

EMERGING RESEARCH ON SHELLFISH, AQUACULTURE, AND MARINE PLASTICS

Hannah Collins, Department of Marine Sciences, University of Connecticut
Sandra Shumway, Department of Marine Sciences, University of Connecticut



Freshly harvested oysters from Long Island Sound. Photo: Tessa Getchis

Introduction

Over the past century, plastics have become an essential part of daily life. Worldwide production of plastics is upwards of 367 million metric tons as of 2020 (PlasticsEurope, 2021), and projected to further increase in the coming years. The term “plastics” encompasses a wide range of fossil fuel-derived materials, including polyethylene, polystyrene, polypropylene, polyvinyl chloride, polyamide, and polyethylene terephthalate. These plastics are lightweight, inexpensive, and have a variety of uses, including in agriculture, textiles, electronics, automobiles, and more (Thompson et al. 2009, Scarascia-Mugnozza et al. 2011, Steer & Thompson 2020, Patricio Silva et al. 2021). The continuing expansion of plastic use has provided many benefits; however, an unintended consequence has been the overwhelming increase in plastic pollution, both on land and in the ocean. Most of the plastic produced is not efficiently recycled, with estimates of up to 12,000 metric tons ending up in landfills or in the natural environment by 2050 (Geyer et al. 2017). The majority of plastic pollution in the ocean is a result of mismanaged waste, unintentionally transported from the land to the ocean via wind and rivers (Jambeck et al. 2015, Moss et al. 2021).

Plastic pollution can be broken down into two broad categories: large or macroplastics (such as plastic bags and bottles) that are particles greater than 5 mm in size, and microplastics that are less than 5 mm in size. Microplastics can enter the marine environment directly, including those

manufactured for personal care products such as microbeads (Avio et al. 2017), and also enter through the weathering and breakdown of larger macroplastics (Lambert et al. 2014). Plastics are now found in marine and freshwater aquatic ecosystems across the globe.

Both macro- and microplastic pollution can have negative effects on marine organisms. Birds and sea turtles may become tangled in abandoned fishing gear (Butler & Matthews 2015, Consoli et al. 2019), inhale or ingest pieces of plastic, causing stomach blockages and starvation, and exposing animals to potentially hazardous chemical additives (Thompson et al. 2004, Devriese et al. 2017, Caron et al. 2018).

When organisms at the base of the food chain (e.g., zooplankton, filter-feeding shellfish) consume microplastics, those plastics enter the food web. People may therefore have unwarranted concerns about potential effects on human health. Typical concentrations of microplastics found in shellfish such as clams, oysters, mussels, and scallops are particularly low, on average between 0-10 particles per animal (Covernton et al. 2019, Cho et al. 2021, Mladinich et al. 2023). When put into context, these concentrations are much lower than the number of microplastics humans are routinely exposed to through, for example, bottled water (3,569,000 particles/capita/year, Danopoulos et al. 2020) and dust fallout (13,731-68,415 particles/capita/year, Catarino et al. 2018).

Emerging Research on Shellfish Aquaculture and Plastic Pollution

Plastics in the aquaculture industry are common due to their durable and inexpensive nature. Varying types of plastics are used in hatcheries, cages, buoys, and many more materials and have contributed to the success of shellfish aquaculture in recent decades. Concerns have been raised regarding the potential for aquaculture materials to further contribute to plastic pollution; however, these claims remain unsubstantiated (Koelmans et al. 2017, Danopoulos et al. 2020). Past research has indicated that aquaculture may not, in fact, be a significant contributor to microplastic pollution and that textile production is a bigger source (Covernton et al. 2019). The role of aquaculture activities in production of microplastics and purported contamination of bivalve molluscs has been critically reviewed (Shumway et al. 2023). To date all studies reported extremely low concentrations of microplastics. A recent locally relevant study aimed to explore whether aquaculture practices are contributing to microplastic loads in southern New England waters (see Mladinich et al. 2023).



Crew members sort oysters grown in cages on the Niantic Bay Shellfish Farm in CT. Photo: Kayla Mladinich Poole

Samples of seawater, aquaculture gear, and eastern oysters (*Crassostrea virginica*) were taken from an oyster aquaculture site that deploys plastic bottom trays in Niantic Bay, CT. In addition, a two-week transplant experiment was performed in which oysters were taken from the aquaculture site and a plastic-free cage at the University of Connecticut-Avery Point campus in Groton, CT. Oysters were transplanted between both sites, and at the end of two weeks the gut was sampled. Microplastics were then isolated from seawater and oyster tissue and compared across sample types to determine whether aquaculture activities represented a significant source of microplastic pollution.

Very few microplastics were found in either seawater or oyster tissue samples during the experiment. Water samples contained 0-0.3 microplastics particles per liter of water, and oyster gut samples contained only 0-2 microplastic particles per animal at the aquaculture site or 0-3 microplastic particles per animal at the Groton location. There was little evidence of aqua-

culture influence on the composition of microplastics sampled, with only one type of plastic fiber (polyester terephthalate or PET) identified in an oyster transplanted to the aquaculture site matching to the rope used to suspend cages at that site, i.e., no evidence that the aquaculture gear is contributing plastic pollution to the surrounding waters or the oysters.

Conclusions

The results of this study indicate that aquaculture gear is not contributing to microplastic pollution at this oyster farm. In fact, while the oysters sampled contained low concentrations of MP polymers, they contained a wider variety of microplastic types, shapes, and sizes than identified in the surrounding water. Because the distribution of microplastics changes with the currents and tides, it is likely that the relatively wide assortment of microplastics found in oyster samples is representative of their ability to capture particles over an extended period of time. Farmers on the East Coast of the United States recently updated their best management practices guide and state that "Gear loss and marine debris should be avoided at all costs" to avoid the potential for marine debris. The guide includes recommendations such as "avoid single-use plastic fasteners and instead opt for reusable bungees, hooks, clips or twine" (Flimlin et al. 2023).

While aquaculture gear is not a primary source of microplastic pollution, new "plastic-like" products derived from natural or sustainable sources are increasing in prevalence in many industries and may have positive applications for aquaculture. Such biomaterials can reduce environmental negative impacts and enable the circular use of bio-based materials (Arantzamendi et al. 2023). Artificial substrate composed of a biodegradable plastic (poly- β -hydroxybutyrate) has been shown to be beneficial to survival and resilience of cultivated shrimp when compared to PVC substrate (Ludevese-Pascual et al. 2019). Prototype trays of a biodegradable material (Mater-Bi®) molded for aquaculture showed properties suitable for use in the industry, such as a long life span and relatively low biodegradation rate in seawater (Pavia et al. 2023). Seaweed-derived polymers may also represent a potential naturally derived "plastic" for use in aquaculture practices (Pacheco et al. 2022). Aquaculture currently does not represent a significant source of microplastic pollution; however, the transition away from petroleum-derived plastics to sustainable, bio-based materials can promote sustainable practices and reduce global emissions (Stegman et al. 2022).

Consumers should recognize that aquaculture gear is not a main contributor of microplastic pollution in the marine environment, and that bivalve molluscs are not significantly contributing to the number of microplastics ingested by humans. False claims or negative publicity can have far-reaching and detrimental impacts on the aquaculture industry and, to date, there are no convincing data to support negative claims regarding the contributions of aquaculture to microplastics in the environment or the shellfish.

References

- Arantzamendi, L., Andrés, Basurko, O.C., Suárez, M.J., 2022. "Circular and lower impact mussel and seaweed aquaculture by a shift towards bio-based ropes." *Reviews in Aquaculture* 15:1010-1019.
- Avio, C. G., Gorbi, S., Regoli, F., 2017. "Plastics and microplastics in the oceans: From emerging pollutants to emerged threat." *Marine Environmental Research* 128:2-11.
- Butler, C.B., Matthews, T.R., 2015. "Effects of ghost fishing lobster traps in the Florida Keys." *ICES Journal of Marine Science* 72:i185-i198.
- Caron, A.G.M., Thomas, C.R., Berry, K.L.E., Motti, C.A., Ariel, E., Brodie, J.E., 2018. "Ingestion of microplastic debris by green sea turtles (*Chelonia mydas*) in the Great Barrier Reef: Validation of a sequential extraction protocol." *Marine Pollution Bulletin* 127: 743-751.
- Catarino, A.I., Macchia, V., Sanderson, W.G., Thompson, R.C., Henry, T.B., 2018. "Low levels of microplastics (MP) in wild mussels indicate that MP ingestion by humans is minimal compared to exposure via household fibres fallout during a meal." *Environmental Pollution Bulletin* 237:675-684.
- Cho, Y., Shim, W.J., Jang, M., Han, G.M., Hong, S.H., 2021. "Nationwide monitoring of microplastics in bivalves from the coastal environment of Korea." *Environmental Pollution* 270:116175.
- Consoli, P., Romeo, T., Angiolillo, M., Canese, S., Esposito, V., Salvati, E., Scotti, G., Andaloro, F., Tunesi, L., 2019. "Marine litter from fishery activities in the Western Mediterranean sea: The impact of entanglement on marine animal forests." *Environmental Pollution* 249:472-481.
- Covernton, G., Collicutt, B., Gurney-Smith, H., Pearce, C., Dower, J., Ross, P., Dudas, S., 2019. "Microplastics in bivalves and their habitat in relation to shellfish aquaculture proximity in coastal British Columbia, Canada." *Aquaculture Environment Interactions* 11:357-374.
- Covernton, G.A., Dietterle, M., Pearce, C.M., Gurney-Smith, H.J., Dower, J.F., Dudas, S.E., 2022. "Depuration of anthropogenic particles by Pacific oysters (*Crassostrea gigas*): Feasibility and efficacy." *Marine Pollution Bulletin* 181:113886.
- Danopoulos, E., Jenner, L.C., Twiddy, M., Rotchell, J.M., 2020. "Microplastic contamination of seafood intended for human consumption: a systematic review and meta-analysis." *Environmental Health Perspectives* 128:126002.
- Devriese, L.I., De Witte, B., Vethaak, A.D., Hostens, K., Leslie, L.A., 2017. "Bioaccumulation of PCBs from microplastics in Norway lobster (*Nephrops norvegicus*): An experimental study." *Chemosphere* 186:10-16.
- Flimlin, G., Macfarlane, S., Rhodes, E. and Rhodes, K., 2023. "Best management practices for the East Coast shellfish aquaculture industry." Revision 2023. *East Coast Shellfish Growers Association*. <https://ecsga.org/wp-content/uploads/2023/11/ECSCGA-BPs.pdf>
- Geyer, R., Jambeck, J.R., Law, K.L., 2017. "Production, use, and fate of all plastics ever made." *Science Advances* 3:e1700782.
- Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A.L., Narayan, R., Lavender Law, K., 2015. Plastic waste inputs from land into the ocean. *Science* 347:768-771.
- Koelmans, A.A., Kooi, M., Law, K.L., van Sebille, E., 2017. "Risks of plastic debris: unravelling fact, opinion, perception, and belief." *Environmental Science & Technology* 51:11513-11519.
- Lambert, S., Sinclair, C., Boxall, A., 2014. "Occurrence, degradation, and effect of polymer-based materials in the environment." *Reviews of Environmental Contamination and Toxicology* 227:1-53.
- Ludevese-Pascual, G., Laranja, J.L., Amar, E., Bossier, P., De Schryver, P., 2019. "Artificial substratum consisting of poly-β-hydroxybutyrate-based biodegradable plastic improved the survival and overall performance of postlarval tiger shrimp *Penaeus monodon*." *Aquaculture Research* 50:1269-1276.
- Mladinich, K., Holohan, B.A., Shumway, S.E., Ward, J.E., 2023. "The relationship between microplastics in eastern oysters (*Crassostrea virginica*) and surrounding environmental compartments in Long Island Sound." *Marine Environmental Research* 189:106040.
- Moss, K., Allen, D., González-Fernández, D., Allen, S., 2021. "Filling in the knowledge gap: Observing MacroPlastic litter in South Africa's rivers." *Marine Pollution Bulletin* 162:111876.
- Pacheco, D., Cotas, J., Marques, J.C., Pereira, L., Gonçalves, A.M.M., 2022. "Seaweed-based polymers from sustainable aquaculture to 'greener' plastic products." In: Ranga Rao, A., Racishankar, G.A. (eds) *Sustainable Global Resources of Seaweeds Volume 1*. Springer, Cham.
- Patrício Silva, A.L., Prata, J.C., Walker, T.R., Duarte, A.C., Ouyang, W., Barcelò, D., Rocha-Santos, T., 2021. "Increased plastic production due to COVID-19 pandemic: Challenges and recommendations." *Chemical Engineering Journal* 405:126683.
- Pavia, F.C., Brucato, V., Mistretta, M.C., Botta, L., La Mantia, F.P., 2023. "A biodegradable, bio-based polymer for the production of tools for aquaculture: processing, properties and biodegradation in sea water." *Polymers* 15(4): 927.
- PlasticsEurope, 2021. *Plastics – the facts 2020* ed PlasticsEurope (available at: www.plasticseurope.org/de).
- Scarascia-Mugnozza, G., Sica, C., Russo, G., 2011. "Plastic materials in European agriculture: Actual use and perspectives." *Journal of Agricultural Engineering* 42:15-28.
- Shumway, S.E., Mladinich, K., Blaschik, N., Holohan, B.A., Ward, J.E., 2023. "A critical assessment of microplastics in molluscan shellfish with recommendations for experimental protocols, animal husbandry, publication, and future research." *Reviews in Fisheries Sciences & Aquaculture*. <https://doi.org/10.1080/23308249.2023.2216301>
- Steer, M., Thompson, R.C., 2020. *Plastics and Microplastics: Impacts in the Marine Environment*. Pages 49-72. Springer International Publishing.
- Stegman, P., Daioglou, V., Londo, M., van Vuuren, D.P., Junginger, M., 2022. "Plastic futures and their CO₂ emissions." *Nature* 612: 272-276.
- Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D., Russell, A.E., 2004. "Lost at sea: Where is all the plastic?" *Science* 304:838.
- Thompson, R.C., Swan, S.H., Moore, C.J., von Saal, F.S., 2009. "Our plastic age." *Philosophical Transactions of the Royal Society B: Biological Sciences* 364:1973-1976.