IMPACT OF OCEAN DEBRIS ON MARINE TURTLES: ENTANGLEMENT AND INGESTION

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ABSTRACT

Marine turtles are affected to an unknown but potentially significant degree by entanglement in, and ingestion of, synthetic oceanic debris. Nearly all known records of olive ridley turtle, Lepidochelys olivacea, in the Hawaiian Islands have resulted from entanglement in drifting scraps of fishing gear. In the North Pacific (lat. 35°-45°N), incidents of leatherback turtle, Dermochelys coriacea, fatally entangled in pieces of monofilament mesh have been recorded. However, as with many such cases involving marine turtles, it is unclear if entanglement occurred in discarded fragments or in intact gear being actively fished.

Marine turtles have been found to eat a wide array of synthetic drift items, including plastic bags, styrofoam beads, and monofilament fishing line. Toxic chemicals released by these materials, as well as physical obstruction to the digestive tract, are two possible adverse impacts.

INTRODUCTION

International efforts to conserve and manage sea turtles effectively have been periodically hampered by the discovery of new or previously unidentified impacts on surviving populations. Sea turtles are already known to be directly threatened by an array of human activities on nesting beaches and in marine foraging habitats. Major impacts include intensive exploitation for meat, eggs, shell, and skin (all of which are often taken for commercial purposes), the incidental capture and drowning of turtles in shrimp trawls, and alteration of habitat by coastal development. Other problems that have received far less attention in the literature include petroleum and toxic chemical pollution, incidental catch by a variety of fisheries (e.g., pound nets, gill nets, drift nets, purse seines, longlines, lobster and other types of traps), ingestion of plastics and tar, disease, cold waves, and predation by large sharks. Considered separately, each of these lesser known impacts may not necessarily cause high rates of mortality or morbidity. However, their combined effect over an extended

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period could very well be a significant retardant to the recovery of certain populations. It is, therefore, imperative that each adverse element be adequately examined and understood.

All sea turtles have been legally protected in the United States since 1978 under provisions of the Endangered Species Act. A number of other countries have also implemented protective measures in recent years and engaged in cooperative efforts to conserve and study these turtles (Bjorndal 1982; Groombridge 1982; Bacon et al. 1984).

A basic problem in determining the scope and magnitude of impacts on sea turtles is that all species lead an oceanic existence during portions of their life history. Broad gaps exist in the knowledge of sea turtles away from land because they are seldom seen, let alone studied. In contrast, reasonably good ecological data exist for the breeding phase when adult females, eggs, and hatchlings are accessible on land. The leatherback, Dermochelys coriacea, and olive ridley, Lepidochelys olivacea, seem to be the most pelagic species, living well offshore from the time they leave the beach as hatchlings until they return to breed as adults. Others, like the green turtle, Chelonia mydas, loggerhead, Caretta caretta, and hawksbill, Eretmochelys imbricata, inhabit coastal waters as adults, but spend varying segments of their immature life in the open ocean. Even then the adults regularly undertake breeding migrations which place them for a time over deep water. The limited information available on the Australian flatback, Chelonia depressa, and the severely depleted Kemp's ridley, Lepidochelys kempi, suggests that these species also pass through pelagic phases of development.

Man-made debris floating at the surface in the same oceanic habitat occupied by sea turtles presents a potential for substantial interaction. The amount of refuse now entering the world's oceans, especially plastics and tar, appears to have reached huge proportions (Carpenter and Smith 1972; Venrick et al. 1973; Wong et al. 1974, 1976; Morris 1980a, 1980b; Van Dolah et al. 1980; Eldridge 1982). For example, Horsman (1982) estimates that 639,000 plastic containers (including bags) are dumped into the sea daily from merchant ships alone. Floating material of a natural and synthetic nature is known to collect in drift lines that result from converging offshore currents or strong winds sweeping the sea surface. In the Caribbean, where rafts of sargassum are prominent, such areas are believed to be preferred habitat for some, and possibly most, small sea turtles of the region (Fletemeyer 1978; Carr and Meylan 1980; Carr 1983). A similar situation probably occurs in the Pacific and elsewhere, although sargassum rafts would not be a common feature since in many areas they do not exist. Plastic particles, tar, and other floating debris that aggregate in drift lines are likely to be consumed by turtles that normally feed on small surface-dwelling invertebrates and other plankton. Another form of discarded plastic, transparent bags and sheets, has also been implicated in recent years as being harmful to sea turtles, particularly adult leatherbacks. This material is apparently mistaken for drifting jellyfish (Scyphomedusidae), a principal food item of the leatherback.

Another aspect of the debris problem--the entanglement of turtles in floating and bottom-fouled scraps of line, net, or other lost or abandoned gear--has only infrequently been noted in the literature. Unlike the ingestion of plastic bags, little publicity has appeared in the mass media on debris entanglement. Because turtles are incidentally caught in many kinds of fisheries, there is difficulty in determining whether entanglement actually involves debris per se, or represents capture in actively fished gear that somehow tore free. Nevertheless, it is apparent that sea turtles are prone to all kinds of entanglement as a result of their body configuration and behavior. Entanglement in debris may therefore be best considered as an extension of the incidental catch problem.

The phenomena of sea turtles ingesting and becoming entangled in debris have not previously been the subject of a comprehensive review. The objective of this paper is to assemble and evaluate existing information, most of which is scattered throughout the literature or contained in unpublished records. The availability of a consolidated source of data may then serve as a useful starting point to assess the scope and magnitude of the problem. It will also provide a basis for determining what future research is needed to address the problem adequately.

METHODS OF DATA COLLECTION

Documented records of turtles that had ingested or become entangled in debris were compiled through an extensive literature search, and by personal inquiries to numerous researchers worldwide. In addition, a relatively large number of unpublished cases for the Hawaiian Islands were included that had been gathered by the author since 1973.

To the extent that they exist, pertinent details from each case were abstracted and assembled in an annotated data table. This information included the species of turtle, date, location, carapace length, weight, sex, and a concise description of the event, often with quotations from the original source. For cases of ingested debris, usually only synthetic items were listed, and not the natural food items present. The literature citation or other origin of the report was also entered into the data table. Summaries of all cases were tabulated to identify geographic distribution, species involved, age composition of the turtles, and types of impacting debris.

In accomplishing this study, it was realized that many more cases undoubtedly exist than are contained herein. With the circulation of this paper, it is hoped that old and new reports of debris ingestion and entanglement will be sent to the author for use in a future revision.

RESULTS

Overall Findings

Concise case-by-case descriptions of debris ingestion and entanglement by species are presented in Tables 1 and 2. It was possible to locate 79 reports dealing with ingestion (Table 1) and 60 dealing with entanglement (Table 2). None of the cases occurred before the 1950's; 95% have taken place since 1970.

Debris ingestion involving only single turtles comprises 60% of the cases shown in Table 1, while 32% cover multiple accounts representing at

Table 1.--Worldwide records of the ingestion of oceanic debris by marine turtles.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
			***Chelonia mydas*, green turtle and *C. agassizi*, black turtle**		
I-Cm-1	Late 1950's	Golfito, Costa Rica (Pacific coast)	--	Mass mortality attributed to the ingestion of plastic banana bags thrown from a wharf.	A. Carr. pers. commun. cited in Cornelius 1975; Hirth 1971b; Wehle and Coleman 1983; Meter 1983.
I-Cm-2	1958, 1976-77	Tortuguero, Costa Rica	Adult, F	"Some rather unconventional kinds of food" were consumed in the internesting habitat, including terrestrial plant material. Four of 11 turtles (37%) had eaten plastic, and 2 (18%) had eaten cloth.	Meylan 1978.
I-Cm-3	1972-73	Ascension Is.	--	"When refuse is dumped from ships or from shore, turtles sometimes move in to feed on it." Turnip tops have been found in stomachs.	Carr et al. 1974; A. Carr pers. commun. cited in Coston-Clements and Hoss 1983.
I-Cm-4	1979	Pisco, Dep. Ica, Peru	52 to 89 cm	Nine of 39 stomachs (23%) examined contained plastic bags.	Brown and Brown 1982.
I-Cm-5	Ca. 1980	New South Wales, Australia	"Subadult"	Washed ashore freshly dead "with length of fishing line hanging out both its mouth and cloaca." Preserved in the Australian Museum (Sydney) but not dissected.	C. Limpus pers. commun.
I-Cm-6	1/4/72	Kochi Prefecture, Japan	S-43 cm	"Vinyl film" found in stomach.	I. Uchida pers. commun.
I-Cm-7	9/5/83	Wakasa Bay, Fukui Prefecture, Japan	S-74 cm, 55 kg, F	Orange, yellow, and green pieces of synthetic line found in stomach. Also a transparent plastic bag and pieces of a synthetic fishing net with fish eggs attached.	I. Uchida pers. commun.
I-Cm-8	9/69	Iles Scilly (Motu-Honu), Fr. Polynesia	--	Long piece of plastic found in one of several stomachs examined.	Hirth 1971a, 1971b.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Cm-9	10/23/81	Fakaofo Atoll, Tokelau (lat. 9°22'S, long. 171°16'W)	C-105 cm, F	Entire digestive tract empty except for a 2 by 15 cm piece of blue plastic sheet.	Balazs 1983b.
I-Cm-10	1976	Kwajalein, Marshall Is.	--	Turtles scavenge on kitchen scraps that are thrown into the ocean each day from the U.S. military facility.	Pritchard 1977.
I-Cm-11	1974-79	Hawaiian Is.	--	Items occasionally found in the digestive tract include hard plastic fragments, pieces of plastic bags, cloth, small diameter line, and terrestrial vegetation. Also tar stains in the mouth.	Balazs 1980.
I-Cm-12	1975	Oahu, Hawaii, U.S.A.	30 cm	Turtle that had been reared in captivity from a hatchling ingested a sheet of transparent plastic ca. 20 by 20 cm that accidentally fell into its pen. Twisted tip of plastic seen protruding from cloaca and pulled out. Turtle appeared unharmed. It is unknown if turtle could have voided plastic without assistance.	G. Balazs unpubl. data.
I-Cm-13	12/13/76	Tern Island, FFS, NWHI	S-45 cm	Fresh dead stranding 19 months after release from captive rearing. Sighted regularly during this period feeding on food scraps discarded by U.S. military facility. Digestive tract contained synthetic fiber cloth 8 by 20 cm, and numerous fish bones. Cause of death undetermined.	G. Balazs unpubl. data.
I-Cm-14	5/82	Midway, NWHI	C-36 cm	Man-made fibers in stomach, as well as crab legs and Janthina. Same as Case E-Cm-8 found entangled in a scrap of blue net.	G. Balazs and M. Pillos unpubl. data.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Cm-15	10/78	Lanai, Hawaii	C-96 cm, F	Large pieces of black and transparent plastic bags twisted throughout the intestines of a turtle speared by a fisherman. Plastic in feces near cloaca suggested that blockage had not occurred.	Balazs 1980.
I-Cm-16	2/9/76	Hutchinson Is., Florida, U.S.A.	10 cm	Found dead on the beach with tar in its mouth. Had been released 20 days earlier following captive rearing.	Witham 1978.
I-Cm-17	8/2/77	Merritt Is., Florida, U.S.A.	32 cm	Found in the surf zone "upside down and disoriented." Tar was removed from the mouth, and the turtle recovered.	L. M. Ehrhart pers. commun. cited in Witham 1978.
I-Cm-18	1978-79	Florida Keys to Cape Canaveral, Florida, U.S.A.	"Small"	Weathered petroleum (tar) sealed the mouths and nostrils. Impacted turtles can be cleaned using vegetable oil or a soapless hand cleaner followed by thorough rinsing. This procedure "rehabilitated some tar-impacted turtles, but all oiled turtles died." "Widespread dispersal of petroleum residues suggests that indeterminate numbers of sea turtles may be dying at sea." "27 small sea turtles of three species were handled," but the number of green turtles was not stated. See also Case I-Cc-8 and I-Ei-43.	Witham 1983.
I-Cm-19	9/5/80	Port Canaveral, Florida, U.S.A., (lat. 28°24'30"N, long. 80°35'00"W)	12 cm	Found alive with "tar ball" in mouth. Treated and released. Turtle had previously been reared in captivity by the Florida Department of Natural Resources.	Mann and Lee 1981.
I-Cm-20	2/14-19 1981	Hutchinson Is., Florida, U.S.A.	9 to 14 cm	Seven turtles found stranded alive with tar in mouth and on body.	Anonymous 1981a.
I-Cm-21	2/18/81	Indian Harbor Beach, Florida, U.S.A.	14 cm	Found alive with dense tar packed in the throat. Treated and released 3/24/81.	Anonymous 1981b.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Cm-22	4/20/82	Long Key, Florida, U.S.A. (lat. 24°45'N, long. 80°45'W)	18 cm	Found alive covered with tar which had also been ingested.	Roche and Witham 1982.
I-Cm-23	6/29/82	Homestead Bayfront Park, Florida, U.S.A. (lat. 25°30'N, long. 80°25'W)	22 cm, 16 cm	Live strandings with tar in mouth and covering body.	Kasqowitz 1982.
I-Cm-24	9/14/84	Mustang Island, Texas, U.S.A. (lat. 27°49.8'N, long. 97°03.3'W)	S-5.6 cm	Dead stranding with tar in roof of mouth and "minute pieces of plastic-colored foil and spherule of plastic used when polyethylene is cast." Pieces of three flippers missing.	A. F. Amos pers. commun.
I-Cm-25	10/9/84	Kaena Point, Oahu, Hawaii	S-35 cm	Died 1 day after being found floating offshore and unable to dive. Turtle not emaciated. Intestine contained a distinct blockage consisting of frayed plastic line and hard dried fecal matter.	G. Balazs unpubl. data.
			***Caretta caretta*, loggerhead turtle**		
I-Cc-1	10/67	Madeira (lat. 32°45'N, long. 17°W)	--	Pieces of plastic in the stomach. "Like picknickers may litter the countryside with refuse, ships are beginning to litter the surface of the sea. While cruising in an area north of the Azores, where sometimes a day or two went past without ships being sighted, their presence at sea was demonstrated by boxes, jars, etc., made of plastic floating on the surface of the sea. Apparently turtles mistake these objects for food and swallow them. One wonders whether in the end the intestine of the turtle will not become blocked by such undigestable matter.	Brongersma 1968, 1969.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Cc-2	1968-73	Cape Agulhas, South Africa	6.6 cm	Strandings of posthatchlings revealed that 2 of 32 stomachs (6%) with contents contained small plastic beads (1-2 mm cylinders and two 1-mm sphere). Pieces of fine plastic sheet 2 by 3 cm were found in two other turtles. The nature of identifiable contents "suggests that loggerhead hatchlings will eat anything that is floating and small enough to swallow."	Hughes 1970, 1974a.
I-Cc-3	<1974	South Africa	C-60 to 70 cm	Stomach contents from four of nine turtles (44%) contained synthetic debris including plastic strip, plastic bags, and pieces of glass. Bark and sugarcane also present.	Hughes 1974b.
I-Cc-4	8/2/75	Cabrera, Balearic Is., Mediterranean	40 cm, 10 kg	Intestines contained pieces of plastic, rope, tar, and onion.	Salvador 1978.
I-Cc-5	>1974	Cumberland Is., Georgia, U.S.A.	--	Dead stranding with an iron bolt imbedded in roof of the mouth causing distortion of the skull.	C. Ruckdeschel and C. R. Shoop pers. commun.
I-Cc-6	4/6/80-11/1/80	Cumberland Is., Georgia, U.S.A.	--	Seventeen of 43 guts (43%) examined from stranded turtles contained large amounts of ocean-dumped, man-caught food, including fish, shrimp carapaces, and squid remains. The intestines were often packed with fish bones. Likely sources of this food debris included unwanted catch from shrimp trawlers and discharge from seafood processors. Incidental feeding may cause an artificially large turtle population in the trawler impacted fishing area.	Shoop and Ruckdeschel 1982
I-Cc-7	11/78	Cape Canaveral, Florida, U.S.A.	82 kg	Live capture in trawl. Heavy monofilament fishing line protruding from mouth. 60-90 cm piece pulled out. Numerous encrusting organisms, primarily mussels, growing on line and partly digested. Presence of bile on swallowed portion suggested that the line had entered the small intestine.	L. Ogren pers. commun.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Cc-8	1978	Florida Keys to Cape Canaveral, Florida, U.S.A.	"Small," 57 cm	Weathered petroleum (tar) sealed the mouths and nostrils. "27 small sea turtles of three species were handled," but the number of loggerheads was not stated. A 57-cm loggerhead was seen with a small amount of tar in its mouth, but appeared to be unaffected. See also Case I-Cm-18 and I-Ei-4.	Witham 1983.
I-Cc-9	1976-79	Texas, U.S.A.	--	Digestive tract of dead stranding contained pieces of a plastic bottle, as well as bird feathers and sargassum seaweed.	B. Fulls pers. commun. in Rabalais and Rabalais 1980.
I-Cc-10	Early 1970's	Mon Repos, Queensland, Australia	Adult, F	Stomachs of three turtles drowned in shrimp trawls in internesting habitat contained fish, shrimp, and cuttlefish. Though not suggested by the author, the apparent atypical nature of this food indicates it may have been unwanted catch discarded by trawl fishermen (compare with Case I-Cc-5).	Limpus 1973.
I-Cc-11	10/31/72	Hyogo Prefecture, Japan	S-30 cm	Plastic debris found in stomach. Had been released at Tokushima Prefecture 90 days earlier following captive rearing from a hatchling.	I. Uchida pers. commun.
I-Cc-12	5/19/75	Owase, Japan	S-69 cm, 35 kg, F	Transparent and blue plastic sheet found in stomach.	I. Uchida pers. commun.
I-Cc-13	6/75	Kushimoto, Japan	S-60 cm, 33 kg, F	Plastic debris found in stomach.	I. Uchida pers. commun.
I-Cc-14	9/29/80	Hyogo Prefecture, Japan	S-84 cm, 83 kg, F	Plastic debris found in stomach.	I. Uchida pers. commun.
I-Cc-15	5/14/84	Shimane Prefecture, Japan	S-33 cm	Plastic bag, piece of synthetic line, and domestic vegetables found in stomach. Had been released at Okinawa 50 days earlier following captive rearing from a hatchling.	I. Uchida pers. commun.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Cc-16	12/29/78	Cocoa Beach, Florida, U.S.A.	S-73 cm, 54 kg	Found with 3 monofilament lines protruding from the mouth and cloaca. Lines were cut flush with the jaw and skin, and the turtle was kept in captivity. It floated abnormally at the surface and would not feed. After 6 weeks in this condition, it excreted 4.6 m (15 ft) of line. Thereafter, a dramatic change occurred in its behavior and it fed voraciously. It was released 1 month later on 3/14 weighing 48 kg. At the time the line was passed, it weighed 45 kg.	L. Ehrhart, T. Clabaugh, S. Gravel, and R. Witham pers. commun.
I-Cc-17	10/5/84	Chesapeake Bay, Virginia, U.S.A.	S-51 cm	Captured alive in a pound net and found to have the "half-round base of a plastic champagne cork stuck around the base of the lower left jaw." Turtle appeared healthy but had a small necrotic spot on the jaw beneath the cork.	J. A. Musick pers. commun.
I-Cc-18	1979-80	Madeira (lat. 32°45'N, long. 17°W)	S-27 to 52 cm	Three turtles purchased at Funchal were found to contain pieces of glass up to 4 cm long, pieces of plastic, nylon thread, and numerous small clots of oil throughout the digestive tract.	Van Nierop and Hartog 1984
I-Cc-19	6/4/81	Sao Miguel, Azores (lat. 37°33'N, long. 25°27'W)	S-26 cm	Purchased from fisherman. The caecum contained a piece of white paper 3 by 3 cm, 4 pieces of nylon thread 1-3 cm, a ball of thread 4 by 1 by 1 cm, 6 pieces of polyethylene 1 by 1 by 0.5 cm, and clots of oils throughout the digestive tract.	Van Nierop and Hartog 1984
I-Cc-20	5/25/80	Selvagen Grande (lat. 30°09'N, long. 15°52'W)	S-22 cm, F	Caught 1 mile offshore. Gut contained a piece of nylon thread 5 cm long, 5 pieces of firm transparent plastic up to 1 cm long, and clots of oil dispersed throughout the tract.	Van Nierop and Hartog 1984

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Ei-8	2/16/81-2/17/81	Hutchinson Is., Florida, U.S.A. (lat. 17°17'N, long. 80°13'W)	10 cm, 15 cm	Two turtles found alive with tar in mouth and around head. One died the next day.	Anonymous 1981a.
I-Ei-9	6/23/82	Big Pine Key, Florida, U.S.A. (lat. 24°39'N, long. 81°19'W)	18 cm	Stranding with tar in mouth and covering body. Cleaned and released.	Klett 1982.
I-Ei-10	7/13/83	Hutchinson Is., Florida, U.S.A.	S-20 cm	Beach stranding with styrofoam, plastic sheet, plastic particles and tar droplets in digestive tract. Carapace and limbs coated with tar. Nostrils and mouth sealed.	Meylan 1984.
I-Ei-11	10/15/84	Kahana Bay, Oahu, Hawaii	S-36 cm, 5.4 kg	Died 2 days after stranding in an emaciated condition. Left front flipper completely amputated but healed. Gooseneck barnacles on carapace suggested a pelagic existence. Large pocket of numerous plastic particles and semi-hard fecal matter found at midpoint of intestine. Intestinal wall had expanded into stomachlike compartment. Plastic and fecal matter mass weighed 780 g.	G. Balazs unpubl. data.
			Dermochelys coriacea, leatherback turtle		
I-Dc-1	8/4/68	Ameland Is., Netherlands	158 cm, 485 kg, F	Dead stranding with piece of plastic in the gut.	Brongersma 1969, 1972.
I-Dc-2	7/7/70	Ramsgate, Natal, South Africa	C-160 cm, 340 kg, F	Dead stranding. "Duodenal tract completely filled by a sheet of heavy plastic measuring 3 by 4 m when spread out. The sheet was so tightly packed that considerable force was required to open it initially, and it must have had a serious effect on the passage of food from the stomach. Whether a complete blockage had been effected was difficult to ascertain because there was pink fluid in the lower gut." 697 well-developed eggs present.	Hughes 1974a.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
				***Eretmochelys imbricata*, hawksbill turtle**	
I-Ei-1	--	Ascension Is.	--	Invertebrate fauna "appears to be extremely lean, and there is little submerged vegetation of any kind. This may account for the peculiarly scrawny look of Ascension hawksbills, and also may explain their observed tendency to group about any refuse that is dumped in shore waters."	Carr and Stancyk 1975
I-Ei-2	1970-72 (July-October)	Tortuguero Bank, Costa Rica	Adults, 2 F, 2 M	Four out of 20 stomachs (20%) containing food were found to have plastic and other man-made litter. "A compacted ball of well-chewed sheet plastic" was present in one of the stomachs.	Carr and Stancyk 1975, cited in Witzell 1983.
I-Ei-3	10/22/78	Selvagen Pequena, eastern Atlantic (lat. 30°2'N, long. 16°1'W)	36 cm, M	"Colon and rectum appeared to contain a variety of man-made litter, viz., 15 pieces of hard plastic (two orange coloured, the rest white; largest piece measuring about 28 by 20 by 3 mm) and several thin membranaceous fragments (one yellow, one black, rest whitish or transparent)." Turtle taken from "bay on east coast."	Hartog 1980, cited in Witzell 1983.
I-Ei-4	1978-79	Florida Keys to Cape Canaveral, Florida, U.S.A.	"Small"	Weathered petroleum (tar) sealed the mouths and nostrils. "27 small sea turtles of three species were handled," but the number of hawksbills was not stated. See also Case I-Cm-18 and I-Cc-8.	Witham 1983.
I-Ei-5	1/16/81	Jupiter Island, Florida, U.S.A.	S-21 cm, F	Emaciated beach stranding with styrofoam precursor (plastic bead) and paper in digestive tract. Injury to front flipper.	Meylan 1984.
I-Ei-6	2/81	Ft. Lauderdale, Florida, U.S.A.	S-14 cm, F	Emaciated beach stranding with plastic particles and tar droplets in digestive tract.	Meylan 1984.
I-Ei-7	2/16/81	Jensen Beach, Florida, U.S.A.	S-14 cm	Beach stranding with styrofoam precursors in digestive tract. Tar present on head and throughout digestive tract.	Meylan 1984.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Dc-3	7/29/71	Cornwall, England	C-142 cm, 224 kg, F	Small plastic bags found in the stomach and posterior gut. Turtle had become entangled in the lines of lobster pots.	Brongersma 1972; Hartog and Van Nierop 1984.
I-Dc-4	7/30/77	Hyogo Prefecture, Seto Sea, Japan	S-120 cm	A 60 by 70 cm piece of twisted vinyl fiber was pulled from the cloaca after a 5 cm piece became visible. The turtle had been entangled 10 days earlier in a gill net. Died the following day.	I. Uchida pers. commun.
I-Dc-5	9/22/80	Smith Point State Park, New York, U.S.A. (lat. 40°45'N, long. 72°48'W)	183 cm	Badly decomposed. Had ca. 180 m of heavy duty nylon fishing line in the gastrointestinal tract, with leading piece extending from the mouth.	Sadove 1980.
I-Dc-6	10/22/81	Beach Haven, New Jersey, U.S.A. (lat. 39°33'33"N, long. 74°14'10"W)	150 cm, F	Fresh dead stranding. "Large number of plastic bags in posterior stomach and extending 13 cm into intestine; claylike mass blocking intestinal valves."	Schoelkopf 1981.
I-Dc-7	Summer 1982	Long Island, New York, U.S.A.	--	Eleven out of 15 leatherbacks (73%) that washed ashore during a 2-week period had plastic bags "totally blocking their stomach openings." Ten of the beached turtles had four to eight quart-sized bags in their stomachs. One had eaten 15. Turtles have been seen swimming around transparent bags in the ocean with their mouths open, as if they thought the discarded plastic was their favorite meal. The turtles found were too badly decomposed for full autopsies, but "the plastic bags either contributed to the cause of death or may have been the cause of death." (All information was provided by Samuel Sadove, see also Sadove[3].)	Anonymous 1983b.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Dc-8	1980-84	New York Bight, U.S.A.	--	"Of a total of 42 sea turtle strandings reported since 1980, almost 50% of these animals contained significant amounts of plastic in their stomachs. One animal had 15 quart-size clear plastic bags in its stomach. Although death from plastic ingestion could only be determined for four animals, it is possible that a number of animals' demise or susceptibility to injury causing death could be the result of stress from partial blockage caused by the plastic."	Sadove[3].
I-Dc-9	1979-80	Pucusana, Depto. Lima, Peru	--	Plastic bags and film were noted in intestinal tracts of 19 of 140 specimens (13%) examined. All cases involved sizable pieces of plastic. The plastic was within the lumen of the digestive tract and in a twisted, elongate form suggesting peristaltic transport.	Fritts 1982.
I-Dc-10	1970-80	Worldwide	--	Evidence showing that ingestion of plastic is common; 7 out of 16 stomachs (44%) contained plastic or cellophane. Turtles are different from those quantitatively summarized by Fritts (1982) and Sadove (see footnote 3).	Mrosovsky 1981.
I-Dc-11	--	--	--	Large amounts of plastic commonly occur in the intestines.	J. Frazier personal observations in Eisenberg and Frazier 1983.
I-Dc-12	--	Coast of France	--	Seven out of eight (87.5%) turtles had swallowed plastic.	Duron and Duron 1980.
I-Dc-13	1980	Coast of France	--	Plastic bags were found in the stomachs of 2 of the 3 dead stranded turtles examined.	Duguy and Duron 1981.
I-Dc-14	1981	Coast of France	C-160 cm, M C-152 cm, M	Plastic bags were found in the stomachs of 2 of the 3 dead stranded turtles examined.	Duguy and Duron 1982.

Table 1.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
I-Dc-15	6/10/79	Coast of France	C-160 cm, F	Dead stranding with plastic bags in the stomach that appear to cause a blockage to the movement of food.	Duguy et al. 1980; Duguy 1983.
I-Dc-16	1980-84	Massachusetts, U.S.A.	--	Of 9 dead strandings examined over a 5-year period, 4 contained plastic. Two had balls of accumulated plastic in the upper part of the colon, and 2 had pieces of plastic in the esophagus. One of the latter cases involved a small piece of a plastic bag and the plastic-coated label from a prescription bottle of medication.	R. Prescott and N. Frazer pers. commun.
I-Dc-17	10/17/83	Chesapeake Bay, Virginia, U.S.A.	C-130 cm	Bloated stranding that was found to have a "plastic wrapper from a ketchup packet in its intestine."	J. A. Musick pers. commun.
I-Dc-18	1979-80	Bay of Plenty, New Zealand	Adult	Died shortly after beaching itself. Necropsy revealed the esophagus to be "packed with polythene bread bags."	Cawthorn 1985.
I-Dc-19	9/7/80	Scilly Isles, England	Est. 500 kg, M	Caught alive in the lines of a lobster pot. Pylorus of stomach was "more or less blocked by a ball of compressed plastic composed of a transparent plastic bag 15 by 17 cm, a frayed sheet of white plastic and many small shreds 0.4-4 cm."	Hartog and Van Nierop 1984.
I-Dc-20	8/4/81	Terschelling Is., Netherlands	510 kg, M	Caught alive at sea, but died aboard the vessel. Stomach contained a "well-preserved plastic bag 13.5 by 17.5 cm." A small bird feather was found in the intestine.	Hartog and Van Nierop 1984.
				Lepidochelys kempi, Kemp's ridley turtle	
I-Lk-1	6/27/82	Ft. Lauderdale, Florida, U.S.A.	23 cm	Tar in mouth and covering body. Taken for treatment.	Fletemeyer 1982.

Table 2.--Worldwide records of marine turtles entangled in oceanic debris

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
			Chelonia mydas, green turtle		
E-Cm-1	--	Tortuguero, Costa Rica	Adults, F	Several times over the years nesting turtles have come ashore with monofilament line wrapped around a flipper, sometimes so tight there was considerable tissue necrosis. Loss of limb predicted if the line had not been removed. No cases have been published.	K. Bjorndal and A. Carr pers. commun.
E-Cm-2	1982	Bundaberg, Queensland, Australia	"Subadult"	"Washed in dead tangled in rope with a light reef anchor attached. Origin and purpose of anchor undetermined."	C. Limpus pers. commun.
E-Cm-3	7/30/84	San Gabriel California, U.S.A.	Est. 90 kg	Reported to be seen with fishing line entangled around the tail and a long piece of wood.	H. S. Stone unpubl. data.
E-Cm-4	6/29/74	East Is., FFS, NWHI	Adult, F	Synthetic line and large float found entangled around the neck of a turtle coming ashore to nest.	G. Balazs unpubl. data.
E-Cm-5	5/19/80	Trig Is., FFS, NWHI	Adult, F	Large piece of synthetic trawl net found entangled around the neck of a turtle lying motionless on a nesting beach. Net cut free and turtle released in apparently good health.	G. Balazs unpubl. data.
E-Cm-6	9/80	East Is., FFS, NWHI	S-5 cm	Dead hatchling found on land with right front flipper entangled in strip of cloth debris.	J. Andre pers. commun.
E-Cm-7	4/8/82	Lisianski Is., NWHI	S-43 cm	Left front flipper entangled in large piece of synthetic net snagged on reef flat close to shore. Necrosis at site of constriction. Turtle tagged and released.	Henderson 1984.
E-Cm-8	5/82	Midway, NWHI	C-36 cm	Found dead floating nearshore entangled in a piece of blue synthetic net. Deep cut in right front flipper.	G. Balazs unpubl. data.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
E-Cm-9	4/18/82	Whale-Skate, FFS, NWHI	Adult, M	Rib bones and metal flipper tag found entangled in a scrap of synthetic trawl net washed ashore.	J. Andre pers. commun.; Balazs 1983a.
E-Cm-10	6/30/84	Tern Is., FFS, NWHI	Adult, M	Stranding with neck and left front flipper entangled in long piece of blue synthetic rope. Deep flipper abrasion from line. Rope snarl was also entangled in anchor line of lobster larvae collector which came ashore with the turtle. Tumors present.	J. R. Henderson pers. commun.
E-Cm-11	6/7/84	Trig Is., FFS, NWHI	Adult, M	Heavy monofilament fishing line tightly entangled around left front flipper producing a deep cut. Line removed and turtle released.	G. Balazs unpubl. data.
E-Cm-12	12/76	Oahu, Hawaii	C-34 cm	Found severely emaciated and entangled in rope. Died within a few days.	R. Bourke pers. commun.
E-Cm-13	8/3/77	Waimanalo Bay, Oahu, Hawaii	C-44 cm	Portion of a plastic container stuck tightly around turtle's neck. Object sawed-off and the turtle released in apparently good condition.	Balazs 1980.
E-Cm-14	1/23/78	Punaluu, Kau, Hawaii	S-57 cm	Hand captured while scuba diving. Monofilament fishing line wrapped tightly about right front flipper producing deep wound. Turtle tagged and released after cutting out line. Injury completely healed when recaptured 6 years later at same location.	G. Balazs and A. Kam unpubl. data.
E-Cm-15	6/79	Maunalua Bay, Oahu, Hawaii	S-47 cm	Drowned turtle with right front flipper tangled in monofilament fishing line snagged on the bottom.	J. Rutka pers. commun.
E-Cm-16	4/81	Oahu, Hawaii	--	Entangled in a piece of synthetic green trawl net floating offshore; turtle released alive.	S. Kaiser and L. Aguiar pers. commun.; Balazs 1982b.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
E-Cm-17	6/19/81	Kailua Bay, Oahu, Hawaii (lat. 21°24'N, long. 157°43'48"W)	C-64 cm	Entangled in rope attached to an abandoned anchor. One turtle dead, the other very weak--treated and released.	Mooney and Naughton 1981.
E-Cm-18	2/83	Kawainui marsh, Oahu, Hawaii	S-43 cm	Found entangled in "kite string" in a lethargic condition. Died in captivity a few days later.	P. Burnett pers. commun.
E-Cm-19	6/23/83	Malaekahana, Oahu, Hawaii	--	Decomposing carcass washed ashore with synthetic netting and line imbedded in the neck.	D. Eckert pers. commun.
E-Cm-20	1/10/84	Kailua-Kona, Hawaii	C-85 cm, F	Found resting on the bottom in a small boat harbor. Large quantity of monofilament fishing line wrapped tightly around right front flipper. Large tumors also present.	K. Spinney, P. Hendricks, K. McCoy pers. commun.
E-Cm-21	8/30/84	Kiholo, Hawaii	S-66 cm	Hand captured while snorkeling. Monofilament fishing line wrapped around right front flipper producing wound. Line removed and turtle released.	G. Balazs and A. Kam unpubl. data.
E-Cm-22	7/28/79	Texas, U.S.A.	Juvenile	Found with a fishing line wrapped around its flipper. The flipper was gangrenous and had to be amputated. "Young juveniles seem to have a propensity for becoming entangled in fishing line."	Hildebrand 1980.
E-Cm-23	6/24/81	Boca Raton, Florida, U.S.A. (lat. 26°23'N, long. 80°04'W)	19 cm	Found alive with "fishing line around right front flipper" which had "cut into bone."	Anonymous 1981c.
E-Cm-24	10/8/84	Kahului, Maui, Hawaii	Est. 46 kg	Front flipper tangled in buoy line of derelict, bottom fouled gill net. Turtle swam off with a piece of the line still attached to it.	F. Ball pers. commun.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
E-Cm-25	ca. 1980	Johnston Atoll (lat. 16°45'N, long. 169°31'W)	--	Large dead turtle found "tangled in a Japanese fish net" washed up near East Peninsula of Sand Island.	Balazs in press.
			Caretta caretta, loggerhead turtle		
E-Cc-1	5/29/78	Panama City, Florida, U.S.A.	C-84 cm, F	Fresh dead; found by scuba diver entangled in monofilament fishing line at "Warsaw Hole" 4 miles offshore at depths of 23-24 m (75-80 ft). Line fouled in limestone reef outcrop. Death presumed to be from drowning.	L. Ogren pers. commun.
E-Cc-2	1979	Panama City, Florida, U.S.A.	Subadult	Skeletal remains found on the beach. Humerus encircled with heavy monofilament fishing line twisted numerous times.	L. Ogren pers. commun.
E-Cc-3	6/30/84	Ponce Inlet, North Channel, Florida, U.S.A.	C-27.6 cm, 2.8 kg	"Caught and drowned in an abandoned gill net that had washed up on a rock jetty at the mouth of the inlet."	L. M. Ehrhart pers. commun.
E-Cc-4	1980-83	Barbuda, Leeward Is., Lesser Antilles (lat. 17°40'S, long. 61°50'W)	--	On several occasions a fisherman found loggerheads floating at sea entangled in pieces of netting. Sightings were believed to be associated with Japanese fishing boats in the area. Believed that the entangled turtles had been cut loose from trawls and left to drift.	Meylan 1983.
E-Cc-5	>1974	Cumberland Is., Georgia, U.S.A.	--	Dead stranding entangled in rope. Growth of a flipper was stunted due to constriction.	C. Ruckdeschel and C. R. Shoop pers. commun.
E-Cc-6	7/28/82	Hutchinson Is. Florida, U.S.A.	C-70 cm	"Foreflippers entangled in line and netting."	J. R. Wilcox pers. commun.
E-Cc-7	8.24/84	East Florida, U.S.A.	S-65 cm 37 kg	Left front flipper nearly severed by piece of monofilament line. Injured limb was amputated and the wound sutured prior to tagging (No. AAH-724) and release.	R. Witham pers. commun.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
			Eretmochelys imbricata, hawksbill turtle		
E-Ei-1	8/14/77	Kaneohe Bay, Oahu, Hawaii	S-76 cm, F	Found entangled and decomposing in a lost but intact 183 m (600-ft) long monofilament gill net.	Balazs 1978.
E-Ei-2	4/13/82	Palm Beach, Florida, U.S.A. (lat. 26°40'N, long. 80°02'W)	15 cm	Found entangled in fish net by surfers. Taken for treatments where it recovered but "damaged flipper dropped off."	Fletcher 1982.
E-Ei-3	4/24/82	Delray Beach, Florida, U.S.A. (lat. 26°30'N, long. 80°03'30"W)	20 cm	Washed up in surf alive covered with tar and entangled in fishing line.	Wolf 1982.
E-Ei-4	6/11/82	Rock Harbor, Florida, U.S.A. (lat. 25°05'N, long. 80°27'W)	15 cm	Found alive with monofilament line wrapped around left front flipper, causing edema of limb.	Broadrick 1982.
E-Ei-5	7/14/83	Melbourne Beach, Florida, U.S.A.	S-19.5 cm, 0.9 kg	Found stranded in a weakened condition entangled in a 1-m length of braided synthetic rope 1.3 cm in diameter. Unraveled strands at the rope end were tightly bound around the base of the left front flipper. A "flat metal clip" deeply imbedded in the flesh held the line in place. A heavy mass of sargassum was also caught in the tangled rope. The turtle was held in captivity for 2 months where it recuperated, but lost its necrotic flipper.	Redfoot et al.[3]
E-Ei-6	5/25/77	Texas, U.S.A.	Juvenile	Found with line wrapped around a front flipper that developed gangrene and had to be amputated.	Hildebrand 1980.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
E-Ei-7	1/78	Texas, U.S.A.	Juvenile	Found with a fishing line "wrapped around the upper body." Line was caught on an obstruction and apparently the turtle had been on a tether for a considerable time. "Although emaciated, the animal was healthy. A large number of oysters had settled under the raised edges of the scutes."	Hildebrand 1980.
E-Ei-8	8/9/83	Port Aransas, Texas, U.S.A. (lat. 27°50.3'N, long. 97°03.1'W)	C-29 cm	Found with a "piece of plastic onion bag" entangled around neck. "Abraded a groove in neck, but no infection was present." Turtle held in captivity, then tagged and released on 9/3/83 near an offshore oil rig.	A. F. Amos pers. commun.
E-Ei-9	12/20/83	Port Aransas, Texas, U.S.A. (lat. 27°50'N, long. 97°03'W)	C-25 cm	Found entangled in monofilament fishing line in a boat basin with 6.5°C seawater. Severe constriction to left front flipper. Turtle revived after being warmed up, but died 3 days later.	A. F. Amos pers. commun.
			Lepidochelys olivacea, olive ridley turtle		
E-Lo-1	3/73-6/73	Eastern Pacific (ca. lat. 2°-10°N, long. 85°-97°W)	--	Shipwrecked sailors adrift in a rubber raft occasionally had turtles become entangled in the ropes securing their drogue. Turtles were an important food source for survival.	Bailey and Bailey 1974.
E-Lo-2	7/20/81	Kailua-Kona, Hawaii	C-78 cm, F	Entangled in a large piece of synthetic trawl net floating several miles offshore. Turtle was tagged and released in good condition.	P. Hoogs and L. Ahlo pers. commun.; Balazs 1982b.
E-Lo-3	11/28/81	Pukoo, Molokai, Hawaii	S-22 cm	Washed ashore entangled in synthetic line. Deep cuts from the line present on three flippers. Turtle moderately emaciated, but successfully rehabilitated at the Waikiki Aquarium.	Afelin and Puleloa 1982; Balazs 1982b.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
E-Dc-5	6/16/81	Watch Hill, New York, U.S.A. (lat. 40°43'43"N, long. 72°52'56"W)	157 cm, M	Found dead, "tied up in rope" in an advanced state of decomposition.	Sadove and Smith 1981.
E-Dc-6	1982-84	Rhode Island, U.S.A.	--	Dead stranding; a rope with longline fish hook imbedded in a flipper.	C. R. Shoop pers. commun.
E-Dc-7	8/1/84	Cape Town, South Africa	Adult	Came ashore with a piece of nylon rope around a foreflipper. Wound caused by rope appeared to have healed, but there was a huge weight of *Mytilus* mussels and gooseneck barnacles growing on the rope.	G. R. Hughes and R. Rau pers. commun.
E-Dc-8	11/18/79	Saint-Clement-des-Baleines, France	C-157 cm, M	Dead stranding; nylon line snarled around decomposing remains of left front flipper.	Duguy 1983.
				Species unknown	
E-Un-1	8/79	Eastern Mediterranean	"Small"	Turtle seen at the surface attempting to swim with a large piece of what appeared to be plastic sheet wrapped around its shell.	Morris 1980a.
E-Un-2	8/82	Oahu, Hawaii	Subadult	Vertebrae and ribs of sea turtle found tightly entangled in a piece of trawl net floating about 10 miles offshore.	J. Naughton pers. commun.
E-Un-3	5/82	West Molokai, Hawaii	--	Entangled in a piece of green synthetic trawl net floating offshore.	S. Kaiser and L. Aguiar pers. commun.
E-Un-4	1/1/84	Waianae Harbor, Oahu, Hawaii	Est. 45 kg	Observed swimming entangled in a piece of brown net. Seen by others at different times at the same location. Likely to have been a green turtle.	A. Endo and P. Conant pers. commun.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
E-Lo-4	7/29/82	Oahu, Hawaii	S-38 cm	Entangled in a piece of green synthetic net floating 6-7 miles offshore. Turtle tagged and released in good condition.	S. Henderson pers. commun.
E-Lo-5	5/19/83	Hana, Maui, Hawaii	C-62 cm	Entangled in a 1.5 m^2 piece of green, synthetic net floating 1 mile offshore. Rehabilitated, tagged, and released.	E. Merrill pers. commun.
E-Lo-6	1980-84	Pacific coast of Costa Rica	Adults, F	A few turtles (3-4) found with "short pieces of monofilament and nylon webbing wrapped around limbs." One had a flipper totally paralyzed from webbing. Great numbers of nesting olive ridleys have been examined over the past 5 years, but only these few have been found entangled.	S. Cornelius pers. commun.
			Dermochelys coriacea, leatherback turtle		
E-Dc-1	8/8/67	Bermuda	150 cm "head to tail," est. 500 kg.	"Tangled in a fishing net and drifting helplessly."	D. B. Wingate cited in Lee and Palmer 1981.
E-Dc-2	8/79	North central Pacific (lat. 41°N, long. 178°W)	Adult	Observed swimming at the surface trailing a piece of rope.	G. Naftel pers. commun.
E-Dc-3	1980	North central Pacific (lat. 35°-45°N, east of long. 170°E)	Adult	At least five dead turtles seen floating at the surface entangled in pieces of monofilament squid net. Probably cut adrift by Japanese or Taiwanese fishermen.	J. Ray pers. commun.; Balazs 1982.
E-Dc-4	12/82	Kailua-Kona (OTEC buoy), Hawaii	682 kg, F	Entangled at night 2 miles offshore in a "parachute anchor." Turtle reportedly dragged a boat around for several hours before being killed. Carcass brought in and weighed on a scale to within 10 kg.	Anonymous telephone calls to G. Balazs.

Table 2.--Continued.

Case No.	Date	Location[1]	Carapace length,[2] weight, and sex	Description	Reference
E-Un-5	5/84	High seas southwest of Hawaii	--	Turtle entangled in fishing line seen floating at the surface by personnel of the NOAA ship <u>Townsend Cromwell</u>.	B. Burch pers. commun.

[1]FFS = French Frigate Shoals; NWHI = Northwestern Hawaiian Islands.
[2]C = curved; S = straight.
[3]W. E. Redfoot, L. M. Ehrhart, and P. W. Raymond. A juvenile Atlantic hawksbill turtle, *Eretmochelys imbricata*, from Brevard County, Florida. Manuscr. in prep. Seminole Community College, Sanford, FL 32771.

least 160 turtles. The remaining cases (8%) describe instances of turtles seen foraging on debris, but the actual numbers were not given. Except for this latter category and Case I-Cm-12 and I-Dc-4, all accounts of debris ingestion were derived from stranded turtles (74%) or turtles taken by fishermen (26%), where the mouth, or some portion of the gastrointestinal contents, had been examined. Most of the stranding cases (84%) involved dead animals. Case I-Cm-12 and I-Dc-4 dealt with the removal of plastic sheets from the cloacae of live turtles.

Cases of debris entanglement shown in Table 2 almost exclusively (92%) involved single turtles. Slightly more than half came from strandings, and the remainder from chance sightings at sea. Only 38% of the entangled turtles were dead or later died. Many more would undoubtedly have died in the absence of human intervention.

It is apparent that strandings represent a principal source of information on debris ingestion and entanglement. A stranded turtle, to be of scientific worth, must be found by someone who properly reports it before it washes or swims away, becomes covered with sand, or decomposes completely. Even when a prompt and accurate report has been made, it is likely that a carcass showing advanced decay would not be cut open and inspected for ingested contents as often as a fresh specimen. A further constraint to collecting data on debris ingestion and entanglement is that most turtles dying in the water probably do not stay afloat long enough to reach shore. This would be especially true for those turtles living on or migrating through the high seas.

Several reports that were located or received were significant for their absence of findings relevant to debris ingestion and entanglement. Mortimer (1981) found no signs of synthetic debris in the stomach contents of 243 green turtles taken in a fishery off the Caribbean coast of Nicaragua. At Cumberland Island, Georgia (U.S.A.), more than 600 dead stranded loggerheads have been cataloged between 1974 and 1984. Gastrointestinal contents were examined in many of these turtles. No plastics or other debris were seen, except for an iron bolt in the roof of one turtle's mouth and a fishhook in the small intestine of another (C. Ruckdeschel and C. R. Shoop pers. commun.). Also, only a single instance of entanglement (E-Cc-5, Table 2) was found among these 600 strandings. At Little Cumberland Island, Georgia, no entanglement in debris has been recorded in stranded or nesting loggerheads monitored since the early 1960's (J. I. Richardson pers. commun.). Only two cases of plastic ingestion have been found in hundreds of turtles (loggerhead, Kemp's ridley, and leatherback) examined during recent summers in Virginia, Maryland, and Delaware (J. A. Musick pers. commun.).

Geographic Distribution

Reports on debris ingestion originated from 19 worldwide locations, and those on debris entanglement came from 10 (Table 3). The coastal continental U.S. accounted for a large portion of debris ingestion (40.8%) and entanglement (31.7%). An established reporting network in the region undoubtedly influenced the outcome. Hawaii, which is listed separately in Table 3, accounted for 46.7% of entanglement cases. This was due to firsthand reports compiled by the author. If better coverage could be achieved, a similar increase would likely be experienced at certain other locales.

Table 3.--Geographic distribution of known cases of debris ingestion and entanglement by marine turtles.

	Percent cases reported in this paper	
Location	Ingestion	Entanglement
Azores	1.3	--
Ascension Island	2.6	--
Australia	2.6	1.7
Balearic Islands	1.3	--
Bermuda	--	1.7
Costa Rica	3.9	3.3
England	2.6	--
France	5.3	1.7
French Polynesia	1.3	--
Hawaii (U.S.A.)	9.2	46.7
Japan	10.5	--
Johnston Atoll	--	1.7
Lesser Antilles	--	1.7
Marshall Islands	1.3	--
Madeira (Portugal)	2.6	--
Mediterranean (eastern)	--	1.7
Netherlands	2.6	--
New Zealand	1.3	--
Pacific Ocean (high seas)	--	6.7
Peru	2.6	--
Selvagen Islands	2.6	--
South Africa	3.9	1.7
Tokelau	1.3	--
United States (mainland)	40.8	31.7

Debris Ingestion

Debris was ingested by five species of sea turtles (Table 4). The green turtle was the most commonly documented (32%), followed by the loggerhead (26%), leatherback (24%), and hawksbill (14%). Only a small number of reports on Kemp's ridley was obtained (4%). No reports were located for the olive ridley or flatback. In four of the five species found to eat debris, immature turtles were more frequently involved than adults (Table 5). This could be due to the greater proportion of immature turtles expected in the population, or a greater tendency for immature turtles to feed on floating debris. The leatherback alone contrasted sharply with this pattern; only adults ingested debris. Immature leatherbacks, especially juveniles, are rarely seen anywhere.

The various types of ingested debris were grouped into 14 categories (Table 4). Plastic bags and sheet were the most prevalent material (32.1%), followed by tar balls (20.8%), and plastic particles (18.9%). Some of the more unusual, but less frequently reported, items consisted of cloth, fishing net, paper, glass, and metal. Pieces of synthetic rope and

Table 4.--Percent occurrence of types of debris found ingested by marine turtles. (Compiled from data listed in Table 1 where many cases involve turtles that ingested two or more types of debris.)

Species	Plastic bags and sheets	Plastic and styrofoam particles	Tar	Kitchen scraps	Synthetic line and thread	Monofilament fishing line	Cloth	Fishery by-catch	Net	Paper	Glass	Metal	No. of cases from Table 1
Green turtle	25.8	6.5	32.3	9.7	12.9	3.2	6.5	--	3.2	--	--	--	25
Loggerhead	14.7	32.4	11.8	5.9	11.8	5.9	--	5.9	--	2.9	5.9	2.9	20
Hawksbill	16.7	38.9	33.3	5.5	--	--	--	--	--	5.5	--	--	11
Leatherback	94.4	--	--	--	--	5.6	--	--	--	--	--	--	19
Kemp's ridley	20.0	--	40.0	--	--	--	--	--	--	20.0	--	20.0	3
All species	32.1	18.9	20.8	5.7	7.5	3.8	1.9	1.9	1.0	2.8	1.9	1.9	78

Table 5.--Age composition of marine turtles ingesting and becoming entangled in debris.

Species	Percent composition from cases reported in this paper		Sample size N
	Adult	Immature	
	Ingestion		
Green turtle	19.0	81.0	21
Loggerhead	18.7	81.3	15
Hawksbill	9.0	90.9	11
Leatherback	100.0	0	11
Kemp's ridley	0	100	3
All species	30.6	69.4	62
	Entanglement		
Green turtle	41.7	58.3	24
Loggerhead	0	100	4
Hawksbill	11.1	88.9	9
Olive ridley	50.0	50.0	4
Leatherback	100.0	0	7
All species	41.7	58.3	48

monofilament line showed up in the digestive tracts of green, loggerhead, and leatherback turtles under conditions that did not seem to involve swallowing a baited hook. Another interesting aspect shown in Table 4 is the ingestion by loggerheads of unwanted fishery by-catch jettisoned from shrimp trawlers.

Quantitative data of debris ingestion were available in 16 of the cases covering 4 species (Table 6). Various plastics were again the most prevalent items, ranging from 6 to 87% occurrence in the turtles sampled. Noteworthy among these were Case I-Dc-9 where 13% of 140 leatherbacks examined had eaten plastic bags, Case I-Cm-4 where 23% of 39 green turtles contained plastic bags, and Case I-Cc-6 where 43% of 43 dead stranded loggerheads contained discarded fishery by-catch.

Debris Entanglement

Five species of sea turtles were involved in entanglement with debris (Table 7). Species identification was not possible in 5 of the 60 cases. The green turtle accounted for 42% of all cases; no records were located for Kemp's ridley or the flatback. Immature turtles were entangled more frequently than adults, but the pattern was not as pronounced as in debris ingestion (Table 5). Again, only adult leatherbacks were found entangled.

The debris responsible for entanglement was grouped into nine categories (Table 7). Monofilament fishing line accounted for 33.3% of all

Table 6.--Quantitative reports cited in this paper of debris found ingested by marine turtles.

Species	Sample size N	Type of debris	Percent with debris	Case No. in Table 1
Green turtle	11	Plastic	37	I-Cm-2
	11	Cloth	18	I-Cm-2
	39	Plastic bags	23	I-Cm-4
Loggerhead	32	Plastic beads	6	I-Cc-2
	32	Plastic sheet	6	I-Cc-2
	9	Plastic and glass	44	I-Cc-3
	43	Fishery by-catch	43	I-Cc-6
	3	Plastic, glass, and thread	100	I-Cc-18
Hawksbill	20	Plastic and other synthetic litter	20	I-Ei-2
Leatherback	42	Plastic bags	50	I-Dc-8
	140	Plastic bags	13	I-Dc-9
	16	Plastic	44	I-Dc-10
	8	Plastic	87	I-Dc-12
	3	Plastic bags	33	I-Dc-13
	3	Plastic bags	33	I-DC-14
	9	Plastic	44	I-Dc-16

Table 7.--Percent occurrence of types of debris found entangled on marine turtles. (Compiled from data listed in Table 2 where each case was considered to involve only a single type of entangling debris.)

Species	Monofilament fishing line	Rope	Trawl net	Monofilament net	Plastic object	Plastic sheet or bag	Line with hook	Cloth	Parachute anchor
Green turtle (N = 25)	36.0	24.0	24.0	8.0	4.0	--	--	4.0	--
Loggerhead (N = 7)	57.1	28.6	--	14.3	--	--	--	--	--
Hawksbill (N = 9)	55.6	1.1	--	22.2	--	11.1	--	--	--
Olive ridley (N = 6)	--	33.3	50.0	16.7	--	--	--	--	--
Leatherback (N = 8)	12.5	37.5	--	25.0	--	--	12.5	--	12.5
Unknown species (N = 5)	20.0	--	60.0	--	--	20.0	--	--	--
All species (N = 60)	33.3	23.3	20.0	13.3	1.7	3.3	1.7	1.7	1.7

cases. Some of these could have resulted from encounters with tended fishing gear. However, none of the reports appearing in this category mentions a fishhook attached to monofilament line, or hooked into the turtle. For several cases (E-Cm-15, I-Cc-1, and E-Ei-7), it is evident that turtles had become entangled in lost pieces of line snagged on the bottom.

Other major categories of debris found on turtles included segments or snarls of rope (23.3%), pieces of trawl webbing (20.0%), and monofilament net (13.3%). Fishing-related debris was involved in 68.3% of all cases. The category of "rope" is not included in this figure, even though a fair amount of rope debris probably does come from fishing efforts.

DISCUSSION

Impacts of Ingested Debris

Sea turtles occasionally consume naturally occurring debris such as bird feathers, terrestrial vegetation, bottom substrate, and pumice. In this paper it has been well documented that they may also eat all sorts of man-related litter. However, in most instances the actual impact of this material is unclear in terms of mortality or morbidity. Certainly the adverse effects of tar balls and oil droplets can be readily perceived when a turtle's jaws become stuck together, throats are packed with tar, and toxic hydrocarbons are transported across the gut wall. As for plastic bags and sheets being eaten, the available evidence for direct harm or mortality is much less conclusive. Seven of the strandings presented in Table 1 describe the ingestion of plastics in quantities large enough or compacted in such a manner to have definitely caused blockage (Cases I-Cm-25, I-Ei-11, I-Cc-16, I-Dc-2, I-Dc-8, I-Dc-15, and I-Dc-18). In contrast, some reports documenting ingestion of plastics deal with seemingly healthy turtles caught by fishermen (Case I-Cm-4, I-Cm-15, I-Ei-2, and I-Dc-90). The twisted configuration of the plastic found throughout the intestines in several turtles suggests that such material can be moved along and voided naturally by peristaltic transport. In Case I-Dc-4, the twisted tip of a plastic sheet was seen protruding from the cloaca of a large leatherback accidentally caught alive in a net. A similar condition was observed in a juvenile green turtle raised in captivity (Case I-Cm-12). However, in both cases, the plastic was pulled out manually by researchers before they discerned whether it would have been expelled naturally.

Even if there is no direct mechanical blockage, there are still potentially serious problems such as lost nutrition, reduced absorption of nutrients while the plastic lines the gut wall, and absorption of toxic plasticizers (PCB's). Unfortunately, very little is known of these aspects in sea turtles, although PCB's have been found in the eggs of green turtles nesting at Ascension Island (Thompson et al. 1974), and Duguy (1983) reports that high levels of PCB's and DDE were found in tissue from three female turtles and one male leatherback turtle (see also Duguy et al. 1980).

Similar effects could be envisioned for turtles that ingest hard plastic fragments, styrofoam, synthetic line, and other plastic derivatives that make up 31.2% of the debris types shown in Table 4. An additional adverse factor may result from plastic objects grinding upon each other during muscular contractions in the digestive process. Such abrasive action could cause pinocytotic absorption of microscopic particles of plastic in the intestine, as has been suggested for albatrosses by Pettit et al. (1981). Furthermore, there would be a reduced ability to maneuver and dive away from predators when buoyant pieces of plastic and styrofoam are present in the gut. Buoyancy of this sort was clearly evident in Case I-Ei-11.

Another potentially serious aspect of the debris ingestion problem, but one that may prove easier to assess and alleviate, is the consumption of fishery by-catch by loggerheads. As suggested in Case I-Cc-6 by Shoop and Ruckdeschel (1982), the unwanted catch dumped from shrimp trawlers could be creating artifically high concentrations of foraging turtles. The turtles attracted would then be more susceptible to accidental capture and drowning from the intensive shrimp fishery. Increasing numbers of dead loggerheads washing ashore in the southeastern United States suggest that attraction to by-catch may indeed be a contributing factor.

Factors Causing Debris Ingestion

Several plausible explanations can be offered as to why sea turtles eat various debris. First, the object may resemble an authenic food item in size, shape, and even movement as it drifts at the surface or through the water column. Its color, translucence, and reflection may also be stimuli that induce a feeding response. In considering these factors, Hartog (1980) raised the interesting question as to why pieces of litter, particularly plastic objects, are not rejected by a turtle once "seized and tasted." A logical answer might be that marine organisms commonly encrusting or residing on debris may emanate an acceptable natural smell that masks the artificial nature of the object. Drift plastic is often covered with growth and, with increased ocean dumping, is considered to be an expanding pelagic niche for marine invertebrates (Winston 1982). In some cases, a luxuriant growth of marine life may be the principal sensory cue to initiate feeding by turtles. In Case I-Cm-7, a piece of synthetic net taken from the stomach of a green turtle had numerous fish eggs cemented to it. Although certain kinds of fish eggs are commonly attached to seaweed, floating debris like nets and other objects are also suitable habitat. Fritts (1981) presented information indicating that clumps of fish eggs may be an important nutritional source to sea turtles in the pelagic environment. In Case I-Cc-7, a piece of heavy monofilament fishing line pulled from the digestive tract of a loggerhead was found to have numerous encrusting organisms, the most abundant of which were mussels. It was surmised that the turtle ingested the line due to the presence of typical forage items for this species (L. Ogren pers. commun.). Gooseneck barnacles have been found in the stomachs of juvenile green turtles in Hawaii and elsewhere. These same barnacles have also been seen growing on small tar balls that have washed ashore in the Northwestern Hawaiian Islands. In the Atlantic, similar lumps of tar have been sighted at sea covered with barnacles, other crustaceans, and algae (Heyerdahl 1971). However, marine life of this sort may not always be necessary to attract turtles to eat floating tar. Owens (1983) mentioned preliminary studies suggesting that tar balls or soluble oil fractions by themselves might be inherently attractive to neonatal sea turtles (see also Hall et al. 1983).

The ingestion of plastics by turtles has recently generated some interest in Florida, where plastic seaweed mats may soon come into common use to control beach erosion (Van Dam 1984). Concern has also been expressed about fish aggregating devices made of vinyl screen which are anchored offshore 18 m (60 ft) beneath the surface. Foraging turtles, especially loggerheads, might bite into the vinyl while trying to eat encrusting organisms, or they may mistake the entire 1.8-m (6-ft) long parasol for a giant jellyfish (Benet 1984; R. Witham pers. commun.).

Under conditions of extreme hunger, turtles may be motivated to feed on debris that they would not otherwise eat. For example, at certain breeding sites there is a scarcity of forage to help sustain females through the 1- to 3-month nesting season. Ingestion of plastics, cloth, and other refuse by green turtles and hawksbills has been recorded in internesting habitats off Costa Rica and Ascension Island (see Case I-Cm-2, I-Cm-3, I-Ei-1, and I-Ei-2).

Another way in which sea turtles might ingest debris is through a secondary route, where the turtles' prey items have themselves eaten litter. There are no cases known at present to support such a mechanism; nevertheless, the increasing volume of minute plastic particles dispersed over the seas makes it a distinct possibility. For example, plastics and vegetables believed to have been dumped from fishing boats have been found in the stomachs of squid in the North Pacific (Araya 1983).

Impacts of Debris Entanglement

The adverse effects of debris entanglement on sea turtles are far more direct and obvious than more subtle negative impacts resulting from ingestion. As shown in Table 2, when turtles become entangled most of them are unable to function normally in feeding, diving, surfacing to breathe, and other basic behaviors. Constricting line and netting can inflict lesions and reduce blood supply to limbs, causing necrosis. Escape from predators is made more difficult, if not impossible. In addition, dense marine growth on entangling debris can weigh down a turtle, making it less likely to survive (see Case E-Dc-7). With the widespread use of synthetic line and net over the past few decades, there is little chance for entangling debris to rot away, or for a turtle to break loose on its own. Unfortunately for sea turtles, fishing gear of even greater durability (hence persistence) is now being advertised for sale (Anonymous 1983a).

Factors Causing Debris Entanglement

It is easy to understand how turtles can become entangled and drown in nearly invisible gear like monofilament netting. If the material is difficult to see underwater, a turtle may simply swim into it and become hopelessly tangled. Mortality from this cause has been reported from the intensive use and loss of large monofilament drift nets on the high seas northwest of Hawaii (Case E-Dc-3; Neuweiler 1982). Entanglement in other kinds of debris besides monofilament netting is more difficult to comprehend, since most are readily visible. Sea turtles, especially leatherbacks and green turtles, have a distinct propensity for entangling their front flippers and heads in rope. It is unknown exactly how these bizarre entanglements take place. Lazell (1976) describes a possible entanglement scenario for a leatherback trying to "eat" a buoy tied off with a rope.

Scraps of trawl net at sea seem to act like magnets to sea turtles. A likely explanation for this behavior is that floating masses of net offer the same advantages as sargassum mats or drift lines, where shelter and concentrated food can be obtained.

Once residency is established around a piece of net, the chances for a turtle becoming entangled may be quite high as it swims over and through the netting seeking food. In Hawaii, floating scraps of trawl net (often called "cargo" net) are viewed by fishermen as an asset due to their fish aggregating capabilities. Olive ridleys have been rescued alive from these nets by fishermen trolling around them (Case E-Lo-2, E-Lo-4, and E-Lo-5), even though this species does not normally occur in the nearshore waters of Hawaii. It is unknown if the surrounding high seas are normal habitat, or if the turtles became entangled at a distant site and passively drifted here.

Many kinds of drifting debris in addition to netting are known to aggregate marine life under and around them (Gooding and Magnuson 1967; Tsukagoe 1981). Sea turtles themselves can even act as natural aggregating objects. In Hawaii, trollers have caught several game fish at once lingering beneath a healthy immature turtle floating at the surface (Balazs 1981). Possibly the schooling behavior sometimes observed at sea for olive ridleys and other species has the benefit of attracting sources of food that can then be directly exploited by the turtles. Shipwrecked survivors adrift in a rubber raft north of the Galapagos Islands often had turtles (probably olive ridleys) around them in association with other marine life (Bailey and Bailey 1974). The turtles would rub against the bottom of the raft and, as might be expected, sometimes become entangled in ropes securing a sea anchor (Case E-Lo-1).

RECOMMENDATIONS

Short of severely curtailing the ocean dumping of all plastics and other material identified in this paper, there is probably not much that can be done to lessen the adverse effects of debris on sea turtles. The ubiquitous nature of the material and the mostly concealed oceanic life of many turtles, especially in their early development stages, present a difficult setting in which to work. There are, however, some immediate activities that could be undertaken to better understand the nature of the impacts. Of course the recognition that a problem exists, as has been facilitated through this debris workshop, is in itself an important first step.

It is recommended that the following actions be carried out.

1. There should be greater efforts worldwide to record stranded turtles and conduct necropsies aimed at documenting debris ingestion and entanglement.

2. Studies should be conducted that involve the controlled feeding of plastics and other debris to turtles in captivity to gain definite information on intestinal obstruction, absorption of plasticizers, and feeding behavior.

3. Field studies aimed at elucidating the pelagic life of sea turtles along drift lines in the Pacific should be undertaken north of the Hawaiian Islands.

4. A more thorough assessment should be made of sea turtle interactions with jettisoned by-catch from shrimp trawlers and other fisheries.

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