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Science-policy-public interface toward ocean sustainability: An empirical study using legal documents, scientific publications, and public inquiry logs in Japan

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Many countries have governmental fisheries science organizations, each of which should play a critical role in achieving ocean sustainability by leading the fisheries science in each country's specific contexts and beyond. In the context of the UN Decade of Ocean Science (UNDOS), understanding the interface of science, policy, and public interest around fisheries is increasingly recognized as critically important for realizing effective knowledge exchange and co-creating desired futures. This study aims to illuminate the interface of the above three facets as a guide to have better outcomes in the UNDOS timeframe. We used a case study of Japan – a country with extensive seafood production and consumption, and analyzed 1) the scientific performance of the Japan Fisheries Research and Education Agency (JFRA), a national fisheries research organization in the country through peer-reviewed papers published by JFRA researchers from 2004–2018, 2) policy needs through annual white papers published by Fisheries Agency from 1989–2018, and 3) public interest around fisheries through public inquiry logs accumulated at JFRA from 2004–2018. The results indicated the following: 1) JFRA was originally a part of fisheries policies, and both science and policy were inherently based on the fisheries practices in the "real world" in Japan. However, over the last fifteen years, the scientific performance has heavily focused on bio-physical dimensions of fisheries such areas as "Stock assessment," "Fisheries Oceanography," and "Stock enhancement." 2) Japanese fisheries policy priority has shifted from relatively simple, straightforward keywords focusing on primary fisheries production (from 1989 to 1998) to more complex, multidimensional fisheries systems, including marine resources, producers, processors, and consumers in/outside of the country (from 2009–2018) over the last three decades. 3) Public fisheries/ocean literacy seems limited, despite the rich history of

seafood consumption, cultural bond with fisheries, and inherent close relationship among fisheries science, policy, and resource users. Based on the results, we discuss that JFRA sciences, fisheries policy, and the public are contemporary pursuing different interests. To overcome this situation, one important area that JFRA (and any other marine/fisheries research organizations) needs is to reconnect science and public interest through strengthening human dimension works and science communication. For the public side, literacy development among wider stakeholders is one of the most emergent works to be addressed. This is one of the first case studies of science-policy-public interface through empirical data, particularly with the public inquiry log, and the "non-Western" country case study on this topic. This will encourage other empirical studies from countries with various social/cultural/political backgrounds to enrich the perspective of fisheries science-policy-public interface studies globally.

KEYWORDS

ocean sustainability, science-policy interface, fisheries/ocean science organizations, science communication, text content analysis

1 Introduction

It is widely recognized that sustainable development can be achieved on social and economic justice as well as within the biophysical limits of the earth system (Brundtland 1987; United Nations, 2013). Humankind needs systemic change that involves changes to society itself to realize a sustainable future (Patterson et al., 2017; Bennett et al., 2019; Diaz et al., 2019). The ocean, the largest ecosystem on our planet, provides civilization with numerous benefits, and humankind urgently needs to change our behavior when interacting with it (Nash et al., 2017; Jouffray et al., 2020). After finding that a considerable proportion of the ocean has suffered serious degradation (United Nations, 2016), the Decade of Ocean Science for Sustainable Development (hereinafter, UNDOS) was launched in 2021 to catalyze the shift of ocean science so that it can drive the desired changes of global society to achieve sustainability, such outcomes as illuminated by UN 2030 Agenda, also known as SDGs (United Nations, 2013; Ryabinin et al., 2019; Claudet, 2020; Pendleton et al., 2020; Singh et al., 2021). In the context of UNDOS, ocean science is defined as "natural and social science disciplines, including interdisciplinary approaches; the technology and infrastructure that supports ocean science; the application of ocean science for societal benefits, including knowledge transfer and applications in regions that are currently lacking science capacity; as well as science-policy and science-innovation interface" (IOC-UNESCO, 2020: 5-6). The call for UNDOS reflected the increasing demand from various policy and industry sectors to improve the interface of ocean science while tackling the sustainability challenges, which are not restricted to ocean sustainability in a narrow sense (i.e., Goal 14) but also encompass wider societal goals represented by any other SDG goals (IOC, 2017; IOC-UNESCO, 2020; Claudet, 2020; Nash et al., 2021; Singh et al., 2021).

Fisheries are critical components of ocean sustainability. Global fish production is estimated to have reached about 179 million tonnes with a total first sale value of USD 401 billion, of which 82 million tonnes, valued at USD 250 billion, were produced by aquaculture activities in 2018 (FAO, 2020). Small-scale fisheries (hereinafter SSF) are particularly important for social and economic sustainability, which employ more than 90 percent of the world's capture fishers and fish workers, about half of whom are women (FAO, 2015). In addition to these contributions to food security and income generation, it has also been evidenced that fisheries are important in local cultures and the well-being of numerous coastal communities and people living there (Urquhart and Acott, 2014; Ban et al., 2017; Kittinger et al., 2017; Bennett et al., 2021). Given this significance, many countries have governmental fisheries science organizations, each of which should take a critical role in achieving ocean sustainability by leading the fisheries science in each country's specific contexts and beyond. Effective knowledge exchange at the interface of such science organizations and decision-makers has been an important study field that has attained considerable attention in fisheries and ocean sciences as well as in other disciplines over the last few decades (Cash et al., 2003; Fazey et al., 2013; Cvitanovic et al., 2015; McConney et al., 2016; Soomai, 2017; Cvitanovic and Hobday 2018). In addition to these studies, there is an increasing call for understanding how the general public

perceives fisheries and ocean sciences, given the demand for engaging wider stakeholders/citizens to approach ocean sustainability (Kopke et al., 2019; Kelly et al., 2021). Therefore, the aim of this study is to describe the interface of three facets, i.e., science, policy, and public interest, in fisheries as a guide to having better outcomes in the UNDOS timeframe.

We used Japan—a country with extensive seafood production [ranked 8th in marine capture production (FAO, 2020)] and consumption habits, with seafood being one of the most important sources of animal protein intake for the citizens (Makino, 2011; Sugimoto et al., 2022) —as a case study. To approach the science-policy-public interface in fisheries, we investigated 1) the scientific performance of the Japan Fisheries Research and Education Agency (JFRA), a national fisheries research organization in the country, 2) policy papers published by the Fisheries Agency, and 3) the public interest around fisheries through public inquiry logs accumulated at JFRA. As has been pointed out by past works, most of the case studies on fisheries and ocean science-policy interface came from developed, and more precisely, Western countries (Evans et al., 2011; Bennett and Dearden, 2014; Cvitanovic et al., 2015) with exceptions such as McConney et al. (2016) and Xavier et al. (2018). To our knowledge, the present work is the first Asian-based study and is critically important for ocean sustainability, including fisheries, adding to the significance of the study. In this regard, our discussion will include the context-specific uniqueness of the science-policy-public interface of the country to forge localized and, thus, hopefully, more effective ocean sustainability building. We will discuss what can be detected about the science-policy-public interface around fisheries in the Japanese context, as well as what national fisheries research organizations need to improve for approaching ocean sustainability in both Japanese and global contexts, such as the institutional arrangement which is suitable for and capable of achieving ocean sustainability, which has been discussing by recent works under the context of UNDOS (Blythe and Cvitanovic, 2020; van Putten et al., 2021).

2 Methods

2.1 Data collection

We applied quantitative and qualitative content analyses to the three types of text data mentioned in the Introduction. To analyze the scientific performance, we reviewed the documents describing the organization's background, history and priority areas. The documents included three laws defining the principles of national fisheries policy and science: Fisheries Basic Act (Act No. 89 of 2001), Fishery Act (Act No. 267 of 1949, amended in 2018), Act of National Research and Development Agency, Japan Fisheries Research and Education Agency (Act No. 199 of 1999), and "One Century of Fisheries Research" which was published by JFRA celebrating its 100th anniversary (JFRA 2000). Secondly, we analyzed peer-reviewed papers published by JFRA researchers from 2004–2018,which were collected through an internal performance evaluation database (hereinafter, internal DB). We referred to the original data from the JFRA annual reports from fiscal years 2004–2018 (https://www.fra.affrc.go.jp/bulletin/report.html) but removed some internal journals such as JFRA's internal reports. In addition, we categorized the papers written in English but published in Japanese journals as Japanese publications, which were not included in the present analysis.

To analyze fisheries policy needs, we analyzed annual white papers published by the Ministry of Agriculture, Forestry and Fisheries from 1989–2018). To analyze public interest, we utilized the internal database (DB), collecting the logs of enquiries by the media and public from 2004–2018, which every researcher must report every time they get an inquiry. Data collection was conducted from May 2018 to March 2021. Internal DB data was only available from 2004–2018. In terms of the fisheries policy white papers, we used data of 30 years from 1989–2018. We presumed that this would represent the shift in policy trends.

2.2 Data analysis

The results are presented by the following order: we show the background, history, and priority areas of the organization by reviewing the most relevant documents (Section 3.1). Content analysis of peer-reviewed papers (N=2,110) is presented in Section 3.2, which was conducted by using KH coder (https://khcoder.net/en/), a software for quantitative content analysis. Papers written in Japanese were not included in the analysis in Section 3.2. However, the overview is presented in Table A1. We visualized the results as a network diagram showing the words with similar appearance patterns, known as a co-occurrence network (Higuchi, 2014). This method was applied because it enables us to understand the major groups of key research topics during the past fifteen years. Additionally, the software was developed by a Japanese scientist, proving linguistic suitability. Next, content analysis of annual fisheries policy white papers (1989–2018) is presented in Section 3.3. We performed the analysis using the quantitative software NVIVO (https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home/). This method was used due to the large amount of text data (96,845 words per year, collected for thirteen years). After identifying the frequently used words used over the 30 years, we visualized the occurrence pattern of each decade using the similarity of the top 100 words by correspondence analysis. Lastly, content analysis of the public inquiry logs (N=7,572) is presented in Section 3.4, which was conducted using the KH coder, mainly because of linguistic suitability. Similar to the content analysis of peer-reviewed papers in Section 3.2, the result was visualized as a co-occurrence network

to enable us to understand the major groups of key inquiry topics during the past fifteen years.

3 Results

3.1 Legal base and history of JFRA: Fishery science and policy for resource users

We focused on The Fisheries Basic Act, Fisheries Act, and Act of National Research and Development Agency, Japan Fisheries Research and Education Agency as the most important legal base of JFRA. The Fisheries Basic Act defines the principle of Japanese fisheries policy that "Stable supply of quality marine products at reasonable prices shall, in view of an importance of marine products for the sound dietary pattern and as a basis for the healthy and fulfilling life, be secured for the future." (Translation from: https://www.japaneselawtranslation.go.jp/en/laws/view/4010 last accessed on 9th September, 2022) in Chapter 1, Article 2, right after the Article 1 "Purpose" of this Act. Chapter 1, Article 2 includes two more sentences about appropriate resource management and aquaculture appropriate combination of domestic production and international trade. Chapter 1, Article 3 includes two sentences about "sound fisheries development" which can support healthy seafood diet among national citizens and fishing communities as the base of this industry. In addition to The Fisheries Basic Act, Fisheries Act, which was reformed in 2018 almost 70 years after initial establishment in 1946 (Act Partially Amending the Fishery Act, etc.), states that its main purpose is to achieve both appropriate resource management and transformation of the fisheries industry into a growth industry at the same time. Therefore, basic fishery production systems concerning resource management measures and fishing permit and license systems, etc. will be reviewed in an integrated manner (Ministry of Fisheries 2018). JFRA was placed as the body which implement stock assessment by the Minister of Agriculture, Forestry and Fisheries (Chapter 2, Article 9). Lastly, Act of National Research and Development Agency, Japan Fisheries Research and Education Agency) defines the mission of JFRA as "to carry out research and scientific activities which can contribute to the technical development of fisheries, the artificial hatching and stocking for the maintenance of the population of salmon and trout among anadromous fish as well as to promote education for the people engaged in fisheries"(translated by the authors from the original Japanese version: https://elaws.e-gov.go.jp/document?lawid=411AC0000000199, last accessed on 9th September, 2022).

The above three legal documents show us the following. Firstly and most importantly, the principle of Japanese fisheries policy is defined as "Stable supply of quality marine products at reasonable prices shall, in view of an importance of marine products for the sound dietary pattern and as a basis for the healthy and fulfilling life." Secondly, and following the first principle, the reformed Fisheries Act placed JFRA as the body to implement appropriate stock assessment, which was also one of the most important aims of the policy reform itself. Thirdly, the Act of National Research and Development Agency, Japan Fisheries Research and Education Agency defines the mission of JFRA as to conduct science and education for the sake of fisheries development.

When looking at the institutional history through JFRA (2000), the Agricultural Promotion Division inside the Ministry of Interior was established in 1877, with two important principles of fisheries policy: "application of the advanced Western fisheries techniques" and "establishment of a well-organized system of coastal fisheries." After that, in the *Showa* era (1926–1988) when Japan experienced rapid development in many industries, including fisheries, the Ministry of Agriculture and Forestry launched a research organization that specialized in fisheries to rationalize the industry based on scientific evidence. Since 1949 when the eight sea organizational structures was formed, five main areas of the research were promoted: "Stock assessment," "Fisheries Oceanography," "Stock enhancement," "Fisheries food science," and "Fisheries engineering." JFRA (2000) states that "Stock assessment" research mainly focused on sustainability for fishery production of small pelagic fishes such as Japanese sardine, chub mackerel, and Japanese common squid; "Fisheries Oceanography" on oceanographic research that contributes to predicting fluctuations of fisheries stocks, in cooperation with the field of fishery resources; "Stock enhancement" on breed improvement, fishing ground improvement for coastal fisheries promotion; "Fisheries food science" on the technical development of processed products; and "Fisheries engineering" on the technical development of fishing gear and vessels to promote the productivity of the industry (JFRA2000: 11-12). This institutional history shows that JFRA's science was for supporting fishery practices from the beginning. During the 2000's when the Japanese Government was promoting the restructuring of public services, JFRA was also reformed as an independent research organization separate from the Government and the Fisheries Agency, to be precise. Thus the history of JFRA shows that it was originally a part of the fisheries policy and became independent to meet the increasing need of scientific support for fisheries development in the country. Both fisheries science and policy were inherently based on and aimed at developing fisheries practices by resource users in Japan, which is also well evidenced by the history of co-management in the country (e.g., Makino, 2011). By the latest institutional restructure in 2020, JFRA established the Fisheries Resource Institute and Fisheries Technology Institute instead of the eight sea organizational structures. The former focuses on

the stock assessment and oceanographic research related to wild fisheries resources; the latter focuses on the stock enhancement and technical development of cultured fishery resources.

3.2 Recent scientific performance of JFRA

We quantitatively categorized research areas of JFRA by using the text data of published papers by JFRA researchers. As a result, we gained the eight groups (subgraphs) shown in Figure 1 and Table 1.

Subgraph 1 included the words indicating larval development research areas related to stock assessment and enhancement. It also includes the studies of the effects of natural and artificial environmental factors.

Subgraph 2 included the words indicating the studies on wild and hatchery-reared Pacific bluefin tuna.

Subgraph 3 included the words indicating the studies on coastal environments, including the relationship with fisheries resources.

Subgraph 4 included the words indicating biological studies of fishery species and algae, such as red tide. It also includes studies on the distribution of bioactive molecules.

Subgraph 5 included the words indicating the research about salmonid fishes, including maturation and the size component of fishery stock, including salmon.

Subgraph 6 included the words indicating population genetic structure analysis using DNA markers.

Subgraph 7 included the words indicating the studies on Japanese eel, particularly on stock enhancement, including full-life cycle aquaculture.

Subgraph 8 included the words indicating the fishery biology, stock assessment, and fisheries oceanographic research around the western North Pacific.

Figure 1 indicates that three of JFRA topic areas, i.e., "Stock assessment," "Fisheries Oceanography," and "Stock enhancement," largely occupy the scientific performance of the organization during the last 15 years. Thus, the combined results indicated that JFRA was a part of fisheries policy. Both science and policy were inherently based on the fisheries practices in the "real world" in Japan, and it has heavily focused on bio-physical dimensions of fisheries, represented by such areas as "Stock assessment" (subgraph 1, 2, 3, 5, and 8), "Fisheries Oceanography" (subgraph 3,4 and 8), "Stock enhancement" (subgraph 1, 2, 4, 5, 6, and 7) over the last 15 years Figure 1 and Table 1.

3.3 Shift of fisheries policy priorities during the last three decades

Figure 2 shows the distribution of the keywords detected from fisheries policy white papers described by correspondence analysis (the full list of text data is available in Table A5). Each

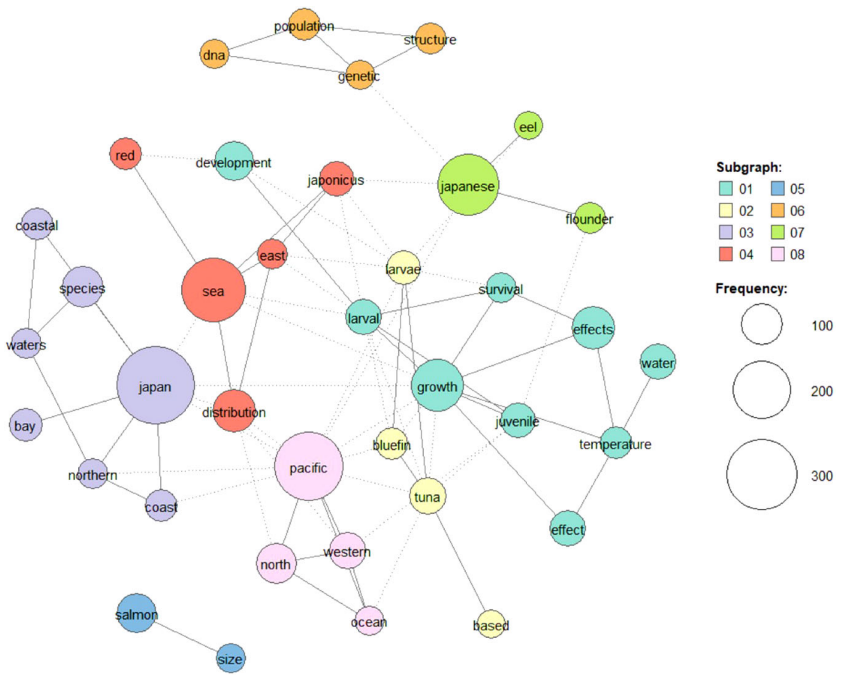

FIGURE 1
Co-occurrence network of the most frequent keywords among the published papers by JFRA researchers from 2004–2018.

TABLE 1 Titled subgraphs and included words in the Co-occurrence network of the most frequent keywords among the published papers by JFRA researchers during 2004 and 2018 (Figure 1).

S	Words included	Title of Subgraph
1	growth	larval development
1	effects	
1	survival	
1	larval	
1	juvenile	
1	temperature	
1	effect	
1	water	
1	development	
2	larvae	pacific bluefin tuna
2	bluefin	
2	tuna	
2	based	
3	japan	coastal environment
3	species	
3	coastal	
3	waters	
3	northern	
3	coast	
3	bay	
4	sea	biological studies of fishery species and algae
4	distribution	
4	east	
4	japonics	
4	red	
5	salmon	salmonid fishes
5	size	
6	population	population genetic structure analysis
6	structure	
6	dna	
6	genetic	
7	japanese	Japanese eel and flounder
7	eel	
7	flounder	
8	pacific	North Western pacific ocean
8	western	

(Continued)

TABLE 1 Continued

S	Words included	Title of Subgraph
8	north	
8	ocean	

decade (1989–1998, 1999–2008, and 2009–2018), also the first, second and third decade of *Heisei* in the Japanese traditional era, had a unique representation of keywords.

From 1989–1998, words indicating direct and concrete relevance to fisheries primary production, such as "stable," "income," "tonnes," "effort," "increase," "decrease," and "business management," appeared. During this period, the basic law for fisheries promotion was the "Coastal Fisheries Promotion Act (Act No. 165 of 1963)," and the main policy of this law was to "Improve the productivity and livelihood standards of fishers." Many of the keywords shown around this group in Figure 2 are closely related to this policy.

From 1999–2008, there appeared the words such as "measures," "plan," "making," "circulate," "expansion," "business," "safety," "system," "aiming," "distribution," "development," and "basic." During this period, the basic law for fisheries promotion was changed to the "Fisheries Basic Act" (2001). The policies of this law were "Sound development of Fishery" and "Securing a stable supply of marine products." Under this law, the targets of promotion included not only the conventional fishing industry but also the processing and distribution industries. In addition, the formulation of the "Basic Plan for Fisheries" (2002) was obligatory, and this plan has been revised every five years since 2002. In addition, based

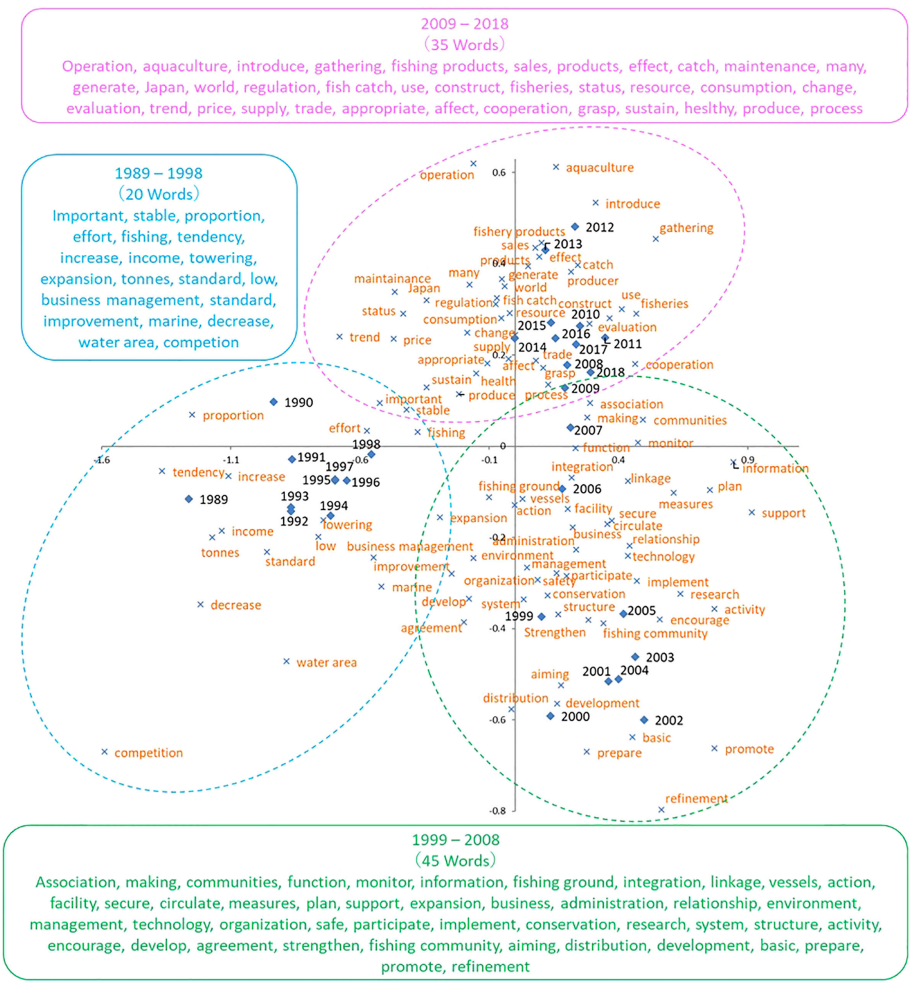

FIGURE 2
Results of correspondence analysis using frequently mentioned words in fisheries policy white papers (1989–2018).

on the "Marine Biological Resource Conservation and Management Act Act No. 77 of 1996)" that came into effect in 1996, resource management systems such as TAC (total allowable catch) system were widely spread and implemented during this period.

Lastly, from 2009–2018, words indicating wider areas of "fisheries systems" from production to consumption, including international trade dynamics, such as "fishery products," "sales," "world," "consumption," "use," "supply," and "price." The symbolic events during this period were the long-term reconstruction measures against disasters that occurred at that time, such as the Great East Japan Earthquake in 2011, and the formulation of measures to prevent and adapt to the effects of environmental changes on a global scale. In recent years, the "Plan of measures to Cope with Global Warming" (2017) and "Plan for Adaptation to the Impacts of Climate Change" (2018) have been formulated. In 2018, the Fishery Act (1949) was amended with the aim of more effective and scientific management and evaluation of resources and restoration of fishing grounds. Further emphasis has been placed on the promotion of sustainable aquaculture. With the progress of globalization, exports of marine products have also been promoted.

Here it was indicated that Japanese fisheries policy priority has shifted over the last three decades from relatively simple, straightforward keywords focusing on primary fisheries production (from 1989–1998) to more complex, multidimensional fisheries systems including marine resources, producers, processors, consumers in/outside of the country (from 2009–2018), with the mediated time which formulated a series of measures and plannings related to fisheries (from 1999–2008). These results implies that domestic policies have been developed in response to the progress of globalization over the past three decades. The amount of marine product imported from overseas and exported from Japan has increased. The supply chain has expanded, and marine products have become global commodities traded across borders. In addition, rising attention has been paid to such issues as international fisheries management and climate change. Thus over the past three decades, stakeholders of the fisheries industry, such as producers, processors, and consumers, increased inter dependence not only on domestic marine resources and products, but also on the quantity and quality of marine products produced overseas as well as the trends of the international fisheries policies Figure 2.

3.4 Public interest in fisheries

Figure 3. shows the co-occurrence network of the public inquiry log. Given that there appeared six species' names (hereinafter "six significant species") in the network, i.e., eel, Pacific saury, salmon, tuna, squid, and snow crab, the following analysis focuses on those. At first, it was found that the inquiries about these six significant species occupied nearly 40% (38.35%) of all the inquiries (Table A2). Further, Figure 3 shows the monthly trends of inquiries of these species, which indicates that eel (Jun and Jul), Pacific saury (Aug and Sep) and snow crab (Nov) had strong tendencies of increasing interest in specific months (season); salmon (May, Sept, and Oct) and tuna (May, Jun, and Aug) had weak tendencies; and squid did not have that tendency. To note, we used general classification, such as tuna and squid, which included individual species such as bluefin tuna and Japanese common squid, for example, during the coding process. However, snow crab was an exception because we did not find any other significant data including the term "crab;" therefore, we used "snow crab" during coding.

Detailed analysis is presented below.

Eel data showed higher interest levels in the early summer (June and July). This period matched with "*Doyo-no-Ushi-no-hi (土用の丑の日)*", a day with a tradition of eating broiled eel. The "Doyo," in the oriental natural philosophy, means the transitional period of the seasons, and people consume nutritional eel to enhance nourishment to prepare for the next season. Japanese people started favoring this custom in the Edo era (17-19c) until now. In addition, full-lifecycle aquaculture seed production of this symbolic species has gained strong public attention over many years. However, the natural resource status and ecology of eel have received much less attention. These results suggest that the two major factors, i.e., "seasonality" closely linked to culture and "significant new research," strongly influenced the public attention growth.

Pacific saury data also showed higher interest levels in specific months (August and September), matching the optimal fishing period and the continuous observation of this resource around the high seas. In addition, since 2015, inquiries regarding the reasons for poor catches have been repeated, including the ones about Illegal, Unreported and Unregulated fishing by non-Japanese vessels. Furthermore, it was observed that the focus of inquiries had shifted from asking about the cause of catch decline to the more general nature of ecology and resource status after several years. It is also worth noting that the public inquired about the cause regardless of whether the catch status was good or bad once attention was paid to poor catches at the time, indicated by the growing number of inquiries about good catches of the species in 2018.

Salmon data showed growing attention during the poor catch during the autumns of 2016–2018, the season when Japanese people think it is best to eat salmon. Furthermore, it was observed that the focus of inquiries had shifted from asking about the cause of catch decline to the more general nature of ecology and resource status. Additionally, IUU was included in the inquiry contents (in 2017), similar to Pacific saury data.

Tuna data showed slightly increasing attention in the summer season (May, June, and August). It appeared to be influenced by significant new research such as the establishment of cultured tuna research centers and big projects, irregular catch (for instance, in Hokkaido, the most northern prefecture where tuna is not normally caught), its relation to increasing water temperature, and the occurrence of fish disease in aquariums.

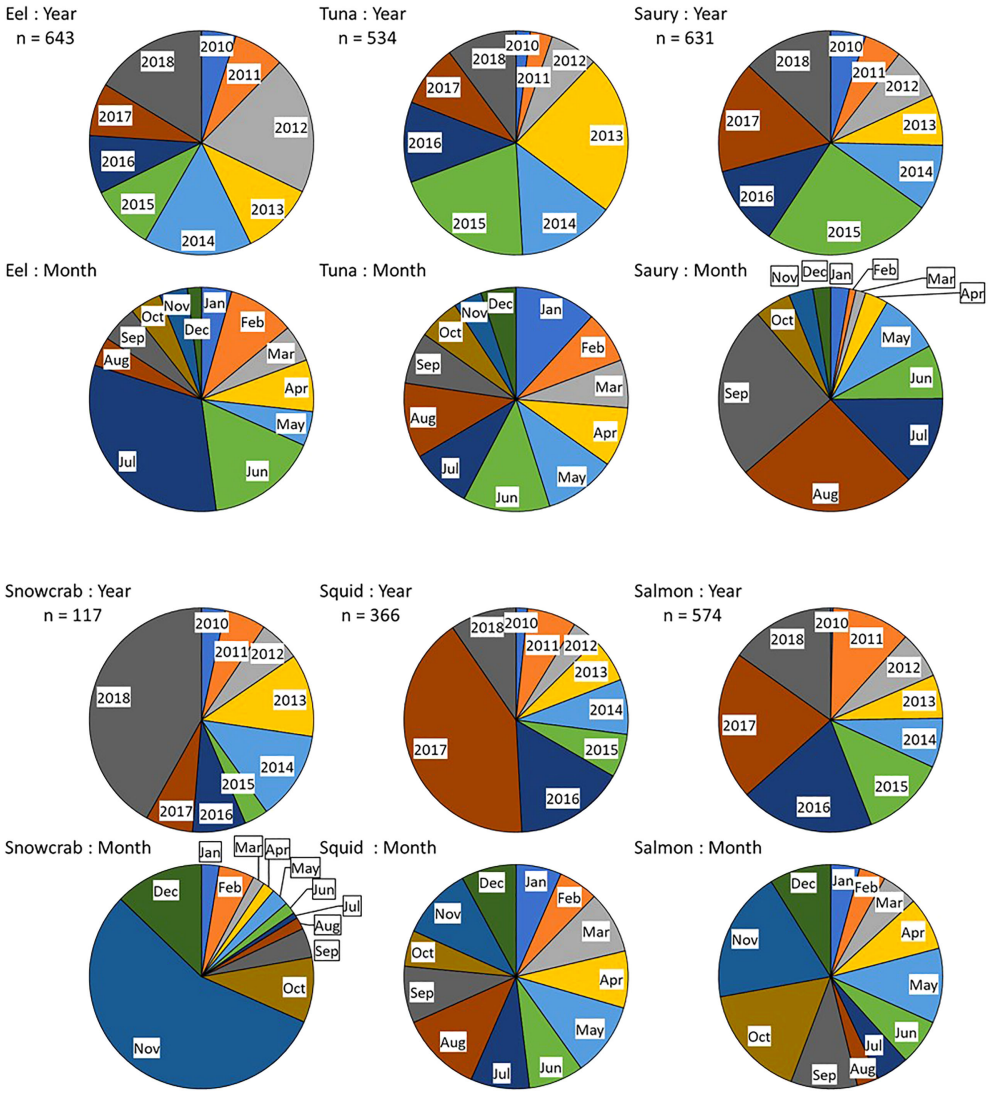

FIGURE 3
Yearly and monthly trend of the public inquiries for six significant species. (To note, all the six significant species showed the data from 2010 because there were no relevant inquiry records during 2004 and 2009 on the internal DB. This is partly due to the very small record during this period (see Tables A3, A4 for the full data).

Public attention to tuna seems to have increased since 2013, which could be because of the growing international tension on resource decline such as the IUCN's registration of the bluefin tuna as a category VU (Vulnerable).

Squid data showed growing attention during the poor catches in 2016 and 2017. The focus of inquiries also shifted from asking about the cause of catch decline to more general nature of ecology and resource status.

Snow crab data showed higher interest levels in specific months (November), matching the beginning of fishing period. Furthermore, it showed a sudden increase in attention in November 2018. This is in response to the results of a stock assessment that predicted that the stock would decline by nearly half in three years (Yuji Ueda, personal communication).

The above results indicate the following points. As shown by the results of eel, Pacific saury, and salmon, seasonality seems to have a considerable influence on the rising trend of public attention. This may be because these species are very symbolic in the Japanese cultural context with a strong connection with seafood consumption customs in the country. However, the repeated, similar inquiries on these species over the years could imply that the public is only interested in "whether the resource is/will be available for us or not." However, it is not certain how much mass media communication (as shown by Figure A2, most

of the inquiries were came from the mass media and occasionally from individual citizens and organizations) contributes to the building of public literacy of fishery sciences. Hence, our results indicated that public fisheries/ocean literacy seems limited, despite the rich history of seafood consumption, cultural bond with fisheries, and historically inherently close relationship among fisheries science, policy, and resource users described in Section 3.1.

4 Discussion and conclusion

4.1 Summary of the results

Analysis of the history of JFRA revealed that it was originally a part of fisheries policy, and both science and policy were inherently based on fisheries practices in the real world. However, the last 15 years' performance of JFRA has heavily focused on bio-physical dimensions of fisheries science, such as "Stock assessment," "Fisheries Oceanography," and "Stock enhancement." The analysis of policy papers indicated that the priority of Japanese fisheries policy has shifted from relatively simple, straightforward keywords focusing on primary fisheries production to more complex, multidimensional fisheries systems, including marine resources, producers, processors, and consumers in/outside of the country over the last three decades. The analysis of public interest around fisheries indicated that public fisheries/ocean literacy seems limited, and the public strongly cares about resource availability, but without enough attention to marine ecology, stock status, fishery sector participants, and fishing communities despite the rich history of seafood consumption, cultural tie with fisheries, and inherently close relationships among fisheries science, policy, and resource users since long ago. Here we can see that fisheries policy appears to recognize the importance of a holistic approach to the marine ecosystem, fisheries production, and supply chain, including consumption, even though this paper has not investigated how much fisheries policy indeed "practices" such holistic approach, since we only dealt with the three most important policy documents and white paper in the work. On the other hand, JFRA sciences seem to concentrate more on the biological and environmental dimensions of the marine ecosystem, and the public interest seems to be focused on the consumption availability of popular species, respectively. Close connection among the central Government, JFRA, and resource users (fishers), well represented by a rich history of co-management, is a symbolic characteristic of Japanese fisheries which has generated social and ecological benefits for a long time (Makino and Matsuda, 2005; Makino, 2011; Yagi, 2020). At the same time, our results showed that JFRA sciences and public attention are contemporary pursuing different interests.

4.2 What we should improve on the interface among science, policy, and public interest around fisheries for ocean sustainability

In this section we discuss how science, policy, and public interest around fisheries can get closer, and work together to co-produce a sustainable future in the time of UNDOS. As mentioned earlier, there used to be a close connection among the central Government, JFRA, and resource users (fishers), well represented by a rich history of co-management for a long time (Makino and Matsuda, 2005; Makino, 2011; Yagi, 2020). However, the governmental policy, JFRA science, and public interest contemporary pursuing different interests. We suspect that this 'disconnection' between direct fisheries stakeholders and wider indirect stakeholders (general public) was caused from the rapid post-war demographic movement (from rural to urban areas, from primary to secondary and third industry), which resulted in the considerable knowledge and interest gap. Considering this, one important area that JFRA (and any other marine/fisheries research organizations) needs is to reconnect science and public interest through strengthening human dimension works and science communication. Even though our analysis of the last 15 years' performance of JFRA did not detect it, there are a few transdisciplinary works among JFRA multidisciplinary scientists, Government (particularly Fisheries Agency), and resource users (fishers) Makino et al., 2017; (Watari et al., 2017; Hirose et al., 2017). It usually involves prefectural fisheries institutions as key counterparts which can function as knowledge translators (Sato et al., 2018). Given this history, it should be invaluable for ocean sustainability if JFRA could function as a 'reconnector' between direct and wider indirect stakeholders (general public). For the public side, it is essential to enhance the attention on the marine ecosystem, fisheries production, and supply chain, including the people (and communities), which also fits the international argument for ocean literacy building (Kopke et al., 2019; Kelly et al., 2021). In contrast, low public capacity for ocean/fisheries science could drive the policies in the appropriate direction. In this sense, literacy development among wider stakeholders is one of the most emergent works to be addressed. In this regard, effective partnership with mass medias should be also critically important for science organizations to establish. Additionally, as recent study suggests, strategic brand establishment can make greater credibility of the information that research organization publish (Blythe and Cvitanovic, 2020). To accelerate the ocean literacy building, this kind of innovative science communication approach is surely needed, particularly when considering the context of super-aging societies including Japan, where literacy building only among young generation should not be sufficient to transform the society before the collapse of marine ecosystem. One important, and concrete implication from this study related to this literacy-building aspect is

that the public showed a tendency to shift the attention from simply asking about the cause of catch decline to more general nature of ecology and resource status fishery stock dynamism, marine ecosystems, and fishing communities/cultures after a series of declining catch trends of multiple species. We suggest that science and policy organizations consider utilizing this tendency for effective ocean literacy building, also by collaborating with mass medias. Symbolic species in Japanese context, such as eel, salmon, tuna, and crab, should help this effective public engagement. Furthermore, this shift of the attention found in this work could imply the potential that public might be more interested in the marine ecology, resource status and fishing communities from the beginning, rather than just being anxious about availability of popular seafoods. In this sense, there should be the need for science/policy organizations and mass medias to know the "real" information needs of the public more properly. It will bring science, policy, and public interest around fisheries get closer, which could also help exploring culturally suitable strategies of sustainability interventions. Some works recently pointed out the socio-cultural diversities that can hinder environmental sustainability interventions from being successfully mainstreamed in certain societies, such as the case of Marine Stewardship Council ecolabel in Japan (Swartz et al., 2017; Blandon and Ishihara, 2020). It should be one of the emergent duties of fisheries/ocean sustainability scientists to consider localized, culturally suitable strategies to implement sustainability interventions rather than simply applying the 'foreign (and Western, in most times)' approaches.

4.3 Future works

To our knowledge this is the first study on the fisheries science, policy, and public interface through empirical data. Particularly, the text content analysis on public inquiry log at JFRA enabled us to find some valuable implications about how research organizations could improve ocean literacy of citizens, such as effective partnership with mass medias. The inquiry log data, at the same time, had certain limitations with regard to the representation. Firstly, it was mainly occupied by mass medias but not the individual citizens (Figure A2). We used this data by trusting that mass media should represent the general public's interests, however, it is important for the future works to examine the findings of this paper through random sampling survey for citizens to gain potentially more unbiased results. Secondly, the data was those accumulated at JFRA, but not including the inquiries for other ocean/fisheries research organizations such as local, national governmental bodies, universities, and private research companies. Hence, the future works also needs to examine the findings of this paper by investigating more holistic target data by collaborating with other research organizations outside of JFRA.

We used Japan as a sample, which also adds significance of this paper, as it is the first study in this topic from non-Western countries. It is valuable to include the context-specific uniqueness of the country's interface to forge localized and, thus, hopefully, more effective ocean sustainability building in Japan and globally. Cvitanovic et al. (2015) synthesized four models of effective knowledge exchange between scientists and policymakers: co-production, embedding, knowledge broker, and boundary organization. Among those, "embedding" scientists in decision-making agencies (or per se) can function as one of the effective knowledge exchange models. This has been used by Japanese national science organizations, including JFRA and governmental divisions, which are "in charge of" those science organizations. However, we suspect that this could have positive and negative effects: timely and effective knowledge exchange as a positive; however, neutral, objective scientific performance could be sacrificed. In countries like Japan with a history of "inherently close" science-policy-practice described by this work, careful attention must be paid to retain the balance between embeddedness and independence at the science-policy interface. As the most recent significant event of fisheries science-policy-public interface which is happening in Japan after the Fisheries Act reform (see also 3.1), stakeholder involvement process has been promoted for the more effective fisheries management (Sugimoto et al., 2020; Ganseforth, 2021; Hanzawa et al., 2021). This process can also make the interface of three facets better, and the future works need to monitor and analyze the process so that it could function in a meaningful way.

This work is among the first case studies of "non-Western" countries on this topic, and Japan is known for its long history of coastal fishing and seafood consumption (Makino and Matsuda, 2005; Makino, 2011; Yagi, 2020). In such places with such history, we presume that the fisheries science-policy interface should still increase the complexity. It is implied that colonization, war, and other historical (and often political) events could greatly influence the shape of the fisheries science-policy interface (See Makino and Matsuda, 2005; Makino (2011) for detailed documentation on how post-war colonization of Japan by the United States (GHQ) influenced the institutional framing of fishery policies). This study will encourage other empirical studies from countries with various social/cultural/political backgrounds to enrich the perspective of fisheries science-policy interface studies globally. Particularly for considering ocean sustainability, including fisheries, we suggest having more studies from Asia, which have extensive seafood production and consumption culture, as well as conflicts and challenges.

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

AS designed, collected data, analyzed data on 3.1, 2, 4 and wrote the manuscript. HT collected, analyzed data and wrote the manuscript on 3.3 part. TS contributed to the discussion part from the perspective of aquaculture and fisheries technology research fields. SW contributed to the discussion part from the perspective of stock assessment research field, and offered guidance as a senior author when needed. 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/fmars.2022.1098647/full#supplementary-material

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