Proceedings of The National Conference
On Undergraduate Research (NCUR) 2018
University of Central Oklahoma
Edmond, Oklahoma
April 5-7, 2018

Foraging Strategy May Predict Anthropogenic Debris Consumption in Wetland Fishes

Ric DeSantiago
Department of Environmental and Ocean Sciences
University of San Diego
San Diego, California

Faculty Advisor: Dr. Drew M Talley

Abstract

Anthropogenic debris is present in aquatic environments around the world. Multiple studies have logged the presence of plastics in terrestrial and aquatic food webs, yet little is known about microplastics in wetland habitats. The health of salt marshes in Southern California is of particular concern, as the vast majority of wetlands have been lost and the ones that remain are threatened by stressors such as climate change and pollution. Due to the low tidal velocity of salt marshes, they are host to numerous anthropogenic pollutants from urban runoff. Improperly discarded plastics, which photodegrade into microplastics (<5mm) during dry periods, are washed down the watershed, ending up in rivers, lakes, reservoirs, and estuaries. The ingestion and/or bioaccumulation of microplastics has the potential to damage the health of marsh communities, exacerbating the loss of functioning wetlands. This study assessed the consumption of anthropogenic debris by three common and abundant wetland fishes with distinct feeding strategies, California killifish (*Fundulus parvipinnis*), flathead gray mullet (*Mugil cephalus*), and longjawed mudsucker (*Gillichthys mirabilis*) in Kendall-Frost Mission Bay Salt Marsh, California. The results showed 24.8% of *F. parvipinnis* (benthic picker) and 5.7% of *M. cephalus* (benthic detritivore) had microplastics in their guts, while no plastics were found in the guts of *G. mirabillis* (sit-and-wait predator). This suggests that foraging strategy may predict anthropogenic debris consumption in wetland fishes, and future studies should focus on active feeders.

Keywords: *Fundulus parvipinnis*, anthropogenic debris, microplastics

1. Introduction

Plastics are ubiquitous in aquatic environments throughout the globe and it is expected that the quantity of plastic litter will continue to grow, as most plastic is typically disposed of within a year of production[1]. There has been dramatic increase of anthropogenic debris on beaches over the last few decades[2]. While the presence of microplastics is highly variable at smaller spatial scales, abundance strongly correlates (Pearson's correlation= 0.971, $p<0.001$) with human populations at large spatial scales[2]. The accumulation of plastics in Southern California wetlands is of particular concern, as more than 90% of California's wetland habitats have been lost[3] and continue to decline. Coastal habitats attract human settlement and development, leading to increasing pressure on coastal wetlands. Additionally, the accumulation of microplastic may be facilitated by the low water velocity of estuarine habitats[4]. The ingestion and/or bioaccumulation of microplastics by wetland organisms has the potential to damage the health of marsh communities, exacerbating the loss of functioning wetlands. It is therefore crucial to understand the relationship between anthropogenic debris and wetland fishes as one possible gateway for plastics into the food webs. The climate and seasonal precipitation patterns of southern California add to the risk of plastic contamination in coastal systems. The long, dry, sunny summers allow plastics to photodegrade into microplastics, while the brief but occasionally intense wet season transports microplastics through the watershed and storm drains into the coast[5,6].

In addition to the physical and anthropogenic factors, biological and ecological traits among consumers also have the potential to alter risk of microplastic contamination. In studies of both freshwater and marine systems, the trophic guild or foraging strategy of consumers has been shown to profoundly affect the likelihood of microplastic ingestion[7,8]. This study used gut content analysis to quantify microplastic ingestion of three numerically dominant fishes with distinct foraging strategies in a southern California salt marsh.

2. Methods

2.1 Materials And Sampling

Three species of fishes with distinct foraging strategies were selected for this study. *Fundulus parvipinnis* feed by picking from the benthos and water column for small invertebrates, such as polychaetes, isopods and crustaceans. *Mugil cephalus* feed on benthic detritus, while *G. mirabilis* are opportunistic sit-and-wait predators that burrow into the mud and ambush invertebrates and small fishes.

We sampled 6 locations within the salt marsh in the Kendall-Frost Mission Bay Reserve in the northern portion of Mission Bay, California (Figure 1) on ten different dates in 2016: June 20, 22, and 27; Jul 1, 12, 17, 18, 26, 28, and 29. Three methods were used to capture fishes, including seine nets, cast nets, and minnow traps.

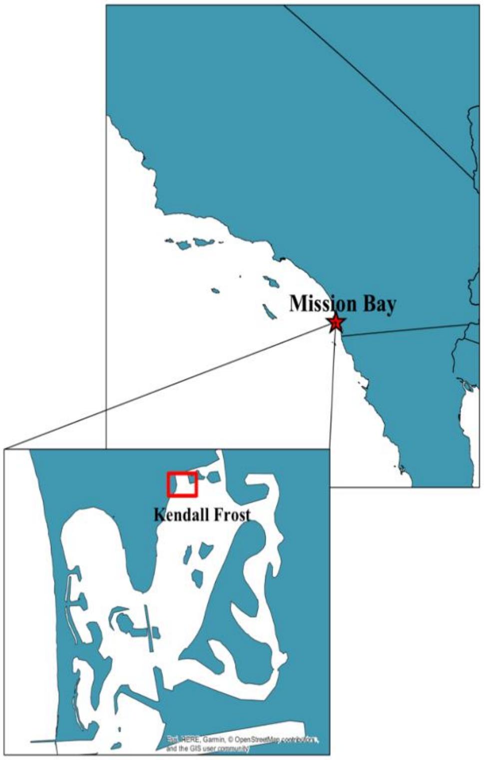

Figure 1: Kendall Frost, Mission Bay Reserve, California

Minnow traps (Gee® G-40, 6.25mm mesh) were baited with canned cat food in fine mesh bags, to attract fishes while preventing consumption. Traps were attached to stakes with 2–3 m of rope and collected after a 24-hour period. Seine nets (5 m long bag-seine with 3mm mesh) and cast nets (Goture® 3mm mesh) captured *F. parvipinnis* and *M. cephalus*, while minnow traps captured the vast majority of analyzed *G. mirabilis*. Once caught, all fishes were placed on ice to prevent further digestion and excretion of gut contents, transported to the lab, and stored frozen until analysis.

2.2 Gut Content Analysis Using Microscope

The entire gastrointestinal tract of each fish was removed and examined under a dissecting microscope, with any anthropogenic debris found retained. The remains were examined under a compound microscope and anthropogenic debris was stored in labeled glass vials. All anthropogenic debris collected from the GI tracts was categorized by type (e.g., cosmetic beads, plastic fragments, and fibers), counted, and the total volume was measured using a 1mm gridded counting chamber.

2.3 Gut Content Analysis Using KOH Solution To Dissolve Organic Matter

A second method was used to determine the presence of anthropogenic debris in the guts of the fishes using a 10% KOH solution[9]. The entire gastrointestinal tract of each fish was placed in glass vials and the KOH solution was added at an amount of at least three times the volume of organic matter. The glass vials were stored without stirring or agitation for approximately two weeks at room temperature, until the biological material was observed to be deliquesced. Previous experiments have proven that plastics are resistant against 10% KOH solution[9]. The glass vials were emptied onto petri dishes and individually examined under a dissection microscope. Anthropogenic debris was collected and categorized by type, counted and the total volume was measured using a 1mm gridded counting chamber. All data were examined for statistically significant differences between the microscope dissection method and the KOH solution method, because the differences were not significant ($p>0.1$), all data were grouped together for further statistical analyses.

2.4 Contamination Controls

To account for possible contamination during analysis, lab benches, microscopes and related equipment were cleaned using acetone to dissolve potential microplastic particles. Before conducting gut content analyses, we recorded the colors of fabrics of every person who entered the laboratory. We added water to petri dishes and placed four at each work station to collect any airborne fabrics. If any fabrics found during fish analysis matched the fabric colors of clothing worn in the lab, they were dismissed.

3. Results

Overall, 24.8% of *F. parvipinnis* (n=105) and 5.7% of *M. cephalus* (n=53) contained anthropogenic debris in the gut while *G. mirabilis* (n=78) had none (Figure 2). In individuals that contained plastics in the gut, an average of 8.2 % (SE= ± 3.1%) of the gut contents of *F. parvipinnis* and 7.0 % (SE= ± 2.7%) of the gut contents *M. cephalus* were anthropogenic debris (Figure 3). Anthropogenic debris consumption was significantly affected by species (χ^2= 63.093, DF = 1, p = 1.972 x 10^{-15}). None of the fishes contained non-fibrous anthropogenic debris except for a single plastic bead in one *F. parvipinnis.*

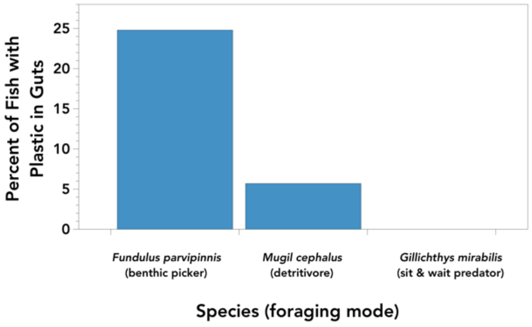

Figure 2 Percent of total fishes with anthropogenic debris in the gut. Out of 105 *Fundulus parvipinnis* and 53 *Mugil cephalus*, 24.8% and 5.7% contained plastics in their guts, respectively. None of the 78 *Gillichthys mirabilis* contained any plastics in their gut.

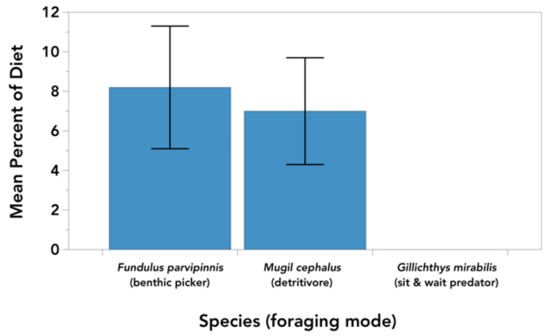

Figure 3 Mean percent of diet consisting of anthropogenic debris in *Fundulus parvipinnis* = 8.2% (SE= ± 3.1%), *Mugil cephalus* = 7.0% (SE= ± 2.7%), *Gillichthys mirabillis* = 0.

4. Discussion

The occurrence of microplastics was significantly higher in *F. parvipinnis* than *G. mirabilis* and *M. cephalus.* This finding suggests that active feeders of the benthos and water column are more likely to consume anthropogenic debris than sit-and-wait (*G. mirabilis*) and benthic detritivores (*M. cephalus*) fishes. It should be noted that most microplastics consumed by *F. parvipinnis* were in the form of red fibers. These fibers closely resemble small oligochaetes, which could suggest that *F. parvipinnis* mistake the fibers for benthic prey. The majority of *G. mirabilis* were captured using minnow traps that remained in the field for a period of 24 hours. Because the gut transit time of *G. mirabilis* is likely shorter than 24 hours, it is possible that these data are biased, as most *G. mirabilis* examined had empty gastrointestinal tracts. Nonetheless, we consider it unlikely that this factor alone accounts for the complete absence of microplastics in *G. mirabilis* in this study. Firstly, these findings match those of another study in a nearby brackish creek, where none of the *G. mirabilis* recovered using 20-minute trap sets had microplastics in their guts[10]. Second, one of the few studies of trap retention rates showed escape rates as high as 1 individual per minute[11]. Even if the rates of escape and ingress are considerably lower for *G. mirabilis* in this study, many individuals would have been sampled well before material could have transited through their digestive tract.

Regardless, the high occurrence of anthropogenic debris in the guts of *F. parvipinnis* demonstrates that microplastics have entered the wetland food web in Kendall-Frost Mission Bay Reserve. *Fundulus parvipinnis* are abundant, representing as much as 80% of the catch in some areas of southern California[11]. Additionally, *F. parvipinnis* are mid-level carnivores in wetlands, thus making them a likely conduit for coastal debris into open oceans organisms and food webs. It is, therefore, crucial to not only understand the impacts of anthropogenic debris on the fitness of *F. parvipinnis*, but also potential bioaccumulation of plastics in their predators, as this has the potential to affect community dynamics, and as a result, hindering the functionality of the salt marsh and estuary ecosystems.

This work suggests that researchers should consider the foraging strategy of the organisms to help predict rates of consumption of available microplastics. While anthropogenic debris was found in the guts of detritivores, which may have incidentally consumed plastics accumulated on the detritus, a significantly higher percent of selective feeders consumed plastics. It is possible that *F. parvipinnis* actively targets plastics as it forages through the water column and picks from the benthos. Furthermore, organisms in other ecosystems (e.g., rocky intertidal and subtidal) may similarly target microplastics as they forage. Focusing on active feeders may help us better understand how plastics enter food webs and, as a result, may help with mitigation of anthropogenic pollution across various systems.

Despite the overwhelming evidence of the accumulation of plastic particles, calls for plastics to be classified as hazardous[12] and legislation to restrict the accumulation of microplastics have been unsuccessful due to a lack of evidence that marine litter causes harm to ecosystems[13]. Understanding the negative impacts of microplastics in Kendall-Frost Mission Bay Reserve may help further efforts to prevent upstream pollution in the tributaries that drain into Mission Bay and may push forward legislation to classify plastics as hazardous material.

5. Acknowledgements

The author wishes to express his appreciation to the Department of Undergraduate Research at the University of San Diego, and the National Science Foundation for support. He also wishes to express his appreciation to Amber Clay for the countless hours of work, and Nima Farchadi for his help creating the figures in this study. This material is based upon work supported by the National Science Foundation under Grant No. 1460645.

6. References Cited

1. Thompson, R. C., C. J. Moore, F. S. V. Saal, and S. H. Swan. 2009. Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences 364:2153–2166.

2. Barnes, D.K.A., F. Galagani, R.C. Thompson, and M. Barlaz. 2009. Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions Royal Society B: Biological Sciences 364:1985-1998.

3. Madon, S.P., G.D. Williams, J.M. West, and J.B. Zedler. 2001. The importance of marsh access to growth of the California killifish, *Fundulus parvipinnis*, evaluated through bioenergetics modeling. Ecological Modelling 136:149-165.

4. Browne, M.A., T.S. Galloway, and R.C. Thompson. 2010. Spatial patterns of plastic debris along estuarine shorelines. Environmental Science & Technology 44:3404-3409.

5. Anderson, B., B. Philips, D. Markiewicz, and M. Stillway. 2012. Toxicity in California Waters: San Diego Region. California Water Board Surface Water Ambient Monitoring Program. http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/reglrpts/rb9_toxicity_2012_new.pdf. Accessed 1 October 2017.

6. Derraik, J.G.B. 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44:842-852.

7. Scherer, C., A. Weber, S. Lambert, and M. Wagner. 2017. Interactions of microplastics with freshwater biota *in* Freshwater Microplastics: Emerging Environmental Contaminants? 58:153-180.

8. Wesch, C., A. Barthel., U. Braun, R. Klein, and M. Paulus. 2016. No microplastics in benthic eelpout (*Zoarces viviparus*): An urgent need for spectroscopic analyses in microplastic detection. Environmental Research 148:36-38.

9. Foekema, E.M., C. De Gruijter, M.T. Mergia, J.A. van Franeker, A.J. Murk, and A.A. Koelmans. 2013. Plastic in North Sea fish. Environmental Science and Technology 47: 8818-8824

10. Talley, T.S. unpublished data.

11. Talley, D.M. 2000. The role of residential fishes in linking habitats of a southern California salt marsh. University of California, San Diego. Dissertation.

12. Rochman, C.M., M.A. Browne, B.S. Halpern, B.T. Hentschel, E. Hoh, H.K. Karapanagioti, L.M. Rios-Mendoza, H. Takada, S. Teh, and R.C. Thompson. 2013. Policy: Classify plastic waste as hazardous. Nature 494 169-171.

13. Galloway, T.S., and C.N. Lewis. 2016. Marine microplastics spell big problems for future generations. Proceedings of the National Academy of Sciences of the United States of America 113:2331-2333.