**Impacts of Marine Debris measured by Beach COMBERS: plastic ingestion and entanglement in Marine Birds and Mammals**

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## I. Introduction

Marine debris can cause harmful impacts to marine birds, mammals, sea turtles and fishes (Derraik et al. 2002, Hyrenbach et al. 2013). These impacts include entanglement in lost or abandoned fishing gear, traps, balloons, and line material (Raum-Suryan et al. 2009) and ingestion of plastic fragments, foam, and other substances (Spear et al. 1995, Laist et al. 1997). Sources of potentially harmful marine debris include land-based sources (beaches, waterways, and storm runoff), ship-based sources (recreational, commercial vessel) and catastrophic events (hurricanes, typhoons, tsunamis). The March 2011 *Japan Tsunami* created an estimated 5 million tons of marine debris input into the North Pacific Gyre and impacts in the California Current System are expected in 2014-2016[1]. As of April 2014, the General NOAA Operational Modeling Environment (GNOME) predicts a high concentration of tsunami-related marine debris particles 500-700 miles offshore of central California, near the out edge of the California Current.

There is a need to understand the threats from the Tsunami debris and other sources on wildlife within the Monterey Bay National Marine Sanctuary (MBNMS) to determine if there has been an increasing or decreasing trend in these impacts. By tracking these inter-annual trends in marine debris impacts to wildlife, we also hope to inform policies directed towards reducing marine debris (i.e., lost gear recovery, plastic bag and Styrofoam take-out container bans) and make recommendations for future mitigation.

Entanglement in fishing gear is a chronic source of mortality for seabirds and marine mammals in California (Moore et al. 2009). During 2001–2005, Moore et al. (2009) documented 31 bird species and nine marine mammal species. The most frequently entangled species were Common Murres (*Uria aalge*), Western Gulls (*Larus occidentalis*) and California sea lions (*Zalophus californianus*). The entanglement materials identified were primarily fishing related including monofilament line, hooks, and weights.

In this study, we examined beach stranding records over a longer time period (15 years) to establish the baseline rate of wildlife impacts (entanglement and ingestion) prior to significant known impacts of the 2011 Tsunami. We used records from on-going Coastal Ocean Mammal and Bird Education and Research Surveys (BeachCOMBERS) conducted by volunteers monthly in MBNMS. Since 1997, the BeachCOMBERS program has coordinated >200 volunteers to monitor human and natural impacts to coastal wildlife by documenting the deposition of marine birds, mammals, and sea turtles. This long-term monitoring program has successfully informed resource managers about wildlife impacts from oil spills, starvation, fishery interactions, and harmful algal blooms (Nevins et al. 2011).

We also present data from the Seabird Health Study a collaborative project with Oikonos Ecosystem Knowledge and CA Dept. of Fish and Wildlife (CDFW) since 2005 to document rates of plastic ingestion in seabirds[2]. BeachCOMBERS and other rehabilitation centers throughout the Monterey Bay region participated in collecting seabird carcasses for necropsy (dissection). Nevins et al. (2005) found that the

[1] http://marinedebris.noaa.gov/tsunamidebris/
[2] http://oikonos.org/plastic-ingestion/

incidence of plastic ingestion in Northern Fulmars (Fulmarus glacialis) from birds collected in Monterey Bay was as high as 72% in 2003. These data will provide important pre-tsunami metrics for comparisons should the surface currents transport an increase availability of fragments to these surface-feeding birds in the coming years from sources such as the 2011 Tsunami.

**II. Methods**

*Beach Surveys*

We summarized 15 years of entanglement records collected by BeachCOMBERS in the MBNMS (1997-2013). We report species affected, extent of interaction, and of type of entanglement gear. When possible, birds were collected and examined by the Department of Fish and Wildlife –Marine Wildlife Veterinary Care 7 Research Center, Santa Cruz as part of the Seabird Health Study to determine cause of death.

Each month volunteers walk a designated beach segment in central California to collect data on all dead marine bird, mammal, and sea turtles (Fig. 1). Volunteers identify each species and record new and old deposition, condition of carcass, cause of death (including oiling, entanglement), mark the carcass to avoid recounting, and collect seabird species prone to ingesting plastic (Procellariids) for examination. BeachCOMBERS use standardized effort that allows comparison of relative changes in the deposition rate of marine birds and marine mammals and by providing a monthly index of ecosystem health (Nevins et al. 2009).

The survey study area began with ten beaches (1997-1998), expanded to 11 beaches (1999), then to 17 beaches including surveys in San Luis Obispo County (mid-2001-2002), and grew to 30 beaches by 2009 to present time (including Morro Bay Sandspit and Cayucos Beach not represented on the map).

*Plastic Ingestion Analyses*

For plastic ingestion analyses, the stomach were examined at MWVCRC at the CDFW facility in Santa Cruz, California The proventriculus and ventriculus were processed and weighed separately. All stomach contents were collected in a 0.5 mm mesh sieve and rinsed to remove prey soft tissues. Hard parts, plastics, and other remaining non-food hard particles were collected from the sieve and placed in a segregated petri dishes or vials. We used a binocular microscope to precisely separate items into specified categories per Franker and Meijboom (2002). We report the incidence of ingestion as the proportion of birds examined with pellets, user fragments and total plastics. Pellets refer to pre-manufactured plastic have a distinct small, round shape; user fragments are all post-consumer pieces of plastic; all plastic is a summation of pellets, user plastics, and additional categories of plastic (e.g. foam, monofilament threads, rubber, balloons).

**III. Results**

*Entanglement*

We tallied the reports of entanglement by year (1997-2012) and species from monthly BeachCOMBER surveys (Table 1). Over the 15 year study period, 279 entanglements were reported by surveyors affecting 24 seabird species (n = 263, 98%), and at least three marine mammal species (n = 6, 2%). There were no reports of entangled sea turtles in this data set.

The greatest reported entanglements occurred in 1997, 1998 and 2001 (n = 29) when Common Murres and Sooty Shearwaters were the main species affected (Table 1). Five species dominated in number of entanglements over the 15 year time span: Common Murres (23%), Sooty Shearwaters (12.5%), Brandt's Cormorants (10%), Western Gulls (9%), and Brown Pelicans (7%). Alcids (24%) and gulls (21.5%) and cormorants (15%) were the taxa most affected.

For almost all entanglement interactions, monofilament fishing line was the dominate source of entanglement, most likely from recreational fishing interactions, of which 58 were documented cases that included the presence of a hook or lure. There were 7 reports of net interactions (herring, gill, and fishing nets), which are likely commercial fishing interactions. Three reports mentioned entanglement via balloon string around the legs and/or wings, and 1 report of a balloon piece observed in the stomach of a Common Murre, and another in a fulmar (Fig. 6).

In June of 2013 we received a report of an entangled Black-footed Albatross on Marina State Beach, a program survey beach. The carcass was clearly entangled by balloon strings with deflated balloons still attached (Fig. 4). This photo was displayed on the Science Integrated Monitoring Network (SIMON) and Oikonos Ecosystem knowledge websites with a summary explaining the entanglement case in addition to a the rescue of a live, entangled Western Grebe on Aptos beach brought to a local rehabilitation center for treatment[3].

*Plastic Ingestion*

We examined incidence of plastic in Northern Fulmars collected in MBNMS during three die-off events in 2003, 2007 and 2010 (Fig. 3). We found variable but generally high incidence of plastics overall (72-98%) including a great propospre-manufactured plastic ingestion (referred to as pellets because of their small, round shape) and post-consumer plastics; Fig. 6). In 2013, we also examined one Sooty Shearwater containing no plastics and one Red Phalarope that contained 3 pellets and 3 pieces of user plastic.

**IV. Discussion**

We found that entanglement in marine debris continues to be an important conservation issue within the Monterey Bay National Marine Sanctuary. Each year marine wildlife are killed at an average of 17 ± 8 cases per year at minimum. During the last 15 years, BeachCOMBERS documented more than 250 cases of entanglements affecting 24 species of marine birds (99%), three species of marine mammals (1%) and no sea turtles. Because BeachCOMBERS documents very few stranding records of sea turtles in the MBNMS (i.e. 1 in the last 8 yrs) and determining cause of death is rare in stranded animals, it is not

[3] http://sanctuarysimon.org/news/index.php/2013/06/seabird-and-marine-mammal-entanglement/

surprising that we found no cases of entangled sea turtles in this study. For species like Leatherback Sea Turtles (Dermochelys coriacea), entanglement in long-line fisheries continues to be a threat during migration in areas outside of the Sanctuary. The hard shelled turtles (Green, Loggerhead and Olive Ridley) typically occur south of MBNMS waters and are threatened by entanglement in coastal gill net fisheries off Southern California (Julian and Beeson 1998).

We found that certain groups of birds are more vulnerable to entanglement in marine debris than others. Our results indicate that diving birds (i.e. alcids, loons, grebes) and surface-feeding seabirds (i.e. gulls, tubenoses) are predominantly affected by entangling marine debris. The source of entanglements have been mainly from presumably from lost or abandoned fishing gear, such as monofilament line, net, hooks and lures – which are either ingested, or wrapped around the birds' bodies, wings, or legs, impairing mobility and ultimately leading to starvation or drowning (Fig. 7). Large-bodied pelicans are somewhat of an exception, although our data would suggest they have few entanglements, many of the cases of entanglement are from live birds which were subsequently treated at wildlife rehabilitation centers. This was evident in 2001, when numerous pelicans were found to repeatedly entangled at fishing piers throughout the Bay (Native Animal Rescue), very few (5) were reported dead by BeachCOMBERS. Thus the BeachCOMBERS records are limited in representing a proportion of those entangled and released each year. Until those rehabilitation data are better quantified, these estimates remain the minimum for those species affected.

We also found that plastic ingestion is pervasive issue with marine birds in Sanctuary waters as it has been recognized globally. Comparatively, fulmars collected in Monterey Bay (70-80%) have more than Alaska (60-70%, Oikonos unpublished data ), but less than the highly contaminated waters of the North Sea (100%, van Franeker 2005). Rosevelt et al. (2012) recently conducted the first beach litter study in MBNMS and indicated that areas of accumulation occur primarily in the inner beaches (Zmudowski to Marina; beaches 5, 6, 7, 8) where the majority of fragments of plastics are within the size range (<2 cm) that would be ingested by Northern Fulmars (0.5 – 2 cm), Red Phalarope (1-3 mm) and other surface-feeding marine birds within Monterey Bay (Bond 1971). Because there is no way to distinguish between land and sea based source of this plastic pollution, we assume the incidence of plastics we measured is a combination of both sources in the area. Baltz and Morejohn (1976) measured 100% plastic ingestion in fulmars collected in Monterey Bay, but only examined three birds in their study.

**V**. **Future Research Needs**:

Marine Debris has been a long-term conservation issue for wildlife globally (Ryan 1988) and has been recognized in Monterey Bay since the 1970s (Baltz and Morejohn 1976). Data from this study can help inform future management decisions, monitoring of marine debris and potential risks from Tsunami related debris. Entanglement of wildlife continues to be a chronic source of mortality for marine birds and mammals in the Monterey Bay Sanctuary. These harmful impacts to marine wildlife can be mitigated through fisher awareness and training, promoting monofilament recycling, beach and seashore clean-up activities.

For the future, we recommend continued reporting of wildlife entanglement interactions through the BeachCOMBERS program. We plan to develop protocols for marine debris surveys on surveyed beaches with the addition of new volunteers. The debris surveys would give an improved indication of the accumulation of marine debris within MBNMS beaches and inform clean-up activities and identify areas of increased wildlife interactions. Given the high diversity of marine birds in the Sanctuary and the vulnerability to plastic ingestion, this topic warrants further study. In particular, identifying areas of accumulation at the sea surface within the Monterey Bay area would be important to identify and potentially mitigate through targeted removal. As Gregory (2009) pointed out, the "hitch-hiking" invasive species may accelerate the dispersal of invasive species, posing other deleterious impacts to marine ecosystems.

To complete our understanding of wildlife impacts, we also recommend augmenting documentation of dead animal entanglements with live entanglement cases of through collaboration with groups that respond to live stranded seabirds, marine mammals and sea turtles within the Sanctuary (The Marine Mammal Center, Monterey Bay Aquarium, Monterey SPCA Wildlife Facility, Native Animal Rescue, California Department of Fish and Wildlife). In doing so, we would obtain a larger-scale depiction of how many marine mammals, seabirds, and sea turtles are entangled in the MBNMS each year.

There is a need to understand sub-lethal impacts of plastic ingest from lipophilic compounds such as persistent organic pollutants. Teuten et al. (2009) has suggested that these chemicals may adhere to floating plastic fragments increasing the potential negative effects of ingestion. The Sanctuary waters are adjacent to large agricultural areas, where land to sea run-off and historic accumulation of pesticides and fertilizers are likely to contribute to these impacts if they are transported by marine food webs via plastic ingestion. Future work specifically on identifying the prevalence and potential impacts on wildlife from these impacts would be important to identify and mitigate if possible.

Ocean literacy campaigns have made great strides in bringing awareness of ocean issues to the consciousness of citizens, galvanizing community-supported action such as beach clean-ups and recycling campaigns. Given the importance of the Monterey Bay Sanctuary to wildlife, continued efforts to promote ocean conservation are essential. Because we found much of the items causing entanglement of marine birds and mammals was likely from recreational fishing activities – efforts to target educational outreach to this group would be most beneficial in reducing wildlife entanglements in the MBNMS.

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**Table 1. Entanglements by year and species from monthly Beach COMBER surveys, 1997-2012.**

| Family/species | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | Subtotal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alcids** | | | | | | | | | | | | | | | | | |
| Murre, Common | 14 | 5 | 2 | 3 | 7 | 5 | 2 | 6 | 4 | | 3 | 1 | 4 | | 7 | 2 | 65 |
| Auklet, Cassin's | | 1 | | | | | | | | | | | | | | | 1 |
| Guillemot, Pigeon | | | | | | | | | | | 1 | | | | | | 1 |
| **Cormorants** | | | | | | | | | | | | | | | | | |
| Cormorant, Brandt's | 3 | 1 | | 1 | 2 | 1 | 1 | 3 | 2 | 1 | 1 | 1 | 6 | 1 | 2 | 1 | 27 |
| Cormorant, Double-crested | | 2 | | | | 1 | | 1 | | 2 | 2 | | | | | | 8 |
| Cormorant, Pelagic | | 1 | | | | | | | 1 | 1 | | | | | | | 3 |
| Cormorant, Unidentified | | | | | | | | | 1 | | | | | | 2 | | 3 |
| **Pelicans** | | | | | | | | | | | | | | | | | |
| Pelican, Brown | | | | | 5 | 5 | 1 | | | | 1 | | 1 | | 4 | 3 | 20 |
| **Sea Ducks** | | | | | | | | | | | | | | | | | |
| Scoter, Surf | | 1 | | | | | | | | | 1 | | | | | 2 | 4 |
| Scoter, species | | 1 | | | | | | | | | | | | | | | 1 |
| Merganser, Red-breasted | 1 | | | | | | | | | | | | | | | | 1 |
| Merganser, Common | | | | | | 1 | | | | | | | | | | | 1 |
| **Shorebirds** | | | | | | | | | | | | | | | | | |
| Shorebird, unidentified | 2 | | | | | | | | | | | | | | 1 | | 3 |
| Willet | | 1 | | | | | | | | | | | | | | | 1 |
| **Grebes** | | | | | | | | | | | | | | | | | |
| Grebe, Western | | 1 | | | 1 | 1 | 2 | 1 | | | | 3 | | | 1 | 1 | 11 |
| Grebe, *Aechmophorus* spp. | | | | 1 | | | 1 | | | | 3 | | | | 2 | 1 | 8 |
| Grebe, Clarks | | | | | | | | | | | | | | | 2 | | 2 |
| Grebe, unidentified | 1 | | | | | | | | | | | | | | | | 1 |
| **Gulls** | | | | | | | | | | | | | | | | | |
| Gull, Western | 3 | 1 | 1 | | 2 | 2 | 3 | 4 | 1 | 2 | 3 | 1 | 2 | 1 | | | 25 |
| Gull, unidentified | 1 | 2 | | | 1 | 4 | 1 | | 1 | | 1 | 1 | 1 | 3 | 1 | 1 | 18 |
| Gull, Heermann's | | 2 | | 1 | 2 | | | 1 | | 1 | 1 | | | | 1 | | 9 |
| Gull, California | | | | | | 2 | 1 | | | | 2 | 1 | | | | | 6 |
| Gull, Ring-billed | | | | | | | | 1 | | | | | | | | | 1 |
| Gull, Glaucous-winged | | | | | | | | | | | | | | | 1 | | 1 |
| **Loons** | | | | | | | | | | | | | | | | | |
| Loon, Pacific | | | 1 | | 1 | | | | 1 | | | | 2 | | | | 5 |
| Loon, Common | | | | | | | | | | | 1 | | | | | | 1 |
| Loon, species | | | | 1 | | | | | | | | | | | | | 1 |
| **Procellariids** | | | | | | | | | | | | | | | | | |
| Shearwater, Sooty | 4 | 8 | 1 | 4 | 7 | 1 | | 2 | | 1 | | | 1 | 1 | 2 | 3 | 35 |
| Fulmar, Northern | | 2 | | | | | 1 | | 1 | | 1 | | | | 2 | | 7 |
| Shearwater, Species | | | | | 1 | | | | | | | | | | | | 1 |
| Shearwater, Pink-footed | | | | | | | | | | | | | | | | 1 | 1 |
| **Marine Mammals** | | | | | | | | | | | | | | | | | |
| CA Sea Lion | | | | | | | | 1 | | | | 2 | | | | | 3 |
| Harbor Porpoise | | | | 1 | | | | | | | | | | | | | 1 |
| Otariid, unidentified | | | | 1 | | | | | | | | | | | | | 1 |
| Harbor Seal | | 1 | | | | | | | | | | | | | | | 1 |
| **Grand Total** | 29 | 30 | 5 | 13 | 29 | 23 | 13 | 20 | 12 | 8 | 21 | 10 | 17 | 6 | 28 | 15 | 279 |

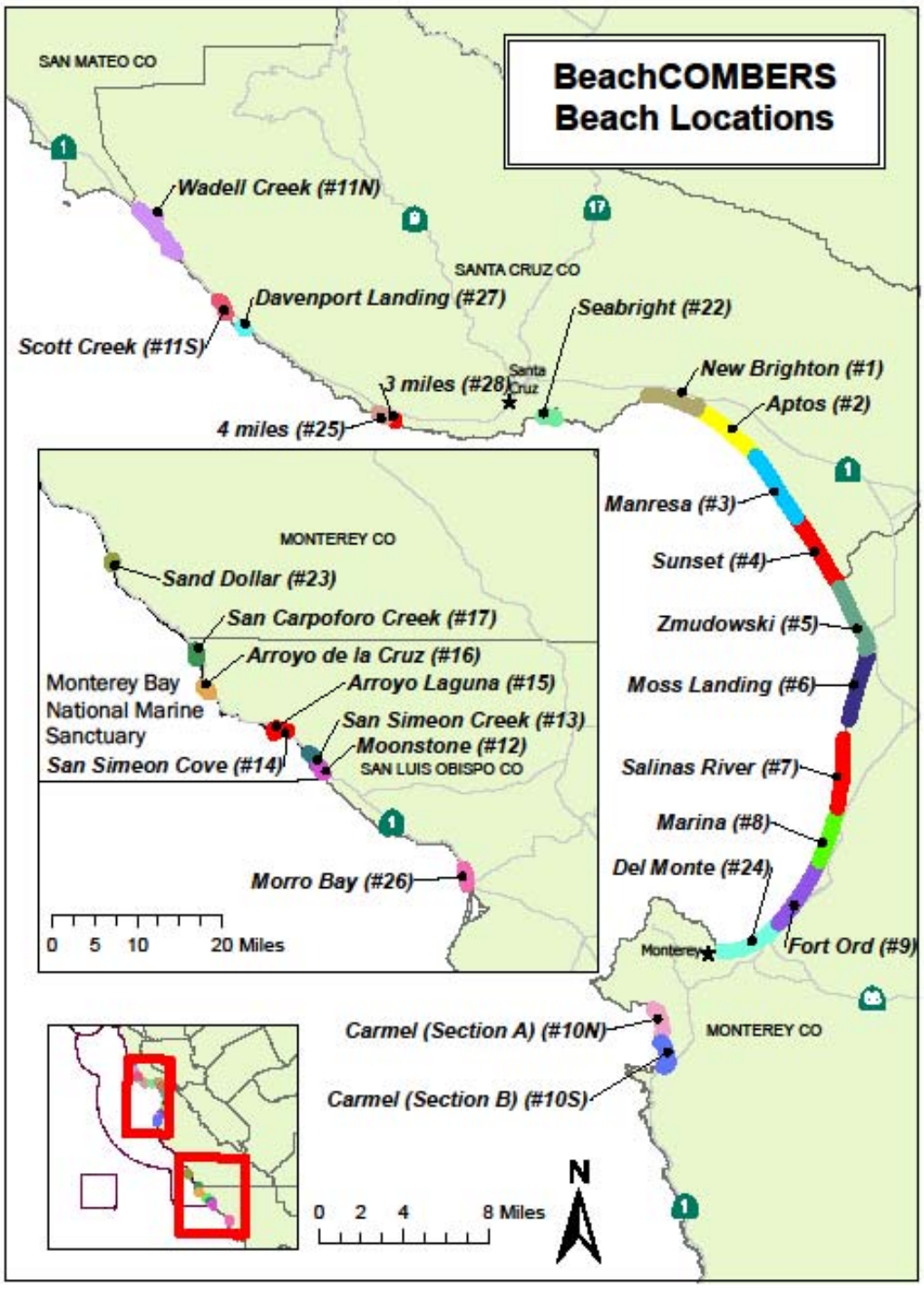


**Figure 1. BeachCOMBER survey beaches within northern (upper inset) and southern (lower inset) Monterey Bay National Marine Sanctuary (black boundary line).**

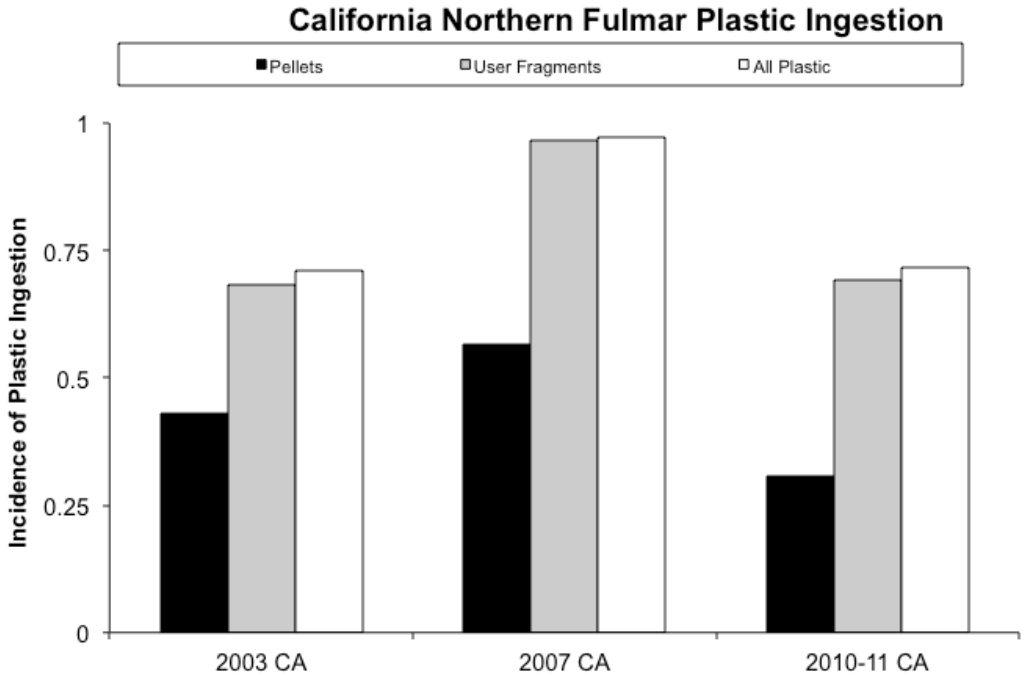


**Figure 3.** Incidence of Plastic Ingestion in Northern Fulmars collected in CA from three die-off events (2003, 2007, and 2010). Incidence is represented as the frequency of Total Plastic (white bars), fragments of user plastics (gray bars), and pellets (black bars). (Oikonos unpublished data)

**Figure 4. A Black-footed Albatross carcass entangled in party balloons and string and recovered from Marina State Beach in June of 2013. Photo taken by BeachCOMBER volunteers Chris Miller and Patty Brown.**


Figure 5. A sample of plastics from a Northern Fulmar collected in Monterey Bay in 2010. Often fragments of plastic cannot be attributed to a particular source, but note the latex party balloon with promotional message indicates a land-based source.


Figure 6. A sample of plastics from a Northern Fulmar collected in Monterey Bay in 2010. Often fragments of plastic cannot be attributed to a particular source, but note the latex party balloon with promotional message indicates a land-based source.


Figure 7. Diving seabirds such as Common Murre and Cormorants often are most affected species by fishing line and net entanglements. (A) An adult murre in breeding plumage found on beach survey entangled in monofilament net (photo: BeachCOMBERS ). (B, C)Common Murre carcass entangled on the right wing in monofilament net, [inset] close-up of monofilament netting (BeachCOMBERS, April 2005). (D) Pelagic Cormorant carcass entangled on both wings in monofilament fishing line with hooks still attached (Jon Hubbard, BeachCOMBERS, Salinas River State Beach, August 2005).