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EDITED BY
Charles Weirich,
NOAA National Sea Grant Office,
United States

REVIEWED BY
Stephanie Otts,
University of Mississippi, United States
Mark Rath,
National Oceanic and Atmospheric
Administration (NOAA), United States
Tori Spence,
Pacific Islands Regional Office (NOAA),
United States

*CORRESPONDENCE
Bela H. Buck
Bela.H.Buck@awi.de

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Resolving the term "offshore aquaculture" by decoupling "exposed" and "distance from the coast"

Bela H. Buck[1,2*], Hans V. Bjelland[3], Abigail Bockus[4], Michael Chambers[5], Barry Antonio Costa-Pierce[6,7], Tobias Dewhurst[8], Joao G. Ferreira[9], Heidi Moe Føre[3], David W. Fredriksson[10], Nils Goseberg[11,12], John Holmyard[13], Wolf Isbert[1], Gesche Krause[14], Till Markus[15], Nikos Papandroulakis[16], Tyler Sclodnick[17], Bill Silkes[18], Åsa Strand[19], Max Troell[20,21], Daniel Wieczorek[22], Sander W. K. van den Burg[23] and Kevin G. Heasman[24]

[1]Marine Aquaculture, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven, Germany, [2]Applied Marine Biology, University of Applied Sciences Bremerhaven, Bremerhaven, Germany, [3]SINTEF Ocean, Trondheim, Norway, [4]AquaRange Research LLC, Bozeman, MT, United States, [5]School of Marine Science and Ocean Engineering, University of New Hampshire, Durham, NH, United States, [6]Ecological Aquaculture International, LLC, Biddeford, ME, United States, [7]Faculty of Biosciences & Aquaculture, Nord University, Bodø, Norway, [8]Kelson Marine Co., Portland, ME, United States, [9]Longline Environment Ltd., London, United Kingdom, [10]Center for Sustainable Seafood Systems, University of New Hampshire, Durham, NH, United States, [11]Leichtweiß-Institute for Hydraulic Engineering and Water Resources, Technische Universität Braunschweig, Braunschweig, Germany, [12]Coastal Research Center, Joint Research Facility of Leibniz University Hannover and Technische Universität Hannover, Hannover, Germany, [13]Offshore Shellfish Ltd., Brixham, United Kingdom, [14]Science and Society, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven, Germany, [15]Helmholtz-Centre for Environmental Research UFZ, Leipzig, Germany, [16]Institute of Marine Biology, Biotechnology and Aquaculture, Hellenic Center for Marine Research, AquaLabs, Hersonissos, Crete, Greece, [17]Innovasea, Bedford, NS, Canada, [18]American Mussel Harvesters, Inc., North Kingstown, RI, United States, [19]Department of Environmental Intelligence, IVL Swedish Environmental Research Institute, Fiskebäckskil, Sweden, [20]Beijer Institute of Ecological Economics, Royal Swedish Academy of Sciences, Stockholm, Sweden, [21]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, [22]National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Office of Aquaculture, Silver Spring, MD, United States, [23]Wageningen Economic Research, Wageningen, Netherlands, [24]Blue Technology Group, Cawthron Institute, Nelson, New Zealand

The terms "offshore" and "open ocean" have been used to describe aquaculture sites that are further from the coast or in higher energy environments. Neither term has been clearly defined in the scientific literature nor in a legal context, and the terms are often used interchangeably. These and other related terms (for example "exposed", "high-energy") variously refer to aspects of a site such as the geographic distance from shore or infrastructure, the level of exposure to large waves and strong currents, the geographic fetch, the water depth, or some combination of these parameters. The ICES Working Group (ICES, 2024) on Open Ocean Aquaculture (WGOOA) therefore identified a need to define the terminology to reduce ambiguity for these types of aquaculture sites or more precisely, to: (1) promote a common understanding and avoid misuse for different classifications; (2) enable regulators to identify the characteristics of a marine site; (3) allow farmers to be able to assess or quantitatively compare sites for development; (4) equip developers and producers to identify operational parameters in which the equipment and vessels will need to operate; (5) provide insurers and investors with the terminology to consistently assess risk and premiums; and (6) circumvent the emergence of narratives that root in different cognitive interpretations of the terminology in public discourse. This paper describes the evolution of the use of the term "offshore aquaculture" and define the most relevant parameters to shift to a more definitive and robust term "exposed aquaculture" that can inherently relay clearer information. Adoption of this more definitive definition of "exposed" will allow the user to define a site with more than just distance from shore. Key differences and the importance of these terms are discussed that affect various interest groups. Follow-up articles in this compilation from scientific members of the WGOOA as well as other scientists outside ICES are incorporated that develop a set of definitions and a rigorous exposure index.

KEYWORDS

offshore aquaculture, exposed aquaculture, definition of aquaculture locations, terminology, aquaculture location parameters

1 Introduction

Aquaculture production in estuarine and coastal habitats has grown substantially over the past 3-4 decades (FAO, 2022), and environmental sustainability has improved (Naylor et al., 2021), and the importance of aquaculture's contributions to Sustainable Development Goals (SDGs) emphasized (Troell et al., 2023). At the same time, coastal and marine industries of other sectors have also grown (Buck et al., 2004; Wilding et al., 2018; Weitzman et al., 2019). Traditional activities such as shipping (commercial and naval), fishing, mining for oil, gas, and minerals, or tourism have expanded, and new types of activities have emerged (such as different types of renewable energy, etc.) (Kleingärtner, 2018) in this zone referred to as "offshore". Hence, Smith (2000) has aptly coined this overall development as the "industrialization of the world ocean" and others have referred to it as the marine urbanization (Dafforn et al., 2015) and the "blue acceleration" (Jouffray et al., 2020). These developments have increased competition for space and resources, primarily in less energetic inshore and nearshore waters. In many cases this has led to increased stakeholder conflicts and limited the expansion of marine aquaculture (Holm et al., 2017).

Increased conflicts nearshore have led to the search for sites that will allow for the expansion of aquaculture operations that will increase production by permitting larger sites with more distance between them that will decrease conflicts. For the last 40 years there has been an active scientific and policy forum to a move of marine aquaculture away from the nearshore habitat to more exposed and distant ocean areas. In most of these efforts, the quest to find new concepts for more robust designs and equipment enabled aquaculture to develop in areas with fewer user conflicts. Efforts have not always been fully successful since every site is complex, having different geographic, topographic, physical, geological, chemical, biological, and oceanographic parameters. Nearly all marine aquaculture to date has been concentrated in "sheltered" and/or "nearshore" areas due to the lower hydrodynamic energy in these waters with lower investment capital and operational costs. Aquaculture operations located in such areas require less investment in robust technology and worker safety, generate lower insurance costs, are easier to manage logistically by not requiring expensive wave energy robust service vessels.

Aquaculture farmers, scientists, administrators and policymakers often operate with concepts such as "onshore", "inshore", "nearshore", "offshore", or "open ocean", to name a few of numerous terms. Such concepts have been interchangeably used to characterize different types of aquaculture sites referring to farms' location in relation to the shoreline, aspects of a site such as the geographic distance from shore, exposure to waves and currents, geographic fetch, water depth, or some combination of these parameters. But the industry's efforts to continue expanding beyond sheltered, nearshore sites have revealed that such concepts and terms are neither very precise nor do they provide clear information about the site's environmental, technical, economic, and social conditions for aquaculture operations. As a result, too often these concepts are used arbitrarily depending on sectoral perspectives of, for example, scientists, conservationists, fisheries, lawyers, ocean engineers, to name a few. This particularly holds true with regard to the term "offshore" (Froehlich et al., 2017; Morro et al., 2021). Currently, "offshore aquaculture" is predominantly used to describe any farm that could be exposed to strong currents, high waves, and other unfavorable environmental conditions. It is argued here that the present uses of the term "offshore" conflate distance from a coastline with the degree of exposure to adverse environmental, logistical, or other conditions. Distance from the coast has minimal relevance with regard to the equipment or species required, or suited to, the site. Consequently, for the adequate description of aquaculture site conditions to identify suitable aquaculture sites, a more precise terminology is needed to support governments policymakers, administrators, scientists, farmers and other stakeholders in the planning and execution of aquaculture operations.

Outside of the aquaculture fraternity the use of the term “offshore” can cause confusion and uncertainty. First, a generic concept such as “offshore” is difficult to distinguish from other vague concepts such as ‘inshore’, ‘nearshore’, ‘open ocean’, ‘sheltered’ or ‘exposed’, forcing stakeholders to clarify the description of an area in each case. Second, most of these terms do not correspond to legal terms defined in international treaties or national laws. To make matters worse, these terms are often used and interpreted inconsistently by both lawyers and scientists. For example, while Dua (2023) would argue that ‘onshore’ operations include activities or assets located within a country’s borders, lawyers would argue that ‘within a country’s borders’ would also include ‘territorial waters’ as defined by international law, which can extend up to 12 nautical miles (nm) into the sea.

2 Objectives and research requirements

In order to clarify more precisely, we, as members of the ICES “Working Group on Open Ocean Aquaculture” (ICES, 2024), are appointed to scientifically define the terminology of “offshore aquaculture” and “exposed aquaculture” more precisely. The main objectives are to: (1) discuss the understanding, terminology, and linguistic use of the term “offshore” in comparison to the other terms, (2) examine the different published definitions of the terms, and (3) recommend a new term for this kind of aquaculture. Results of this work will better classify aquaculture operations that take place in various zones of the ocean (distant and/or exposed) and clarify the definitions to interest groups of different levels of expertise and origins (farmers and fishermen, scientists, regulators, NGOs, insurers etc.). We aim to develop an ontology for “offshore” and “exposed” aquaculture, encompassing a representation, formal naming, and definition of the categories, properties and relations between the concepts, data and entities that substantiate all domains of discourse (Buttigieg et al., 2013; Arp et al., 2015, 2016).

We argue that a clear interpretation of the terminology will yield the following new advantages to (1) promote a common understanding and avoid misuse of arbitrary classifications which can lead to misinterpretation and confusion among different actors, such as NGOs, licensers, and government agencies; (2) enable regulators to identify the characteristics of a marine aquaculture site; (3) allow farmers to assess or quantitatively compare sites for development; (4) enable developers, equipment suppliers, and producers to identify operational parameters in which the equipment and vessels must operate; (5) provide insurers and investors with the terminology to consistently assess risk and premiums; and (6) circumvent the emergence of narratives that root in different cognitive interpretations of the terminology in public discourse arenas.

3 Illustrating the importance to develop generic geographic terms and quantitative criteria

The urgency as to why such a definition is required has been established however two questions remain to be addressed:: “For whom?” and “Which parameters are needed to clearly differentiate new descriptions from current uses of the term “offshore?” For example, Farmer A is located at an exposed, nearshore site with up to 6 meters (m) significant wave heights, while Farmer B is located at a further distance from the coast but in shallower waters, sheltered and with lower wave heights (Table 1). Farmer A invests in robust design and engineering to survive the strong forces of waves and currents. Farmer B has more of a focus on logistics, smart operational features, and the design and engineering needed to overcome issues related to accessibility of the remote farm. Both farmers see their concepts as challenges, although these are fundamentally different development scenarios. Nevertheless, the two farmers have one aspect in common; they are categorized as being part of “offshore aquaculture”. Conversely, if these two farmers engage within, for example policy and licensing procedures, they may warrant very different sets of approval/support conditions under the same “offshore” terminology. This current term’s ambiguity causes potential conflicts and disruptions in the communication processes that hamper advancements in the development.

In contrast to the term “offshore”, the term “exposed” aquaculture refers to the energetic characteristics of aquaculture sites. Exposed locations are generally understood to be “unprotected” or “not-sheltered” and experience high hydrodynamic energies induced by waves, currents, and winds. Consequently, “exposed” areas can be understood relatively in contrast to “sheltered” areas, as the site has an increased level of

TABLE 1 Representation of the different perceptions of the two farmers “A” and “B”.

	Conditions at the farm site (wave height)	Distance from harbor	Investment
Farmer A	Exposed (up to 6 m)	Nearshore	High due to robust system design
Farmer B	Sheltered (low wave height)	Far	Moderate due to existing infrastructure of the shelf, but has to invest in remote operation and in longer travel times[1]

1 = includes additional work hours of personnel.

energy and exposure as it becomes less sheltered. In addition, exposed sites may also be far from land. Thus, the combination of the degree of exposure and the distance from the coast is an important feature. However, what does the term “nearshore” then mean? – and when is a site considered “sheltered”? The explanation to-date is relatively simple and may appear intuitive, but is in fact very complex. Our rationale to explain this type of aquaculture is that all aquaculture that is not “exposed” is “sheltered”; and that all aquaculture that is not “offshore” is “nearshore”. One cannot describe terms by listing what they do not mean; i.e., only mentioning its antonym. To provide a basic understanding of how different aquaculture sites can vary in two of these main characteristics, distance to shore and energy of the site, four regions, which are not mutually exclusive, are presented in Figure 1, which show how both degree of energy and the distance from shore describes the characteristics of a site: (1) sheltered (protected), (2) exposed, (3) near to land (nearshore), and (4) far from land (offshore).

We develop an analytical approach that de-emphasizes aspects such as distance from shore that focuses and collates the most influential factors when assessing farmer activities. Therefore use the energy levels at farm sites as a proxy for the degree of exposure of aquaculture installations.

4 The evolution of the definition and interpretation of the term “offshore”

Semantically, the term offshore consists of two elements. The word “off” usually indicates a certain degree of separation between different entities (“away from”, “removed from”, “separated”, “not at” etc.). The term “shore”, on the other hand, is most commonly used to describe an area of land that stretches along the edge of a body of water. Merely joining together such relatively straightforward terms, however, does not allow for an objective definition of a specific area at sea. Based on a literal interpretation alone, the exact location, i.e., the geographical line where the shore begins and ends, as well as the distance between that line and a chosen geographical point at sea, lying “off” the “shore”, remains open to interpretation. Accordingly, the term “offshore” has been used traditionally in combination with an action or an installation, which was clearly distant from the shore, but at some undefined distance. Similarly, the content of the term “offshore” was also sometimes shaped by legal/regulatory distinctions of a specific country, i.e., federally managed waters opposed to state managed. Intuitively, “offshore” suggested something that was “far away”. At the beginning of the 20th century, the term “offshore” was also introduced in the economic realm to describe the relocation of financial assets to other national jurisdictions, i.e., some of the Caribbean Island nations (Suss et al., 2002; Gravelle, 2009; Ogle, 2017). Due to the fact that some of these sites are remote islands used by institutions thousands of kilometers away, the term “offshore” acquired the semantic characteristic to describe something very far away – meaning, out of one’s reach or out of sight.

As time progressed, the term “offshore” was also used for the technically rooted exploration and exploitation of marine resources by other economic sectors, for example offshore drilling (Cruz and Krausmann, 2008), offshore oil & gas (Drumond et al., 2018), and offshore hydrocarbons (Makogon, 2010), as well as for other operations, such as offshore servers, offshore wind etc (Blanco, 2009). In particular, the offshore oil industry, with large-scale

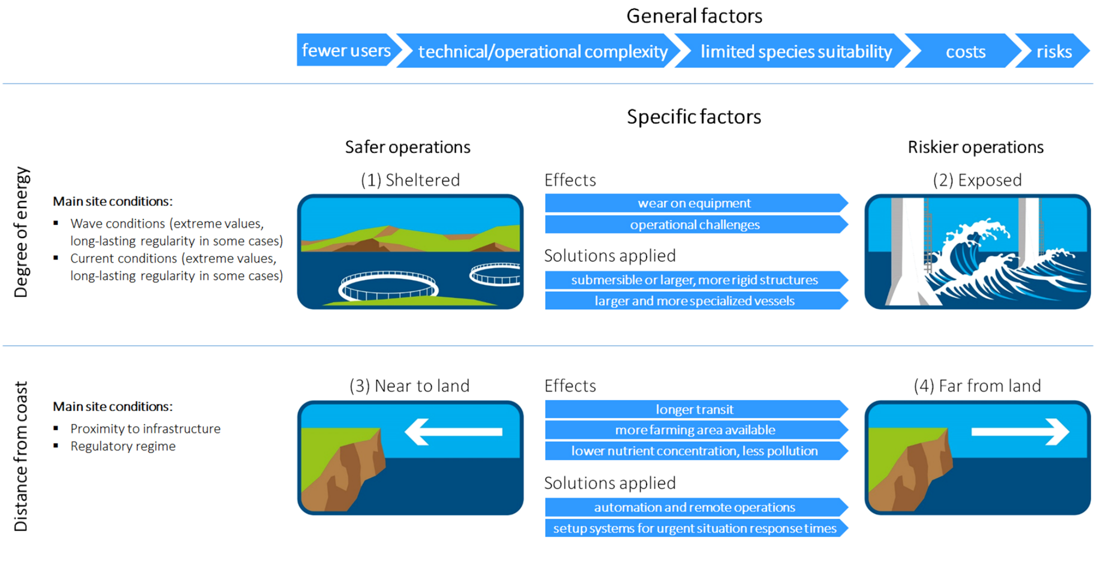

FIGURE 1
Comparison of “sheltered” vs. “exposed” (top) as well as “near to land” vs. “far from land” (bottom) environments along with a selected collection of general and specific descriptions of each.

structures far out at sea, operating at any time of the day or night, armed against all forces of the ocean, with many accessible only by helicopters, emphasizes how inaccessible offshore infrastructures are. However, the basic understanding remains the same, i.e., that all of these operations take place in locations that are geographically distant from the shoreline. Therefore, the main reason for perceiving the term "offshore" with a distance from the coast or an imaginary place far away is due to terminology that is triggered by other offshore undertakings unrelated to aquaculture. This is reflected in the usage of the word "offshore" as a primary or secondary term in published literature.

The Google N-gram Viewer platform is an online search engine that determines the occurrence of any search term based on an annual count of n-grams in printed sources. Using these n-grams, we want to determine in which causal context the term 'offshore' has been used in recent decades. Data shown in Figure 2 are based on Michel et al. 2010 for the period from 1970 until 2019. N-grams with the term "offshore" in combination with another term ("offshore" + "X"), such as offshore wind, offshore aquaculture, offshore bank, offshore gas, as well as other combinations are shown. An N-gram is the result of breaking down a text into individual words or fragments, such as word combinations and counted in frequencies (Bohannon, 2010; Michel et al., 2010; Russell, 2011; Lin et al., 2012). There may be some inaccuracy in the Google N-gram Viewer data, especially since words from books are only counted if there are more than 40 entries. Nevertheless, one aspect of the data set is unmistakable: at the beginning of the 1970s, all activities that took place in geographically remote regions were frequently associated with the term "offshore". For example, the use of the term "offshoring" began in earnest in the 1970s (Metters and Verma, 2008). After a dry spell of about 30 years, the term suddenly became prominent, frequently used to describe the spinoffs of many businesses and company combinations to other countries, typically to leverage cost advantages such as lower labor costs, favorable economic conditions, or tax benefits. There is no question that this term implies "distance". Therefore, the semantic understanding of that term was shaped many years before the combination "offshore" and "aquaculture" was used.

5 Present definitions

Present definitions of "offshore" aquaculture and related terms use various combinations of distance from shore, fetch, wave conditions, and water depth.

The term "offshore" is used differently in different sectors. Most wind farm operators, associate distance with the term "offshore" (Böttcher, 2013). In the US, however, "offshore" wind generally encompasses any wind turbine that is not on land (Madsen and Krogsgaard, 2017). It becomes even more confusing in risk and safety groups, who declare that all areas that are "off" the shore are "offshore", i.e., any amount of separation from the coastline (SOMOS, 2018). Similarly, in international law the term "offshore" does not indicate a specific distance from the shore (Markus, in press). Sailors also like to use the term offshore for those areas where there are severe weather conditions. In US aquaculture, the term "offshore" is often used for areas located outside of state-controlled waters which generally extend to 3 nm. All in all, in the public mind, the term is afflicted with many different confusing definitions. Several distance-based boundaries have legal implications, but none is equated to the term "offshore". The exclusive economic zone (EEZ) is defined in international law as "an area beyond and adjacent to the territorial sea" which may extend up to 200 nm from a coastal states' baseline. The territorial sea may extend up to a limit of 12 nm, i.e. it may cover smaller areas (sometimes reaching 2, 6, or 9 nm into the sea, depending on a country's claims in this regard, e.g., Cicin-Sain et al., 2001). Hansen (1974) summarized the results of a project funded by the US NOAA Sea Grant in 1970 to exploit the oceans away from the coast and defined "Open Ocean Mariculture" as being conducted in unprotected areas, whether near to or far from the shoreline. For offshore kelp farms, Cannon (1980) focused on distance and space; with regard to the US, he defined its EEZ as offshore, i.e., beyond the 3 nm zone and extending outwards to 200 nm. Twu et al. (1986) described "offshore aquaculture" conducted along the southern coast of Korea where, during the winter monsoon, waves could reach a significant wave height of 3 m and wave periods of about 10 s. During summer the entire Korean coastline is found to be

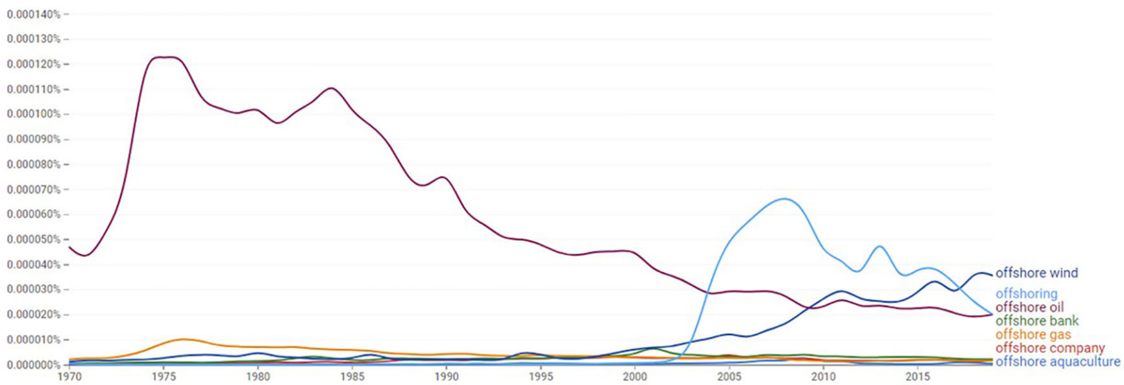

FIGURE 2
Frequency of N-grams in our everyday language used in combination with the word "offshore" in published literature between 1970 and 2019, based on Michel et al. (2010).

vulnerable to typhoon-generated waves of up to 10 m. Muir and Basurco (2000) chose a minimum distance of 2 km from the coast and a depth of 50 m, as well as reduced access due to bad weather conditions (high waves) and the need to incorporate some kind of remote operations such as automatic feeding, remote monitoring, etc. Since the mid-1980s, research on aquaculture in exposed and often distant waters, particularly in the US, increased. Results were communicated to users and other interested parties in a series of four US-based conferences on open ocean aquaculture (Polk, 1996; Hesley, 1997; Stickney, 1998; Bridger and Costa-Pierce, 2003). The first major gathering in Europe took place in Cork (Ireland) in 2004 and was followed by other conferences organised by the European Aquaculture Society (EAS) and workshops (Rosenthal et al., 2012a, b), and a series of events (the Offshore Mariculture Conference by Mercator Media).

The conference in Cork gave rise to a definition based on a four-tier classification system. It equally focused on distance and a lack of shelter but was adapted primarily to the coast of Ireland A modified site classification system originating from the Norwegian Aquaculture Site Classification Scheme and ranging from class 1 (sheltered) to class 4 (offshore), based solely on a site's significant wave weight (Ryan, 2004). Definitions that followed accepted Ryan's definition with additional parameters, such as Drumm (2010) who developed requirements for equipment and servicing vessels to survive and operate in severe sea conditions. HR (2011) used the EEZ to define "offshore". Lovatelli et al. (2013) identified a minimum distance of 2 km (approx. 1.1 nm) from shore and a depth of 50 m and deeper. Bak et al. (2020) defined sites as offshore when located >3nm from the shore regardless of local water depth, while nearshore was defined as <3nm distant from shore, being sheltered in <50m depth and exposed >50m depth. Buck and Langan (2017) and Buck et al. (2018) defined the term "EEZ-Aquaculture" to distinguish it from "coastal aquaculture". These were all valuable attempts at a better explanation and preliminary definition of the terms, but these works still reflect the need to find a more suitable definition, since none of the available definitions provides a clear-cut and holistic view on the multidimensional question of "offshore" terminology. However, despite recent and ongoing developments (EU-funding, development of robust technologies in Norway and elsewhere, conferences on "open ocean aquaculture"), the term "offshore aquaculture" remains unclear. In Table 2, further terms are described, which should serve to complete the common terms related to the location of a farm in the sea. Figure 3 underpins this overview. The need and time are now to define aquaculture in exposed, hostile, and highly energetic environments in greater scientific detail, aiming at multidimensional descriptors that enable state-of-the-art definitions for complex siting questions.

6 Distinction between "offshore" and "exposed", and its relevant parameters

The resulting challenge is how to compile a uniform set of scientific standards from these rather incomplete and legally non-binding definitions. Whether a legally binding definition can develop from this sooner or later cannot be predicted in the current state. This can only be decided once the terminology has been implemented and is therefore not part of this publication. An often-used classification to describe the conditions of a location are its geophysical and oceanographic characteristics and their parameters. Identifying these is complex as different clusters of parameters need to be considered. There are many publications on the parameterization of the term "offshore" or "exposed" aquaculture. Froehlich et al. (2017) examined a wide range of peer-reviewed and grey literature; they made a structured parameter list based on the number of mentioned parameters. But their classification was not unique as additional parameters were identified previously by Hansen (1974), Cannon (1980), Twu et al. (1986), Ryan et al. (2005), Drumm (2010), Lovatelli et al. (2013), Buck and Langan (2017), and Buck et al. (2018).

Figure 4 provides, in six groups, parameters that we have synthesized, and commonly agreed upon in the published literature as suitable descriptors of the offshore character of sites used for aquaculture operations. Parameters are grouped into (1) oceanographic data, (2) descriptors of water column, (3) operation and location parameters, (4) technology, (5) licensing and qualification, and (6) other relevant descriptors. The grouped parameters are weighted or correlated, discussed in depth, and also provide a basis for the additional works presented in this special issue.

Important questions relate to what importance should be given to the different parameters in Figure 4 and which of these are the most crucial for the diverse types of species and farming systems (for example of fish, crustaceans, bivalves, or macroalgae) at a given site. Engineers developing technologies could identify different parameters than those chosen from farmers, insurance companies, lawyers/regulators, or other stakeholders. However, in order to organize a classification, it is necessary to identify different target groups that are active in either "offshore" and/or "exposed" aquaculture. Hence, in order to produce a classification of "exposed aquaculture", the perspectives of different aquaculture related stakeholder groups must be integrated, requiring a multi-actor approach.

There is a plethora of parameters which pertain to the distinction of both "offshore/nearshore" and "exposed/protected" (Figures 1, 4), but these are not intrinsic to a definition. Parameters show trends across these two continuums, but the implications of these trends may vary depending on target culture species, which is important to understand for planning and management. For example, open ocean sites typically have a higher capacity to assimilate nutrients, which can allow for higher stocking densities in cage farming and larger biomasses without significantly increasing the impact on the environment in terms of fed aquaculture (Welch et al., 2019), but may imply different challenges in terms of management of the ecological carrying capacity for extractive species (Filgueira et al., 2015; Smaal and van Duren, 2019). It is therefore preferable to regulate production densities at sheltered and exposed locations differently to maximize the value of the resource. For example, Fujita et al. (2023) point out how SalMar's Ocean Farm 1 plans to measure the effects of their offshore farm on the benthic environment using hyperspectral imaging, a technique that has not been necessary for commercial nearshore farms.

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TABLE 2 Further definitions of terms in addition to "offshore" and "exposed", which serve to complete the common terminology in connection with the location of an aquaculture operation in the sea.

Term	Description
Coastal Aquaculture (antonym: EEZ-A[1])	"Coastal aquaculture" describes operations in the coastal sea, usually referred to as the "territorial sea". These areas can range from the coastline to the adjacent EEZ, but mostly refers to nearshore environments. Coastal aquaculture therefore covers a broad area, as it includes all areas where inshore and nearshore aquaculture takes place and, in rather rare cases, offshore aquaculture. Nevertheless, a distinction is generally made between the two terms, namely that "coastal aquaculture" is carried out close to the coast and "offshore aquaculture" in open sea areas further away from the coast.
Inshore Aquaculture antonym: OA[1], OOA[1]	The exact distance that "inshore" is from the coastline can vary considerably and depends on various factors. These vary greatly depending on the user and how "inshore" is used in context. In principle, there is no set distance that is generally considered to be "inshore" as this depends on the particular activity or area of interest. Generally speaking, "inshore" refers to waters that are relatively close to the coast, often not deep, as opposed to "offshore" which describes areas more distant from the coast. However, to be clear about the antonym "offshore", "inshore" should definitely be in the territorial sea and at a short distance from the coastline, as certain parameters stand out in proximity to the coast: (1) control of environmental conditions can be carried out more easily, (2) which leads to a simpler O&M, (3) due to the short distance, the sailing to the farm is of shorter duration, which (4) results in lower costs, and (5) the investment in a more stable technology can be lower, as the weather and wave/current conditions are usually less challenging compared to offshore locations. Often, however, too many farms are built in favorable inshore locations, which in turn exceed the ecological carrying capacity. Inshore activities take place within the coastal sea.
Nearshore Aquaculture antonym: OA, OOA	"Nearshore", like "inshore", refers to operations that take place in waters in the immediate vicinity of the coast. In the context of aquaculture, "nearshore" thus refers to farming activities in water close to the coast, which may be shallower and closer to shore. Again, there is no clear distance to the coastline that can be defined as "nearshore", and this in turn depends on the type of activity. The terms "inshore" and "nearshore" are therefore often used interchangeably but can have slightly different meanings depending on the context. However, there may be some differences: While "inshore aquaculture" can refer specifically to waters that are very close to shore, possibly in shallow bays, estuaries or intertidal zones, "nearshore aquaculture" would encompass a slightly wider spatial area and refer to waters that are relatively close to shore, but not necessarily as narrowly defined as "inshore". The same applies to water depth, as "inshore" is often defined as having a shallower water depth. "Nearshore" could therefore refer to waters that may be slightly deeper but are still close to the coast. It is important to note that these terms can be interpreted differently in different regions and contexts. In many cases, they are used as interchangeable terms to generally refer to the proximity of aquaculture activities to the coast. Nevertheless, "nearshore" aquaculture would arguably be located behind "inshore" aquaculture when viewed from the coastline, possibly with some overlap. As shown in Figure 3, "nearshore" activities take place within the territorial sea.
Foreshore Aquaculture (antonym: OA, OOA, EEZ-A)	The term "foreshore" refers to the part of a sea and shore area that lies between the high and low tide line, i.e. the eulittoral zone in the classic sense. Aquaculture is thus practiced in this zone, which is exposed to the tides (for example some oyster farms and pile cultures for mussels). "Foreshore" activities take place within the coastal sea (see Figure 3).
Onshore (antonym: any other term defined here)	"Onshore aquaculture" is synonymous with land-based aquaculture and refers to any farm that is located on land or within a fairly small water body (i.e. ponds, but not lakes). This includes indoor farms (RAS[1], pRAS[1], or flowthrough) or outdoor farms (ponds or raceways). The size of waterbody that would differentiate onshore aquaculture from production in a lake or other enclose water body is outside the scope of this article.
OOA (antonym: inshore, coastal, nearshore aquaculture)	"Open Ocean Aquaculture" (OOA) refers to the farming of aquatic species that takes place in open oceans, as opposed to traditional methods that are carried out near the coast or in protected marine water bodies. Very often, these areas are deeper than those in the in- or nearshore. OOA aims to utilize the space beyond coastlines to enable the production of marine organisms with high biomass yields. In contrast to coastal aquaculture facilities, where environmental impacts and space constraints can play a role, open ocean aquaculture potentially offers more space for the cultivation of the farmed species organisms. There are challenges and concerns associated with OOA, including environmental impacts, potential effects on wildlife populations, seabed pollution and social acceptability issues. The terms "open ocean aquaculture" and "offshore aquaculture" are often used interchangeably, but may have slight differences depending on the specific context. In general, both refer to aquaculture in open waters, far from the coast, however, there are some differences: From a spatial perspective OOA emphasizes farming in the open oceans, in most cases very far from the coast and beyond the 12 nm zone. The term "offshore aquaculture" refers to a shorter distance from the coast, which we believe should be set at 3 nm. This means that, in some countries, "offshore aquaculture" can take place in the territorial sea, beyond the 3 nm mark and up to 12 nm. Regarding the depth, OOA specifically targets farming in deep waters characteristic of open oceans, while "offshore aquaculture" can be conducted in both, relatively shallow or deeper areas.
EEZ-A (antonym: coastal aquaculture)	EEZ aquaculture" describes aquaculture activities in the exclusive economic zone. In countries where the EEZ begins 12 nm seawards from the baseline close to coasts, efforts to practice aquaculture are more in the research status. A special type of aquaculture here is the combination of offshore wind farms (OWF) and aquaculture, which is known as "multi-use". In those countries, for example the USA, where the EEZ lies either 3 or 9 nm off the coasts (baselines), there are already commercially operated aquaculture farms.
Sheltered (antonym: exposed aquaculture)	"Sheltered aquaculture" refers to aquaculture activities that take place in protected or sheltered water bodies. These environments offer natural or artificial protection from the effects of strong currents, high waves, tidal influences or other extreme environmental conditions. Shelter can be provided by location (bays, lagoons, etc.), by natural structures (islands, reefs, etc.) or by artificial structures (piers, harbors, etc.). Often the term "protected" is used as a synonym, but this leads to misunderstandings, as "protected aquaculture" can also mean (1) that special measures are taken to protect the environment from the potential impacts of aquaculture, and (2) that aquaculture activities are protected by special laws or regulations to ensure that they are operated sustainably and have no negative impact on the environment or other interests. To avoid this uncertainty, aquaculture that is protected by its location should be labelled exclusively as "Sheltered Aquaculture". These activities take place predominantly in the coastal sea.

[1]EEZ-A, Exclusive economic zone aquaculture; OA, Offshore Aquaculture; OOA, Open Ocean Aquaculture; RAS, Recirculating Aquaculture System; pRAS, partial Recirculating Aquaculture System.

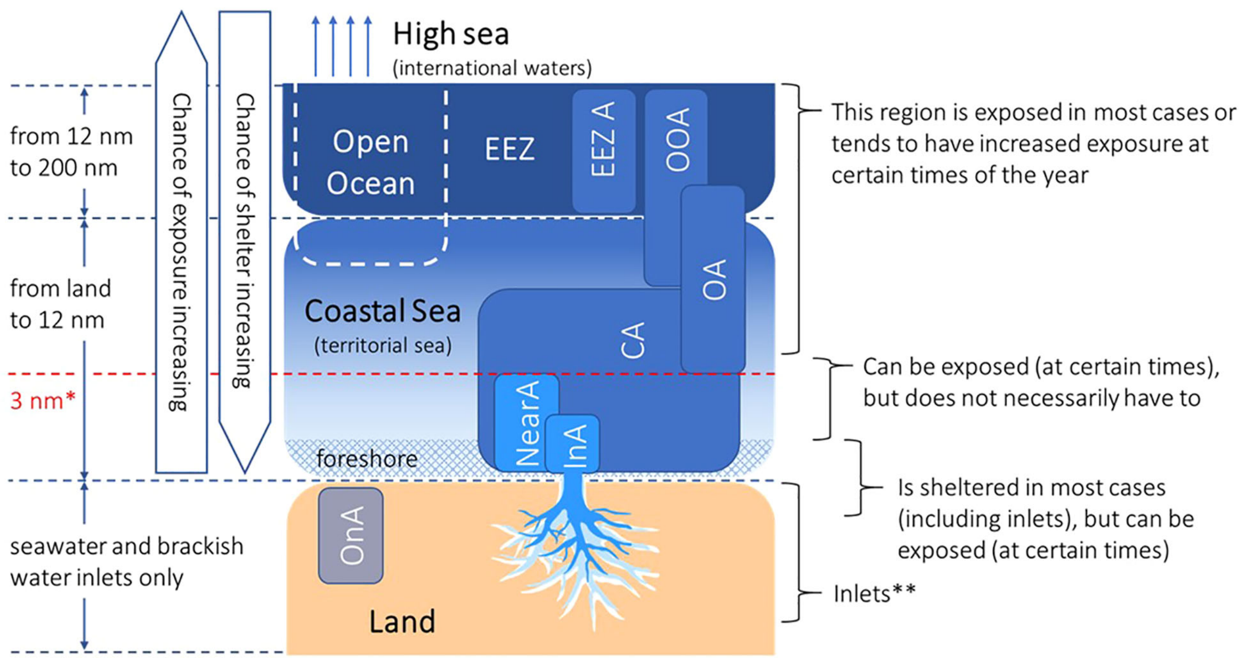

FIGURE 3
Illustration of the different aquaculture terms that have to do with a location description. * = red dotted line shows where the offshore area starts towards the open ocean; ** = by "Inlet" is meant any kind of body of water as an arm of the sea inland, such as fjords, bays, estuaries, lagoons, etc.; CA, Coastal Aquaculture; EEZ, Exclusive Economic Zone; EEZ A, EEZ Aquaculture; InA, Inshore Aquaculture; NearA, Nearshore Aquaculture; OA, Offshore Aquaculture; OnA, Onshore Aquaculture; OOA, Open Ocean Aquaculture.

Establishing definitions that allow for the clear partitioning of sites as one category or another also enables the analysis of trends in other parameters across the spectrum of site types. Parameters that describe the water column with reference to species suitability, such as oxygen (particularly important for fish), chlorophyll (secondary site quality characteristic for filter feeders, such as mussels and oysters), nutrient concentrations (relevant for macroalgae) or temperature (all species), are essential in the context of site selection criteria studies for the evaluation of the biological production potential and must never be neglected. Nevertheless, these parameters are not the typical barriers to practicing aquaculture in relation to "offshore" or "exposed" environments (even though we know that nutrient concentrations, for example, can decrease with distance from the coast to the open ocean in many marine bodies of the world, e.g., Cravo et al., 2003; Aziz et al., 2019). Similarly, "other factors" (see Part 6 in Figure 4) should not be underestimated, as fouling (Bannister et al., 2019; IOC-UNESCO and GEF-UNDP-IMO GloFouling Partnerships, 2020), predators (Freeman, 1996), or conflicts (Buck et al., 2004; Hipel et al., 2018) with other users are known to have a significant effect on the success of aquaculture operations in nearshore and/or protected areas. Additionally, the concept of synergies in terms of multi-use (for example, offshore wind farms [OWF] and aquaculture) of areas is of increasing interest globally (Buck and Langan, 2017) and, in particular, low-trophic aquaculture (LTA) in OWF can make a significant contribution to achieving the Sustainable Development Goals of the United Nations (Maar et al., 2023; Troell et al., 2023).

Similarly, other parameters in Figure 4 all have their specific importance for the success of a commercial aquaculture farm, but are more general than specific to offshore or exposed areas. In the first instance, a site is defined according to the most important parameters (depth, wave height, current velocity) that will determine how it is farmed, distance from shore and energy environment (i.e., classified as "offshore/nearshore" and "exposed/sheltered"). It is important to characterize and describe the site according to all the other parameters afterwards, as they will still impact the suitability of the site and the species and equipment chosen to farm there.

This work has surfaced and is agreed upon amongst a substantial number of authors from various disciplines, the two parameters "wave" and "current" in all their facets (height, frequency, velocity, direction). It is therefore necessary to work out a way to use these parameters as a basis to discuss a definition of the terms. Although it is known that the depth of a site will have a significant effect on the expression of the wave (Lojek et al., Heasman et al., in press), we consider the depth as a secondary effect in this publication, as the wave data itself is sufficient to describe the degree of exposure of the site.

7 Discussion

Members of the ICES Open Ocean Aquaculture Group (WGOOA; ICES, 2024) have defined a terminology to distinguish "offshore aquaculture" from "exposed aquaculture" more precisely by developing an index that better describes the degree of exposure (see Lojek et al., in press). We suggest that the definition of "offshore" versus "nearshore" and "exposed" versus "sheltered" be defined exclusively according to the distance from shore based on visibility and the wave

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(1)	No.	Parameter	Effect mode
Oceanographic data	1.1	current velocity	direct
	1.2	wave action	direct
	1.3	wave variation	direct
	1.4	wave period	direct
	1.5	wave direction	direct
	1.6	wind speed / fetch	direct
	1.7	depth of seabed and farm position in the water column	direct
	1.8	degree of exposure	consequence

(2)	No.	Parameter	Effect mode
Water column	2.1	oxygen	indirect
	2.2	pH	indirect
	2.3	temperature	indirect
	2.4	salinity	indirect
	2.5	plankton	indirect
	2.6	nutrients	indirect
	2.7	sediment load	indirect

(3)	No.	Parameter	Effect mode
Technology	3.1	system design	consequence
	3.2	technical complexity	consequence
	3.3	wear on equipment	consequence
	3.4	materials used	consequence
	3.5	ecosystem-friendly material	consequence
	3.6	life expectancy of material	consequence
	3.7	buoyancy type	consequence
	3.8	mooring	consequence
	3.9	submersible modes	consequence

(4)	No.	Parameter	Effect mode
Opeartion & location	4.1	smart operations	consequence
	4.2	larger/specialized vessels	consequence
	4.3	remote monitoring	consequence
	4.4	distance and transit time	none
	4.5	farm size	none
	4.6	multi-use of offshore sites	none
	4.7	IMTA	none

(5)	No.	Parameter	Effect mode
Licensing & qualification	5.1	health & safety training	consequence
	5.2	specialized diving operations and requirements	consequence
	5.3	emergency preparedness	consequence
	5.4	special qualification for personnel	consequence
	5.5	offshore certification of vessel, personnel, equipment	consequence

(6)	No.	Parameter	Effect mode
Other factors	6.1	predators	indirect
	6.2	pathogens	indirect
	6.3	carrying capacity	consequence
	6.4	biofouling	consequence
	6.5	species choice	consequence
	6.6	nutrition/feed	consequence
	6.7	stakeholder/user conflicts	consequence
	6.8	pollutants/contaminations	indirect
	6.9	visibility from shore	consequence
	6.10	costs	consequence

FIGURE 4
Parameters/factors that will impact performance and characteristics of aquaculture carried out in "exposed" and/or "offshore" waters. Parameters were extracted from the common literature (e.g. Hansen, 1974; Cannon, 1980; Twu et al., 1986; Ryan et al., 2005; Drumm, 2010; Lovatelli et al., 2013; Buck and Langan, 2017; Froehlich et al., 2017; Buck et al., 2018) and coincide with the authors' experience of carrying out aquaculture in exposed and/or remote locations.

and current conditions respectively, creating discrete categories for each term. We establish clear site descriptions as an "exposed-offshore site", and an "exposed-nearshore site". Other adjectives describing different parameters (such as temperate or oligotrophic, high/low saline or eutrophic, etc.) would only be applied during specific discussions evaluating the site.

Members of the ICES Open Ocean Aquaculture Group (WGOOA; ICES, 2024) have defined a terminology to distinguish "offshore aquaculture" from "exposed aquaculture" more precisely by developing an index that better describes the degree of exposure (see Lojek et al., in press).

As part of a more accurate description on exposure, the physical attributes can now be associated with engineering (structural requirements, robustness of equipment, vessel design, technology); logistics (requirements to operate in that physical environment); biology (potential cultivated species at the site); health and safety (improved requirements, vessel/equipment design and automation); operations and management (vessel size, site access and visit frequency, seeding and harvest windows); social and environmental license (acceptability associated with the site); economics (cost of engineering, logistics and production relative to species yield and value) and policy and regulation (all the above) are more tangible.

Finally, we want to clarify the question of what should be understood by the term "offshore aquaculture". How can the term be defined, and what does this mean for current and future aquaculture?

In addition to all these facets, there is always the idea that the distance a service vessel has to travel from the port to the aquaculture operation should be considered in the "offshore" definition. After all, long travel distances play a significant role in the economic feasibility of an aquaculture enterprise, which are influenced by high costs incurred by staff, fuel, etc. Thus, long distance travel routes to the farm site may also be due to designated shipping routes, where vessels rarely reach a destination via the bird's-eye route, but take longer due to other navigational barriers such as shoals, rocks, nature conservation areas, intensively used commercial shipping routes, etc. An aquaculture enterprise can be 500 m off the coast but many nautical miles from the nearest port "offshore"? Here we need to understand an essential difference between "long travel time" and "offshore", because "offshore" is precisely "off the shore", i.e., for example a few kilometers perpendicular to the coastline, and should not be confused with "off-port", i.e., several kilometers away from the port. So how do we classify, for example a shellfish operation far from the harbor, which is in fact only 500 m off the coast, and, how do we distinguish it from those that exist, for example, several nautical miles towards the "open ocean"? In this case, we would call the site that is 500 m away from the coast "inshore", "near the coast" or "nearshore", because only the distance to the port is the cost driver here, not the distance to the sea. Here, the 500 m specifies the degree to which the farm is offshore, not the distance to the harbor. One exception to this guiding principle is proximity to small islands that do not provide any meaningful operational advantage. A site that is far from the mainland but near to some small, uninhabited islands, or where these islands have no influence on operations (landing of products, crew changes, bunkering, etc.) could still be considered offshore.

A definition that would make the most sense for us to apply is a farm that is operated out of sight - and from our point of view this farm is "offshore". Of course, this kind of approach depends on many factors, namely how high the farm's superstructure is, for example a mussel backbone vs. Ocean Farm 1 (Buck et al., 2018) or the height of the person standing on the beach and looking towards the sea, because stature certainly conditions how far a person can see - especially if, opposite a calm sea, a wave now integrates, which can block the view. A range could be given based on an average human height of 159 to 170 cm and an average height of aquaculture facilities (100 cm), so the calculated distance for a facility out of sight would be approximately 3 nm, based on an observer standing at sea level at the edge of the coast (see Figure 3). This definition does not employ a highly technical approach as is taken with the "exposure" definition, but this is appropriate for "offshore" since it is already in use by a larger number of different stakeholders and has a less direct impact on farm operations, equipment choice, and economics. If the term "offshore" is used it should refer to the distance only, unrelated to the requirements of an aquaculture site and/or the exposure of that specific site. Further, the effort to measure and communicate the precise distance of a farm from shore is not excessive (for example Farmer A can describe their farm as "an exposed farm that is for example 8 nm from shore"). As such, a precise and consistent use of the term is less necessary, yet still provides value to a maturing industry that needs to partition and discuss its sub-sectors.

The 3 nm distance is also used in many legislative contexts. It is consistent with the historical limit of territorial seas under which many countries recognized control up to 3 nm from the baseline from the 1600s until the 1958 Geneva Convention on the Territorial Sea and the Contiguous Zone (Swarztrauber, 1970). This 3 nm limit still separates state and federal waters in the USA, where waters beyond this limit are legally the "Outer Continental Shelf" (BOEM, 1953).

8 Conclusions and recommendations

The previously used definitions or characterizations of "offshore" or "open ocean" aquaculture have been unable to be established as generally accepted definitions. While some terms were established to demonstrate a particular point at sea or create a framework for analysis, they were never intended nor adequate for widespread adoption (Lovatelli et al., 2013; Morro et al., 2021). Therefore, the question arises how this newly proposed terminology will be adopted by the various user groups (farmers, scientists, engineers, insurers, NGOs, etc.; see Section 2) or, at best, be accepted. The need for a clearly defined terminology stems from those user groups, as a precise universally accepted, standardized definition has been unresolved for decades and consequently terms have been used somewhat arbitrary (Buck and Langan, 2017; Froehlich et al., 2017).

We present a strict definition of "exposed" aquaculture primarily focused on the physical attributes of a site and the parameters of "depth", "waves", and "currents" in all their facets are considered to be the principal considerations. The effects of all other factors characterizing a site (see Figure 4) are considered subordinate to these oceanographic parameters. Thus, this work advocates that the terms "exposed/sheltered" can be defined in such a way that discussion about the nature of the site in question is unambiguous. In contrast, such understanding enables the terms "offshore/nearshore" to be utilized more accurately to simply describe a farm's distance from shore. Consequently, an "offshore" site with a certain degree of exposure, must be described using both terms: i.e., a site that is far from the coast and additionally exposed to harsh weather conditions is an "exposed offshore" site. In conclusion, although we maintain that "offshore" is a continuum, which can be quantified, we recommend that whenever a specific threshold must be defined, a distance of 3 nm from shore (not port) should be used (Figure 3).

The establishment of specific definitions for these terms, particularly to distinguish "exposed aquaculture" from "offshore aquaculture", comes at an appropriate and crucial time in industry development, as there are several open ocean farms operating in different regions of the world today. Though, the continuous implementation of term dissemination can only be achieved through an ongoing dialogue and a common roadmap orientated towards stakeholder/user groups and has to (1) go far beyond scientific publications, (2) support and awaken an understanding for the introduction of this terminology, and (3) use and disseminate the defined terms correctly at different levels (ICES, FAO, NGOs, peer-reviewed and grey literature, research projects and reports, company catalogues, technical and conferences papers, and many more).

Our vision for where and how the industry will continue to develop is well established, based on a substantial amount of real-world experience, and reflects empirical data that is oceanographic, operational, and financial in nature. Significant growth is anticipated in most of these regions which will need to be supported by focused R&D efforts (and funding opportunities), regulatory environments that encourage such growth, and interactions between various stakeholders which can be facilitated by specific and well-defined terminology. We hope that these definitions and the discussion presented in the Special Edition will be useful in progressing the collective understanding of aquaculture in exposed sites, the environments that this industry sub-sector operates in, and the challenges and opportunities created.

Finally, the question arises as to how this new terminology, as we understand and propose it, will reach the various user groups (farmers, scientists, engineers, insurers, NGOs, etc.; see Section 2) and, at best, be accepted. It is important that the user groups understand the motivation behind the steps we have taken, as this is the only way that the terms will become part of the general linguistic usage of these user groups in the future.

Firstly, it should be emphasized that the need to give the terms a clear definition stems from these user groups themselves. The question of a precise universally accepted, standardized definition has been unresolved for decades and the use of the terms has been somewhat arbitrary for just as long (Buck and Langan, 2017; Froehlich et al., 2017).

Nevertheless, there needs to be a common roadmap for how the user groups (1) learn about these efforts (not every user reads scientific publications), (2) support the understanding of this terminology, and (3) use and disseminate the defined terms correctly at different levels (ICES, FAO, NGOs, journals and grey literature, research projects, reports, company catalogues, technical papers and conferences, and many more) in the future.

The solution can only lie in the continuous implementation of term dissemination, and acceptance can only be achieved through an ongoing dialogue at the above-mentioned levels. The process will certainly take a few more years, but the foundation has been laid and will be disseminated, at least among the authors of this article.

The authors understand if some stakeholders find it difficult to accept or apply this terminology. Many farmers farm and do not go into the clarification of terms. Costs may also be incurred if, for example, print media has to be changed or advertising adapted. Nevertheless, we want to encourage the industry to develop an understanding of why terminology is important (see Section 2). Understanding comes first; direct implementation can follow.

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

BB: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing. HB: Writing – original draft, Writing – review & editing. AB: Writing – original draft, Writing – review & editing. MC: Writing – original draft, Writing – review & editing. BC-P: Writing – original draft, Writing – review & editing. TD: Writing – original draft, Writing – review & editing. JF: Writing – original draft, Writing – review & editing. HM: Writing – original draft, Writing – review & editing. DF: Writing – original draft, Writing – review & editing. NG: Writing – original draft, Writing – review & editing. JH: Writing – original draft, Writing – review & editing. WI: Writing – original draft, Writing – review & editing. GK: Writing – original draft, Writing – review & editing. TM: Writing – original draft, Writing – review & editing. NP: Writing – original draft, Writing – review & editing. TS: Writing – original draft, Writing – review & editing. BS: Writing – original draft, Writing – review & editing. ÅS: Writing – original draft, Writing – review & editing. MT: Writing – original draft, Writing – review & editing. DW: Writing – original draft, Writing – review & editing. SV: Writing – original draft, Writing – review & editing. KH: Writing – original draft, Writing – review & editing.

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Conflict of interest

HB and HF were employed by SINTEF Ocean. TS was employed by Innovasea. JF was employed by Longline Environment Ltd. BC-P was employed by Ecological Aquaculture International, LLC. AB was employed by AquaRange Research LLC. TD was employed by Kelson Marine Co. JH was employed by Offshore Shellfish Ltd. And BS was employed by American Mussel Harvesters, Inc.

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Publisher's note

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