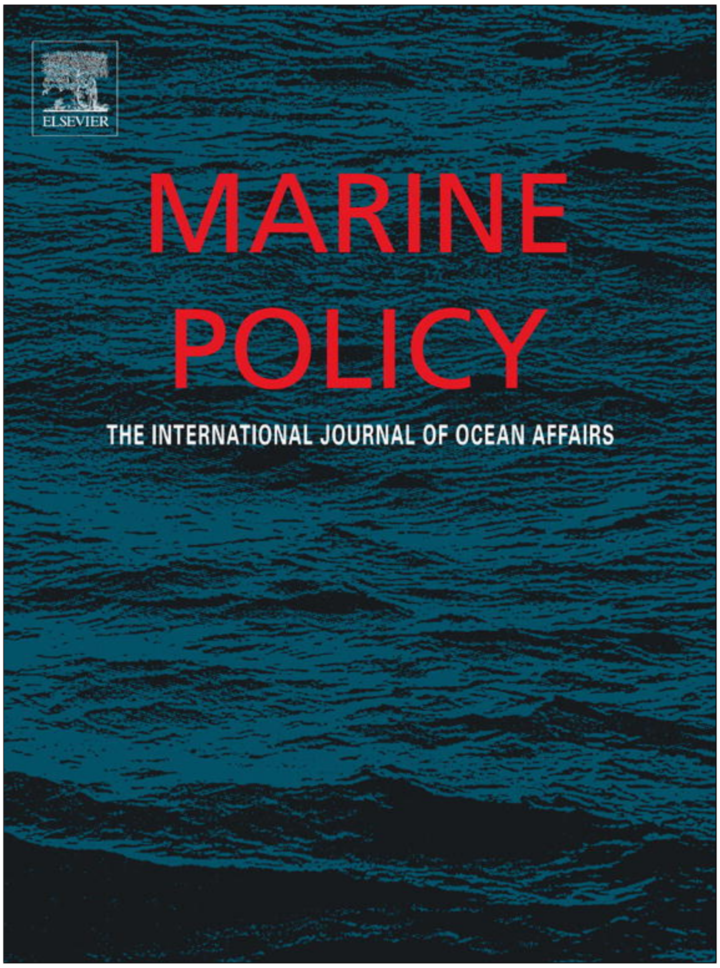
ELSEVIER
MARINE POLICY
THE INTERNATIONAL JOURNAL OF OCEAN AFFAIRS

Marine Policy 40 (2013) 34–40

Contents lists available at SciVerse ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Fill the gap: Developing management strategies to control garbage pollution from fishing vessels

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ARTICLE INFO

Article history:
Received 10 November 2012
Received in revised form
1 January 2013
Accepted 2 January 2013

Keywords:
Garbage pollution
Marine debris
Fishing vessels
MARPOL 73/78

ABSTRACT

It is widely documented that marine debris is detrimental to the marine ecological environment. While there are various sources of marine debris, that generated by ships constitutes a significant proportion. Annex V of MARPOL 73/78 is to regulate the discharge of garbage from ships; in particular, it prohibits all kinds of plastics from being discharged into ocean. However, most fishing vessels are virtually exempt from such regulations due to their low gross tonnage, below 400 t. Given the great number of fishing vessels operating around the world, it can be argued that fishing vessels are a common source of marine debris. This paper aims to propose measures that will fill the gap in international regulations in addressing the problem of vessel-source garbage pollution. An understanding of what constitutes the underlying causes leading to fishers' decision on debris disposal is needed when designing effective measures to reduce garbage pollution from ships. Thus, this paper seeks to identify factors that have the potential to influence fishers' disposal behavior and investigate the association between factors and fishers' intention of bringing garbage back to port. Major factors of a well-developed recycling practice, adequate collection facilities placed at port, fishers' positive views towards marine environments and provision of rewards are identified, which have significant implications for management strategies. Finally, the papers offers suggestions regarding future efforts focusing on debris reduction strategies to further address the problem of garbage pollution from fishing vessels.

1. Introduction

Marine debris, a global pollution problem, has long been considered as a major environmental problem in the global ocean. It refers to any manufactured or processed solid waste material (typically inert) that enters the marine environment from any source [1]. The seas in all parts of the world are littered with man-made debris, most of it plastics, which are practically indestructible [2,3]. Marine debris occurring in greater concentrations within specific regions in the North Pacific and North Atlantic regions (known as the "Garbage Patches") further demonstrates the ongoing problem of marine debris pollution [4–6].

It is widely documented that marine debris, such as plastics and derelict fishing gear, has negative impacts on many aspects, including human health, marine wildlife, marine ecological systems, biological biodiversity, beach quality, navigational safety, and fisheries economic benefits. Marine debris would cause damage to people's health (physical injuries, disease) from litter on beaches and in bathing water, including medical waste [7]. Seabirds [8], sea turtles [9–11], seals, sea lions [12–14], and whales [15] are injured or killed by ingestion and/or entanglement. Movement of derelict fishing gear across shallow reefs destroys benthic reef flora and fauna and entangles macrofauna, posing a persistent threat to coral reef systems [16]. Drift plastics serve as vectors for the introduction of alien species to new environments, causing potential loss of biodiversity [17,18]. Derelict fishing gear or plastics would damage vessel engines by entangling propellers or blocking the water intake pipe [19]. Marine debris that washed up on beaches can reduce the recreational and aesthetic value of the beach and can be dangerous to beachgoers and coastal wildlife [12]. Lost or abandoned fishing gear continues to catch (often referred to as ghost fishing) commercial species without economic benefit but with economic (and ecological) loss [7].

Most marine debris comes from land-based sources, accounting for up to 80%, which is transported via sewage/drainage systems, natural waterways, wind or human neglect [20]. The remaining comes from sea-based sources, mainly ships. As for the debris from ships, there is an institutional response at the international level to regulate its discharge. It is Annex V, Regulations for the Prevention of Pollution by Garbage from Ships of the 1973 International Convention of the Prevention of Pollution from Ships as modified by the Protocol of 1978, known as MARPOL 73/78. Annex V provides the framework for the control

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http://dx.doi.org/10.1016/j.marpol.2013.01.002

of garbage generated by vessels.[1] It prohibits the disposal into the sea of all plastics (including synthetic ropes, synthetic fishing nets, plastic garbage bags and incinerator ashes from plastic products), sets restrictions on the discharge of other ship-generated wastes and imposes stringent controls on garbage disposal within designated special areas.[2] Although Annex V applies to all ships, only ships of 400 gross tonnage (GT) and above are required to carry out a garbage management plan in accordance with the guidelines developed by the International Maritime Organization (IMO).[3] In addition, ships are provided with garbage record books (GRBs) which are used to record each discharge operation or completed incineration, including date and time, position of the ship, description of the garbage, and estimated amount incinerated or discharged.[4] This book is subject to inspection by the competent authority of a party to MARPOL 73/78 when the ship is in port.[5] By virtue of these regulations, if any entry in the GRB is deemed to be "unreasonable" by port authorities and the amount of garbage brought in by a ship is too small, the inescapable inference would be that the ship had discharged garbage in violation of Annex V. As a result, port authorities may take necessary actions against the ship according to the relevant international regulations. Specifically, to ensure compliance by ships with all applicable IMO regulatory requirements (i.e., safety, pollution control, manning and security), port authorities would exercise the power to board vessels, inspect documentation and physical conditions and where appropriate, detain vessels until the relevant deficiencies were remedied [21]. However, ships under 400 GT are not required to carry out the garbage management plan or record any discharge operation. These ships are not liable for checks by relevant authorities regarding their garbage disposal and therefore are virtually exempt from the garbage discharge restrictions.

The fishing fleet is made of up about 4.3 million vessels of which 59% are powered by engines [22]. Among the motorized fishing vessels, about 86% are less than 12 m length and less than 2% corresponds to industrial fishing vessels of more than 24 m in length, which are, by and large, greater than 100 GT. This clearly shows that most of the global fishing fleet is below 400 GT; consequently they are exempt from the international garbage disposal regulations. This loophole, coupled with the reality that detecting garbage discharge at sea in violation of Annex V is extremely difficult, means that fishing vessels are not regulated and are, essentially, free to discharge any amount of garbage at sea. In view of this gap in the control of garbage pollution from ships, it is very likely that fishing vessels simply discharge garbage at sea as convenience or necessity dictates. A previous study by Topping et al. [23] showed that a high percentage of the observed vessels (75.2%) operating along Canada's east coast threw debris into sea, when Annex V came into force.

The debris generated by a fishing vessel is small, especially when compared with that generated by other sources such as gigantic ocean-going ships and land-based waste. However, given the huge number of vessels (around 2.5 million motorized fishing vessels) operating in the world's oceans and seas, the cumulative input from fishing vessels may be considerable, especially in areas with heavy fishing activities. A survey showing that 23,900 t, accounting for 20% of total marine debris, came from fishing vessels in Korea in 2002 demonstrates that debris pollution from fishing vessels is significant [24]. In light of modern ecological expectations, failure to tackle the problem of garbage discharge arising from fishing vessels appears to conflict with the critical need to protect and preserve the marine environment. In recognition of this problem, relevant management measures should be made applicable to fishing vessels in order to minimize debris pollution caused by them.

This paper does not intend to propose amendments to Annex V or recommend new regulatory initiatives pertaining to the garbage control rules at the international level on ships under 400 GT. It does aim to develop management strategies at the national level to prevent garbage generated by fishing vessels from being discharged into sea. This reason is two-fold. One is that international regulations on marine pollution inherently involve a multitude of actors which makes revising Annex V or adopting new regulations a lengthy, arduous and politically sophisticated process. The other is that, given that most fishing vessels operate in the jurisdictional waters of their flag states (except for a limited number of distant water fishing vessels), it would be more practical to propose management strategies at the national level rather than revising international regulations.

An understanding of what constitutes the underlying causes leading to fishers' decision on debris disposal is needed when designing effective measures to reduce garbage pollution from ships. Therefore, this paper seeks to identify factors that have the potential to influence fishers' garbage disposal practices. In addition, this study also investigates the debris items generated by fishing vessels and their disposal methods. It is noted that a relevant study by Topping et al. was conducted in 1990–1991 [23]. Since then there has been very limited literature on the recent status or statistics on marine debris disposal by fishing vessels.

The paper is organized as follows. It begins by listing the methods used to examine debris types, debris disposal practices, and the factors that have the potential to influence fishers' disposal practices; these provide implications for deriving effective measures to prevent debris from being discharged into sea. An analysis of the results follows. Finally, potential management strategies are discussed and recommended as references for coastal states which intend to reduce the problem of debris pollution from fishing vessels.

2. Methods

2.1. Interview

A two-stage approach was used in this study. First, in-depth personal interviews were used to obtain information regarding the debris items,[6] debris disposal methods, and the factors that have the potential to influence fishers' disposal methods. The research used purposive sampling techniques to select interviewees based on the information provided by fishermen's associations. It was intended that fishers selected to be interviewed would be as diverse as possible, in terms of their fishing areas, fishing methods, fishing days per trip and age in a hope that the data solicited would cover a wide variety of aspects. A total of 30 fishers who are engaged in offshore fisheries participated in the interviews. Among them, 12 are engaged in gillnetting, 8 in longlining, 6 in trawling, and 4 in torchlight netting. In addition, four staff members from fishermen's associations were consulted for their understanding of debris disposal by fishers.

[1] Annex V entered into force on 31 December 1988 and as at July 31, 2012, there were 144 state parties, representing 97% of the world's tonnage, to the MARPOL Annex V.

[2] Annex V, reg. 3, 4 and 5.

[3] Annex V, reg. 9(2).

[4] Annex V, reg. 9(3).

[5] Annex V, reg. 9(5).

[6] Visual observations of fishing vessels staying in harbor were also conducted to examine the debris items, hence supplementing the interview method. These surveys included relevant debris identification and documentation.

Each interview typically lasted about 30 min and each interviewee was initially informed of the purpose of the project and reminded of possible debris items that may be generated during fishing operations. Then the interviewees were asked to recall the debris items generated during fishing operations, the ways in which these were disposed of and the factors that had the potential to influence the disposal methods.

It is noted that frequently mentioned factors generally had to do with incentives for bringing the garbage back to port, waste reception facilities at ports, recycling of household waste and personal views regarding the protection of the marine environment. For the last factor, it is interesting to note that there were two divergent perspectives. Some informants stated that they were concerned about the health of the marine environment and were more inclined to bring garbage back to port so that their fishing-dependent livelihood could be sustained. Others argued that since garbage was littered everywhere in the sea, it did not matter whether or not they discharge theirs into sea, and that garbage disposal was a very trivial matter compared to catching fish. In considering these two divergent viewpoints, an interesting dimension would be to examine whether fishers' attitudes towards the marine environment could have a behavioral impact on the discharge of garbage into sea or bringing it back to port. All the above mentioned factors, based on their attributes, were divided into categories (motive and constraint) and utilized in the next stage.

2.2. Questionnaire survey

A structured questionnaire was used in the survey. The questionnaire consisted of three parts. The first part included questions on fishers' demographic information, fishing methods, and debris disposal practices. The second part dealt with the factors that potentially encourage or hinder fishers' bringing garbage back to port. Respondents were asked to indicate their agreement level for the factors on a five-point scale, ranging from 1, strongly disagree to 5, strongly agree. The third part had only one question regarding fishers' intention of bringing garbage back to port. A binary classification was used to divide the intention into 'yes' and 'no'. The intention was viewed as an immediate antecedent of actual behavior (bringing garbage back to port). That is, an individual who expresses an intention to take action will more likely engage in the action than an individual who expresses no such intention. Previous studies have established the link between behavioral intention and behavior [25,26].

The draft of the questionnaire was revised and finalized based on feedback from two staff members of fishermen's associations and a pilot sample of 6 fishers. They were chosen to evaluate the clarity of language, the smoothness of flow of the questions, the appropriateness of the length of the questionnaire, and the time taken to answer the questions. For obvious reasons, the survey was conducted in Taiwan and some adjustments were made to cater to local circumstances.

Fishers working in vessels under 400 GT were the target population. To select the respondent samples, the survey used a two-tier sampling procedure. First, 10 of 38 fishermen's associations spreading along Taiwan's coastal areas were chosen. These 10 associations are located in the north, south, east and west of Taiwan as well as the adjacent islets and are comprised predominantly of fishers who are engaged in fishing activities. Second, a convenient sampling procedure was used to select samples from the 10 associations; the intention was to select 50 fishers from each association.[7] With the help of the associations, researchers approached fishers when they came to the association office for business or when they were in fishing harbor preparing for fishing trips or offloading catch. They were asked whether they were willing to participate in the survey. From December 2011 to May 2012, a total of 427 fishers completed the questionnaires. The respondent sample, though not a random sample of the total eligible fisher population, comprised fishers affiliated to the major associations which are located in different areas of Taiwan. The sample was 92.7% male. Over 82% of the respondents were aged 51 and over. About 58% and 29% of the respondents had a primary and a secondary educational background, respectively. 64.2% of the respondents have worked in the fishing sectors for more than 20 years and 30.4% for 11–20 years. About one third of the respondents engaged in gillnetting, 27% in longlining and 19% in trawling.

3. Results

3.1. Debris types

Fishing vessels dispose of various types of debris. The most common debris includes: plastic bottles, plastic bags, metal cans (tin or aluminum), fishing gear (consisting mainly of fishing nets and lines, buoys and ropes) and batteries.[8] Other types of debris were also sighted, but they are less frequently generated by most vessels. They include: glass, packaging bands, cardboard and Styrofoam. The debris profile is roughly similar to that recorded in the previous study by Topping et al. [23]; however, it did not record batteries. Perhaps batteries were not commonly used in fishing operations at the time when the data were collected in 1990–1991.

Among various debris types, derelict fishing gear has been a major international issue over the last 50 years with increasing levels of fishing capacity and activity in the world's oceans [27]. Many publications have focused on its sources, location, quantities, and oceanic drift pathways [4,12,28–31]. In contrast, other types of vessel-source debris or the debris problem in its entirety seem to receive scant attention, and there is a paucity of information in the available literature.

Batteries have three purposes: first, they are widely used to power flashlights, which are carried on board at all times. Second, they are used to power small flashlights which are attached to floats. Currents would cause nets or lines to drift away from where they were originally deployed at sea; by tracing the light emitting from the flashlights attached to the floats, fishers can locate their nets or lines. Third, longline vessels use many batteries in electric floats. Longline vessels use a long mainline which is suspended horizontally in the water by floats and float lines attached at regular intervals. Branched lines, which have baited hooks at their ends, are attached to the mainline at regular intervals. Since the deployed mainline could extend several kilometers at sea, electric floats are used to transmit radio signals for fishers to trace where the lines are. Typically, an electric float needs 36 batteries. A vessel with 10–20 GT, usually uses five to ten electric floats, which use up the enormous number of 180–360 batteries per fishing trip.

Plastic bottles are a ubiquitous debris item. Bottled water is carried on board for drinking and/or cooking purposes. The number of bottles generated by each vessel per trip is difficult

[7] A more "objective" stratified quota sampling procedure was first considered to be used to select the respondent samples. However, due to the lack of information regarding the number of fishers who are affiliated to the association and are also engaged in fishing activities, it was not possible to adopt this procedure.

[8] While Annex V refers garbage to be all kinds of victual, domestic and operational waste excluding fresh fish (including parts thereof), oil, noxious liquid substances, sewage and air pollutants, this study excludes victual waste due to its biologically degradable nature.

to estimate. It depends on the bottle volume, fishing days, number of fishers on board and whether portable water producing equipment is placed on board. It is estimated that for vessels engaged in a one-day trip of operation, every fisher uses three to four water bottles of water (600 ml) per day. For an overnight trip, six to seven bottles would be used. When vessels are engaged in a longer period of operation and with more fishers on board, more bottles would certainly be generated. However, it is noted that large vessels, which go further afield and stay at sea for a longer period of time (several weeks or months), are usually equipped with portable water producing machines and drinking fountains. When these facilities are installed, there may be fewer water bottles carried on board. In addition to water bottles, a limited number of beverage bottles were also sighted.

Plastic bags are commonly used to pack goods such as food, bait or other types of waste. Metal cans come from canned beverages and canned food.

3.2. Debris disposal practices

Two major debris disposal methods are employed by fishers: discharged into sea and brought back to port. In terms of environmental concerns, the latter is certainly a better method than the former and deserves to be promoted among fishers. It is noteworthy that the previous study by Topping et al. [23] recorded three disposal methods: offloaded at port, discharged into sea and incinerated at sea. Our study found that incinerated at sea was rarely used in Taiwan. This is perhaps due to safety concerns and space limitations in accommodating an incinerator on board.

It is encouraging to find that fishers did engage in some form of waste recycling. They would bring the recyclables (such as plastic bottles, batteries, metal cans, fishing nets and lines) back to port, which were then either given away or sold to local recyclers. For example, damaged fishing nets/lines made of petrochemical material (which has a good market price, reaching NTD 20 per kilogram) can fetch a good price if sold to recyclers. Therefore, if fishing gear is damaged to the extent that it cannot be repaired, fishers would not intentionally discard it, but instead bring it back to port for sale. In addition, the price of waste batteries is NTD 15 per kilogram. It is argued that the monetary incentive coupled with the recycling practice drive fishers to bring recyclable debris back to port. However, if the debris is non-recyclable (such as plastic bags and plastic packaging), fishers might just throw it into sea. This indicates a potential link between debris types and their disposal methods.

To understand how fishers dispose of each type of debris (referring to the five major types), a question on the disposal methods applied to each type of debris was asked in the survey questionnaire. It was found that more than half of the respondents reported that they brought recyclable plastic bottles, batteries, metal cans and fishing nets/lines (62.5%, 78.7%, 57.4% and 72.6%, respectively) back to port for further treatment. However, a substantial proportion of fishers (74.5%) reported that they discharged plastic bags into sea (see Table 1).

Table 1
Debris disposal methods used by fishers ($n=427$).

Debris disposal method	Frequency	Percentage (%)
Plastic bottles		
Discharged into sea	160	37.5
Brought back to port	267	62.5
Batteries		
Discharged into sea	91	21.3
Brought back to port	336	78.7
Metal cans		
Discharged into sea	182	42.6
Brought back to port	245	57.4
Plastic bags		
Discharged into sea	318	74.5
Brought back to port	109	25.5
Fishing nets/lines		
Discharged into sea	117	27.4
Brought back to port	310	72.6

3.3. Factors to debris disposal practices

A total of nine factors were identified to either promote or hinder fishers' bringing garbage back to port. They were indexed and classified into two categories: motive and constraint. The mean scores of factors in descending order are shown in Table 2. For the motive items (M_1–M_6), 'M_1: a well-developed household waste recycling practice' and 'M_2: captains requiring crews to bring garbage back to port' were rated as the items with high agreement (4.04 and 4.01, respectively). This indicates these two factors feature most in fishers' decision-making on bringing garbage back to port. The items 'M_3: positive attitude towards the protection of the marine environment', 'M_4: adequate collection facilities placed at port' and 'M_5: providing a reward for the garbage brought back to port' came second with mean scores of 3.81, 3.70 and 3.46, respectively. A t-test showed that the mean scores are significantly greater than three but less than 4, indicating that fishers slightly agreed with these items. The last item 'M_6: making regulations to prohibit fishing vessels from discharging garbage into sea' was the least agreed with a mean score of 3.12. A t-test showed the score is significantly equal to 3, indicating that fishers keep a neutral view towards this factor. In addition, it is noted that the standard deviation of factors M_5 and M_6 appears to be slightly bigger, compared with other items. This suggests that there exists a larger extent of different views among fishers towards making regulations and providing rewards.

For the constraint items, the most agreed item that poses a barrier to fishers' bringing garbage to port is 'C_1: catching fish is far more important than dealing with garbage at sea' with a mean score of 4.10. It was followed by the item 'C_2: indifference to the garbage being dumped at sea' with a mean score of 3.91. A t-test showed that score is significantly equal to 4. This indicates that fishers agreed with both items. The item 'C_3: collecting garbage on board causes inconvenience to fishing operations' is with a mean score of 3.09. A t-test showed that the score is significantly equal to 3, indicating fishers keep a neutral view towards this factor.

3.4. Association between factors and intention to bring garbage back to port

Slightly more than half of the respondents (58.5%) revealed the intention of bringing garbage (including all the above five items) back to port. A binary logit regression was used to examine the association between fishers' intention and the above identified factors. The dependent variable (intention) is binary and independent variables (factors) are numeric, measured by the five-point scale. The result was displayed in Table 3. With a Nagelkerge R-squared value of 0.462 and a Chi-square value of 97.82, the model is statistically significant and can effectively differentiate fishers with intention (yes) from those without intention (no). The model correctly classified 68.1% of the cases. Among the group 1 cases (total=250), 158 were correctly classified; among the group 0 cases (total=177), 133 were correctly classified.

As indicated by the coefficients of independent variables in Table 3, the positively significant factors (at 0.05 level) in determining fishers' intention to bring garbage back port are 'M_2: captains requiring crews to bring garbage back to port' and 'M_3: positive attitude towards the protection of the marine environment'. This suggests that the higher agreement the fishers indicate to this factor, the higher the intention they reveal to act on bringing

Table 2
Mean ratings of factors to fishers' bringing garbage back to port (n=427).

Factors	Mean[a]	S.D.[b]
Motive items		
M_1: a well-developed household waste recycling practice	4.04	1.04
M_2: captains requiring crews to bring garbage back to port	4.01	0.97
M_3: positive attitude towards the protection of the marine environment	3.81	1.14
M_4: adequate collection facilities placed at port	3.70	1.08
M_5: providing a reward for the garbage brought back to port	3.46	1.23
M_6: making regulations to prohibit fishing vessels from discharging garbage into sea	3.12	1.30
Constraint items		
C_1: catching fish is far more important than dealing with garbage at sea	4.10	1.25
C_2: indifference to the garbage being dumped at sea	3.91	1.18
C_3: collecting garbage on board causes inconvenience to fishing operations	3.09	1.13

[a] Five-point Likert scale was used for rating the agreement level of each factor, ranging from 1 (strongly disagree) to 5 (strongly agree).
[b] S.D. is standard deviation.

Table 3
Results of the binary logit model.

Factors	M_1	M_2	M_3	M_4	M_5	M_6	C_1	C_2	C_3
Coeff.	−0.156	−0.568*	0.621*	0.106	0.113	0.078	−0.314*	−0.412*	0.062
Wald	3.042	12.148	17.842	2.768	3.102	3.812	11.567	10.214	5.661

Notes: 1. n=427, Chi-square=97.82, p=0.000, Nagelkerge R-squared=0.462. 2. The variables are defined as: intention=1 if fishers have intention to bring garbage back to ports; 0 otherwise; M_1–M_6 and C_1–C_3 are motive items and constraint items, respectively (see Table 2) and are numeric values measured by the five-point scale.
* Significant at the 5% level.

garbage back to port. On the other hand, the negatively significant factors were 'C_1: catching fish is far more important than dealing with garbage at sea' and 'C_2: indifference to the garbage being dumped at sea'. The negative coefficients indicate that the higher agreement fishers reveals for the factors, the lower the intention they bring garbage back to port. It is noted that M_3, C_1 and C_2 factors are relevant to fishers' view towards the marine environment.

4. Discussion on management implications

The proceeding survey identified 6 motive and 3 constraint factors that potentially either promote or hinder fishers' bringing garbage back to port. Of the nine factors, seven received agreement from respondents, while two gained neutral views. From a policy perspective, it would be interesting to infer potential management measures from the results to encourage fishers to dispose of debris in a more sustainable way (that is, by bringing it back to port) and thus reduce the impact of the garbage produced by fishing vessels on the marine environment.

4.1. Implications for developing a waste recycling practice

The factor of a well-developed household waste recycling practice was agreed as a strong motive to promote fishers to bring garbage back to port; such motivation would be stronger if the garbage could be sold for recycling. It is worth noting that since 1997, the Taiwanese government has actively engaged in a waste recycling campaign by collaborating with communities, recycling enterprises, municipal trash collection teams and the recycling fund. In 1998, the Recycling Management Fund was established to handle all aspects of recycling. In 2006, a compulsory nation-wide garbage sorting program was initiated to further enhance the household recycling rate [32]. The recyclables are diverse, including iron/aluminum/plastic containers, paper tableware, batteries, tires, lubricants, electronic IT objects, house appliances (televisions, washing machines etc.) and light bulbs. In the years after the implementation of the program, the public has engaged in various forms of recycling and has gradually developed the practice of separating waste and collecting recyclables for further treatment by municipal recycling systems. The recycling rate[9] is high, reaching 38.15% in 2010, a more double increase from the year of 2002 [32]. It is perhaps this recycling practice that encourages fishers to bring recyclable debris to port. The recyclables can be sold, an added incentive for fishers to bring them back to port.

Additionally, in order to encourage fishers to bring plastic bottles back to port, the environmental authority has given bottle compactors to fishers. By using this tool, the volume of plastic bottles can be reduced, resolving the space limitation problem that concerns fishers [33]. However, it should be noted that while more than half of the respondents will bring recyclables back to port, a large percentage of them will not do the same thing with plastic bags. This is because plastic bags are not a recyclable item and provide limited economic incentive for reuse.

4.2. Implications for environmental education

The highly agreed factors regarding the fishers' views towards the marine environment (M_3, C_1, C_2) reveal that fishers' disposal practices might be dictated by altruistic environmental goals, which provides implications for encouraging environmental education for fishers. Moreover, as the binary logit regression analysis showed, these factors also had a significant relation with fishers' intention to bring garbage back to port. The results indicate a link between fishers' views toward the marine environment and their disposal practices. This link can be strengthened through education. Environmental education holds that we can change behavior by making people more knowledge about the environment and its associated issues [34]. It is also argued that raising awareness and education are needed to reduce marine litter [35]. In this regard, it is suggested that authorities or fishermen's associations encourage educational and outreach programs for fishers. The programs might focus on

[9] The rate does not include the recycling rates of food waste and huge recyclable waste (such as washing machines, televisions).

raising fishers' awareness of the marine environment, their potential contribution to the problem of marine debris, the adverse impacts of marine debris on the ecosystem health and fishing activities. It is expected that such programs can help create a sense of environmental responsibility among fishers and fostering their behavior changes in a more sustainable way.

In addition, the study found out that captains (who are usually the owners of vessels) play a role in initiating change in the crew's behavior regarding debris disposal, as indicated in the high agreement on the factor of M_2 and a positive relation between this factor and fishers' intention to bring garbage back to port. Fishing operations at sea require teamwork and the captain, as the leader, has the final say on all the things on board. Therefore, if captains demand the disposal of debris in an environmental-sound manner, they can require crews to make changes in the shipboard solid waste management practices to reduce the discharge of debris. Support of this view can be found in Butt [36] who stated that implementing environmental sustainable practice on board is generally a reflection of the ship operators' environmental commitment and the diligence of their crews. In this regard, environmental education programs for captains or ship owners are particularly encouraged. It is hoped that through the captains' commands, the practice of bringing garbage back to port will be fostered among crews.

4.3. *Implications for reception facilities at port*

Fishers generally agreed that placing adequate reception facilities at port promotes them to bring garbage back to port. It should be noted that fishers are very busy when they return to port; they are occupied with unloading and selling their catch and cleaning out the vessels after a tiring fishing trip. If garbage collection facilities are conveniently located, fishers would be more inclined to bring garbage back to port with them and put it into a reception facility when returning to port rather than finding such activity difficult. Adequately located reception facilities would help to reduce the difficulties incurred by fishers when they bring garbage back to port. Just as Ball [37] stated, the inadequacy of port reception facilities is one of the main reasons for the illegal operational discharge of oil and garbage from ships. It is apparent that the availability of adequate reception facilities is critical for the prevention of the discharge of pollutants by ships. Related studies on reducing waste discharged into sea by ships, such as waste oil from fishing vessels by Lin et al. [38] and waste from cruise ships by Butt [36], also recommend that ports should provide adequate collection facilities.

4.4. *Implications for providing rewards*

It is understandable that fishers regard the provision of a reward as a motive for bringing garbage back to port. Rewards can act as an incentive to encourage people to adopt a new policy, especially during the early stages of policy implementation. However, it should be noted that if the perceived benefit of the reward is less than the perceived cost of the additional effort and time taken to collect, sort and hand over the debris to the authorities, then the reward would be meaningless. Given that the rewards are not clearly specified in the questionnaire, it is not surprising to find that there were several divergent views of this topic among the fishers, as indicated by the big standard deviation. In addition, it is also noted that providing rewards has its flaws and may not encourage a long-term sustainable behavior [24].

4.5. *Implications for making regulations*

Besides the factors that gained agreement from fishers, this study found out that the factor of making regulations to prohibit fishing vessels from discharging garbage into sea gaining fishers' neutral views is worth further discussion. While it is recognized that making regulations might compel fishers to follow the rules, this study argues that this approach would not be effective in deterring illegal discharge. The reasons for this argument are two-fold. One is that such command-and-control regulations would be difficult to enforce at sea. Enforcement at sea is terrifically expensive and technically difficult to implement. Enforcement cost typically involves surveillance of compliance with laws and a role in the prosecution of fishers who do not comply with those laws [39]. It involves a huge investment of administrative effort, personnel and financial resources, which entails the commitment of massive resources. It is, therefore, highly doubtful that regulations could be effectively enforced. The other is that if the expected gain from breaking rules being greater than the expected loss from complying with rules, fishers will tend to violate rules, as indicated in the Becker model that focuses on decision makers being inclined to make rational economic decisions when deciding compliance or non-compliance [40].

Taiwan's case provides a good illustration. To control marine pollution by ships, the Marine Pollution Control Act stipulates that wastewater, oil, waste and other polluting substances shall remain on board or be discharged into on-shore reception facilities. An exception is made for legally permitted waste discharge. However, there are no further conditions specified for legal discharge and have no cases reported against the regulations, indicating that the regulations have virtually no deterrent effect.

4.6. *Summary*

Based on the above analysis, this study suggests that developing a recycling practice among fishers, placing adequate reception facilities at port, encouraging environmental education for fishers, and providing a reward for the garbage brought back to port are the recommended management strategies to prevent garbage generated by fishing vessels from being discharged into sea. However, it should be noted that the last one is not a long-term approach to achieve sustainable behavior. The above recommended measures are administrative by nature and can be implemented at the national level, serving as supplementing measures to Annex V of MARPOL 73/78 in addressing vessel-source garbage pollution. In contrast to those administrative measures, this study also argues that the legislative measure is not preferred due to its difficulty to detect and high enforcement cost.

It is also noted that the above recommended strategies are derived from the empirical survey based on fishers' "demand". A related question might emerge on whether these recommended strategies can be "supplied" or carried out by policy makers. This question is surely another research topic and is beyond the scope of this study. However, it can be argued that implementation of these recommendations depends on policy makers' political will, capacity, financial and administrative resources. In different political, technological, social and economic context, policy makers will have their own concerns in dealing with garbage pollution from fishing vessels. In all, this study presents recommended strategies in a hope that they can serve as references for policy makers to devise their own appropriate strategies to address garbage pollution by fishing vessels, or even by other types of vessels.

5. Conclusions

This paper has illustrated several points of general significance regarding debris generated by fishing vessels. First, international regulations which concern garbage pollution such as Annex V of MARPOL 73/78 are almost exclusively aimed at large ocean-going ships with tonnage over 400 GT. The regulation of the garbage generated by fishing vessels is not targeted due to such vessels' low tonnage-under 400 GT. This leaves a gap in the international efforts to address vessel-source garbage pollution. Second, garbage generated by fishing vessels is diverse, including derelict fishing gear, batteries, plastic bottles, plastic bags, metal cans, which would degrade marine environmental quality if dumped into sea. Third, given that a large number of fishing vessels are operating around the word and various types of garbage, particularly plastics, are generated, fishing vessels are a common source of marine debris. The need to prevent debris from being discharged into sea is essential if comprehensive protection of the marine environment from vessel-source garbage pollution is pursued. Fourth, the proceeding survey findings disclosed that fishers were engaged in some form of recycling on board and their environmental concerns have resulted in an environmentally responsible behavior regarding debris disposal. Fifth, based on the survey findings, management strategies are proposed to encourage fishers to bring garbage back to port, including: developing a waste recycling practice, placing adequate reception facilities at port, encouraging environmental education for fishers and providing a reward for the garbage brought back to port. To implement these measures relies on the government's initiation and support.

Lastly, with the proposed management measures, it is hoped that policy-makers take notice of the potential problem of debris pollution arising from fishing vessels and take them as references to initiate necessary actions to protect the marine environment in a more comprehensive manner. It is hoped that fishers will eventually make it a normal seafaring practice to gather garbage on board and bring it back to port. From an environmental perspective, it is advised that future efforts focus on reducing the debris at the source where it is generated. Future research on debris reduction strategies could consider reducing the amount of garbage, particularly plastics, going aboard, reusing plastic material, using rechargeable batteries that can resist the sea environment or inventing new environmentally-friendly material that can replace plastic material.

Acknowledgements

The authors wish to express sincere thanks to the people from fishermen's associations for providing valuable information and assistance, especially Rong-Hui Kuo, Shyan-Jyh Young, Yin-Yin Pang, Shu-Xian Liao, Xiu-Wen Hong, Mei-yun Chen. Thanks also go to the 30 anonymous interviewees and the 427 fishers involved in the research. Any opinions, findings and conclusions or recommendations expressed in this article are those of the authors and any error remains the sole responsibility of the authors. Funding from the National Science Council (NSC 100–240-H-006–105) is greatly acknowledged.

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