Seabirds Indicate Plastic Pollution in the Marine Environment: Quantifying Spatial Patterns and Trends in Alaska

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Seabirds and plastic debris: global perspective

As far-ranging and upper-trophic predators, seabirds are valuable biological indicators of climatic and human-related perturbations of marine food webs, including the incidence of pollutants (e.g., Furness and Camphuysen 1997, Burger and Gochfeld 2004). In particular, seabirds have proven sensitive indicators of trash in oceanic systems because they often ingest debris resembling their prey (Van Franeker and Meijboom 2002, Nevins et al. 2005). However, studies to date have largely focused on documenting the incidence and type of plastic ingestion. The available research has documented global marine debris distributions (Ayre 2006, Weiss 2006) and pervasive plastic ingestion in seabird populations worldwide (Collins 2005, Edwards 2005), from the tropics to subpolar regions.

Seabirds and plastic debris: local perspective

Seabirds are an integral and conspicuous component of the Alaska marine ecosystem, with large breeding populations (~29 million seabirds belonging to 35 species) nesting in the Gulf of Alaska and the Bering Sea each spring/summer and large populations of seasonal visitors (~20 million), including migratory species from the western Pacific and the Southern Hemisphere (Hunt et al. 2000, Stephensen and Irons 2003). Because seabirds eat the same zooplankton, fish, and squid prey consumed by commercially valuable fish species (e.g., salmon), they provide valuable information about the pollutant loads of marine resources consumed by humans (e.g., Burger and Gochfeld 2004, Blais et al. 2005). In fact, the subsistence harvest of seabirds and their eggs by indigenous inhabitants of Alaska potentially transfers pollutants directly from these upper-trophic marine predators to human consumers (e.g., Denlinger and Wohl 2001, Vander Pol et al. 2004).

Herein, we review published information on plastic ingestion by Alaska seabirds, offer suggestions for the establishment of standardized time series to quantify this phenomenon, and discuss future research needs to develop an understanding of the ecological impacts of plastic ingestion on seabirds.

Current knowledge

One of the key ecological factors influencing the incidence of plastic ingestion by seabirds is feeding mode. Surface feeding species that feed opportunistically are most susceptible to ingesting floating marine debris. In particular, several tubenose seabirds (order Procellariiformes) are characterized by a high degree of plastic ingestion, with 62-84% of fulmars and 100% of albatross examined in recent studies containing plastic (Nevins et al. 2005).

To date, only three studies have quantified temporal trends in plastic debris ingestion by Alaska seabirds. A colony-based survey of multiple species revealed species-specific differences in the incidence of plastic ingestion among Alaska breeding seabirds. Overall, 62.5% (15 out of 24 species, n = 1,799 individual birds) had ingested plastic debris (Robards et al. 1995). Of the 4,417 plastic items examined, 76% were industrial preproduction pellets, 22% were fragments of user plastic, and 2% were unidentified. Although most seabird species ingested marine debris, this study highlighted the differential incidence of plastic ingestion among feeding modes; surface-feeding species showed a greater rate of plastic ingestion than diving species (86% vs. 47%), and took a relatively greater proportion of user plastics. Furthermore, Robards et al. (1995) compared plastic ingestion in the 1970s and the 1980s, and documented a higher prevalence (incidence and magnitude) and an increase in the number of breeding Alaska seabird species affected by plastic ingestion. For example, the plastic ingestion rate for the northern fulmar (*Fulmarus glacialis*) increased from 58% (1969-1977) to 84% (1988-1990).

The second study addressed the long-term (decadal) trends in the amount and the types of plastics ingested by a far-ranging seasonal visitor from the Southern Hemisphere, the short-tailed shearwater (*Puffinus tenuirostris*). Vlietstra and Parga (2002) documented a change in the types of ingested debris, with a shift from industrial pellets (1970-1978) to user plastics (1997-2001), but no change in the overall incidence (86%) of plastic ingestion by this species in the southeastern Bering Sea.

More recently, the third study quantified the amount of plastic ingested by northern fulmars washed up dead along the west coast of North America during the winter of 2003-2004 (Nevins et al. 2005). Plastic fragments occurred in 71% of the 190 fulmar stomachs examined in central California, with an average of nine post-consumer fragments (range = 1-41), two industrial preproduction pellets (range = 1-8), two polystyrene foam fragments (range = 1-10), and two other pieces of debris (range = 1-6; including rubber bands, party balloons, fishing line, lure fragments, plastic film, artificial sponge fragments). The mean (± SD) size of the user plastic fragments ingested by fulmars was 5.7±2.8 mm (n = 733).

Knowledge gaps

The results of these three studies underscore the need for standardized time series of plastic ingestion by Alaska seabirds, designed to capture regional patterns in the type (e.g., plastic, Styrofoam, fishing line), the amount (e.g. incidence, number, mass), and the source (e.g., industrial, user) of the ingested debris. Such seabird monitoring programs are already under way in the European Union (Van Franeker and Meijboom 2002, Van Franeker 2004).

The tendency of seabirds to reproduce in large aggregations at predictable localities, and the broad geographic distributions of many species, will facilitate regional and basin-wide comparisons of plastic ingestion in breeding populations (Stephensen and Irons 2003, Vander Pol et al. 2004). In particular, comparisons of widespread species (e.g., storm-petrels, fulmars) in different regions (e.g., Gulf of Alaska, Bering Sea) and ocean basins (e.g., North Pacific, North Atlantic) will provide valuable information for assessing spatial and temporal trends.

Comparative studies involving diverse perspectives (e.g., colony-based studies during the breeding season, at-sea sampling in the winter range) will also facilitate regional and seasonal comparisons of plastic ingestion rates. Nevertheless, monitoring programs for Alaska seabirds will need to address the different migration patterns and foraging grounds of locally breeding and migratory seabirds. The interpretation of these data will be constrained by the spatial scales of the foraging movements of the different seabird species.

For instance, while northern fulmars forage close (tens to hundreds of kilometers) to their colonies in summer, after the breeding season they migrate widely and disperse to the west coast of North America (Hunt et al. 2000, Nevins et al. 2005).

Next steps

We advocate the development of research and monitoring programs designed to (i) identify those species more susceptible to plastic ingestion and therefore better suited to serve as bio-sensors of marine debris; (ii) develop standardized metrics to quantify the regional and temporal patterns of plastic ingestion by Alaska seabirds; and (iii) enhance public awareness about this pervasive problem by applying the research and monitoring results in outreach and educational materials. Moreover, using seabirds as biological samplers of marine debris distributions will require identifying those life history and ecological traits that influence the ingestion of plastic debris, characterizing those physical processes that concentrate and make marine debris accessible to foraging seabird, and quantifying short-term and long-term health effects (lethal and sublethal) on seabird populations from the ingestion of plastic debris.

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