# Estimation of Plastic and Other Waste Disposed of by Longline and Gillnet Fleets Operating from Cilacap

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*Abstract*

*Tuna-fishing boats based at the Cilacap Oceanic Fishing Port are potential contributors to marine debris in the Indian Ocean. Without a quantitative assessment of the types and amount of debris, port management cannot develop a strategy to address this problem. This study estimated the quantities of plastics and cartons disposed of by these fisheries in the Indian Ocean. Data were collected through observations and interviews with boat managers/owners or fishermen in the port, from August to November 2019, to evaluate the boat supplies loaded on board in the port and the waste returned to the port. The marine disposal per fishing trip (the difference between the quantity of supplies taken to sea and the quantity of waste returned to port) was calculated for 89 trips of gillnet and longline boats, for a size range of 20 to 90 GT. There was no at-sea disposal of used engine oil, rice plastic sacks, styrofoam boxes, nor plastic gallon bottles. Other plastics and cartons from consumable packaging were disposed of at sea. The estimates of the plastic waste disposed were 0.8-4.4 kg.boat$^{-1}$.trip$^{-1}$ or 2,143-12,024 pieces.boat$^{-1}$.trip$^{-1}$ while the estimates of the cartons disposed were 3.5-19.4 kg.boat$^{-1}$.trip$^{-1}$ or 203-1,140 pieces.boat$^{-1}$.trip$^{-1}$. The study concluded that fishers could easily keep the waste onboard for disposal on return to port. In addition, port management should initiate a system in which the amounts of waste returned to boats returning to port are considered in granting future port clearance to those boats.*

***Keywords:*** *Marine waste, Consumable boat supplies, Tuna fisheries*

## Introduction

Longline and gillnet fishing boats that target tuna and tuna-like species are potential contributors to marine debris in offshore waters. The issue is of concern to global communities because the disposal of solid materials and the loss of fishing gear at sea pose threats to marine wildlife populations (Macfadyen *et al.*, 2009; Richardson *et al.*, 2017). The most recent concerns include discovering micro particles of plastics in the digestion system of fish (Markic *et al.*, 2018). Indonesia has committed to combat marine debris through a National Plan of Action (NPOA), as detailed in the appendix of Presidential Regulation No. 83/2018. However, the Government of Indonesia requires a quantitative assessment of the situation to make informed decisions about measures to mitigate marine pollution issues. Achieving the implementation of Indonesia's NPOA would be a highly significant addition to the substantial efforts of other global nations in marine pollution mitigation, e.g., the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 and implemented with the 2017 Guidelines for the Implementation of MARPOL Annex V (Zou and Zhang, 2017; Schmaltz *et al.*, 2020).

Similarly, information on the amount and types of marine wastes, particularly plastic materials, is essential to Cilacap Oceanic Fishing Port (COFP) managers in addressing the problem of marine disposals made by fishing boats at sea. As stipulated in the Regulation of Ministry of Marine Affairs and Fisheries No. 3/2013 article 28 (MMAF, 2013), fishing port management in Indonesia is responsible for implementing marine environment protection, that is, supervising boat captains and crews to prevent and mitigate marine pollution during fishing operations. The regulations also state that inspection of pollution prevention equipment on any boat requesting a port clearance should be carried out by the port management. In 2020, COFP accommodated approximately 4,500 units of fishing boats of various sizes and gear types. Among them were 771 units of motorized inboard fishing boats consisting of 171 units of longliners, 317 units of gillnetters, 219 units of seine net boats, 20 units of handliners, 8 units of

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purse seiners, and 36 units of squid fishing boats (PPS Cilacap, 2020). Combined with motorized outboard fishing boats, these COFP-based fishing fleets directly employed about 33,000 fishers. Such a large number of fishing boats may contribute a significant amount of marine debris to the Indian Ocean, especially when fishers hold insufficient concerns about the environmental consequences of disposing waste at sea.

This study was done to estimate the amount of plastics and other waste disposed of by Cilacap-based longline and gillnet fishing boats operating in the Indian Ocean, measured per boat and fishing trip. Most of these fishing boats operated off southern coast of Java that includes the Exclusive Economic Zone of Indonesia (Widodo *et al*., 2011; 2014; Sutono *et al.,* 2020). This study provides the COFP management with some basic information for implementing measures to reduce the marine disposals from their fishing boats and to establish appropriate waste management at the port.

## Materials and Methods

Data on the supplies uploaded to boats at COFP and wastes returned from those boats to the port were collected from observations and interviews with boat managers/owners or captains/crew from August to November 2019. This study focused on the fishing boats operating gillnets and longlines for tuna offshore, in the size range of 20 to 90 GT (Dharmadi *et al*., 2010; Prisantoso *et al*., 2010; Saputra *et al*., 2011; Widodo *et al*., 2014; Lestari *et al*., 2017). Data were collected from 89 fishing boats consisting of 54 gillnetters and 35 longliners that covered 4 groups (Table 1.). The boats were selected based on their arrival at the berth or their presence in the port.

The amount of supplies uploaded for 40 of the boats were obtained from direct observations at the port and interviews with the captains or crew of the sampled boats, port management officers, and suppliers of materials or goods. For another 49 boats surveyed that had been berthed in port, the data on supplies were collected by interviews with boat managers/owners. The wastes were classified into several categories on the basis of physical properties (i.e., solid and liquid waste) and chemical properties (i.e., organic and nonorganic materials). The wastes were also classed according to purpose; human consumable materials (foods, beverages, etc.), machinery materials (fuel, oil, machinery spare parts), and fishing gear.

The amount of consumable supplies required by a fishing boat per trip was determined by at least two input factors, that are, technical characteristics and labor input. The first factor was determined by the duration of a fishing trip and the type of fishing boat, while the second factor was determined by the duration of the fishing trip and the number of crew on board. Estimates of the amount of wastes disposed of at sea by each boat were based on the difference between the amount (pieces) or weight (g) of potential waste that could be generated from supplies uploaded to the boat in port before sailing and the volume of waste returned to the port after the trip (Irawan *et al*., 2020). If a boat did not return to port with any waste from the uploaded supplies, the boat was considered to have disposed of all such items at sea. The potential amount of the waste disposed of was determined for each type of uploaded supplies.

Since most of the wastes were packaging materials, this study used packaging units as the basis for calculating the amount of waste. Each packaging unit was defined a complete box or a bag or a wrap, not fractions or parts of them. In the case of cigarettes, a big carton box of cigarretes contained 100 packs @ 16 pieces of cigarettes, therefore, the potential wastes generated from one big carton of cigarettes consisted of 1 piece of big carton box, 100 pieces of cigarettes carton packs and 1600 cigarette butts. In the case of instant noodles, a carton box of 40 packs of noodles could generate 40 pieces of plastic wrap and 80 pieces of plastic sachets. The samples of packaging units were weighed using two types of balance at the laboratory. Light - small sized packaging units were weighed using an analytic scale of a capacity of 400 g with a precision of 0.001 g. Larger packaging units (such as carton boxes) were folded into smaller size and placed on a digital scale of a capacity of 30 kg with a precision of 0,1 g.

**Table 1**. Number of samples of fishing boats for calculation of estimates of waste disposed of at sea

| Boat size groups | Gillnetters (units) | Longliners (units) | Total (units) |
|---|---|---|---|
| 20 < GT ≤ 30 | 15 | 14 | 29 |
| 30 < GT ≤ 50 | 24 | 12 | 36 |
| 50 < GT ≤70 | 11 | 6 | 17 |
| 70 < GT ≤ 90 | 4 | 3 | 7 |
| Total | 54 | 35 | 89 |

When data on supplies for some boats were not fully reported or incomplete because the boats were resupplied at sea by other boats, estimates of the volume of the disposed waste items were estimated from an empirical formula describing linear relationships between the volume of the wastes and the volume of labor input measured in man.days. This approach was applied to large fishing boats (i.e., 50 < GT ≤ 90). Therefore, the volume of waste produced per labor input (*W*), both in weight (g) or amount (piece), by large groups of fishing boats was estimated from an empirical formula describing a linear relationship between the volume of waste and the labor input for small-sized fishing boats (20 < GT ≤ 50):

$$W_{i,j} = a + bL_{i,j} \quad (1)$$

Note: a= a constant; b= a coefficient; L= labor input = man.days; i = size group of fishing boat; j= type of fishing gear.

The *b* coefficient represents the amount of waste produced by one person per day. The formula was determined by regressing the volume of the waste on the volume of labor input with a = 0; hence the formula becomes:

$$W_{i,j} = bL_{i,j} \quad (2)$$

Estimation of waste materials was made for the weight (g) and amount (pieces) of carton and plastics materials based on the minimum and maximum labor input for each boat size group and gear type. The minimum labor input and the maximum labor input were calculated as:

$$L_{i,j} = C\,[\overline{D}._{i,j} \pm t_{0.025(n-1)} \frac{s_{i,j}}{\sqrt{n_{i,j}}}] \quad (3)$$

Note: *C*= number of fishing crews; $\overline{D}$ = average trip duration (day); *s* = standard deviation of $D$; n= number of boat samples; $t_{0.025}$ = t value for α = 0.025 at the degree of freedom $n - 1$; *i*= size group of fishing boat; j= type of fishing gear.

The total annual amount of waste (*AW*) disposed of by a type of fishing boat, with the associated behaviours of the respective fishers, was estimated by applying the following formula (4) :

$$AW_{i,j} = \sum_{j=1}^{g}\sum_{i=1}^{n} B_{i,j}T_{i,j}W_{i,j} \quad (4)$$

Note: *j*= type of fishing gear, *g*: total number of type of fishing gear; *i*= fishing boat size group; *n*= number of fishing boat size group; *B*= number of fishing boat; *T*= number of fishing trips per year; *W*= volume of waste per trip (g or pieces).

## Results and Discussion

### *Duration of fishing trips and number of crews per trip*

The number of fishing crews per fishing boat in the sampled boats ranged from 8 to 13 people. Unsurprisingly, in general, larger boats had more crew than the smaller boats, but no significant difference in the size of crew was identified between the boat size groups of 20 < GT ≤ 30 and 70 < GT ≤ 90 (Figure 1A). The gillnet boats carried fewer crew than the longline boats for both the 20 < GT ≤ 30 and 50 < GT ≤ 70 size groups. The number of crews carried by the gillnet and longline boats for the largest boat group was the same, i.e., 12 persons. The duration of fishing trips varied among the size groups of the boats, but the larger boats tended to have longer trips (Figure 1B). The fishing trip duration of the gillnet boats of sizes 20 < GT ≤ 30 and 30 < GT ≤ 50 appeared to be significantly shorter than the trips of longline boats of any size group and those of the gillnet boats of sizes 50 < GT ≤ 70 and 70 < GT ≤ 90.

Since the number of crews per boat and the duration of the trip was higher for the larger boats, the amount of labor input deployed in each fishing trip was also higher for the larger boats (Figure 2 and Figure 3.). On average, the labor input for the gillnet boats of sizes 20 < GT ≤ 50 and 70 < GT ≤ 90 was 263±40.8 (SD, man.days) and 960±196.0 (SD, man.days), respectively. Meanwhile, the labor input

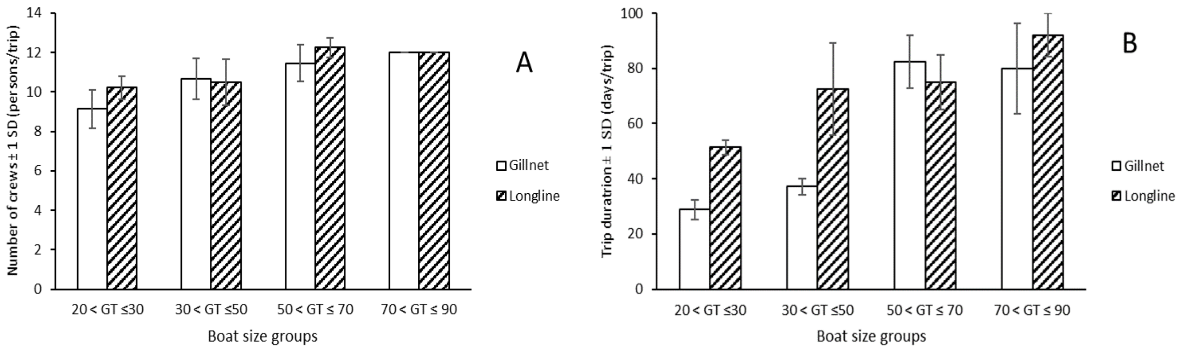


**Figure 1**. The average number of crews per fishing boat (persons, A) and trip duration (days, B) by boat size groups for gillnet and longline fishing boats operated from Cilacap Oceanic Fishing Port, identified in August-November 2019.

Table 2. Type of supplies uploaded by fishing boats at Cilacap Oceanic Fishing Port and wastes generated during their fishing trips.

| Types of consumables | Packaging units | Wastes from the supplies |
|---|---|---|
| **Human consumables:** | | |
| Instant noodle | a carton box of 40 packs of noodles | carton boxes, plastic wraps, and plastic sachets |
| Rice | a plastic sack of 25 kg | plastic sacks |
| Instant coffee | a multipack of 10 sachets | instant coffee plastic sachet |
| Ground coffee | a plastic bag of 2 kg | coffee plastic bags |
| Snacks | pack of snacks | plastic wraps of biscuits |
| Shampoo | a multipack of 10 sachets | plastic sachets |
| Soap bar | a soap bar | soap bar wraps |
| Cigarette – filter | a large carton box containing 100 packs of 16 pieces of cigarettes | large carton boxes, cigarette packs, cigarette butts with filter |
| Clove cigarettes | a large carton box containing 100 packs of 16 pieces of cigarettes | large carton boxes, cigarette packs, cigarette butts |
| Cooking oil | a bag of 2 liters | plastic bags |
| Fruits and vegetables | kg | fruits and vegetables |
| Drinking water | a plastic gallon bottle of 19 liters | none |
| **Non-human consumables:** | | |
| Fish baits | a styrofoam box | none |
| Diesel oil | a drum of 200 liters | none |
| Engine oil | a drum of 200 liters or jerrycans | used oil |
| Fishing gear | a package of bucket | fragments of fishing gear materials |

for longline boats of sizes 20 < GT ≤ 50 and 70 < GT ≤ 90 was 524±35.0 (SD, man.days) and 1104±94.5 (SD, man.days), respectively.

*Boat supplies and wastes*

In general, there were at least 16 types of supplies uploaded at the fishing port (Table 2.). Both gillnet and longline boats carried supplies for human consumption in the form of ready-to-eat foods (e.g., instant noodles), rice, vegetables, coffee, and snacks (crackers and biscuits). The snacks provided per fishing trip by boat owners/managers consisted of 40-50 packs of cracker biscuits and 2-12 packs of other snacks for gillnet boats and 50-60 packs of cracker biscuits and 4-12 packs of other snacks for longline fishing boats. Other supplies included cooking oil, other necessities needed by the crew (e.g., cigarettes), and technical consumables (i.e., fish baits, diesel oil, and engine oil). The amount of supplied soap bars per fishing trip ranged from 20-60 pieces for gillnet boats and 24-60 pieces for longline fishing boats. Supplies were generally larger in fishing trips with more significant labor input (Figures 4, 5, and 6.). The supplies came in various forms and in different packaging sizes. Instant noodles and cigarettes were in large packages that contained some smaller packages. The snacks, coffee, cigarettes, soap bars and shampoo came in single packages or multipacks consisting of many smaller packages. Small plastic sachets were standard. Drinking water was stored in 19-liter plastic gallon bottles. Diesel oils were generally stored in cylindrical steel drums of 200 liters, while engine oil was stored in drums or jerrycans. The fish baits were stored in styrofoam boxes in the tuna longline boats, housed inside the fish holds of the boats.

The amount of supplies recorded as loaded for some fishing trips by large boats may not have been sufficient to sustain the crews and their boat for the entire trip. For instant noodles and rice, the amount of supplies uploaded to the port for gillnet and longline trips of more than 700 man.days were the same as the supplies for fishing trips of 700 man.days (Figure 4.). The same patterns were also identified for two other human consumables: drinking water and cigarettes (Figure 5.), and for diesel oil and engine oil (Figure 6.). As confirmed by respondents, fishing boats engaged in the longer duration fishing trips (i.e., with labor input greater than 700 man.days) are commonly resupplied at sea by other boats under the same management.

The wastes were mainly packaging materials from the supplies for human consumption. These can be distinguished into two categories: cartons and plastics. These packaging materials were rarely observed as waste on boats returning to port because carton/paper and plastic packaging were generally disposed of at sea. Such disposals were confirmed by some of the captains/crew/boat managers.

The exceptions were plastic bags that house rice and drinking water containers, i.e. plastic gallon bottles. Boat crews also retained packaging and other

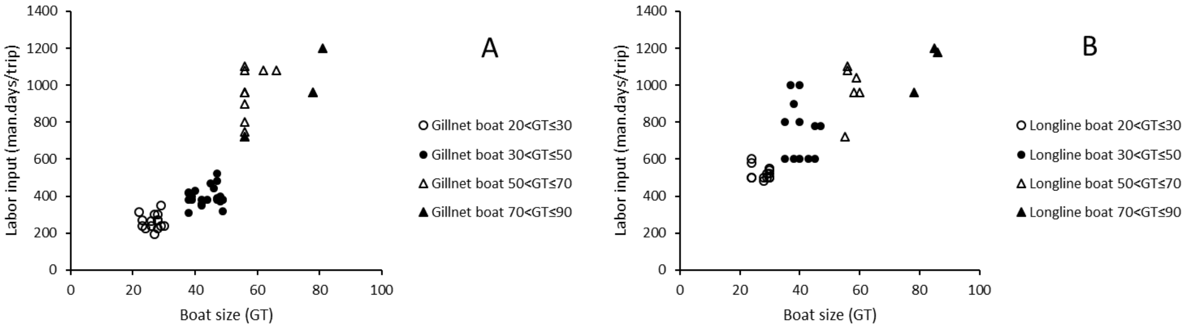


Figure 2. The amount of labor input (man.days.trip$^{-1}$) in fishing operations of Cilacap-based gillnetters (57 trips, A) and longliners (42 trips, B) in August - November 2019 by boat size groups and gear types.

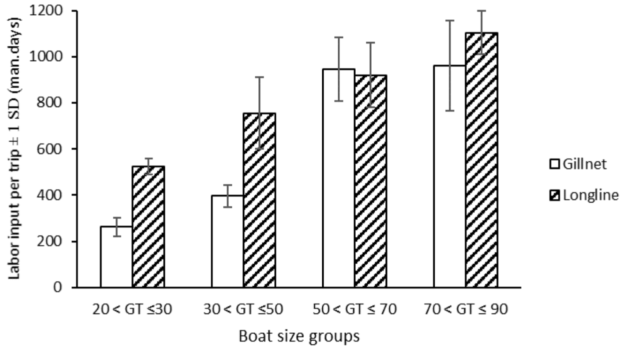


Figure 3. The average amount of labor input (man.days) per fishing trip by boat size groups for gillnet and longline boats operated from Cilacap Oceanic Fishing Port, identified in August-November 2019.

items with economic value or potential re-usability. As examples, used-toothbrushes, fishing gear materials, and used-engine oils were retained, with the latter sold to used-oil collectors at the port.

The styrofoam boxes were retained and reused for the subsequent fishing trips. The 89 fishing boats surveyed in this study, without including waste generated from consumable goods resupplied at sea, contributed a total of at least 642.1 kg of carton materials and 161.7 kg of plastic materials as waste to the marine environment. The proportion of plastic materials disposed of by the longline and the gillnet boats appeared similar, i.e., an average of 20% of the total weight (Figure 7A.). In terms of the number of wastes measured in pieces, the two types of boat together contributed at least 36,802 pieces of carton materials (various sizes) and 392,869 pieces of plastic materials (various sizes). The numerical proportion of plastic materials also appeared to be similar between the longline and the gillnet fishing boats, i.e., an average of 91% of total weight (Figure 7B.). Cigarette filters, considered harmful to the marine environment (Pasternak *et al.*, 2017, Epperson *et al.*, 2021), constituted 66% of plastic materials (260,800 pieces). Plastic wraps of instant noodles were also significant, making up 23% of the total amount of plastic wastes, i.e., 89,280 pieces. These two plastic items contributed almost 90% of the total plastic waste disposed of at sea by fishing fleets.

Regarding weight, the total estimate of cigarette filters was 70.4 kg, while that of instant noodles wraps was 129.5 kg. Regarding the quantity measured in pieces, plastic materials were relatively consistent as the significant component of waste disposed of by fishing boats for each size group and gear type (91.4% of total waste consisting of plastic and carton materials). In terms of weight, plastic materials constituted about 20% of the total waste.

### *Estimates of marine waste disposals made by Cilacap-based fishing fleets*

The weights and amount (in pieces) of carton and plastic materials disposed of at sea per trip appeared to be higher from the longline than from the gillnet fishing boats of size groups of 20 < GT ≤ 30 and 30 < GT ≤ 50 GT (Figure 7 and Figure 8.). This study was unable to directly estimate marine waste disposals from fishing boat operations of size groups

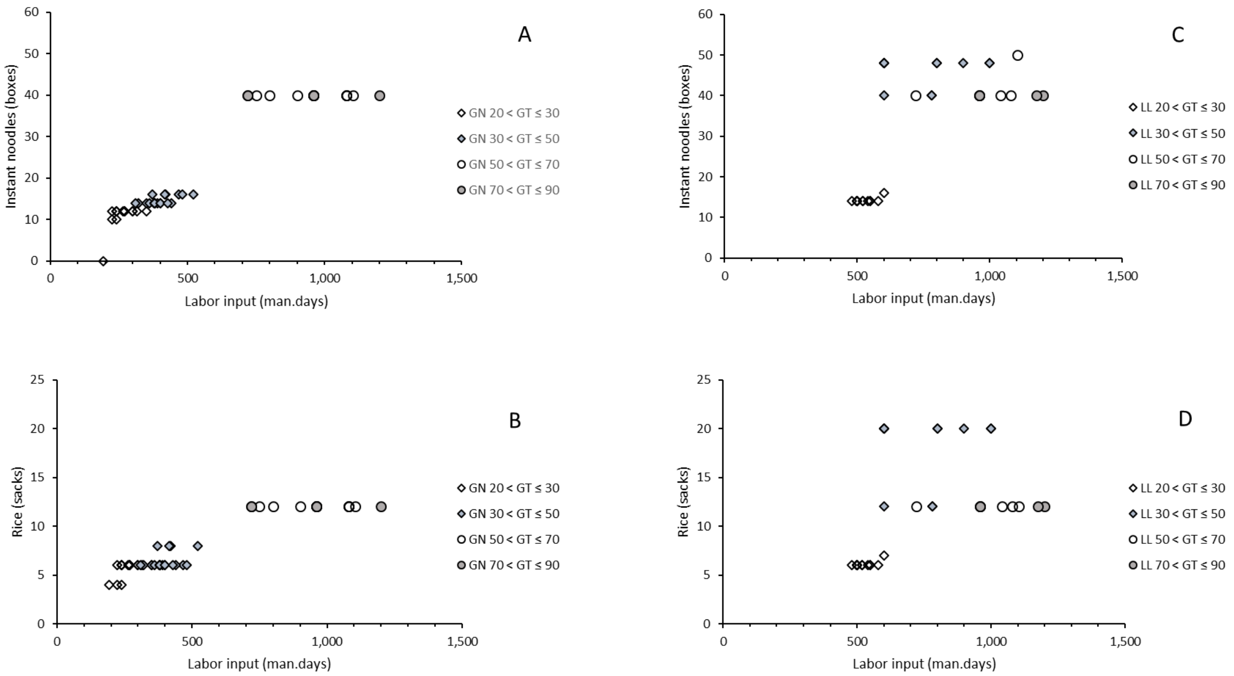


**Figure 4.** The amount of instant noodles supplies (A and C, boxes of 40 pieces) and rice (B and D, 25 kg sacks) for the fishing operations of Cilacap-based gillnetters (54 trips, GN) and longliners (35 trips, LL) by labor input in August - November 2019, by boat size groups and gear types. Notes: without wastes generated from consumable goods resupplied at sea.

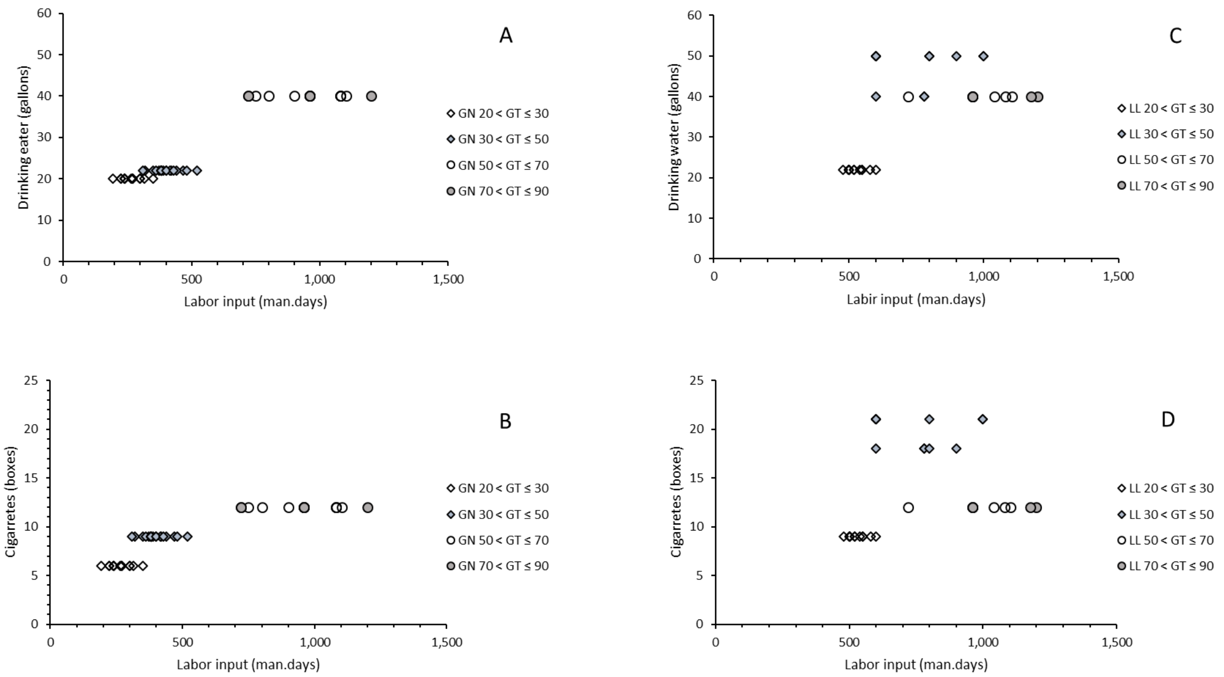


**Figure 5.** The amount of supplies of drinking water (A and C, gallons) and cigarettes (B and D, boxes of 100 packs @ 16 pieces) for fishing operations of Cilacap-based gillnetters (54 trips, GN) and longliners (35 trips, LL) by labor input in August - November 2019 by boat size groups and gear types. Note: without waste generated from consumable goods resupplied at sea.

of 50 < GT ≤ 70 and 70 < GT ≤ 90 because the supplies reported by the respondents were limited to the first shipment of the supplies (that is, those uploaded to port). The operation of gillnet and longline fishing boats from the size group of 20 < GT ≤ 30 GT and 30 < GT ≤ 50 GT were used to estimate the waste from larger fishing boats that had longer trip durations and larger labor inputs (Figure 9.). The slope (*b*) for each linear equation on the figures represents the quantity of waste generated by a crew per day or man.day, a unit of labor input. Table 3 provides the calculation results of the waste generated per trip by the fishing boats of each size group for each gear type. The amounts of carton wastes disposed of at sea by the surveyed fishing boats were 3.5-19.4 kg.boat$^{-1}$.trip$^{-1}$or 203-1,140 pieces.boat$^{-1}$.trip$^{-1}$ whereas the amounts of plastic wastes disposed of were 0.8-4.4 kg.boat$^{-1}$.trip$^{-1}$or 2,143-12,024 pieces.boat$^{-1}$.trip$^{-1}$.

At the time of data collection, the COFP had registered 80 gillnet boats and 132 longline boats of 20 < GT ≤ 30 and 13 longline boats of 30 < GT ≤ 50 (PPS Cilacap, 2020). By consulting Table 3, these boats' estimates of cartons disposed of at sea were 9,423 – 11,494 kg.y$^{-1}$. Cartons or corrugated fibreboards are made of biodegradable materials from wood (Pereira *et al*., 2020). Therefore, they are considered less harmful to the marine environment, and their disposals at sea have received less attention than plastic-based waste (Beaumont *et al*., 2019).

**Table 3**. Estimates of the minimum and maximum volumes of waste disposal per trip by Cilacap-based fishing boats by gear types and size groups, based on boat supplies proportional to the number of crew and duration of fishing trips.

| Types of waste material | Labor input (man.day) | Gillnet fishing boats | | | | Longline fishing boats | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 20-30 GT | 30-50 GT | 50-70 GT | 70-90 GT | 20-30 GT | 30-50 GT | 50-70 GT | 70-90 GT |
| Cartons (kg) | min | 3.5 | 5.1 | 12.0 | 9.8 | 7.1 | 8.9 | 11.8 | 12.4 |
| | max | 4.4 | 6.0 | 15.2 | 17.6 | 8.3 | 13.0 | 17.0 | 19.4 |
| Cartons (pieces) | min | 203 | 302 | 705 | 579 | 419 | 522 | 697 | 731 |
| | max | 259 | 355 | 896 | 1037 | 489 | 768 | 1003 | 1140 |
| Plastics (kg) | min | 0.8 | 1.2 | 2.7 | 2.2 | 1.6 | 2.0 | 2.7 | 2.8 |
| | max | 1.0 | 1.4 | 3.4 | 4.0 | 1.9 | 2.9 | 3.8 | 4.4 |
| Plastics (pieces) | Min | 2,143 | 3,186 | 7,434 | 6,106 | 4,423 | 5,509 | 7,349 | 7,714 |
| | Max | 2,731 | 3,745 | 9,453 | 10,934 | 5,162 | 8,096 | 10,576 | 12,024 |

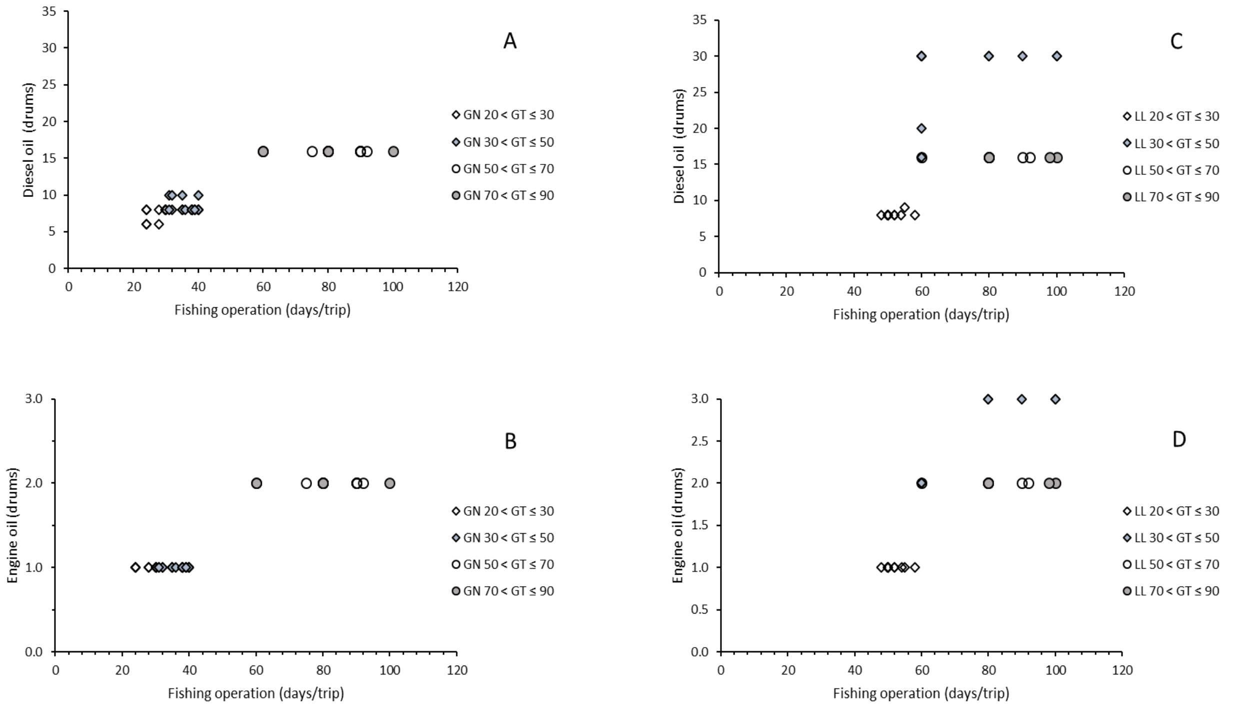


**Figure 6.** The amount of diesel oil supplies (A and C, drums of 200 liters) and engine oil (B and D, drums of 200 liters) by the duration of the fishing operations of Cilacap-based gillnetters (54 trips, GN) and longliners (35 trips, LL) in August - November 2019 by boat size groups and gear types.

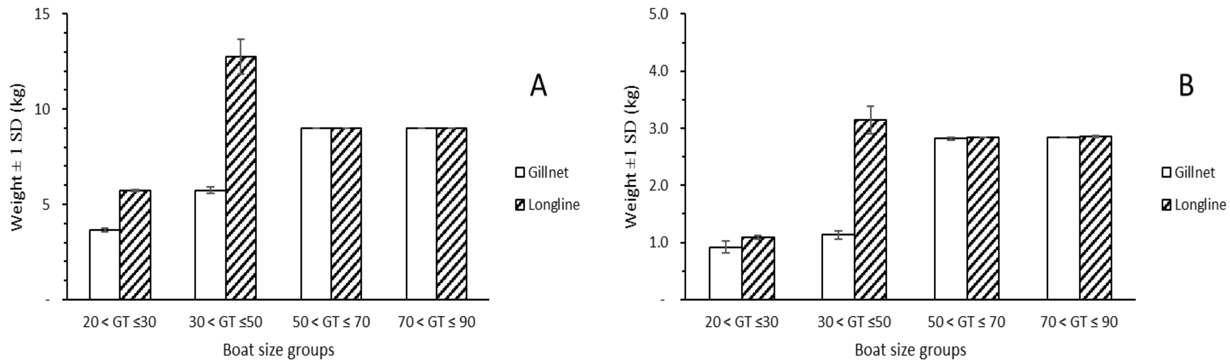


**Figure 7.** The estimated weight of waste generated in fishing operations of Cilacap-based gillnetters (54 trips, GN) and longliners (35 trips, LL) in August - November 2019 by type of materials, cartons (A) and plastics (B). Notes: The wastes from the two largest boat groups for both gear types were minimum estimates, not including waste generated from consumable goods resupplied at sea.

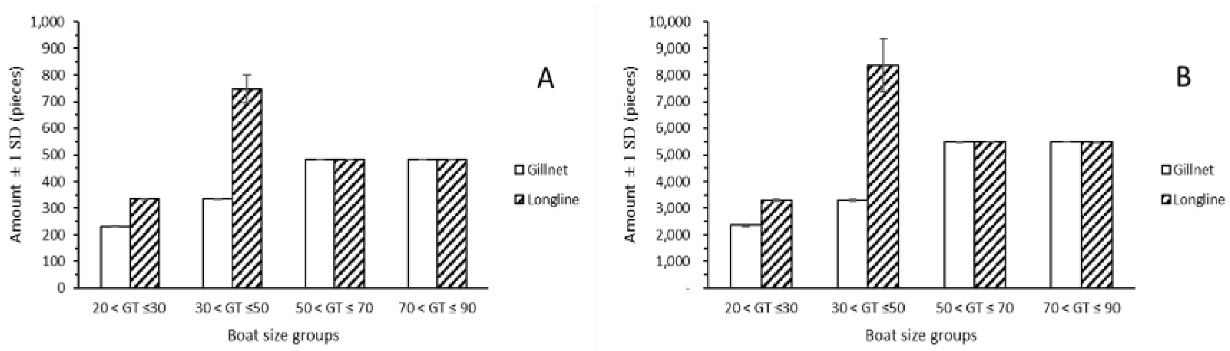


**Figure 8.** The estimated amount (pieces) of waste generated in fishing operations of Cilacap-based gillnetters (54 trips, GN) and longliners (35 trips, LL) in August - November 2019 by type of materials, cartons (A) and plastics (B). Notes: the wastes shown for the two largest boat size groups for both gear types are minimum estimates.

However, some cartons were made with chemicals that improve their resistance to water or moisture. In addition, layers of polyethylene film and aluminum foils are commonly used to strengthen the structure of carton packages and protect the surface from water splash. Therefore, it is suggested that the boat crews return the cartons to port for reuse, recycling or for environmentally appropriate means of disposal on the land.

The plastic wastes generated by the registered boats during their trips are generally of a more manageable amount than the cartons, i.e., less than 5 $kg.boat^{-1}.trip^{-1}$ (Table 3.). Therefore, concerning the existing regulations, the port management order requires all captains and fishing crews to retain plastic wastes on board and bring them back to the port. It is recommended that a monitoring program on such wastes be added to regular port activities. The COFP management can use the figures in Table 3 as a reference for assessing compliance of a boat's captain and crew to the regulations at the boat's return to port. Furthermore, COFP management can consider the level of compliance when granting or denying that boat's owner/captain port clearance for subsequent fishing trips.

By consulting Table 3, the estimate of the amount of plastic wastes disposed of at sea by the gillnet boats was 746 - 951 $kg.y^{-1}$ or 2,056,955 - 2,622,069 $pieces.y^{-1}$. The estimate of plastic waste disposed of by the 132 small longline boats was 1,271-1,483 $kg.y^{-1}$ or 3,503,196-4,088,340 $pieces.y^{-1}$, while the estimate for the 13 large longline boats was 104 -153 $kg.y^{-1}$ or 286,451- 421,005 $pieces.y^{-1}$. The estimated total amount of wastes disposed of at sea by these three boat types reveals their major contribution to marine pollution in the Indian Ocean, i.e., 2,120-2,587 $kg.y^{-1}$ or 5,846,602-7,131,414 pieces of plastic $materials.y^{-1}$. A more detailed study and a more extensive assessment to include all the fishing fleets at COFP would undoubtedly reveal higher estimates of disposed of wastes at sea that need to be addressed by the COFP management. An important component of addressing this issue is for COFP management to develop a strategy for receiving and dealing with the waste materials returned on boats to port.

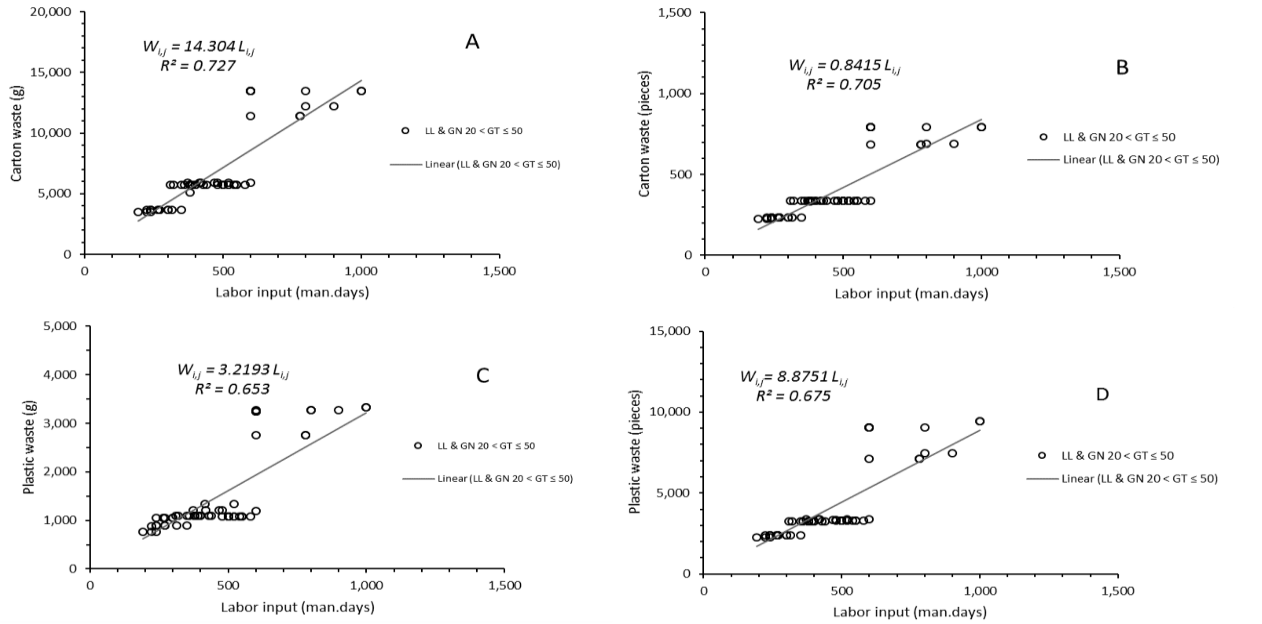


**Figure 9.** Coefficients of correlation between the volume of disposed waste (*W*) and the volume of labor input (*L*) by type of waste materials for the weight (g) and amount (pieces). A, B: carton waste, C, D: plastic waste. GN: gillnet fishing boats. LL: longline fishing boats.

This study presents quantitative information on the disposal of waste from tuna fishing boats that operate from Cilacap into the Indian Ocean. To produce a broader understanding of the scale of waste disposal at sea by Indonesia's fishing boats, similar studies could be done for the boats that operate from other major tuna landing sites, including those along the western coast of Sumatera, the southern coasts of Java and Nusa Tenggara. Such studies may reveal different estimates of the amounts of waste disposed of and potentially employ different formulae for the quantifications. Collectively, these studies will contribute to the implementation of the NPOA, particularly in building governance around marine pollution and providing options for imposing at-port law enforcement and for improving land-based infrastructure to handle wastes returned to port. An appropriate response of the Government of Indonesia to the findings of such studies will aid in mitigating marine pollution, not only in Indonesia's in-shore coastal waters, its archipelagic waters but also in the less observed far offshore waters within Indonesia's Exclusive Economic Zone and beyond. Indonesia's mitigation measures will also assist other countries in the Indian Ocean and those more broadly to combat marine pollution (Duhec *et al.*, 2015; Hardesty *et al.*, 2021).

## Conclusion

The gillnet and longline boats from COFP disposed of cartons and plastic wastes at sea. The fishing crews retained their used water containers, plastic rice sacks, fishing gear fragments, and used engine oils. Styrofoam boxes were also retained for reuse. Instant noodles, plastic wraps, and cigarette filters were two significant components of plastic waste. The amounts of plastic waste disposed were 0.8-4.4 $kg.boat^{-1}$ or 2,143-12,024 $pieces.boat^{-1}$ while the disposed cartons were 3.5-19.4 $kg.boat^{-1}$ or 203-1,104 $pieces.boat^{-1}$. The amount of plastic waste from the boats was generally manageable, less than 5 $kg.boat^{-1}.trip^{-1}$. COFP management should make a dedicated effort to ensure that captains and fishing crews retain their plastic waste for return to port. Their compliance with such regulation must be considered when granting (or denying) port clearance for their future fishing trips. To assist in engendering such a change in fishers' behavior, port management must improve the existing waste handling system in the port.

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