

At-sea solid waste production by a small-scale fishery in Peru

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Abstract

Marine litter is a growing environmental problem for which fisheries-sourced waste remains poorly understood. In Peru, there is an ongoing challenge of waste management from the small-scale fisheries fleet given the lack of facilities to receive the variety of debris produced by fishers, which includes hazardous wastes such as batteries. In this study, onboard solid waste production was monitored daily by land-based observers upon landing at the port of Salaverry, Peru, from March to September 2017. The analysed small-scale gillnet and longline fishing fleets produced annually an estimated 11,260 kg of solid waste. Of particular concern is the production of single use plastics (3427 kg) and batteries (861 kg) due to their potential long-lasting impacts on the environment and challenges related to their proper disposal. A management plan for solid waste has been developed for Salaverry; therefore, a subsequent assessment was conducted in 2021–2022 of the behaviours and perceptions of fishers regarding the implementation of this plan. Most fishers (96%) reported disposing of their waste on land, except organic waste which is disposed of at sea. While fishers in Salaverry have become more conscious of the issues surrounding at-sea waste disposal and have an interest in better segregating and managing their waste, there remains a need for improved waste management and recycling protocols and procedures at the port to make this possible.

Keywords

Marine debris, solid waste, small-scale fisheries, Peru, single use plastic, Salaverry

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Introduction

Marine debris or litter is defined as ‘any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment’ (UNEP, 2009), is a growing environmental problem that continues accumulating in the ocean, affecting the marine environment (Woods et al., 2019). Around 4.8–12.7 million metric tonnes of solid waste was calculated to have entered the ocean in 2010 from 192 countries (Jambeck et al., 2015). Direct impacts of marine debris on megafauna have been widely documented, including entanglement, ingestion, suffocation and general health debilitation, affecting not only individuals but also populations, and hindering the recovery of threatened species (Gregory, 2009; Watson et al., 2016). Other effects include socio-economic impacts to tourism, declines of fish stocks, high removal costs, as well as human health effects (Watson et al., 2016; Woods et al., 2019).

Increasing quantities of marine litter enter the ocean from various land- and sea-based activities because of non-existent waste management, poor implementation of management plans, sewage overflow, beach littering, mismanaged tourism, marine-based activities and natural waterways (Galgani et al., 2015; Purba et al., 2019; Walker et al., 2006; Woods et al., 2019).

Marine litter can be characterized in different ways and includes a wide range of materials such as metal, wood, glass and plastic (Galgani et al., 2015; Watson et al., 2016). However, among the various components of marine litter, plastic items constitute the dominant pollutant, representing up to 95% or even 100% of the waste accumulated on shorelines, the sea surface or the sea-floor (Galgani et al., 2015, Tekman et al., 2019; Williams and Rangel-Buitrago, 2019). It has been estimated that by 2050 about 12 million metric tonnes of plastic will be either in landfills or in the natural environment (Geyer et al., 2017).

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Among marine-based sources of marine litter, fisheries are an underestimated source of plastic debris (Xue et al., 2020). Fisheries waste composition, despite being dominated by plastic items, also includes glass, metal, cloth or Styrofoam items (Niaounakis, 2017; Ramos et al., 2019). There have been attempts in some countries to assess waste production during fishing activities (Purba et al., 2019; Unger and Harrison, 2016) and to promote management of waste produced during fishing activities, including through incentive programmes (Ortiz-Alvarez et al., 2022; Purba et al., 2019; Ramos et al., 2019; Unger and Harrison, 2016).

In Peru, the generation and management of solid waste is one of the main environmental and health problems faced in both continental and marine environments (Alfaro, 2006; Orihuela, 2018; Ortiz-Alvarez et al., 2022; Solano Sare and Buitrón, 2017). Advances have been made through the Solid Waste Management National Plan (Mejía et al., 2020) by providing a framework to articulate efforts among governmental institutions and reinforce initiatives. Thus, efforts have been developed by coastal municipalities to address marine litter issues through beach and seabed clean-ups. However, it is still necessary to develop better strategies to manage waste produced during at-sea economic activities such as fisheries (Alfaro-Shigueto et al., 2010; De la Puente et al., 2020; Gozzer-Wuest et al., 2021).

In Peru, the small-scale fishing (SSF) fleet consists of approximately 17,920 vessels (Castillo et al., 2018). The large number of vessels, the informality of the sector and the area where this activity occurs (pelagic and oceanic waters), increase the difficulties in quantifying and monitoring waste production by government institutions. Efforts to assess waste produced during fishing activities have been made for the port of San Jose, with the authors recommending implementation of a solid waste management strategy for this port (Ortiz-Alvarez et al., 2022). A management plan for solid waste produced during fishing activities has been developed for another locality, Salaverry, which is an important small-scale fishing port home to SSF vessels that use either gillnet or longline fishing gear (Castillo et al., 2018). However, there is no evidence that the fisher community is acting in compliance with the guidelines. Given this situation, this study aims to identify social and operational obstacles to implementation of the solid waste management plan through an estimation of solid waste production by offshore gillnet and longline SSF vessels in the port of Salaverry, followed by an assessment of the behaviours and perceptions of fishers regarding the implementation of the solid waste management plan. This information can be used to further evaluate the need for the management plan and to promote its application by fishers.

Materials and methods

Study area

The study was conducted in the port of Salaverry (08°13'27"S) (78°59'52"W), Trujillo, Peru. Salaverry hosts a fishing community of ca. 320 artisanal fishermen, with 136 SSF vessels

dedicated to gillnet (82%) and longline fishing (18%). Vessels have hold capacities up to 10 tonnes (Clemente, 2010) and crew numbers between 3–4 for gillnets and 5–7 for longlines (Solano Sare and Buitrón, 2017). The main target species of these fleets are hammerhead sharks (*Sphyrna zygaena*) and dolphinfish (*Coryphaena hippurus*).

Data collection

Solid waste assessment. Onboard waste production was monitored daily by land-based observers upon landing at Salaverry port from March to September 2017. Solid waste bags brought to land were weighed using a 100 kg digital scale, labelled with the fishing vessel name, departure and arrival date and total weight. Later, samples were separated into the following categories and weighed: cardboard/paper, metal, low-density polyethylene (LDPE), polyethylene terephthalate (PET), glass, wood, organic, non-recyclable single use polyethylene (NRSUP), rubber, cloth, batteries, asbestos, CDs, electronics, petrol filters, foam (polyurethane), leather, medication containers and Styrofoam.

All information was recorded in data sheets and later digitized on a spreadsheet for further analysis.

Fisher perceptions assessment. A total of 28 surveys were conducted with fishers from Salaverry port between October 2021 and January 2022 to assess fisher perceptions about solid waste management and patterns of waste discard while conducting fishing activities after the voluntary waste management plan was presented to the community. The surveys were conducted in the port of Salaverry by a trained local scientist with previous experience in this type of study, fishers were chosen following snow-ball and stratified sampling (Albert et al., 2009). Previous contacts of fishers were chosen randomly to survey, the respondents assisted us in choosing other participants. We interviewed mainly captains to avoid duplicating information from the same vessel. The survey consisted of 12 closed, multiple-choice questions about solid waste production and management of their fishing trips and vessel landing (see survey as S1). Before the survey, a brief introduction was provided about the study objective to participants, all who were informed about the confidential and voluntary nature of the survey and asked for their consent to conduct the survey.

Data analysis

Waste assessment. We recorded data on 13 gillnet and longline vessels during 81 fishing trips, corresponding to 1010 fishing days. We calculated solid waste produced during the fishing trips as the total weight of each solid waste category. Recyclable and non-recyclable daily waste per capita (DWC; $\text{kg} \times (\text{person} \times \text{day})^{-1}$) were estimated as the total weight of each category in each fishing trip divided by the number of fishers and the length in days of the trip. *Recyclable waste* was sorted into the following categories: cardboard/paper, metal, LDPE, PET, glass, wood and organic; *non-recyclable waste* was sorted into the

Table 1. List of predictors (independent) variables included in the generalized linear mixed-effects models.

Predictor variable	Fixed/random effect	Type	Description
Gear type	Fixed	Categorical	Type of fishing gear used in a trip: longline or gillnet
Waste category	Fixed	Categorical	In the model for recyclable waste, categories were cardboard/paper, metal, LDPE plastic, PET plastic, glass, wood and organic. In the model for non-recyclable waste, categories were NRSUP, rubber, cloth, batteries, asbestos, CDs, electrics, petrol filters, foam (Polyurethane), leather, medication containers, Styrofoam.
Vessel ID	Random	Categorical	Unique code given to each vessel

LDPE: low-density polyethylene; PET: polyethylene terephthalate; NRSUP: non-recyclable single use polyethylene.

Table 2. Best-fit models (GLMM) selected for the estimation of waste production on fishing vessels.

Models			Conditional fixed effects		Binomial fixed effects	AIC	Weight
Waste type	Family	Response	Gear type	Waste category	Waste category		
Recyclable	Gamma	DWC	–	+	+	–1996.0	0.743
Non-recyclable	Gamma	DWC	–	+	+	–925.1	0.741

AIC: Akaike's information criterion. Weight: Akaike's weight; GLMM: generalized linear mixed-effect model.

Waste type: data analysed in the model. Family: error distribution used for the model. Response: the dependent variable, daily waste per capita. Conditional/binomial fixed effects: presence (+) or absence (–) of the explanatory variables 'Gear type' and/or 'Waste category' in the continuous/binomial component of the model.

following categories: NRSUP, rubber, cloth, batteries and other materials (i.e. infrequent items such as asbestos, CDs, electronics, petrol filters, foam (Polyurethane), leather, medication containers, Styrofoam). The selection for recyclable and non-recyclable materials was made based upon the categorization proposed by the Peruvian Ministry of Environment (<https://perulimpio.minam.gob.pe/yo-reciclo/>), and grouping organic and reusable waste, as well as unusable and hazardous waste.

We analysed solid waste characterization data using separate generalized linear mixed-effect models (GLMM) to estimate recyclable and non-recyclable DWC produced by the Salaverry SSF fleet, including explanatory variables such as fishing methods. The dependent variable (DWC) was semi-continuous, had a right-skewed distribution and displayed excess zeros. Gamma distributions do not allow for zero values, thus we modelled the zeros separately from the non-zeros using a Gamma hurdle model with log-link function, that is a two-part model: one model considers the likelihood of producing waste or not producing it at all (the binomial component), the other model considers the amount of weight generated (the continuous component with gamma distribution) (Nobre et al., 2017).

We first fitted full models whose continuous component (gamma model) included DWC per trip as the dependent variable, 'Waste category' and 'Gear type' as fixed effects and 'Vessel ID' as random effects (Table 1 describes predictor variables). A ziGamma family with a log-link function was used. We included in the binomial component 'Waste category' as fixed effect and used the binomial family with log-link function as a default. We then performed model selection and we used the best fit models to estimate DWC (Table 2).

We used the statistical modelling programme R 4.0.2 (R Core Team, 2020) for statistical analyses. We used the 'glmmTMB' function (Brooks et al., 2017) to fit statistical models. We performed information theoretic (IT) model selection based on Akaike's information criterion (AIC; Akaike, 1998) and Akaike weights (Burnham and Anderson, 2002). The 'dredge' function in the 'MuMIn' package (Barton, 2013) was used to generate a set of the most parsimonious models (i.e. with lowest AIC; Richards, 2005; Richards et al., 2011). For the analysis we used the model with the highest Akaike weight, that is, the best-fit model (Burnham and Anderson, 2002). The 'DHARMa' package (Hartig, 2019) was used for model diagnostics. We used the 'predict' function in the 'stats' package to compute expected mean recyclable DWC and mean non-recyclable DWC from the models; results are presented as mean recyclable DWC ($\pm$ SE) and mean non-recyclable DWC ($\pm$ SE) by waste category.

Fisher perceptions assessment. A cumulative analysis was performed with the interview data about solid waste production (types) onboard while fishing, solid waste fate per type after landing and perceptions about solid waste management.

Results

Solid waste assessment

Descriptive analysis. The mean trip length and crew per vessel was 12.5 ± 3.1 days and 4.2 ± 0.9 fishers, respectively (mean $\pm$ s.d.). 434 kg of recyclable waste (cardboard/paper, metal, LDPE plastic, PET plastic, glass, wood and organic) and

Table 3. For each waste category, total weight (kg) of waste generated by all fishing trips and percentage of total waste produced.

Recyclable			Non-recyclable		
Category	Total weight	%	Category	Total weight	%
Cardboard/paper	80.5	18.5	Batteries	49.4	25.8
Glass	28.6	6.6	Cloth	40.4	21.1
LDPE	79.5	18.3	NRSUP	62.0	32.2
Metal	40.2	9.3	Rubber	26.1	13.6
Organic	81.9	18.8	Other	13.7	7.2
PET	116.8	26.9	–	–	–
Wood	7.0	1.6	–	–	–
Total	434.5	–	–	191.6	–

LDPE: low-density polyethylene; NRSUP: non-recyclable single use polyethylene.

191 kg of non-recyclable waste (NRSUP, rubber, cloth, batteries and other materials) were generated from 13 vessels during the fishing trips. We obtained more recyclables (i.e. 434 kg) than non-recyclable waste (i.e. 191 kg; Table 3).

Statistical analysis. The selected models (composed by (1) continuous (gamma) component and (2) binomial component) used to compute recyclable and non-recyclable DWC generated by the Salaverry fleet were as follows:

- (1) $\sim$ Waste Category + (1|Vessel_ID)
- (2) $\sim$ Waste Category.

Supplemental Tables S2 and S3 show the fixed effect estimates and the random effect variance components for the recyclable and non-recyclable waste. The model for recyclable waste resulted in a DWC in $\text{kg} \times (\text{person} \times \text{day})$ of 00.018 (± 0.002) for cardboard/paper, 0.020 (± 0.003) for organic waste, 0.018 (± 0.002) for LDPE and 0.027 (± 0.004) for polyethylene (Figure 1). The model for non-recyclable waste resulted in a DWC in $\text{kg} \times (\text{person} \times \text{day})^{-1}$ of 0.011 (± 0.001) for batteries, 0.009 (± 0.001) for cloth, 0.015 (± 0.002) for NRSUP and 0.006 (± 0.001) for rubber (Figure 2). DWC estimates for other materials are summarized in Table 4.

Fishery waste in Salaverry

According to the model predictions, in Salaverry, a SSF vessel produces $0.10 \text{ kg} \times (\text{person} \times \text{day})^{-1}$ of recyclable solid waste and $0.04 \text{ kg} \times (\text{person} \times \text{day})^{-1}$ of non-recyclable solid waste for a total of $0.14 \text{ kg} \times (\text{person} \times \text{day})^{-1}$. The average number of crew members on the vessels was four and, according to the latest census of small-scale fishers (Castillo et al., 2018), Salaverry has 111 SSF vessels that use gillnets while 25 use longline. Fishing trips last 12 days for gillnet vessels and 16 days for longline vessels on average. As a result, we estimate $78 \text{ kg} \times \text{day}^{-1}$ of solid waste produced by the fleet, of which 71.4% are recyclable (including PET, organic, LDPE and cardboard, beyond others). Considering a mean trip length of 12 days and vessels having one trip each month, an estimated 11,260 kg of solid waste are generated annually by the gillnet and longline vessels in the port of

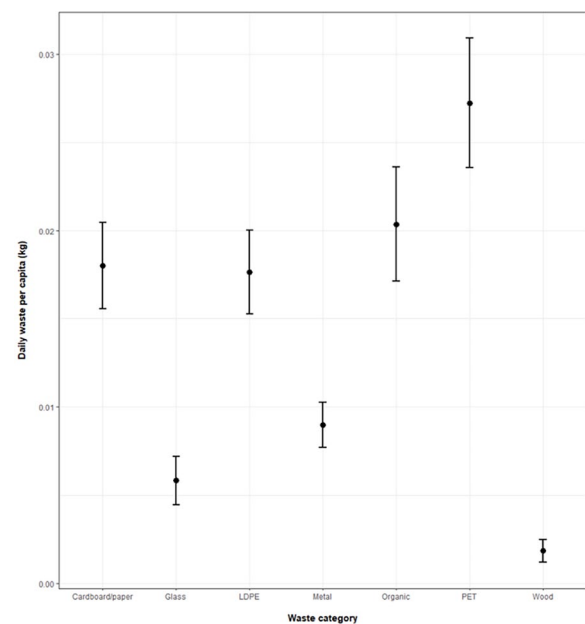


Figure 1. Estimated recyclable daily waste per capita ($\text{kg} \times (\text{person} \times \text{day})^{-1}$) for the waste categories generated on Salaverry fishing vessels. Error bars are SE.

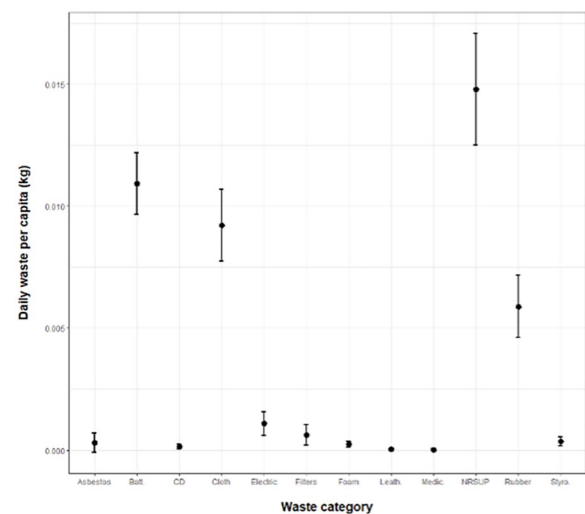


Figure 2. Estimated not recyclable daily waste per capita ($\text{kg} \times (\text{person} \times \text{day})^{-1}$) for the waste categories generated on Salaverry fishing vessels. Error bars are SE.

Table 4. Model predictions from GLMM models of mean $\pm$ SE recyclable and not recyclable daily waste per capita ($\text{kg} \times (\text{person} \times \text{day})^{-1}$) generated on Salaverry SSF vessels.

Recyclable		Non-recyclable	
Waste category	DWC $\pm$ SE	Waste category	DWC $\pm$ SE
Cardboard/paper	0.018 $\pm$ 0.002	Asbestos	0.0003 $\pm$ 0.0004
Glass	0.006 $\pm$ 0.001	Batteries	0.011 $\pm$ 0.001
LDPE	0.018 $\pm$ 0.002	CDs	0.0001 $\pm$ 0.0001
Metal	0.009 $\pm$ 0.001	Cloth	0.009 $\pm$ 0.001
Organic	0.020 $\pm$ 0.003	Electronics	0.001 $\pm$ 0.0005
PET	0.027 $\pm$ 0.004	Foam (Polyurethane)	0.0003 $\pm$ 0.0001
Wood	0.002 $\pm$ 0.001	Leather	0.00003 $\pm$ 0.00005
		Medication containers	0.00002 $\pm$ 0.00003
		NRSUP	0.015 $\pm$ 0.002
		Petrol filters	0.0006 $\pm$ 0.0004
		Rubber	0.006 $\pm$ 0.001
		Styrofoam	0.0004 $\pm$ 0.0002

GLMM: generalized linear mixed-effect model; NRSUP: non-recyclable single use polyethylene; SSF: small-scale fishing.

Salaverry (see Supplemental Table S4 for the total annual amount estimated per type of waste).

Fisher perceptions assessment

Survey responses indicate that plastic bottles are the most produced solid waste in fishing trips from the port of Salaverry. The vast majority (96%) of respondents indicated that they bring their solid waste back to port and discard their organic waste at sea. Even though fishers bring their waste back to port, they do not segregate this waste (100%) or recycle it. Almost half (46%) of the fishers responded positively about their willingness to segregate their waste (Table 5).

Discussion

Litter produced by SSF is of concern due to the high uncertainty about the types and amounts of waste that continue to be produced and discarded, despite international agreements and local regulations (Falk-Andersson et al., 2019; Ortiz-Alvarez et al., 2022; Unger and Harrison, 2016). In this study, we provide a solid waste assessment of the port of Salaverry, Peru, an important SSF port (Clemente, 2010). The analysed gillnet and longline fleets were estimated to produce 11,260 kg of solid waste annually. Of particular concern is the production of single use plastics (3427 kg) and batteries (861 kg) due to their high impact and long-lasting effects in the environment and challenges related to their proper disposal (Hahladakis, 2020; O'Brine and Thompson, 2010; Villarreal-Archila et al., 2021). Most fishers (96%) reported disposing of their waste on land, except the organic waste which is disposed of at sea. More than half of the fishers interviewed said that they are interested in recycling their waste, but the remainder expressed concerns about the time it will take to segregate their waste.

From the category of recyclables, PET plastic, cardboard/paper and LDPE plastic had the highest production (26.9%,

18.5% and 18.3%, respectively). The DWC generation of PET and LDPE in our study were 0.027 ± 0.004 and 0.018 ± 0.002 ($\text{kg} \times (\text{person} \times \text{day})^{-1}$), respectively, while according to Ortiz-Alvarez et al. (2022) plastic DWC for small-scale gillnet fishery in San José, another fishing community in Peru, was $0.008 \pm 0.010 \text{ kg} \times (\text{person} \times \text{day})^{-1}$. This would mean that the amount of plastic generated at sea in Salaverry is considerably higher than in San Jose. This difference could be due to several reasons, for example in San Jose the mean trip duration was 6.3 days while in Salaverry it was 12 days. Therefore, as the trips are further offshore and longer, they may use more plastics and batteries and thus generate more daily waste on a daily basis.

Marine plastic on the open ocean surface is estimated to be around 7000–250,000 t worldwide (Cózar et al., 2014; Eriksen et al., 2014). The marine environment and human health are under severe threat due to the growing presence of microplastics in marine fauna (e.g. fish, bivalves, crustaceans; Barboza et al., 2018; De-la-Torre, 2020; Elizalde-Velázquez and Gómez-Oliván, 2021; Guzzetti et al., 2018; Miller et al., 2020). Our results also indicate that a high proportion of waste produced in Salaverry is not locally recyclable (i.e. batteries ($861.7 \pm 78.34 \text{ kg}$), cloth ($705.02 \pm 78.34 \text{ kg}$), rubber ($470.02 \pm 78.34 \text{ kg}$) and NRSUP ($1175.04 \pm 156.67 \text{ kg}$) produced per year). These results highlight the ongoing challenge of waste management from the SSF given the lack of facilities to receive the variety of debris produced by fishers, which includes hazardous wastes such as batteries. Even though most respondents said they bring their waste back to land, additional studies will be needed to verify this and to assess the extent to which this behaviour occurs in other fisheries and other ports. For example, Ortiz-Alvarez et al. (2022) found that in San Jose port in northern Peru, fishers disposed of most of their waste directly at sea.

Responses to our survey showed that waste is not segregated, and most respondents (67%) were unwilling to do so. Recycling of waste from fisheries is still minimal around the world with many important factors to consider, for example

Table 5. Fisher responses per question % (n) of the interview about solid waste production and perception of management in Salaverry.

Questions	Responses	% (N)
What are the most produced solid waste types while on board fishing vessels?	Food leftovers	86 (24)
	Plastic bottles	100 (28)
	Cardboard/papers	18 (5)
	Plastic bags	39 (11)
	Cans	4 (1)
	Other	0
Do you bring the solid waste produced on board back to port?	Yes	96 (27)
	No	4 (1)
(If the answer was yes) Do you segregate the solid waste produced while fishing before disposing it on land?	Yes	0 (0)
	No	100 (27)
(If the answer was yes) Which ones?	–	–
(If the answer was no) Would you be willing to segregate your solid waste for latter management?	Yes	37 (10)
	No	67 (18)
Where do you dispose of the solid waste when it returns to the port?	Salaverry landing port	71 (20)
	Solid waste bin	18 (5)
	Beach	7 (2)
	Discard at sea	4 (1)
Do you use empty plastic bottles or container waste?	Yes, I sell to waste pickers	0 (0)
	Yes, I sell to recyclers	0 (0)
	No, I throw them away	93 (26)
	No, I throw it into the sea	4 (1)
	Did not respond	4 (1)
Do you use organic waste (food leftovers)?	Yes, to feed farm animals	0 (0)
	No, I throw it away	0 (0)
	No, I throw it into the sea	93 (26)
	Did not respond	7 (2)
Do you use paper/cardboard waste?	Yes, I sell to waste pickers	0 (0)
	Yes, I sell to recyclers	0 (0)
	No, I throw it away	71
	No, I throw it into the sea	0 (0)
	Other	4 (1)
	Did not respond	25 (7)
Do you use empty glass bottles or container waste?	Yes, I sell to waste pickers	0 (0)
	Yes, I sell to recyclers	0 (0)
	No, I throw them away	82 (23)
	No, I throw it into the sea	4 (1)
	Did not respond	14 (4)
Do you know if there is a solid waste management plan for your locality?	Yes	46 (13)
	No	50 (14)
	There is not	4 (1)
Would you be willing to participate in a management plan to recycle solid waste from your locality/vessel?	Yes	43 (12)
	No	54 (15)
	We already do it	4 (1)

waste segregation (as they have limited space in their vessels), barriers with raising awareness with fishers (as they spend the majority of their time at sea), promotion of resource recovery, efficient collection and waste transport systems (Kanehiro, 2004; Olsen et al., 2020; Wyles et al., 2019). In Salaverry, solid waste is currently received at the Small-Scale Fishing Landing Port (SFLP), known in Spanish as Desembarcaderos Pesqueros Artesanales, for its subsequent transfer to the Municipality of Salaverry, that would manage the waste. This reticence towards segregating and recycling waste is related to multiple factors, including the time involved, limited municipal budgets, the absence of legislation or regulations, failure to clearly identify

responsibilities, space limitations and due to the lack of recycling programmes developed and implemented in collaboration with fishing communities (Orihuela, 2018; Ortiz-Alvarez et al., 2022). This scenario is like that found at other locations where the disposal of waste to the ocean, reduced waste management and limited recycling practices are the principal reasons for the accumulation of marine litter (Bergmann et al., 2015). In Peru, most municipal solid waste (i.e. 70%) ends in open dumpsites and only 21% in sanitary landfills (Orihuela, 2018), demonstrating limited infrastructure available in the country to support recycling practices. While a portion of this unmanaged waste is in fact recycled informally, this sector remains unmonitored,

unregulated and hazardous. A long-term recycling solution would seek to recognize and include this sector and its workers in formal waste management planning, thus acknowledging the socio-economic contribution of this sector and allowing for more informed monitoring and decision-making. In addition, there are about 87 fishing ports in Peru similar to Salaverry. Of these, 38 do not even have complete infrastructure to disembark (e.g. pier, landings port and facilities; Castillo et al., 2018); therefore, there is even less space available to remove or store vessel waste. In the Barents Sea, Olsen et al. (2020) concluded that increasing awareness in fishers is limited if it is not accompanied by practical arrangements like appropriate infrastructure. In trying to address waste disposal management in Peru, in advance even of implementing a waste management plan, we recommend seeking ways to reduce the use of non-degradable, single-use products towards decreasing the amount of waste generated onboard.

In Peru, the navy (i.e. La Direccion General de Capitanias y Guardacostas DICAPI) is responsible for controlling and preventing the release of solid waste into the ocean (Resolucion Ministerial (RL) N° 26620). Municipalities are also responsible through the 'Ley de Gestión Integral de Residuos Sólidos' (Decreto Legislativo (DL) N° 1278), for the final disposal of solid waste of household or commercial origin in their jurisdiction, and of waste produced from industrial activities, excluding all hazardous waste. Despite this regulatory framework, limited enforcement and implementation have led to continued mismanagement of waste, including dumping of waste in rivers, the ocean or on beaches (Ortiz-Alvarez et al., 2022).

The Solid Waste Management Plan for Artisanal Fisheries in the port of Salaverry was created through a multi-institution collaboration which includes local and regional authorities (Mejía et al., 2020). This plan describes management actions for solid waste generated through artisanal fishing activities and considers aspects related to the generation, segregation, conditioning, collection, central storage, transport, treatment and final disposal of waste. It is based on a strategy with three main steps: reduction and reuse, through recycling. The first two steps require a behavioural change in fishers to reduce their use or consumption of non-essential products and reusing products (i.e. glass jars). The last step also requires high levels of collaboration from fishers as different types of solid waste containers with specific characteristics will need to be placed in their vessels to promote waste segregation and ease its characterization on land. While this is the ideal scenario envisioned, our results indicate that fishers are reticent to segregate their waste at sea, even though they are currently bringing unsegregated waste back to land. A consultation process between fishers and other stakeholders seems necessary towards modifying management measures so that they address fisher concerns and meet the needs of the management plan. Coordination with the administration of the municipality (which oversees the final disposition of waste) will also be important as they are responsible for coordinating with companies to retrieve recyclables, non-recyclables and hazardous items. Finally, to make these arrangements accurately, it would be important to improve the estimation of solid waste production onboard, since

the plan uses values that in total are ~8 times higher (4.55 kg/day) than our estimation. At this stage, the implementation of the Solid Waste Management Plan is voluntary, but from the results of our surveys we see that most fishers report bringing their waste back to port, indicating their willingness to participate in the waste management plan. This could be considered an early success for the plan. The successful full implementation of this plan will require raising awareness among fishers and to provide further training in waste management. This is proposed in the plan but will require a first evaluation of fisher behaviour and attitudes to establish an implementation timeline with realistic goals. As stated previously, we believe that this should be a collaborative process that acknowledges fisher opinions, the logistical constraints aboard fishing vessels, and that also coordinates activities with the SLFP and the municipality.

Conclusions

This study shows that fishers in Salaverry are conscious of the issues surrounding waste disposal into the ocean. The Salaverry waste management plan is a starting point and can be improved upon but has the potential to serve as an example for other ports. Expanded studies that characterize solid waste production and disposal at the national level would also make possible the development of management plans of greater scope but that can also be applied to local fisheries. It will be important to involve fishers from the beginning on the development of any such plans, not only to develop awareness on the benefits of not discarding solid waste into the ocean, but also to raise awareness of the importance of committing time to waste reduction, reuse and recycling, as effective conservation depends largely on people's compliance with regulations. The insights described here can be applied elsewhere in Latin America or in situations where waste ends up in the ocean due to inappropriate disposal practices by municipalities and fishers.

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Supplemental material

Supplemental material for this article is available online.

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