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Quantifying the risk that marine debris poses to cetaceans in coastal waters of the 4-island region of Maui

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ABSTRACT

Marine debris poses considerable threat to biodiversity and ecosystems and has been identified as a stressor for a variety of marine life. Here we present results from the first study quantifying the amount and type of debris accumulation in Maui leeward waters and relate this to cetacean distribution to identify areas where marine debris may present a higher threat. Transect surveys were conducted within the 4-island region of Maui, Hawai'i from April 1, 2013 to April 15, 2016. Debris was found in all areas of the study region with higher concentrations observed where the Au'au, Kealaikahiki, and Alalakeiki channels converge. The degree of overlap between debris and cetaceans varied among species but was largest for humpback whales, which account for the largest portion of reported entanglements in the 4-island region of Maui. Identifying areas of high debris-cetacean density overlap can facilitate species management and debris removal efforts.

1. Introduction

Marine debris, classified as any solid material from man-made origin that enters the marine environment (Coe and Rogers, 1997), presents a serious hazard to ocean habitats across the world. Marine debris poses considerable threat to marine life, biodiversity, and ecosystems (Sheavly and Register, 2007) and has been identified as a stressor for a variety of marine life (Moore, 2008).

The wide distribution of marine debris in conjunction with the low recovery probability of marine mammals that have ingested debris makes debris interactions difficult to quantify. Understanding the risk that marine debris poses to cetaceans in specific regions requires an understanding of the distribution of both the debris as well as the species of concern, which can be used to identify the potential risk for interaction. Debris items, particularly plastics, threaten marine organisms either indirectly by altering habitat or directly through fatal interactions (Wallace, 1985; Carr, 1987; Laist, 1997; Henderson, 2001; Gregory, 2009; Moore et al., 2009; Hong et al., 2013). An estimated 100,000 animals die each year from either ingesting or becoming entangled in debris (Wilks, 2006). Among these are several recorded instances of cetaceans which have died from such interactions (false killer whales: Oleson et al., 2010; minke whales: Pierrepont et al., 2005; pygmy sperm whale: Stamper et al., 2006; beaked whales: Simmonds and Nunny, 2002; harbor porpoise: Baird and Hooker, 2000). With a steady increase in the number of interactions between cetaceans and marine debris (Baulch and Perry, 2014), there is a growing need to understand and assess the risk that debris poses to these species.

Debris entanglement and ingestions have been documented for cetaceans in Hawaiian waters with 55 entanglements with marine debris reported by Bradford and Lyman (2015) from 2007 to 2012. Two of these instances involved Hawaiian spinner dolphins, one of which had a plastic ring/band around its rostrum preventing the mouth from opening. Another instance involved a juvenile humpback whale entangled in over 21 different types of rope and netting. Ingestion of debris is often an underreported metric as it often requires recovery and necropsy of dead animals. However, several instances of ingestion of debris by cetaceans in Hawaiian waters have also been reported (Laist, 1997). To date there has been no published work on the quantification of marine debris and potential interaction with marine mammals in the four-island region of Maui, Hawaii, an area which consists of a large portion of the Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS).

In this paper we quantify the abundance and distribution of marine debris within the 4-island region of Maui and relate this to potential threats to four resident odontocete species and one migratory mysticete species. Such areas were determined by spatially overlaying the density of marine debris with the densities of each cetacean species, similar to the methods detailed in Williams et al. (2011). Effectively evaluating these threats requires the determination of "risk", or the likelihood that an undesirable event will occur (Harwood, 2000): in this instance the event being marine debris entanglement or ingestion. Williams et al.

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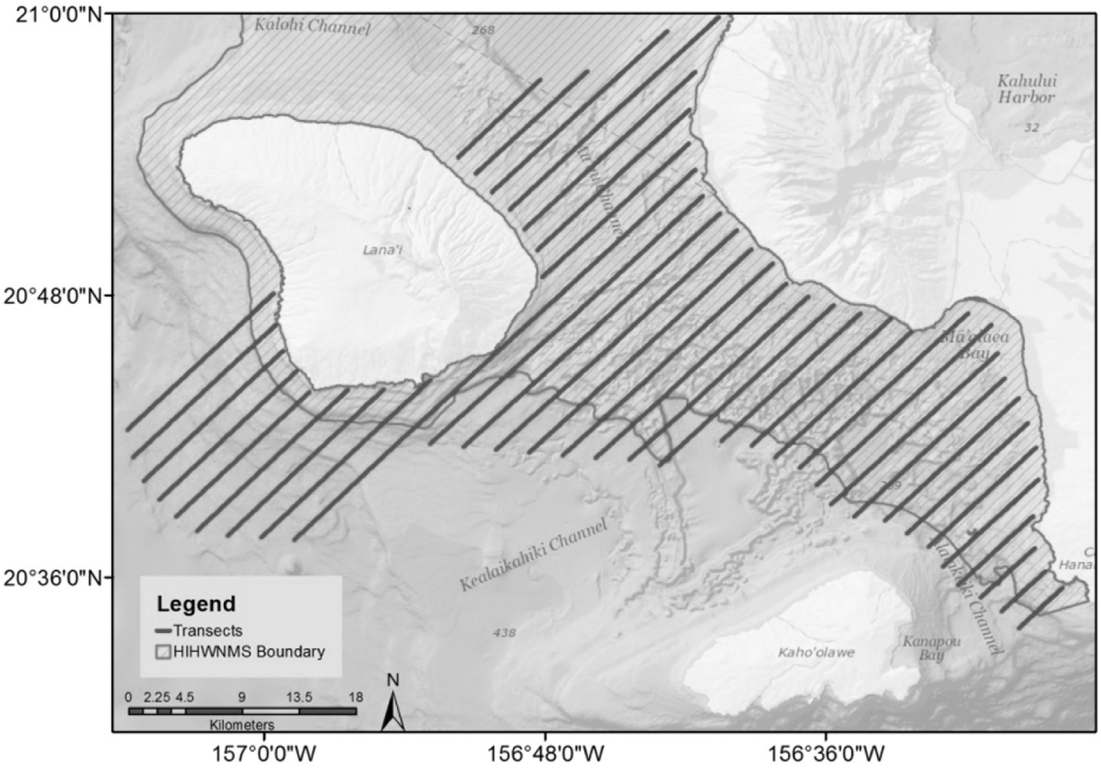

Fig. 1. Map depicting survey transects within the 4-island region of Maui, Hawaii.

(2011) note that the proximity between a particular species and marine debris is a key determinant of risk but does not necessarily result in ingestion or entanglement. As such, relative risk can be determined by multiplying the density of debris with the density of the study species, and the resultant overlap, or co-occurrence, of both a species and marine debris is the risk of interaction (Brown et al., 2015). This is the first study to quantify the potential interaction of marine debris and cetaceans in the Maui 4-island region with the following main objectives: 1) quantify the amount and type of debris accumulation in Maui leeward waters; 2) identify areas within these waters where marine debris may present a higher threat to cetacean species; with the aim of identifying areas where risk is elevated and guide potential mitigation and prevention strategies.

2. Methods

2.1. Study area and survey effort

Line transect surveys were conducted within the 4-island region of Maui, Hawai'i, consisting of the islands Maui, Molokai, Lana'i, and Kaho'olawe, between April 1, 2013 and April 15, 2016 (Fig.1). The starting point of each survey was chosen randomly at the beginning of each survey day. To ensure no missed occurrences of debris and cetaceans, locations of all sightings while both on- and off-effort were recorded during the study period. Survey effort varied my month and time of year covering an area of 1004 km^2 (Fig. 2). The study area consists predominantly of nearshore habitat < 200 m in depth. However, some areas south of Lana'i reached depths up to ~600 m. Survey lines were separated by 1 nautical mile and laid out perpendicular to the depth contours within the study area. Surveys were conducted onboard a 26-foot research vessel equipped with two outboard engines, departing from either Lahaina or Ma'alaea Harbors on Maui. As both on- and off-effort data were used, survey speeds ranged from a minimum of 5 knots when slowing down to pick up debris to 20 knots when transiting the survey area. On-effort surveys were conducted at a consistent speed of 15 knots.

To reduce detectability error, surveys were only conducted when Beaufort and Douglas Sea States were ≤ 3 (Tyson et al., 2011). Four individuals rotated through positions of observers and data recorder. One observer was stationed on the port and starboard sides of the helm, respectively, scanning equal sections of water from the bow to 90^0 on either side using a continuous scanning methodology (Mann, 1999) by naked eye and with reticle binoculars (7 × 50). The boat captain was also an on-effort observer, while the remaining personnel, including the data recorder, did not contribute to the scanning effort. Eye height of observer varied based on observer height, but ranged from 1.6 to 1.9 m. All sightings of both marine debris and of cetaceans were called out by the observers and logged by the data recorder. It is important to note that despite completing line transects, distance sampling was not completed for debris items and precludes traditional distance sampling analysis presented in Williams et al. (2011). As such the results presented here represented presence only sightings, which have not been correct for detectability.

2.2. Data collection

2.2.1. Cetaceans

Four resident odontocete species were recorded when present during the survey period: bottlenose dolphins (*Tursiops truncatus*), Hawaiian spinner dolphins (*Stenella longirostris*), pantropical spotted dolphins (*Stenella attenuata*), and false killer whales (*Pseudorca crassidens*). One migratory mysticete species was recorded when present from December to April during the survey period: humpback whales (*Megaptera novaeangliae*). Upon sighting the species, pod size and sighting location (latitude and longitude) were recorded.

2.2.2. Marine debris

All floating debris items encountered were sampled during the survey period. When a piece of debris was sighted, the item was collected if possible and GPS location (latitude and longitude), and the type of material were recorded. If the item could be collected, it was photographed and recorded. All debris items were classified into the