

Marine Debris Survey and Plastic Ingestion of Pacific Albatross
on Sand Island, Midway Atoll.
1997

Kater Bourdon
Senior Thesis
Marine Science Department
University of Hawai'i at Hilo

Advisor:
Dr. Karla J. McDermid
Assistant Professor, Marine Science Department,
College of Arts and Sciences
University of Hawai'i at Hilo

Abstract

Marine debris, more specifically, pelagic plastics have major effects on marine life, especially seabirds that feed on the water's surface. Midway Atoll, a remote atoll in the North Pacific, is the destination for large accumulations of marine debris brought either by currents, or by adult albatrosses foraging to feed their young. This study was undertaken to look for a similarity between debris found on the shore, and debris in the stomach contents of dead chicks. A marine debris survey of West Beach on Sand Island, Midway Atoll was conducted. This study also looked closely at the gastrointestinal tract contents of Laysan albatross chicks (*Diomedea immutabilis*). Chicks' stomachs contained 50% plastics. Plastic accounted for 31.9% of the total composition of debris found on shore. Individual plastic pieces were found to account for 75.4% of the total debris composition on the beach. Periodic monitoring and assessment of incidence of marine debris in Laysan albatross chick diet will provide essential information for the survival of Midway Atoll's flagship species. The results of this study may increase the understanding of the abundance and effects of floating marine debris on Pacific seabird populations in general.

Introduction

For centuries, the world's oceans have been viewed as an endless reservoir of productivity with an unlimited capacity to carry anthropogenic marine debris and synthetic compounds (Coe and Rogers, 1997). As early as the 1930's, scientists began seeing the first signs that debris in the marine environment was going to be very hazardous and have long term effects on marine life (Coe and Rogers, 1997). However, it was not until recently that the public have become more aware of the marine debris crisis.

Scientists have defined marine debris as any manufactured or processed solid waste material (typically inert) that enters the marine environment from any source (Coe and Rogers, 1997). The terms "floatables" and "litter" are often used due to the fact that unlike oil spills, marine debris is not usually accidental. Sources of marine debris, often lacking proper waste management, may discharge, dump, release, or abandon wastes as a convenience or lack of a better place to store it. Trash released on land eventually ends up in our oceans, and then circulates for weeks up to years, and may wash ashore where it originated or on distant shores.

Marine debris can be classified into types by composition. According to some scientists, plastic, is the single most human-made threat to marine species (Corbin and Singh, 1993). Plastics have become a large part of our everyday life. Many factors and attributes make plastics desirable: lightness, strength, cost effectiveness, safety (for humans), adaptability, versatility, and flexibility in manufacturing (Gregory, 1991). In addition, plastics have great durability and resistance to microbial and other decomposing processes. These factors make plastic very consumer-friendly, however not environment-friendly.

Anthropogenic plastic found in the world's oceans have been classified into two main groups: "user/consumer-friendly" product particles and raw pellets (Day *et al.*, 1984). User-friendly plastics are classified as those particles and pieces of such things as buckets, bottles, caps, lighters, and fishing

floats. Raw pellets are shipped around the world to manufacturing sites where they are then melted down and made into consumer products. These pellets of plastic are then fabricated into bags, toys, squeeze-bottles, etc. There are many ways in which these deadly little pellets may enter the oceans. Plastic-synthesis plants in India basically dump their waste pieces of plastic into the nearby rivers and out to sea (Day *et al.*, 1984). Pellets are also used for packaging and sometimes lost in ports. Practices of covering decks with pellets to aid in decreasing the friction when loading cargo also has an effect on the amount of plastics in harbors. These pellets are simply washed off the decks when all the cargo is safely on board (Day *et al.* 1984,). Once raw pellets or user-friendly plastics enter the oceans, it is then up to circulation patterns, winds, and currents to distribute pelagic plastic debris throughout the world.

Marine debris of all shapes, sizes, and composition gathers in the oceans. Accumulation of marine debris is associated with the wind and current circulation patterns at the sea surface. Debris will float in the seas until it hits the first piece of solid land, often being remote islands. Debris gathers north of the Hawaiian Islands by a simple three-step process of current flows (Kubota, 1991). First, debris accumulates in the Eckman convergence zone (trade-wind related), then the debris moves eastward by the geostrophic currents. The debris then becomes densely accumulated north of Hawai'i by the Eckman drift, which is due to the atmospheric North Pacific subtropical high (Kubota, 1991). These theories were tested by monitoring buoys in the North Pacific (Kubota, 1991). After 400 days at sea in the circulation patterns, the buoys became concentrated and stationary. This is a possible explanation for the large amount of marine debris on and around the Northwest Hawaiian Islands, despite their remoteness and low number of human inhabitants. Further studies need to be conducted in order to confirm that these current and circulation patterns exist year round, and play a large role in accumulation of marine debris in the North Pacific. Studies have found that pelagic or open ocean plastics are most abundant in the central subtropical and western North Pacific (Robarbs *et al.*, 1997). This research also suggested that there is a direct association with large tanker and ship traffic in the

Western Pacific. A "downstream" effect of debris entering the ocean near Japan, which is a main plastic producing country, also seemed to be present.

Marine debris, more specifically, pelagic plastics, have major effects on marine life, especially seabirds that feed on the water's surface. Plastic items have the potential to be mistaken for food in the marine environment. In the 1970's, biologists first made an interesting observation: seabirds were eating plastics. Certain species seem to pick out raw pellets of plastic, perhaps because the pellets resemble the birds' normal prey items. Generally, species of seabirds from Alaska that eat crustaceans and cephalopods have a higher frequency of plastic ingestion than birds hunting for fish species (Day et al., 1984). Surface feeding seabirds have the highest rate of plastic ingestion (Day et al., 1984). Members of the class Procellariiformes or "tube noses" are surface prey-seizers. Albatrosses, are members of this class and settle on the surface and grab prey items. Laysan albatrosses (*Diomedea immutabilis*) feed mainly on squid species which occur in the upper water column where debris floats. Due to their food location, it is easy to see why these seabirds pick up floating plastics while feeding. Laysan albatrosses are reported to have a greater incidence, a larger variation, and higher volume of ingested plastics than any other seabird species (Sileo et al., 1990). Other species of albatrosses also feed on flying fish eggs that stick to floating objects in the water (Auman, 1994). Albatross species, as well as other seabirds, scavenge refuse from ships at sea. In a study by Kenyan and Kridler (1969), it was documented that almost all plastic particles ingested by seabirds float at the water's surface (Day et al., 1984). Of 109 identifiable items, found in Laysan albatrosses in Hawai'i, 108 were found to have originated in Japan (Robarbs et al., 1997).

Probably the largest immediate effect of plastic ingestion is regurgitation to seabird chicks from parents. Parent birds pick up plastic from the ocean surface, and later regurgitate it to their hungry, unknowing chicks along with food (Sileo et al., 1990). The plastic particles and pellets then accumulate in a chick's proventriculus, the thin-walled glandular section of the stomach and gizzard (Auman, 1994). Ingested plastics have been shown to cause internal lacerations or block normal

digestive and respiratory processes (Auman 1994). Studies conducted on Midway Atoll, the world's largest breeding colony of Laysan albatrosses, have shown that plastic ingestion plays a role in mortality of chicks (Auman, 1994). Besides bodily harm, chicks may become satiated and feel full with all the plastics in their body, and starve to death (Sileo et al., 1990). All ingested plastics found in seabirds have been found in the gizzards and proventriculi, both of which are in the anterior section of the gastro-intestinal tract. Plastic has yet to be found in the intestinal tract or feces (Day et al., 1984). This indicates that seabirds cannot digest plastic. Fledgling chicks normally egest a bolus or lump of indigestible swallowed food, but large pieces of plastic may prohibit this process causing suffocation and death (Auman, 1994). Seabirds ingest plastics that are discarded into the marine environment. In 1983, an average of 76.7 g of plastic were found in dead albatross chicks (Fry et al., 1987). Sileo et al., (1990), also studied causes of mortality of chicks at Midway, and found an average of 46 cc of plastic in birds sampled in 1986. Recently, Auman (1994), included a plastic ingestion assessment in her thesis, and found an average of 23.8 g of plastic in dead chick samples. Plastic ingestion seems to vary among years, but it is always prevalent. A study by Day et al. (1984), showed that seabirds actually prefer certain colors of plastic debris. Out of 11 recognized colors of plastic ingested by seabirds in Alaska, 85% of the particles were light brown. These light brown pellets and particles closely resemble flying fish eggs, which are a main diet for many species of seabirds.

Numerous questions are still unanswered that pertain to seabird feeding behavior, however with modern sophisticated tracking devices, scientists have been able to get a better idea of the individual parent birds' foraging range. In fact, scientists have pinpointed three Black-footed albatross that roamed 2,600 miles from their tiny Hawaiian atoll (Tern Island) to San Francisco (Martin, 1998). An individual Laysan albatross flew more than 2,000 miles to the Aleutian Islands, flew back to Tern Island stayed a day, then flew straight back to the same place on the Aleutian Island (Martin, 1998). Further studies will still need to be conducted to find the exact feeding ground location for pelagic surface feeders, such as the Laysan albatross. Scientists are gaining a better understanding as to where

the albatross go, but it is still not completely clear why they are going there. However, we do know that these gliders of the wind are feeding on our trash floating in the oceans, and later indirectly killing or harming their chicks.

Midway Atoll is located in the Northwest Central Pacific Ocean (28° 11' N, 77° 22' W), about 1200 miles northwest of Honolulu. Midway Atoll is a National Wildlife Refuge, and home to millions of seabirds. Midway houses the world's largest breeding colony of Laysan albatross. This study was undertaken to look for a similarity between debris found on shore, and debris found in the stomach contents of dead albatross chicks. Periodic monitoring and assessment of incidence of marine debris in Laysan albatross chick diet will provide essential information for the survival of Midway Atoll's flagship species. The results of this study may increase our understanding of the abundance and effects of floating marine debris on Pacific seabird populations in general.

Methods

Part I.- Marine Debris Survey

A marine debris survey/collection was conducted on West Beach of Sand Island, Midway Atoll. Midway Atoll is located in the Northwest Hawaiian Islands (28° 11' N, 177° 22' W), and is about 5 miles in diameter. West Beach was selected because it is the largest stretch of beach on the atoll and faces northwest out to the open Pacific Ocean (Figure 1).

Randomly hand-picked debris was collected by ten volunteers over a half mile stretch of beach. Debris was placed in 33 gallon plastic bags. The debris was collected in the littoral fringe zone of the coast, to avoid disturbance of the resident endangered Hawaiian Monk Seals (*Monachus schauinslandi*) that frequent West Beach on the atoll. Debris was sorted by composition: plastic, styrofoam, glass, cloth, metal, and rubber. Special note was taken of debris items that could be ingested by seabirds. If possible, debris was identified by its primary use such as fishing, household

Midway Atoll

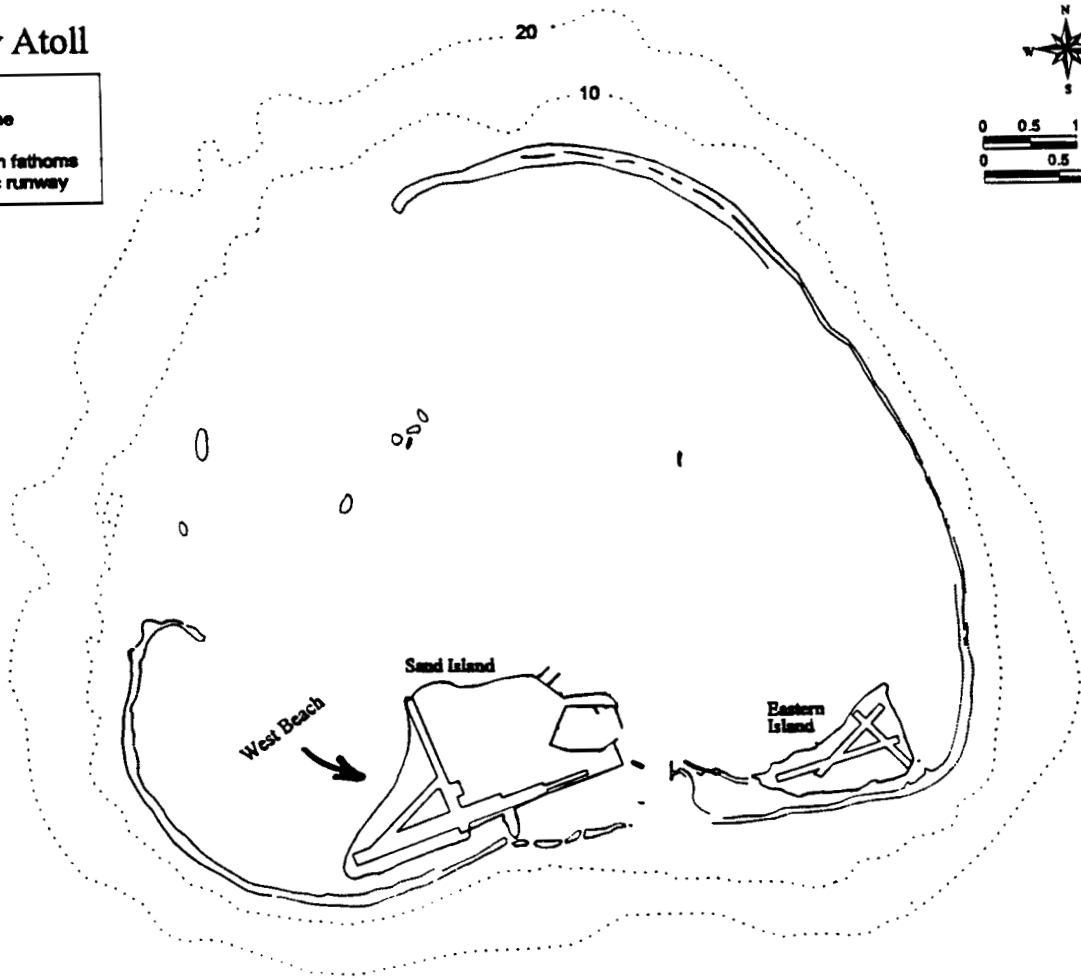
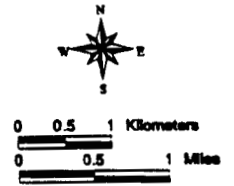
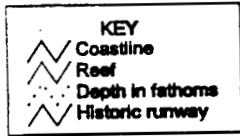


Figure 1. Midway Atoll, NWR, Sand Island (far left) site of marine debris survey and plastic ingestion study.

use, or industrial. Although there is no way to determine exact source of debris, any information on labels was examined to estimate the likely country of origin. The number of pieces of each category of debris from each bag was counted. Total weights of debris were calculated, statistically analyzed, and graphed to find the most commonly found type of debris occurring on West Beach.

Part II.- Albatross Ingestion Study

Between June 20-July 4 1997, late in the nesting season, when Laysan albatross (*Diomedea immutabilis*) chicks are abundant and about 4 months old, 23 carcasses were dissected at Sand Island (28°11'N, 177°22'W) of Midway Atoll (Figure 1). Sand Island is the site of a National Wildlife Refuge, operated and supervised by U.S. Fish and Wildlife Service. A special use permit was obtained in advance in order to conduct research on the refuge (see Appendix). Dead chicks were randomly collected daily by the atoll's pest control personnel. From these chicks, a visual assessment of the glossiness of the eyes determined which carcasses were selected for necropsy. This quick selection helped ensure that only the most recently dead chicks were necropsied, and that decomposition of organs and tissues was minimal. No birds with visible maggots were selected. Birds were processed as soon as they were delivered by the pest control personnel.

The carcasses were opened by a ventral incision. The proventriculus of each bird was removed along with the gizzard, following the procedure of Auman (1994). The proventriculus and gizzard contents were then placed into clean baggies and frozen. The intact proventriculus and gizzard contents were defrosted, opened, rinsed with bleach and water (to reduce the odor), and the contents were identified. Contents were sorted by composition, dried at 40° C for 72 hours, air dried, and color noted. Ingested items were categorized as plastic, rock/pumice, squid beaks (normal prey item), glass, styrofoam, metal, rubber, raw pellets, fishing line, and miscellaneous. Contents were then weighed according to categories using a Mettler Balance. Results of the ingestion study (Part II.) were

compared with the results of the marine debris survey (Part I.) to look for a similarity between debris ingested by the albatross and debris found on the beach (see Figure 2 and Figure 3).

Results

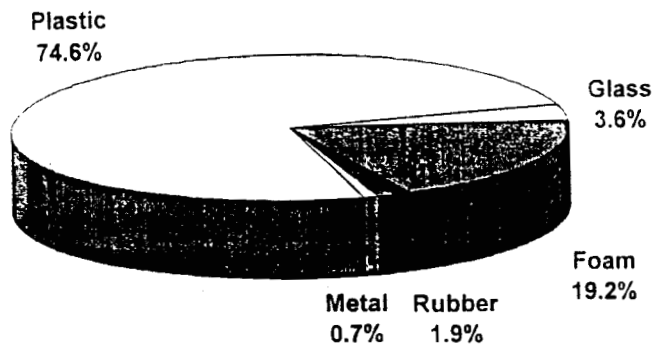
Marine Debris Survey

Overall, pelagic plastics comprised 74.6% of the total amount of debris pieces found on West Beach. Styrofoam comprising 19.2%, glass 3.6%, rubber 1.9%, and metal less than 1.0% (Figure 2). Comparisons of debris by weight showed plastic to account for 31.9%, glass 39.6% (remember these comparisons are by weight, glass generally weighs more), styrofoam 15.4%, rope 6.8%, rubber 2.8%, metal 2.0%, and the remainder making up a total of 730 kg. of debris found on the beach.

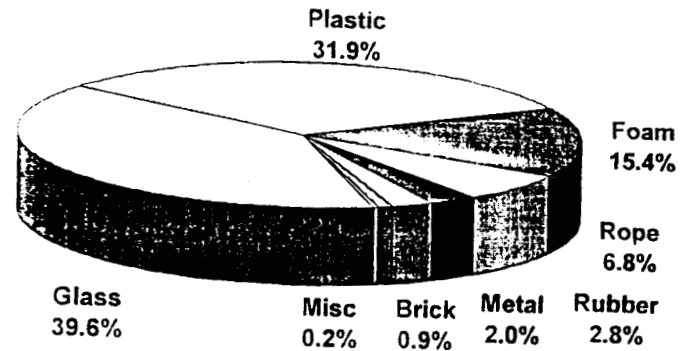
Albatross Ingestion

Of 23 total necropsied chicks, all contained plastic of some sort. All dead chicks' ingested stomach contents were sorted and weighed. Amounts of plastics in albatross chicks varied, with some birds containing 1.6 grams and others containing more than 101 grams of ingested plastic particles. Recognizable plastic items in the proventriculi are listed in Table 1. Besides plastic items, non-anthropogenic items such as rock/pumice, wood, seeds, coral fragments, and seaweed were also found. Squid beaks which are indigestible to chicks, but represent the remains of a natural food item, were found in every proventriculus analyzed. A small, glass medical vial was also recovered from one chick.

Plastic accounted for 50% of the total mean of ingested items by weight. Rock and pumice 28%, squid beaks 13%, fishing line 2.0 %, and styrofoam, rubber, raw pellets, misc. making up the remainder (Figure 3). The mean weight of total stomach contents was 53 grams.



(A)



(B)

Figure 2. West Beach marine debris mean percent composition by piece (A) and weight (B). Debris was categorized as plastic, glass, styrofoam, rope, rubber, metal, brick, and miscellaneous.

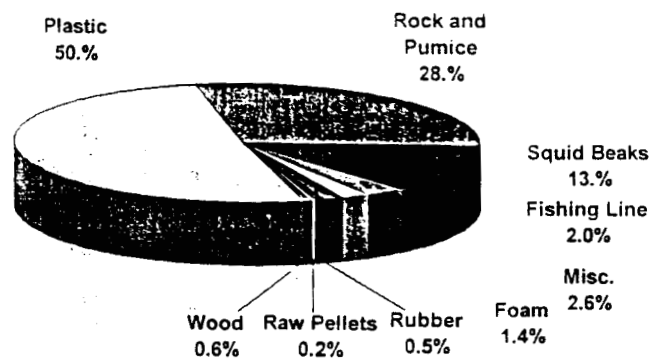


Figure 3. Sand Island albatross stomach contents mean percent composition by weight. Ingested particles categorized as plastic, rock/pumice, squid beaks (normal prey item), fishing line, styrofoam, rubber, raw pellets, wood, and miscellaneous.

Percent similarity between marine debris composition and albatross stomach contents was 34% , $PS = \sum \min (p_v, p_d)$ (Krebs, 1989). Plastic had the largest mean weight at 29.8 grams. It is interesting to note that pumice, which floats on the ocean surface was also found in the stomach contents, and significant. Squid beaks, which are the normal prey items were found the third most commonly, and the mean weight for glass weighed the least, at 0.071 grams (Figure 4).

Discussion

Plastic pollution has risen dramatically with an increase in the production of plastic resin during the past decades (Robarbs et al., 1997). Just in the U.S., plastic production has increased from 2.9 million tons in 1960, to 47.9 tons in 1985 (Robarbs et al., 1997). This increase in production has paralleled the significant increase of plastic debris on oceanic surface waters of the North Pacific (Day et al., 1984). The rates at which plastics degrade and disintegrate, either afloat or stranded on the shore are not well established (Gregory, 1991). Studies show that most common plastics in marine debris are more durable if left floating in seawater, than if exposed on land at the same location (Gregory, 1991). It is often speculated that the survival time for beached, common domestic-purpose plastics (detergent containers, etc.) is up to 5 years (Gregory, 1991).

As suspected, pelagic plastics were a extremely significant component of the marine debris survey conducted on West Beach of Midway Atoll located in the North West Hawaiian Islands (NWHI). The distribution of plastic debris appears to be more abundant in the NWHI than on other remote islands in the Central Pacific, and it is probable that much of the plastic found on the NWHI beaches has been carried by the Kuroshio Extention (Fry et al., 1987).

The amount of plastic pollution surrounding the NWHI has increased in the past 15 years. Relatively large quantities of a variety of debris including fishing nets and floats, boxes, bottles, manufactured plastic items and fragments of a wide diversity of sizes and types are now found on remote beaches (Fry et al., 1987), including beaches at Midway (see Figure 2 and Table 1). The most

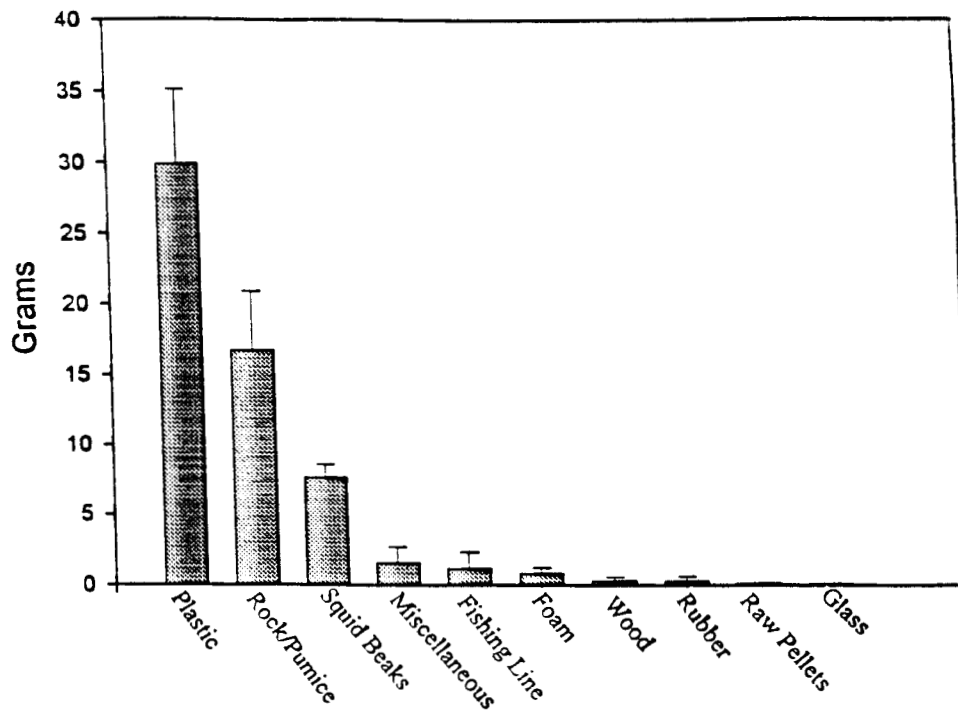


Figure 4. Mean weight of items in stomachs. Bars represent standard error.

Table 1. Ingested anthropogenic debris found in chicks' stomachs.

- Bottlecaps
- Lighters
- Toothbrush
- Miscellaneous plastic fragments
- Ball point pen
- Tampon applicator
- Part of comb
- Toy part
- Raw resin pellets
- Fishing line
- Strapping band
- Plastic flower
- Styrofoam pieces
- Rope
- Pen top
- Glass vial

common types of debris found on West Beach were plastics. Most of the plastics recovered were related to fishing industries. Plastic floats from longline driftnets were extremely common in all bags of debris analyzed. Much of the debris found was apparently from the Asia as indicated by the markings on items, and the proposed downstream effect from Japan.

The occurrence of plastic in seabirds and its potential hazard has been well documented (Day *et al.*, 1984, Fry *et al.*, 1987, Sileo *et al.*, 1990, and Auman, 1994). The results presented in this study demonstrated that albatross chicks at Midway Atoll, ingest plastics and other debris during the pre-fledging period when they are being fed by foraging parent birds. Floating plastic debris is ingested by adult albatrosses while they forage. Later, the adult birds regurgitate the food along with plastics to their chicks. The finding of the 34% similarity between West Beach debris and stomach contents supports the link between pelagic floating debris and Laysan albatross foraging.

Plastic fragments are abundant on the ground at Midway Atoll and other remote NWHI breeding colonies (Fry *et al.*, 1987). Plastic litter is most common on beaches where wave action deposits debris, but small fragments are found in the albatross colonies as part of castings regurgitated by resident albatross (Fry *et al.*, 1987, and this study). While it is possible that plastics may have contributed to the cause of death in the albatross chicks sampled, the exact cause of death is undetermined. Laysan albatross are protected by the Migratory Bird Treaty, therefore making it impossible to conduct a controlled experiment with live albatross chicks.

Literature Cited

- Auman, Heidi Joan.
1994. Plastic ingestion, biomarkers of health, PCBs and DDE in two species of albatross on Sand Island, Midway Atoll. Master's Thesis, Michigan State University. Department of Fish and Wildlife. 73 pp.
- Corbin, C.J. and Singh, J.G.
1993. Marine debris contamination of beaches in St. Lucia and Dominica. *Marine Pollution Bulletin*. 26: 325-328.
- Coe, J.M. and Rogers, D.B.
1997. *Marine Debris*. Springer, New York. 432 pp.
- Day, Robert H., Wehle, Duff H.S., and Coleman, Felicia C.
1984. Ingestion of plastic pollutants by marine birds. IN: Proceedings of the workshop on the fate and impact of marine debris. 26-29 November, 1984, Honolulu, HI. Shomura, R.S., and Yoshida, H.O. (eds.) U.S. Dept. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. :345-386.
- Fry, D.M., Feber, S.I. and Sileo L.
1987. Ingestion of plastic debris by Laysan albatross and wedge-tailed shearwaters in the Hawaiian Islands. *Marine Pollution Bulletin*. 18: 339-343.
- Gregory, M.R.
1991. The hazards of persistent marine pollution: drift plastics and conservation islands. *Journal of the Royal Society Of New Zealand*. pp: 83-100.
- Krebs, Charles J.
1989. *Ecological Methodology*. Harper and row, New York. pp: 304-307.
- Kubota, M.
1994. A mechanism for the accumulation of floating marine debris north of Hawaii *American Meteorological Society and Correspondence*. 24: 1059-1064.
- Martin, Glen
1998. Flight of the albatross. *San Francisco Chronicle*, March 25, 1998.
- Robarbs, Martin D., Gould, Patrick J., and Platt, John F.
1997. The highest global concentrations and increased abundance of oceanic plastic debris in the North Pacific: evidence from seabirds. IN: *Marine debris sources impacts and solutions*. Springer, New York. pp: 71-80.
- Sileo, Louis, Sievert, Paul R., and Samuel, Michael D.
1990. Causes of mortality of albatross chicks at Midway Atoll. *Journal of Wildlife Diseases*. 26(3): 329-338.

Special Use Permit--Midway Atoll NWR

Title: Assessment of gastrointestinal tract contents on Laysan albatross at Midway Atoll

Background: Midway Atoll is an important breeding colony for Laysan albatross (*Diomedea immutabilis*). Laysan albatross are surface-feeders and travel great distances to obtain food for themselves and their chicks. Floating marine debris, especially plastic debris, is prevalent throughout the world's oceans, and poses a significant threat to Laysan albatross health and survival. In 1983 an average of 76.7 g of plastic were found in dead chicks (Fry *et al.* 1987). Sileo *et al.* (1990) studied causes of mortality of albatross chicks at Midway and found an average of 46 cc of plastic in birds sampled in 1986 and 5 cc in 1987. Auman (1994) included an assessment of plastic ingestion in her thesis and found an average of 23.8 g of plastic in dead chick samples. Plastic ingestion seems to vary among years. Periodic monitoring of the incidence of marine debris in Laysan albatross chick diet will continue to provide important information for the management of Midway's flagship species.

Objectives:

1. To collect, identify, and characterize contents of upper gastrointestinal (GI) tracts of Laysan albatrosses.
2. To later compare GI contents with composition of marine debris on West Beach, Sand Island.

Justifications: Periodic monitoring of the plastic ingestion by Laysan albatross on Midway Atoll is needed to assess current effects of marine debris, and determine any changes in patterns of ingestion.

Procedure: Fifteen to twenty randomly sampled dead Laysan albatrosses will be collected on Sand Island and weighed. The carcasses will be opened by a ventral incision and the proventriculus and gizzard will be removed, following the procedure of Auman (1994). Contents of the proventriculus and gizzard will be removed, rinsed, identified, and weighed.

Personnel:

Kater A. Bourdon
Marine Science Department, University of Hawaii at Hilo
63 Maemae St.
Hilo, HI 96720

Dr. Karla J. McDermid
Assistant Professor, Marine Sciences Department, University of Hawaii at Hilo
200 W. Kawili St.
Hilo, HI 96720

Nanette Seto
Fish and Wildlife Biologists, U.S. Fish and Wildlife Service
Midway Atoll National Wildlife Refuge

Costs: Request the use of a scale. The applicants will provide all supplies including gloves, scissors, baggies, data sheets, and scalpels.

Schedule: This survey will be conducted June 25- July 4, 1997.

Reports: A preliminary report of the findings will be provided to the Refuge by September 30, 1997. A final report including results of beach marine debris survey will be provided by May 1, 1998.

Publications/Presentations: The findings of this survey will be presented at the Marine Options Program Symposium in 1998 and the University of Hawaii at Hilo Marine Science Senior Thesis Symposium.

Literature Cited:

Auman, H.J. 1994. Plastic ingestion, biomarkers of health, PCBS and DDE in two species of albatrosses on Sand Island, Midway Atoll. Master of Science Thesis Michigan State University. 73 pp.

Fry, D.M., Fefer, S.I. and Sileo, L. 1987. Ingestion of plastic debris by Laysan albatrosses and wedge-tailed shearwaters in the Hawaiian Islands. *Mar. Pollut. Bull.*, 18:339-343.

Sileo, L., Sievert, P.R. and Samuel, M.D. 1990. Causes of mortality of albatross chicks at Midway Atoll. *J. Wildl. Dis.*, 26:329-338.