Short Note

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*Short Note*

# Microplastics and morphometrics relationship in coastal fish

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**ABSTRACT.** This study found microplastics in selected commercial fish species in Governor Generoso, Davao Oriental. A total of 80 samples of fish were taken from the nearshore area (0-5 km) and from the farshore area (6-15 km). The fish samples were taken by a handliner (with GPS tracker), then dissected in the laboratory to remove its gut. Microscope analysis of gut contents showed 4 microplastic fibers found in the 40 fish samples collected from 0-5 km and only 2 microplastic fibers in the 6-15 km, among the 80 fish samples collected. Moreover, fish morphometrics were not related to the number of microplastic ingestion, but to mouth size for fish from the nearshore (0-5 km) and pectoral fin for fish from the farshore (6-15 km). While this study is not conclusive given that only 6 microplastics were found, it supports the thesis that nearshore areas are sink of microplastics.

**Keywords:** fishgut; fish ingestion; Governor Generoso; marine fish; microplastics

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Plastic waste had been rapidly accumulating in the marine environment, causing pollution in the ocean and creating potential hazard to marine animals and to humans. Several studies have already shown that the presence of small plastic debris, i.e. microplastics, in fish and shellfish consumed by humans could affect human health (Bonanno and Orlando-Bonaca 2018). Plastics have been found inside the stomach of various marine species that blocked their digestive systems leading to starvation or death (Abreo *et al.*, 2016a, 2016b). According to Derraik (2002), plastic debris have been reported in the stomachs of over 180 species, including fish, turtles, marine mammals and birds. In recent decades, the composition of marine debris changed from being dominated by natural biodegradable materials like seaweed, shells, pumice, and wood to being dominated by floating plastic particles either partially degraded or intact (Thiele *et al.*, 2021). In addition, experimental research has also demonstrated the possibility of trophic transmission of microplastics where intake of microplastics may result in anatomical and functional alterations in the digestive tracts of animals, affecting their nutrition and development (Bhuyan, 2022). Numerous studies have been conducted to show that microplastics are a hazard to human health through fish consumption (Zhao *et al.*, 2024; Bersaldo *et al.*, 2024).

Moreover, studies have shown that microplastic particles are abundant in marine fishes perhaps because of mistaken prey or trophic transfer from prey to predator with the carnivores and large predatory fish ingesting more microplastics (Boerger *et al.*, 2010; Lusher *et al.*, 2013; Markic *et al.*, 2018). Plastic ingestion by carnivorous fish was approximately 3.5 times higher than that of herbivorous fish over a 24-hour period, according to Markic *et al.*, (2018). Pelagic fishes had more microplastics than demersal fishes, but there were no significant differences when examined and compared together (Lusher *et al.*, 2013; Rummel *et al.*, 2016).

Despite being one of the highest contributors of plastic to the marine environment, there is little scientific research on microplastic ingestion by marine fish in the Philippines (Jambeck *et al.*, 2015; Lebreton *et al.*, 2017; Bersaldo *et al.*, 2024). There is a scarcity of information regarding the actual ingestion of microplastics by fish in marine aquatic environment (Katzenberger, 2015). To conduct investigations and document the prevalence of microplastics in fish, we designed our sampling to collect fish living in

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nearshore (0-5 km) and far shore area (6-15 km). Fish was collected using a simple hook and line and GPS trackers were used to document boat movement in the water.

This study was conducted in the coastal area of Barangay Tibanban where a number of fishers live. Tibanban is situated in the municipality of Governor Generoso in the Province of Davao Oriental, laying 6.6340° North Latitude and 126.0981° East Longitude (Figure 1). The coastal area of this barangay is known to be the municipality's richest fishing ground.

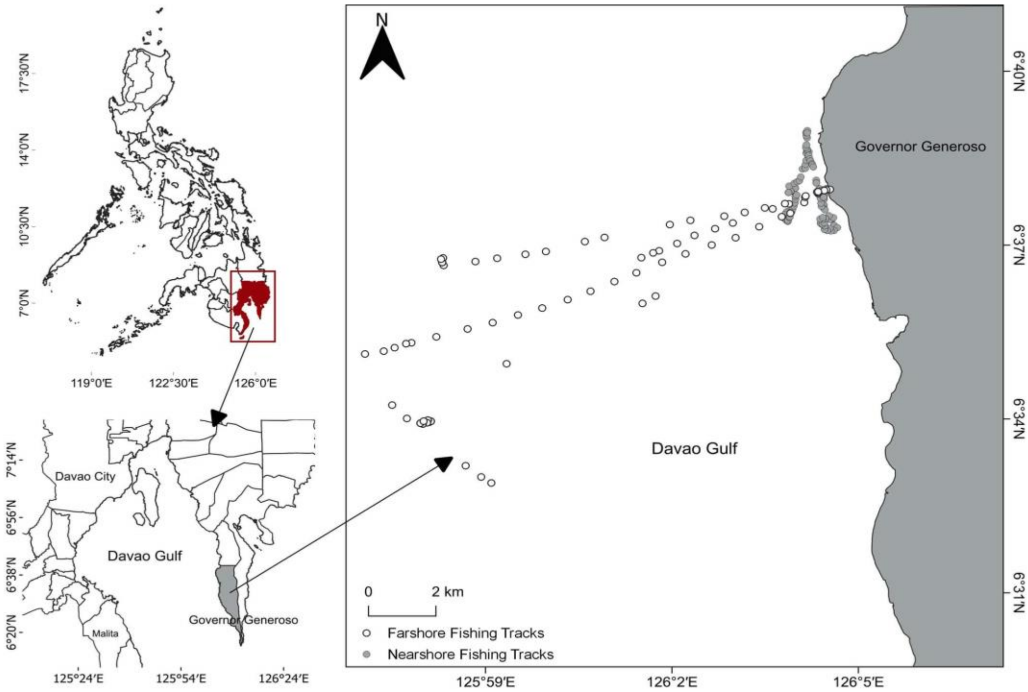


**Figure 1.** Map of the study area in Tibanban, Governor Generoso, Davao Oriental and the GPS tracks of the fishers, both nearshore and farshore areas.

In this study, fish were collected by simple hook-and-line fishers near the shore at 0-5 km and another fisher who fished at 6 to 15 km. Both fishers were given GPS trackers and fished for three days. Trackers provided their real time locations that was later shown on a map. Fish caught by fishers were immediately placed inside an icebox with crushed ice and degutted in the laboratory of Regional Integrated Coastal Resources Management Center of the university (RIC-XI). Reports from literature mentioned that some fish species regurgitate their stomach contents making it essential to keep fish samples in crushed ice during the fishing. Fish taxonomy was later identified using nomenclature from Fishbase (Froese and Pauly 2024) and all basic measurements were recorded, including length, from mouth to central point of caudal fin (mm), body weight (g) and girth, the maximum distance between dorsal and ventral sides (n=80).

Before use, all apparatus and equipment were cleaned with alcohol and inspected under microscopes for contamination (Boerger et al. 2010; Davison and Asch 2011). The following approach was based on a standard protocol for dissecting the gastrointestinal tract of fish devised by the Civic Laboratory for Environmental Action Research (civiclaboratory.nl). Gastrointestinal tracts that were not immediately examined were frozen and then thawed at room temperature for microplastics identification of microplastic fibers. Sometimes, samples were preserved by using plastic-friendly fixatives (e.g., formalin). According to Welden (2017), the period between sampling collection and the preservation of the fish was important to avoid physical damage. Microplastics were extracted from the fish by dissection of the gastrointestinal tract and classified for size, shape, and color under an optical stereomicroscope and forceps following Choy and Drazen (2013) and Lusher et al. (2013). The main criteria for determining whether an item was a microplastic were its shape and color. Identification of source, kind, form, degradation stage, and color of particles from Hidalgo-Ruz et al. (2012) was used to define visually sorted microplastics. To avoid including airborne contamination, all utensils were washed carefully but also during the examination, a clean petridish was kept inside the room of examination and checked for fiber contamination from time to time (Woodal et al.,

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2015). In order to relate the various fish morphometrics to the microplastic count, we used logistic regression to explore how the various explanatory variables can be related to the count of fibers.

There were 40 fish samples that were caught from 0-5 km and another 40 fish samples that were also caught from 6-15 km in Tibanban, Governor Generoso, Davao Oriental (Table 1). The fish samples from 0-5 km distance comprised of eight parrotfish (*Scarus rivulatus*), six samples of fusilier (*Caesionida*e), four surgeon fish (*Acanthuridae*), five samples of bigeye snapper (*Lutjanus lutjanus*) and one sample of kawakawa (*Euthynnus affinnis*) followed by 11 samples of monocle bream (*Scolopsis ciliata*) and three samples of grouper (*Epinephelinae*) and another four samples of black jack (*Caranx lugubris*).

For the fish samples caught from 6-15 km from the shore, three samples of roundscad (*Decapterus macrosoma*) were caught followed by 17 samples of bigeye scad (*Selar crumenophthalmus*) and six samples of frigate tuna (*Auxis thazard*) and another three samples of bullet tuna (*Auxis rochei*) and four samples of Indian mackerel (*Rastrelliger kanagurta*) then four samples of yellowfin tuna (*Thunnus albacares*) followed by three samples of pomfret (*Brama japonica*) (see Table 1).

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**Table 1.** Average morphometry of fish caught from nearshore (0-5 km) and farshore (6-15 km) in Tibanban, Governor Generoso, Davao Oriental, Philippines.

| Local Name | Scientific Name | Count | Distance (km) | Standard Length (cm) | Width (cm) | Weight (g) | Mouth (cm) | Eyes diameter (cm) | Dorsal Fin (cm) | Pelvic Fin (cm) | Pectoral Fin (cm) | Caudal Fin (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monocle bream | *Scolopsis ciliata* | 11 | nearshore | 15.89 | 4.06 | 0.07 | 0.57 | 1.82 | 1.5 | 2.19 | 2.9 | 2.44 |
| Grouper | *Epinephelinae* | 3 | nearshore | 14.56 | 4.23 | 0.05 | 0.99 | 1.69 | 2.2 | 1.16 | 3.38 | 1.09 |
| Bigeye snapper | *Lutjraus lutjanus* | 5 | nearshore | 24.06 | 7.38 | 4.12 | 0.56 | 2.05 | 7.26 | 0.69 | 2 | 3.25 |
| Fusilier | *Caesionidae* | 6 | nearshore | 21.68 | 5.43 | 1.66 | 0.79 | 1.8 | 2.51 | 1.44 | 2.94 | 2.88 |
| Surgeon fish | *Acanthuridae* | 4 | nearshore | 25.73 | 7.66 | 3.71 | 0.44 | 1.03 | 2.32 | 1.41 | 1.42 | 3.26 |
| Parrot fish | *Scarus rivulatus* | 8 | nearshore | 26.86 | 6.83 | 3.49 | 0.46 | 0.56 | 6.11 | 1.98 | 1.81 | 2.44 |
| Black jack | *Caranx lugubris* | 4 | nearshore | 21.39 | 8.23 | 6.91 | 0.31 | 1.34 | 1.26 | 1.42 | 0.32 | 2.36 |
| Kawakawa | *Euthynnus affinis* | 1 | nearshore | 15.49 | 4.31 | 0.09 | 0.3 | 1.52 | 0.38 | 3.56 | 3.81 | 4.82 |
| Frigate tuna | *Auxis thazzard* | 3 | farshore | 22.57 | 5.18 | 3.49 | 0.75 | 1.1 | 1.38 | 1.46 | 1.07 | 3.33 |
| Bigeye scad | *Selar crumenophthalmus* | 17 | farshore | 19.93 | 4.23 | 1.43 | 0.57 | 1.52 | 1.44 | 1.64 | 3.57 | 3.26 |
| Bullet tuna | *Auxis rochei* | 3 | farshore | 18.31 | 4.4 | 3.49 | 1.82 | 1.6 | 0.75 | 1.2 | 4.03 | 3.34 |
| Mackerel | *Rastrilleger kanagurta* | 4 | farshore | 22.61 | 3.64 | 5.05 | 0.33 | 1.46 | 3.36 | 1.63 | 2.2 | 2.49 |
| Pomfret | *Brama japonica* | 4 | farshore | 27 | 8.64 | 10.21 | 1.16 | 1.32 | 1.37 | 1.66 | 2.1 | 3.31 |
| Roundscad | *Decapterus macrosoma* | 3 | farshore | 23.79 | 5.24 | 4.45 | 0.43 | 2.03 | 1.18 | 1.66 | 1.46 | 1.76 |
| Yellowfin tuna | *Thunnus albacares* | 4 | farshore | 24.96 | 3.7 | 6.28 | 0.47 | 1.34 | 1.26 | 1.64 | 0.39 | 1.79 |

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Six microplastic fibers were isolated from the fish gut of 80 fish samples (Table 2). In the nearshore distance of 0-5 km, four microplastic fibers, all elongated in shape were found. Two microplastic fibers, irregular in shape were observed from the samples in the farshore distance of 6-15 km (Table 2). Plastic fragments were the dominant type in *Scarus rivulatus* (parrotfish) with a size of 2019.20 µm and 1121.83 µm, *Naso lituratus* (unicornfish) with a size of 516.77 µm, and *Scolopsis ciliatus* (saw-jawed monocle bream) with a size of 1424.07 µm in 0-5 km. In 6-15 km, plastic fragments were found in *Rastrelliger kanagurta* (mackerel) with a size of 671.87 µm and *Decapterus macrosoma* (roundscad) with a size of 595.46 µm. Samples taken from 6-15 km from the shore showed that only one white color from *Rastrelliger kanagurta*, and one red color from *Decapterus macrosoma* were observed. Four of which might have come from the deterioration of transparent plastic packaging or from those Styrofoam, also used in food packaging. These fragments or fibers could be from common plastic products which are commonly mistaken as food or prey items by aquatic organisms (Figure 2).

**Table 2.** Sizes and relative density of microplastics found in the fish samples caught in Tibanban, Governor Generoso, Davao Oriental, Philippine.

| Species Name | English name | Size (µm) | Relative Density |
|---|---|---|---|
| *Scarus rivulatus* | Parrotfish | 2019.2 | 0.34 |
| *Scarus rivulatus* | Parrotfish | 1121.83 | 0.49 |
| *Naso lituratus* | Unicornfish | 516.77 | 0.33 |
| *Rastrelliger kanagurta* | Mackerel | 671.87 | 0.47 |
| *Decapterus macrosoma* | Roundscad | 595.46 | 0.9 |
| *Scolopsis ciliatus* | Monocle | 1424.07 | 0.37 |

Using logistic regression, the number of fibers found was related to fish morphometrics and mouth width as a predictor associated with the ingestion of microplastics in the gut of the fish collected with the presence of microplastic from 0 to 5 km distance from the shore. While in terms of farther distance e.g. 6 to 15 km distance from the shore, pectoral fin height was associated with a significant predictor for the presence of microplastic in the gut of the collected fish samples. No relationship between fish location and standard length ($df$=1, MS=24.89, $F$=1.23, $P$=0.271) and fish location and microplastic ($df$=1, MS=0.05, $F$=0.71, $P$=0.402) was found, meaning that the ingestion of microplastic was not related to distance from the shore or location and the standard length of the fish. This could be due to the low number of sampled fish (total of 40 for 0-5 km and another 40 fish sampled for 6-15 km) and low turn-out of microplastics found in the fish.

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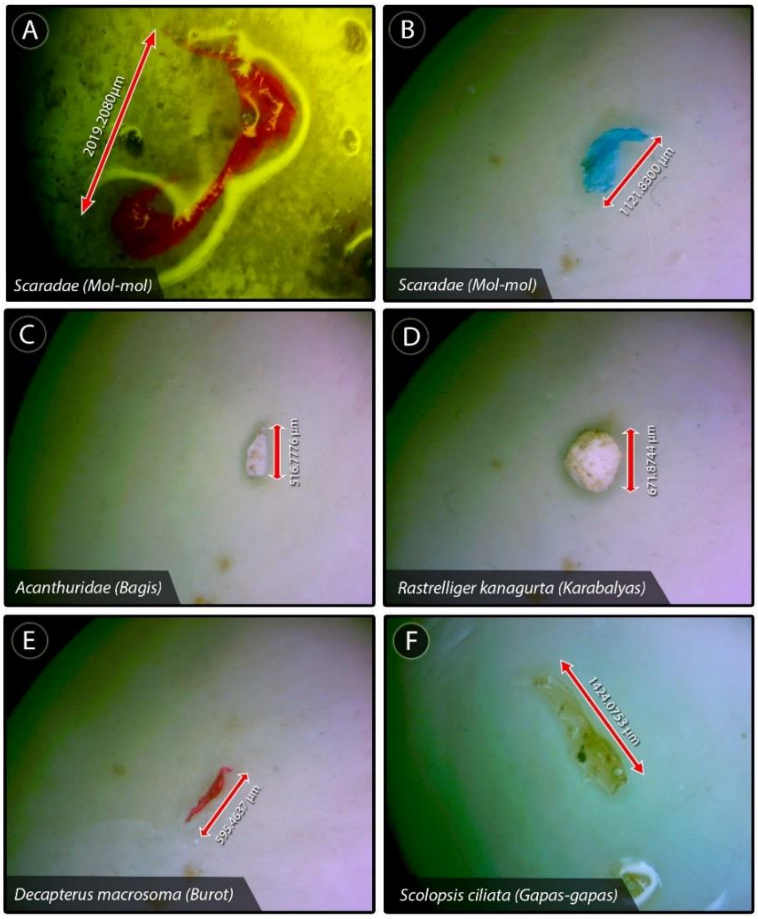


**Figure 2.** Microplastic particles found from the fish samples. A.) Plastic fragment in *Scarus rivulatus* (parrotfish) B.) Plastic fragment in *Scarus rivulatus* (parrotfish) C.) Plastic fragment in *Naso lituratus* (unicornfish) D.) Plastic fragment in *Rastrelliger kanagurta* (Indian mackerel) E.) Plastic fragment in *Decapterus macrosoma* (roundscad) F.) Plastic fragment in *Scolopsis ciliatus* (Saw-jawed monocle bream).

**Table 3.** Result of the logistic regression of the presence of microplastic in the gut of fish and selected variables.

| Distance | | 0-5 km (mouth width) | | | | 6-15 km (pectoral fin height) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | *Df* | Adj Dev | Mean | $X^2$ | *P* | Adj Dev | Mean | $X^2$ | *P* |
| Regression | 1 | 10.18 | 10.18 | 10.18 | 0.001 | 5.21 | 5.21 | 5.21 | 0.023 |
| Variable | 1 | 10.18 | 10.18 | 10.18 | 0.001 | 5.21 | 5.21 | 5.21 | 0.023 |
| Error | 38 | 15.82 | 0.42 | | | 10.67 | 0.28 | | |
| Total | 39 | 26.01 | | | | 15.88 | | | |
| $R^2$=39% | | | | | | $R^2$=33% | | | |

Microplastic ingestion of fish has already been reported in numerous areas around the world (Aytan et al., 2020). In Asia alone, 422 fishes were contaminated with microplastics, from which omnivorous and carnivorous fishes displayed higher vulnerability to microplastic ingestion (Oza *et al.*, 2024). The smaller the size of microplastic, the higher the probability of it being mistakenly identified as food prey posing a threat to other aquatic organisms (Cole *et al.*, 2011).

Similar examples of plastic ingestion occurred in other Asian fishes with microplastic fiber color dominated by black and blue colors (Oza *et al.*, 2024), and transparent in the commercial fishes in the lower Gulf of Thailand (Azad *et al.*, 2018). In this study, our results were similar to those found in the Black sea, dominated by fragmented microplastics (Aytan *et al.*, 2020). In the study conducted in the North Sea of seven fish taxa, the size of the microplastic particles was not conclusively linked to the size of the fish sampled (Müller 2021)). Moreover, the size of the microplastic fibers consumed by fish caught in Turkish territorial waters was not correlated with the size of the fish itself (Güven *et al.*, 2017). In another study of 60 damselfish *Pomacentrus moluccensis* from two locations of the Great Barrier Reef, Jensen *et al.*, (2019), the correlation between the number of microplastic ingested and the length of fish was also not observed. Similarly, in another study, neither the frequency of microplastic ingestion by fish nor the number of particles per individual fish was found to be correlated with the total length or weight of the 132 red mullet *Mullus barbatus barbatus* and 97 European hake *Merluccius merluccius* that were sampled (Giani *et al.*, 2019). In contrast to our study, Azad *et al.*, (2018) also investigated whether there was a connection between the mouth size and the frequency of microplastics as well as the size of the microplastics found but no relationship was proven to be related in his investigation. Other studies of the same species, found no correlation between the number of ingested microplastics, either with the total body weight or total body length, and other measurements (Hastuti *et al.*, 2019 and Alomar *et al.*, 2017). In connection with this study, it is well known that microplastics sink in the coral reefs' bottom water (Ismail et al., 2018), which may explain why the fish samples taken between 0 to 5 km from the shore, accumulated more microplastics than those fish sampled from 6 to 15 km. In Asian fishes, marine plastic ingestion was prevalent in benthopelagic, demersal, and reef-associated fishes (Bersaldo *et al.*, 2024; Oza *et al*, 2024). Lower microplastic concentrations per fish were also reported by Sun et al., (2019) in which the fish were caught farther inland and in the center of the Yellow Sea. This study has shown that microplastic ingestion can be found in commercially caught fish, whether nearshore or farshore and demonstrates the need to document other fishing areas for microplastics and the need for serious implementation of waste management and food safety especially in coastal residential areas.

**References**


1. Abreo, N. A., Macusi, E.D., Blatchley, D.D., Cuenca, G.C. (2016a). Ingestion of marine plastic debris by Green Turtle (*Chelonia mydas*) in Davao Gulf, Mindanao, Philippines. Philippine Journal of Science, 145(1), 17-23.
2. Abreo, N. A. S., Macusi, E. D., Blatchley, D. D., & Cuenca-Ocay, G. (2016b). First Evidence of Plastic Ingestion by the Rare Deraniyagala's Beaked Whale (*Mesoplodon hotaula*). IAMURE International Journal of Ecology and Conservation, 19(2), 16-36. http://ejournals.ph/form/cite.php?id=10740
3. Alomar, C., Sureda, A., Capó, X., Guijarro, B., Tejada, S., Deudero, S. 2017. Microplastic ingestion by Mullus surmuletus Linnaeus, 1758 fish and its potential for causing oxidative stress. Environ Res:159:135-142. doi: 10.1016/j.envres.2017.07.043.
4. Aytan, U., Esensoy, F. B., Senturk, Y., Agirbas, E., and Valente, A. 2020. Presence of microplastics in zooplankton and planktivorous fish in the southeastern Black Sea. In: Aytan, Ü., Pogojeva, M., Simeonova, A. (Eds.) Marine Litter in the Black Sea. Turkish Marine Research Foundation (TUDAV). No: 56, Istanbul, Turkey (pp.314-325).
5. Azad, S. M. O., Towatana, P., Pradit, S., Patricia, B. G., Hue, H. T. T., and Jualaong, S. 2018. First evidence of existence of microplastics in stomach of some commercial fishes in the lower Gulf of Thailand. Applied Ecology and Environmental Research 16(6):7345-7360. DOI:10.15666/aeer/1606_73457360
6. Bersaldo, M.J.I., Lacuna, M.L.D.G., Orbita, M.L.S., Tampus, A.D., Avenido, P.M., Macusi, E.D. 2024. First Evidence of Potential Microplastic Ingestion of Yellow Striped Goat Fish *Upeneus vitattus* (Forsskal, 1775) Caught in Malita, Davao Occidental, Philippines. ILMU KELAUTAN: Indonesian Journal of Marine Sciences, 29 (1), 48-60 doi:10.14710/ik.ijms.29.1.48-60
7. Boerger, C.M., Lattin, G.L., Moore, S.L., Moore, C.J., 2010. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin 60 (12), 2275–2278. http://dx.doi.org/10.1016/j.marpolbul.2010.08.007
8. Bonanno, G. and Orlando-Bonaca, M. 2018. Perspective on using marine species as bioindicators of plastic pollution. Marine Pollution Bulletin 137:209-221. DOI: 10.1016/j.marpolbul.2018.10.018
9. Choy, A. C. and Drazen, J. C. 2013. Plastic for dinner? Observations of frequent debris ingestion by pelagic predatory fishes from the central North Pacific. Marine Ecology Progress Series, 485:155-163. DOI:10.3354/meps10342
10. Cole, M., Lindeque, P., Halsband, C., Galloway, T.S., 2011. Microplastics as contaminants in the marine environment: a review. Mar. Pollut. Bull. 62, 2588–2597

11. Davison, P. and Asch, R. G. 2011. Plastic ingestion by mesopelagic fishes in the North Pacific Subtropical Gyre. Marine Ecology Progress Series, 432:173-180. doi: 10.3354/meps09142
12. Derraik, J.G.B., 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44 (9), 842–852. http://dx.doi.org/10.1016/ S0025-326X(02)00220-5
13. Froese, R., Pauly, D. (Eds.), 2024. FishBase. World Wide Web electronic publication. www.fishbase.org.
14. Giani, D., Baini, M., Galli, M., Casini, S., and Fossi, M. C. 2019. Microplastics occurrence in edible fish species (*Mullus barbatus* and *Merluccius merluccius*) collected in three different geographical sub-areas of the Mediterranean Sea. Marine Pollution Bulletin, 140:129-137. https://doi.org/10.1016/j.marpolbul.2019.01.005
15. Güven, O., Gökdağ, K., Jovanović, B., and Kıdeyş, A. E. 2017. Microplastic litter composition of the Turkish territorial waters of the Mediterranean Sea, and its occurrence in the gastrointestinal tract of fish. Environ Pollut, 223:286-294. doi: 10.1016/j.envpol.2017.01.025.
16. Hastuti, A. K., Lumbanbatu, D. T. F., Wardiatno, Y. 2019. The presence of microplastics in the digestive tract of commercial fishes of Pantai Indah Kapuk Coast, Jakarta, Indonesia. Biodiversitas. Vol. 20 (Nov. 5, 2019) pp. 1233-1242
17. Hildalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. 2012. Microplastic in the Marine Enivironment: A Review of the Methods used for Identification and Quantification. Environmental Pollution, 185 (November 2013), 352-364.
18. Ismail, M. R., Lewaru, M. W., & Prihadi, D. J. 2018. Microplastics Ingestion by Fish in the Biawak Island. 106(August), 230–237.
19. Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., Law, K. L. 2015. Plastic waste inputs from land into the ocean. Marine Pollution. Vol 347 Issue 6223.
20. Jensen, L.H., Motti, C.A., Garm, A.L., Tonin, H., and Kroon, F. Sources, distribution and fate of microfibres on the Great Barrier Reef, Australia. Sci Rep 9, 9021 (2019). https://doi.org/10.1038/s41598-019-45340-7
21. Katzenberger, T. D. 2015. Assessing the Biological Effects of Exposure to Microplastics in the Three-Spined Stickleback (Gasterosteus aculeatus) (Linnaeus 1758). (Doctoral Thesis), University of York.
22. Lebreton, L. C. M., van der Zwet, J., Damsteeg, J-W., Slat, B., Andrady, A., and Resisser, J. 2016. River plastic emissions to the world's oceans. Nature Communications. DOI: 10.1038/ncomms15611
23. Lusher, A.L., McHugh, M., Thompson, R.C., 2013. Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Mar. Pollut. Bull. 67 (1e2), 94e99.
24. Markic, A., Niemand, C., Bridson, J. H., Mazouni-Gaertner, N., Gaertner, J-C., Eriksen, M., and Bowen, M. 2018. Double trouble in the South Pacific subtropical gyre: Increased plastic ingestion by fish in the oceanic accumulation zone. Marine Pollution Bulletin. Vol. 136 (547-564). https://doi.org/10.1016/j.marpolbul.2018.09.031
25. Müller, C. 2021. Not as Bad as It Seems? A Literature Review on the Case of Microplastic Uptake in Fish. Systematic Review. DOI: 10.3389/fmars.2021.672768.
26. Oza, J. Rabari, V., Yadav, V. K., Sahoo, D. K. Patel, A., and Trivedi, J. 2024. A Systematic Review on Microplastic Contamination in Fishes of Asia: Polymeric Risk Assessment and Future Prospectives. Environmental Toxicology and Chemistry. Vol. 43:4. 671 – 685 pp. https://doi.org/10.1002/etc.5821
27. Rummel, C.D., Löder, M.G.J., Fricke, N.F., Lang, T., Griebeler, E.-M., Janke, M., Gerdts, G., 2016. Plastic ingestion by pelagic and demersal fish from the North Sea and Baltic Sea. Mar. Pollut. Bull. 102 (1), 134–141.
28. Sun, X., Li, Q., Shi, Y., Zhao, Y., Zheng, S., Liang, J., Liu, T., and Tian, Z. 2019. Characteristics and retention of microplastics in the digestive tracts of fish from the Yellow Sea, 249:878-885. https://doi.org/10.1016/j.envpol.2019.01.110
29. Thiele, C.J., et al. 2021. Microplastics in Fish and Fishmeal: an emerging environmental challenge? Scientific Reports. Article number: 2045 (2021)
30. Zhao, B., Rehati, P., Yang, Z., Cai, Z., Guo, C., & Li, Y. (2024). The potential toxicity of microplastics on human health. *Science of The Total Environment*, *912*, 168946. https://doi.org/https://doi.org/10.1016/j.scitotenv.2023.168946
31. Welden, N.A., Cowie, P.R., 2017. Degradation of common polymer ropes in a sublittoral marine environment. Mar. Pollut. Bull. 118, 248–253. http://dx.doi.org/10.1016/j. marpolbul.2017.02.072.
32. Woodall, L. C., Gwinnett, C., Packer, M., Thompson, R. C., Robinson, L. F., & Paterson, G. L. J. (2015). Using a forensic science approach to minimize environmental contamination and to identify microfibres in marine sediments. *Marine Pollution Bulletin*, *95*(1), 40-46. https://doi.org/https://doi.org/10.1016/j.marpolbul.2015.04.044