SURVEY OF MARINE DEBRIS INGESTION BY ODONTOCETE CETACEANS

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ABSTRACT

Odontocete cetaceans are affected to an unknown degree by the ingestion of oceanic debris. Published accounts discuss primarily the sperm whale, *Physeter macrocephalus*.

The pathologic effects of foreign body ingestion on captive cetaceans are well documented, and provide background information on the potential effects of debris ingestion on wild, free-ranging animals. A survey of major institutions reveals 40 incidences of debris ingestion in 16 species of stranded odontocete cetaceans. Plastic debris was prevalent, with a total occurrence of 80.0%. Evidence indicates ingestion of debris may be secondary to the stranding syndrome. A survey of prior food habits analyses on 10 species of odontocete cetaceans was conducted. All species combined, a total of 1,790 stomachs were examined. Marine debris was encountered only in Baird's beaked whale, *Berardius bairdii*, taken at two localities in the coastal waters of Japan. In *B. bairdii* taken off the Pacific coast of central Japan, debris incidence in 86 stomachs was 26.7%. Plastic debris made up 39.1% of the foreign material ingested. Off northern Hokkaido, in the southern Okhotsk Sea, incidence of debris in 20 stomachs was 15.0%. Food habits data indicate that the lower frequency of debris ingestion is related to differences in feeding strategy in the northern region.

In the wild state odontocete cetaceans are probably discriminating feeders. Evidence indicates that the high occurrence of debris in *Physeter macrocephalus* and *B. bairdii* is due primarily to incidental ingestion along with benthic prey.

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INTRODUCTION

The quantity of increasingly diverse marine litter discarded into the world's oceans is reaching enormous proportions. Billions of pounds of debris are dumped into the sea each year (Carpenter and Smith 1972; Venrick et al. 1973; Wong et al. 1974; Morris 1980a, 1980b; Van Dolah et al. 1980; Eldridge 1982; O'Hara et al. 1988). Recent studies reveal this to be more than an aesthetic problem. Debris, particularly nonbiodegradeable plastics, is accumulating in the marine environment and causing significant mortality in some marine animals (Wallace 1985).

In 1984, the first Workshop on the Fate and Impact of Marine Debris was held in Hawaii. Papers presented confined their data on ingestion of marine debris largely to marine birds (Day et al. 1985) and turtles (Balazs 1985; Cawthorn 1985). The potential problem of debris ingestion by marine mammals was not addressed, with only anecdotal accounts appearing in the proceedings (Cawthorn 1985; Mate 1985).

Ingestion of debris by cetaceans does occur. Early accounts of an impressive array of nonfood items ingested by the sperm whale, *Physeter macrocephalus*, are well known (Turner 1903; Millais 1906; Hollis 1939; Pike 1950; Sleptsov 1952; Clarke 1956; Berzin 1959, 1971; Caldwell et al. 1966). Berzin (1971) discusses accounts of "several vinyl chloride bags" found in North Pacific sperm whale stomachs as early as 1961. More recent accounts of debris ingestion involve stranded cetaceans (Wehle and Coleman 1983; Cawthorn 1985; Mate 1985; Cowan et al. 1986).

It is evident that there is a need for research on the occurrence and potential impact of cetacean debris ingestion. This study, though confined to the toothed cetaceans (odontoceti), begins to address this subject. It is divided into three major areas of inquiry. 1) Investigate the effects of foreign body ingestion by captive cetaceans maintained by marine aquariums in order to assess the potential effects of debris ingestion in the wild. 2) Conduct a survey on incidences of debris ingestion in stranded cetaceans. 3) Survey incidence of marine debris in food habits analyses conducted on free-ranging cetacean populations.

METHODS OF DATA COLLECTION

Information on the pathologic effects of captive cetacean foreign body ingestion was derived from the literature and the senior author's personal experience as biologist and curator at Marineland of the Pacific during the period 1968-74.

Records of debris ingestion in stranded odontocete cetaceans were solicited from institutions and persons known to include stomach content examination as part of a coordinated stranded animal recovery program. Due to variation in recordkeeping and necropsy techniques imposed by a 24-year time frame (1963-86), frequency of occurrence data on debris ingestion could not be reliably derived. Accounts from the literature were not included unless sufficient information on time frame, locality, and nature of ingested debris was available.

Data on evidence of debris ingestion in free-ranging odontocete cetaceans were obtained from food habits studies conducted on animals collected at sea as a result of incidental fisheries interactions or directly taken for research or commercial purposes. In each case, personnel directly involved in the preliminary stomach content sorting procedures were interviewed. Unusual items encountered during this stage tend to be remembered (though not necessarily recorded). An "I don't recall" response during the interview resulted in elimination of the study from the data base.

In some instances determinations as to whether ingested objects constitute debris directly ingested or introduced secondarily through prey species presented a problem. Tiny bits of plastic and isolated fishhooks are particularly suspect. Fish are well known to be attracted to and ingest man-made objects. Recently ingestion of plastic particles by oceanic squid has been documented (Araya 1983; Machida 1983). For purposes of this study, animals containing only isolated fishhooks were noted but not included in the frequency data presented.

As this study progressed, it became apparent that there are probably more isolated incidences of debris ingestion in odontocete cetaceans than we were able to locate in the time allowed. We welcome any oversights brought to our attention so the records may be included in a future revision of this report.

RESULTS

Captive Cetacean Foreign Body Ingestion

Mortality in marine parks and zoos due to foreign body ingestion is well documented in the literature. Brown et al. (1960) described causes of mortality in a major oceanarium, Marineland of the Pacific, during the first 5 years of operation. Three of those years were summarized as follows: "The losses occurring during the years 1955 to 1958 were, with few exceptions, caused by animals swallowing indigestible foreign material and resulting in gastric and enteric impactions." Nakajima et al. (1965) reported that 18 of 92 (19.6%) dolphin casualties at Enoshima Aquarium in Japan between 1958 and 1965 had foreign material in their stomachs. Caldwell et al. (1965) described a simultaneous mortality of three trained bottlenose dolphins at Gulfarium in Florida. They died from ingesting plastic strips from the tank enclosure. "Balls of plastic up to four inches in diameter were found in the first stomach of these animals."

During the senior author's tenure at Marineland of the Pacific, numerous cetaceans died as a result of ingestion of foreign material. One trained Pacific bottlenose dolphin was particularly noteworthy in that it had ingested a piece of a polyethylene plastic bag ca. 0.19 m (2 ft square). Necropsy findings revealed that while the major portion of the bag remained in the forestomach, a small section extended through the sphincter and into the gastric stomach. Tissue pathology was extensive. Approximately one-half of the forestomach lining and submucosa had eroded away, with necrotic tissue and inflammation extending deep into the

musculature of the stomach wall. The stomach wall and serosa adjacent to this lesion were edematous and thickened five to six times beyond normal. It was surmised that the effect of the plastic protruding through the sphincter into the gastric stomach caused an excess of digestive fluids to be released into the forestomach, severely injuring those portions of stomach lining insulated by plastic.

Captive cetaceans have been known to ingest a wide variety of foreign material. Objects such as cotton gloves, tin cans, plastic bags, bottles, pens, coins, flashbulbs, plastic combs, nails, steel wool cleaning pads, plastic toys, and women's jewelry are some of the articles reported (Brown et al. 1960; Amemiya 1962; Caldwell et al. 1965; Nakajima et al. 1965; Ridgway 1965, 1972; Brown et al. 1966).

The reasons for the high incidence of foreign body ingestion in captive cetaceans are not clear. The captive environment, due to its obvious spatial limitations, is at best an abnormal one. The social behavior of these animals has been severely altered (Caldwell et al. 1968). Ridgway (1972) suggested that since captive animals are taught to consume dead fish, they may consider any object entering the pool as edible. Excitement of training, performing, play behavior, and competition for food may also be contributing factors (Nakajima et al. 1965).

What is clear from the accounts on captive cetacean ingestion of foreign objects is that it has the potential for being a direct cause of mortality, or at least debilitating to a degree which could predispose animals to disease or predation in the wild state.

Stranded Animal Debris Ingestion

Case descriptions of stranded animal debris ingestion by species are presented in Table 1. A total of 43 accounts were available, spanning a period of time from 1963 to 1986. Sixteen species of odontocete cetaceans were involved.

Reports on debris ingestion came primarily from the east and west coasts of North America (37 and 58%, respectively). Only one record each was obtained from the Gulf of Mexico (Texas) and Hawaii. The differences in frequency probably reflect regional variation in stranded cetacean recovery and detailed necropsy techniques rather than true geographic differences in abundance of marine debris.

The kinds of debris ingested varied considerably. Plastic bags and plastic sheeting were the most prevalent items (62.5%). Other miscellaneous plastic articles such as drinking straws, bottle caps, discarded fishing net, synthetic rope, and a small container occurred in 17.5% of the cases. The total occurrence for all plastic debris was 80.0%. Nonplastic debris such as rubber balloons, asphalt, cellophane, cloth, paper, and metal articles (excluding fishhooks) was encountered in 37.5% of the cases reported. Fragments of marine plants, which are also abnormally ingested, were encountered in 32.6% of the stomachs examined.

Table 1.--Records of the ingestion of marine debris by stranded odontocete cetaceans.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
			Physeter macrocephalus, sperm whale			
--	6/79	Florence, OR	--	--	About 1 L of tightly packed trawl net in stomach. One of 38 stomachs examined from a mass stranding of 41 animals	Mate 1985.
Sp-1	6/7/79	Purgatory Bay, Bonavista Cove, Newfoundland, Canada	1,030	F	Small length of nylon rope and unidentified debris	U.S. National Museum.[a]
MME01362	7/1/85	Seaside, NJ	510	--	Mylar balloon	U.S. National Museum.[a]
			Kogia simus, dwarf sperm whale			
USNM504132	12/4/74	Corolla, NC	178	F	Plastic Wonderbread bread wrapper	U.S. National Museum.[a]
			Kogia breviceps, pygmy sperm whale			
CMNH0216	4/27/76	Sullivan's Island, SC	318	F	Two small pieces of thin plastic	Charleston Museum.[b]
MME00549	1/1/84	Galveston, TX	182	M	Pounds of plastic bags clogging its stomach chambers	U.S. National Museum;[a] Wehle and Coleman 1983.
MME01263	5/17/85	Brevard Co., FL	320	M	Plastic bag	U.S. National Museum.[a]

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
			Ziphius cavirostris, Cuvier's beaked whale			
JRH-087	11/20/80	San Diego, CA	526	M	Piece of asphalt	Southwest Fisheries Science Center.[c]
USNM550111	1/7/81	Assawaman, VA	580	F	Large plastic bag and plastic wrappers	U.S. National Museum.[a]
USNM550734	1/27/86	Seaford, VA	512	F	Plastic straw and a horse chestnut	U.S. National Museum.[a]
			Mesoplodon europaeus, Gervais' beaked whale			
USNM550018	11/22/80	Hatteras Island, NC	311	M	Large piece of clear plastic bag	U.S. National Museum.[a]
USNM550362	12/28/83	Cape May, NJ	371	F	Stomach filled with plastic bag	U.S. National Museum.[a]
			Mesoplodon densirostris, Blainville's beaked whale			
USNM550754	2/14/86	East Hampton, NY	420	M	One plastic bottle cap	U.S. National Museum.[a]
			Globicephala macrorhynchus, short-finned pilot whale			
USNM550310	5/18/83	Corolla, NC	275	M	Small plastic container	U.S. National Museum.[a]
			Steno bredanensis, rough-toothed dolphin			
USNM504462	6/28/76	Maui, HI	215	F	Plastic bag in stomach. This animal was one of nine mass stranded on 6/28/76.	U.S. National Museum.[a]

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
USNM504486	10/12/76	Sandbridge, VA	206	M	Two pieces of heavy black plastic. This animal and one below are part of mass stranding of 13 on 10/12/76	U.S. National Museum.[a]
USNM504494	10/12/76	Sandbridge, VA	233	M	One large fishhook loose in stomach	U.S. National Museum.[a]
		Lagenorhynchus obliquidens, Pacific white-sided dolphin				
--	8/29/63	Santa Monica, CA	165	M	Piece of paper wadded into a 5.1 cm (2-in) ball along with seaweed, squid beaks, and roundworms.	Caldwell et al. 1965.
WAW-130	8/15/71	Santa Monica, CA	167	M	Stomach contained numerous small plastic bags, pieces of cardboard, and waxed paper. Numerous kelp fronds (*Macrocystis pyrifera*) also present. This animal had been observed inside a yacht harbor for 10 days prior to stranding. Necropsy diagnosed parasitic central nervous system pathology and hepatitis as cause of death.	W. Walker, unpubl. data; Cowan et al. 1986.
WAW-174	9/21/72	Long Beach, CA	176	F	Forestomach half full of four plastic bags, two plastic bottle caps, and numerous small sticks, twigs, leaves, and kelp fronds	W. Walker, unpubl. data. Pathology data from Cowan et al. 1986

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
					(*Macrocystis* and *Egregia*). One No. 4 fishhook snagged in stomach lining. Necropsy diagnosed central nervous system pathology due to parasitism by the trematode, *Nasitrema* sp.	
WAW-192	7/18/83	Santa Monica, CA	188	F	Three small plastic bags, one plastic drinking straw, one Calif. Dep. Fish Game mackerel fish tag No. M-11283. Tag is 5.1 cm (2 in) long, yellow, spaghetti type. Necropsy diagnosed central nervous system pathology due to parasitism as cause of stranding.	W. Walker unpubl. data. Pathology data from Cowan et. al. 1986.
			Delphinus delphis, common dolphin			
WAW-148	2/12/72	Malibu, CA	173	F	One 15 * 15 cm plastic bag, several kelp fronds (*Macrocystis pyrifera*). Cause of stranding diagnosed as parasitism of central nervous system.	W. Walker unpubl. data. Pathology data from Cowan et al. 1986.
WAW-172	9/8/72	Will Rogers State Beach, Los Angeles County, CA	190	M	Two 20-cm^2 pieces of cellophane; one small piece of black plastic plastic (approximately 3 cm^2), and portions of marine plants (*Macrocystis*, *Egregia*, and	W. Walker unpubl. data. Pathology data from Cowan et al. 1986.

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
					Phyllospadix). Cause of stranding diagnosed as parasitism of central nervous system.	
LACM72286	11/24/80	Hermosa Beach, CA	197	F	One rusted fishhook embedded in stomach wall. Necropsy revealed an apparently unrelated massive tumor or abscess in abdomen adjacent to left kidney.	Los Angeles County Museum of Natural History.[d]
JEH331	4/25/86	Will Rogers State Beach, Los Angeles County, CA	193	F	Stomach contained one partial red balloon (3 × 13 cm), one piece of clear plastic (8 × 13 cm), and kelp fronds (*Macrocystis pyrifera*).	Los Angeles County Museum of Natural History.[d]
		Tursiops truncatus, bottlenose dolphin (All southern California coastal population)				
WFP-559	2/5/77	La Jolla, CA	302	M	One rusted metal bottle cap beach sand, fragments of kelp fronds	W. Walker unpubl. data.
WAW-141	12/26/71	Huntington Beach, CA	207	F	Three approximately 20-cm^2 pieces of heavy clear plastic approximately 3 mil thick; several littorinid snail shells	W. Walker unpubl. data.
WFP-535	8/9/76	La Jolla, CA Diego County, CA	313	M	Two cellophane cigarette wrappers one rusted fishhook, kelp fronds (*Egregia* sp.)	W. Walker unpubl. data.

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
WFP-537	8/31/76	Encinitas, CA	--	F	One blue vinyl plastic strip (3 × 30 cm); kelp frond fragments, one gastropod operculum.	W. Walker unpubl. data.
WFP-565	1/27/77	Del Mar, CA	267	M	One black rubber "bungie cord" with metal hooks at ends (2 × 1 × 40 cm), sand, mollusc shell fragments	W. Walker unpubl. data.
WAW-553	9/2/78	Huntington Beach, CA.	231	F	One partial shoelace, beach sand, mollusc shell fragments	W. Walker unpubl. data.
JRH-057	5/13/80	La Jolla, CA	251	F	Two plastic bags, one 20 × 20 cm, other partial 40 × 15 cm; kelp fronds (*Macrocystis pyrifera*), beach sand, gravel, shell fragments	W. Walker unpubl. data. data.
LJH-006	11/14/81	San Diego, CA	236	F	Metal spring (2.0 × 20 cm)	Southwest Fisheries Science Center.[d]
HJB-036	9/3/86	Solana Beach, CA	U	M	Two fishhooks ca. 2.5 cm (1 in) long	Southwest Fisheries Science Center.[c]
			Grampus griseus, Risso's dolphin			
SEAN7595	5/6/82	Martha's Vineyard, MA	230	M	Plastic bag in throat	New England Aquarium and U.S. National Museum of Natural History.[a]

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
LACM47145	12/8/84	Manhattan Beach, CA	225	--	Blue balloon, partial (20 × 2.5 cm)	Los Angeles County Museum of Natural History.[d]
			Stenella coeruleoalba, striped dolphin			
DAP-001	3/22/83	Cape Point, NC	220	M	Plastic bag in stomach	U.S. National Museum[a] of Natural History, Smithsonian Institution, Wash., D.C.
			Lissodelphis borealis, northern right whale dolphin			
WAW-194	8/2/73	Will Rogers State Beach, Los Angeles County, CA.	211	F	One partial plastic bag in mouth, remainder 25 × 30 cm in forestomach; fronds of marine plants *Macrocystis*, *Cystoseira*, and *Egregia*; one honey bee (hymenoptera); three white bird feathers. Necropsy diagnosed parasitism of central nervous system as cause of stranding *Cystoseira*, and *Egregia*; one honey bee (hymenoptera); three white bird feathers. Necropsy diagnosed parasitism of central nervous system as cause of stranding	W. Walker unpubl. data.

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
WAW-209	10/4/73	Santa Monica, CA	225	F	Several small bits of blue vinyl plastic (ca. 2 cm^2); one rusted metal bottle cap; 10-12 pieces of kelp fronds (*Macrocystis pyrifera*). Cause of stranding undetermined.	W. Walker unpubl. data.
			Phocoena phocoena, harbor porpoise			
USNM504220	3/1/75	Corolla, NC	--	--	Piece of cloth and plastic in stomach	U.S. National Museum.[a]
			Phocoenoides dalli, Dall's porpoise			
LACM54739	7/2/73	Venice Beach, CA	222	M	Stomach jammed with debris as follows: 13 pieces of clear plastic sheets ranging in size from 4 × 9 cm to 35 × 41 cm; 1 piece black plastic 5 × 16 cm; 3 heavy, clear plastic bags 20 × 39 cm; 2 sandwich bags both 14 × 20 cm; 2 plastic bread bags both 23 × 47 cm; 1 plastic drinking straw; 2 pieces of crumpled cardboard approximately 10 × 13 cm; kelp fronds (*Macrocystis pyrifera*). Necropsy not performed due to autolysed condition of tissues. Cause of stranding undetermined.	Los Angeles County Museum of Natural History[d] and Walker unpubl. data.

Table 1.--Continued.

Specimen No.	Date	Location	Length (cm)	Sex	Description	Information source
WAW-197	8/10/73	Santa Barbara Yacht Harbor, CA	190	F	One blue plastic bottle cap; one 20 × 20 cm plastic bag. The remainder of the forestomach is jammed with kelp, *Macrocystis pyrifera*. Necropsy diagnosed parasitic central nervous system disorder as cause of stranding. Animal had been observed in the harbor 3 days prior to stranding.	W. Walker unpubl. data; Cowan et al. 1986.
SBMNH 78-47	11/8/78	Carpenteria State Beach, Santa Barbara County, CA	204	M	Pieces of plastic bags and kelp in stomach	Santa Barbara Museum of Natural History, Santa Barbara, CA.

[a]Charleston Museum of Natural History, Charleston, S.C.
[b]U.S. National Museum of Natural History, Smithsonian Institution Washington, D.C.
[c]Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, Calif.
[d]Los Angeles County Museum of Natural History, Los Angeles, Calif.

In one case (WAW-192), a small spaghetti-type mackerel fish tag was found in the stomach. This item was undoubtedly introduced secondarily through ingested prey (*Scomber japonicus*).

Autopsy data were available in eight (18.6%) of the cases (WAW-130, 174, 192, 148, 172, 194, 197, and LACM 72286). Chronic pre-existing disease was present in all instances. In seven of these cases, brain parasitism by the trematode *Nasitrema* sp. was diagnosed as the primary cause of stranding. All these cases occurred in southern California. In two isolated instances (WAW-130 and 197), the animals were observed for up to 10 days inside a boat marina breakwater prior to stranding.

In the southern California area, brain parasitism due to *Nasitrema* sp. has proven to be a common pathologic factor in individual strandings of small cetaceans (Ridgway 1965; Ridgway and Dailey 1972; Dailey and Walker 1978; Cowan et al. 1986). Cowan et al. (1986) found 91% parasitized brains in 44 brains examined in 4 species of stranded cetaceans. No marine debris-related gastrointestinal pathology was evident in any of the 23 southern California strandings summarized in Table 1.

Naturally occurring disease factors may predispose these animals to ingest abnormal objects. The high incidence of pre-existing brain parasitism and the absence of debris-induced gastrointestinal pathology suggest that the significance of marine debris in stranded cetaceans should remain questionable unless accompanied by related pathologic changes and a complete necropsy and tissue analysis of all major organ systems.

Marine Debris Encountered in Food Habits Analyses of Free-Ranging Animals

Data on 10 species of odontocete cetaceans were available (Table 2). All species combined, a total of 1,790 stomachs had been examined. The geographic regions covered in the sample are diverse. Localities in the North Pacific and Bering Sea represented 81.5% of the sample. The Okhotsk Sea represented 5.9% and the remaining 12.6% were collected off the coast of Uruguay in the South Atlantic. Of the 10 species of cetaceans reported, only the Baird's beaked whale, *Berardius bairdii*, taken at 2 different localities in the coastal waters of Japan had ingested debris. In 86 *B. bairdii* taken off Chiba Prefecture, central Japan, the frequency of debris ingestion was 26.7%. A lower incidence of debris was evident in 20 *Berardius* examined from the southern Okhotsk Sea, where frequency of ingestion was 15.0%. Overall frequency for both areas sampled was 24.5%.

The nature of debris material ingested by *B. bairdii* from both regions was diverse (see Tables 3 and 4 for detailed accounts). Occurrence of plastic bags and sheeting was 30.8%. Other plastic articles including discarded fishing gear had a frequency of 11.5%. All plastic material combined was 42.3%. Miscellaneous nonplastic material such as vegetable refuse, wood boards, concrete fragments, pieces of glass, cigarette filters, cellophane, rubber material, a roof tile fragment, bottle caps, rusty hinge, aluminum can pull tabs, and a metal butane lighter top had an occurrence of 76.0%. Observations made during collection of stomach

content samples revealed no debris-associated lesions or evidence of impaction.

Examination of the data in Tables 3 and 4 reveals that the major portion of debris found in *B. bairdii* stomachs were negatively buoyant items probably ingested at or near the ocean bottom.

Differences in the frequency of debris ingestion between the Pacific coast of central Japan (26.7%) and the southern Okhotsk Sea (15.0%) are probably due to regional differences in feeding strategy. Off the Pacific coast of central Japan, *Berardius* are known to feed primarily on benthic prey. In this region they are documented to be feeding on bottom-dwelling morid and macrourid fishes (81.7%). Cephalopods represented only 18.0% of the consumed prey. In addition, stones and gravel were encountered in all stomachs examined and were undoubtedly consumed incidentally during bottom feeding (Walker and Mead 1988). In the southern Okhotsk Sea, *Berardius* feeding strategy changes considerably. In this region, cephalopod prey are dominant (87.6%) in the food habits sample. The predominantly benthic morid and macrourid fishes represent only 8.2% of the prey. Stones and gravel were encountered in only 10.0% of the stomachs examined (W. A. Walker unpubl. data).

The other nine species of cetaceans summarized in Table 2 are known to feed primarily in the epipelagic and mesopelagic zones in the upper water column. Debris occurrence in all 1,684 stomachs examined was 0. The stomach sample for these nine species is small compared to conservative, stock-level, population estimates. As a result, the absence of marine debris in the species summarized in Table 2 is inconclusive. However, some inference can be made from the Dall's porpoise, *Phocoenoides dalli*, samples from the northern North Pacific and Bering Sea. Both these regions are documented to have a high density of marine debris (Venrick et al. 1973; Feder et al. 1978; Shaw and Mapes 1979; Dahlberg and Day 1985). Eight hundred fifteen *Phocoenoides* stomachs were examined from these regions and no debris items were encountered.

DISCUSSION

Accounts of mortality and pathology caused by foreign body ingestion in captive cetaceans leave little doubt as to the potential effects of marine debris in wild, free-ranging cetaceans.

Most of the available records of debris ingestion are from stranded odontocete cetaceans. However, debris ingestion in singly stranded animals may be, in a large percentage of cases, part of the stranding syndrome. Pre-existing disease factors related to parasitism occurred in almost all cases accompanied by complete necropsy observations.

Debris ingestion data on free-ranging animals derived from previously conducted food habits studies were, with the exception of Baird's beaked whale, negative. Of the 10 species summarized in Table 2, *B. bairdii* is the only species of cetacean known to demonstrate regionally varying degrees of deepwater bottom-feeding strategy. All the remaining nine

Table 2.--Summary of ingested marine debris encountered in food habits analyses of free-ranging small cetaceans.

Species	Date	General location	Collection method	Sample size	Debris occurrence	Information source
Berardius bairdii	1988-89	Taken in the southern Okhotsk Sea off northern Hokkaido, Japan	Shore-based harpoon fishery	20	15.0%	W. Walker unpubl. data. For detailed summary see Table 4.
Berardius bairdii	1985-87	Taken off the Pacific coast of central Japan	Shore-based harpoon fishery	86	26.7%	W. Walker and J. G. Mead unpubl. data. Food habits data in Walker and Mead 1988. For detailed summary see Table 3.
Steno bredanensis	1977-87	Offshore waters of the eastern tropical Pacific	Incidental take in the yellowfin tuna fishery	16	0	W. Walker and J. G. Mead unpubl. data.
Lagenorhynchus obliquidens	1979-72	Collected off the coasts of Washington and California	Collected at sea for research purposes	44	0	C. Fiscus, food habits data presented in Stroud et al. 1981.
Delphinus delphis	1977-80	Offshore waters of the eastern tropical Pacific	Incidental take in the yellowfin tuna pursue seine fishery	32	0	Southwest Fisheries Science Center, La Jolla, CA, unpubl. data.
Tursiops truncatus	1972 87	Offshore waters of the eastern tropical Pacific	Incidental take in the yellowfin tuna purse seine fishery	35	0	W. Walker unpubl. data; food habits data presented (in part) in Walker 1981.
Stenella attenuata	1968-77	Offshore waters of the eastern tropical Pacific	Incidental take in the yellowfin tuna purse seine fishery	231	0	Southwest Fisheries Science Center, La Jolla, CA, food habits data (in part) published in Perrin et al. 1973.

Table 2.--Continued.

Species	Date	General location	Collection method	Sample size	Debris occurrence	Information source
Stenella coeruleoalba	1977-80	Offshore waters of the eastern tropical Pacific	Incidental take in the yellowfin tuna purse seine fishery	104	0	Southwest Fisheries Science Center, La Jolla, CA, unpubl. data.
Stenella longirostris	1968-80	Offshore waters of the eastern tropical Pacific	Incidental take in the yellowfin tuna purse seine fishery	78	0	Southwest Fisheries Science Center, La Jolla, CA, published (in part) in Perrin et al. 1973.
Phocoenoides dalli	1988	Okhotsk Sea, Japan ca. lat. 44#10'N, long. 144#30'E	Shore-based hand-harpoon fishery	86	0	W. Walker unpubl. data.
Phocoenoides dalli	1979-86	Northern North Pacific and Bering Sea	Incidental take of Japanese high seas salmon gillnet fishery	815	0	T. Crawford and L. Tsunoda, Northwest and Alaska Fisheries Center, National Marine Mammal Laboratory, Seattle, Wash. Food habits data presented (in part) in Crawford 1981.
Phocoenoides dalli	1958-72	Collected off the coasts of Washington and California	Collected at sea for research purposes	17	0	C. Fiscus; food habits data in Stroud et al. 1981.
Pontoporia blainvilli	1969-75	Off the coast of Uruguay, South America (ca. lat. 34#30'S)	Incidental take in local shark gillnet fisheries	226	0	R. Brownell, Jr. and W. Walker. Prey species accounts on 11 animals in Fitch and Brownell 1971.

Table 3.--Summary of ingested marine debris in 86 *Berardius bairdii* taken at Wadaura, Chiba Prefecture, Japan, 1985-87.

Specimen No.	Date	Length (m)	Sex	Age (year)	Description of debris
85-008	7/23/85	10.10	M	23	Vegetable refuse--approximately 1 dozen coffee beans.
85-015	7/28/85	9.85	M	73	Three small glass fragments (two clear, one brown) approximately 1.5 × 2 × 0.5 cm, edges worn; two cigarette filters.
85-017	7/29/85	10.05	F	23	One cigarette filter and a piece of tree bark.
85-018	7/30/85	10.43	M	31	One No. 2 size rusted fishhook.
85-021	8/1/86	10.00	M	51	One piece of wadded-up longline approximately 15 cm diameter with 15-20 rusted No. 2 size hooks. The main lines and branch lines are made up of braided No. 7 nylon net twine with hooks set approximately 120 cm apart. Condition of this object suggests recent ingestion of discarded fishing gear.
85-022	8/1/85	9.90	M	21	One piece of black plastic (25 × 15 cm) approximately 1.5 mil thick and vegetable refuse--two corn kernels, *Zea maise*.
85-023	8/2/85	10.70	F	54	One fishhook--only rusted shank and small portion of leader remain.
85-024	8/2/85	9.90	M	84	One piece of black vinyl plastic (130 × 135 × 0.3 cm).
85-026	8/3/85	9.65	M	8	One 45 × 3 cm mahogany stick with staples.
85-033	8/6/85	9.62	M	70	One 20 × 15 cm thin plastic sheet (food wrapper?); cellophane package material (8 × 6 cm). Vegetable refuse--one undigested potato (5 × 6 × 3 cm) two pieces of tree bark (3-4 × 5-6 cm).

Table 3.--Continued.

Specimen No.	Date	Length (m)	Sex	Age (year)	Description of debris
85-031	8/5/85	9.50	M	60	One 8 × 10 × 0.5 cm irregular-shaped piece of clear plastic (PVC?).
86-004	7/27/86	10.75	F	22	One 10 × 15 × 1.0 cm piece of pine board.
86-011	7/29/86	10.40	F	53	One 12 × 2 × 1 cm piece of wood; one 20 × 30 cm black plastic sheet approximately 3 mil thick.
86-012	7/30/86	9.70	M	17	Two fragments of clear plastic 4 × 3 cm and 6 × 2 cm, both approximately 3 mil thick.
86-020	8/7/86	9.10	F	8	One 5 × 6 × 2 cm fragment of blue glazed roofing tile, two cigarette filters.
86-026	8/9/86	10.20	M	26	One 10 × 10 cm piece of concrete; one bottle cap; one 6 × 6 × 2 cm piece of tree bark.
86-028	8/10/86	9.70	M	38	One fragment of 20 × 15 × 0.3 cm rubber mat and 3-4 bird feathers.
87-013	7/29/87	10.32	M	56	Vegetable refuse--25-30 soybeans; one badly rusted metal hinge.
87-014	7/29/87	10.80	F	40	One 3 × 4 × 3 concrete fragment; two pieces of cellophane (both approximately 8 × 15 cm).
87-015	8/1/87	10.60	F	19	Vegetable refuse--10-15 soybeans, 8 corn kernels, *Zea maise*; 1 aluminum pull tab.
87-016	8/1/87	10.20	F	17	One corroded fishhook; one metal portion (top) of a butane cigarette lighter.
87-017	8/2/87	10.35	M	68	Four clear glass fragments 2 to 4 cm^2 and approximately 0.3 cm thick, all worn smooth on edges.

Table 3.--Continued.

Specimen No.	Date	Length (m)	Sex	Age (year)	Description of debris
87-021	8/10/87	10.40	F	51	One piece of wood with nail (not protruding) 17.5 × 4.5 × 7.0 cm (weight 130 g).
87-023	8/13/87	10.30	F	44	One large concrete fragment 9.5 × 6.5 × 3.0, weight 230 g; one piece of 3 mil thick black plastic 18 × 23 cm.
87-024	8/14/87	10.58	M	41	One fragment of brown glass, 4 × 2 × 0.3 cm, edges smooth, one piece of brown plastic sheet 30-35 cm^2.

species summarized are known to feed primarily in the epipelagic and mesopelagic zones.

Experimental evidence suggests that odontocete cetaceans are probably very discriminating feeders. Mistaken ingestion of oceanic debris due to its resemblance to preferred prey species is unlikely because of odontocete cetacean echolocation capabilities. In captive experiments, the bottlenose dolphin, *Tursiops truncatus*, has been shown to be capable of making fine discriminations in size, shape, texture, and composition of objects (Kellogg 1958, 1959a, 1959b; Norris et al. 1961; Evans and Powell 1967; Norris 1969). Kellogg (1959a) demonstrated the use of echolocation by *T. truncatus* to locate preferred food fish but avoid inedible objects. Selection between a water-filled 2-cm gelatin capsule and an equal-sized piece of cut fish has been demonstrated (Norris et al. 1961). Evans and Powell (1967) determined that *T. truncatus* could discriminate between identical-sized sheets of different metals, or even between sheets of the same metal but of different thicknesses. Monofilament about 1 mm in diameter was determined to be at the threshold of detection for a captive harbor porpoise, *Phocoena phocoena* (Busnel et al. 1965).

The two species of free-ranging odontocete cetaceans documented to ingest marine debris are the sperm whale *Physeter macrocephalus*, and the Baird's beaked *B. bairdii*. Both these cetaceans are known to spend some time feeding at or near the bottom, particularly in coastal waters. This is verified by the behavior of preferred prey species and by the common occurrence of stones and gravel in examined stomachs (Betesheva and Akimushkin 1955; Nemoto and Nasu 1963; Tomilin 1967; Berzin 1971; Walker and Mead 1988). Ingestion of debris in these two species of cetaceans is very likely to be incidental, the debris being consumed along with bottom-dwelling prey.

Table 4.--Summary of ingested marine debris in 20 *Berardius bairdii* taken at Abashiri, Hokkaido, Japan, 1988-89.

Specimen No.	Date	Length (m)	Sex	Description of debris
Ab-88-03	8/28/88	10.70	M	One No. 2 size fishhook with short, approximately 15 cm, portion of leader attached.
Ab-88-08	9/7/88	10.10	M	Two No. 2 size fishhooks.
Ab-88-18	9/24/88	10.20	F	One badly rusted, partial No. 2 size fishhook.
89-HK-101	9/1/89	9.40	M	One cotton sleeve from rubber glove, black rubber fragments still attached to anterior edges.
89-HK-102	9/2/89	10.78	F	One No. 2 fishhook and three ca. 30 cm^2 portions of clear plastic sheeting. All appear to be portions of the same material and are ca. 3 cm thick. Vegetable refuse--three pieces of citrus fruit (orange?) peels.
89-HK-104	9/9/88	10.20	M	One ca. 10-cm diameter wad of thin, clear plastic sheeting ca. 1.5 mil thick.

Records presented in this report of marine debris ingested by *Berardius* off central Japan all came from off the Boso Peninsula, Chiba Prefecture, an area extending from the northern edge of the entrance to Tokyo Bay north to Choshi off the Pacific coast of Japan (lat. 34°39'-35°57'N). The animals were taken primarily along the 1,000-m depth contour line. Due to the proximity to Tokyo Bay and Choshi (a major fishing port), the entire area is subject to extremely heavy merchant and commercial fishing vessel traffic. The *Berardius* stomach samples from off northern Hokkaido were from two general areas in the southern Okhotsk Sea: 1) The immediate vicinity of the major commercial fishing port of Abashiri (ca. lat. 44°30'N, long. 144°30'E) and 2) Nemuro Strait between the Shiretoko Peninsula (Japan) and Kunashir Island (U.S.S.R.) (ca. lat. 44°15'N, long. 145°30'E). Both these areas are also subject to heavy commercial fishing activity.

Debris encountered in *Berardius* stomachs from both the Pacific coast of Japan and the southern Okhotsk Sea consisted almost exclusively of negatively bouyant material. The varied nature of the debris (e.g., broken glass, vegetable refuse, aluminum pull tabs, bottle caps) and the deep

offshore location strongly suggest shipboard refuse as the primary source of the ingested debris.

It should be noted that the absence of debris-related pathology in the Baird's beaked whale sample does not rule out the occurrence of debris-related mortality in the study areas. To the contrary, the high incidence of ingested debris, the varied nature of the debris material, and records of debris-related mortality in captive cetaceans permit some speculation on the potential for incidental debris ingestion as a mortality factor in this species. *Berardius* is a large animal (up to 12.8 m in length). Death or debilitation through gastrointestinal impaction would probably require a relatively large volume of indigestible material. However, some of the debris material summarized in Tables 3 and 4 has considerable pathologic potential. Ingestion of relatively small items such as sharp metallic objects or freshly broken glass poses a real identifiable hazard and is a well-documented factor in human as well as veterinary disease. Complications through mechanical trauma to the gastrointestinal tract by such objects range from laceration and hemorrhage to perforation of the gut wall and acute bacterial peritonitis. These conditions are eminently life threatening. In the wild state, the elapsed time from onset to death would probably be short and accompanied by marked behavioral alterations. As a result, the probability of encountering these acute states in the fisheries sample would be very low. In the commercial fisheries sample we should expect only chronic, prolonged disease conditions to be manifest. Some bias toward the taking of chronically ill whales in commercial harpoon fisheries is suspected. Walker (1988) suggested, on the basis of a parasite survey, that the prolonged chase procedure in the Japanese *Berardius* fishery may involve selection toward the taking of some physically infirm individuals.

Wallace (1985) raised the question of whether sinking truly constituted debris removal. Results of this study indicate that negatively buoyant debris are not neutral, but still may pose a potential hazard to large predators feeding on benthic prey.

RECOMMENDATIONS

The worldwide trend toward curtailment of the commercial take of marine mammals restricts opportunities for future food habits sampling. In the future, food habits studies are likely to become more reliant on samples obtained from incidental fisheries' interactions and strandings. The following recommendations should be incorporated into future research:

- Develop and incorporate a consistent format for recording the presence as well as the absence of marine debris in stomach content analyses conducted on both free-ranging and stranded marine mammals. The recording of negative findings should also be emphasized, as they are crucial in establishing reliable information on the frequency of debris occurrence in future studies.

- Whenever possible, occurrence of ingested debris should be

of the debris should also be kept (e.g., size, shape, consistency). In the case of stranded animals, the necropsy should include examination and evaluation of all major organ systems. Data presented in this report suggest that ingestion of debris may be secondary to other naturally occurring disease factors.

- The filter-feeding strategy of the baleen whales, Mysticeti, may make them particularly vulnerable to incidental debris ingestion in both the benthic zone and zones of the upper water column. Researchers should be encouraged to take advantage of the few remaining commercial fisheries to record evidence of ingested debris. The stomachs and oral cavities of stranded baleen whales should be examined whenever possible. Individuals involved in past food habit studies of baleen whale species should be interviewed.

- Research on marine mammal food habits as well as debris ingestion should continue in order to establish preferred prey species and feeding behavior, and increase the data base on debris ingestion.

- The data presented in this report are limited to gross observations on the acute effects of ingested debris (e.g., gastrointestinal impaction, ulceration). Research into the potentially insidious effects of absorption of hydrocarbon contaminants such as plasticizers should be conducted.

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