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Stepwise Analysis of the Ecosystem-based Fisheries Assessement and Management Approach Linked to the DPSIR Framework

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DPSIR framework와 연계한 생태계 기반 어업평가 및 관리 방법의 단계별 분석

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Abstract

In this study, the traditional DPSIR (Driver, Pressure, State, Impact, Response) framework was extended to use for the analysis of the assessment and management of fisheries resources, by adding measures(M) as another new element to be DPSIRM. Marine fisheries are usually carried out to obtain foods from the seas and oceans, which are the main driver(D) of the framework. The fishing operations affect the marine ecosystems as pressures(P). Such pressure will cause the state(S) of ecosystem component, such as changes in abundance and distribution of fish, and deterioration of the marine environment. These changes will have impacts(I) in the productivity and economy of fisheries. In response(R) to these impacts, various scientific management advice will be proposed, which will be developed into measures (M), such as policy-making or legislation. This DPSIRM framework was used to analyze and evaluate the ecosystem-based fisheries assessment and management (EBFAM) approach. An EBFAM approach with a link to the DPSIRM framework makes it easy to identify each element of DPSIRM that corresponds to a step in the EBFAM process. Thus, in the event of uncertainty in the fisheries assessment and management system, based on a feedback system that uses the framework as a complementary and synergistic approach. The EBFAM approach with links to the DPSIRM framework can ensure that each step of the assessment and management process is in the science domain or policy domain, which can enhance and strengthen the Science-Policy Interface(SCI) highlighted by the UN's Regular Processes. In addition, the new framework, which adds the measures(M) element, can identify the location of the science or policy domain more clearly because the response(R) element of the DPSIR framework represents both areas together.

Key words : DPSIR framework, EBFAM, Fisheries, Assessment, Management

Ⅰ. Introduction

As a new paradigm in the field of ocean and fisheries in the 21st century, all countries on the planet are actively promoting ecosystem-based fisheries assessment and management methods (EBFAM) (UN, 2021). The goal of ecosystem-based management is to maintain the sustainability and biodiversity of species within ecosystems, to achieve socioeconomic benefits without damaging

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habitats, and to sustainably utilize adequate amounts of fishery resources. Ecosystem-based management is mandated by the United Nations Law of the Sea and the FAO's Code of Conduct for Responsible Fisheries. In addition, several international organizations are calling for the replacement of traditional fisheries resource management with ecosystem-based management (Kang and Zhang, 2023).

Driver-Pressure-State-Impact-Response (DPSIR) was developed by the European Economic Agency (EEA) and is an extension of the Pressure-State-Response (PSR) concept developed by the Organization for Economic Coorperation and Development (OECD).

DPSIR is understood to be based on the causal relationship that drivers of society generate pressure in human society, pressure affects the state, states cause responses, and reactions again affect each of the other four factors (Lee et al., 2010). DPSIR has been criticized for assuming only a single-way function, despite its value in environmental assessment and management (Carr et al., 2007). As such, according to researchers, the concept of DPSIR has not yet been clearly established, so it is confusing to understand. And the definition of 'driver' is not yet clearly established.

Meanwhile, the United Nations has used the DPSIR method in the Second World Ocean Assessment of the United Nations Regular Process (UNRP), and as it is used in many studies, there is a need to adopt it in fisheries resource research. To this end, the DPSIR framework must first be accurately understood, and based on this, scientific and efficient methods should be developed that can be used to evaluate and manage fisheries resources.

Therefore, the purpose of this study is to analyze the assessment and management method of fishery resources in conjunction with the DPSIR framework of fisheries resources, and to provide basic information that can be applied in practice to the assessment and management of ecosystem-based fishery resources. In this study, we analyzed the DPSIR framework and reviewed the United Nations World Ocean Assessment using it. Next, the structure of utilizing fisheries resources in conjunction with the DPSIR framework was presented. Finally, the ecosystem-based fishery assessment and management method of fishery resources was introduced, and this method was analyzed step by step in conjunction with the DPSIR framework.

Ⅱ. Materials and Methods

This study used the United Nations World Ocean Assessment, ecosystem-based fisheries assessment and management methods, and DPSIR-related literature for analysis.

The materials used in this study were: The Second World Ocean Assessment (2021), World Ocean Assessment Overview (2016), 100 Years of Fisheries Resources Research in Korea and the Future (2020), Carr et al. (2007), Dzoga et al. (2020), Gari et al. (2014), Kim and Min (2017), and Lan et al. (2014). Lee et al. (2010), OECD (1993), and Rapport and Friend (1979).

In this study, first, the history, definition, characteristics, and utilization methods of DPSIR were examined and analyzed. Second, we developed a structure for the use of fisheries resources in conjunction with the DPSIR framework, and third, we analyzed ecosystem-based fishery assessment and management methods of fishery resources. Finally, for the analysis of the ecosystem-based fishery assessment and management method (EBFAM) in conjunction with the DPSIR framework, the components of DPSIR-EBFAM were identified, the elements were matched step by step, and the association between them was analyzed.

Ⅲ. Results

1. DPSIR Framework Analysis

Statistics Authority of Canada developed Stress-Response (SR) in 1979 to investigate environmental issues (Rapport and Friend, 1979). Based on this, the Pressure-State-Response (PSR) was developed by the OECD (1993) to evaluate environmental performance, and the EEA elaborated it in 1995 to develop the Driver-Pressure-State-Impact-Response (DPSIR). Since then, DPSIR has been widely used among researchers and policymakers (Carr et al., 2007).

DPSIR is one of the widely applied methods worldwide in assessment, resolution and communication related to environmental issues. This method provides a link between the causes of environmental problems and their pressures, their associated impacts, and the countermeasures needed to address and manage specific environmental problems and challenges (Gari et al., 2014).

DPSIR is an adaptive management tool for analyzing environmental problems by establishing causal relationships between anthropogenic activities and environmental and socio-economic outcomes. These adaptive management tools were integrated with the natural and social sciences and considered human activities as an essential part of the ecosystem (Zaldivar et al., 2008).

As a tool for environmental management, DPSIR has often been applied by natural scientists and has proven useful in identifying drivers of environmental degradation, related institutions, and policy responses (Lan et al., 2014).

Elliott et al.(2017) developed DAPSI(W)R(M) for ocean management by improving DPSIR to include elements that capture complex marine environmental interactions between ecological structures and functions, physicochemical processes, and socioeconomic systems. As the basic human needs, driver (D) requires activity (A) that leads to pressure (P). Pressure shifts the state (S) on natural systems, resulting in human welfare (W) and ecosystem disturbance effects (I). Next, a response (R) is required against them, and thus measure (M) is taken.

On the other hand, Kim and Min (2017) reported that among DPSIR elements, driver and pressure elements are important determinants of state and impact elements, and that DPSIR models are often used to select elements to assess the sustainability of environmental ecosystems.

The actions between the drivers, pressures, states, impacts, and response that make up the DPSIR framework do not proceed sequentially in only one direction. Response factors can directly affect state and impacts, while drivers and pressure factors can directly change impacts and response factors (Kim and Min, 2017). State factors can not only directly change the impact factor, but also directly change the response. Dzoga et al. (2020) also reported that between two factors, such as drivers and pressure, can be considered as a flexible bidirectional perspective.

The second World Ocean Assessment (UN, 2021), which recently published the United Nations Regular Process (UNRP), assessed the world's oceans with the following modified DPSIR framework: In this assessment, the entire ocean was evaluated rather than by sector, such as fisheries, aquaculture, shipping, and seabed development, with drivers (D) being evaluated separately as Part 3, state (S) as Part 4, pressure (P) and impact (I) as Part 5, and response (R) as Part 6. As a result, there was no room for consideration of the relationship between the elements D, P, S, I, and R, and no specific response (R) was proposed for each sector of the ocean.

The existing DPSIR framework, used as a tool for environmental management, has been used primarily by natural scientists to formulate policy responses. However, this framework is not sufficient for assessing and managing fisheries resources. This is because the existing DPSIR framework refers to the preparation of scientific response (R) to solve the problems caused by the impacts (I) on the state (S) of the environment caused by the pressure (P) of human activities. In fact, for the management of fisheries resources, it is essential to take measures that lead to policy or legislation at the government level from the response (R) proposed by scientists.

Therefore, in this study, we tried to adopt this new DPSIRM structure because DPSIRM with M (Measures) added to the existing DPSIR can be a suitable structure for the assessment and management of fisheries resources. This structure excludes activity (A) and human welfare (W) from the DAPSI(W)R(M) structure (Elliott et al., 2017).

In other words, for the assessment and management of fisheries resources, by adding M to the existing DPSIR, DPSIRM is a suitable method for the assessment and management of fishery resources. DPSIRM refers to the enactment of laws and policy decisions at the national level as a measure to solve the problem (M) when the pressure (P) caused by human activity is imposed due to the human demand for food (D) for living and the response (R) is proposed to solve the problem caused by the impact on the state (S) of the environment (I) by this pressure.

2. Structure of utilization of fisheries resources in conjunction with DPSIR framework

<Table 1> shows the DPSIRM structure adopted in this study related to the use of fisheries resources by factor. Drivers include social, economic, socio-cultural human activity that increase pressure on the oceans, including population growth, coastal development, and increased personal consumption, such as the pursuit of food security, economic profits, and the desire for recreation (<Table 1>).

Pressure is the pressure on marine ecosystems such as fisheries resources and habitats due to human activities, that is, pressure on the natural environment, including fishing, fishery pollution, and climate change. Multiple pressures interact cumulatively in a way that amplifies the expected effect from each pressure (<Table 1>).

'State' means status and trend. It is a situation and trend that appears as a result of the pressure placed on marine ecosystems such as fisheries resources and habitats by human activities. These include changes in the amount of fisheries resources, biodiversity and habitats (<Table 1>).

'Impact' is a change in state as results of a shock caused by human activity. These include reduced production due to excessive fishing, reduced income for fishermen, and deteriorating fishery ecosystem health (<Table 1>). 'Response' is a scientific response to conserve fishery resources and the fisheries. These mainly include the allocation of catch quotas, the establishment of fish

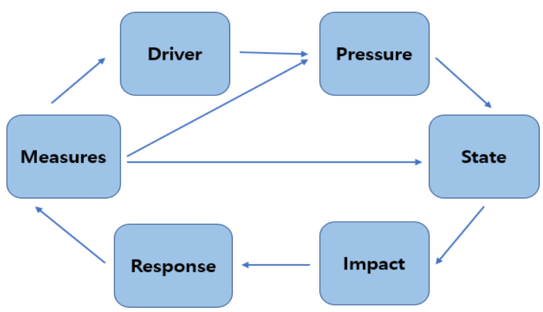
<Table 1> DPSIR framework for fisheries

Driver (Human needs)	-Food security -Resource use for profit demands of industry -Recreational demands
Pressure (Human activities)	-Capture fisheries -Habitat degradation -Climate change
State (Status and Trend)	-Fish abundance/biomass -Biodiversity -Altered marine habitats
Impact (On Services)	-Decrease in fish catch -Fishery Ecosystem health -Decrease in fishers' income
Response (Management advice)	-Catch quota setting -Fish size limit -Closed area/season -Releasing larvae and juveniles
Measures (Policy-making or Legislation)	-Fisheries Management Act -Fisheries Resource Management Basic Plan -Fish Rebuilding Program

size limit, prohibited fishing area and fishing season, and releasing fish larvae and juuvenes (<Table 1>). 'Measures' refers to the establishment of national policies or, where important, the enactment of laws and regulations on the scientific response methods proposed in the previous steps (responses), such as the prohibition of illegal fishing, and the protection of habitats and ecosystems, as well as the allocation of fishing quotas, the allocation of catch quotas, the establishment of fish size limit, prohibited fishing area and fishing season in order to preserve fishery resources and their fisheries (<Table 1>).

The DPSIRM adopted in this study shows the relationship between each element as an effective structure for assessing and managing the sustainability of fisheries resources and their fisheries [Fig. 1].

As shown in [Fig. 1], each driver (D), pressure (P), state (S), influence (I), response (R), and measures (M) cyclically affects the elements of the next step. However, the 'measures (M)' also affects the pressure (P) and the state (S). In effect, measures (M) can indirectly operate to recover state (S) by limiting pressure (P), but also measures (M) can take direct action to mitigate state (S) (i.e., releasing larvae and juveniles, cleaning wastes of fishing grounds). And the measures (M) again creates a new driver (D). For example, the United Nations Sustainable Development Goals (SDGs), which regulate maritime activities resulting from a scientific response (R) to deteriorating ocean conditions (S), become measures (M), which in turn acts as a new driver (D).



[Fig. 1] The DPSIRM causal assessment framework for describing the relationship between human activities and the environment, and the typical interdependence of the fishing and fishery management.

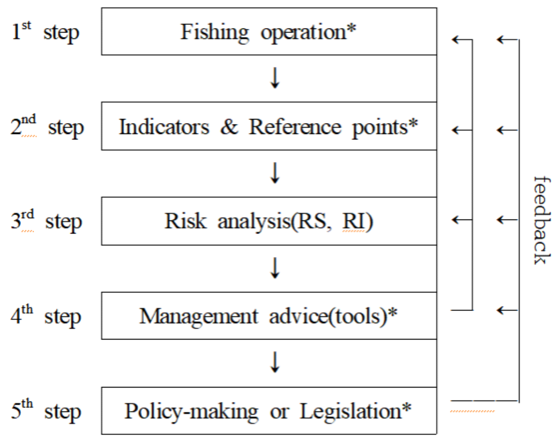
3. Ecosystem-based fisheries assessment and management method

Ecosystem-based fisheries assessment and management (EBFAM) is mandated by the United Nations Law of the Sea and FAO. Other international organizations have also mentioned the necessity for the shift to ecosystem-based management (Kang and Zhang, 2023). In particular, ecosystem-based fisheries assessment and management methods are proposed as a new paradigm in the 2030 Sustainable Development Goals (SDGs), which leaders of more than 160 countries called the "Post-2015 Agenda" in 2016 (Kang and Zhang, 2017; Zhang and Kang, 2018).

Traditionally, fisheries resources have been managed only to maintain the sustainability of the target species. Fisheries resource management policies and projects should be carried out in a situation where the positive and negative impacts on marine ecosystems can be predicted in advance. Therefore, for efficient fishery management, it is necessary to assess at the ecosystem level, including socio-economic feasibility analysis as well as ecological analysis of fishery resources, and establish a marine ecosystem-based fishery assessment system to derive accurate assessment results.

The ecosystem-based fisheries assessment method (EBFA) (Zhang et al., 2009), known as a practical method for ecosystem-based resource assessment and management, is a system that evaluates resources by setting resource management goals and objective-specific indicators, and suggests management measures based on the evaluated results (Zhang et al., 2010). [Fig. 2] shows the steps and procedure of the ecosystem-based fisheries assessment and management approach, by adding management (M) component to the ecosystem-based fisheries assessment (EBFA).

First, in the first phase, a general review of the fisheries in the target ecosystem is carried out. At this stage, the type, method, fishing gear and method and target species of the fishery must be accurately identified. The next step is to set up the indicators for each goal and the reference points for each indicator. There are two reference points: a target reference point and a limit reference point. In step 3, the reference points are used to estimate the risk score for each indicator and obtain a risk index from the risk level, including risk indexes for target species, fishery, and ecosystem. Step 4 is to propose scientific management tools to mitigate risk. In this process, if necessary, it will be fed back from step 1 to step 3 and go through the verification process. In fact, steps 1 through 4 fall under the Ecosystem-Based Fisheries Assessment (EBFA).



* : denotes steps that the involvement of stakeholders, in particular, fishermen is required.

[Fig. 2] Steps and procedure of the ecosystem-based fisheries assessment and management approach.

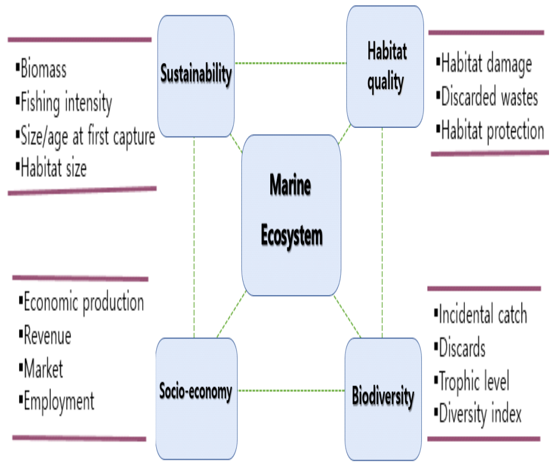
Finally, in step 5, the scientific management plan proposed in step 4 is adopted as a policy, or legislation for some important management matters. Even at this stage, if necessary, steps 1 to 4 can be fed back and confirmed.

In the assessment and management of fisheries resources in consideration of ecosystems, all four factors must be taken into account, including the maintenance of biodiversity, the environmental status of habitats, and socioeconomic benefits, as well as the maintenance of the sustainability of the target resources. Therefore, the objectives set for ecosystem-based resource management are, as shown in [Fig. 3], first, sustainability, second, biodiversity, third, habitat conservation, and fourth, socioeconomic benefits.

Indicators of sustainability include resource-related characteristics such as biomass, fishing intensity, size or age at first capture, and habitat size, as well as community structure, reproductive potential, and productivity. Indicators of biodiversity include bycatch and discards, trophic level, and diversity index. Habitat indicators include habitat degradation for each species, habitat conservation and recovery, and so on. Finally, indicators of socio-economic benefits include income, profitability, and employment ([Fig. 3]).

The ecosystem-based fishery assessment system consists of quantitative, semi-quantitative and qualitative analysis according to data/information on the target species and ecosystem environment. In these two-stage assessment systems, the objectives are kept the same, and the indicators for each goal are set taking into account the characteristics of the resources to sustain the fishery and the characteristics of the communities and ecosystems to which they belong. The two-level ecosystem-based resource assessment system is due to differences in available data and information about the ecosystem, fisheries, and species being assessed (Zhang et al., 2020).

Indicators for the four objectives of sustainability, biodiversity, habitat and socioeconomic benefits can be selected according to the characteristics and data of the species being assessed. Sustainability can include indicators to assess resource sustainability as well as indicators to assess impacts on fisheries and ecosystems, such as illegal fishing management. In the assessment of biodiversity, habitat and socioeconomic benefits, indicators are also selected according to the characteristics and data of the species to be assessed.



[Fig. 3] Management objectives and major indicators of ecosystem-based EBFAM approach (Modified from Zhang et al., 2010).

<Table 2> shows indicators and reference points for the sustainability in step 2 of the ecosystem-based fisheries assessment and management system in [Fig. 2].

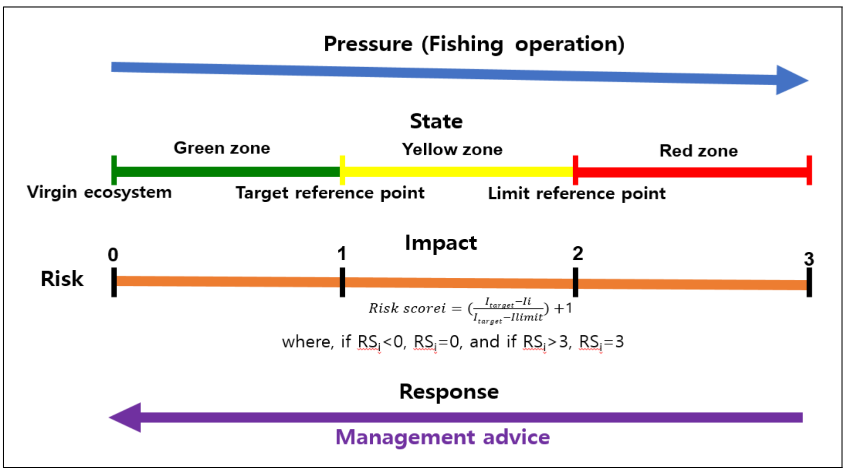
On the other hand, in the ecosystem-based fishery assessment and management system, the role of reference points for each indicator, the step 3 process of assessing the risk of this indicator, and the step 4 process of establishing a management plan using the assessment results are as shown in [Fig. 4]. [Fig. 4] also shows the pressure, state, impact, and response corresponding to these processes. <Table 3> is an example of the management plan established through this process, showing strategies and tactics for achieving sustainability goals.

<Table 2> Example of Indicators and reference points for sustainability of the ecosystem-based fisheries assessment approach(Modified from Zhang et al., 2011)

Indicator	Reference points	
	Target	Limit
Biomass(B)	B_{MSY}	1/2 B_{MSY}
Fishing mortality(F)	F_{MSY}	2 F_{MSY}
Habitat size(H)	H_{target}	H_{LIMIT}
Mean trophic level in catch(TL)	TL=3.43	TL=3.26

<Table 3> Example of Indicators Strategies and tactics for sustainability of the ecosystem-based fisheries assessment approach(Modified from Zhang et al., 2011)

Management objective	Strategies	Tactics
sustainability	Increasing biomass	TAC adjustment and/or reduction
	Reducing fishing capacity	Reducing number of licences or permits or limiting number of trips and/or fishing days
	Maintaining community structure	Development new fishing gears and methods



[Fig. 4] Relationships among reference points, risks and management advice of the ecosystem-based fisheries assessment approach(Modified from Zhang et al., 2011).

4. Analysis of ecosystem-based fishery assessment and management in conjunction with the DPSIRM framework

In the ecosystem-based assessment and management system, which is a new paradigm in the 21st century in the marine fisheries field, there is a five-step process: in-depth analysis of the fishery in the ecosystem to be assessed, setting indicators for each target and reference points for each indicator, estimating the risk index using the risk score and risk, presenting management tools to mitigate risks, and making policy decisions or enacting laws.

<Table 4> Relationship between elements of DPSIRM framework and steps of EBFAM approach

	step	Driver	Pressure	State		Impact	Response	Measures
				Status	Trend			
EBFAM		Food security						
	1		Fishing*					
	2a			Indicators*				
	2b				Reference points*			
	3					Risk score/index		
	4						Management advice*	
	5							Policy-making or legislation*
			←――――― Science domain ――――――――→					←Policy domain→

*: denotes steps that the involvement of skateholders, in particular, fishermen is required.

<Table 4> is the result of applying the items of the five steps of the ecosystem-based assessment and management system to the six elements of DPSIRM. First, the driver in the management of fisheries resources is to obtain food from the ocean. In order to obtain this food, human activity of fishing puts pressure on the marine ecosystem ([Fig. 1]).

In other words, it affects the sustainability of marine ecosystems (fishery resources and their fisheries), biodiversity, habitat, and socio-economic status. The state of this marine ecosystem can be expressed as status and trend as indicators and reference points for each indicator, respectively. The impact of human activity on marine ecosystems can be determined by the risk score for these indicators and the risk index calculated from them. Response is a variety of management tools to mitigate the risk level and the risk index calculated from them, and the enactment of laws and regulations or the establishment of policies for them correspond to measures. As shown in < Table 4>, elements of pressure, state, impact, and response are in the domain of science, and measures can be seen in the policy domain.

Ⅳ. Discussion

The analysis method of the ecosystem-based fishery assessment and management system linked to the DPSIRM framework has been shown to have several advantages. First, it is easy to identify where the step-by-step assessment and management process of EBFAM for the six elements of DPSIRM corresponds to the position of DPSIRM(<Table 4>). Therefore, when uncertainties occur in the fishery assessment and management system, it can be seen as a complementary and synergistic method that can be efficiently promoted by reaffirming the assessment stage or management stage of fishery resources by the feedback of the DPSIRM framework in [Fig. 1].

Second, The analysis method of the ecosystem-based fishery assessment and management system linked to the DPSIRM framework can easily determine whether each step of the step-by-step assessment and management process corresponds to the scientific analysis domain or the policy domain, as shown in Table 4. Therefore, it also has the function of strengthening the Science-Policy Interface, which has recently been actively promoted by the UN to strengthen capacity.

Third, the ecosystem-based fishery assessment and management, a new paradigm, is a participatory fishery management method that requires fishermen's participation in the process of being carried out ([Fig. 2], [Fig. 4]). As shown in [Fig. 2], in the assessment process, the weight of the indicators is determined by utilizing the experience and knowledge of fishermen. In addition, management plans are prepared and proposed based on fishermen's views on the risk of indicators and various alternatives to mitigate the respective risk indexes calculated from them, and fishermen's participation in their legislative processes and policy formulation is required. As such, the ecosystem-based fishery assessment and management method is a co-management approach that can utilize the experience and knowledge of fishermen. Just as EBFAM shows the stages of fisherman participation, [Fig. 4] shows the elements that require fisherman’s participation in the DPSIRM framework.

Fourth, in the DPSIR structure, the response (R) includes two components: the presentation of scientific management tools and the formulation of policies and legislation. Therefore, it is difficult to distinguish between the scientific domain and the policy domain based on response (R) alone. In this study, the DPSIRM structure with M can be linked to science by developing scientific management tools corresponding to responses (R) into policy formulation or legislation corresponding to measures (M). In the United Nations World Ocean Assessment, D, P, S, I, and R are evaluated separately for the entire ocean, and the results of the scientific ocean assessment are not effectively used in the formulation of ocean policy. In this study, using the assessment and management system of the fisheries sector, which is one of the marine sectors, as an example, M can be added to the DPSIR structure to establish policies or enact laws, and the connection between each element D, P, S, I, R, and M can be clearly understood.

Therefore, in the future marine assessment, it is expected that each element of D-P-S-I-R-M will be linked and the causal relationship between each element can be considered by marine sector. This method will be applicable not only to fisheries and aquaculture, but also to the assessment of other sectors such as shipping and seabed resource development. Since the EBFAM method includes socio-economic aspects pursued by UNRP as one of its goals, as shown in [Fig. 3], and this method is recommended in the United Nations World Oceanographic Assessment (2021) as an applicable method for assessing the cumulative impact of marine ecosystems (United Nations, 2021), the EBFAM method in conjunction with the DPSIRM framework is expected to be used in various fields in the future.

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