squamiferum* may lead to innovations in military equipment, vehicles, construction machinery or astronautics (Yao et al., 2010). These ecosystems also harbor rich microbial communities that are sources of natural pharmaceuticals since some unique bacteria and archaea have so far been reported only from SWIR and CIR vents (Thornburg et al., 2010; Han et al., 2018; Dick, 2019; Dasgupta et al., 2021). More novel operational taxonomic units have been found at Edmond and Kairei than at most other vents (Han et al., 2018).

4 Discussion

Hydrothermal ecosystems in the Indian Ocean were discovered and explored much later than those in other regions, yet the uniqueness and vulnerability of each active Indian vent stands out. The application of scientific criteria for protection of these vents highlights the need for protection of active vent ecosystems in the Indian Ocean.

4.1 The ecology of Indian Ocean vent fields

The present review outlines the historic role of this region in supporting population connectivity among biogeographic provinces and reveals the similarities and differences between vents of the Indian ridges. The Indian Ocean was hypothesized to be a corridor between the Atlantic and Pacific biological communities in the past. Here, we recognize the importance of the Indian population as both a copious source of unique vent species and a central point on the global ocean floor, with widespread connections to the Atlantic, Antarctic, West-, and East-Pacific (van Dover et al., 2001; Rogers et al., 2012; Watanabe and Beedessee, 2015; Perez et al., 2021). The Indian meta-population is much like a patchwork, with clear subpopulations that may even belong to separate provinces, and are strongly linked to particular regions (Sun et al., 2020; Han et al., 2021; Perez et al., 2021).

For example, both the nSWIR-CIR and CR have a bias towards the West Pacific meta-community, with taxa like neolepas stalked barnacles, alviniconcha snails, and bythograeid crabs common in both communities (van Dover et al., 2001; Watanabe et al., 2018). The CR was also suggested to have a direct biogeographic linkage to the East Pacific because different *Amphisamytha* polychaetes from the CR are genetically closely related to their East Pacific counterparts (Zhou et al., 2019).

While nSWIR-CIR and CR vents were dominated by *Rimicaris* and *Mirocaris* shrimp assemblages reminiscent of the MAR, except Onnuri, sSWIR vents had high abundances of mussels and snails (Watanabe and Beedessee, 2015) (Table 1). Consistent with its relative geographical position, sSWIR vents seem to have strong ties to the East Scotia Ridge (ESR) in the Southern Ocean, characterized by high abundances of the stalked barnacle *Neolepas* spp., yeti crab *Kiwa* spp., and peltospirid snail *Gigantopelta* spp. (Chen et al., 2017a; Zhou et al., 2019). Similarity in community structure at species level to the ESR decreases over distance, as there is a clear continuum in community structure along the SWIR, CIR and CR (Sun et al., 2020). A proposed dispersal pathway from the Southern Pacific to the CIR *via* the SEIR was contradicted by molecular evidence on neolepas barnacles, indicating historic dispersal through the Southern Ocean was more likely (Watanabe et al., 2018). Still more research is needed, as the SEIR is the least studied Indian ridge and the only known active vent is merely 167 km away from Kairei, which may explain the high affinity between Pelagia and CIR vent communities.

The concept of "nearest vent, dearest friend" is further exemplified by the Tiancheng vent field, which is a nSWIR vent highly similar to CIR vents (Sun et al., 2020; Zhou et al., 2022). Besides the immediate proximity to the CIR vent fields and Kairei in particular, another important determinant of vent connectivity may be ridge continuity. Major transformation faults exist on the SWIR between Tiancheng and the other SWIR vents that presumably severely restrict larval dispersal (Sun et al., 2020). Previous genetic analyses in the East Pacific have also indicated animal dispersal is often constrained by geographical barriers common on mid-ocean ridges, such as trenches, transform faults, and microplates (Beedessee et al., 2013).

Consequently, future research should focus not only on biodiversity and functioning of single vent fields but also vent fields at a network scale. To date, only four studies have examined genetics across at least two Indian ridges and reported population connectivity of six different species (Chen et al., 2015; Watanabe et al., 2018; Sun et al., 2020; Zhou et al., 2022). However, recent work on population plasticity and genetic structure of the deep-sea mussel *Bathymodiolus platifrons* (Xu et al., 2017), the deep-sea limpet *Bathyacmaea nipponica* (Xu et al., 2021), and the deep-sea squat lobster *Shinkaia crosnieri* (Xiao et al., 2020) clearly showed that populations of these species from vent and cold-seep fields thousands of kilometers apart in the west Pacific Ocean could be well connected. Hydrodynamics plays a more important role than habitats or geographic distance in driving the gene flow and divergence for these populations (Xiao et al., 2020; Xu et al., 2021). These findings (and unpublished data on population genetics and connectivity from Qian Pei-Yuan's laboratory) clearly demonstrate that population genomic surveys should be applied to future population connectivity studies of deep-sea animals.

Furthermore, there are many inferred active vent fields that have not been thoroughly studied yet. Based on the Interridge database, biological communities of 3 vents on the CR, 16 vents on the CIR, 50 vents on the SEIR and 22 vents on the SWIR wait to be described, and even more wait to be discovered. Disturbances at single vent fields may affect entire metacommunities due to the source-sink dynamics of vent species (Vrijenhoek, 2010; Mullineaux et al., 2018). Yet mining is likely to target vent fields with the largest PMS deposits, which may often be older vent fields with more developed community structures.

Such vent fields can be the most diverse and likely serve as the sources of larval supplies for other vents. Before we decide on particular vent fields as representative management areas, characterization of individual locations must be done adequately while the paucity of knowledge on inter-vent connectivity within and between biogeographic provinces should also be addressed.

4.2 Governance

Previously, the International Guidelines of Deep-Sea Fisheries in the High Seas published by the FAO stated that vent fields and their associated communities "often display characteristics consistent with possible VMEs" (FAO, 2009). Lost City, Broken Spur, TAG, and Snake Pit are four active vent fields on the nMAR that have already been recognized as EBSAs by the CBD[5] and in the same CBD report it was suggested other MAR vent fields should also be considered to be EBSAs. Moreover, an area of 135,688 km^2 comprising 2 inferred active vents on the CIR has already been designated and implemented as a Benthic Protected Area (BPA) by the Southern Indian Ocean Fishery Agreement (SIODFA). The SIODFA BPA protects from deep-sea and mid-water trawling (Menini and van Dover, 2019) but does not prohibit other human activities. These measures are in line with the mandate to take precautionary action when managing deep-sea hydrothermal vent ecosystems (Levin et al., 2017b; van Dover et al., 2018).

Ten Indian deep-sea hydrothermal vent species are currently red-listed by the IUCN, with more than half being Critically Endangered.[4] This number is likely to increase, as more deep-sea species are considered by the IUCN, due to the imperiled status of Indian vents compared to other vents globally (Thomas et al., 2021). Gollner et al. (2021) suggested that active nMAR vents are ecosystems in need of protection. In this review, we conclude that all active vent fields in Indian Ocean are also in need of protection, calling for a global effort to protect these unique ecosystems.

5 Conclusion

Hydrothermal vents are extraordinary ecosystems that may be at risk of serious harm due to future deep-sea mining or other anthropogenic impacts. This review provides an overview of the unique geochemical and biological attributes of each confirmed active vent in the Indian Ocean. The Indian meta-population was long hypothesized to be a mixture of Atlantic and Pacific communities yet is instead composed of taxa known from other biogeographic provinces and vent species unique to the Indian Ocean. Criteria previously used to classify vulnerable and significant marine ecosystems were used to assess vents at the Indian mid-ocean ridges. All active vent fields in the Indian Ocean meet the scientific criteria for protection, and both the high degree of uniqueness and fragility of these ecosystems stand out. This review and other scientific analyses underpin the important role of science in the ocean sector development. Future efforts should be focused on understanding population connectivity (gene flow), life-history, convergence, and divergence of deep-sea fauna in order to develop solid scientific evidence based regional environmental management plans for active hydrothermal ecosystems in the Indian Ocean.

Author contributions

NM drafted the article, P-YQ, YG, and SG contributed to the writing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.1067912/full#supplementary-material

5 https://chm.cbd.int/database/record?documentID=204107

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Putting coastal communities at the center of a sustainable blue economy: A review of risks, opportunities, and strategies

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New approaches to ocean governance for coastal communities are needed. With few exceptions, the *status quo* does not meet the diverse development aspirations of coastal communities or ensure healthy oceans for current and future generations. The blue economy is expected to grow to USD2.5–3 trillion by 2030, and there is particular interest in its potential to alleviate poverty in Least Developed Countries and Small Island Developing States, and to support a blue recovery from the COVID-19 pandemic. This paper presents a selective, thematic review of the blue economy literature to examine: (i) the opportunities and risks for coastal communities, (ii) the barriers and enablers that shape community engagement, and (iii) the strategies employed by communities and supporting organizations, which can be strengthened to deliver a 'sustainable' blue economy and improve social justice for coastal communities. Our review finds that under business-as-usual and blue growth, industrial fisheries, large-scale aquaculture, land reclamation, mining, and oil and gas raise red flags for communities and marine ecosystems. Whereas, if managed sustainably, small-scale fisheries, coastal aquaculture, seaweed farming and eco-tourism are the most likely to deliver benefits to communities. Yet, these are also the sectors most vulnerable to negative and cumulative impacts from other sectors. Based on our evaluation of enablers, barriers and strategies, the paper argues that putting coastal communities at the center of a clear vision for an inclusive Sustainable Blue Economy and co-developing a shared and accessible language for communities, practitioners and policy-makers is essential for a more equitable ocean economy, alongside mainstreaming social justice principles and integrated governance that can bridge different scales of action and opportunity.

KEYWORDS

blue economy, coastal communities, justice, sustainability, marine

1. Introduction

The UN Decade of Ocean Science for Sustainable Development (2021–2030) signifies a new level of policy and research attention on the ocean. It provides a critical opportunity to advance a more socially just and sustainable blue economy to improve the lives of millions of people living in coastal communities, globally, whose livelihoods, cultures and identities depend on healthy marine ecosystems (WWF, 2015a; FAO, 2022).

The blue economy is estimated to be worth USD1.5 billion and is expected to grow to USD 2.5–3 trillion by 2030 (WWF, 2015b; OECD, 2016). There is growing interest in the potential of the blue economy to alleviate poverty in Least Developed Countries (LDCs) and Small Island Developing States (SIDS), and to support a blue recovery from the COVID-19 pandemic (OECD, 2021). For example, the blue economy is declared as "the next frontier" in the African Union's Agenda 2063 (in UNECA, 2016; Okafor-Yarwood et al., 2020). In parallel, a recent analysis reveals exponential growth across diverse marine sectors (Jouffray et al., 2020): the seafood sector is the fastest growing food industry; coastal tourism is the fastest growing tourism sector; shipping accounts for 80% of global trade; 70% of new oil and gas discoveries are offshore; and more than 1.3 million km^2 of the seabed in Areas Beyond National Jurisdiction (ABNJ) is currently licensed for Deep-Sea Mining (DSM) exploration. This so-called "blue acceleration" is occurring under climate change and rapidly shifting geopolitics, which are concentrating activities where conditions are favorable and creating new opportunities and risks for coastal communities (Jouffray et al., 2020). In this paper, we review recent literature on the blue economy, sustainable blue economy and so-called blue justice. We focus on what this literature reveals about how coastal communities are impacted by and engaging in blue economy activities. Our aim is to examine the opportunities and risks posed by the emergent blue economy, and reveal tangible ways to operationalise a more socially just approach to deliver a Sustainable Blue Economy.

2. Approach

The paper is based on a selective, thematic review of published ($n = 23$) and grey literature ($n = 12$) on the blue economy, with emphasis on literature pertaining to coastal communities and the blue economy (Supplementary Table 1). We conducted a search of published articles on the Web of Science using the key search terms: "blue economy" OR "blue growth" OR "blue grabbing" OR "blue justice" OR "blue equality" OR "ocean economy" OR "ocean justice" OR "ocean grabbing" OR "ocean equality". From this database, we selected recent articles that provided an overview of the field with particular emphasis on the implications for coastal communities [from (Silver et al., 2015) analysis of blue economy discourse at Rio+20 to date]. We supplemented the review of published articles with a review of grey literature from a range of key organizations shaping the blue economy agenda, including: WWF, UNDP, UNEP, OECD, the Commonwealth and the High Level Panel for a Sustainable Ocean Economy. Our review is not intended to be systematic or comprehensive, rather it highlights key themes emerging in the literature around coastal communities and the blue economy.

Specifically, the review examines current narratives around the blue economy, the opportunities and risks of an emerging blue economy for communities, and the enablers, barriers and strategies shaping how communities can meaningfully engage in a Sustainable Blue Economy (SBE). Hence, when reviewing each document, we extracted information and examples on risks, opportunities, enablers, barriers and strategies. Based on this review, the paper ends with a discussion of the narratives that support community engagement in a SBE, through highlighting some of the internal contradictions in these agendas, and outlines tangible next steps to promote social (blue) justice for coastal communities in a sustainable blue economy. In this paper, social justice is understood as both a set of principles and as a social movement intended to achieve fairer process and outcomes for coastal communities in the ocean economy (*sensu* Schlosberg and Collins, 2014; see also Jentoft et al., 2022).

3. Coastal communities and the blue economy

3.1. The fragmenting blue economy narrative

The blue economy agenda was first and foremost about improving ocean health and the sustainability of ocean uses: the term was first introduced in a book published for the Club of Rome, which framed the blue economy as innovation, technology and entrepreneurship for a greening of the ocean economy (Pauli, 2004). Literature on the subject has accelerated since 2010/2011, and the blue economy discourse has taken hold in international policy circles (e.g., The Economist, 2015).

Most definitions of the blue economy point to it having three pillars—environment, economy and society (Louey, 2022). As the concept of a blue economy has gained traction in academic and policy circles it has splintered and moved away from its central premise as a parallel to the green economy. Different strands of the discourse emphasize different pillars and specific problems, solutions and participants. Silver et al. (2015) identify four strands: oceans as natural capital; oceans as good business; oceans as integral to (Pacific) Small Island Developing States (SIDS), and; oceans as small-scale fisheries livelihoods (Table 1). More recently, social justice and equity framings are gaining high-level attention, as illustrated by reports released by

TABLE 1 Summary of diverging blue economy narratives (based on Silver et al., 2015).

Oceans as ...	Emphasis of different blue economy narratives
Natural capital	This framing focuses on how nature is under-valued, particularly economically. Approaches focus on quantification, valuation and subsequent conservation and restoration of natural capital, with nature-based infrastructure and solutions, payments for ecosystem services, and blue carbon being prominent. This framing does not preclude coastal communities; benefits are expected to accrue through, for example, people-centred biodiversity conservation and focused investments in building the resilience of coastal 'blue carbon' habitats, plus local carbon markets.
Good business	This strand acknowledges that some activities are unsustainable but argues that new markets, incentives, regulation, and private sector investment can bring the ocean into the green economy with benefits 'trickling down' to citizens of ocean states. Terms associated with this perspective include blue growth and oceans as untapped, under-utilised and under-explored potential.
Integral to (Pacific) Small Island Developing States (SIDS):	In the run-up to Rio+20, Pacific SIDS delegates claimed that the Alliance of Global SIDS would adopt the blue economy terminology to frame their interests. While contested internally, this was taken forward primarily to ensure oceans and ocean states were brought into discussions about the green economy. For SIDS, adopting a blue economy framing aims to increase equitable distribution of benefits from their Exclusive Economic Zones (EEZ); improve fisheries governance within and beyond their EEZs; and build resilience to climate change. It aims to assert their identity as nations with ocean territories far in excess of their land territories, and to mobilise international NGO and donor support that aligns with their livelihood and development priorities. Healthy marine ecosystems are seen as integral to growth of SIDS' ocean economies.
Small-scale fisheries livelihoods	This framing of the blue economy has emerged as an important counter-narrative to oceans as good business and oceans as natural capital. It expands the oceans as integral to SIDS framing to all coastal people. Its focus is on communities, marginalised groups and poverty reduction, articulated through a concern for small-scale fisheries (Voyer and Leeuwen, 2019). At Rio+20 The International Collective in Support of Fishworkers (2012) issued a statement emphasising sustainable and equitable distribution of ocean resources, the cultural and collective value of small-scale fisheries and ocean-based food-security, and the need to protect fishers' rights with respect to privatisation, Illegal, Unreported and Unregulated (IUU) fishing, and enclosures, including no-take protected areas. More recently, the African Confederation of Professional Artisanal Fishing Organisations (CAOPA, 2022), representing artisanal fishing communities from Africa and the Pacific, called for a prohibition of deep-sea mining stating that: "our fishing zones, our EEZs, are too precious to be ever exposed to the risks posed by deep sea mining."

the High Level Panel for a Sustainable Ocean Economy (e.g., Toward Ocean Equity[1] and A Sustainable and Equitable Blue Recovery to the COVID-19 Crises[2]) Other efforts to re-frame the blue economy discourse include: community-based blue economies (UNDP, 2018; Bradford et al., 2020; Phelan et al., 2020); community-supported fisheries (Campbell et al., 2014); Blue Communities (Campbell et al., 2021); and Blue de-growth (Ertor and Hadjimichael, 2020).

Nevertheless, the social pillar of the blue economy is the least developed; the economic pillar has dominated in practice. Consequently, social and equity issues need to be considered alongside the environment in discussions about ocean futures (Bennett et al., 2021). One way to centralize social justice and advance the social pillar of a sustainable blue economy is to foreground the experiences of coastal communities who depend on healthy oceans and are highly impacted by transitions in ocean governance, as we aim to do in this review. Reflecting emphasis to date on the economic and environmental pillars of the blue economy, in the next sections we distinguish between the blue economy as business-as-usual or blue growth, and a Sustainable Blue Economy, defined by WWF as one which: "*restores, protects and maintains diverse, productive and resilient marine ecosystems; is based on clean technologies, renewable energy and circular material flows, and; provides social and economic benefits for current and future generations*" (WWF, 2018).

3.2. Opportunities and risks of the blue economy for coastal communities

3.2.1. Opportunities

The blue economy is said to offer *indirect opportunities* to coastal communities through: (i) national (blue) economic development "trickling down" to coastal citizens *via* creation of jobs and new financial opportunities; (ii) increased ocean rents and re-direction of subsidies and investment toward the environmental and social pillars of the blue economy; iii) improved infrastructure and technology enhancing access to information, energy and other services; iv) co-location of activities with co-benefits including climate change adaptation, provision of substrate or infrastructure, and enhanced cultural value; v) potential to enhance protection and restoration of ecosystem services, and vi) strengthened national sovereignty (Table 2).

Recently, attention has focused on the prospect of a blue recovery from the COVID-19 pandemic. COVID-19 restrictions severely disrupted the movement of people and goods, with considerable adverse impacts on tourism, shipping, and international trade. SIDS and vulnerable groups, like women, were deeply affected (Northrop et al., 2020). During the pandemic, self-sufficiency at local and national levels became vital, highlighting the importance of sectors such as

1 https://oceanpanel.org/the-agenda/ocean-equity/

2 https://live-oceanpanel-wp.pantheonsite.io/sustainable-and-equitable-blue-recovery-COVID-19-crisis/

TABLE 2 Summary of the key opportunities for coastal communities offered by a sustainable blue economy, and the risks posed by business-as-usual.

	Opportunities	Risks
Indirect	- Jobs and new financial opportunities - Rents, investment, subsidies - Innovation, infrastructure, new technology - Co-location and co-benefits - Enhanced protection and restoration of ecosystem services - National sovereignty and security - Leverage COVID-19 recovery plans and funds	- Economy prioritised over sustainability and equity - Acceleration of unsustainable resource use - Sectoral trade-offs and increased ocean conflict - Elite capture and inequality - Marginalised communities
Direct	- Livelihoods and new markets - Food and nutritional security - Payments for ecosystem services - Capacity development and education - Improved governance, equity, rights	- Dispossession and displacement - High dependence on vulnerable livelihoods - Risks to food security - Rights violations - Inequitable distribution of costs and benefits

The information in this table was extracted from the published and grey literature reviewed (references in Supplementary Table 1).

small-scale fisheries, community-based aquaculture and other local enterprises. Moving forward, the literature identifies opportunities to leverage the COVID-19 recovery agenda to mobilize and re-direct financing and resources toward the environmental and social pillars of the blue economy. For example, the USA's Coronavirus Aid, Relief and Economic Security Act provides fisheries allocations for states, tribes and territories negatively impacted by COVID-19. The OECD (2021) identifies particular opportunities for SIDS to use support for a blue recovery through addressing debt, creating and seizing new investment opportunities, and building resilience and sustainability of critical sectors (greening ports, sustainable tourism, ocean health).

Our review suggests that a sustainable blue economy can present *direct opportunities* for coastal communities through improving markets, catalyzing new sustainable development sectors and directing investment into community development and livelihoods projects. Direct opportunities include: (i) alternative, enhanced and sustained livelihoods; (ii) enhanced food and nutritional security; (iii) Payments for Ecosystem Services; (iv) capacity development, and; (v) improved governance, equity and rights (Table 2). An example from Costa Rica involves a partnership between CoopeSoliDar[3] and local women to improve the value chain; shortening it for high quality, local products and labeling it as fair trade. The literature also notes the potential to improve the availability and access to nutritious aquatic foods locally and globally through better-managed capture fisheries and sustainable mariculture and aquaculture under a SBE. Sustainable mariculture production of a diversity of seafood, including shellfish and seaweed, in particular, is highlighted as being a source of sustainable and healthy food that can be accessed by poor communities (Farmery et al., 2021).

Other direct benefits can be derived from Payments for Ecosystem Services (PES) to communities, with the literature noting the particular potential for payments for bundles of ecosystem services contributing to key outcomes such as water quality (Vanderklift et al., 2019). To give a detailed example, Okafor-Yarwood et al. (2020), outline the case of the Mikoko Pamoja project in Gazi Bay, Kenya, the first mangrove PES project in the world. Approximately 117 hectares of natural and planted mangrove forests are under a co-management regime between communities, government agencies and NGOs, with carbon credits verified through Plan Vivo and sold on the international voluntary carbon market. By raising income from stacked services including carbon credits and other income-generating activities such as beekeeping and ecotourism, the project safeguards the mangroves and the multiple services they provide to the local community. Between 2014 and 2020, the community participants received USD 96,915 in PES payments.

The literature points to opportunities for capacity development and community empowerment relating to improved ocean and financial literacy, technological capacity, and entrepreneurship. It also identifies improvements in governance, equity and rights as direct opportunities for communities as well as key enablers of an inclusive SBE. For example, coaching for gender equity in the blue economy can lead to improvements in self-confidence, negotiating-skills and assertiveness for women more broadly (Österblom et al., 2020). Equity in particular is presented as important as a means (enabler) and as an end (opportunity). It can represent a virtuous cycle: improved experiences of equitable treatment and outcomes in some areas can lead to expectations about a minimum standard of socially just practice in other areas and across scales (Österblom et al., 2020).

Despite the huge potential for social and economic prosperity in a healthy and resilient ocean economy, there are three important considerations to note. First, there are competing requirements for space across marine sectors and they cannot all develop to their full potential simultaneously (Crona et al., 2021). Second, the capacity of these sectors to contribute to the blue economy varies across regions in

3 https://coopesolidar.org

response to natural resource availability and, more importantly, enabling conditions (Cisneros-Montemayor et al., 2021). Third, as highlighted in the following sections, many of the indirect and direct opportunities rely on a *sustainable* blue economy where sustainable use, protection and recovery of marine ecosystems is central, and where costs, benefits, and livelihood and food security opportunities are shared. Notably, the specific opportunities for coastal communities to engage in these sectors directly can be relatively limited.

3.2.2. Risks

There are concerns that the dominant blue economy agenda prioritizes economic growth over sustainability and equity, with oceans viewed "as a source of wealth and prosperity … whose economic potential needs unlocking" (Childs and Hicks, 2019, p. 324). The blue economy agenda has been described as akin to a *blue frontier* or a *blue rush*. Importantly, despite continued prominence in some blue economy narratives, evidence suggests that the 'trickle-down' of benefits from ocean-based economic growth to communities is unlikely (Wieland et al., 2016; Akinci, 2018), and prioritization of economic over environmental and social objectives can accelerate unsustainable use of marine resources, increase sectoral and user conflict, lead to elite capture and exacerbate inequities. Such business-as-usual and blue growth trajectories pose *indirect and direct risks* to coastal communities (Table 2).

A review of sectoral interactions in the blue economy noted that 13 out of 14 ocean sectors have interactions resulting in negative ecosystem impacts (Crona et al., 2021). The diverse suite of impacts identified can adversely affect coastal communities through loss of valued ecosystem services, with fisheries found to be particularly sensitive to negative impacts from other sectors mediated by marine ecosystems. Importantly, the authors note the potential for cumulative impacts driven by particular sectors: drilling, mining, aggregates, shipping, fishing, and aquaculture. Others also note that distant activities, such as DSM or fishing in ABNJ still impact vital coastal ecosystems through ecological connectivity and ocean circulation and advocate for a total prohibition of activities in ABNJ (Popova et al., 2019; UNEP FI, 2022). This includes calls directly from small-scale fishers' representatives in Africa and the Pacific to prohibit activities, noting a "blue fear" of DSM and "other destructive polluting activities promoted as part of the blue economy" (CAOPA, 2022).

Sectoral interactions can also result in direct conflict within and between marine sectors. Crona et al. (2021), identify military operations, shipping, and drilling as three sectors most commonly associated with conflicts. Aside from issues relating to climate change and pollution, oil and gas operations, in particular, are detrimental to capture fisheries, aquaculture, tourism and shipping (Jouffray et al., 2020); and fisheries and tourism are the sectors most vulnerable to conflicts with other marine uses (Crona et al., 2021). Moreover, the ability of communities to voice their concerns in an increasingly contested space will be challenging, with a risk that conflict is resolved in favor of more powerful economic interests (Voyer and Leeuwen, 2019).

Indeed, in a "business-as-usual" blue economy many coastal communities, small-scale sectors, and minority groups are marginalized from the high-level decision-making processes that are defining the blue economy, and from its implementation and governance (Cohen et al., 2019). The exclusion of coastal communities is particularly associated with offshore sectors, such as DSM and industrial fishing, suggesting a lack of connection between more remote initiatives and coastal communities.

A blue economy that fails to address or exacerbates unsustainable use, sector conflicts and marginalization of communities presents a number of significant *direct risks* to coastal communities' lives, livelihoods, food security and rights. As competition for ocean space increases, less politically powerful local communities and traditional resource users could be displaced or dispossessed of the ocean resources they depend upon (Bennett et al., 2019; Phelan et al., 2020). In particular, prioritization of larger-scale economic activities and growth sectors can mean activities such as small-scale fisheries are "subtly and overtly squeezed for geographic, political and economic space" (Cohen et al., 2019, p. 171), with important implications for access to resources, community livelihoods and food security. Reflecting development-induced displacement on land, Okafor-Yarwood et al. (2020), report the adverse impacts of port development on the livelihoods of fishers and farmers along the African coast. They give the example of Kribi Port in Cameroon where efforts to relocate communities were ineffective in addressing the wellbeing and livelihoods of displaced communities. Note too that top-down marine spatial planning processes and, specifically, the expansion of poorly sited and planned (no-take and highly regulated) Marine Protected Areas have been found to displace and dispossess Indigenous groups and other local communities from the marine ecosystems on which they depend economically, socially and culturally (Farmery et al., 2021).

In sum, community livelihoods that depend on marine ecosystems can be adversely impacted by environmental degradation, dispossession, displacement, direct conflict with other sectors, all of which are exacerbated by marginalisation from top-down planning and blue economy decision-making. In addition, the literature notes that as part of a developing blue economy, increased reliance on livelihoods (e.g., fisheries and tourism) that are already highly precarious and vulnerable to external perturbation (e.g., climate change and terrorism) may escalate adverse impacts on coastal communities. The blue economies of low-lying coastal areas, SIDS and LDCs

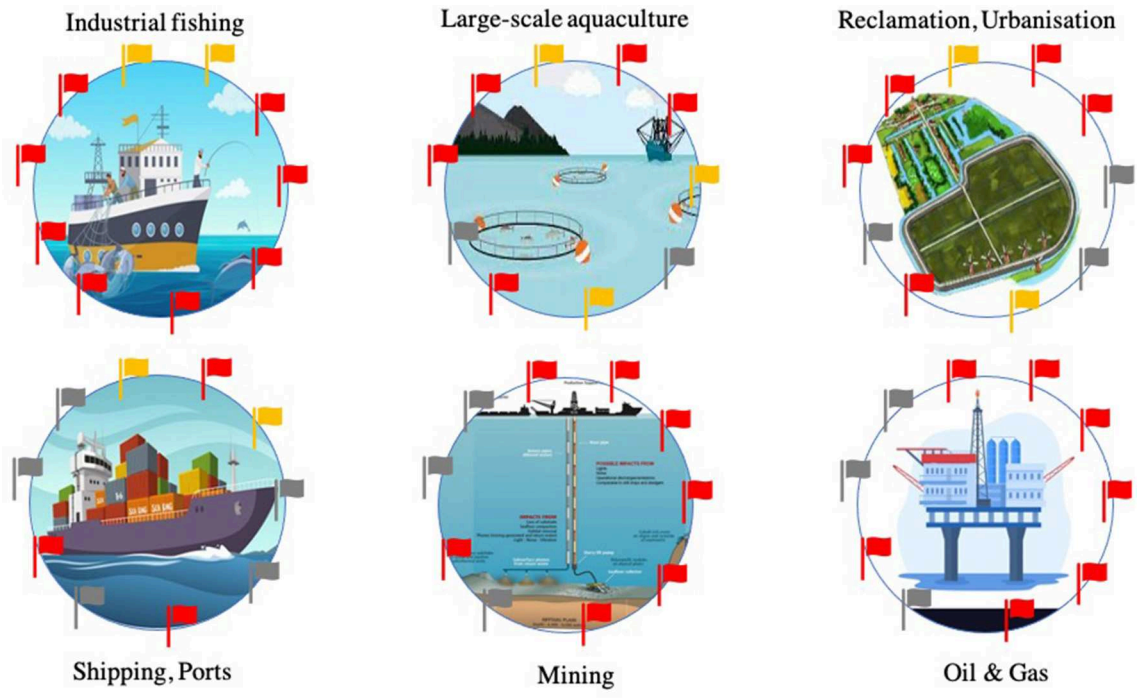

FIGURE 1
Illustration of red flags for coastal communities based on the consolidation of evidence from literature indicating risks to communities from key blue economy sectors. Red indicates high risk. Amber indicates moderate or mixed risks. Grey indicates uncertainty or no clear references in the study materials reviewed. Key (clockwise from 1): Rapidly expanding; Poor environment record; Unequal; Exclusive; Conflict; Displaces communities; Rights violations; Adversely impacts livelihoods; adversely impacts food security; Lack of benefit overall.

are disproportionately affected by direct impacts of the blue economy on coastal livelihoods (Österblom et al., 2020).

Food and nutritional security are similarly impacted by risks generated by an unregulated blue economy and external perturbations. In particular, the commodification of aquatic food production has the potential to dramatically alter local food systems. Small-scale fisheries provide a key source of micro-nutrients and protein for over a billion low-income consumers globally (Cohen et al., 2019). In a "business-as-usual" blue economy, this sector faces challenges from trade-offs among local, domestic and export markets; demand for high value seafood; and volatilities in global food markets and distribution channels. For instance, mariculture and coastal aquaculture are widely promoted to make up for declining wild-capture fisheries, yet production remains relatively low compared to wild-capture fisheries, and assumptions around substitutability fail to value the highly-dispersed subsistence uses and cultural importance of small-scale fisheries (Govan, 2017).

Finally, a blue economy that prioritises economic growth over social objectives risks perpetrating human rights violations and social injustice directly against members of coastal communities. Growth in the blue economy poses risks to health, safety and wellbeing, with evidence of human trafficking, bonded labour, and health impacts in industries including industrial fisheries and shipping (ship-breaking) (UNEP, 2021).

More broadly, existing inequalities in access to ocean resources can lead to unequal ability among ocean sectors, nations, communities and peoples to claim rights, take up opportunities, and influence the blue economy agenda thereby further exacerbating inequality (Crona et al., 2021). The literature suggests economic growth does not "trickle down" and that in the absence of explicit efforts to improve societal welfare, it can result in the poorest people being made worse off, as seen in the seafood trade (Farmery et al., 2021). Literature also contests assumptions that income from large-scale enterprises and government revenue is redistributed to those in need, raising important questions about the social benefits of offshore sectors such as DSM (Béné et al., 2016).

The sectors that come up consistently in the literature as concerns for coastal communities are mining, oil and gas, coastal development (urbanisation, port development, land reclamation), and industrial fishing (Figure 1). These industries are expanding rapidly, for example: larger-scale aquaculture production is driving exponential growth in the seafood industry; 12 of 15 mega-cities are coastal; oil and gas is the largest ocean-based industry by value with further growth expected offshore; and sand and gravel mining and deep-sea mining exploration are accelerating to keep up with the construction and high-tech industries (Jouffray et al.,

2020). These sectors have poor environmental records, and are shown to adversely impact communities in a number of significant ways, yet, they deliver very few to no benefits for communities. They are highlighted here as red flags that will require specific attention in developing a socially just SBE.

3.3. Barriers and enablers shaping engagement of communities in the blue economy

As well as understanding the opportunities and risks posed by the emerging blue economy for coastal communities, our review aimed to understand the conditions, broadly speaking, which influence the ability of coastal communities to influence the blue economy agenda, buffer its risks and take up its opportunities. In this section, we outline the barriers to and enablers of community engagement in a (sustainable) blue economy identified in the literature; organised into three themes related to power, capacities and governance. In Section 2.4 we then review the strategies used by coastal communities and supporting agencies to improve coastal community uptake and experiences of the blue economy.

3.3.1. Reducing power imbalances and structural inequalities

Power differentials between global north and south, governments and communities, and large-scale and small-scale producers are recognised as a key barrier to a more equitable (and sustainable) blue economy (Govan, 2017; Österblom et al., 2020; Bennett et al., 2021; Cisneros-Montemayor et al., 2021). The blue economy is currently characterised by the persistence of structural inequalities in political negotiations, international trade-agreements, global markets and value chains, resources and capacities (Table 3). For example, in Africa, 25% of all the marine catches in the continent are made by non-African states, resulting in the loss of USD 3.3 billion in potential earnings (Okafor-Yarwood et al., 2020). Such power imbalances and inequalities are exacerbated by top-down and exclusive blue economy decision-making (Okafor-Yarwood et al., 2020), alongside a lack of recognition for indigenous, customary and community knowledge, cultures and rights (Österblom et al., 2020). To enable a shift to a more equitable and sustainable blue economy requires improved international co-operation, clearly defined territorial rights for nations and communities, formalised mechanisms to ensure inclusive decision-making at all scales (including large-scale and/or off-shore activities), and more attention to a broad suite of human rights. In particular, areas traditionally and collectively governed by Indigenous peoples and local communities should be appropriately recognized and secured.

3.3.2. Addressing a lack of capacity, knowledge and resources

A lack of capacity is often cited as a barrier to community involvement in the blue economy. Specifically, this relates to a lack of knowledge, financial capital, education and skills, time and interest (UNDP, 2018; UNEP, 2021). Underpinning (scientific and technical) knowledge deficiencies are: scientific and knowledge inequalities; lack of appreciation for Indigenous and local knowledge; insufficient knowledge-sharing and promotion of best-practice; as well as widespread data and information gaps around the environmental, social and cultural impacts of blue economy activities (Österblom et al., 2020). In response, valuing Indigenous knowledge, decolonising and democratising ocean research, and accounting for social impacts and social limits to growth are key enablers for a more equitable and sustainable blue economy.

Financially, the investments required to catalyse development of a sustainable blue economy, particularly at the community level, are substantial. The USD 13 billion of philanthropy and Overseas Development Assistance spent over the last decade is regarded as insufficient (Sumaila et al., 2021). Ocean investments are often seen as high risk and there is a perceived lack of high-quality investment opportunities (Sumaila et al., 2021), exacerbated by widespread under-valuation of marine and community resources (Chen et al., 2020). Moreover, financial institutions are concentrated in the Global North and dominated by large corporations and multinationals (UNEP, 2021). As such, finance can be challenging to access for the countries and communities that need it most (UNDP, 2018; Okafor-Yarwood et al., 2020). Improving access to sustainable finance, as well as capacity building around business planning and enterprise development are key enablers for coastal community engagement in the blue economy. To this end, key frameworks, such as the Sustainable Blue Economy Finance Principles[4] have been developed to help re-direct harmful subsidies and market mechanisms; capture and re-distribute revenues for ocean uses; improve community access to finance and credit, and; foster new and innovative investments in green and social enterprises (WWF, 2018). Beyond knowledge and financial resources, a broad suite of capacity and resource issues can limit communities' ability to and interest in engaging with the blue economy, from poverty and lack of social security; to lack of education, literacy and skills; to remoteness and organisational challenges. These present immediate barriers to accessing finance, understanding policy or scientific language (including the language of the blue economy), and navigating bureaucratic processes. To

4 https://www.unepfi.org/blue-finance/the-principles/

TABLE 3 List of factors identified in a strategic review of the literature as blocking and enabling the emergence of a more equitable sustainable blue economy.

Barriers	Enablers
Elite capture of the blue economy - Existing power imbalances - Top-down and fragmented decision-making **Existing inequalities and lack of rights** - Structural inequalities - Lack of recognition - Lack of rights	**Equitable partnerships** - Improved international co-operation - More inclusive decision-making involving diverse stakeholders across scales, including accountable public consultation and formal requirements to include communities. - Improved understanding of the value communities contribute economically, socially and culturally. - Enhanced advocacy of community rights - Right to free, prior and informed consent of Indigenous peoples and local communities is recognized and respected. - More collaborative processes with communities, including shared visions for a SBE **Secure tenure and human rights** - Legally defined national jurisdictions - Improved mechanisms to fairly allocate rights over ABNJ - Communities' customary and territorial rights secured - Recognition of human rights to food, equality and non-discrimination, Indigenous rights and labour rights - Use of (human) rights-based approaches
Uncertainty and knowledge gaps - Knowledge gaps in ecological, technical, financial, management and socio-cultural information - Scientific and knowledge inequalities - Lack of appreciation for local and Indigenous knowledge - Insufficient knowledge sharing **Market and finance barriers** - Inadequate financial investment - Ocean investments (in sustainability and community development) seen as high risk - Under-valuation of marine and community resources - Concentration of financial institutions and resources - Available finance difficult to access - Questionable financial and market practices common **Community capacity and heterogeneity** - Limited education, skills, time, capital, technology and infrastructure - Challenges with community organisation, governance and heterogeneity - Lack of interest and engagement in the blue economy agenda - Remoteness - Small economies - Poverty and lack of social security	**Knowledge-sharing and evidence-based decision-making** - Generation of evidence on social and cultural impacts; tangible and intangible values; social and ecological limits to growth - Better inclusion of a multiplicity of knowledge systems (including Indigenous/local) and knowledge exchange across diverse stakeholders - Strengthened adaptive learning about risks and opportunities - Democratisation of ocean research **Improve access to markets and innovative, sustainable finance** - Re-direction of harmful market subsidies and mechanisms in place to promote sustainable and equitable uses - Mechanisms implemented to capture revenues from ocean use through taxes, levies, and fees - Improved access to financing, savings, micro-credit and insurance - Private sector, donor and government investment guided towards blue-green and social enterprises - Consumer preferences for sustainable and fair-trade goods and services leveraged **Capacity to address risks and take up opportunity** - Emphasis on satisfying people's basic needs - Community capacities accounted for in programme design - Improved access to innovative environmentally appropriate technologies and infrastructure - Strengthened capacity to lobby and network strategically
Lack of and ineffective governance - Loopholes in international obligations - Lack of clear jurisdictions, accountability, criteria, targets, and indicators - Politics and power dynamics, including geopolitical manoeuvring, lobbying by industry, colonial legacies and corruption - Lack of formalised benefit-sharing obligations - Substantial costs of developing and enforcing regulation - Lack of political will to drive necessary policy and regulatory change for a SBE - Policy prioritisation of large-scale economic industry - Low institutional capacity and resources - Lack of integrated planning	**Improved governance** - Improved implementation of existing regulation - New regulation and institutions developed to deal with emerging sectors - Inclusion of clauses to mitigate social (as well as environmental) impacts of activities, and associated impact assessments. - Good governance principles fully applied - Decentralised governance approaches implemented - Rights to participation and fair outcomes formally recognised

The information in this table was extracted from the published and grey literature reviewed (references in Supplementary Table 1).

10.3389/fpos.2022.1032204

TABLE 4 Key strategies identified in a strategic review of the literature to ensure communities can address risks and take up opportunities in the blue economy.

Strategy	Options
Showcasing customary practices	- Continue (and adapt) customary practices and management - Utilise and (re-)assert coastal territories and tenure - Use the narratives of conservation and climate change to reinforce and authenticate customary practices
Documenting and evidencing	- Document and map existing patterns of resource use to allow communities to evidence and claim associated rights - Valuation of small-scale marine resource uses for economies - Monitor and enforce compliance to existing management regulations - Record social and environmental impacts and risks of unsustainable blue economy interventions - Develop and apply best-practice models - Use and value local knowledge, and democratise science and data gathering
Co-production and collaboration	- Foster community ownership, engagement and participation - Develop partnerships with NGOs, CBOs, governments and private sector - Create bridging organisations and multi-stakeholder forums - Cross-sectoral blue economy planning - Build social capital and trust
Providing resources	- Provide infrastructure and technologies, including Information and Communication Technologies (ICT) - Set up financial mechanisms accessible to communities, engage the private and finance sectors to attract donors, and support communities to comply with funding requirements - Create good conditions for investment and support with incubation and acceleration of innovations and enterprises. - Translate concepts, framework and approaches so they are accessible for communities
Capacity building	- Provide education and skills training (financial literacy, technical know-how, business skills, research and monitoring, resource management, value chain efficiencies, organisational skills, risk awareness) - Empower communities and small-scale producers to understand and claim rights; access and participate in decision-making - Support marginalised groups (e.g., women and youth) in leadership, governance and business
Improving governance	- Alter financial and other incentives (e.g., certification schemes) - Planning and designation of marine areas for community development - Nurture and improve community leadership - Develop new policy and institutions for community participation

The information in this table was extracted from the published and grey literature reviewed (references in Supplementary Table 1).

enable effective community engagement in the blue economy, approaches need to accommodate and address capacity issues within communities.

3.3.3. Improving governance of the blue economy

Non-existent, fragmented and poor governance are major barriers to a sustainable and equitable blue economy. Table 3 identifies constraints at the international/regional level (e.g., loopholes in international obligations and geopolitical manoeuvring) and at the national/sub-national level (e.g., poor planning, impact assessment and accountability), driven by factors such as low institutional and financial capacity, lack of political will, corruption and pressure from vested interests (Govan, 2017; UNDP, 2018; Okafor-Yarwood et al., 2020; Österblom et al., 2020). Yet, effective governance is arguably the most significant enabler of an equitable and sustainable blue economy, including improved implementation of existing regulation and development of new policy and institutions to govern emerging and expanding sectors (Sumaila et al., 2021). Clear governance frameworks, good governance principles, and inclusive and decentralised forms of governance are identified in the literature as critical to the delivery of an inclusive SBE. Our review also noted the need for civil society and private sector participation (including communities) to play a role in blue economy governance (e.g., voluntary agreements and codes of conduct, corporate social responsibility, social license to operate, certification) (Voyer and Leeuwen, 2019; UNEP, 2021).

3.4. Strategies used by and to support communities navigate the blue economy

The risks and barriers associated with unsustainable blue growth being faced by coastal communities are numerous and the effort needed to deal with risks, in turn, limits the time and capacity communities have to create and take advantage of new opportunities from an emerging sustainable blue economy. There is high dependence on civil society groups, the third sector and/or governments to develop solutions in partnership with communities. Aligning with enabling factors, the literature review identified a diverse range of strategies that offer multiple avenues for pro-active support of communities and that can be employed as portfolios of activity (Table 4).

Several facets of community and customary practice are significant for the development of the blue economy. These include: recognising that the oceans are not "uninhabited" empty spaces but replete with local and customary practices, knowledges and values; acknowledging that these practices, knowledges and values are under-documented and -recognised in scientific and policy discourses in terms of their importance to communities, to economies and to sustainable resource management; and being aware that formal recognition in the form of rights is, therefore, often missing (Bennett et al., 2019, 2021; Cohen et al., 2019; Österblom et al., 2020).

Many of the strategies that communities employ aim to showcase, document, defend and reinforce these customary practices and rights, which in turn can provide the authority to regulate their own and others' blue economy activities within coastal areas. Governments and supporting agencies can play a vital role in documenting, evidencing, monitoring and enforcing blue economy activities and their social and environmental impacts (UNDP, 2018). For example, the Illuminating Hidden Harvests[5] and Too Big to Ignore[6] initiatives set out to document the value of small-scale fisheries. The literature notes the importance of valuing local knowledge systems, fostering access to available scientific and monitoring data, and democratising scientific processes to enable communities to generate new knowledge and information (e.g., through citizen science).

A co-production approach is often highlighted as a key strategy. Three scales of collaboration are important: (i) community participation in and ownership of blue economy initiatives from conception to monitoring (Chen et al., 2020); (ii) collaboration between communities and government, private sector, and civil society (UNDP, 2018); and (iii) co-operation at a regional and international level, among nations, multi-lateral agencies and the private sector (Govan, 2017). Collaboration with diverse stakeholders across scales is seen as integral to scaling up the potential benefits of a SBE for communities (Chen et al., 2020).

High levels of social capital, participation, and trust – and strategies that promote these – underpin effective partnerships. NGOs can play a vital role as trusted partners mediating relations between communities and other actors (e.g., governments and the private sector). A good example of where high social capital in communities and strong partnerships with NGOs has been effective in influencing blue economy outcomes is in the Arctic. Here, Indigenous Peoples and Local Communities (IPLCs) of the Arctic Council[7] and NGO allies have, among many other examples: (i) developed a vision for the Arctic's Blue Bioeconomy; (ii) scaled up efforts to document and digitise Arctic cultural heritage "including food heritage as a foundation for diversification of local economies and new approaches to adapt to Arctic change", and; lobbied against oil exploration and extraction and successfully won a moratorium in court (PAME, 2021). In the absence of trusting partnerships, local communities can resort to non-compliance, resistance and protest. These strategies did not feature in the blue economy literature (even where there was dissatisfaction with blue economy interventions such as the Kribi port development example detailed earlier), but are a well-known strategy in wider natural resource management literature (Boonstra et al., 2017).

The role of governments and supporting agencies is particularly important in providing resources, building capacity and enhancing governance of the blue economy. Improved access to financial, technical, human and other resources can encourage adoption of new innovations, enable development of new livelihoods and market opportunities, incentivise changing practices, and improve transparency and accountability in supply chains and governance (UNDP, 2018). Strategies to build capacity typically focus on the community level–for instance, in financial literacy, business skills and leadership–but can also target supporting agencies, the private sector and government agencies.

Finally, communities and supporting agencies play a critical role in influencing, developing and implementing blue economy governance across scales. Strategies include shaping incentive systems, planning and designating marine uses, lobbying and advocacy, and developing new policy and regulation directly. Factors seen as integral to scalability were: co-production approaches, peer-to-peer exchanges, collaboration with the private sector, financing, and innovative technologies (e.g., ICT can enable scaling up of citizen science data collection from manual inputs to a large database, which in turn has the potential to be rolled out across other areas).

4. Discussion and ways forward

Coastal communities are increasingly impacted by a blue acceleration whether or not it is explicitly driven by the blue economy agenda. Blue economy transitions are not currently shaped by communities' visions for development, nor are they necessarily explicitly aligned to Agenda 2030. Further, the capacity of communities to engage effectively with such rapid economic and governance transitions is limited. As a result, many of these change processes are experienced as external risks and barriers by communities.

Certainly, the review finds that there is a significant lag in blue economy governance and regulation to protect communities and the marine ecosystems they depend on. Ambitious individual growth trajectories across blue economy sectors threaten to collectively exceed the carrying capacity of the ocean and significantly escalate ocean conflicts. Fisheries

5 https://www.cgiar.org/news-events/event/illuminating-hidden-harvests-ihh-a-snapshot-of-key-findings-webinar/

6 http://toobigtoignore.net

7 https://www.arctic-council.org/projects/

and tourism — sectors on which communities often rely — are particularly vulnerable to adverse impacts from other blue economy sectors. Regulation of expanding, emerging and high-risk sectors such as shipping, oil and gas, deep-sea mining, large-scale aquaculture, and industrial fishing is currently inadequate to ensure sustainable outcomes and equitable sharing of benefits. There is also a lack of tailored governance frameworks to support benefit sharing and community engagement in a SBE. Ocean policies are described as "equity-blind", with blue economy narratives, in particular, criticised for homogenising, de-peopling, and de-politicising the oceans (Österblom et al., 2020; Bennett et al., 2021). In their comparative analysis of regional blue economies, Cisneros-Montemayor et al. (2021), found equity, human rights and infrastructure to be the enabling conditions most lacking across regions.

As this review shows, communities have not been able to negotiate the processes and outcomes of the blue economy on an equal footing. Blue economy decision-making processes have failed to recognize and facilitate the effective and inclusive engagement of coastal communities, present and future. As our review highlights this is a result of structural inequalities, a lack of recognition for community knowledges, values, customary rights and small-scale practices, and difficulty engaging diverse and dispersed communities in decision-making processes that are not fit for purpose. Such inequalities become more pronounced when the other actors are powerful financial institutions, corporations and governments vying for political favour and competitive advantage in large EEZs and ABNJ with little regard for the downstream impacts on marine and coastal ecosystems and people. Inter-generational equity is particularly challenged by current narratives around blue growth.

Practical action can, however, be taken to address some of these key challenges. We propose four priority actions to advance a more inclusive SBE.

1. *Co-developing a shared vision and language on the SBE*: The discourses of the blue economy and sustainable blue economy have been dominated by multi-lateral actors such as the UN agencies, the European Commission, Commonwealth Secretariat and the Organisation for Economic Cooperation and Development (Childs and Hicks, 2019), as well as global NGOs, and blue economy policy and strategies are proliferating rapidly. Moving forward, it will be vital to include community representatives in co-developing regional, national and local SBE visions and plans, using a shared language that is accessible and can be deployed by governments, practitioners and communities alike. Developing plans at multiple levels will be better able to take into account the varied regional and local contexts that are so important to coastal communities and that shape their experiences of the blue economy.
2. *Mainstreaming social justice principles:* Mainstreaming recognition, procedural and distributive justice in decision-making for current and future generations is key to delivering an inclusive and equitable SBE (Österblom et al., 2020). Bennett et al. (2021), summarise key steps for advancing social justice, including: differentiating rights-holders and other stakeholders; acknowledging customary rights and tenure; building capacity for participation and co-management; respecting principles of free, prior and informed consent, and; providing fair compensation, mitigation and conflict management mechanisms. Implementing such solutions will require policy support, capacity building, access to sustainable and low-cost finance, and improved data and transparency (UNDP, 2018; Sumaila et al., 2021). Partnerships with rights-based organisations and building capacity in rights-based advocacy will be key. It may also be important to concentrate SBE resources on particularly vulnerable groups and communities, for instance, women, young people, Indigenous groups and communities in SIDS and LDCs to mitigate past inequalities (Sumaila et al., 2020; Gill et al., in press).
3. *Strengthening integrated governance across scales and sectors*. There are three important aspects to the governance of an inclusive SBE. First, existing governance mechanisms need to be effectively implemented. Many governance solutions are already in place–ranging from sectoral and inter-sectoral regulations, through to legislation designating rights to participation and legal redress, to principles for sustainable and ethical investment–but they are not sufficiently implemented, enforced and monitored (Sumaila et al., 2020; UNEP, 2021). Second, integrated governance is needed to strengthen and fill gaps in existing regulation and, importantly, to address the potential impacts and environmental and social implications of new and emerging sectors (UNEP FI, 2022). Strategies to integrate ministries, strategies and approaches will be critical to ensuring that equity and sustainability remain primary objectives of key decision makers as well as offering necessary efficiencies (Govan, 2017). Third, specific policy and institutions are required to more comprehensively protect the rights of coastal communities to a healthy environment, to food, nutrition and health, and to participation and inclusive decision-making, among other rights (Jouffray et al., 2020; Österblom et al., 2020). To date, even examples of new and relatively progressive policy and legislation, for instance, regional management of fisheries by the Pacific Island States, highlight the continued imbalances in negotiating power and how benefits from the blue economy are distributed (Govan, 2017). Furthermore, an important task of sustainable blue economy governance will be to recognise and manage tensions and potential trade-offs among multiple and equally important environmental, economic and social objectives such as marine protected areas, marine renewables, small-scale fisheries livelihoods, sustainable aquaculture, and food and nutritional security–not all of which may be able to be reconciled.

4. *Bridging different scales of action and opportunity*: There is notable under-investment by the public and private sector in sustainability (Österblom et al., 2020; Sumaila et al., 2020) and in marine resource-dependent coastal communities. Knowledge of and access to available finance can be limited for the countries and communities that need it most (UNDP, 2018; Okafor-Yarwood et al., 2020). For an inclusive SBE, it will be critical to develop mechanisms and approaches that support the flow of sustainable finance and other resources and opportunities to the community level, to support their sustainable development ambitions and needs, as well as their role as stewards of coastal ecosystems. Voyer et al. (2021), highlight the importance of innovative financing linking community and civil society expectations with private and public sector investment, giving the recent example of the Global Fund for Coral Reefs[8]; a finance initiative which could foster a blue COVID-19 recovery. Opening up coastal communities' access to environmentally appropriate technology solutions, sustainable infrastructure, education and skills training, and knowledge and research processes, as advocated by SDG 17, will also be integral to more equitable development of the sustainable blue economy (UNEP, 2021; Voyer et al., 2021). Equitable partnerships across scales, stakeholders and sectors are fundamental (UNDP, 2018; Okafor-Yarwood et al., 2020).

5. Conclusion

To conclude, our review reiterates that coastal communities are facing an uncertain future. Whilst coastal ecosystems can offer substantive goods and services that support their societal needs, these ecosystems are under severe threat from over-exploitation and direct destruction due to escalating coastal development, pollution and climate-related impacts. Trillions of dollars of public and private sector finance is expected to be targeted at coastal development over this decade which, alongside COVID-19 stimulus finance, could further exacerbate the biodiversity crisis and negatively impact coastal communities if not directed towards sustainable development pathways.

Equity is a prime issue when considering how such large-scale coastal development is affecting coastal communities. Communities have *the right* to sustain their way of life and develop in ways that support their future aspirations and underpin their environmental, social and economic resilience. They also have a distinctive and critical role to play as stewards of our coastal ecosystems, and whilst many self-organise around community-based conservation, locally managed marine areas or other governance structures to fulfil this role, our review shows that they face significant barriers in accessing income or finance to support key functions relating to restoration and protection and to take up other opportunities from a SBE. Importantly, many coastal communities are also themselves developing in ways that don't always serve their long-term needs. Modern approaches to small-scale fishing and increasing access to domestic and international markets, as well as increasing population sizes and limitations on available income and food sources due to degraded ecosystems, are all placing additional pressures on diminishing ecosystem goods and services.

Business-as-usual is a lose-lose situation for all–developers, maritime sectors, financiers and dependent coastal communities. It is crucial that the transition to a sustainable blue economy is delivered at all levels–ensuring that coastal communities are empowered to develop in ways that secure their long-term needs without negatively affecting the natural ecosystems on which they depend. They also need to be supported in their role as environmental stewards of coastal ecosystems, through free, prior and informed consent and recognition of their customary rights, territories and practices.

This paper has outlined the risks associated with current business-as-usual practices to coastal ecosystems and the communities dependent upon them and how the voice and actions of communities might be better included into sustainable blue economy strategies, planning approaches, and decision-making, in order to deliver a more equitable and sustainable development trajectory within the blue economy.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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8 https://www.undp.org/press-releases/new-un-multi-partner-trust-fund-coral-reefs

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Supplementary material

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Corrigendum: Putting coastal communities at the center of a sustainable blue economy: A review of risks, opportunities, and strategies

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In the published article, there was an error in the caption for Figure 1 as published. The text states: "Illustration of red flags for coastal communities based on the consolidation of evidence from literature indicating risks to communities from key blue economy sectors. Red indicates high risk. Amber indicates moderate or mixed risks. Grey indicates uncertainty or no clear references in the study materials reviewed. Key (clockwise from 1): Unequal; Exclusive; Conflict; Displaces communities; Rights violations; Adversely impacts livelihoods; adversely impacts food security; Lack of benefit overall."

The corrected caption appears below:

"Illustration of red flags for coastal communities based on the consolidation of evidence from literature indicating risks to communities from key blue economy sectors. Red indicates high risk. Amber indicates moderate or mixed risks. Grey indicates uncertainty or no clear references in the study materials reviewed. Key (clockwise from 1): Rapidly expanding; Poor environment record; Unequal; Exclusive; Conflict; Displaces communities; Rights violations; Adversely impacts livelihoods; adversely impacts food security; Lack of benefit overall."

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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Operationalizing the blue economy in the Gulf of Guinea, Africa

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The Blue Economy is crucial for sustainable development in Africa, and the Gulf of Guinea, one of Sub-Saharan Africa's most economically dynamic countries, faces several challenges in transitioning into this economy. This study assesses the situation of the Blue Economy in the Gulf of Guinea and proposes strategies for its operationalization. A qualitative research approach was used to examine each member state's marine conservation initiatives, regional collaboration, management approaches, and strategic frameworks. Findings show that the Gulf of Guinea is already experiencing blue economy activities, but challenges like rapid population growth, urbanization, piracy, unsustainable anthropogenic activities, poor institutional frameworks, and climate change hinder the transition. The Gulf of Guinea's ocean economy accounts for less than 10% of GDP, so integrating the blue economy into trade strategies is crucial for its transformation. A systematic approach based on national priorities, social context, and resource base is needed to foster social inclusion, economic progress, and sustainable ocean development. Enablers of blue growth, such as integrated coastal zone management, marine spatial planning, marine protected areas, marine biodiversity, and blue justice discourse, must be integrated into policy design, prioritizing sustainability and equity. A cautious, phased approach is suggested, focusing on establishing traditional sectors, growing them, integrating value chains, and implementing regional collaboration so that the blue economy delivers on its social, environmental and economic goals in the Gulf of Guinea.

KEYWORDS

Blue Economy, Gulf of Guinea, strategic framework, regional collaboration, blue growth

1. Introduction

The ocean covers approximately seventy percent of the earth's surface, including the ocean, seas, rivers, streams, and lakes, serving as man's most vital support system (Allison et al., 2020). It contributes significantly to global wealth creation by supplying food, drinking water, clean air, job opportunities, climate regulation, waste treatment, biodiversity habitat, and functioning coastal and marine ecosystems (Sandifer and Sutton-Grier, 2014). For example, the ocean food sector provides nutrients in the form of protein for over 3 billion people and provides as many as 260 million jobs globally (Teh and Sumaila, 2011). Globally, it has been estimated that the value of the world's marine environment is US$2.5 trillion per annum (Hoegh-Guldberg et al., 2015). Recent studies indicate that the oceans contribute more than a quarter (US$24 trillion) of the world economy (US$94 trillion), and increased protection of critical marine habitats will result in additional net benefits of US$3 trillion by 2030 (Hoegh-Guldberg et al., 2015; OECD, 2016; Bax et al., 2021).

Given its potential for economic growth, employment, eradicating poverty, and ensuring food security, among other things, the ocean is considered a frontier for environmental sustainability and a necessary tool for achieving sustainable economic development

(United Nations Economic Commission for Africa, 2020). Due to human activities like overfishing, coastal development, pollution, climate change, ocean acidification, and as well as the fact that the oceans' carrying capacity is at its limit, the ecosystems of the ocean are changing, thus significantly impacting human wellbeing (Nash et al., 2017). The rapid expansion of economic activities in the oceans without precaution will have significant implications for the already overburdened marine environment and resources, leading to injustices (Ehlers, 2016; Golden et al., 2017; Nash et al., 2017; Klinger et al., 2018). The injustices because of blue growth include dispossession, displacement, ocean grabbing, environmental justice concerns, degradation, undermining livelihoods, access to marine resources, inequitable distribution of economic benefits, social and cultural impacts, marginalization of women, human and Indigenous rights abuses, and exclusion from decision-making and governance (Bennett et al., 2020). As a result, immediate global and regional action is required to shield the oceans from the numerous pressures they encounter (United Nations, 2017).

Similarly, there is a need for a course that can advocate for the sustainable development of ocean spaces without jeopardizing their ability to perform their natural functions (Smith-Godfrey, 2016; Wenhai et al., 2019). The preservation and responsible utilization of oceans, seas, and marine resources for sustainable development are critical due to the significant alterations occurring in ocean ecosystems. This is a key focus of one of the 17 Sustainable Development Goals (SDGs) - SDG14 - that must be given top priority (Nash et al., 2017). This has necessitated increased efforts and investments by governments and stakeholders worldwide in policy reforms and rule changes to better safeguard and restore functionality in ocean ecosystems (OECD, 2019), resulting in the development of the Blue Economy concept. Furthermore, procedural, distributive, and recognition justice dimensions may be used as a comprehensive, all-encompassing framework to direct the planning, execution, and administration of ocean-based development efforts to ensure blue justice in the ocean environment (Bennett et al., 2020).

The Blue Economy (BE) aims to protect the world's ocean resources by promoting economic growth, social inclusion, and livelihood preservation/improvement while ensuring environmental sustainability and resilience (Smith-Godfrey, 2016; World Bank and UNDESA, 2017; Olteanu and Stinga, 2019; Essen, 2020; Martínez-Vázquez et al., 2021; Lee et al., 2022). BE seeks to decouple socioeconomic activities and development from environmental degradation while maximizing the benefits of coastal and marine resources (Lee et al., 2020). The Blue Economy concept is consistent with agreements that established the United Nations Convention on the Law of the Sea (UNCLOS), which defines nations' rights and responsibilities regarding their use of the world's ocean and establishes guidelines for ocean economy, environment, and marine natural resource management (World Bank and UNDESA, 2017).

The Blue Economy concept has emerged as a significant driving force in achieving global sustainable development and the conservation of ocean and coastal resources (Union for the Mediterranean, 2017; Wenhai et al., 2019). This necessitates considering all three pillars of sustainable development: economic, environmental, and social, resulting in the development of initiatives that are environmentally sustainable, inclusive, and climate-resilient (United Nations, 2022). BE is based on Integrated Coastal Zone Management (ICZM), which implements policy, activity, and investment coordination to improve the sustainability of coastal and ocean resources (OECD, 2019). Diversifying a country's economy to sea-based activities is crucial for achieving sustainable development goals (SDGs) and inclusive economic growth, ensuring increased economic benefits from sustainable marine resource use.

BE's overarching goal is to construct integrated economic activities and businesses related to ocean space to maintain a healthy economy without jeopardizing other parts of sustainable development (Spalding, 2016). BE promotes maritime and coastal resource protection by allowing for the formation of both international and regional integration, where member nations of a given region may foster collaboration and coordination (Haimbala, 2019). It also enhances land and sea management and the management and administration of marine ecosystems.

In Africa, the BE concept is being adopted internally and externally (Childs and Hicks, 2019). This is evident in the "Agenda 2063: the Africa We Want", the 2050 African Integrated Marine Strategy, Policy Framework, and Reform strategy for fisheries and aquaculture in Africa (Pretorius and Henwood, 2019). Indeed, the African Union (AU) stressed the need to transition into the BE and therefore develop an initiative for a sustainable BE urgently to improve the socioeconomic wellbeing of Africans by fostering increased wealth creation along African oceans and seas in an environmentally sustainable manner (African Union, 2012). The African Union (AU) plays a significant role in developing and implementing the Blue Economy policy and strategy in the region (United Nations Economic Commission for Africa, 2016). Indeed, the African Union Commission has developed a pan-African agreement on the Blue Economy's vital role in encouraging structural transformation by 2030 (United Nations Economic Commission for Africa, 2016). The Blue Economy is now a primary goal and priority of the African Union 2063 Agenda, with Goal 6 focusing on the Blue/Ocean Economy for accelerated economic growth (AU-IBAR, 2019). Many African countries have already become signatories to the AU 2063 Agenda.

Only a few African nations, primarily those in the south of the continent, have successfully transitioned to the BE others are drafting policies to include the approach in their national development plans (Lopes, 2016). For instance, to generate employment, reduce poverty, and improve social equity, Operation Phaskisa (unlocking the ocean's economy) was launched in South Africa, while in Seychelles, "The Seychelles Blue Economy Strategic Policy Framework and Road map: Charting the Future (2018–2030)" was developed with four specific goals. It even established a ministry whose sole purpose was to advance the BE (Findlay, 2018). Although Madagascar is still establishing its own BE framework, it has made significant progress thanks to sustainable practices.

The Gulf of Guinea, which encompasses the sub-Saharan countries, is a diverse region stretching from Guinea Bissau to Angola (Ibe and Sherman, 2002), covering approximately 6,200 kilometers of coastline. The region is a crucial hub for shipping and transporting various products, such as oil, gas, and goods, to and from other parts of Africa (European Union, 2021). This

region, known to be Africa's most populous and economically dynamic (Giulini, 2021), is yet to transit into the BE despite the tremendous progress made in Africa. Some reasons include weak political institutions, vicious clashes, climatic and demographic pressure, lack of economic growth, and misappropriation of natural resource revenues (Sartre, 2014). Others include a need for more government monitoring of the sea, an adequate awareness of the marine economy, which is responsible for the lack of an appropriate institutional framework, and unsupervised anthropogenic activities in the coastal and marine regions (Zhang and Xing, 2022). Therefore, actions of pirates, kidnapping, human and drug traffickers, and illegal fishermen, among other factors, have impeded security and, thus, threatened the achievement of BE goals in the region (Lindley, 2021). Overlooking these issues will hinder the potential economic growth that the ocean bestows as it calls for interventions in the area and beyond. Additionally, the natural resources presumed to support the BE are exposed to various hazards and environmental degradation. For instance, four West African countries (Benin, Côte d'Ivoire, Senegal, and Togo) lost an estimated $3.8 billion (5.3% of GDP) in 2017 to flooding, coastal erosion, pollution, oil pollution, and industrial and domestic wastes (Okafor-Yarwood et al., 2020).

Transitioning into the BE will aid in capturing economic marine opportunities while addressing the causes and risks of economic degradation and loss of natural capital (Patil et al., 2018). Transitioning to BE will discover and unlock the potential of the marine economy, thereby reducing ocean degradation and alleviating poverty (Kathijotes, 2013). Furthermore, the BE will stimulate economic growth, generate employment and investments, and reduce poverty while protecting healthy oceans and providing a clear vision for the national or regional development of the marine sector (Union for the Mediterranean, 2017). To this end, this study aims to assess the existing situation of the Blue Economy in the Gulf of Guinea and recommend strategies for its operationalization.

2. Research locale

The Gulf of Guinea is situated in the northeastern part of the tropical Atlantic Ocean, extending from Guinea Bissau to Angola (Ibe and Sherman, 2002; UNESCO, 2021). It runs through countries like Guinea Bissau, Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Sao Tome and Principe, Gabon, Republic of Congo, Democratic Republic of Congo, and Angola (See Figure 1). It also contains Islands such as Bioko, Sao Tome, Principe, Llehu, BomBom, Caroko, ElobeyGrandey, Elobey Chico Annobon, Corisco, and Bobowasi. This region is where a seasonal upwelling takes place along the equator and its northern coasts between Benin and Ivory Coast (Ali et al., 2011).

The region has oil reserves of 51.34 billion barrels (3.11% of global reserves) and gas reserves of 202,346,000 million cubic feet (2.91% of global reserves) (Worldometer, 2016a,b). It is also endowed with lush rainforests, one of the world's principal suppliers of oxygen (Ghosh, 2021). It also contains one of the richest fishing grounds in the world, accounting for around 4% of worldwide fish output (Giulini, 2021; Morcos, 2021). Ten of the sixteen nations in the Gulf of Guinea have proven oil reserves, with Nigeria and Angola leading the way, accounting for 88.6% of total oil production in the region. Minerals found in this region include petroleum products, bitumen, diamond, gold, tin, manganese, and silver.

The area has some of the most dynamic economies in terms of socioeconomic aspects. For example, despite having a vast population of over 200 million people and a GDP growth rate of 2.7%, Nigeria still needs a significant proportion of export income and GDP from a broadly diverse blue economy base (Hamisu, 2019). Similarly, Cape Verde, with many islands and the largest Exclusive Economic Zone in the Gulf of Guinea, offers enormous potential for the BE through encouraging investments in ports and marine transportation, tourism, fisheries, and aquatic ecotourism (Fonseca, 2021). The area is recognized for issues such as high unemployment, poverty, informality in their economies, and poor infrastructure, exacerbated in the face of the COVID-19 problem (Grynspan, 2021). This region has many sovereign states that share similar economic qualities of poverty with a rapidly growing population.

3. Methodology

This study utilized a qualitative research approach to scrutinize the blue economy activities, marine conservation initiatives, regional collaboration, management approaches, and strategic frameworks to transition into the BE in each Gulf of Guinea member state. Content analysis as a research tool was used to determine if these countries have developed a broad BE-based structure for their economies through textual evidence from the literature. The mode of data collection includes documents that refer to the blue economy or any other relevant existing marine initiative, blue agenda, blue growth, and ocean governance in each member state. This process entailed verifying whether member states have any framework for operationalizing the BE concept. The extent of transition into the BE was also assessed to determine if there are existing strategies or if these strategies are underway. It also proceeds to resolve the challenges hindering the operationalization of this concept. Further, it recommends an approach that will coordinate and incorporate the BE into trade strategies and industrial policies.

The analyzed documents were policy documents, reports, online documents, government reports, journals, and conference proceedings. These documents were derived from an extensive internet search for literature on the blue economy, blue growth, blue agenda, and strategies. Likewise, information was obtained through a focused web search on websites of national and continental government agencies and organizations and non-governmental organizations involved in marine activities.

Documents about the transition to the blue economy were gathered from the official websites of each nation for content analysis. Many documents were received from several authorities that have established projects to shift toward the blue economy. Some of these papers have already been published, while others are planning frameworks presently being developed, yet others are in the implementation stage. Forty-nine papers

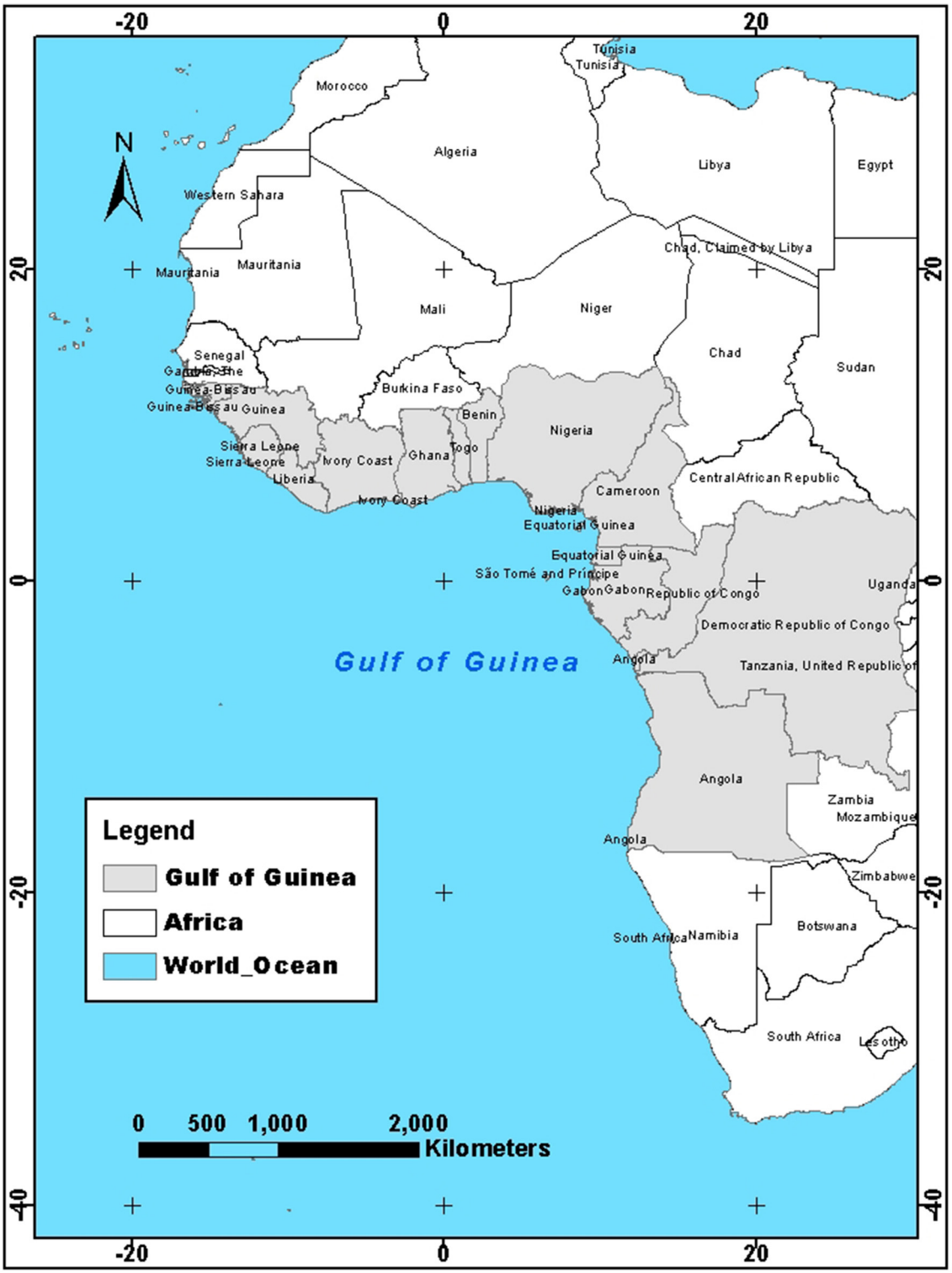

FIGURE 1
Countries adjacent to the Gulf of Guinea in the context of Africa. Source: Adapted from UNESCO (UNESCO, 2021).

on the blue economy were discovered in the Gulf of Guinea nations. Three (3) policy documents, twelve (12) reports, twenty-two (22) online documents, eight (8) government reports, and four (4) journal articles/conference proceedings are among them. Table 1 lists the documents used in the content analysis.

The study used blue economy derivatives such as blue economy activities, marine conservation initiatives, regional collaboration

TABLE 1 Documents consulted in the content analysis showcasing the organizations involved in blue economy related activities in the Gulf of Guinea.

Countries	Policy documents	Reports	Online documents	Government reports	Journals and conference proceedings
Guinea Bissau	N/A	N/A	A multi-faceted national blue economy strategy with a common goal (United nations development programme). Conservation of Nature (International Union for Conservation of Nature).	National blue economy strategy and corresponding investment plan. (United nations development programme).	N/A
Guinea	Strategic framework for the Blue Economy (United Nations Development Programme).	N/A	Coastal marine and biodiversity management project (RAMSAR).	N/A	N/A
Sierra Leone	N/A	Updated nationally determined contribution (NDC). (United Nations framework convention on climate change).	Validation of Blue economy strategic framework. (United nations development programme).	Ocean governance and legislation. Life-saving society/center for sustainable blue economy development Wetlands international.	N/A
Liberia	N/A	N/A	N/A	Supporting a green/blue economy: Liberia blue ocean program (Liberia project Dashboard).	N/A
Ivory Coast	N/A	National blue economy strategic framework and investment plan (The integrated management of the marine and coastal area of Abidjan to Assinie - GIAMAA).	Côte D'Ivoire Pilot Project (Mami Wata - Ivory Coast) Marine turtle conservation project (The small-scale initiatives program).	N/A	N/A
Ghana	N/A	Developing the blue economy of Ghana. Ecosystem-based approach to Integrated marine and coastal environment management - EIMCEM).	Ghana drafts plan to protect blue economy (Africa Defense Forum). Coastal and marine conservation drive project (Coastal and marine conservation drive project) Ghana Pilot Project (Mami Wata - Ghana).	N/A	N/A
Togo	N/A	A five-year plan to develop the blue economy (Togo First). National Node (Early Career Ocean Professional, 2022).	Marine Spatial Planning (MSP) Roadmap (MSPGLOBAL2030).	N/A	N/A
Republic of Benin	Benin Blue bond strategy roadmap SDG2 (United Nations development programme). Community-based coastal and marine biodiversity management project (Agence Beninoise pour l'Environnement).	N/A	Benin pilot project (Mami Wata - Benin).	Combined Report on the Mid-Term Review of the 2017–2021 Country Strategy (African development bank group).	N/A
Nigeria	N/A	Regulating IUU Fishing in Nigeria - (MSc. Thesis - World Maritime University, Sweden). Deep blue marine security project (Nigerian maritime administration and safety agency -NIMASA).	Global blue economy (The Sun News). Blue economy legal and institutional frameworks (Atakpa, 2017 - Review Article). Nigeria for Sea Turtles Conservation. (Nigeria Conservation Foundation).	N/A	The Abuja declaration (Ukeje, 2015).

(Continued)

TABLE 1 (Continued)

Countries	Policy documents	Reports	Online documents	Government reports	Journals and conference proceedings
Cameroon	N/A	Fisheries committee for the west central Gulf of Guinea (United Nations development programme).	African Marine Mammal Conservation Organization. Hail the Whale: sustaining marine life in Cameroon (United Nations development programme).	N/A	Coastal Risk Management in a Context of Climate Change (Kevin and Abubakar Ali, 2022).
Equatorial Guinea	N/A	Combined Country Strategy Paper 2018–2022 (African Development Bank Group, 2022).	N/A	Country strategy paper mid-term review validation note. (African Development Bank Group, 2022).	N/A
Sao Tome and principe	N/A	Blue Investment Program (Food and agricultural organization of the united nations). An assessment of the impact of Maritime (In)security in the Gulf of Guinea (MSc. Thesis - World Maritime University, Sweden).	Protecting the unique and threatened seas and forests of São Tomé and príncipe (Fauna-Flora).	National Ocean Policy (Division for Ocean Affairs and the Law of the Sea, United Nations).	Conserving Marine Life in Sao Tome and Principe (Brito, 2021).
Gabon	N/A	N/A	Gabon Bleu (Gabon Vert). Gabon provides blueprint for protecting oceans (Science Daily; University of Exeter).	N/A	N/A
Republic of Congo	N/A	N/A	Protecting the threatened sharks and rays of the Republic of Congo (https://saveourseas.com)	Congo Marine Program (Wildlife Conservation Society).	N/A
Democratic Republic of Congo	N/A	N/A	N/A	N/A	N/A
Angola	N/A	Creation of Marine Protected Areas in Angola (United Nations Development Programme).	Angola with potential for Blue Economy (The Angola Press Agency - ANGOP).	N/A	N/A

for ocean sustainability, management approaches adopted for ocean management, strategic frameworks for the blue economy, goals and objectives of ocean management strategies, blue growth and blue agenda, coastal and marine spatial planning to narrow down on key search items that capture the blue economy for the content analysis. The study looked at the denotative incidence of these essential phrases as solo words or in conjunction with other notions associated with blue economy narratives. Where the blue economy was not expressly addressed, the research identified it using proxies such as ocean management, ocean governance, coastal/marine management, and marine protected zones. This strategy is congruent with Bauler and Pipart (2013), who proposed that empirically validating the first step of conceptual adoption begins with a question about how frequently the term is used in policy papers. In addition to keyword research, the study included direct content analysis (Geneletti and Zardo, 2016), which scans all available blue economy contents for information about each Gulf of Guinea nation.

4. Findings and discussion

4.1. Blue economy activities in the Gulf of Guinea

This section scrutinized variables for attaining the blue economy, including the blue economy activities, marine conservation initiatives, regional collaboration, management approaches, and strategic frameworks to transition into the BE in each Gulf of Guinea member state. Regarding the blue economy activities in the member states, many of the member states in the Gulf of Guinea share several similarities, including fisheries, aquaculture, port services, maritime transportation, and tourism (Economic Commission for Africa, 2014). Some countries such as Guinea Bissau, Guinea, Nigeria, Cameroon, Gabon, Republic of Congo, Democratic Republic of Congo, and Angola are engaged in oil and gas, with their scale of activity varying from one country to another. There are cases of some member states, such as Guinea

TABLE 2 Regional collaboration, management approaches and strategic frameworks for transitioning into the blue economy in the gulf of guinea.

Countries	Regional collaboration	Management approaches	Strategic frameworks	Objectives
Guinea Bissau	The West African Coastal Areas (WACA) program, Mangroves for the Future (MFF) program, Wetlands International Africa, the African Forest Forum (AFF). The Regional Center for Mapping of Resources for Development (RCMRD).	Strategic support to partner organizations to improve their growth and impact. This includes practical assistance like training, research, equipment, and funding to manage protected areas and species recovery plans.	National Blue Economy Strategy and Corresponding Investment Plan (UNDP, 2022a)	Protect species and habitats through the Global Trees Campaign, the International Gorilla Conservation Programme and the Rapid Response Facility to support emerging conservation leaders, such as through the Conservation Leadership Programme.
Guinea	West African Economic and Monetary Union (WAEMU). The Abidjan Convention Secretariat, the United Nations Development Programme (UNDP). The Global Environment Facility (GEF).	Creation of MPAs in Ramsar Sites and support to their management. Capacity Building for MPAs management. Support to participative local development. Project Management, Monitoring and Evaluation	Management of Natural Resources; monitoring and evaluation mechanism; Legal and Institutional Reform; legal and regulatory framework; social and economic development; sustainable use of marine; management of biodiversity (World Bank Group, 2015).	Promoting rational management of the Recipient's coastal biodiversity for conservation and sustainable development, focusing on assisting communities to plan, implement and maintain alternative livelihood options.
Sierra Leone	The Sierra Leone National Conservation Society. The Coastal Biodiversity Management Committee. The West African Biodiversity and Climate Change programme. Wetlands International and local communities.	Establishment of Marine Protected Areas. The demonstration of small-scale pilot activities, supported by communications, capacity-building, and engagement of local and national stakeholders.	Strategic Framework for the Blue Economy (UNDP, 2022d)	A coordinated, whole of Government approach that establishes the necessary condition for the successful implementation of the Blue Economy. A resilient and diversified economy that reduces economic vulnerability and reliance on a small number of traditional sectors. An increase in the proportion of GDP derived from marine sectors. Creation of high-value jobs and local investment opportunities. Food security and wellbeing. Respect for the integrity and sanctity of habitats and ecosystem services, sustainable use, and climate resilience.
Liberia	The West Africa Regional Fisheries Program (WARFP), West Africa Biodiversity and Climate Change (WA-BiCC) program, Abidjan Convention, Regional Partnership for Coastal and Marine Conservation (PRCM), and the Mano River Union.	Integrated Coastal Zone Management (ICZM). Marine Protected Areas (MPAs). Sustainable Fisheries Management. Ecosystem-based Management (EBM). Climate Change Adaptation.	No strategic framework exists.	Not Applicable
Cote d'Ivoire	The Mami Wata Project, the Marine Turtle Conservation Project, and the Atlantic Coast Protection Programme. These collaborations involve multiple stakeholders, including governments, local communities, NGOs, and other relevant partners.	Establishment of marine protected areas. Research and monitoring activities, Community engagement. capacity building. Advocacy for policies that support conservation efforts.	National Blue Economy Strategy and Investment Plan (African Development Bank Group, 2022)	Identify the main drivers of the blue economy and develop a national investment plan for its promotion. Carry out a detailed feasibility study of a priority programme for the promotion of the blue economy including the strengthening of national public and private capacities.
Ghana	COMAD-RIP in collaboration with local communities, NGOs and state actors.	Community-based management. Ecosystem-based management. Integrated Coastal Zone Management. Policy and institutional reforms Innovation and technology.	Marine Protected Area (MPA) management strategy for the Greater Cape National Integrated Maritime Strategy (NIMS) (ADF, 2022).	Protect vital coastal habitats, support the livelihoods of coastal communities in selected fishing villages, and play a significant role in shaping policy outcomes related to marine protected areas at both local and national levels. Ensure a safe maritime domain and a thriving blue economy. The focus is on safety, security, marine environmental protection, blue economy development, capacity building and cooperation.

(Continued)

TABLE 2 (Continued)

Countries	Regional collaboration	Management approaches	Strategic frameworks	Objectives
Togo	Partnership with the Intergovernmental Oceanographic Commission (IOC) of UNESCO. Collaboration with other ECOP chapters, universities and research institutions, and government agencies to advocate for policies and programs that support ocean conservation and sustainable development. Collaboration with civil society organizations.	Provide a platform for networking, knowledge sharing, and collaboration among early-career ocean professionals, and promote their skills and knowledge development. Advocate for policies supporting ocean conservation and contribute to the achievement of the United Nations Decade of Ocean Science for Sustainable Development and Sustainable Development Goals. Raise public awareness about the importance of the ocean and its resources, Engage with stakeholders to promote cooperation on ocean conservation issues and support the development of innovative solutions for challenges facing the ocean science and conservation community.	No strategic framework.	Not Applicable
Benin	Partnerships among different stakeholders, South-South cooperation, and collaboration with the private sector and government agencies.	Participatory management involves stakeholders in decision-making, ecosystem-based management, integrated management, capacity building to enhance skills and knowledge, and policy and institutional reforms.	No Strategic Framework	Not Applicable
Nigeria	Partnerships with the West African Marine Ecoregion (WAMER), West Africa Biodiversity and Climate Change (WA BiCC) program, West Africa Network of Marine Protected Areas (WANMPA), Marine and Coastal Protected Areas (MCPA) network, and Regional Partnership for Coastal and Marine Conservation (PRCM).	Ecosystem-based management. Integrated Coastal Zone Management. Adaptive management and participatory management.	No Strategic Framework	Not Applicable
Cameroon	N/A	Integrated coastal zone management	No Strategic Framework	Not Applicable
Equatorial Guinea	Collaboration and partnerships between the government, academia, NGOs, and local communities	A comprehensive marine spatial planning framework through collaboration between government agencies, NGOs, and local communities to identify and prioritize areas for conservation. An ecosystem-based management approach. Community engagement and participation. Strengthening the legal framework	Blue Economic Framework for Equatorial Guinea (Independent Development Evaluation, 2022)	Economic diversification strategy through structural transformation. Develop a forward-looking strategy for economic diversification in Equatorial Guinea leveraging the blue economy (maritime sector).
Sao Tome and Principe	The Gulf of Guinea Conservation Group, Congo Basin Forest Partnership, West Africa Biodiversity and Climate Change Program, and Bird Life International are all regional collaborations that aim to promote conservation initiatives in West Africa.	Creating and managing protected areas. Promoting sustainable land use practices Working with local communities to promote conservation and sustainable livelihoods. Conducting scientific research to better understand ecology and biodiversity. Building the capacity of local organizations and individuals to carry out conservation activities.	Transition Strategy toward the blue economy (FAO, 2023)	Promote "Blue Cabotage" (transportation of people and goods from port to port along the coast). Improve tourism and the coastal environment. Modernize coastal artisanal fishing fleet

(Continued)

TABLE 2 (Continued)

Countries	Regional collaboration	Management approaches	Strategic frameworks	Objectives
Gabon	The collaborations involved in Gabon Bleu are between the Gabonese government and conservation organizations such as the Wildlife Conservation Society (WCS) and the Gabonese National Parks Agency (ANPN)	Partnerships between government ministries and departments, industry, national and international institutions, and NGOs (Alegre, 2009).	No Strategic framework.	Not Applicable
Republic of Congo	The government of the Republic of Congo, the Coastal and Marine Resources Management Project (COMAR), the Regional Partnership for the Conservation of the Coastal and Marine Zone of West Africa (PRCM), the Congo Basin Forest Partnership (CBFP), and the Global Ocean Refuge System (GLORES).	Establishing marine protected areas. Strengthening law enforcement to monitor illegal activities. Supporting community-based management of marine resources. Promoting sustainable fisheries. Conducting research and monitoring to assess ecosystem health. Developing partnerships with regional and international organizations.	No Strategic Framework	Not Applicable
Democratic Republic of Congo	Protected areas conservation trust (PACT), Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development	Supporting marine and coastal ecosystem conservation. Raising awareness and building capacity for climate-resilient practices through surveys and behaviour change communication strategies. Supporting project management and implementation, monitoring and evaluation, and data collection.	No strategic framework	Not applicable
Angola	Ministry of Fisheries and the Ministry of Environment.	Ecosystem-based management (EBM). Adaptive management. Participatory management. Integrated coastal zone management (ICZM). Science-based management.	National Strategy for the Angolan Sea (ENMA) (VerAngola, 2023)	To contribute to the improvement of social wellbeing, through the economic enhancement of maritime space, its resources, and natural values, in an integrated and sustainable way. To provide guidelines for the organization of marine space in the oceanic territory of the Exclusive Economic Zone. To provide high-level guidance for the implementation of Marine Spatial Planning in the context of national legislation and policies, as well as preparing the basis for planning activities in marine areas.

Bissau, Sao Tome and Principle, and Angola, that are involved in wind energy generation (Economic Commission for Africa, 2014).

4.1.1. Marine conservation initiatives in the Gulf of Guinea

This study's findings indicate that many member states along the Gulf of Guinea have developed or have ongoing marine conservation initiatives. Guinea Bissau has developed a mangrove restoration project to rehabilitate damaged ecosystems and protect species and habitats (International Union for Conservation of Nature, 2019). Guinea has an ongoing project on coastal marine and biodiversity management. This project includes creating marine protected areas (MPAs) in RAMSAR sites, capacity building for MPAs management, support to participative local development, and project management, monitoring, and evaluation. The management approach focuses on the sustainable use of marine resources, biodiversity management, legal and institutional reform, and social and economic development (World Bank Group, 2015).

The marine conservation initiatives of Sierra Leone focus on sustainable coastal zone management, seagrass conservation, and the establishment of marine protected areas to promote the long-term ecological, social, and economic wellbeing of coastal communities and ecosystems (Wetlands International, 2008). Regarding Liberia's marine conservation initiatives, the primary goals are to improve science-based understanding of factors affecting the health and services provided by coastal and marine ecosystems, address marine pollution, implement effective governance, manage coastal and marine ecosystems in concert, and increase public awareness and education (Liberia Project Dashboard., 2019).

TABLE 3 Blue economy documents, agenda and ocean governance along the Gulf of Guinea.

Countries	Documents that referred to the blue economy	Blue agenda/blue growth	Ocean governance
Guinea Bissau	National development plan 2020–2023. African development Bank Group. Guinea-Bissau economic outlook.		National biodiversity strategy and action plan (NBSAP). National capacity self-assessment (NCSA) for Global Environment Management.
Guinea	None		
Sierra Leone	Updated nationally determined contribution (Government of Sierra Leone., 2021) Sierra Leone life saving/center for sustainable blue economy development (UNDESA, 2022)	Yes	The fisheries policy of 2003. Biodiversity strategic action plan. Ministry of Fisheries and Marine Resources, 2003. Sierra Leone Institutional Support to Fisheries Management 9th EDF ACP SL 019/1 June 2009. Maritime Administration Act. 2000 and 2007. The National Protected Area Authority and Conservation Trust Fund Act (Intergovernmental Oceanographic Commission, 2021)
Liberia	Not Applicable	Not applicable	Not Applicable
Ivory Coast	Cote D'Ivoire – National blue economy strategic framework and investment plan (African Development Bank Group, 2022)	Not APPLICABLE	Not yet developed. However, the Action Plan for the Protection and Development of the Marine United Nations Environmental Programme (1983) of the Abidjan Convention is in use. National Action Plan on Sea-Based Marine Plastic Litter from Shipping and Fisheries (Kleverlaan, 2023)
Ghana	Many documents for example Developing the Blue Economy of Ghana (Gulf of Guinea Maritime Institute., 2019; ADF, 2022; vanDyck, 2022)	Yes	National integrated maritime strategy (ADF, 2022)
Togo	MSPGlobal (MSPglobal., 2022; Dossavi, 2023)	Yes. through marine spatial planning	Integrated ocean management. This is still at the preparation stage
Republic of Benin	Benin Blue Bond strategy and roadmap (A Proposal) (Niyonzima, 2022; UNDP, 2022b). Benin Country Strategy Paper 2022–2026 (West Africa Regional General Directorate, 2022). Mid-Term Review Strategy Paper 2017–2021 (Directorate General for West Africa, 2021).	Not applicable	A legal framework for integrated marine and coastal management. Embedded will be the law on the environment, fisheries and aquaculture, the protection of the littoral, and the use of non-biodegradable plastic bags
Nigeria	Various but by Newspapers and blogs. A proper document is detailed in the following. Harnessing the Blue economy for sustainable development in Nigeria (UNDP, 2018).	Not applicable	It follows the Proposals of the United Nations law of the sea convention
Cameroon	Capitalize on blue economy to cash in on Africa's free trade area (Ticha, 2015).	Not Applicable	Fishing and repression of related offences, and decentralization in ocean governance.
Equatorial Guinea	Combined country strategy paper 2018–2022 Mid-Term Review and 2021 Portfolio Performance Review Report (African Development Bank Group, 2022).	Not Applicable	Regional Fisheries committee for the Gulf of Guinea. To assess the status of fish stock, to harmonize fisheries policy, and to preserve and protect marine and inland waters (United Nations Environment Programme, 2020).
Sao Tome and Principe	United Nations sustainable development cooperation framework (United Nations, 2023).	Yes, through fishing and aquaculture, renewable energy, ecotourism, and maritime transport (FAO, 2023). Blue Investment Program in Sao Tome and Principe (Hand-in-Hand Initiative., 2018)	Adoption of the integrated coastal areas management (Alegre, 2009).
Gabon	Gabon Bleu (Gabon Vert, 2023). Fulfilling global marine commitments; lessons learned from Gabon (Metcalfe et al., 2022).	Yes, through Gabon's Network of Marine Protected Areas (Science Daily, 2022)	Marine Protected Area network. A national framework for building long-term stakeholder support and focusing on research that guides implementation and policy (Metcalfe et al., 2022).
Republic of Congo	Congo Marine Programme (Wildlife Conservation Society, 2021)	Yes, through Marine Protected Areas and Marine Spatial Planning.	Marine spatial planning has already been approved for ocean governance since 2019 (Green, 2023)
Democratic Republic of Congo	Not Applicable	Not Applicable	Not Applicable
Angola	The importance of integrated ocean governance for a blue economy in Angola (Ginga, 2020). Angola with potential for Blue Economy (Angop, 2022)	Yes, through the National Strategy for the Angolan Sea (ENMA)	Marine spatial planning (Finke et al., 2020)

TABLE 4 Marine uses and trade strategies of member states along the Gulf of Guinea.

Countries	World export (Goods)	World export (Services)	Per cent of GDP
Guinea Bissau	Coconuts, Brazil Nuts, Cashews, Petroleum Gas, Non-fillet Frozen Fish, Scrap Vessels, Oily Seeds	Communication services, travel, business services, financial services, and transportation	14.39% (1970–2021)
Guinea	Gold, Aluminium Ore, Aluminium Oxide, Iron Ore, and Cocoa Beans	Computer and information services, Transportation, Business Travel, Financial, and Insurance services	64.32% (1986–2021)
Sierra Leone	Titanium Ore, Iron Ore, Rough Wood, Diamonds, and Aluminum Ore	Transport, personal and business travel, computer and information services, royalties and license fees, and financial services.	16.93% (1964–2021)
Liberia	Rubber, Iron Ore, Gold, Cocoa Beans, Passenger and Cargo Ships	Insurance services, government services.	28.7% (2000–2021)
Ivory Coast	Cocoa Beans, Rubber, Cocoa Paste, Gold, Coconuts, Brazil Nuts, Cashews	Transport, personal, and business travel	26% (1960–2021)
Ghana	Gold, Crude Oil, Cocoa Paste, Coconut, Brazil Nut, Cashews, Gems and Precious Stones, Rubber, Wood, Ores, Fruit and Nuts, Meat and Sea Food	Transportation, personal travels, business travels, and construction services	30% (1960–2021)
Togo	Refined Petroleum, Calcium Phosphates, Cement, Electricity, Soybeans	Business travel	23.3% (1960–2021)
Republic of Benin	Ginned Cotton, Cotton Cake, Cotton Seed, Cashew, Shea Butter, Cooking Oil, Raw Copper, Gold, Soybeans	Travel services	19.9% (1960–2020)
Nigeria	Crude Petroleum, Petroleum Gas, Cocoa Beans, Scrap Vessels, Oil Seeds, Zinc, Aluminum, Gold, Tobacco, Lead, Raw Hides, Skin, Copper, Ores, Fruits and Nuts	Transport, personal, and business travel	14.2% (1960–2019)
Cameroon	Crude Oil, Petroleum Gases, Cocoa Beans, Sawn Wood, Plantains and Bananas, Fruits and Nuts, Aluminum, Rubber, Cotton, Coffee and Tea Spices, Copper	Transport, personal, and business travel	18.04% (1965–2021)
Equatorial Guinea	Crude Petroleum, Petroleum Gas, Acyclic Alcohols, Rough Wood, Veneer Sheets	Computer and information services	55.5% (2005–2021)
Sao Tome and Principe	Gas Turbines, Cocoa Beans, Aircraft Parts, Palm Oil, Iron Fasteners	Personal travel	N/A
Gabon	Crude Oil, Manganese, Ore, Sawn Wood, Veneer Sheet, Refined Petroleum	Miscellaneous business, personal travel, and sea transport	55.8% (1960–2021)
Republic of Congo	Crude Oil, Tin Ore, Refined Copper, Wood, Refined petroleum, Textiles,	Government services	73.8% (1960–2019)
Democratic Republic of Congo	Copper, Unwrought Alloy, Cobalt, Unrefined Copper, Copper Ores, Crude Oil, Textile, Wood, Art and Antiques, Foot and Headwear, Animal Production	Business travel	40.1% (1994–2021)
Angola	Crude Petroleum, Petroleum Gas, Diamond and other Precious Stones, Asphalt Mixtures, Salt, Sulphur Stone, Beverages, Spirits, Vinegar, Fish, Iron, Steel, Optical, Technical and Medical Apparatus, Petroleum Gas, Granite	Business and personal travel	37.9% (2000–2021)

Source: Observatory of Economic Complexity (2020) and The Global Economy (2022).

Cote d'Ivoire has set up a marine initiative to conserve marine ecosystems and biodiversity through the Integrated Management of the Marine and Coastal Area of Abidjan to Assinie (GIAMAA). The initiative's objective is to promote responsible and sustainable utilization of resources while ensuring that ecosystem services continue to be available in the long run, thereby supporting economic growth and the wellbeing of coastal communities (Mami Wata., 2018a). Another initiative is the Marine Turtle Conservation Project (The Small-Scale Initiatives Program, 2014). In Ghana, the Coastal and Marine Conservation Drive Project has been embarked on to promote local economic development and nature protection and contribute to the achievement of some sustainable development goals 1, 2, 8, and 14, which are to reduce poverty, reduce hunger, provide decent work and economic growth, and life below water (Lighthouse Foundation., 2021). Another initiative in Ghana is the Ecosystem-based approach to Integrated Marine and Coastal Environment Management (EIMCEM). This initiative adopts a marine spatial planning approach that is expected to enable Ghana to use integrated management tools inclusively to reduce excessive human pressures on marine resources for sustainable use (Mami Wata., 2018b).

Togo has an active Early Career Ocean Professional (ECOP) that supports ocean conservation and sustainable development (Early Career Ocean Professional, 2022; Dossavi, 2023). Togo has already developed a marine spatial planning (MSP) roadmap

under the MSPGLOBAL2030 initiative to manage its marine resources sustainably (MSPglobal., 2022). Indeed, there are already underway Blue Economy initiatives in Togo (Dossavi, 2023). Benin's focus on fisheries, tourism, and aquaculture aligns with its goals of increasing economic growth and reducing poverty. The country has a Community-Based Coastal and Marine Biodiversity Management Project that aims to promote the conservation and responsible utilization of biological diversity of coastal wetlands and marine resources while supporting the livelihood and economic opportunities of the coastal and marine communities (Agence Beninoise pour l'Environnement, 2010). Benin has also embarked on the Integrated Marine and Coastal Zone Management (GIZMaC) project to promote sustainable management of marine and coastal resources (Mami Wata., 2018c).

Nigeria's existing marine conservation initiatives include the West Africa Coastal Management Program, Nigeria Conservation Foundation, and Nigeria for Sea Turtles Conservation (Nigeria Conservation Foundation, 2020). Noticeable marine initiatives in Cameroon include sustaining marine life in Cameroon (Ayissi et al., 2018; UNDP, n.d.) and the initiative of the African Marine Mammal Conservation Organization (AMMCO), whose task is to make the coastal and aquatic environment a threat-free home for aquatic wildlife (AMMCO, 2021). Equatorial Guinea has tried to conserve marine areas through cumulative impact mapping to prioritize marine conservation efforts (Trew et al., 2019). Sao Tome and Principe is implementing measures to protect threatened seas and forests by establishing marine protected areas and sustainable use zones (Fauna-Flora, 2023). This will restore biodiversity and improve indigenous communities' economic prospects. The community actively creates and manages these protected areas, demonstrating their unwavering dedication to the cause (Fauna-Flora, 2023). Likewise, concerted actions regarding marine life conservation have been adopted, with implementation in progress (Brito, 2021).

Gabon has launched the Gabon Bleu initiative, which aims to protect endangered marine biodiversity through protected areas and a sustainable fisheries management plan (Gabon Vert, 2023). The Republic of Congo's conservation initiative is the Congo Marine Program which focuses on the designation of marine protected areas, the development of an Integrated Marine Spatial Tool for maritime reforms, and capacity building for fisheries management, surveillance, and law enforcement by local administrations (Wildlife Conservation Society, 2021). Another marine initiative in the Republic of Congo is the 'Save Our Seas' initiative, which seeks to protect the threatened sharks and rays in the country to increase the knowledge base on these taxa and to apply informed and appropriate solutions for conservation (Doherty, 2023). The Democratic Republic of Congo does not have a marine conservation initiative at the time of this study. Angola has created marine protected areas in response to the country's degradation of coastal and marine ecosystems (UNDP, 2022c).

4.1.2. Regional collaboration, management approaches, and strategic frameworks

Fostering regional collaboration among Gulf of Guinea member states is crucial for achieving blue economy growth. This is because regional collaboration can promote ocean-based good governance in areas such as environmental protection of regional marine commons, maritime surveillance to prevent marine resource pillage, and mitigation of climate change impacts on marine resources (Bolaky, 2020). Sustainable management approaches and strategic frameworks are essential in transitioning to a blue economy. As detailed in Table 2, findings from this study indicate that many of these countries have a series of regional collaborations meant to promote a blue economy. Likewise, many management approaches are being undertaken by these countries, which could help to transition into a blue economy. Still, strategic frameworks have yet to be in existence in many of the nations. The Regional Collaboration in the member states is commendable, with collaborations involving governments, local communities, NGOs, and other relevant partners. These collaborations have contributed to achieving sustainable development goals, including conserving marine ecosystems, protecting marine life, and promoting local economic development. For instance, in Cote d'Ivoire, the Mami Wata project, Marine Turtle Conservation Project, and Programme for the Protection of the Atlantic Coast involve multiple stakeholders in achieving marine conservation and biodiversity conservation (Mami Wata., 2018a).

Marine protected areas (MPAs), Integrated Coastal Zone Management (ICZM), Sustainable Fisheries Management, Ecosystem-based Management (EBM), community engagement, capacity building and knowledge sharing, innovation and technology, and community-based management of marine resources are among the management approaches being used. Seven of the sixteen Gulf of Guinea nations have created or are building strategic frameworks for transitioning to the blue economy (Table 2). For example, Guinea Bissau and Cote D'Ivoire have a National Blue Economy Strategy and Investment Plan, Sierra Leone has a Strategic Framework for the Blue Economy, Ghana has a National Maritime Strategy, and Equatorial Guinea has a Blue Economic Framework. Angola, on the other hand, has produced the Angolan Sea National Strategy. These results suggest significant external involvement, collaboration, and activity in the area connected to ocean and marine resources. Despite this, there is a lot of disparity and poor alignment about the Blue Economy since only 7 of the 16 nations have frameworks that appear to support the blue economy.

Furthermore, as shown in Table 3, which refers to the Blue economy documents, blue agenda, and ocean governance along the Gulf of Guinea, it is evident that actions and strategies are in place in many member states that can serve as enablers of blue growth. These enablers are biodiversity and conservation strategy, marine spatial planning, marine protected area, integrated coastal zone management, and maritime strategies. However, nearly 20% of the countries in the region still need documents that refer to the blue economy. This demonstrates that these nations need a BE. Framework, which prevents them from exploiting ocean resources sustainably for economic development, improved quality of life, employment possibilities, and maintaining the health of ocean ecosystems.

Additionally, research reveals that 50% of the nations in the Gulf of Guinea need more documentation outlining the blue agenda/growth development. As a result, these nations need to execute the core components of the Blue Agenda/Blue Growth initiatives, which include understanding the marine environment,

marine spatial planning, and integrated surveillance. Where they have been implemented, the blue agenda/growth has been tilted toward maritime spatial planning, including identifying marine protected areas.

Despite some of these nations' success in securing and managing ocean space, a formal model is needed to enhance the environmental performance of the BE sectors. This agrees with the findings of Martínez-Vázquez et al. (2021) that the BE sectors' growth presents challenges, such as a lack of standard and agreed-upon goals for blue growth. Other factors include maximizing economic growth from marine and aquatic resources (Boonstra et al., 2018) and maximizing inclusive economic growth derived from marine and aquatic resources (Eikeset et al., 2018).

So far, progress in capitalizing on the rising demand for BE goods and diversifying into the BE has been slow in the Gulf of Guinea since none of these initiatives focuses on ultimately capturing the financial advantages of the Gulf of Guinea's ocean resources in a coordinated manner. This assertion is in line with the findings of Rustomjee (2017) that despite these initiatives and measures adopted in the Caribbean, little headway has been made in leveraging the rising global demand for the goods and services that the small island nations presently provide or in diversifying into new and developing blue economy sectors and industries. As a result, remedial efforts such as research into the ocean environment, coordinated surveillance, and well-developed marine spatial planning are required throughout the Gulf of Guinea to transition into the Blue Economy.

4.2. Challenges to the development of BE framework

Maritime insecurity and safety are among the factors hindering the development of a framework for BE in the Gulf of Guinea. The Gulf of Guinea has gained disrepute over the years as a danger zone with security challenges such as piracy, kidnapping, and human and drug trafficking (Ukeje, 2015). Despite the economic potency of this region, being a significant source of crude petroleum, oil and gas, and an essential global maritime corridor, maritime insecurity has grown to become a considerable challenge compromising and threatening its development over the years (Ikein, 2009; Ukeje and Ela, 2013). The Nigerian marine space, for example, has reports of diverse forms of illicit trafficking, kidnapping, the prevalence of piracy, and armed robbery, which has resulted in some shipping companies avoiding these waterways (Ugwueze and Asua, 2021). Moreover, the Port of Cotonou in the Republic of Benin has experienced a significant decrease of 70 percent in the number of vessels calling because piracy and armed robbery are common occurrences at sea (Okafor-Yarwood et al., 2020). Security challenges are perceived to be more severe in smaller Islands like Sao Tome and Principe, where issues like oil and cargo theft are predominant because of geographic remoteness and high reliance on natural resources (De Ceita, 2020). However, BE can only thrive in a safe, secure, well-regulated maritime environment (Quak, 2019; De Ceita, 2020).

Environmental degradation is another major hindrance to BE in the Gulf of Guinea, as achieving a sustainable BE requires a healthy coastal and marine ecosystem (Okafor-Yarwood et al., 2020). Sources of pollution from chemicals, particles, domestic wastes, industrial wastes, agricultural wastes, and noise, or the spread of invasive organisms affect the ocean in the Gulf of Guinea, resulting in habitat degradation, loss of biodiversity, and degeneration in human health (Akita et al., 2020). These led to various forms of environmental debacle such as flooding, coastal erosion, pollution of various degrees and types, chronic illnesses, loss of species, and the inability of the ocean to perform its natural function (Popoola, 2012, 2022). Coastal and ocean degradation is caused by impacts of climate change with grave consequences such as fishery depletion, rising sea levels, and threat to the survival of ecosystem biomes which serve as habitats for ecosystem wildlife (Popoola et al., 2019; Popoola, 2021). Similarly, the inadequate institutional structure for administrating and developing marine and coastal environments presents a significant obstacle (Adibe et al., 2018; Denton and Harris, 2019).

Other challenges include unstrained and uncontrolled numerous anthropogenic activities in the coastal and marine space, poor ocean governance, and inadequately trained personnel on climate change and environmental mismanagement, which need to be addressed to reap the full potential of BE (Bolaky, 2020). Additionally, the region has been unable to create a just and inclusive ocean economy due to the neglect of social inequities caused by the quick and unrestrained expansion of maritime resources in the area. Harnessing the benefits of the BE requires immediate attention to the challenges of insecurity and environmental degradation, as failure to address these could deprive these nations of the economic gains derivable from the ocean (Okafor-Yarwood et al., 2020).

4.3. Integrating blue economy into trade strategies

Harnessing the potential of blue economy growth and development is crucial for Africa's transformation and regeneration (Karani et al., 2022). In the Gulf of Guinea, various activities or limited BE activities are carried out in the marine area (though unsustainably), contributing to <10% of the GDP in member states (Giulini, 2021). The ocean economy contributes as little as a quarter of all revenues and one-third of export revenues (Saghir, 2016). The reason for this is that broad-based BE needs to be integrated or weakly integrated into the trade strategies of these countries. Therefore, implementing the BE into the trading strategy of member countries will be the right step in the direct direction of harnessing economic and social benefits (Hamisu, 2019). This is because there are various benefits and gains to be accrued from trade and deepened integration of these countries in global and regional trade once the related constraints are addressed (Bolaky, 2020).

As revealed in Table 4, Angola earns 37.9 percent of its GDP mainly from exporting crude petroleum, among other goods and services such as precious stones, beverages, and foodstuff. The only blue economy-based goods and services are fisheries such as non-filet frozen fish, mollusks, fish filet, and crustaceans which reduced from 4.6 percent of the country's GDP in 2011 to 2.1% in 2018

(The Global Economy, 2022). Crude oil, petroleum gases, and cocoa beans dominate Cameroon's export products. Its top blue economy-based export product consists of fish, crustaceans, and mollusks constituting 1.8 percent of total goods exports. The same applies to many countries in the Gulf of Guinea, where the only blue economy-based goods and services are fisheries and aquaculture, constituting only a minute percentage of each county's GDP. Other blue economy-based activities such as shipbuilding, offshore oil and gas, marine construction, marine seabed mining, marine research and development, and marine transport still need to be explored.

In terms of export services, travel services in the form of business and personal travels dominate in many countries such as Ivory Coast, Togo, Republic of Benin, Nigeria, Cameroon, Gabon, Sao Tome and Principe and DR Congo, and Angola. However, sea transportation under-exploited needs to be more explored in these countries as the primary mode of international travel is by air. Marine tourism is another service that remains to be tapped in these countries except in Ivory Coast and Togo, where the service is gradually being developed (Agbota, 2019). The development of maritime tourism requires a secure and clean waterway which is a challenge in the Gulf of Guinea as the ocean is troubled by insecurity and environmental degradation. Once the related challenges hindering the transition of member countries have been addressed, there are significant opportunities to be gained from international and regional trade among nations (Failler et al., 2020).

4.4. A framework for the blue economy

Achieving a sustainable BE as a continent requires a certain level of cooperation internationally and regionally (Haimbala, 2019). Given this, the AU proposed many strategies for African nations to transition into BE. For instance, the Inter-Agency/Transitional cooperation on maritime safety and security to address maritime security and safety, thereby providing situational awareness in the maritime province of African countries (African Union, 2012). Another strategy plan is the establishment of the Combined Exclusive Maritime Zone of Africa (CEMZA) to boost African trade by simply eliminating or simplifying administrative procedures in intra-AU maritime transport (African Union, 2012).

Furthermore, the African Blue Economy Strategy (ABES) was developed in 2019 by merging five detailed thematic areas considered essential to the growth of the African Blue Economy (Failler et al., 2020; Karani et al., 2022). The first is the conservation of aquatic life and the sustainability of aquatic ecosystems. Second, it includes shipping, marine transportation, security, and safety, while the third area is concerned with coastal and marine tourism, climate change, resilience, environment, and infrastructure. The fourth thematic area relates to sustainable energy, mineral resources, and marine industrialization, and the fifth is policies, institutional frameworks and governance, employment, job creation and poverty eradication, and innovative financing (Karani et al., 2022). The strategy is designed to assist and support AU member countries and other regional institutions in developing their own individual national and regional BE strategies based on SDG 14, "Life below water," and Agenda 2063.

Transitioning into the BE is ambiguous and complex, so it must be done in phases. The Blue Economy encompasses several sectors with significant potential for collaboration, giving positive incentives for progress toward more integrated legal, regulatory, and institutional frameworks (Economic Commission of Africa, 2016). This study proposes three stages for moving into the blue economy. The first phase focuses on existing and traditional sectors of the BE, which necessitates the development of policies to increase and deepen profit and benefits from current blue industries and projects (World Bank and UNDESA, 2017). Examples include fishing, marine transport, shipping, mining, and marine food processing. Fostering regional collaboration and enhancing additional growth in these areas is vital. While some sectors require little effort, others may necessitate better encouragement and additional governance to achieve their full potential and yield maximum output (World Bank Group, 2016).

The next phase focuses on directing policies, incentives, and regional collaboration toward emerging sectors of the BE (Bolaky, 2020). Successful implementation of existing sectors of the BE enhances the diversification of the economy into emerging ocean-based activities and sectors (Rustomjee, 2017). These sectors include marine aquaculture, deep-water oil and gas exploration and drilling, offshore wind energy, ocean renewable energy, marine and seabed mining, marine biotechnology, and high-tech marine products (Martínez-Vázquez et al., 2021). The final stage focuses on fostering blue-based regional value chains based on a mix of traditional and non-traditional BE-based industries (Bolaky, 2020). It is vital to intensify the creation of regional, blue-based value chains that integrate traditional and non-traditional industries. Due to its potential to increase production and processes and improve cross-border marketing of marine products and international markets, value chain development significantly boosts the BE (Haimbala, 2019).

4.5. Key drivers of BE implementation

Trade, investment, technology, private sector activities, state and state-owned firms, regional collaboration and integration, and cooperation are some of the factors that enable the implementation of the blue economy (Purvis, 2015). Even if the exportation of marine products and services will increase investment profitability, these elements will support the BE's goals. The many social actors, including the government, the commercial sector, and the scientific ones, must cooperate for a country or region to transition into the BE successfully (Roy, 2019). Due to the multisectoral character of the concept, stakeholders, especially among research institutions, must be fully engaged and involved in the development of the BE. The business sector and ocean users could collaborate to address crucial monitoring needs by considering the appropriate role and innovative alternatives for various levels of government, as they can generate and direct scientific breakthroughs (Howard, 2018; Wenhai et al., 2019).

Government agencies provide direction, planning, coordination, and oversight. Additionally, they promote and create legal and policy frameworks for sustainable oceans, draw in private

investors, and take the initiative to help launch the developing blue industry, which must be regulated by accountability and transparency. There is also the place of the private sector, which quickly embraces the BE concept to invest and explore ocean-based resources and services (Voyer and van Leeuwen, 2019). At the same time, they must be involved in implementing action plans for sustainable economic growth and enhanced social wellbeing (Whisnant and Vandeweerd, 2019).

Applying blue justice to end all injustices that may arise due to the region's rapid growth of ocean resources is a crucial factor that might influence the implementation of the blue economy. Processes for making decisions about the ocean economy should be guided by an explicit justice framework (Bennett et al., 2020). This might entail a significant shift in ocean governance and a reevaluation of core values about ocean development, raising several concerns with potentially complex answers involving resource grabs and other ideologies prioritizing profit above people and the environment. Recognitional justice, procedural justice, and distributional justice are crucial to lessen or completely eradicate inequities in the ocean environment.

Regional cooperation and member-state cooperation are integral constituents of the development of the BE (Bertarelli, 2020). Regional cooperation tools include economic integration, trade, investment, remittances, debt relief, humanitarian interventions, peacebuilding, and export credit lines (Gay, 2022). The Gulf of Guinea member states are endowed with various resources, which must be managed domestically and regionally if they are to be perpetuated. Regional collaboration will help assess how governments collaborate, as well as with foreign funders and stakeholders, to strengthen maritime security in the broader region in the face of maritime instability in the Gulf of Guinea.

Additionally, cooperation at the national, regional, sub-regional, and global levels will improve collaboration, knowledge sharing, and the exchange of effective practices to assist marine research and development in the Gulf of Guinea. Furthermore, coordination among the member nations would promote joint initiatives so that those wishing to increase capacity might benefit from those who already have it and vice versa (Mohan et al., 2021). With the aid of regional cooperation, combating concerns like piracy, environmental degradation, and climate change becomes simpler.

Through intra-regional commerce in maritime goods, the Gulf of Guinea's member nations' economic integration will strengthen competition. Indeed, intra-African trade is minimal compared to other continents with significant economies (Mold, 2022), despite the assertion that intra-African commerce in marine goods and services will be Africa's primary force behind industrialization (Uranie, 2016). The African Continental Free Trade Area's efforts to increase intra-continental trade between Africa and the Gulf of Guinea are liberalizing deeper levels of trade and improving regulatory harmonization and coordination (Signé, 2022). Additionally, it can bring roughly 30 million people out of poverty by 2030 and increase intra-African commerce from 18 to 50% (World Economic Forum., 2022). Regional organizations like regional markets can strengthen member-state collaboration on BE and increase Africa's sustainable use of its blue resources (Bolaky, 2020).

5. Conclusion and recommendations

The study has established that several blue economy activities are already present along the Gulf of Guinea. As noted, the member states have several marine conservation initiatives. They also have some form of collaboration regionally to promote the blue economy, and several management approaches have been undertaken or are being developed to manage the ocean environment. Some of these management approaches include the establishment of marine protected areas (MPAs), integrated coastal zone management (ICZM), ecosystem-based management (EBM), adaptive and participatory management, and marine spatial planning (MSP). These management strategies are enablers of blue growth. A well-developed marine strategic framework needs to be improved in many of the member states. However, there are pieces of evidence that this is already being developed by some member states such as Guinea Bissau, Sierra Leone, Cote d'Ivoire, Ghana, Equatorial Guinea, Sao Tome and Principe, and Angola.

Furthermore, several ocean governance initiatives exist along the Gulf of Guinea, as detailed in Table 2. However, several challenges hinder the transition into a blue economy in this region, which include rapid population growth, urbanization, piracy, armed robbery, trafficking of people, illicit narcotics and weapons, climate change-induced rising sea levels and ocean acidification, overfishing, unregulated fishing and other unsustainable fishing practices (United Nations Economic Commission for Africa, 2016). A crucial objective for Africa's transformation and regeneration is to fully use the potential of the blue economy for growth and prosperity, hence the need to integrate the blue economy into trade strategies. However, <10% of the GDP of member nations in the Gulf of Guinea comes from marine activities, with the ocean economy accounting for barely a quarter of total revenues and a third of export earnings. Indeed, economic and social benefits are hampered by a lack of broad-based biodiversity (BE), including factors like excluding manufactured goods and services from trade strategies and raw and commodities with added value. Deeper integration and economic progress may result from addressing obstacles and incorporating BE into member nations' trade policies.

Furthermore, blue justice has been presented as a paradigm for achieving sustainable and equitable blue economy governance (Axon et al., 2022). The omission of the blue justice discourse from the Gulf of Guinea's blue economy will impact its implementation with disastrous implications. The effects will include economic disparity, a lack of local advantages, adverse social and cultural repercussions, pollution, and displacement of the local population (Bennett et al., 2019). Unchecked development in the Gulf of Guinea may result in human rights violations and "ocean grabbing" since ocean spaces and resources may be privatized for blue growth, resulting in blue injustices.

Since the BE aims to foster social inclusion, economic progress, and sustainable development to the greatest extent possible, it is

essential to address some of the security, environmental, political, and institutional problems in the Gulf of Guinea that prevent the operationalization of this concept from reaping its many benefits of it. The Economic Community of West African States (ECOWAS) and the Gulf of Guinea Commission (GGC) can work together through trade, investment, finance, technology, and information sharing to address these difficulties at the regional level.

Transitioning into the blue economy requires a systematic approach based on national priorities, social context, and resource base (World Bank Group, 2016). Member states must recognize the need for biophysical characteristics, capacity, and synergies between sectors for efficient management. Marine and coastal spatial planning integrated maritime surveillance, digital mapping, and data-limited stock assessments are essential for authorities, businesses, and communities (World Bank Group, 2016). Mobile technology is needed to gather previously unavailable data in the ocean sector. Integrated coastal zone management (ICZM), an enabler of the blue economy, enhances coastal protection and nearshore resources while increasing efficiency (Popoola, 2012, 2014). Adopting ICZM involves mapping, delineating, and demarcating hazard lines, building capacity for informed decisions about growing the blue economy within the carrying capacity of the natural resource base. Also, the blue economy requires assessing the value of marine resources, which needs to be better measured and understood (Hoegh-Guldberg et al., 2015). Other enablers of blue growth, including strategies like marine protected areas, marine spatial planning, and marine biodiversity and conservation, are essential to transition into the blue economy.

Blue justice discourse must be integrated into the design and implementation process of transitioning into the blue economy in the Gulf of Guinea. This will require proactive, systematic, and bold policies that recognize, meaningfully involve, and treat all coastal people fairly regarding how ocean and coastal resources are accessible, utilized, managed, and enjoyed across the countries in the Gulf of Guinea. Prioritizing sustainability and equity in ocean negotiations, developing comprehensive legislation, fairly treating local populations, and sharing wealth generated by blue growth, inclusive governance, and ocean science insights for policy design, and monitoring impacts are critical for incorporating blue justice into the Gulf of Guinea's blue economy (Bennett et al., 2019; Blythe et al., 2023).

A cautious, phased approach is suggested for a smooth transition into the Business of Enterprise (BE) as Africa's revival frontier. Phase 1 focuses on establishing existing and traditional sectors and deepening their benefits. Phase 2 focuses on growing sectors and launching local initiatives to expand the concept. Phase 3 emphasizes value chain development to integrate traditional and non-traditional sectors. Collaboration between coastal governments, business communities, non-governmental organizations, scientific communities, and local inhabitants is essential to achieve BE objectives. Drawing inspiration from successful areas like the Caribbean, Pacific, and southwest Indian Ocean towns, is recommended for a successful transition into the BE. Regional cooperation is needed to address the Gulf of Guinea's insecurity through maritime security, environmental protection, joint exploration, and marine-based product research and development.

Author's note

The Blue Economy is a relatively new concept that aims to protect the world's ocean resources by promoting economic growth, social inclusion, and the preservation/improvement of livelihoods while ensuring environmental sustainability. This concept is consistent with the UN Convention on the Law of the Sea agreements, which define nations' rights and responsibilities in their use of the world's oceans. Sustainable development and improved livelihoods are guaranteed with the proper application of the Blue Economy. Efforts to transition to the Blue Economy have been welcomed in Africa, with examples from the Southwest Indian Ocean. However, such strategies do not exist in the Gulf of Guinea, resulting in an inability to capitalize on economic marine opportunities and address the causes and risks of economic degradation and natural capital loss. Transitioning to the Blue Economy in the Gulf of Guinea faces challenges such as maritime security and safety, environmental degradation, and uncontrolled anthropogenic activities. This necessitates strategies to integrate the Blue Economy into the Gulf trade strategies. This will entail developing policies to increase profits and gains from existing blue industries and projects; directing policies, incentives, and regional collaboration toward emerging sectors of the BE; and cultivating blue-based regional value chains.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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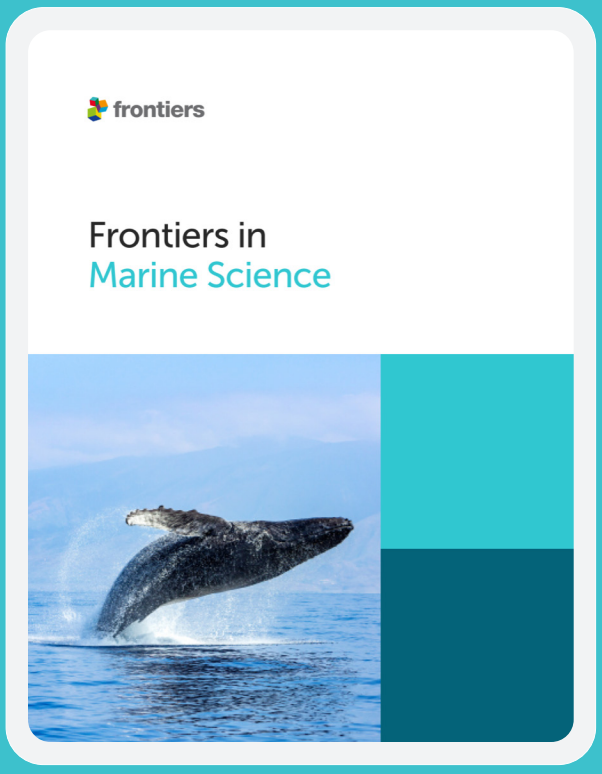

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