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Exploring Ballast Water Management in Taiwan Using the PSR Conceptual Model Based on Stakeholders' Perspectives

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Abstract: Accidental introduction of nonindigenous aquatic species (NIAS) is usually mediated by shipping through ballast water. Ballast water management plans are being developed and implemented around the world to prevent the spread of NIAS. However, for marine environmental management, incorporating stakeholders' perceptions into designing and formulating management plans is key to achieving successful implementation. This study used qualitative interviews and grounded theory to induce the influencing factors and conceptual model of stakeholders' perceptions on ballast water management (BWM) issues. The interplay of the pressure–state–response conceptual model based on grounded theory was established to elaborate on stakeholders' perceptions. The study results indicated that local ballast water management required comprehensive port state control (PSC) and technical competency development. Second, an international commercial port can be used as a demonstration area to demonstrate the effectiveness and the potential benefits of BWM implementation due to its potential to link with international networks. Moreover, legislation, surveying/monitoring, institutional capacity and outreach/education are the four fundamentals to marine bio-invasion management. Initiating ballast water management measures as part of port environmental management aims to enhance marine pollution management capacity, especially in the field of marine bio-invasion management.

Keywords: grounded theory; stakeholder; port management; ballast water; pressure-state-response



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1. Introduction

The services provided by the ocean have direct economic relevance to industries such as fisheries, aquaculture, offshore oil and gas, shipping, and tourism, among which shipping plays an important role in international trade [1]. However, the accidental introduction of nonindigenous aquatic species (NIAS) is usually caused by shipping through ballast water, sediments, or hull biofouling [2–5]. Commercial expansion, globalization of trade, and expanding fleet sizes inadvertently contributed to the spread of NIAS in the oceans [6]. It is estimated that the total turnover of ballast water by all merchant ships is approximately 30 million tons per day in the global oceans [7]. Currently, marine pollution from ballast water has been recognized as one of the four major threats to the ocean [8,9].

The United Nations Environment Programme (UNEP) and International Maritime Organization (IMO) play a leading and dominant role in preventing NIAS introductions under The Convention on Biological Diversity (CBD) and The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM). The CBD calls for action on the prevention, introduction, and mitigation of impacts of NIAS, while the IMO regulates ballast water by requiring all ships to implement a ballast water management plan. Therefore, a complete legal framework of international instruments for the prevention of NIAS invasion include conventions, international practices, and soft

law, which contribute to international cooperation in the field [10,11]. Ballast water management (BWM) regulations attempt to reduce the risk of invasive species and associated negative impacts [12]. As of April 2022, 89 states had ratified the BWMC, accounting for approximately 91.20% of the gross tonnage of the world's merchant fleet [13]. In addition, some countries directly developed or modified domestic legal provisions for ballast water control, thus forming an integrated management system [14].

Currently, most previous studies on ballast water management focus on ship technology, treatment systems, economics, law, and environmental impact [12,15,16]. Some studies have established risk assessment models on vessels' ballast water [17–20]. Ren found that most studies only used the opinions of ships' stakeholders as the weighting indicators to select ballast water treatment systems [21]. Kim et al. indicated that studies on interviewing shipping companies contributed a clearer understanding of shipping companies' plans for response to BWMC and provided implications for their management strategies [22]. Obviously, studies on stakeholders' perceptions and attitudes toward BWM are still limited and just for ship's stakeholders like as ship owner and operators. However, diverse stakeholder participation is key in marine environmental management, and incorporating stakeholders' perceptions to design and formulate the management plan is helpful for achieving successful implementation [23,24]. Therefore, it is crucial to understand the perceptions and attitudes of stakeholders towards ballast water management.

To explore qualitative factors and the conceptual model of stakeholders' perceptions on ballast water management issues, this study collected firsthand qualitative data by interviewing stakeholders. Subsequently, grounded theory and the pressure-state-response concept were employed to analyze interview transcripts to induce and deduce the themes related to management strategies. The propositions generated from stakeholders' perspectives will facilitate the formulation of management plans related to ballast water and invasive species.

2. Materials and Methods

2.1. Semi-Structured Interview

This study adopted a semi-structured qualitative interview to examine stakeholders' perceptions towards ballast water management. The interviewees selected were the stakeholders involved in the process of forming the ballast water management regime. Experts or representatives from marine-related academic institutions, companies related to ballast water treatment systems, an environmental nongovernmental organization (NGO), shipping companies, and governmental sectors were invited to conduct individual interviews. This study employed snowball sampling to select interviewees and was expected to interview 15–20 people. At the end of each interview, each interviewee had the option of voluntarily sharing the contact details of another person who might have been interested in the topics of this study. Researchers used these contact details for interview invitations. This technique of selecting interviewees fits with snowball sampling [25].

By observing the opinions of stakeholders at various dimensions, their views for ballast water management can be discussed. The interviews were conducted in a conversational manner to maintain openness because the underlying reasons behind these issues can be known through face-to-face interviews [26–28]. Apart from occasionally and appropriately reminding the interviewees of key points, the entire interview process was conducted in a relaxed and easy manner to encourage the interviewees to provide more personal opinions. The outline of the qualitative interview adopted in this study was designed to comprehensively examine core problems and facilitate the conversation. The questions are in four parts: (1) ballast water and its impact, (2) legislative aspects, (3) implementation aspects, and (4) social and public aspects. The interview outline and questions are listed in Table 1.

Table 1. The outline and questions for semi-structured interview.

Outline	Questions
1. Ballast water and its impact	1.1. Could you describe any case of nonindigenous species or invasive alien species or bio-pollutants that causes damage/impacts in the region? Is there any target list for unwanted aquatic organisms (such as the most unwanted 10 species)? 1.2. To what degree do you perceive the impacts of invasive species on marine ecology or society economy that are brought by ballast water of ships? 1.3. Is there any Ballast water management/measure that applies to your field/job? 1.4. Do you think that any current control efforts (D1/D2) of the bio-pollutants achieve the desired ecological effect? Will it prevent natural ecological change?
2. Legislative aspects	2.1. Are you aware of the ratification of BWM? Or foreseeing the ratification? 2.2. Are there any legislation/regulation/rule/measure/protocol implemented in the region and allow the regulatory bodies and other authorities to control the bio-pollutants? Will these be enforced for industry, ports, and navigation? 2.3. If yes, what is the authority or agency in charge of it? Do they have the necessary skills, expertise, and personnel? 2.4. If no, what are the reasons for not having one yet? Do you see the needs to develop legislation? At which level should the legal framework be? For example, EU, region, ecosystem, nation or local?
3. Implementation aspects	3.1. Do you agree that BWMS (approved facility by IMO) is a feasible way to solve the issue? Any alternative management system (AMS) other than BWMS you would suggest? 3.2. Is there sampling and analysis protocol in place? What are the role and function? 3.3. Are there financial and labor resources to achieve control? Can the monitoring and eradication, if necessary, be paid for?
4. Social/Public aspects	4.1. Does society agree that this is such a large problem that they are willing to devote the necessary resources or does society tolerate the absence of action? 4.2. Is there the political will to control these organisms? Has public and scientific opinion been communicated to politicians and policymakers?

2.2. Data Collection and Analysis

Interview questions were sent to the interviewee before the interview. The interview took about one hour, if possible. With the consent of the interviewee, the conversation was recorded, and notes were taken during the interview. The interview was conducted and documented as a verbatim transcript in Chinese. In this study, the transcripts were first analyzed based on grounded theory. Grounded theory involves the application of inductive reasoning and is largely applied to qualitative research. In the process of obtaining and analyzing data, researchers summarize abstract concepts directly through actual observation of transcripts [29]. The approach was characterized as an inductive generation of theory from systematically obtaining and analyzing the data. The transcripts of the interviews are analyzed line by line so that the emergent themes are identified. The themes are compared with each other in different situations, and the themes are the basis for the creation of a theory. The coding process is iterative, which leads to a close familiarity with the data, and it facilitates the development of substantial theoretical constructs. In grounded theory, the open coding was developed into axial coding, and finally induced into selective coding [29–31]. NVivo10, a form of computer-assisted data analysis software (CAQDAS), was used to conduct open coding. CAQDAS's main function is to organize and clarify the analysis systematically to allow for the comparison of case studies and formation of themes from the detailed transcripts. [32,33]. Subsequently, this study conducted a deductive thematic analysis that uses a predetermined framework to analyze axial and selective coding results. Ballast water management involves complicated environmental, social, and economic factors. Therefore, the predetermined framework readily reflects the key themes in qualitative analysis. The framework utilized in deductive thematic analysis was the PSR model in this study. The PSR model was originally a kind of evaluation model

for environmental quality and was gradually applied to nonenvironmental issues [34]. The P (pressure), S (state), and R (response) are considered hindrances to the implementation of projects, positive impacts on the development of projects, and reactions based on pressures, respectively [35,36]. The PSR conceptual model can be used to study inter-relations between information categories and contribute to structural discussions and analyses of qualitative data [34,37,38].

3. Results

In this study, a total of 18 respondents from Taiwan were interviewed. There were five primary groups of interviewees and at least three representatives in each group. The interviewees' attributes are outlined as follows: three representatives from shipping companies (Group S), four officers from public sectors (Group P), four representatives from vessel-related industries (Group V), three scholars from academia (Group A), and four representatives from non-governmental organization (NGO) (Group E). Quotations are verbatim, each identified with a code of a letter representing the type of stakeholder group (S: shipping companies; P: public sectors; V: vessel-related industries; A: academia; N: NGOs) and an informant number. The backgrounds and characteristics of the stakeholders are summarized in Table 2.

Table 2. Various groups of stakeholders and their background.

Group	ID	Number	Background	Group-Specific Characteristics
Shipping companies	S	3	Representatives of bulk shipping company and container shipping company	Those directly affected by ballast water management regulations
Public sectors	P	4	Officers in government agencies such as Maritime and Port Bureau, Environmental Protection Administration, International Ports Corporation, National Park Marine Headquarters	Those who have a direct impact on ballast water management, including the formulation and enforcement of relevant regulations or laws
Vessel-related industries	V	4	Representatives of shipbuilding corporation, classification society and maritime company	Those indirectly affected by ballast water management regulations
Academia	A	3	Scholars in the field of oceanography, marine biology, biochemistry, biodiversity and environment	Focus on observation and theoretical verification of the policy about NIAS and ballast water
NGOs	N	4	Secretary, founder and specialist from fishermen's association, local and international environmental protection groups	Focus on environmental and ecological protection and fishery resources

3.1. Semi-Structured Interview

3.1.1. Knowledge about Ballast Water and Its Impact

The interview was typically begun by asking interviewees about their understanding of bio-invasion and a diverse cognition of alien invasive species arose among different groups. Even within the same group, representatives had different viewpoints, for example S1 and S2: "I think fresh water ecosystems might be of some concern but not the salt water ecosystems. I don't think it's going to be a public issue. [S1]" "Ballast water management is an invisible task, and different than air pollution—at least it's visible. [S2]" Some stakeholders suspected the possibility of invasion by expressing their perception of Taiwan's high biodiversity, no serious invasion history, and a strong current in its territorial sea. "We don't have river transportation, so maybe that causes less impact on aquatic ecosystems. [S3]" "To clarify the concerns about foreign vessels discharging ballast water, Taiwan is an importer of commodities so many ships that call at the Taiwan ports are not loaded with ballast water. [V2]" However, contrary to the perceptions of S3 and V2, NIAS already exist in Taiwan. In fact, previous studies confirmed that the bryozoan *Amathia verticillata* and the molluscan *Perna viridis* exist on the coast of Taiwan, and these two species are widely considered NIAS introduced through ballast water [39,40].

Furthermore, the majority pointed out a few examples of invasions and acknowledged their economic and ecological impacts on the local environment. *“Most people don’t know this issue. The profound impacts would be on fishery. In another words, if the fishery is affected by the invasive species, the fisherman will go protest and it would become a political issue. Then things get complicated regardless of the environmental knowledge aspect of it. [P3]”* In general, there is no consensus on the risk of vessels bringing in invasive species. It was mentioned that the invasions already happened and altered the environment for decades. *“Ballast water is underwater, you can’t see it, so what is its impact? Again, I believe it already has been causing changes for decades. [A2]”* In addition, some stakeholders mentioned that NIAS introduced by religious life release may be better known than ballast water because religious life release is a traditional Buddhist event in Taiwan. Due to a lack of knowledge about ecological damage caused by NIAS, the public may mistakenly release farmed NIAS into the wild marine environment [41].

3.1.2. Legislative Perspective

Ballast water management is considered a cross-ministry issue in the public domain, and the division of authority and responsibility is a problem. Stakeholders had various views about the scope and framework of legislation, i.e., whether it should be an amendment to existing marine pollution policy/conservation/port control, a separate bill or just a convention transposed into domestic legislation. *“We must have legislation in place and amending the Marine Pollution Control Act is the most efficient way; a separate bill for ballast water control is troublesome. [N1]”*. *“When the Ministry of Transportation and Communication (MOTC) completes its competent legislation amendments and announcements, and Taiwan Environmental Protection Administration (TEPA) does their part for the Marine Pollution Control Act, the relevant legislation is about done—no need for further actions. [P1]”* *“I don’t see barriers for legislation. The problem comes from the intra-governmental coordination; the public won’t be against the bill. MOTC should just do whatever is needed, regardless of the BWMC schedule. [V1]”* Although some stakeholders could describe the division of authority and responsibility clearly, coordination on invasive species management is difficult due to the policy priorities and resource constraints of different organizations [42]. *“The competent authority for biodiversity is the Council of Agriculture, and sources management is Maritime and Ports Bureau (MPB). The BWM guidelines apply to vessels calling at the ports. We are making it too complicated by splitting the management into several tiers. We think as long as the port state control (PSC) can do their job and include it into the reporting system, that’s enough. [P4]”* However, some stakeholders proposed that the new agency, Taiwan Ocean Affairs Council, could be the savior for all marine issues. *“Overlapping of agency jurisdictions is a problem in Taiwan and if we can identify and define the problem, we can plan a better framework to coordinate. [A2]”*

The stakeholders indicated the difficulty in ballast water regulation enforcement and said that Taiwan should implement practices consistent with international standards. Some stakeholders have observed pressure from the global maritime industry and increasing numbers of ratifying countries pushing Taiwan to act on the issue. *“I think all the regulation of human behaviors is positive. First, we should act on it. Second, we should follow the global standard. If you don’t link up with the world, the downside will be more than just ecological loss. [A2]”* However, the lack of regional collaboration experience and international participation weakens the confidence in effective domestic legislation in Taiwan. Additionally, the lack of opportunity for dialogue with the international community and the IMO may cause non-cohesiveness between the BWMC and the domestic implementation. *“Because we are not a member of the United Nations, we have limited access to the BWMC and its resources. Also, the public sector does not have the capacity to do the research, so it is difficult to keep up with the BWMC details. MPB already set up an internal task team to study the BWMC and it should pay off in the long run. Currently MPB is under great pressure facing the international challenges, such as the VAS (voluntary IMO member state audit scheme). [P1]”* In addition, one interviewee mentioned that it seems impossible for the authority to be proactive with ecological issues like ballast water introducing marine invasive species, as the authority allocates funding

to specific projects and requires certain performances. Likewise, a lack of political will weakens its allocation of resources for this issue.

3.1.3. Implementation Perspective

In general, most interviewees agreed that a ballast water management system (BWMS) would be a feasible and effective way to deal with the issue, and many kinds of technology were mentioned including ultraviolet, filtration, electrochemistry, and ozone and sterilization. *“D1 would have good effects and D2 would create even better effects. Both could achieve the goal of the BWMC. [V1]”* *“The chief officer will schedule the ballast water exchange during the voyage route and ensure the overflow meet the standard. The port will also inspect the logbook based on trust. [V2]”* Kim et al. indicated that selecting efficient technologies and reasonable strategies to ensure compliance with international regulations are key issues [22]. However, some stakeholders expressed concerns about the potential pollution generated by the active substances and excessive energy from the treatment process and questioned the trade-off between the desired outcomes and the pollution produced. *“The control measures D1/D2 can mitigate the species transfer problem but can't cut it off completely. [S2]”* *“It takes energy and chemicals to treat the water, so isn't it unfriendly to the environment? Killing them all is a better way? [P2]”* *“If you use chemicals for the treatment and discharge them into the port, it becomes another problem. [N2]”* In addition, the routes of ships also affect the operation feasibility of ballast water exchange: If the route is too short, there is not enough time to complete the exchange required in D1. Ship experts suggested that alternatives other than D1/D2, such as the technical design of ships, could avoid ballast water problems.

As all ships need to comply with the BWMC, the industry is quite accepting about it. Since the BWMC was adopted in 2004, interviewees agreed that it is a matter of time and cost for the maritime industry to adopt it. Ship owners and vessel-related sectors emphasize that their principle is to comply with minimum cost. Standard wise, it would be the manufacturers' technology and promotion to ship owners. It is notable that the shipping industry is so international that they already apply global standards, and therefore they do not pressure or coerce the Taiwan government with regard to legislation and enforcement; instead, they asked for more transparent information about the policy. *“The government should have more dialogues with shipping companies. There are many things that can be done, not necessarily the legislation. For example, one big issue of preparation is the human resource arrangement—who can do the work, in-house or contractor and their assignment. The government can set up a website to update the progress for environmental groups and the shipping industry. [A1]”* *“Our government declared that we would comply with any UN convention voluntarily. Compliance would need an implementation plan, otherwise the declaration is nothing. [S2]”*

The trend of increasing environmental demands poses additional cost to the industry, and like many environmental regulations, the economy and politics dominate the timing of environmental regulation execution [43]. For enforcement per se, stakeholders perceived sampling and testing as major barriers and critical steps, including the cost, financing, accuracy, and job assignment. *“Sampling and testing is more controversial and the regulation does not specify the penalty for incompliance. [N2]”* *“Oil and air pollution control is easier to enforce than ballast water control, because oil and air pollution are visible. Ballast water requires sampling and testing to examine the compliance. Also, once an oil spill occurs, the media reports it, but the effects of ballast water take a long time to observe. [V1]”*

The domestic resources and capacity for implementing BWM are limited. *“Bio-pollution needs long-term monitoring to validate the effectiveness of the control measures and there should be enough data to convince the public and politicians to regulate bio-pollution. If the public officers don't have enough data, they don't see it as a problem. [S2]”* *“We spent time and money regulating the vessels, but the resulting impacts on the environment were not followed and monitored. The authorities did not want to exceed their jurisdiction and just did their own part without connecting with others. The gap got bigger and bigger. [A3]”* To summarize, BWM is a non-mainstream area for research due to its cross-disciplinary nature (shipping and environmental science), and marine ecosystem

data were not well-established. Moreover, it is not a livelihood issue and lacks public interest. Additionally, the manufacturers are most international brands, and the shipyards just procured the systems to install. As a result, there is a lack of industry knowledge for technical solution consultations by the public sector.

3.1.4. Social/Public Perspective

In general, the stakeholders viewed that the public is not aware of ballast water issues, believing that the lack of marine awareness leads to negligence in marine policy. Some stakeholders support the government doing more to address this issue. *“Communicating the invasive species impacts with the biodiversity issue to the public is necessary, for example, if we don’t prevent it, the ocean will be unpleasant and affect the fisheries. The issue of ballast water itself is hard to understand. [P2]”* *“To gain public support, you need to tell them that if you don’t act now, your children will not be able to swim in the sea because it’s full of bacteria and you will get sick, and so on. [S2]”* Therefore, education programs that deliver active, accurate and attractive science communication with a focus on biodiversity and biological invasions in marine ecosystems need to be developed, and new media technology should be utilized as well [10].

It is interesting to see that some stakeholders thought environmental groups would be aware of ballast water issues; however, the two environmental NGO representatives I interviewed did not know much about the issue. *“It’s hard for people to feel ballast water impacts unless it’s related to public health and creates problems. If that happens, the media would report it and heat up the issue. [N2]”* Ballast water was not an agenda for NGOs because there were other issues more relevant to them, such as sustainable fisheries, biodiversity mainstreaming, and government reorganization for ocean affairs. It was pointed out that it would take high-profile figures or experts to raise and introduce the issue via the media given that there is currently no party with a strong interest in advocating this issue, either scientists or NGOs. *“If the subject is related to our interests, it’s easier to communicate. For the ocean, if the fishing stock is not affected, nobody really cares about the ecological changes to it. [S2]”* *“If the issue wants to get high profile, it will need the media to report it. Otherwise, the government could just close the door and do it on their own way. [P3]”* Many suggested combining BWB with biodiversity as a propaganda theme; this could help to effectively communicate concerns.

In brief, the reasons that BWB receives little attention from the public are: (1) there has been no marine invasive species case in Taiwan’s territorial sea and coast that caused serious ecological impacts or economic loss; (2) marine invasive species are almost invisible, and it takes a long time to detect the environmental changes; (3) for environmental issues, the terrestrial ecosystem is more prominent than the marine ecosystem.

3.2. Themes Found Based on Ground Theory

3.2.1. Axial Coding Induced by Open Coding

During the process of open coding, some keywords were extracted from the sentences and paragraphs of transcripts by understanding the concepts from the interviewees. This process resulted in 95 codes. Subsequently, the open coding results were induced and grouped into 13 themes for the axial coding. Table 3 lists brief descriptions of each of the 13 themes from the axial coding, and highlights of some themes are described in this section.

Table 3. The axial codes and their descriptions.

Axial Code	Description
Overcomplicated division of authority and responsibility	- Several competent authorities and their assignments associated with BWM are mentioned. The attitude of buck passing exists among the agencies due to the complexity of handling the BWM issue.
Domestic regulations and legislation	- The current legislation works to harmonize BWM and the potential development. There is consensus on legislation or amendments.
International participation	- Agencies' participation in global environmental issues
Taiwan proposition and circumstances	- Taiwan's perceived interaction and its circumstances related to global ballast water management
Insufficient implementation capacity	- The required capability and the deficient areas of domestic capacity to implement ballast water management
Consciousness about NIAS	- Understanding about NIAS and the invasion impacts varies among stakeholders, which implies the importance of public communication about science and local environmental issues.
Perception about biodiversity	- Ballast water management could be considered as being within the scope of biodiversity.
Marine awareness	- Consensus on the ecological knowledge of the public and the importance of enhancing public science education
Marine survey and monitoring	- Marine survey and monitoring plan plays an important role for biodiversity management, and it requires improved planning to fit the policy goal of detecting invasions in coastal waters.
Ballast water management system	- There are a few ballast water treatment technologies that meet the performance standard (D2) and approval by government administration on the market. It is inevitable that these must be installed to operate on the vessels for compliance and the ship owners must cover the cost.
Less public attention	- BWM is not getting much attention and political will, so it is not a heated issue for public discussion.
IMO-BWM implementation	- Perceptions about the approaches of the BWM Convention, including its effectiveness, standards, and procedures
Industrial burden	- The environmental challenges that maritime industry has faced and their roles for implementing BWM

Stakeholders identified the Environmental Protection Administration (EPA), Council of Agriculture (COA), PSC, Maritime and Ports Bureau (MPB), Ministry of Transportation and Communication (MOTC), Coast Guard, and Ocean Affairs Council (OAC) as the associated competent authorities on marine pollution, and buck passing was often mentioned by stakeholders. Therefore, the clear division of authority and responsibility among the agencies is considered important and could contribute to a successful management plan. Similarly, on the theme of domestic regulations and legislation, the current legislation works to harmonize BWM at both agency and Executive Yuan (the highest administrative organ) level, as well as the potential developments (no new bill) brought out by the public sector's officers during the interview. Moreover, public sector's officers emphasized their roles within the theme of international participation, and many agreed that connecting to a global standard is essential. Therefore, international participation seems inevitable for handling a global environmental issue like ballast water. Based on no exception for IMO convention, independence from the BWMC schedule, global pressure facilitating BWM implementation, and no local manufacturers of BWM systems, Taiwan's perceived interaction with international society and its circumstances support its propositions on ballast water.

When interviewees expressed their opinions about bio-invasion and how they thought about the social/public perspectives on the issue, it was concluded that (1) the understanding about NIAS and the invasion impacts varies among stakeholders, (2) there is consensus on the deficient marine awareness in the society, and (3) ballast water management falls under the issue of biodiversity, which is getting into the mainstream agenda. Furthermore, almost every interviewee showed concern and demand for long-term marine surveying and monitoring, which could bring scientific evidence and effective management measures

to the issue. Additionally, when the topic arose of the implementation of the ballast water management convention, the stakeholders identified the required capability and the deficient areas of domestic capacity for such implementation. Furthermore, the vessel-related sector and shipping companies are familiar with the current treatment technologies and the necessary works for compliance, such as the additional workload for crew and space on board for installation. In general, the ship owner is the regulatory object, and they well acknowledged the environmental trends in maritime industry.

3.2.2. Selective Coding

To comprehend the issue, eight themes of selective coding were induced from axial coding. Stakeholders' perceptions of BWM were analyzed and examined for how they could fit into the marine pollution management scope. The themes of selective and axial coding are shown in Figure 1. First, the research suggested that outreach and education to the public about marine biodiversity is imperative and that it should be based on valid research and survey data from the local affected and concerned marine areas. Second, to facilitate the implementation of any associated programs or projects, institutional capacity building and legislation are the two key instruments to drive the effectiveness. Therefore, four fundamental elements, "institutional capacity", "legislation", "outreach/education" and "survey/monitoring" were proposed the priorities for addressing marine bio-invasion management. Furthermore, if we focus on controlling ballast water as the vector of NIAS transfer, "technology" and "port state control (PSC)" are the main aspects to be developed in the management plan. More specifically, a "demonstration area" with proper managerial scope is needed for a pilot project and to present the outcomes and benefits of implementation, as well as being an interface to link with the "international network".

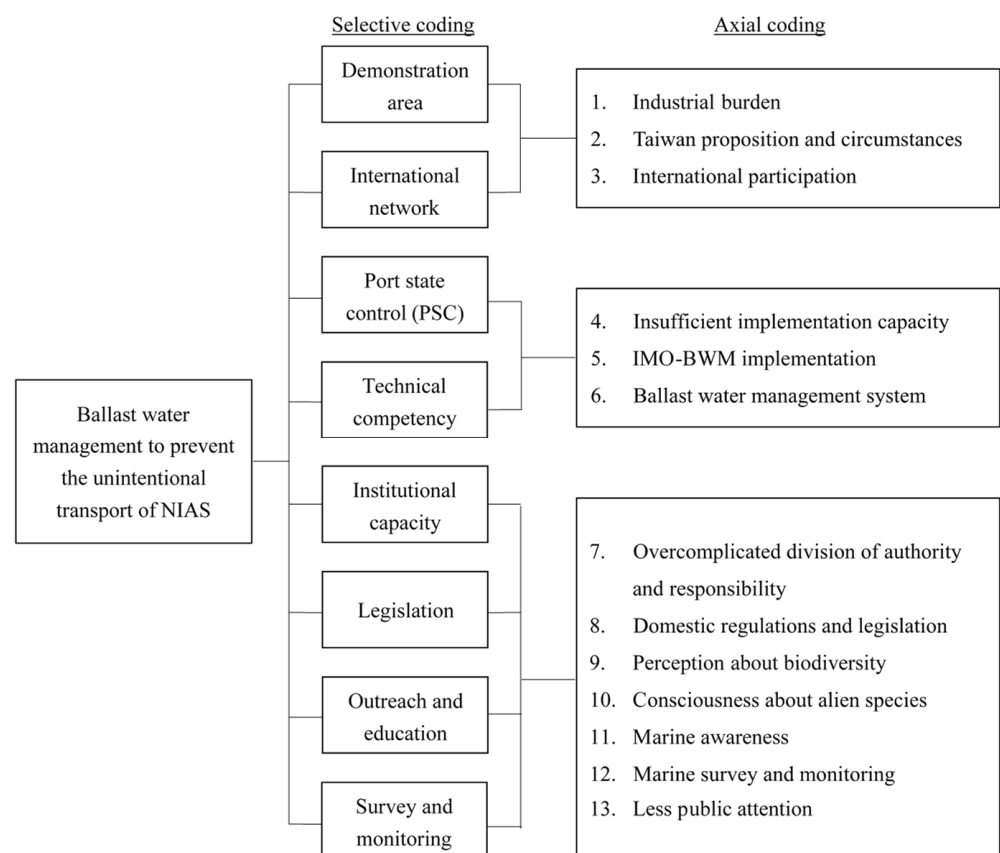


Figure 1. Themes regarding the stakeholders' perceptions of BWM.

4. Discussion

The PSR conceptual model is proposed by the deductive thematic analysis of coding results. The themes of axial coding were categorized as the pressure and state of the model. The themes of selective coding were summarized into port environmental management, ballast water management, and marine bio-invasion management as the response in the model. The interplay of the PSR conceptual model based on stakeholders' perspectives is presented in Figure 2.

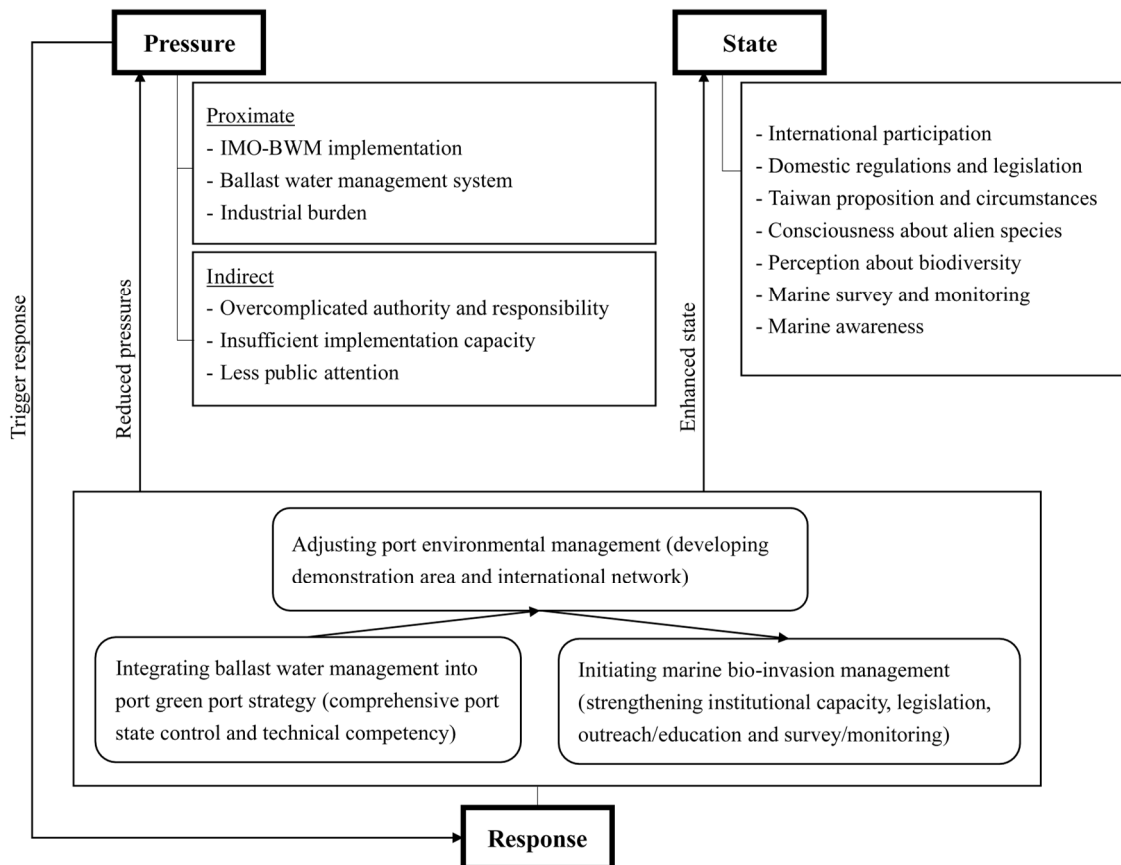


Figure 2. Interplay of the pressure–state–response conceptual model based on grounded theory.

4.1. Pressure and State

According to Zhang’s proposition [35], we considered pressure factors as a hindrance to BWM and state factors as positive impacts on BWM. IMO-BWM implementation, ballast water management systems, and industrial burden are proximate pressure factors for the shipping industry and the public sector. More specifically, BWMC compels ships to have a BWTS installed onboard that can meet the specific size-class discharge standards, which puts pressure on the shipping industry’s operations and the government’s regulatory efforts. Karahalios indicated that the additional costs generated by BWMC implementation may be a significant burden for ship operators, especially those with old ships [44]. In addition, the stakeholders mentioned indirect pressure factors such as overcomplicated authority and responsibility, insufficient implementation capacity, and less public attention. BWM is not receiving much attention and is not a heated issue for the public, which led to no government resources for the development of BWM. Without the support of more administrative resources from the government, the industry’s response to BWM will be hindered. It was noted that the competent authority’s policy of incentives and discounts might support shipping companies to respond to BWM [22].

Taiwan’s shipping and port industries are well developed. For example, the Port of Kaohsiung in Taiwan ranked 14th among the world’s container ports in 2018 [45]. Therefore,

although Taiwan is not an IMO member or a contracting party to the BWMC, the competent authorities still participated in environmental affairs in the international arena through NGOs and implemented BWMC through several administrative orders to link to global standards. Liu et al. also indicated that all shipping companies in Taiwan had ballast water record books on their ships, which showed the industry's positive response to BWM [46]. These actions represent state factors such as international participation, domestic regulations and legislation, and Taiwan proposition and circumstances, which generated positive impacts on ballast water management. Furthermore, stakeholders also believed that if the state factors such as marine survey and monitoring, consciousness about NIAS and biodiversity, and marine awareness are enhanced, they will facilitate the implementation of ballast water management. More specifically, the scientific information from marine surveying and monitoring can be used for science communication and as the foundation of outreach programs for marine awareness to raise consciousness about NIAS and biodiversity. Previous studies also found that the improvement of ocean literacy contributed to awareness of invasive species and acceptance of ballast water treatment [47,48].

4.2. Response

The response factors are considered reactions, plans, or decisions based on the pressure factors [35,36]. In the model, by initiating the ballast water management measures as part of port environmental management, the aim is to enhance the marine pollution management capacity, especially in the field of marine bio-invasion management.

Ports serve as the border control of vessels with regard to a ballast water management plan. Moreover, they are the sites where marine invasive species arrive and depart with vessels, and their expansion could possibly affect the local marine ecosystems and freshwater ecosystems adjacent to the ports [49,50]. As international commercial ports have been a place for trade, they are featured for their commercial value and characterized as industrial and working grounds rather than leisure or environmentally sensitive spots. Their habitat quality and biological resources were often neglected. Green port has been an important strategy for Taiwan commercial port operation and management [51]. Due to its dedication to green port status, the capability of self-financing, and the potential to link with international networks, an international commercial port is the most relevant coastal area for demonstrating the effectiveness and the potential benefits of BWM implementation. Therefore, connecting port ecosystem research as part of a ballast water management program to the green port program is novel and could channel the resources from maritime industry to marine conservation in ports and surrounding coastal areas.

Moreover, with the establishment of the Ocean Affairs Council (OAC) and its Ocean Conservation Administration (OCA) in 2018, the vague division of authority and responsibility that stakeholders were concerned about regarding regulating marine pollution has become clear [52]. For an issue like ballast water discharge categorized as marine pollution jeopardizing marine biodiversity, the OAC and OCA could implement the control measures and curb the potential damage through existing administrative orders and amendments. Therefore, it is not necessary to have a single law to regulate marine bio-invasions or transpose from the BWMC. Furthermore, during the bio-invasion process that might be caused by ballast water, the linkage of invasion control phases and different authorities is essential. The expertise and job assignment towards marine bio-invasion need to be communicated and complementary among different authorities.

However, unlike EU member states that establish surveillance systems, being obliged to provide notification about new incursions and to immediately apply eradication when feasible [43], Taiwan is not obligated to do so under any international instruments. Therefore, to demonstrate the effectiveness of pollution control and port management related to NIAS, a biological baseline survey every decade is recommended as a monitoring program. The monitoring program should include a detailed account of the status (size, distribution, and population) of species and possibly create an accessible database to integrate into the global network [53,54]. Additionally, in Taiwan, public perception about the threats

posed by invasive species is notably diverse. The media (TV, newspaper, social media, YouTube), especially the mainstream media, is key for building the awareness about marine bio-invasions. The aforementioned port biological survey information could be made available and accessible in a way to communicate the port as a habitat to the public and promote biodiversity as a port environmental agenda. Moreover, different approaches might be helpful for outreach to different populations such as students, fishermen, divers, and local tourism businesses on the coast. An effective public participation mechanism should be actively established, such as citizen scientists to report any new or unusual species found in marine waters, and utilize fishermen's knowledge as a complementary tool to coastal and port surveys [55,56].

5. Conclusions

The interview data and the PSR conceptual model provided important insights into the feasibility and sustainability of local ballast water management implementation. The results revealed that incorporating ballast water management into port environmental management could be a novel way to address the marine bio-invasion issue. For ballast water management, the port authority (MPB) should regulate the vessels as the prevention measures based on the BWMC. Furthermore, the port management institution should also take responsibility to survey and monitor the species distribution in order to detect any bio-invasion just like monitoring environmental quality or oil spill. When there is pollution, the port authority or management institution can detect and trigger the contingency action according to the baseline. The launch of containment and eradication might call for more connectivity with the Ocean Conservation Administration (OCA), which is the competent authority over bio-invasion and marine conservation via the aforementioned working group. For taking the port as the pilot project, it is expected that if it could work out in the port, it could work in other coastal waters in terms of marine bio-invasion management.

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