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Marine Debris: A Growing Concern

By Howard O. Yoshida

Entanglement and suffocation by plastics, capture by "ghost fishing" gill nets, or death from discarded glass, metal, wood and rubber trash are constant threats to marine life. Scientists, conservationists and environmentalists are worried about the future of the sea.

A Workshop on the Fate and Impact of Marine Debris was held in November 1984 at the Ala Moana Hotel in Honolulu, Hawaii. Approximately 125 individuals including scientists and interested persons from Japan, Republic of China (Taiwan), United Kingdom, Republic of Korea, Canada, New Zealand, Federal Republic of Germany, and the United States participated in the workshop. Also, about 16 environmental-conservation type organizations were represented.

An uninformed layman could ask, what's so interesting about marine debris, and who cares what happens to it? For the past 10 years or so, marine scientists, conservationists, environmentalists, and others have been worried about the greatly increased amounts of marine debris that are apparent in the oceans around the world. The marine debris of much concern consists of lost and discarded fishing gear and other materials unrelated to fishing such as cargo nets and packing bands. The debris, a form of marine pollution, may be an especially serious problem in the North Pacific Ocean where it contributes to the deaths of marine animals: marine mammals, particularly the northern fur seal, *Callorhinus ursinus*, and the Hawaiian monk seal, *Monachus schauinslandi*, marine turtles, seabirds, and fishes. Marine debris also poses a threat to human safety by fouling the propellers of vessels.

The objectives of the workshop were to (1) review the state of knowledge on the fate and impact of marine debris to determine the extent of the problem; (2) identify and make recommendations on possible mitigating actions; and (3) identify and make recommendations on future research needs. The workshop opened with a review of conventions, laws, and regulations that could provide a legal framework for resolving the marine debris problem. This was followed by technical sessions on the source and quantification of marine debris: the impact of debris on marine resources; and the fate of marine debris in the oceans; and a general session to focus on identification of management needs.

The complete results of the workshop are contained in the "*Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, Hawaii,*" a 580-page document that was published under the auspices of the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA. The document includes all the scientific and technical papers that were presented at the workshop plus summaries of the discussion sessions, and is probably the most comprehensive compilation of information, under one cover, on the subject of marine debris and some of its impacts to date. This article briefly treats the contents of the Proceedings of the workshop. A person interested in more detailed information on the marine debris problem should refer to the Proceedings.

Background: Debris Reported in '30's

The entanglement of marine animals in debris apparently is not a new phenomenon. There are reports of the entanglement of northern fur seals in debris on the Pribilof Islands in the 1930's. In these early incidents the seals were entangled in rubber bands cut from the inner tubes of automobile tires. In the 1960's it was noticed that increased numbers of northern fur seals were being entangled – this time in material lost or discarded by fishing vessels and merchant ships. It also became apparent that the problem of entanglement was not confined to northern fur seals but it also affected other marine mammals, including the Hawaiian monk seal (a species listed as an endangered species under the Endangered Species Act), sea lions, harbor seals, and northern elephant seals. Marine debris also entangled seabirds, sea turtles, and fishes. Furthermore, the problem had other facets: seabirds and sea turtles, for example, feed on debris such as plastic bags, small plastic pellets, and other man-made material. Although most of the observations on marine debris related problems have been made in the North Pacific, observations from other areas indicate that the problem is worldwide.

Marine debris is composed of a wide variety of objects including glass, metal, wood, rubber, and plastics. Plastics are probably the most persistent component of marine debris and material that causes the most

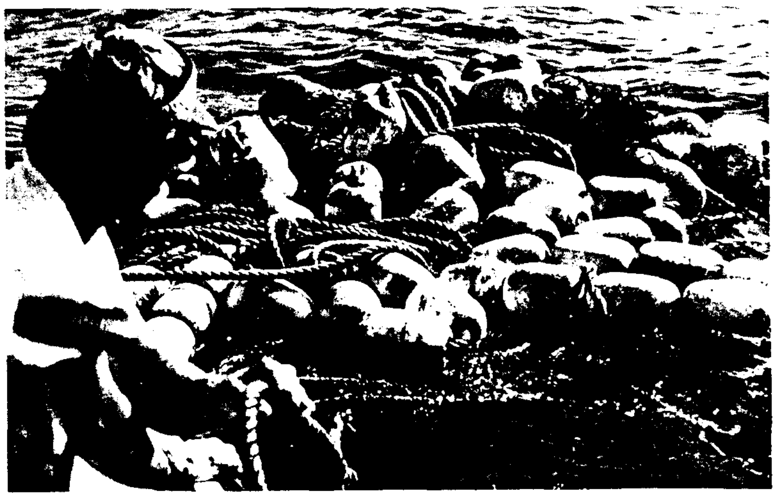


Photo by Susan R. Lautenslager

In the northwestern Hawaiian Islands the surrounding ocean currents may bring lost or discarded gill nets from mid-ocean squid fisheries and trawl net fragments from the North Pacific groundfish fisheries. John R. Henderson, a fishery biologist with the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, hauls in fragments of fishing gear near one of the islands.

problems. Although the sources of debris in general, and plastics in particular, are many and varied, a large amount of persistent plastics appears to originate from the fishing industry.

Quantification of Marine Debris

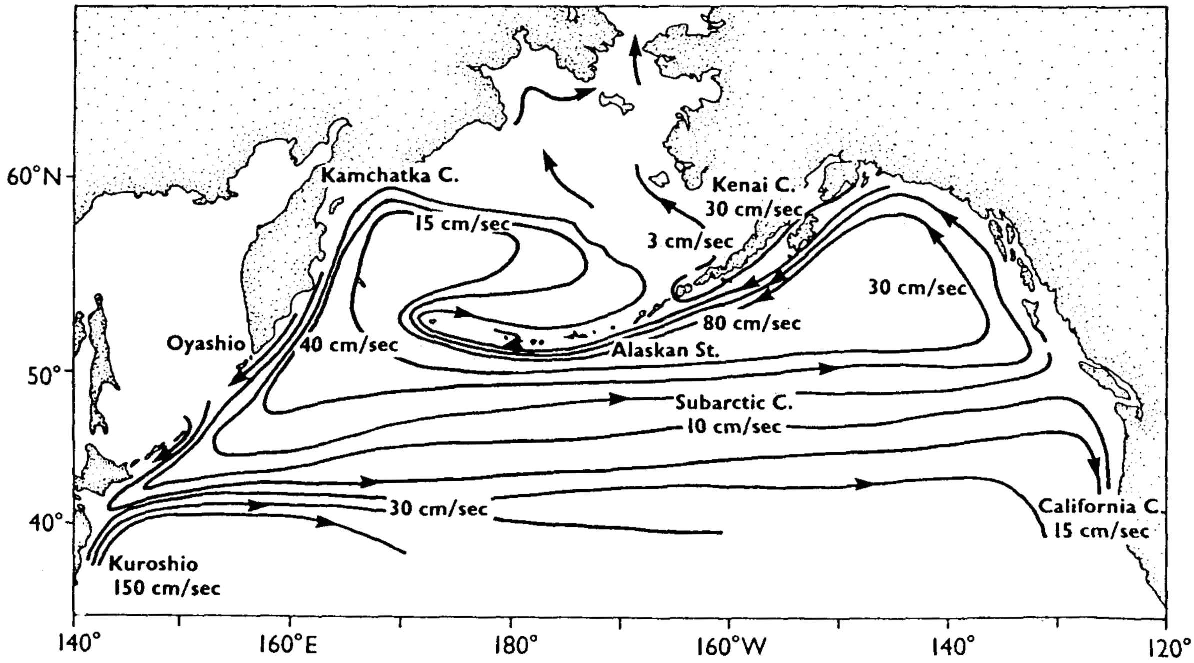
To provide background information for the discussions on marine debris, reports describing the fisheries and fishing effort were reviewed. An idea of how plastics (e.g., polyethylene and other fishing nets and lines) become part of the marine debris can be obtained by the extent of fisheries in the oceans. The Taiwan high seas gill net fishery for squid in the North Pacific is located between lat. 35° and 45°N and long. 152° and 158°W. The Korean gill net fishery for squid in 1981 stretched from lat. 34° to 46°N and long. 142°E to long. 179°W; in 1983 this fishery expanded to the east of long. 165°W. It is estimated that the Korean gillnetters used 139,638 to 4,070,372 units of gill nets (one unit is 50 by 8 meters or 164 by 26 feet) annually from 1980 to 1983. The Japanese have trawl fisheries in the Bering Sea, Gulf of Alaska, northwest Pacific, and the North Pacific. They also have mothership and land-based salmon drift gill net fisheries in the Pacific, a squid drift gill net fishery, and a gill net fishery for marlin and other species. It is estimated that, on the average, trawls of various sizes are fished 71,900 to 94,000 times per year in the Japanese trawl fisheries in the Gulf of Alaska and Bering Sea. In the various Japanese drift gill net fisheries in the North Pacific, the total combined length of all the gill nets fished during a year is estimated to be 1,409,270 km (875,704 miles), on the average. It has been estimated strung end to end there are 170,000 km (105,638 miles) of gill nets available in the North Pacific fisheries at any one time. This amount of net can circle the Earth at the Equator approximately 4.2 times.

Another way to examine the potential problem on loss of fishing gear is to determine the amount of fishing effort in the various fisheries. For example, fishing (mostly exploratory and limited scale) by non-U.S. (predominantly Japanese) trawlers in the Bering Sea-Aleutian Islands area began in 1954. From the late 1950's to the early 1970's there was a severalfold increase in fishing effort. In the past 10-12 years, the effort has remained near the highs of the early 1970's, and in recent years the U.S. vessels in the domestic and joint venture fisheries accounted for an increasing fraction of the total effort.

In the northeast Pacific, a non-U.S. trawl fishery for groundfish started in 1962. The fishing effort fluctuated up and down and reached a record peak in 1975, but has since fallen sharply. Joint venture fishing by U.S. vessels, and to some extent similar ventures by Canadian vessels, have offset a substantial amount of reduced non-U.S. fishing effort. Currently, the combined effort by non-U.S. joint fisheries is about 55% of the 1974-76 peak of the non-U.S. trawling effort. It is estimated that the total annual trawl effort for non-U.S., U.S., and joint venture fisheries in the Bering Sea-Aleutian Islands area, and U.S. and Canadian trawl groundfish fisheries in the British Columbia-California area was 234,000 to 794,000 hours, on the average, between 1956 and 1983. It would take about 27 to 91 vessels fishing every day of the year, 24 hours per day, to accumulate 234,000 to 794,000 hours of fishing.

Attempts were also made to estimate net loss in the trawl fishery for groundfish off Alaska. From 1960 to 1969, 14-27 nets or pieces of nets were lost in the Bering Sea-Aleutians-Gulf of Alaska trawl fisheries. From 1970 to 1979 the loss was 20-27 nets or pieces of nets, and from 1980 to 1983 it was 35-65. The difficulty in determining the reality of the estimates of net loss was pointed out because among other things, the numbers were extrapolated from direct observations made in 1983 only.

Another way to shed some light on the problem was to estimate the density of discarded and lost fishing gear in the ocean. First approximations were made on the density of the type of debris that was affecting the northern fur seal in the eastern North Pacific and Bering Sea. In the eastern North Pacific and Bering Sea it is estimated that there is one fatal encounter of a northern fur



A large amount of the debris in the oceans originates from fishing and maritime vessels. It has been estimated that over seven million tons of waste materials are discarded in the oceans each year from ships. A knowledge of the surface ocean currents provides good guesses as to where buoyant trash dumped in the ocean will eventually end up. The chart of the currents in the subarctic Pacific Ocean shown here is from the paper, "On the general circulation in the subarctic Pacific," by Donald K. Reed and James D. Schumacher.

seal pup per 18,600-93,000 nautical miles of travel, or one fatal encounter with webbing per 200 to 100,548 square nautical mile of water searched by the seal pup (average of 4,484 square nautical miles). It was also estimated that there would be one unit of webbing of the dangerous mesh size (20-25 cm or 8-10 inch stretched mesh) per 3,342-6,683 square nautical mile (average of 4,726 square nautical mile). According to the author of the report, that density of webbing appears to be low, but there appears to be enough discarded and lost webbing to cause the estimated mortalities of northern fur seals. Much of the deaths takes place in the first two years of a seal's life, and it has been estimated that the population of northern fur seals has been declining at approximately 4-8% per year for the past 10 years.

Direct observations have been made on the amount, types, and distribution of debris in the ocean. During one period of observation in the western North Pacific from 1978 to 1983, a trawl net fragment and a gill net fragment were seen in about 196 hours of direct observations over a distance of about 1,768 nautical miles. In 1984, during about 973 hours of direct observations covering 7,559 nautical miles in the western North Pacific and 1,200 nautical miles in the Bering Sea, three 2-meter (6.5 feet) trawl net pieces were seen. Also nine pieces of gill net fragments of about half a meter to 150-meter (2-492 feet) long were seen. In addition, net debris comprising fragments of 4 trawl nets and 20 gill nets was seen in incidental observations. Three northern fur seals were entangled in two of the trawl net fragments. Two northern fur seals, one salmon shark, *Lamna ditropis*, 11 birds of various species, and an undetermined number of salmon were entangled in the gill net fragments. The amount of net debris and the associated entanglements were considered to be low and could have been due to the difficulty in sighting or of the infrequent presence of debris. In similar type of observations, estimates of the average density of marine debris larger than approximately 2.5 cm^3 (0.15 inch^3) of 0.28 per km^2 (0.4 square mile) were obtained between lat. 38° and 56°N and 3.73 per km^2 (0.4 square mile) in lat. 21°-39° and 27°-42°N.

It is estimated that 6.4 million metric tons (7.1 million tons) of material is discarded annually from ships, and in waters around Alaska, about 1,664 metric tons (1,834 tons) of plastic litter is lost or discarded annually from fishing vessels. An unknown fraction of marine debris in the ocean finds its way to shore. To determine if beach surveys are good indicators of oceanic litter the quantities of fish net fragments and other plastic litter were determined on Alaska beaches by foot surveys from 1972 to 1984. Some of the conclusions reached in this study were that most of the litter were from non-U.S. fisheries, and fragments of trawl netting always constituted the bulk of the debris by weight. Also, a decrease in debris on Amchitka Island between 1974 and 1982 was attributed to the smaller number of vessels fishing off Alaska, which indicated that marine debris could be rapidly reduced if disposal could be controlled at sea.

Impacts of Marine Debris on Wildlife

Although the quantitative aspects of the interaction of wildlife with marine debris are not well understood, it is apparent that a wide variety of marine wildlife interacts with debris. Interactions of marine debris with marine mammals, birds, fishes, and turtles were described in reports presented at the workshop.

Intensive observations on entanglement of northern fur seals were started on St. Paul Island, Alaska in 1981, including those on the kinds of entangling debris, the manner of entanglement, the condition of the affected seals, and the frequency of entanglenent by age and sex of seals. Most of the seals that were found to be entangled were entangled in large mesh trawl net fragments. The next most frequently seen entangling debris were plastic packing bands. Other entangling debris noticed included ropes, strings, rubber bands, plastic rings, and metal headlight rings.

These studies indicated that fur seal mortality rates resulting from entanglement may not be as high as had been assumed. For example, the assumption that seriously injured seals would die in a short time were not supported by observations made during this study. Nevertheless, other studies showed that the mortality rates caused by entanglement were consistent with those which would cause the present population trend. It was pointed out, however, that although entanglement appeared to be an important factor, accurate estimates of deaths caused by entanglement were not available.

Observations on Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska and southeastern Alaska showed that these animals also become entangled primarily in packing bands and net fragments. Also, although encounters with marine debris could be confirmed as the cause of entanglement in only a few instances, trawl net fragments and plastic packing bands were confirmed as the entangling debris in a study on northern elephant seal, *Mirounga angustirostris*, California sea lion, *Zalophus californianus*, and harbor seal, *Phoca vitulina richardsi*, at San Nicholas and San Miguel Islands, California.

Off the coast of Oregon the number of marine mammals interacting with marine debris appeared low during observations made since 1968, although entanglements in actively fishing gear have been reported. The animal most frequently involved in encounters with fishing gear was the gray whale. In these encounters the most frequent observation was the snagging of commercial crab pot buoy lines in the jaws of the whales.

In the Northwestern Hawaiian Islands 27 indidents of entanglements by Hawaiian monk seals have been documented through 1984. Also, at least eight additional seals had scars resulting from entanglement. It was speculated that the entanglement was fatal to at least one seal, and that six seals would have probably died if biologists had not intervened. Most of the entanglements of Hawaiian monk seals involved pups. Although weaned pups constitute only about 11% of the population of seals in the Northwestern Hawaiian Islands, they were involved in 41% of the entanglement incidents.

Although the workshop dealt primarily with marine debris in the North Pacific, reports of the interaction of wildlife and marine debris from elsewhere in the world were presented. In New Zealand waters a marked increase in such encounters were observed since 1975. The New Zealand fur seal, *Arctocephalus forsteri*, is now frequently seen with polypropylene strapping bands, usually around the neck. Fur seals have also been seen entangled in discarded fishing nets. Hooker's sea lion, *Phocarctos hookeri*, has also been seen with netting around the neck. A killer whale, *Orcinus orca*, and a southern right whale, *Eubalaena australis*, died as a result of entanglement in fishing gear. A juvenile minke whale, *Balaenoptera acutorostrata*, which became stranded and died had a compacted plastic bag stuck in the esophagus, which was probably the cause of its death. A leatherback turtle, *Dermochelys coriacea*, which beached itself and died had plastic bread bags packed in its esophagus.

To date 50 species of seabirds are known to feed on plastics. The albatrosses, fulmars, and petrels feed on plastics most frequently, and phalaropes (small pelagic shorebirds) and some auk, murre, puffin, etc., type seabirds also have relatively high rates of feeding on plastics. The two major types of plastics ingested by seabirds are plastic fragments and raw plastic pellets, and it appears that the principal sources of plastic fragments are the solid wastes and plastic objects discarded from fishing boats and merchant ships at sea. Also, some of the

Photo by John R. Henderson

In addition to fish and marine mammals, sea turtles also become entangled in marine debris. This green turtle was found entangled in rope and net debris in the northwestern Hawaiian Islands.

plastics found nearshore come from nearby population centers. The effects of the ingestion of plastics by seabirds are not fully understood. It is believed that for most species of birds the rates of feeding and the amounts of plastic fed on are low enough that there is no deleterious effect on the birds. Several species of seabirds, however, show high enough rates of feeding on plastics to cause concern. It has been suggested that high ingestion of plastics may have a detrimental effect on breeding.

Published records indicate that five sea turtle species have fed on various types of marine debris. The green turtle, *Chelonia mydas,* constituted 32% of these records, followed by the loggerhead turtle, *Caretta caretta,* (26%), leatherback turtle (24%), hawksbill turtle, *Eretmochelys imbricata,* (14%), and Kemp's ridley turtle, *Lepidochelys kempi,* (4%). Immature turtles more frequently fed on debris than the adults in four of the five species. The turtles most commonly fed on plastic bags and sheets (32%), followed by tar balls (21%), and plastic particles (19%). Other items ingested by the turtles included cloth, fishing net, paper, glass, and metal. Also, the green, loggerhead, hawksbill, olive ridley, and leatherback turtles have been entangled in debris. The green turtle accounted for 42% of the records. Debris responsible for the entanglements was monofilament fishing lines (33%), rope (23%), pieces of trawl net (20%), and nonfilament net (13%).

In addition to all the entanglement of wildlife discussed above, fishing gears such as gill nets continue to catch the species of fish (and other fishes) they were set for even after they become derelict (ghost fishing). Experiments with commercial style crab pots showed that up to 55% of sublegal Dungeness crab, *Cancer magister,* remained in the traps after 12 days, and 17% of these crabs died. Observations on several pieces of derelict salmon gill nets showed that fish and diving birds continued to be caught for more than 3 years, and crabs continued to become entangled after 6 years. Other ghost gill nets contained live or decaying Atlantic cod, *Gadus morhua,* Atlantic wolffish, *Anarhichas lupus,* spiny dogfish, *Squalus acanthias,* winter flounder, *Pseudopleuronectes americanus,* American lobster, *Homarus americanus,* and crabs.

Fate of Marine Debris

As indicated earlier, one of the goals of the workshop was to determine the fate of marine debris, that is, what happens to the long lasting plastics and other material once they are discarded or (for fishing gear) are lost and become derelict. It is obvious that surface ocean currents would have the greatest influence on floating objects in the sea, and so would provide the best clues as to the fate of marine debris. With this in mind the workshop participants reviewed the surface currents and current systems in the North Pacific and adjacent areas. Also discussed was the "population dynamics" of marine debris, such as how much debris are entering the "population" and how much are leaving per unit time.

The study of ocean currents has progressed from direct ship-drift observations to indirect theoretical computations, and to direct current measurements by current meters and satellite tracking of drifting buoys with attached drogues. Charts of the ocean currents based on ship-drift determinations produced in 1935 show the general circulation as it is known today. In the Pacific Ocean the major currents are the northeastward flowing Kuroshio and the eastward flowing North Pacific Current in the western Pacific. In the eastern side of the Pacific, the North Pacific Current splits into the Alaska current which flows north and the California Current which flows south. The westward flowing South Equatorial Current is between about lat. 5° and 10°N. More recently oceanographers have progressed from describing steady state and average ocean currents to describing the variability of currents. One report presented at the workshop described the general surface water circulation and seasonal variations in the circulation in the subarctic Pacific (lat. 40°N to the Bering Strait). It pointed out that the Subarctic Current is a slow eastward drift but that in the winter its speed increases fourfold as a result of strong winds blowing eastward. Other seasonal variations in current systems within this region were also examined. It also provided a chart showing the "climatological mean surface circulation" in the subarctic Pacific including the speeds of the various currents.

All the charts described above, however, only provide gross or average pictures of the ocean circulation in the Pacific Ocean. They do not provide information on eddies or periodic fluctuations and interannual variations of the currents. To predict the likely movement of marine debris on the ocean surface, it would be desirable to have current forecasts similar to weather forecasts. Without such current forecasts, however, the estimates of the mean climatological surface circulation may be useful in making general predictions on the fate of marine debris. Based on these charts, for example, it can be predicted that debris entering the ocean off northern Japan should arrive off the west coast of the U.S. in about 2 years.

Solution to the Problem

Although marine debris is undoubtedly a problem throughout the world's oceans, the workshop concluded in part that more data and information were needed on the quantity, type, distribution, and change with time of the amount of debris in the oceans. The consequence and quantitative impacts of the interaction of marine animals with debris did not appear to be well understood and documented, although qualitative information showed that deaths of marine animals attributable to marine debris in addition to those caused by natural factors are evident. It was further recommended that studies be initiated to estimate the timing and rates of change of the threat of marine debris, that is, how does debris change mechanically, for example, how nets become balled up; chemically (chemical effects on buoyancy), and biologically (the effects of plant and animal growth on debris). Educational programs should be started to change human attitudes toward the environment, that is, the oceans (even at their greatest depths) and beaches are not limitless garbage dumps, and to encourage and facilitate the proper disposal of debris. Educational programs directed particularly at the world's fishing and maritime community, national and international organizations, and plastics industries are needed to communicate the extent of the marine debris problem. Research should be conducted to determine if materials that may potentially become marine debris can be made degradable.

With regard to some of the marine animals that are affected by marine debris, the primary problem for the fur seals appeared to be trawl net fragments and plastic bands. Research is needed to confirm mortality rates caused by such debris that to date have been estimated by indirect methods. For the monk seals in the Northwestern Hawaiian Islands, trawl net fragments were perceived to be the main source of possible deaths. The mortality rate for monk seals attributable to marine debris is unknown but any loss to this endangered species is serious. Research needs for the monk seal are much the same as for fur seals. As for seabirds, marine debris affects seabirds in two ways: through ingestion of plastics and entanglement. Because the effects of the ingestion of plastics by seabirds are not well understood, physiological studies and experiments are needed to determine such effects. Although sea turtles have been entangled in marine debris, the more serious potential problem appears to be the ingestion of plastics and other debris. Similar studies on the physiological effects of plastics on sea turtles are needed.

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Photos by John R. Henderson, Doris J. Alcorn and William G. Gilmartin

Pups of the Hawaiian monk seal are susceptible to entanglement in fragments of fishing gear and other debris that wash ashore. During 1984, 27 incidents of monk seal entanglement in debris were documented in the Hawaiian Islands. The lower picture shows an injured monk seal with a scar around the neck from an unidentified constricting material. Plastic packing bands are frequent causes of such scars on seals.