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The incidence of plastic ingestion by fishes: From the prey's perspective

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ABSTRACT

One of the primary threats to ocean ecosystems from plastic pollution is ingestion by marine organisms. Well-documented in seabirds, turtles, and marine mammals, ingestion by fish and sharks has received less attention until recently. We suggest that fishes of a variety of sizes attack drifting plastic with high frequency, as evidenced by the apparent bite marks commonly left behind. We examined 5518 plastic items from random plots on Kamilo Point, Hawai'i Island, and found 15.8% to have obvious signs of attack. Extrapolated to the entire amount of debris removed from the 15 km area, over 1.3 tons of plastic is attacked each year. Items with a bottle shape, or those blue or yellow in color, were attacked with a higher frequency. The triangular edges or punctures left by teeth ranged from 1 to 20 mm in width suggesting a variety of species attack plastic items. More research is needed to document the specific fishes and rates of plastic ingestion.

1. Introduction

Plastic pollution alters ocean ecosystems via direct impacts to organisms from ingestion and entanglement (Laist, 1997), transport via rafting (e.g. Barnes and Milner, 2005), leached or adsorbed chemicals (e.g. Teuten et al., 2009), changes to behavior (e.g. Aloy et al., 2011), and alteration of the physical environment (e.g. Carson et al., 2011). This debris has direct and indirect impacts to humans including health and safety concerns, threats to navigation, loss of aesthetic value, and reduced income from fishing and tourism (reviewed in Gregory, 2009).

Chief among the threats from plastic pollution is ingestion. This has been well documented in seabirds (e.g. Avery-Gomm et al., 2012; Azzarello and Van Vleet, 1987), sea turtles (e.g. Bugoni et al., 2001), and marine mammals (e.g. Eriksson and Burton, 2003; Jacobsen et al., 2010). New research has documented ingestion by filter-feeding (Browne et al., 2008; Cole et al. 2013), deposit-feeding (Graham and Thompson, 2009), and scavenging invertebrates (Murray and Cowie, 2011), and even in terrestrial animals such as livestock (Clapp and Swanston, 2009). There has historically been less research into fish and shark ingestion of plastic, despite being recognized in the 1970s (Carpenter et al., 1972; reviewed in Hoss and Settle, 1990). Since then plastic ingestion has been documented in various fish including many sharks (reviewed in Laist, 1997), tuna *Thunnus* spp. (Manooch and Mason, 1983), lancetfish *Alepisaurus* spp. (Kubota, 1990; Jantz et al., 2013), opah *Lampris immaculatus* (Jackson et al., 2000), marine catfish *Cathorops* spp. (Possatto et al., 2011), various small mesopelagic fishes (e.g. Davison and Asch, 2011), estuarine drums *Stellifer* spp. (Dantas et al., 2012), and mojarras in the family *Gerreidae* (Ramos et al., 2012). It is unclear why even more species have not been identified to eat plastic. It may be because many fishes do not consume plastic, many fishes have not been examined for the presence of plastic in stomachs, many fishes that consume plastic are able to pass it through their digestive system (unlike some seabirds, for instance), or past studies of stomach contents did not note any plastic that was encountered. In the past year the interest in this topic has increased sharply, and more formal stomach contents examinations and ingestion records are emerging. A survey of ten fish species in English Channel found that all ten had plastic in their stomachs, even if at low levels (Lusher et al., 2013). A second study this year encountered plastic inside five deepwater fishes in the Mediterranean Sea (Anastasopoulou et al., 2013). A third investigation reported on seven species of predatory fishes in the central North Pacific (Choy and Drazen, 2013), with 19% of individuals found with plastic ingested. In a fourth survey five of seven North Sea species examined were found to ingest plastic at low levels (Foekema et al., in press).

Researchers and volunteers that examine plastic washed onto coastlines often find items that look as if they have been bitten with a vertebrate toothed jaw. Plastic with a recognizable shape, such as a detergent bottle, is often encountered with conspicuous portions missing in a 'bitten' shape, marked with parallel punctures, and flattened as if compressed by a jaw. Such items have been encountered in the open ocean (e.g. Fig. 1f) as well as on coastlines. To date the incidence of these apparently bitten plastics has not been quantified and described. Using data from Kamilo Point on the Island of Hawai'i, an area famous for the accumulation

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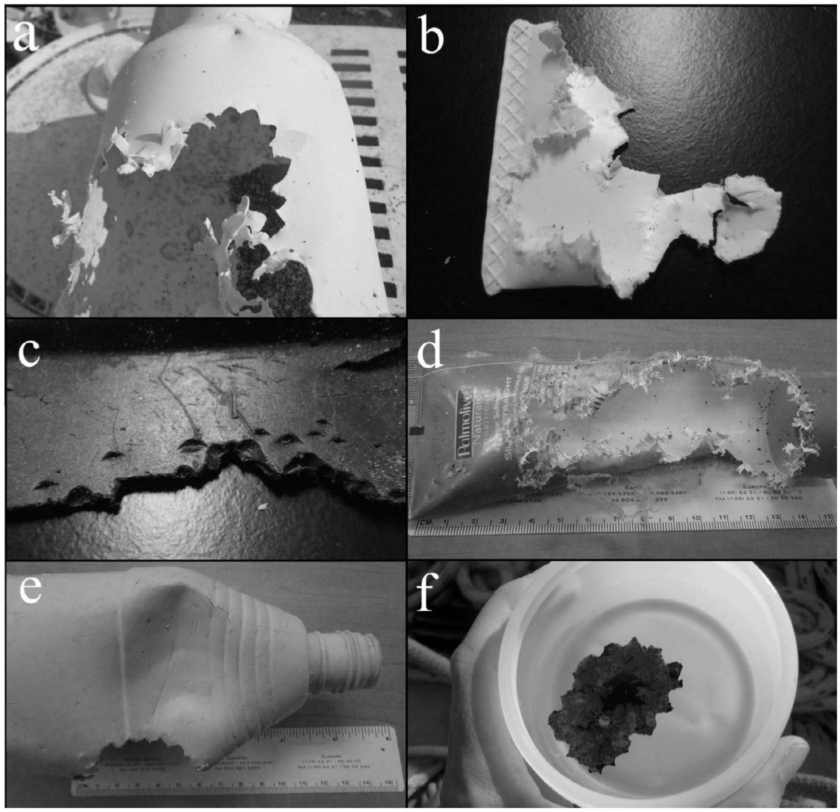

Fig. 1. Example photographs of plastic items with apparent bite marks. (a) a bleach bottle photographed *in situ* (b) a flexible tube fragment (c) a close-up of a fragment exhibiting both marks along the edge and interior chevron-shaped tooth marks (d) a cosmetics tube with numerous fine-scale teeth marks (e) a partially crushed bottle with a one prominent attack mark (f) a fragment collected near the center of the North Pacific Gyre.

of plastic debris from the North Pacific, we answer the following questions:

(1) What percentage of all available plastic items is apparently bitten by fish or sharks?
(2) What range of fish sizes attack plastic debris, as evidenced by the distribution of tooth widths imprinted into the plastic?
(3) Does plastic debris with apparent bite marks have a different color and shape distribution than plastic items that do not appear to have been bitten?

2. Methods

2.1. Site description

Kamilo Point, located near the southern tip of the Island of Hawai'i (Fig. 2), has been known to accumulate ocean debris since prehistoric time (Ebbesmeyer and Scigliano, 2009). In the modern era, this has been predominantly plastic debris from both local and international sources (Carson et al. 2013). Since 2003, the Hawai'i Wildlife Fund (www.wildhawaii.org) has removed an average of 16 metric tons of debris per year from this point and other areas on the adjacent ~15 km of coastline. Debris collected includes nets, rope, buoys, and other fishing debris, durable and single-use consumer plastic items, and many small plastic fragments and pre-production pellets (Carson et al. 2011). Our study site was on the ~0.5 km beach on Kamilo Point, which receives a high intensity of debris accumulation. The reason for this accumulation has not been formally studied, but is likely a combination of the Hawai'ian archipelago's location close to the North Pacific Gyre (Howell et al., 2012), and local surface current and wind patterns. Gyre debris drifting in prevailing southwestern-flowing currents along the Puna – Ka'u coastline (Fig. 2) may be blown toward the coast by persistent and strong onshore winds. Retention of debris reaching the coastline northeast of Kamilo Point may be prevented by low

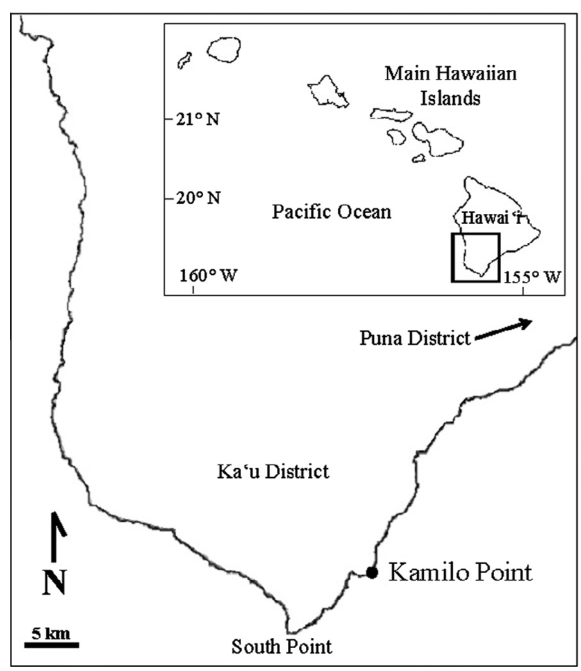

Fig. 2. Map showing the debris collection area at Kamilo Point, Hawai'i Island.