980s ENTANGLEMENTS
AND PLASTICS G.H. BALAZS

University of Hawaii
Sea Grant College
Program

Makai

"Toward the Sea"

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November
1986

PLASTIC POLLUTION A PERSISTENT PROBLEM

by Daniel Bauer

A young, emaciated hawksbill turtle was found stranded on a remote western Hawaiian island beach. It was unable to dive. The cause became apparent 2 days later when the 11-pound turtle died and an autopsy was performed.

Completely blocking its intestinal tract was a mass of plastic and styrofoam chips, monofilament line, and shreds of plastic bags — well over one pound of it — compacted in fecal matter. The bouyancy of the material had the same effect as a life preserver. Unfortunately for the turtle, this meant it could not reach the sea floor to sleep.

For George Balazs, sea turtle biologist with the National Marine Fisheries Service who performed the autopsy, this is becoming a disturbingly frequent problem. Numerous sea turtles have been found with plastic bags hanging from their mouths, lining or totally blocking their intestinal tracts, and extending from their excretory orifices. Balazs is currently compiling data about the effect of marine debris on sea turtles.

A large source of the plastic debris problem is the incredibly large amount of packing material and fishing gear dumped or lost by commercial fisheries and sailing vessels. A recent report by the U.S. Academy of Sciences estimated that up to 50 million pounds are dumped and 300 million pounds are lost each year. Much of it is plastic or plastic-related material, which does not break down like hemp netting or cardboard packaging, materials commonly used before the boom in plastics use following World War II.

Instead, plastic remains remarkably durable, a fact that can have deadly consequences for sea life. Monofilament netting, for example, goes on "ghost-netting" fish for years after it is lost by fishermen. Sea birds, attracted to the netted fish, and sea turtles, which are possibly attracted to marine life encrusted on the netting, become further victims of the ghost nets as they remain awash or snagged on rocks or coral reefs. One case was even reported of a sea turtle found trapped inside a plastic bag floating in the water near French Frigate Shoals. Doomed to drown in such a predicament, it was fortunately rescued by a sympathetic scientist from a passing research vessel.

In the open seas, plastic debris, largely in the form of plastic bags and styrofoam pellets, is blown by prevailing winds into long rows called drift lines, which become virtual highways of concentrated

(Continued on page 2)

Balloon releases, such as this one at the January 1986 Hula Bowl in Honolulu, contribute to the littering of Hawaii's land and ocean environments.

—*Honolulu Advertiser* photo by Carl Viti

Plastic Pollution a Persistent Problem

(Continued from page 1)

floating waste. These persistent, buoyant masses become a target for sea animals who are attracted to the naturally occurring organic material present there. According to Balazs, the plastic itself often has some marine growth on it, possibly making it appear to be food and increasing the likelihood of its being eaten by sea turtles. It is unknown what chemicals or polymers may be released by the plastic as an animal attempts to digest it, or what their effect may be on the animal's health.

Floating, undulating plastic bags may appear to sea turtles as jellyfish, one of their favorite foods. Balazs held up one of those popular round silvery balloons that was found awash in the sea. Its mirror-like aluminum coating had long since oxidized in the salt water, but the extremely durable mylar body itself showed little sign of deterioration. With its curly, 4-foot plastic string trailing beneath it, the opaque balloon looked eerily like a huge jellyfish.

What begins as a visual feast for human eyes — those massive releases of thousands of multi-colored balloons at sporting events and other celebrations — can end as a lethal feast for fish and sea mammals when the balloons return to earth, particularly when the releases take place near coastal areas, such as last January's Hula Bowl halftime release of 20,000 balloons at Aloha Stadium near Honolulu. Another 10,000 balloons were released at the city's waterfront Ala Moana Park on November 16 as part of a nationwide charity fundraiser.

These figures themselves pale in comparison to some recent record-breaking balloon releases undertaken in other coastal areas: 1,121,448 balloons at Disneyland in Anaheim, California (that's 8,000 pounds of latex); 384,000 in Japan to promote instant noodles; 1.5 million in downtown Cleveland (where thousands of them were blown into Lake Erie); 300,000 balloons carrying peace messages released by girls throughout the world;

What begins as a visual feast for human eyes . . . can end as a lethal feast for fish and sea mammals

and 150,000 released by students throughout the United States, including Hawaii, as part of a meteorological survey for National Science Week. Indeed, among the plastic debris George Balazs found compacted in the intestines of that young, doomed hawksbill turtle unable to dive was the neck of a latex balloon.

Controlling the dumping of oceanic plastic debris remains a huge task. New uses are continually being found for ever-more-durable plastics, and the plastics industry remains in a high growth stage. Some laws and international treaties exist which control oceanic dumping of waste, but interpretation of jurisdiction remains vague, and enforcement is hard to maintain. An amendment to the Marine Pollution Convention of 1973 called Annex V, would regulate oceanic dumping of persistent plastics. However, it is just short of the necessary votes for ratification, and the United States has not yet approved it.

Mounting concern over the environmental effect of plastic debris has prompted Senator John Chafee (R-R.I.) to introduce the Plastic Waste Reduction Act of 1986 (#S-2596), which would have a two-fold purpose. First, it would require that all beverage-connecting devices (such as six-pack holders, which commonly lead to entanglement and subsequent strangulation of a wide variety of birds) be biodegradable. Ten states have already passed similar legislation. Secondly, the Enviromental Protection Agency (EPA) would be required to conduct a study on plastic pollution of the environment, including its effects on fish and wildlife. EPA would then report back to the Senate Subcommittee on Environmental Pollution, which is chaired by Chafee. The bill has been referred to this subcommittee, where it is currently awaiting action. Interested persons are encouraged to contact the committee by writing to Senator Chafee at Dirksen Senate Office Building, Washington, D.C. 20510.

According to the plastics industry, some plastic milk and soft-drink bottles are being recycled into insulation and construction materials, and further recycling efforts are underway. The plastics industry can be contacted by writing The Bottle Information Bureau, The Society of Plastics Industry, Inc., 355 Lexington Ave., New York, NY 10017.

Beach cleanup efforts have been organized in several coastal states. A recent cleanup effort at Hanauma Bay, a popular snorkeling site near Honolulu, resulted in more than 50 large trash bags being filled in 3 hours of work, according to Rich Neumann, president of the University (of Hawaii) Aquanauts Dive Club that participated in the cleanup. Most of the garbage picked up was plastic or styrofoam material. Another cleanup effort at Hilo Bay on the island of Hawaii yielded 100 bags of garbage.

Any information, old or new, about sea turtles eating or becoming entangled in marine debris is being sought by George Balazs. He can be contacted at Southwest Fisheries Center, Honolulu Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 3830, Honolulu, HI 96812. ☐

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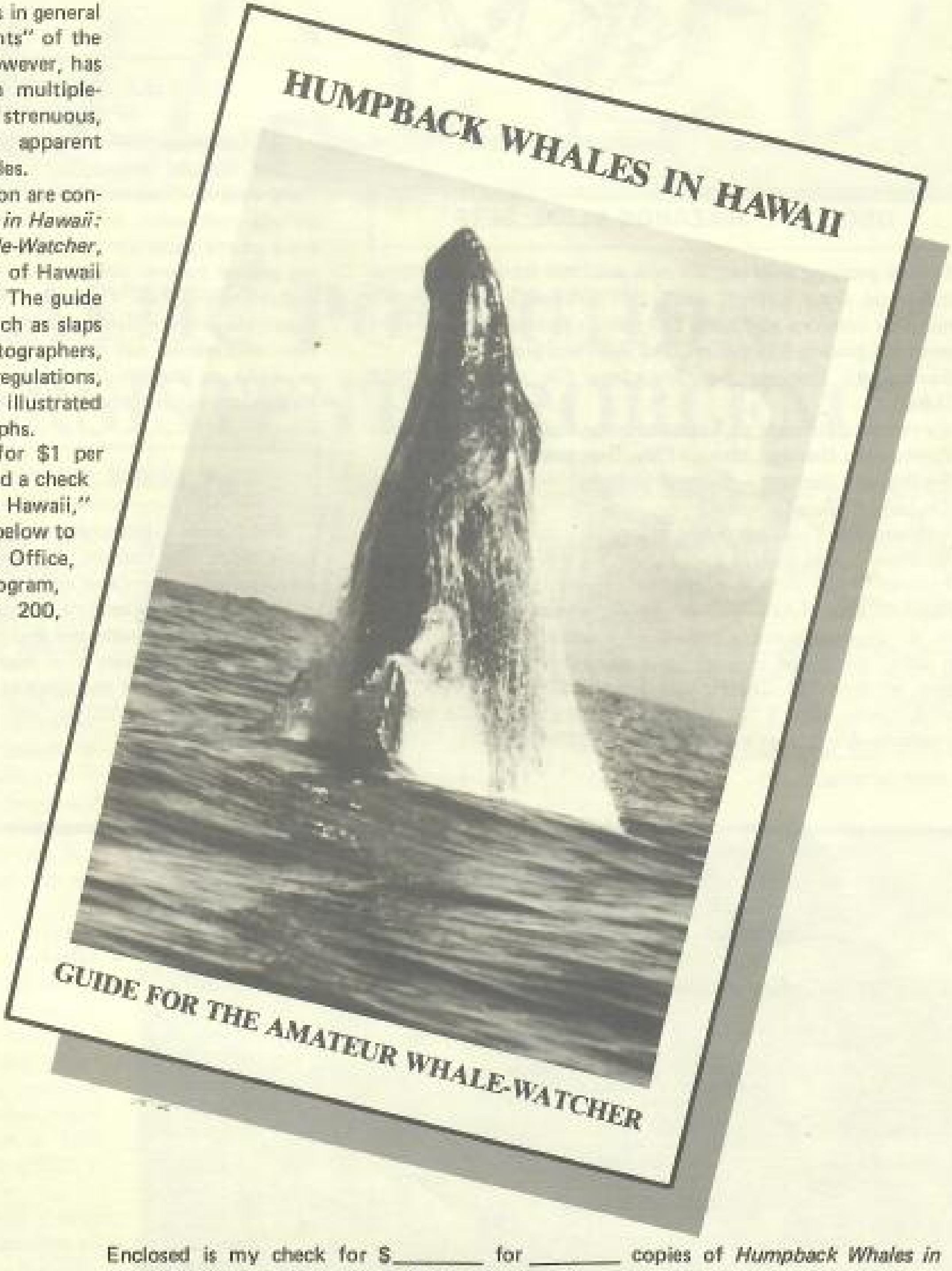
Whale-Watching Guide Available

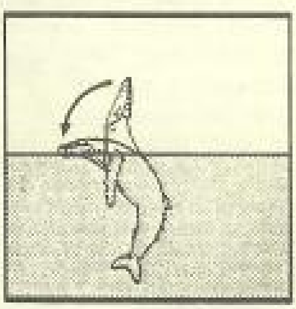
The conception of whales in general has been as the "gentle giants" of the ocean. Recent evidence, however, has shown male humpbacks in multiple-escort pods to engage in strenuous, even violent, combat in apparent contests over access to females.

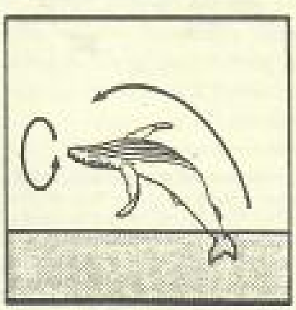
This and more information are contained in *Humpback Whales in Hawaii: Guide for the Amateur Whale-Watcher*, published by the University of Hawaii Sea Grant College Program. The guide explains whale behaviors such as slaps and leaps, offer tips for photographers, describes anti-harassment regulations, and more. The text is amply illustrated with drawings and photographs.

The guide is available for $1 per copy. To obtain a copy send a check payable to "University of Hawaii," along with the order form below to Whale Guide, Publications Office, UH Sea Grant College Program, 1000 Pope Road, Room 200, Honolulu, HI 96822.



LEAPS





Enclosed is my check for $_______ for _______ copies of *Humpback Whales in Hawaii: Guide for the Amateur Whale Watcher*. Please send to:

Name ____

Mailing Address ____________________________________

____________________________________ Zip __________

MARINE MISCELLANY

GEOLOGIC HAZARDS SLIDE SETS

Several geologic slide sets are now available from the National Geophysical Data Center. Each set contains twenty 35-mm slides with captions and costs $31. When two or more sets are ordered the price is $25 per set. The slide sets are:

- Earthquake Damage, San Francisco, CA, April 18, 1906 (b&w)
- Earthquake Damage to Transportation Systems (b&w, color)
- Earthquake Damage, Mexico City, September 1985 (color)
- Earthquake Damage — General (color)
- Tsunami — General (color)
- Volcanoes in Eruption (b&w, color)
- Volcanic Rocks (color)

Payment may be by check or money order payable to COMMERCE/NOAA/NGDC or by American Express, Master Card, or Visa credit cards; include card account number, expiration date, telephone number, and signature with order. Send orders to National Geophysical Data Center, NOAA, Code E/GC4, Department F10, 325 Broadway, Boulder, CO 80303. For telephone inquiries and orders, call (303)497-6541.

WAIKIKI AQUARIUM ANNOUNCES SPRING PROGRAMS

The Waikiki Aquarium has announced its programs for "A Spring of Discovery" and Pacific travel. Scheduled activities include reef walks, courses on marine mammals, and explorations of the aquarium after dark. The aquarium is also sponsoring several natural history tours in 1987, including snorkeling and diving on Maui, Palau, and Fiji and sea kayaking in British Columbia and the Galapagos Islands. For brochures and registration information call the Waikiki Aquarium at (808) 923-9741 or write to Waikiki Aquarium Education Department, 2777 Kalakaua Ave., Honolulu, HI 96815.

NEW GUIDE TO PERMITS AVAILABLE

The Hawaii Department of Planning and Economic Development has a free booklet, *An Applicant Guide to State Permits and Approvals for Land and Water Use and Development*, prepared by the department's Coastal Zone Management Program. The guide is for developers and others unfamiliar with required permits and approvals that apply to their proposed land and water use. Copies of the booklet are available from the department's Information Office, 250 South King Street, 7th Floor, Honolulu, HI 96813.

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The National Sea Grant College Program is a network of institutions working together to promote the wise use, development, and conservation of the nation's coastal, marine, and Great Lakes resources. Provisions of the National Sea Grant College and Program Act of 1966 called for the creation of Sea Grant Colleges, and in October 1972, the University of Hawaii was designated one of the first five Sea Grant Colleges in the nation. Locally, Sea Grant is a unique partnership of university, government, and industry focusing on marine research, education, and advisory/extension service.

GB FYI

MAR. 1 1985 F/M412:CK

3/14 WGG GWI HM

TO: DA - Anthony J. Calio

FROM: F - William G. Gordon William G. Gordon

SUBJECT: Entanglement Issue -- INFORMATION MEMORANDUM

This memorandum provides additional information on the entanglement issue discussed at the Monthly Program Review on February 7, 1985. The Fisheries Service and several other Federal agencies cosponsored an international workshop in Honolulu, Hawaii last November to consolidate information concerning entanglement and to determine scientific and management actions that are needed to reduce the impacts to living marine resources from marine debris. The Workshop Steering Committee has indicated that an executive summary of the workshop will be available in early March 1985 and the full proceedings in July 1985. We will provide you with copies of those documents when they are available.

There is general agreement that entanglement in and ingestion of marine debris can have adverse impacts to marine animals. Workshop participants acknowledged that, although many animals die as a direct or indirect result of entanglement, the extent of these impacts has not been determined. Despite this lack of knowledge, the workshop participants indicated that several actions can be taken to reduce the amount of debris being introduced into the marine environment.

The Fisheries Service has been working with many domestic and foreign organizations to implement some of the actions recommended by the workshop participants. We also have been asked by the Congress to develop a comprehensive plan to address the effects of discarded netting and other debris on marine animals. This plan is being developed in consultation with the Marine Mammal Commission and with many constituent groups. Among the actions identified in the draft plan is to use national and international organizations, laws and treaties to convey information on the effects of debris on marine resources and recommend actions to reduce or eliminate these effects. Therefore, I believe that it is appropriate for the U.S. to bring the issue of entanglement to the attention of the parties to the London Dumping Convention. The Fisheries Service will work with NOAA's Office of Policy and Planning to develop a strategy on how the entanglement issue can be raised at the next conference (October 1985) of the Convention.

CLEARANCES: SIGNATURE AND DATE

ES:RWhite
PP:TMaginnis
GC:RMcManus
AA:JWinchester

DRAFTED BY. Charles Karnella, NMFS, F/M4, 634-7471,2/27/85:gp

cc: F(2), F/M, ES, PP, GCF, F/S, F/S1, F/SWC, F/SWC1

F/GCF

 (E-Cm-84)

Recall for value Buoy entanglement $25 Money sent 10/16

244-4286
JACOB MAU
DOCARE
Box 1006 WAILUKU, MAUI - 96793

10-15-84 Monday Call from Fred Ball - Maui last week off Pier 1 facility (near Electric Plant) a turtle was reported with flipper caught in sole buoy line coming from abandoned gill net. Turtle est. 100lb+. DOCARE motored out there and tried to cut it loose. Line broke and turtle swam off pulling buoy. When net pulled up, it was full of coral - suggesting prostrate on bottom. Snarled-up too.

Keith KEAU

Hawaiian AIR-CARGO 836-7271

"short tail" green turtle "short tail" "TL~30" not measured"

Call from Don Heacock. 2½"x2½"

10/11 Stranded large turtle at Waimea - TMR on left eye. Kiwa member DONNA Lee & reported it. Crawled back into sea and swam off before he arrived. NO tags seen.

10/15 Call from Woodside - ~ Oct 1st he saw hatchling tracks. Dug but couldn't find nest.

10/15 TO LAYSAN/JA
6926 - 6950
+ "PH" applicators (cord on handle)

6860 - 6875 (16) w/o pliers
leave at Farm

Ecological Significance of a Drifting Object to Pelagic Fishes

REGINALD M. GOODING and JOHN J. MAGNUSON[1]

PELAGIC FISHES frequently gather around drifting material in the open sea. Commercial and sport fishermen regard the immediate vicinity of drifting material as a potentially good area for trolling. Commercial seine and pole-and-line fishermen in Japan, Indonesia, and Malta anchor floating material to attract fish. Fish have been reported gathered around floating algae, coconuts, and pumice (Besednov, 1960; Senta, 1965); floating logs (Inoue, Amano, and Iwasaki, 1963; Kimura, 1954; Yabe and Mori, 1950); coconut fronds and slabs of cork (Hardenberg, 1949; Soemarto, 1960; Galea, 1961); and rafts (Kojima, 1960; Heyerdahl, 1950; Evans, 1955). In addition to clustering near these inanimate objects, the young of many pelagic fishes gather beneath jellyfish (Mansueti, 1963); fish-jellyfish associations have much in common with the associations studied in the present paper.

Hypotheses suggested to explain the accumulation of fish around inanimate floating objects include: (1) fish seek shelter from predators (Soemarto, 1960; Suyehiro, 1952); (2) larger fish prey on the concentration of smaller fish (Kojima, 1956); (3) fish feed on algae or decaying coconut fronds (Reuter, 1938; Soemarto, 1960); (4) fish seek the shade under the object (Suyehiro, 1952); (5) fish use floating objects as a substrate on which to lay their eggs (Besednov, 1960); (6) the shadow of the object makes zooplankton more visible to the fish (Damant, 1921). At the beginning of the present study we suggested still another hypothesis: floating objects are cleaning stations, where pelagic fishes have their parasites removed by other fish. Such symbiotic cleaning associations are well documented for fishes in inshore waters (Eibl-Eibesfeldt, 1955; Limbaugh, 1955, 1961; Randall, 1958).

To test these hypotheses, studies were made from a raft with an observation chamber (Fig. 1) built at the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, and set adrift in the central Pacific (Gooding, 1965). The present paper describes and interprets the observations in light of the above hypotheses.

[1] Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii. Manuscript received August 19, 1966.

AREAS AND METHODS OF OBSERVATION

Observations were made in two areas, one off the leeward coast of the island of Hawaii and the other near the Equator in the central Pacific (Fig. 2).

Observations were made in Hawaii between September 28 and October 11, 1962, and between August 1 and August 26, 1965. This area offers two advantages: first, it is sheltered from the northeast trade winds and the sea is relatively calm; second, essentially pelagic conditions (water deeper than 800 m) occur within 1 mile of shore. During 345 hours of drift, 173 hours of daylight observations and 9 hours of night observations were recorded. Eleven drifts were made, the longest of which was 52 hours.

Two drifts were made between February 14 and March 20, 1964 in the storm-free belt at the convergence of the northeast and southeast trade winds near the Equator. On the first drift the raft was launched 9 nautical miles north of the Equator in an area of upwelling. During 194 hours of drift, 91 hours of daylight observations were made. The second equatorial drift began 153 nautical miles south of the Equator. During 215 hours of drift, 100 hours of daylight observations were made.

The raft drifted 585 nautical miles west during the first equatorial drift and 395 nautical miles west during the second. Most of the drift was due to surface currents. To reduce wind-induced drift a 28-foot parachute was used as a sea anchor during part of the first drift and all of the second. (It was also used during several of the Hawaiian drifts.)

While the raft was adrift, wave heights ranged from 0 to 1 m at Hawaii and from 1 to

FIG. 1. The observation raft used in study.

2 m at the Equator. Average wind speeds ranged from 10 to 15 knots. Cloud cover seldom exceeded 30%.

The observation chamber beneath the raft (Fig. 3) accommodated a single observer, who could view the area beneath and around the raft. Two observers manned the drifting raft from dawn to dusk. Watch positions in the chamber were rotated each hour. Nights were spent on the ship, which remained 1–3 miles from the raft. A skiff provided transportation between ship and raft.

The observers noted the number of each kind of fish at the raft, their position under or near the raft, and their reaction to the raft and to other fish or invertebrates. Night observations were made under bright moonlight, but a flashlight was used at intervals to determine more accurately the positions of the fish. The accumulation was quantified by making population counts of the species present at intervals during the day. An estimate of population changes during the night was obtained by comparing the last count in the evening with the first count on the following morning.

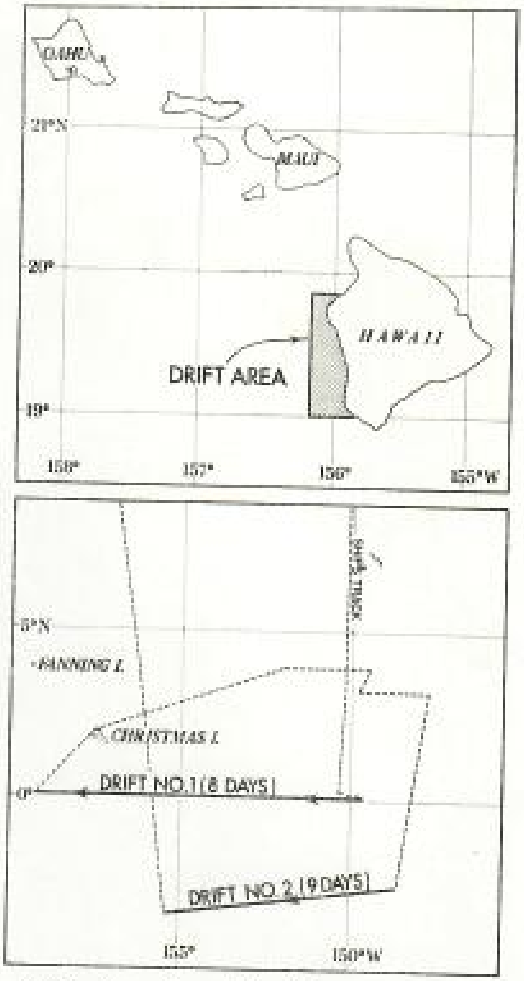

FIG. 2. Areas in which drifts were made with the observation raft, off Hawaii (*upper panel*) and near the Equator (*lower panel*).

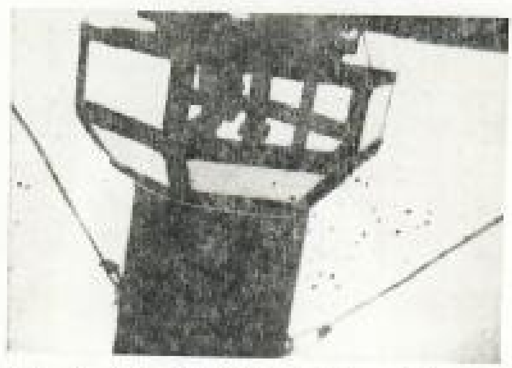

FIG. 3. The observation chamber of the raft. Dark specks to right of chamber are small fish. The white object behind the chamber is the parachute drogue.

In addition to direct observations, 6,200 ft of 16-mm color movies, and numerous still pictures were taken.

Fish were captured at the raft with dip nets, baited hooks on hand lines, casting and trolling lures, and a small purse seine net attached to the sides of the raft. To avoid interference with the accumulation of animals, collections were made only at the end of the drifts. Stomach contents and external parasites of fish captured at the raft were preserved.

FISHES AT THE RAFT

Animals seen from the observation chamber (some are shown, as photographed from the chamber, in Figures 4*a*–*f*) were broadly

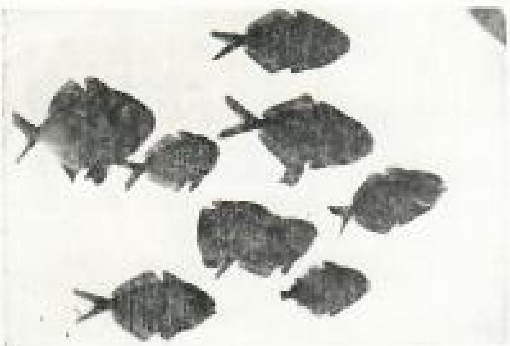

FIG. 4*a*. Freckled driftfish.

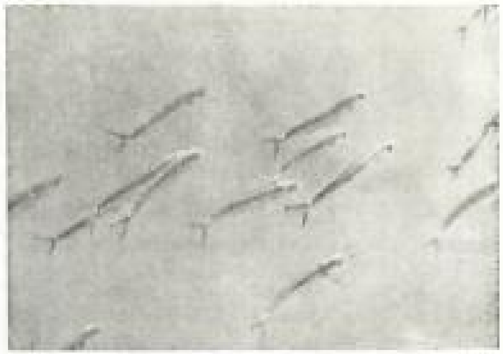

FIG. 4*d*. Juvenile dolphin.

FIG. 4*b*. Adult dolphin.

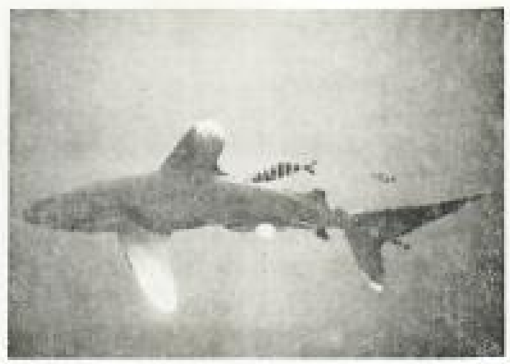

FIG. 4*e*. Whitetip shark accompanied by pilotfish and remora.

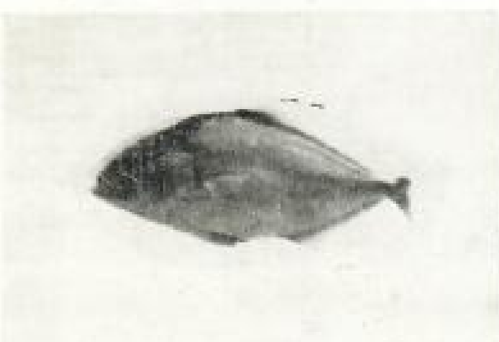

FIG. 4*c*. Amberjack.

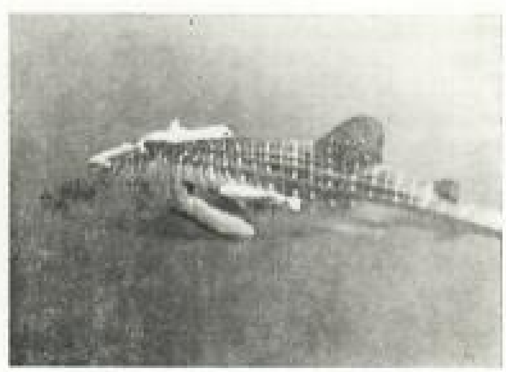

FIG. 4*f*. Whale shark accompanied by remora.

grouped as transients, visitors, or residents (Table 1) on the basis of their reaction to the raft and the length of time they remained near it. Transients (many of which were flyingfish, Exocoetidae) did not appear to react to the raft, but were usually visible only momentarily as they swam by. Visitors did not aggregate at the raft, but appeared to react to it; they usually remained near it for several minutes to an hour. Residents aggregated at the raft; some stayed in view more or less permanently, and others swam out of view for several hours but usually returned. Different individuals of certain species did not always react in the same way to the raft; these species were consequently placed in more than one category.

Residents were of two types: smaller fishes which stayed in the immediate vicinity of the raft and were usually in view of the observer; and large carnivores that were frequently out of view for several hours. When reappearing after a prolonged absence, the individual or group could often be identified by distinguishing characteristics such as abrasions, parasites, scars, the number in the group, and body size. The relation of all resident species to the raft was facultative, since each also occurs independently of any association with drifting objects.

Small resident fishes were: freckled driftfish, *Psenes cyanophrys* (Cuvier); juvenile pilotfish, *Naucrates ductor* (Linnaeus); rough triggerfish, *Canthidermis maculatus* (Bloch); scrawled filefish, *Alutera scripta* (Osbeck) (but only individuals exceeding about 20 cm, smaller ones behaving as visitors); amberjack, *Seriola rivoliana* Cuvier and Valenciennes; juvenile greater amberjack, *Seriola dumerili* (Risso); juvenile jack, *Caranx* sp.; adult and juvenile mackerel scad, *Decapterus pinnulatus* (Eydoux and Souleyet); juvenile skipjack tuna, *Katsuwonus pelamis* (Linnaeus); juvenile yellowfin tuna, *Thunnus albacares* (Bonnaterre); juvenile dolphin, *Coryphaena* sp.; and juvenile stages of four reef fishes—damselfish, *Abudefduf abdominalis* (Quoy and Gaimard); sea chub, *Kyphosus cinerasceus* (Forskål); goatfish, *Mulloidichthys samoensis* Gunther; and squirrelfish, Holocentridae.

The large predatory residents were: dolphin, *Coryphaena hippurus* Linnaeus; wahoo, *Acanthocybium solandri* (Cuvier); rainbow runner, *Elagatis bipinnulatus* (Quoy and Gaimard) and whitetip shark, *Carcharhinus longimanus*, usually accompanied by adult pilotfish and remoras, *Remora remora* (Linnaeus).

The freckled driftfish was by far the most common resident in both drift areas. On all drifts it was the first to appear, had the highest rate of accumulation (Table 2), and attained the largest population. At the end of the second equatorial drift, 729 were caught in the purse seine and several hundred escaped. Many were also caught at the end of other drifts. Freckled driftfish usually came to the raft singly or in small groups. Once a green turtle, *Chelonia mydas*, came to the raft accompanied by nine driftfish and one remora. The turtle left with the remora after a few minutes, but the driftfish remained with the raft.

Residents accumulated more rapidly by day than by night. Statistics on the average rate of accumulation of some of the more common residents appear in Table 2. Less common residents, not listed in Table 2, also accumulated more rapidly by day than by night.

Species composition differed between the Hawaiian and equatorial areas. Only 38% of the 27 fish identified to species in Table 1 were seen in both areas. Three of the more common species off Hawaii, the rough triggerfish, dolphin, and damselfish, were either absent or rare in the equatorial waters. Of species that were residents at some stage in their life history, 62% were common to both areas, whereas none listed only as a visitor was common to both areas. Some of the apparent differences between the areas could have resulted from differences in the time of year or could even be attributable to the sample sizes. For example, the occurrence of rainbow runners, pompano dolphin (*Coryphaena equiselis* Linnaeus), and green turtles in the equatorial but not the Hawaiian area may well be irrelevant, for all are common in Hawaiian waters.

ADAPTIVE SIGNIFICANCE

Our observations provided relevant information on the hypotheses that floating material (1) provides protection from predators, (2) concentrates the food supply, and (3) acts as a cleaning station. These hypotheses, of course,

TABLE 1

ANIMALS SEEN FROM THE OBSERVATION CHAMBER OF A DRIFTING RAFT*

SPECIES, GENUS, OR FAMILY (Common Name in Parentheses)	DRIFT LOCATION	BEHAVIOR CATEGORY	FORK LENGTH (cm)	MAXIMUM NUMBER SEEN AT ONE TIME
Abudefduf abdominalis (damselfish)	H	R	0.7–1.0†	24
Acanthocybium solandri (wahoo)	H03	R	45–90	3
Alutera scripta (scrawled filefish)	H	RV	10–35	2
Canthidermis maculatus (rough triggerfish)	H	R	25–35†	33
Caranx kalla (golden jack)	H	V	30	1
Caranx sp. (jack)	H	R	2.9–5.5†	3
Carcharhinus longimanus (whitetip shark)	H03	RV	125–175	2
Chelonia mydas (green turtle)	0	V	60	1
Coryphaena equiselis (pompano dolphin)	03	V	30	100+
Coryphaena hippurus (dolphin)	H03	R	60–100†	70+
Coryphaena sp.	H03	R	10–15	80
Decapterus pinnulatus adult (mackerel scad)	H03	RT	20–25	1,000+
juvenile	3	R	13.1†	1
Diodontidae (spiny puffer)	0	V	12	1
Echeneidae (free-swimming) (remora)	3	R	8	1
Elagatis bipinnulatus (rainbow runner)	3	R	75	1
Exocoetidae (flyingfish)	H03	T	10–15	10+
Fistularia petimba (cornetfish)	H	V	20–40	2
Globicephala scammoni (pilot whale)	H0	V	375	2
Holocentridae (squirrelfish)	H	R	2	1
Istiophoridae (marlin)	H	T	125	1
Katsuwonus pelamis adult (skipjack tuna)	H3	T	45	1,000+
juvenile	3	RV	10–15	50
Kyphosus cinerascens (sea chub)	H	R	2.5†	13
Manta alfredi (manta ray)	H	V	100–125†	1
Manta sp.	0	V		1

TABLE 1 (*continued*)

SPECIES, GENUS, OR FAMILY (Common Name in Parentheses)	DRIFT LOCATION	BEHAVIOR CATEGORY	FORK LENGTH (cm)	MAXIMUM NUMBER SEEN AT ONE TIME
Mulloidichthys samoensis (goatfish)	H	RV	10–12	1,000+
Naucrates ductor adult (pilotfish)	H03	RV	15–30	7
juvenile	H03	R	2.6–6.7†	7
Nomeus gronowi (man-of-war fish)	0	V	2	1
Prionace glauca (great blue shark)	0	V	150	1
Psenes cyanophrys (freckled driftfish)	H03	R	1.5–12.4†	1,000+
Remora remora (attached) (remora)	H03	RV	15–30	—
Rhincodon typus (whale shark)	3	V	300	1
Seriola rivoliana§ (amberjack)	H	R	20†	1
Seriola dumerili (greater amberjack)	H	R	3.7	1
Sphyraena barracuda (great barracuda)	H	V	50	1
Thunnus albacares (yellowfin tuna)	H3	RV	25–40	37
Tursiops sp. (bottlenose dolphin)	H0	V	150–200	20+

* Drift Location: H = Hawaii; 0 = 0° Latitude; 3 = 3° S.
Behavior Category: R = Resident; V = Visitor; T = Transient.
† Measured length; all other lengths are estimated.
‡ Breadth.
§ The first record for Hawaiian waters, identified by Dr. Frank J. Mather, Woods Hole Oceanographic Institution, from a specimen preserved after capture at the raft.

TABLE 2

AVERAGE NET INCREASE OR DECREASE IN NUMBER OF RESIDENTS* AT THE RAFT PER 12-HOUR DAY AND 12-HOUR NIGHT† IN THREE DRIFT AREAS
(Number of 12-Hour Periods in Parentheses)

FISH	HAWAII OCTOBER 1962 Day (9)	HAWAII OCTOBER 1962 Night (7)	HAWAII AUGUST 1963 Day (8.5)	HAWAII AUGUST 1963 Night (4)	0° LATITUDE FEBRUARY 1964 Day (7.5)	0° LATITUDE FEBRUARY 1964 Night (9)	3° S MARCH 1964 Day (8.5)	3° S MARCH 1964 Night (9.0)
Psenes cyanophrys‡	24	1	107	1	18	1	100	0
Coryphaena sp. (juvenile)	–	–	–	–	11	–2	1	–1
Canthidermis maculatus	7	2	3	1	–	–	–	–
Coryphaena hippurus (adult)	4	1	10	0	–	–	–	–
Abudefduf abdominalis (juvenile)	4	–1	–	–	–	–	–	–
Decapterus pinnulatus (adult)	–	–	10	–5	2	0	3	–3
Katsuwonus pelamis (juvenile)	–	–	–	–	–	–	3	–3
Naucrates ductor (juvenile)	–	–	–	–	1	–1	–	–

* Only the residents with an average accumulation equal to or greater than one fish per 12 hours of daylight are included.
† Population changes during the night were estimated by comparing the last count in the evening with the first count the following morning.
‡ Increases are based on the rate for the first 100 to gather because larger numbers could not be counted accurately.

are not mutually exclusive. The observations provided less information about the other hypotheses mentioned earlier. All the above hypotheses consider the adaptive significance of floating material in the ecology of pelagic fishes. The stimuli that release the approach of fishes to the raft are not discussed.

Protection from Predation

At least nine species of fish, both large and small, reacted to the raft in a way that made them less vulnerable to predation. Typically, when a predator approached the raft, the prey formed a compact group very close to the understructure. When the predator left or ceased harassments, the prey again dispersed about the raft. Often the predator chased the prey to the raft. The value of the raft to the prey was demonstrated by the fact that only one species, the amberjack, frequently caught fishes that had taken shelter under the raft. Observations on individual prey species are described below.

The most common resident, the freckled driftfish, usually took a position far below and downwind from the raft and was sometimes out of view. Driftfish were able to match their background. They had a silvery countershaded coloration when not under the raft, but took on a mottled brown coloration when close under it, and those collected from under an orange drogue buoy had an orange color. Most of their predator-avoidance activity was in response to dolphins, although some was in response to pompano dolphins, wahoos, bottlenose dolphins (*Tursiops* sp.), or to pilotfish which approached the raft swimming with a whitetip shark. The hundreds of such responses followed an unvarying sequence: when one of the predators came into the vicinity, the freckled driftfish suddenly formed a compact school and swam rapidly back to the raft or the parachute drogue. (They also fled to the raft when an observer entered the water.) When an amberjack was preying upon them, they remained within about 20 cm of the viewing chamber. They attempted to stay on the opposite side of the chamber from the amberjack or dodged into the gaps between the frames of the viewing windows. When the amberjack was not actively feeding, the driftfish ranged out again. Small damselfish, pilotfish, greater amberjacks, and jacks behaved similarly to driftfish in response to predation, but did not change coloration.

Rough triggerfish ranged far from the raft, sometimes out of sight. Their rapid return to it usually heralded the appearance of a predator (billfish, a great barracuda, bottlenose dolphin, whitetip shark) or apparent predators (schools of mackerel scad or a powerboat). They resumed ranging before the potential predator departed, except when the predator was a bottlenose dolphin. None of the above species exhibited a predatory response towards rough triggerfish. The triggerfish did not return to the raft when manta rays appeared and they usually swam out and met approaching dolphins. Rough triggerfish and dolphins may often be associated in the absence of drifting material; sometimes they arrived simultaneously at the raft.

On several occasions, the most successful piscivore, the amberjack, itself became the potential prey of dolphins and took shelter beneath the raft. Although amberjacks frequently ranged 10 to 15 m from the raft unmolested, when the dolphin began pursuit the amberjack eluded the predator by swimming close to the chamber. It remained there for some time before ranging out again.

The dolphin, one of the largest residents, took shelter close under the raft three times: once in response to a bottlenose dolphin, once to a billfish, and once to a swimmer. Each time the dolphin swam around the chamber just under the flotation drums and took on a coloration (Fig. 5) that occurred in no other situation

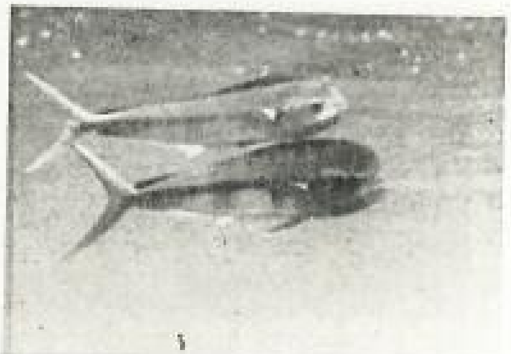

FIG. 5. The lower dolphin assumed the dark coloration when one of the observers entered the water.

and had not previously been recorded (for other colorations of this species, see Murchison and Magnuson, 1966). The dorsal half of the body turned a dark brownish-black. A sharp separation extended longitudinally along the side between the dark dorsal area and the silvery ventral half of the body. The above behavior and coloration, observed only when 1 or 2 dolphins were at the raft, were different from those seen on similar occasions when 13 or more dolphins were present. Then the group of dolphins swam immediately behind a billfish, a whitetip shark, bottlenose dolphin, and a swimmer near the raft. A position immediately behind a potential predator may be of advantage to the prey provided the animal has the speed and maneuverability to maintain such a position.

Large schools of goatfish attempted to avoid dolphins and amberjacks by swimming to the other side of the raft, but only rarely did individuals use the maximum shelter of the raft by swimming under it. As a consequence both predators were able to prey upon them successfully.

One of the most clearcut examples of predator avoidance occurred when a golden jack was chased to the raft by the feeding attacks of five dolphins. The dolphins stopped their feeding passes after the jack swam under the raft. For several hours the jack swam within inches of the chamber. The observer on deck could reach into the water and touch the fish without driving it away. After several hours it began to swim under the flotation drums, but not away from the raft. About 8 hours after it arrived the jack joined a whitetip shark and six pilotfish which swam close by, and left the raft in their company. The dolphins took on their feeding coloration, but did not attack the jack as it swam off with the shark. This incident provided evidence for the protective role that both floating objects and large animals such as sharks play for the fish that accompany them.

Concentration of Food Supply

It has often been said that floating material concentrates the food supply—smaller fish, zooplankton, or sessile biota. Most piscivores did not successfully prey on fish that sought shelter beneath the raft, but they did prey extensively on those that gathered at the raft but did not take shelter beneath it. Zooplankton was not concentrated at the raft, nor did large numbers of sessile organisms attach themselves to it.

Kojima (1956) suggested that dolphins were found near floating objects because more food was available there, but was unable to demonstrate that they fed substantially on other fishes gathered at anchored bamboo rafts (Kojima, 1960, 1961). Yabe and Mori (1950) argued that abundance of food was an inadequate explanation for the presence of yellowfin and skipjack tuna near floating logs because the fish took bait readily and did not have much food in their stomachs. The simultaneous presence of piscivores and potential prey near the raft was well documented, yet, as mentioned above, only amberjack successfully preyed on the small fish that took shelter there. We saw them chase and eat freckled driftfish. The stomach of the only amberjack taken at the raft contained three driftfish. The only other species we saw catch smaller fish was the adult dolphin. Both it and the amberjack, as has been mentioned, preyed on schools of goatfish that were near the raft, but not under it. The stomachs of 53 dolphins caught near the raft contained only 5 scrawled filefish; 1 sargassum triggerfish, *Xanthichthys ringens* (Linnaeus); and 1 puffer, *Diodon holocanthus* Linnaeus. All were juveniles. Once we saw an adult dolphin seize and eat a freckled driftfish which was attempting to reach the raft. This incident suggests that dolphins sometimes intercepted driftfish seeking shelter. Possible supporting evidence for this supposition came from observations off Hawaii. While the raft was anchored for several days, numerous freckled driftfish, 19 dolphins, and 1 amberjack accumulated. The raft was then towed by the ship 30 miles down the coast and set adrift. During the tow the driftfish were outdistanced and all were lost; only the dolphins and amberjack remained. Thus, unlike other drifts, this drift began with a number of fish—19 dolphins and 1 amberjack—at the raft. During 52 hours of drifting no freckled driftfish appeared. Yet in the same area, two weeks earlier, approximately 500 and 200 driftfish gathered at the raft on two drifts of 50 and 32 hours, during which only 2 and 7 dolphins had accumulated.

Two other predators, wahoos and adult pilotfish (with sharks), actively chased smaller fishes at the raft, but were not observed to catch any.

Although zooplankton was not concentrated at the raft, a number of fishes that eat zooplankton gathered there. For example, stomachs of 10 rough triggerfish caught at the raft contained many pteropods and stomatopods, and lesser numbers of crab megalops and zoea, amphipods, and copepods. Stomachs of 81 freckled driftfish contained small pelagic tunicates (*Oikopleura* sp.), copepods, fish eggs, chaetognaths, and various coelenterates. These fish also bit at macroplankton such as ctenophores and tunicate colonies. Stomachs of 24 damselfish contained only *Oikopleura* sp. Stomachs of nine small pilotfish contained mostly copepods. All of these fishes, and also scrawled filefish and goatfish, frequently darted after and caught zooplankton around the raft. The wind slowly pushed the raft through the water at a speed faster than the swimming speed of the small zooplankters. Thus, there was no accumulation of zooplankton, but rather a continuous stream of macroplankton and microplankton slowly moving past the underwater windows.

Finally, fishes at the raft did not feed on the small amounts of sessile or ambulating biota present. Only the rough triggerfish bit at the raft. Crab megalops occasionally settled on the underside of the raft or on the triggerfish, but those in the stomachs could have been taken as well from the plankton as from the raft. Perhaps a greater growth of biota on the raft would have altered the feeding behavior, especially of the triggerfish, which has a dentition suited for grazing. Evans (1955) reported that triggerfishes (*Balistes* sp., and *Canthidermis* sp.) cropped barnacles fringing the waterline of a drifting vessel in the Atlantic North Equatorial Current.

Removal of Ectoparasites

At the beginning of this study we hypothesized that floating objects serve as cleaning stations where fishes may gather to have parasites removed by other fish. Many fish observed at the raft carried ectoparasites, and several events suggested that these were eaten by other fish. Fish also chafed against the raft, another possible aspect of cleaning behavior.

Small copepods were found on captured dolphins, freckled driftfish, and rough triggerfish, and were seen on whitetip sharks and juvenile dolphins (*Coryphaena* sp.). Crab megalops and parasitic isopods were also seen on triggerfish. The megalops walked freely over the fish; the isopods were firmly attached.

Biting behavior was common among rough triggerfish and was directed toward a triggerfish that was headstanding (body oriented head down), apparently soliciting predation on parasites. This behavior occurred only when more than one triggerfish was present; it was common 3 to 12 m from the raft. The headstanding fish did not flee the biting fish and once even appeared to rotate its body, keeping the side with the parasitic isopod toward the biting fish. The biting was always directed at the headstanding fish even though several other fish were very close by. Although we did not witness directly the removal of a parasite, we saw one rough triggerfish bite at a parasitic isopod on the caudal peduncle of another, and soon afterward the isopod was missing. Biting did not appear to represent aggressive behavior; intraspecific aggression among triggerfish frequently occurred immediately under the raft, but did not include headstanding. In aggression one triggerfish repeatedly chased others from under the raft.

Once a rough triggerfish swam to a dolphin and apparently nipped at it. The dolphin, some distance from the raft, had begun leaning to one side. It had also stopped swimming and was almost motionless in the water. It leaned four times within 2 minutes, for periods of about 9 seconds. Similar leaning behavior by dolphins in the presence of rough triggerfish was seen on several other occasions, but did not elicit nipping by the latter. This behavior was not unlike that of inshore fishes soliciting parasite-cleaning labrids (Randall, 1958). Balistids are not among the reported inshore parasite-pickers, but their dentition should make them efficient in this role.

A juvenile dolphin, *Coryphaena* sp., with a small reddish copepod attached near the fork of the caudal fin repeatedly positioned itself so that its caudal fin was close to the head of

FIG. 6. Adult dolphin chafing against a 55-gallon drum beneath the raft.

another juvenile dolphin, *Coryphaena* sp. During the display the fish with the ectoparasite stopped caudal movements and treaded water with its pectorals. It did not lean to one side as did the adult dolphin mentioned above. On numerous occasions, the juvenile dolphin, *Coryphaena* sp., to which the display was directed made passes at the caudal fin of the parasitized fish. At the end of the day, however, the copepod was still attached.

Several species chafed their sides on the raft, skiff, or lines hanging in the water. Adult dolphin commonly chafed against the bottom of the raft and skiff (Fig. 6). Sanchez Roig and Gomez de la Maza (1952) and Heyerdahl (1950) have reported similar behavior. Sometimes dolphin chafe against other fish (Breder, 1949). In one of our film sequences, a small abrasion can be seen on the side that the fish was rubbing against the skiff. Other species at the raft which were seen chafing were rough triggerfish on the bottom of the raft; juvenile dolphin on ropes and on the caudal and dorsal fins of whitetip shark; whale shark, whitetip shark, and scrawled filefish on the rope to the parachute drogue; and a spiny puffer, on a small floating can. This behavior, especially common in the coryphaenids, could remove parasites or relieve skin irritation.

Some predation on ectoparasites occurred at the raft, but the question remains whether the removal of parasites is concentrated near the raft and other floating objects. It is obvious that removal of parasites by chafing on hard objects would be concentrated near floating material or larger fishes. In addition, the opportunity to feed on ectoparasites or to solicit parasite cleaning would appear to be greater near the raft because the fishes usually arrived in small groups or alone and formed larger aggregations at the raft.

Other Possible Explanations

The hypothesis that fishes seek shade under floating objects has no substance. Yabe and Mori (1950) and Kojima (1956) also reached this conclusion. None of the smaller species tended to remain in the shade of the raft. Larger species such as rough triggerfish, wahoo, dolphin, and whitetip shark often ranged far from the raft and were seldom in its shadow. The hypothesis (Besednov, 1960) that fish use floating material as a substance on which to lay their eggs could not be substantiated. Even though fish eggs are frequently found on drifting material, no fish deposited eggs on the raft nor were any eggs seen on the undersurface. No data were obtained to test the hypothesis (Damant, 1921) that the shadow of an object makes the zooplankton more visible to fish. Four species fed upon zooplankton; the visibility of these zooplankters may have been increased by the raft's shadow.

CONCLUSION

A floating object in the pelagic environment provides a relatively rare "superstrate" in an environment notable for its horizontal homogeneity. This superstrate has some of the same ecological significance to certain pelagic fishes that a substrate has to inshore fishes. Obviously, no single biological association or adaptive advantage can explain the occurrence of fish around floating objects at sea. Of the ecological hypotheses considered, shelter from predation is substantiated best and appears to be the most significant factor in the evolution of fish communities that gather beneath inanimate drifting material in the open ocean.

ACKNOWLEDGMENTS

We thank Randolph K. C. Chang, Robert T. B. Iversen, and Everet C. Jones, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, who assisted in making the observations; Frank J. Mather, Woods Hole Oceanographic Institution, who verified the new record for Hawaii of *Seriola rivoliana;* John E. Randall, The Oceanic Institute and the Bishop Museum, Honolulu, Howard E. Winn, University of Rhode Island, Philip Helfrich, University of Hawaii, Thomas A. Manar, and Donald W. Strasburg, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Charles M. Breder, Jr., American Museum of Natural History, and John H. Hunter, Bureau of Commercial Fisheries Tuna Resources Laboratory, La Jolla, California, who reviewed the manuscript during various phases of its development.

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3/4/85 tel. call - NE region A Gordon Warring may let contract this spring

CONSERVATION
EDUCATION
RESEARCH

MASSACHUSETTS AUDUBON SOCIETY
WELLFLEET BAY WILDLIFE SANCTUARY AND NATURE CENTER

January 31, 1985

Mr. Goerge Balazs
National Marine Fisheries Service
Honolulu Laboratory
PO Box 3830
Honolulu, Hawaii 96812

Dear George:

I'm glad the information I sent to you was of use to you. Thank you for the draft paper on ocean debris. This is an area of interest for NMFS and your lab in Woods Hole may let a contract soon to do some work on this problem here. I would like to get involved because of my work with turtles - and also because of gill net ghost fishing and bird entanglements. Could I get the literature cited section of the draft?

sent 2-5-85

In regard to the digested plastick - if it would be of help to you, I could send you half of one. If you want it, please write, and I'll mail it out.

I am also familiar with Sam Sadove work on Long Island. It was a conversation I had with him and Bob Scholkoff of the Marine Mammal Center in New Jersey. Both reported finding plastic bags in esophagus of sea turtles - mostly leatherbacks. There is more plastic being dumped into the water near them than what I see here. Bob may have some information - if you haven't already written to him.

Sincerely,

Bob

Robert Prescott
Director

RP:h

P.O. BOX 236, SOUTH WELLFLEET, MASSACHUSETTS 02663 - TEL. (617) 349-2615

I-Do-16

CONSERVATION
EDUCATION
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MASSACHUSETTS AUDUBON SOCIETY
WELLFLEET BAY WILDLIFE SANCTUARY AND NATURE CENTER

December 13, 1984

Mr. George Balazs
Wildlife Biologist - NMFS
PO Box 3830
Honolulu, HI 96812

Dear Goerge:

1980-84 = 5 years

I'm not sure how much help I can be. I have necropsied nine leatherbacks in the last five years - one each the first three years - in which I found no debris. However, the fourth year (last year) I did find a partially digested ball of accumulated plastic in the upper part of the colon in one of the three turtles' I examined. This year, I found one ball of plastic in the upper colon in one turtle and the second and third turtles with no ball of plastic - but with pieces of plastic in their esophagus.

I feel only the balls of partially digested plastic are of a consequence to the animal. However, pieces of plastic once ingested are probably not excreted and once enough accumulates, it will have an impact on a leatherback.

I have examined literally over a hundred 2-3 year-old ridleys and loggerheads and have found no plastic remains.

A more common cause for strandings of leatherbacks is their entanglement in lobster-pot lines. Eight of the nine leatherbacks stranded this year either were entangled or showed scars from being entangled. I'm not sure that is information you need because I feel these turtles entangle in active gear - not drifting line. If you want to know more about lobster-pot line entanglement, let me know. NMFS here in the Northeast has not shown much of an interest.

If I can be of further help, don't hesitate to write.

Sincerely,

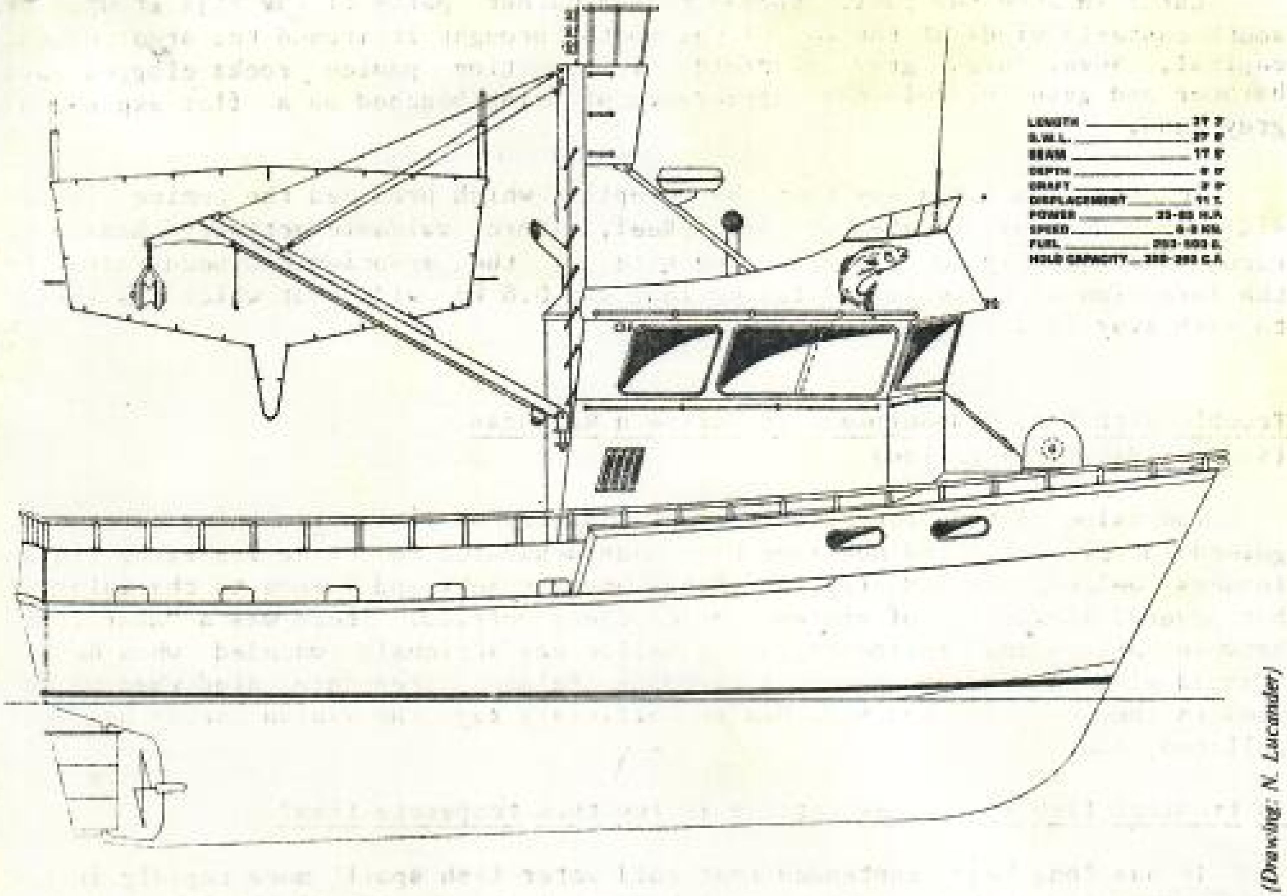
Bob

Robert Prescott
Director

RP:h

P.O. BOX 236, SOUTH WELLFLEET, MASSACHUSETTS 02663 · TEL. (617) 349-2615

April-June 1984 SPC Fish. Newsletter



The Lucander 31-foot (9.3 m) mini-seiner/longliner.

The deep forefoot, easy buttocks and long keel makes it an easily handled boat, with an easy motion, very economical and the flared topsides provide excellent stability. More information from: Nils Lucander, 5307 N. Pearl Street, Tacoma, WA 98407, U.S.A.

Pumice forces fish ashore in Fiji
(Sources:Fiji Sun/Fiji Times/SPC)

Villagers of Ono-i-Lau, Fiji's most southerly inhabited island, crowded their beaches early in June to gather fish apparently trapped and forced to the surface by huge quantities of floating pumice stones.

Masses of pumice were reported in April by SPC Master Fisherman Paul Mead, whose trolling lines were repeatedly clogged by the material. That reported from Ono-i-Lau was much thicker, and villagers were able to walk on the pumice to collect fish floating between the islands of Ono and Doi. The pumice is thought to have originated from one or more underwater volcanic eruptions in Tonga during March.

Ono-i-Lau villagers were disappointed that Fiji's fish collection vessels were far away from their island at the time, and could not assist them in getting their windfall to Suva market for sale. Ono-i-Lau is two days journey from Suva and, as no chill facilities are available on the island, the fish would have been decaying before they could be collected. However, the islanders contented themselves with a huge feast on the more than 2000 large fish they collected.

Later in June the pumice spread to many other parts of the Fiji group, and south easterly winds at the end of the month brought it around the area of the capital, Suva. Thick grey blankets of the tiny pumice rocks clogged Suva harbour and gave vessels the appearance of being beached on a flat expanse of grey sand.

Reports from Tonga say that the eruption which produced the pumice lasted six weeks and was located at Home Reef, where volcanic activity has been recorded frequently in the past. The site of the eruption has been marked by the formation of a new island 1.6 km long and 0.8 km wide, but which is likely to wash away in a strong storm.

Trouble with Tuna Transhipment in Northern Marianas
(Source: Pacific Magazine)

The value of the tuna transhipment industry on Tinian is being debated in government circles, and hearings have been scheduled to decide its fate. Tinian leaders welcome the industry, which has brought jobs and income to the island - but several incidents of violence have others worried. There was a "mini riot" between sailors and residents, and a sailor was seriously wounded when he was stabbed with a fishing spear. A sleeping Palauan stevedore died when he was axed in the neck by another. Health officials say the Tinian harbor has been polluted, too.

Do tropical fish spoil less rapidly in ice than temperate fish?

It has long been contended that cold water fish spoil more rapidly in ice than tropical fish because the normal bacterial flora of their bodies is better able to survive and cause spoilage at ice temperatures. A number of studies have been carried out which add weight to this contention, such as that described in the following article by John Sumner and Elizabeth Gorczyca in FAO's Fisheries Technology News No. 6 (December 1983):

"The considerable circumstantial evidence that tropical fish keep longer when stored in ice than fish from temperate and cold waters led Dr Jim Shewan to propound the theory that keeping times in ice were related to the numbers of psychrotrophic (cold-loving) bacteria present, cold water fish being more likely to have higher numbers of psychrotrophs and therefore to spoil more rapidly. A series of experiments carried out at the Royal Melbourne Institute of Technology (RMIT) lends weight to Shewan's theory. Mullet (*Mugil cephalus*) caught off Brisbane from waters of 23 degrees C kept 26 days in ice compared with 20 days and 21 days for the same species taken from Gippsland (Victoria) waters of 9 degrees C. Rainbow trout (*Salmo gairdneri*) harvested from the same farm in Buxton, Victoria, kept 18 days in ice when taken in summer (water temp. 18 degrees C) compared with 14 days and 15 days in winter (water temp. 5 degrees C). In both sets of experiments at the time the fish was rejected by a trained taste panel total bacterial counts (22 degrees C) were 10 -10 /g, with H S-producers (mainly *Alteromonas putrefasciens*) being 10 -10 /g and comprising 1-10% of the total count. Rejection by the taste panel approximated depletion of the nucleotide, inosine monophosphate (IMP), depletion being accomplished more rapidly in cooler-water fish."

However, a review article by FAO's Carlos Lima dos Santos in Volume 23 of *Tropical Science* suggests that existing data collected from fish storage trials fall far short of validating this theory. Lima dos Santos' article brings together for the first time detailed results of over 200 different trials on

Encounters of Hawaiian Monk Seals With Fishing Gear at Lisianski Island, 1982

JOHN R. HENDERSON

Introduction

Interactions of marine mammals with various fisheries are documented for many species (Mate, 1980; Beverton, 1982; Contos, 1982), though studies have generally emphasized direct interactions which economically impact a fishery, take considerable numbers of marine mammals, and have high public visibility. Less apparent interactions, such as entanglement in lost or abandoned fishing gear, are more difficult to assess, yet may significantly impact some marine mammal species.

Northern fur seals, *Callorhinus ursinus*, have been observed entangled in net debris on shore and at sea (Fiscus and Kozloff[1]; Jones[2]; Scordino and Fisher[3]), and such entanglements may be a source of significant mortality for the species (Fowler, 1982). Collars of rope and plastic strapping have been reported on Cape fur seals, *Arctocephalus pusillus* (Shaughnessy, 1980), and Antarctic fur seals, *A. gazella* (Bonner and McCann, 1982). Hawaiian monk seals, *Monachus schauinslandi*, are also known to become entangled in fishing gear and other synthetic debris. Monk seals with distinctive, garrote scars have been observed, as have animals bearing net fragments and debris (Balazs, 1979; Kenyon, 1980; Gilmartin[4]). A weaned monk seal pup at French Frigate Shoals was found entangled in, and immobilized by, a piece of fishing net to the extent that drowning would likely have resulted had the animal not been freed (Andre and Ittner, 1980).

Fragments of lost or discarded fishing gear regularly wash ashore at all of the Northwestern Hawaiian Islands (NWHI). At Lisianski Island this occurs predominantly on the east (windward) side of the island and the debris includes net fragments, tangles of rope and line (some of which may be mooring line), and assorted glass and plastic floats. In 1978, Fiscus et al.[5] counted 18 pieces of netting at Lisianski which they considered could entangle a seal. Net fragments and tangles of line also foul on the reefs which extend approximately 100 m offshore on the north and east sides of the island, and remain partially submerged in the shallow (<5 m) water. The size of these fragments ranges from small (<1 m^2) pieces to virtually entire nets weighing over 100 kg. Many of these pieces have been identified as originated from Japanese trawls and gill nets (footnote 5).

From March to September 1982, a study was conducted at Lisianski Island to assess the effect of tagging on the behavior of weaned pups. Methods included individually marking all pups. During the course of this study, seals were observed to encounter fishing gear. These observations are reported here.

Observations

Presence and Accumulation of Net Debris

Those net fragments on the island which were deemed hazardous to monk seals were sampled and inventoried early in the season, and such debris which accumulated throughout the field season was similarly monitored. Assessment of the hazard to seals was subjective; criteria included size of the fragment and presence of loops or holes large enough to encircle the head of the seal. Fifty-two net fragments which had been present an unknown time were counted and 21 fragments washed ashore during the 6 months in which field personnel were on the island.

Inventory of debris included recording the size, location, color, and type of material. Samples were taken

[1]Fiscus, C. H., and P. Kozloff. 1972. Fur seals and fish netting. Appendix E in fur seal investigations, p. 124-132. Natl. Mar. Mammal Lab., Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98112.

[2]Jones, L. L. 1982. Incidental take of northern fur seals in Japanese gillnets in the North Pacific Ocean in 1981. Background paper submitted to the 25th Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission, Ottawa, 16 p.

[3]Scordino, J., and R. Fisher. 1983. Investigations on fur seal entanglement in net fragments, plastic bands and other debris in 1981 and 1982, St. Paul Island, Alaska. Background paper submitted to the 26th Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission, held on March 28-April 8, 1983 in Washington, D.C., 33 p. + appendix tables and figures.

[4]W. G. Gilmartin, pers. commun., Honolulu Laboratory, Southwest Fish Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, October 1981.

[5]Fiscus, C. H., A. M. Johnson, and K. W. Kenyon. 1978. Hawaiian monk seal (*Monachus schauinslandi*) survey of the Northwestern (Leeward) Hawaiian Islands. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98112. Proc. Rep., 27 p.

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for subsequent determination of twine and mesh sizes.

Seals Lying on Nets

Seals of all ages often hauled out atop or adjacent to piles of net and line which were high on the beach. No records of this behavoir were maintained, though the behavior was particularly evident among molting individuals who apparently seek objects against which they can roll or rub to facilitate sloughing off old pelage.

Pups Investigating Net Fragments and Flotsam

Five weaned pups, none of which was involved in the entanglement incidents described below, were observed investigating floating net fragments. The pups swam into and around the fragments, often surfacing with mesh covering their head and neck. A sixth weaned pup was observed investigating a large net fragment which was fouled on a rock ledge. Although no entanglement occurred during any of these incidents, encounters such as these could easily result in entanglement if holes large enough to accommodate a head or flipper were present in the fragment.

Weaned pups were also frequently observed nuzzling and investigating plastic and glass floats and other flotsam, often mouthing various objects, including shards of broken glass floats. No injuries from these incidents were noticed. One pup inserted its muzzle into a 7 cm diameter plastic ring which remained tightly encircling the seal's snout for 24 hours before it was removed by field personnel.

Entanglements

Incident One

Soon after arrival at Lisianski on 17 March, field personnel observed a large mass of net approximately 25 m offshore on the east side of the island. Subsequent inspection of the net on 8 April showed that it was fouled on coral rubble in water 3-4 m deep, and the bulk of the net mass was floating. A 43 cm green sea turtle *Chelonia mydas*, and a small ulua, *Caranx* sp. entangled in the net were released.

At 1430 hours on 22 April a weaned male pup was found entangled in the same net. The pup's head and left foreflipper were inserted through a hole in the mesh, and five to six strands encircled the neck and flipper. The pup was lying atop the net mass and not in immediate danger of drowning, but it was so firmly entangled that escape was unlikely and it probably would have starved had it not been released. The net was dragged ashore. It formed a pile 1.5 m high, 2 m in diameter, and probably weighed over 100 kg. The twine was gray polypropylene 2 mm in diameter; the stretched mesh size was 9 cm.

Incident Two

At 0830 hours on 6 May, a weaned pup was observed ashore on the north end of the island with a piece of net around its chest. The net fragment did not impede the seal's movements, but was tightly constricted about the chest, forming a 1-2 cm deep depression around the animal. The net would likely have eventually slipped off due to postweaning weight loss and the attendant reduction in girth. Nonetheless, infection and necrosis of the constricted tissue surrounding the constriction might also have occurred, or the net might have fouled on a piece of coral as the seal swam. The net fragment was removed by field personnel. The gray polypropylene fragment measured 30 × 60 cm, had a stretched mesh size of 10.5 cm, and a 2 mm twine diameter. The pup had been entangled through a hole in the web, not in a single mesh.

Incident Three

At 0830 hours on 8 May, a weaned pup was heard vocalizing repeatedly from the reef edge, approximately 100 m offshore from the east side of the island. Closer inspection revealed the male pup to be entangled in an 80 × 30 cm mass of monofilament net and 25 mm diameter polypropylene line. The net apparently had been fouled on the shallow reef for some time, and the pup had become entangled by four strands of the line, two strands each anterior and posterior to the front flippers, girdling the chest. The entire tangle was in water approximately 0.25 m deep, the tide was low, and the seal was held so tightly that had biologists not released the animal, it would almost certainly have drowned during the incipient high tide.

Incident four

At 0830 hours on 9 May, an adult female seal attended by her 26-day-old nursing pup was seen apparently entangled in a mass of net and line at the reef edge, about 75 m off the northeast side of the island. The female appeared to have several coils of line draped over her neck and back. The pup was swimming and vocalizing near the female.

Research personnel prepared equipment for restraining and releasing the female, but upon returning to the site at about 0930 hours, they found the female had freed herself and was ashore nursing her pup. The net which had entangled the female washed ashore later the same day, 200 m west of the entanglement site. The net mass comprised assorted polypropylene lines and monofilament net.

Incident five

At approximately 0900 hours on 23 June, a weaned male pup was found entangled in a net mass on the east side of the island. The net was the same one that entangled a pup on 22 April (incident one). Though the net mass had been previously dragged ashore, high tides and wave surge had moved it about 400 m north, where it was in the wash zone of the beach. The pup was lying atop the pile entangled by a twisted noose of mesh about its neck (Fig. 1). As in incident one, the pup was not in immediate danger of drowning, but was so firmly bound that escape would have been unlikely. Field personnel released the pup and retained the mesh noose. (The net was later moved high up on the beach.)

Discussion

Although the number of hazardous

nets counted on Lisianski was markedly higher in this study than counted by Fiscus et al. (footnote 5) in 1978 (52 versus 18), this amount does not necessarily represent accumulation over 4 years. Some of the nets cataloged in 1982 were found in vegetation well up the beach, and may not have been seen during the 4-day visit in 1978. Criteria by which a net was deemed hazardous may also have been less stringent in 1982 than in 1978. Nonetheless, the large number of fragments accumulating throughout the 6-month field season in 1982 indicates that floating debris is ubiquitous in the waters of the NWHI.

Twenty-six pups survived to weaning at Lisianski in 1982. When field personnel departed the island on 15 September, 25 pups were still alive. The one pup that died was once entangled (incident one), but the death was unrelated to that incident. During a 1-month field camp from 26 October to 22 November, 24 of these pups were seen.

Since all pups were bleach marked, the identity was known of all individuals observed entangled in or investigating nets. The 10 incidents reported here (4 pup entanglements, 6 observations of pups investigating debris) involved 10 different animals, 38.5 percent of the pups of the year. Three of these entanglements could have resulted in death of the monk seal had researchers not intervened. Moreover, the large percentage of pups known to have interacted with nets suggested a general propensity in pups to explore fishing debris. Entanglement of northern fur seals, *Callorhinus ursinus*, is believed to similarly result from investigative behavior by the seals rather than from accidental blundering[6]. This investigative behavior, coupled with the presence of large amounts of such debris, could lead to considerable mortality among recently weaned monk seals. The escape of an apparently entangled adult female suggests that nets and other debris may present less hazard to adults than to pups.

Figure 1. – Hawaiian monk seal pup (59 days postweaning) entangled in a fragment of fishing net.

[6]Scordino, J., G. Beekman, H. Kajimura, K. Yoshida, Y. Fujimaki, and M. Tomita. 1984. Investigations on fur seal entanglement in 1983 and comparisons with 1981 and 1982 entanglement data, St. Paul Island, Alaska. Background paper submitted to the 27th Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission, March 29-April 6, 1984, Moscow, 26 p. + appendices and figures.

Acknowledgment

Comments by Linda L. Jones and Joe Scordino improved the manuscript.

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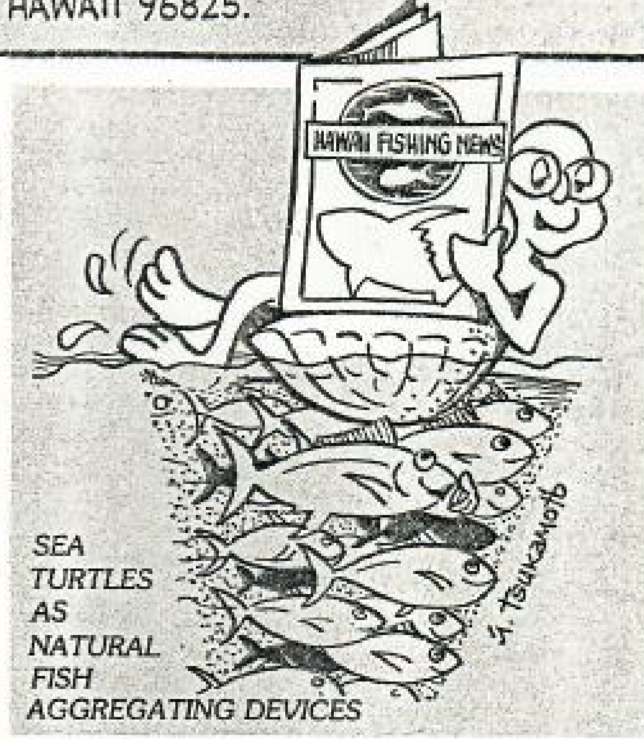

SEA TURTLES AS NATURAL FISH AGGREGATING DEVICES

The value of green sea turtles as ecological, educational and aesthetic components of our Hawaiian marine environment is well-known to many residents and tourists who have seen these great reptiles swimming in Island waters. These reasons alone seem sufficient to justify current protective laws aimed at preventing further population declines following many years of heavy and uncontrolled exploitation. However, an additional benefit of special interest to the fishing community has now come to light. The following short but true "fish story" was recently related to me by my colleague, John Naughton, of the National Marine Fisheries Service:

> *While trolling between Kauai and Niihau during calm weather, a turtle about two-feet long was seen floating at the surface with several seabirds circling overhead. A closer inspection revealed the presence of small fish aggregated under the turtle along with two mahimahi. As the boat passed by, the turtle quickly dove out of sight and both fish were hooked-up and landed. The total catch amounted to a respectable 40 lbs.*

Maybe there is something to the Japanese "Urashima Taro" folk tale where the sea turtle becomes the fisherman's good friend!

George H.Balazs
Honolulu, HI

August 1982 Vol 7, No. 7

Fish and Fishermen

by Capt. Bob Neuweiler

MAIL BUOY

July 8, 1982

Dear Mr. Neuweiler,

Really enjoyed your article on Hawaiian Shrimp, in your June '82 issue of HAWAII FISHING NEWS. I'm really interested in starting this type of fishing. However, I have a few questions which I hope you can answer for me. First, do you put any type of bait in the shrimp trap? If yes, what kind? Second, how long do you normally leave the traps down before checking them?

Your assistance in helping answer these questions will be greatly appreciated.

Mahalo,
Sidney

P.S. Keep up the excellent work and your outstanding magazine.

Shrimp Bait

■ This letter is one of several I received in response to "*Heterocarpus laevigatus* means Hawaiian Ono Shrimp" (June '82 HFN). In my rough draft, I find the sentence: "The traps are baited with aku, kawakawa or any oily, blood fish." Somehow, during the rewrite, this sentence was lost. My apologies for the mistake.

The set time for shrimping varies from 4 to 6 hours. Some Kaua'i shrimpers make overnight sets, dropping their traps in the afternoon and picking them up in the morning. It appears that sets longer than 6 hours do not increase the catch of shrimp; because, first, bait is pretty well washed out and eaten, and second, there is a problem with cannibalism. With several hundred shrimp packed into the trap, shrimp will start to eat each other which is the main reason for shorter 4 to 6 hour sets.

I learned from Dave Lamdin, a shrimper on Kaua'i, that he is having good catches of shrimp using small size (1' × 2' × 2') traps with funnels at both ends. He attributes his success to the fact that smaller traps are easier to handle. He spends less time pulling the lighter traps and more time fishing.

Albacore Fleet Struggles with Driftnets

Reports from returning albacore trollers indicate some conflicts with Japanese gillnet operations. It seems the Japanese ika (squid) fishermen are using longer nets this year (12 miles) and are covering huge expanses of ocean with floating equipment.

Unfortunately, the invisible gillnets catch everything from ika and tuna to albacore trollers' props. American fishermen have no way of knowing where nets are laid, and number of these single screw vessels were tangled in foreign equipment. Trollers lucky enough to spot the nets before running into them are faced with the problem of which way to go next. They may be only a couple miles from one end, but which end? A wrong turn means a 10 mile run and lost fishing time. There are reports of cut float lines and bullet holes in radio buoys used by Japanese to locate nets. There are 400 Japanese drift gillnet vessels in the ika fishery and less than 100 albacore trollers in the American fleet.

It certainly seems to me that both sides have equal right to make a living on the high seas. It appears some communication between the corporate powers in Japan and independent American fishermen is in order before the situation develops into a shootout in the northwestern Pacific.

Opakapaka, Onaga and the MAKALII

The good people at the National Marine Fisheries Service are doing it again. This past month, Fisheries' biologists utilized the submersible vehicle the *MAKALII* to take a close up look at onaga, opakapaka and other commercial bottomfish at the Penguin Banks. They made seven dives on the fingers area, recording the species of fish present, their distribution and notes on their abundance.

The report is not completed yet, but we understand some fabulous photographs were taken. We at HFN appreciate the work being done by the NMFS and look forward to bringing you their findings in future issues.

...Bob

la mort. Celle-ci survient par noyade de l'animal, soit lorsqu'il vient s'entortiller les membres antérieurs dans un orin de casier, soit lorsqu'il reste prisonnier du chalut pendant le trait. Toutefois, lorsqu'une tortue se trouve prise lors de la remontée du chalut, ou lorsque le casier est remonté rapidement après la capture, l'animal a des chances de survivre. C'est précisément à ces circonstances que nous devons d'avoir pu faire le marquage des six Tortues luth, dont nous avons parlé précédemment.

Assez rarement, nous avons constaté que des bouts de lignes se trouvaient accrochés aux tortues par des hameçons. Mais il ne nous paraît pas évident que ces engins de pêche constituent un facteur de mortalité.

Les autopsies pratiquées au cours des cinq dernières années nous ont révélé que les estomacs de Tortues luth pouvaient receler la présence de corps étrangers. Il s'agit de sacs en plastique dont nous avons retrouvé les restes chez cinq animaux, sur douze autopsiés. Dans l'un des cas, la mort de la tortue a pu être rattachée, avec certitude, à cette ingestion accidentelle. Le 6 octobre 1979, une femelle (196 cm de longueur totale et 160 cm de carapace) a été trouvée, affaiblie, sur la plage d'Ars-en-Ré (Charente-Maritime). Après de vaines tentatives de remise à l'eau, elle fut transportée dans un bassin d'eau de mer où elle mourut trois jours après. Son estomac était rempli de morceaux de sacs en plastique dont l'ensemble atteignait un volume de 5 litres, environ. L'examen histologique de la paroi de l'estomac montrait que cet obstacle permanent au transit digestif, en provoquant des contractions anormalement fréquentes des parois, avait entraîné une hypertrophie compensatrice de la musculature, puis une fibrose inflammatoire. La sténose pratiquement totale qui s'est ainsi formée a conduit l'animal, par dénutrition, à l'état cachectique dans lequel nous l'avons trouvé. Bien qu'il soit impossible de dater le début de l'occlusion, on peut vraisemblablement supposer que ce processus s'est déroulé sur plusieurs mois (Duguy, Duron, Alzieu, 1980).

Il est très probable que cette ingestion de sacs en plastique n'est pas accidentelle, en ce sens que les Tortues luth ne les avalent pas en même temps que les méduses mais, au contraire, qu'elles prennent volontairement ces morceaux translucides, par confusion avec des fragments de méduses.

La contamination des Tortues luth par les micropolluants organochlorés a été étudiée chez trois femelles et un mâle, capturés ou trouvés morts, en 1976 et 1979. Les résultats détaillés des analyses pratiquées sur le muscle, la graisse, le foie, le rein et les testicules, publiés dans un précédent travail (Duguy, Duron, Alzieu, 1980) ont été présentés dans le tableau III. Il apparaît que seuls les P.C.B. et le D.D.E. se trouvent en quantité notable, alors que les teneurs en D.D.T. et D.D.D. sont extrêmement faibles. De façon générale, les degrés de contamination des quatre individus analysés sont comparables et les teneurs en P.C.B. et D.D.E., rapportées aux tissus lyophylisés, augmentent sensiblement dans l'ordre : muscle, rein, foie, graisse, c'est-à-dire dans le même sens que la richesse en lipide des tissus. Si l'on examine les teneurs exprimées par rapport aux lipides, on remarquera qu'elles sont du même ordre de grandeur dans tous les prélèvements d'un même individu. Ceci tendrait à montrer que la contamination des lipides est uniforme dans l'organisme, donc d'origine ancienne ou très peu dépendante du métabolisme présent.

TABLEAU III

Date et lieu de capture	Sexe	Organe	%		mg/kg – chair lyophilisée – *lipides*			
			Eau	Lipides	PCB	DDT	DDE	DDD
19.08.1978 St-Gilles-Croix-de-Vie	F	muscle	77,2	0,6	0,12 *4,59*	< 0,02 *< 0,6*	0,03 *0,98*	< 0,01 *< 0,34*
		graisse	12,3	84,2	4,30 *4,47*	< 0,2 *< 0,1*	0,93 *0,88*	< 0,08 *< 0,09*
		foie	69,0	30,7	2,13 *6,15*	< 0,1 *< 0,8*	0,44 *1,28*	< 0,04 *< 0,1*
		rein	76,2	2,4	0,53 *5,93*	< 0,02 *< 0,8*	0,11 *1,1*	< 0,01 *< 0,07*
30.08.1978 Les Sables-d'Olonne	M	muscle	80,4	0,7	0,1 *2,8*	< 0,02 *< 0,48*	0,03 *0,98*	< 0,01 *< 0,30*
		graisse du cou	51,8	43,1	3,37 *3,76*	< 0,27 *< 0,30*	1,47 *1,64*	< 0,11 *< 0,12*
		foie	75,3	2,6	0,44 *4,1*	< 0,03 *< 0,2*	0,13 *1,28*	< 0,01 *< 0,13*
		rein	84,6	1,2	0,25 *3,57*	< 0,02 *< 0,3*	0,11 *1,28*	< 0,01 *< 0,08*
		testicules	79,2	4,3	0,72 *3,68*	< 0,05 *< 0,35*	0,30 *1,46*	< 0,01 *< 0,08*
31.08.1978 La Rochelle avant port de La Pallice	F	muscle	79,6	0,4	0,12 *5,25*	< 0,02 *< 0,86*	0,03 *1,25*	< 0,01 *< 0,18*
		graisse du cou	87,3	6,5	4.71 *8,27*	< 0,12 *< 0,26*	1,09 *2,15*	0,08 *0,18*
		foie	77,5	3,4	0,60 *3,84*	< 0,04 *< 0,23*	0,14 *0,89*	0,01 *0,08*
		rein	84,4	2,2	0,51 *3,55*	< 0,02 *< 0,18*	0,11 *0,77*	0,01 *0,08*
8.10.1979 St-Clément-des Baleines	F	muscle	75,3	0,55	0,13 *6,88*	0,02 *0,65*	0,02 *0,88*	< 0,01 *0,35*
		graisse	39,8	38,3	2,15 *2,28*	0,25 *0,78*	0,36 *0,67*	0,07 *0,10*
		foie	75,7	2,02	0,30 *8,61*	0,07 *0,30*	0,04 *0,62*	< 0,01 *0,11*

Teneurs en polychlorobiphényls D.D.T., D.D.E. et D.D.D. dans les prélèvements de Tortues luth (*Dermochelys coriacea*), (d'après DUGUY, DURON, ALZIEU, 1980).

Hazel Nishimura

For Turtleman --

The autopsies carried out over the last five years have shown us that the stomachs of leatherback turtles may conceal the presence of foreign objects. These are plastic bags, the remains of which we have found in five animals out of twelve autopsied. In one of these cases the death of the turtle could be ascribed with certainty to this accidental ingestion. On October 6, 1979, a female (196 cm total length, 160 cm carapace length) was found in a weakened condition on the beach at Ars-en-Ré (Charente-Maritime). After unsuccessful attempts to return it to the sea, it was moved to a seawater tank where it died three days later. Its stomach was filled with pieces of plastic bags with a total volume of around 5 liters. A histological examination of the stomach walls showed that this permanent obstacle to digestive passage, by provoking abnormally frequent contractions of the walls, had brought about a compensatory hypertrophy of the musculature, and then an inflammatory fibrosis. The practically total ~~kisskagm~~ stenosis which was thus formed had led the animal, by lack of nutrition, to the enfeebled state in which we found it. Although it is impossible to assign a date to the beginning of the occlusion, one can probably assume that the process developed over several months (Duguy, Duron, Alzieu, 1980).

It is very likely that this ingestion of plastic bags is not accidental, in the sense that the leatherbacks do not swallow them together with medusae but, on the contrary they take these translucent morsels voluntarily through confusing them with fragments of jellyfish.

Contamination of leatherback turtles by organochloric micropollutants has been studied in three females and one male, captured or found dead, in 1976 and 1979. The detailed results of analyses carried out on muscles, fat, liver, kidneys and testicles, published in an earlier work (Duguy, Duron, Alzieu, 1980), are presented in Table III. It appeared that only PCB's and DDE were found in considerable quantities, the content of DDT and DDD being very low. In a general way, the degrees of contamination of the four individuals analyzed are comparable, and the contents of PCB and DDE associated with the lyophylized tissues increase appreciably in the order: muscle, kidney, liver and fat, that is to say, with the same tendency as the abundance of lipid in the tissues. If we examine the contents expressed by their relation to the lipids, we will note that they are of the same order of magnitude inx all of the samples from the same individual. This would tend to show that the contamination of the lipids is uniform in the organism and thus of longstanding origin or very little dependent on the current metabolism.

Table III

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Duguy 1983

☆ U.S.GPO:1977-0-765-092/1118

FORM CD-34 (2-76) Prescr. by DAO 214-2 **TRANSMITTAL SLIP**	U.S. DEPT. OF COMM.	DATE 3/6/85
TO: Van Campen-san		REF. NO. OR ROOM, BLDG.
FROM: Hazel		REF. NO. OR ROOM, BLDG.

ACTION

- [ ] NOTE AND FILE
- [ ] NOTE AND RETURN TO ME
- [ ] RETURN WITH MORE DETAILS
- [ ] NOTE AND SEE ME ABOUT THIS
- [ ] PLEASE ANSWER
- [ ] PREPARE REPLY FOR MY SIGNATURE
- [ ] TAKE APPROPRIATE ACTION
- [ ] PER OUR CONVERSATION
- [ ] PER YOUR REQUEST
- [ ] FOR YOUR APPROVAL
- [ ] FOR YOUR INFORMATION
- [ ] FOR YOUR COMMENTS
- [ ] SIGNATURE
- [ ] INVESTIGATE AND REPORT

COMMENTS:

Your turtle friend asked me about the possibility of having the attached translated right after you left. Let himpay you in turtle meat if nothing else! Would you mind?

thanks,

hazel

CHARTERED 1693
COLLEGE OF WILLIAM AND MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

Gloucester Point, Virginia 23062

12 November 1984

Phone (804) 642-2111

Dr. George H. Balazs
Wildlife Biologist
National Marine Fisheries Service
Honolulu Laboratory
PO Box 3830
Honolulu, Hawaii 96812

Dear George:

In response to your letter regarding the problem of debris in turtle guts in our area (Virginia, Maryland and Delaware), there seems to be little if any problem here.

The primary reason for this is not that floating plastic bags, etc., are rare, but rather the most abundant sea turtle is Caretta (>90%) with Lepidochelys next in abundance. We may record only one to half-dozen Dermochelys each summer.

In recent summers I could find records of only two turtles (of hundreds examined) that were involved with plastic trash.

I-Cc-17 → The first of these was a loggerhead (50.5 cm straight line carapace length) taken live in a pound net at the mouth of the Potomac River on 5 October 1984. This animal had the half-round base of a plastic champagne "cork" stuck around the base of the lower left jaw. This did not obstruct the action of the jaw but there was a small necrotic spot on the inner jaw surface beneath the plastic. The turtle was very vigorous, and we released it (sans "cork") after taking measurements and blood samples.

I-Dc-17 → The second turtle was a leatherback (129.7 cm CLS) which stranded, bloated at the mouth of Chesapeake Bay just on the ocean side of Cape Henry on 17 October 1983. This specimen was well along in decomposition, but had a piece of the plastic wrapper from a ketchup packet in its intestine. This plastic piece was too small to have caused intestinal blockage.

I hope this meager information is of interest to you.

Best wishes,

Jack

John A. Musick
Professor of Marine Science

JAM/gbr

	PLASTIC BAGS & SHEETS	PLASTIC PARTICLES	TAR	KITCHEN SCRAPS	SYNTHETIC LINE and Thread	MONO LINE Fish
GREEN	(8) 25.8%	(2) 6.5	(10) 32.3	(3) 9.7	(4) 12.9	(1) 3.2
LOGGER	(5) 14.7	(11) 32.4	(4) 11.8	(2) 5.9	(4) 11.8	(2) 5.9
HAWKS	(3) 16.7	(7) 38.9	(6) 33.3	(1) 5.5	0	0
LEATHER	(17) 94.4	0	0	(0)	0	(1) 5.6
KEMPS	(1) 20.0	0	(2) 40.0	(0)	0	0
ALL SPECIES	(34) 32.1	(20) 18.9	(22) 20.8	(6) 5.7	(8) 7.5	(4) 3.8

CLOTH	BY-CATCH	NET	PAPER	GLASS	METAL	
11 (2) 6.5	0	/ (1) 3.2	0	0	0	31
0	11 (2) 5.9	0	/ (1) 2.9	11 (2) 5.9	/ (1) 2.9	34
0	0	0	2 (1) 5.5	0	0	48
0	0	0	0	0	0	18
0	0	0	/ (1) 20.0	0	/ (1) 20.0	5
([illegible]) 1.9	(2) 1.9	(1) 1.0	(3) 2.8	(2) 1.9	(2) 1.9	105

Table 3

	INGEST. (INGESTION)		ENT (ENTANGLEMENT)	
1. Azores	1	1.3		
2. Ascension	2	2.6	—	
3. Australia	2	2.6	1	1.7
4. Balearic	1	1.3	—	
5. Bermuda	—		1	1.7
6. Costa Rica	3	3.9	2	3.3
7. England	2	2.6	—	
8. France	4	5.3	1	1.7
9. Fr. Poly.	1	1.3	—	
10. Hawaii	7	9.2	28	46.7
11. Japan	8	10.5	—	
12. Johnston	—		1	1.7
13. Lesser Antilles	—		1	1.7
14. Marshalls	1	1.3	—	
15. Madeira	2	2.6	—	
16. Mediterranean	—		1	1.7
17. Netherlands	2	2.6	—	
18. New Zeal.	1	1.3	—	
19. Pacific Ocean	—		4	6.7
20. Peru	2	2.6	—	
21. Selvages Islands	2	2.6	—	
22. South Africa	3	3.9	1	1.7
23. Tokelau	1	1.3	—	
24. U.S. Mainland	31	40.8	19	31.7
	10			
	10			
	76		60	

Oct 15, 1985 HSB A:3

Beach Cleanup Will He

By Carrie Pressly
Star-Bulletin Writer

Plastic junk found floating in the ocean can become killers when they are mistaken for food by sea birds, turtles, seals and whales.

"We think of the ocean like we used to think of the West; a vast frontier . . . (but) whatever is dumped out there ends up somewhere," said Susie White of Greenpeace International.

Greenpeace is helping put together "Get the Drift and Bag It," Hawaii's first organized beach cleanup project that will take place Sunday.

White, coordinator of Greenpeace's Hawaiian Monk Seal Campaign, said, "Sea birds swoop down to the ocean and pick up the plastic rings of soda-pop cans. They become entangled and die.

"They think anything in the ocean is food. It used to be that way."

Susie White
Her message is simple

Metal bands used to bundle fishing nets are dangerous to the Hawaiian Monk Seal, she said. If a pup gets one caught around its neck, the band will cut deeper and deeper into the seal's neck as it grows.

Her message is simple: adults, as well as children, must take home everything they bring to the beach. Mammals and birds don't discriminate between rubbish and food.

KRISTI KAUFMAN, Pacific Whale Foundation vice president, initiated the cleanup project. She witnessed the necropsy of a Risso's dolphin that washed ashore on Maui in 1984. Its death was caused by ingestion of plastic bags.

"To the dolphin, these bags could have resembled jellyfish, food," she said.

On land garbage makes itself felt immediately, she said, the smell and inconvenience of having to walk around it makes people do something about it.

"(But) this is happening out at sea and takes a long time to get here. I spoke to people in Oregon who found a plastic milk carton from Hamburg, Germany," she said.

During whale watches, she has seen people use the ocean as a trash can.

"It does amaze me. The problem is of sheer ignorance or shortsightedness. It's very disconcerting to watch people throw Styrofoam cups and garbage over the side of the boat. It's sad to think that for a state dependent on beaches, water and marine resources, that there isn't more awareness," Kaufman said.

VICTIM—Fish nets like the o
deadly threat to water animal

"Too bad we become aware when there's a problem. It's sad that our wildlife is the first to tell us," she said.

To a sea bird, anything is considered to be food, including a

...elp Save Birds, Sea Life

...ne entangling this Hawaiian Monk Seal are among many kinds of seaborne trash that poses a ...s. The state's first organized beach cleanup is set for Sunday.

piece of a foam cup. A bird will eat it then regurgitate it to feed its chicks. Plastic foam has no nutritional value, but leaves the bird feeling full and prevents it from eating. This can lead to starvation.

Plastics also can damage the intestines.

"Get the Drift and Bag It" is modeled after a similar program started in Oregon two years ago. This year's cleanup in Oregon yielded 25.5 tons of garbage collected by 2,300 volunteers.

The statewide beach cleanup and survey from 9 a.m. to noon is being coordinated by the Community Work Day Program. Interested persons should arrive at 8:30 for last-minute instructions.

To volunteer, answer phones or to be beach captains, call: Greenpeace at 595-4475 on Oahu; Pacific Whale Foundation, 879-4253, Maui; Office of the Mayor, 245-3387, Kauai; and Captain Alii's Charter Locker, 326-2553, Big Island.

Gloves are recommended.

22 Oct 84

Dear George,

Just a quick note to answer your questions and send along info. on debris in the digestive tracts of "lost year turtles." Concerning the latter, I enclose copies of my data and discussion from my dissertation (to be handed in Dec.) I have only seen 4 little hawksbills, but it has been amazing how consistently the garbage (the same garbage) turns up. You can use whatever information you need. You can cite it pers. com., if you like, or cite my diss.: "Feeding ecology of the hawksbill turtle (Eretmochelys imbricata): Spongivory as a feeding niche in the coral reef community." I don't plan to make any changes to this section before the final.

Thanks for your comments on the AKB, and on the use of spearguns for big turtles. I suppose it is a common misconception to think big turtles are not vulnerable to this.

I did not get to see the pieces of netting the Barbudan told me about. He was rather inarticulate, to say the least, and I am ignorant enough about fishing gear that I probably wouldn't have asked the correct questions, anyway. Nor do I know about what the Japanese do around there. I heard they were longlining at one point, but I suspect they do all types of fishing imaginable. There is no control by local island countries --most don't have a vessel to their name!

I suppose you've heard from Anthony Amos by now. He has been sending me dead hawksbills, and he was the one who has documented plastic bags of some sort (he mentioned "onion" at one point). I hope he sends you his stranding reports. He sent me one hawksbill that was ~~hopeful~~ hopelessly bound in monofilament - I'm sure you could use the details. He promised to contact you, but if he doesn't, I'll hunt for the stranding reports he sent me a while back. His phone, in the meantime, is 512-749-6711. He's w/ The Marine Science Institute, U of Texas, Port Aransas, TX. - 78373 (Box 1267) home = 6125

Have to run, deadlines to meet!

Best regards,

Anne

P.S. No news on monk seals in W. Indies! Too bad!

Results

Lost Year Specimens

There appear to be no data in the literature on the diet of wild hawksbills of the size range represented by the four specimens that stranded on Florida beaches (Witzell, 1983). Because of the considerable interest among the scientific community in marine turtles of this size class—particularly as regards their habitat occupation—the results of analyses of the digestive tract contents of these specimens are reported in detail in Table 7.

Table 7. Digestive tract contents of four hawksbill turtles (*Eretmochelys imbricata*) that washed up dead or moribund on beaches in southeastern Florida. Food items are listed in order of decreasing abundance.

Specimen	Food Item	Comments
UF50027 Sex Unknown. 14.0 cm straight carapace length. Jensen Beach FL. 16 February 1981. Tar on head and throughout digestive tract.	*Sargassum fluitans* or *natans*	Over half of volume; both are pelagic species
	Unidentified animal matter	Included numerous nematocysts
	Plastic	Styrofoam, styrofoam precursors, other
	Syringodium filiforme	Two fragments
	Tar droplets	Throughout digestive tract
	Woody plant remains	
UF50028 Female. 21.3 cm straight carapace length. Jupiter Island, FL. 16 January 1981. Injury to front flipper, emaciated.	Unidentified material	Large proportion; animal origin
	Sargassum sp.	Three blades; not *S. fluitans* or *natans*
	Microdictyon sp.	
	Plastic bead	Styrofoam precursor
	Paper	

Table 7 continued

Specimen	Food Item	Comments
UF 56655 Female. 14.0 cm straight carapace length. Ft. Lauderdale, FL. February 1981. Emaciated Condition.	Unidentified material.	Large portion of contents; animal origin
	Sargassum sp.	Vesicles, blades; not *S. flutans* or *natans*
	Unidentified alga	
	Tar droplets	
	Plastic particles	
	Shell fragments	Possibly a barnacle
UF 54846 Sex unknown. 20.2 cm straight carapace length. Hutchinson Island, FL. 13 July 1983. Carapace and limbs coated with tar, nostrils and mouth sealed.	*Sargassum natans* of *fluitans*	
	Shell fragments of goose barnacles	
	Fish eggs	Suborder Exocoetoidei (flying-fish, half-beaks, needlefish); on *Sargassum*
	Tunicate	
	Plastic	Styrofoam, sheet, particles
	Crab chela	
	Tar droplets	
	Unidentified plant material	

Discussion

Data collected by Kajihara and Uchida (1974) on the carapace lengths of 146 hawksbills caught for the taxidermy trade in Southeast Asia offer some of the most convincing evidence ever presented for the existence and length of the lost-year period for hawksbills. In spite of intensive economic incentive for fishermen to supply the taxidermy trade, no turtles under 15 cm carapace length, and only a few in the 15-20 cm range, were found in the factory. The authors suggested that a change in habitat occupation takes place at approximately 16-18 cm carapace length.

An alternative solution to the lost-year puzzle for hawksbills is offered by Witzell and Banner (1980), who reported that at least some post-hatchling hawksbills (> 4 cm) inhabit coral reefs in Western Samoa.

The contents of the digestive tracts of four hawksbills reported here provide corroboration of the theory that the lost year is spent associated with Sargassum rafts, although caution must be taken in interpreting data from stranded specimens. The possibility exists that atypical foods were consumed subsequent to the injury or onset of disease that resulted in death. The food sample from UF 54846 can probably be considered free of this bias because death was almost certainly due to asphyxiation by tar. Food present in the digestive tract was therefore consumed beforehand, and can be assumed to be characteristic of the normal diet.

Sargassum was present in all four specimens, although in only two cases could it be positively assigned to one of the pelagic species of the genus that is known to form large floating mats. Fish eggs of the suborder Exocoetoidei were attached to *Sargassum* in UF 54846. This suborder includes flying fish, half-beaks and needlefish; most of the species within it are known to be pelagic. The presence of these eggs in the digestive tract is evidence of surface feeding, in any case, as is that of bouyant styrofoam particles and plastic beads.

The relative importance of plant and animal matter is difficult to assess with the limited sample. Both were well represented. *Sargassum* was present in sufficient quantity to suggest purposeful ingestion. Norris and Fenical (1982) discuss the apparent avoidance of *Sargassum* by many herbivores in the Caribbean, and suggest that the presence of tannin-like polyphenolic substances within members of the family Sargassaceae may be responsible. In a wide survey of the feeding habits of West Indian fish, Randall (1965) found that relatively few fish feed on drifting *Sargassum*, sea chubs and the triggerfish *Melichthys* being notable exceptions.

The abundance and diversity of man-made debris in the digestive tract contents reveal the vulnerability of marine turtles—at least at this life history stage—to oceanic pollution. All four specimens examined had plastic refuse in the digestive tract; some had several different types. Of the many oceanic pollutants, petroleum products undoubtedly represent the greatest threat to survival. Death of at least one, and probably two of the specimens can be attributed with some confidence to this cause. Two were fouled externally and three had tar present in the digestive tract. The esophagus of UF 50027 was heavily coated and tar aggregates were present throughout the digestive tract.

The presence of oceanic pollutants in the digestive tracts of the turtles may be a result of their association with the Sargassum raft community. Pollutants such as oil, styrofoam and other plastics are well known components of the rafts. Their presence there has been identified by Carr (1983) as a potential threat to marine turtles of lost year size.

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Drift Plastic—An Expanding Niche for a Marine Invertebrate?

JUDITH E. WINSTON
The American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024, USA

Beach collection of plastic litter washed ashore at Fort Pierce on the Atlantic coast of Florida showed that, while some of this material may have had a local source, much of the rest originated in the Caribbean. During its pelagic existence the plastic commonly became encrusted by marine organisms. In contrast to the diverse assemblage of organisms associated with pelagic *Sargassum*, however, the number of species encrusting drift plastic was limited, being dominated primarily by the colonies of the bryozoan, *Electra tenella*, an organism which may be increasing its abundance and distribution, due to increasing amounts of drift plastic substrata.

Strong onshore winds or storms, particularly in winter months, cast tons of *Sargassum* ashore on Florida's Atlantic coast. Entangled with the masses of weed and its associated community, are other pelagic organisms, *Physalia* and (more rarely), *Velella* and *Janthina*, as well as large quantities of tar (the subject of much recent study, e.g. Butler *et al.*, 1973; Cordes *et al.*, 1980; Van Dolah *et al.*, 1980) and an amazing amount of plastic trash, often encrusted with sessile organisms.

The amount of plastic produced worldwide has increased enormously over the last 30 years (Carpenter & Smith, 1972). It is not known how much of this eventually ends up in the oceans, but there is no doubt that plastic pellets and spherules now occur in areas far removed from shore sources or major shipping lanes (Venrick *et al.*, 1973; Morris, 1980b), and that chemicals derived from plastics have become incorporated into the bodies of marine organisms (Fowler & Elder, 1978; Giam *et al.*, 1978; Morris, 1970). Most studies have included only small particles – those that can be collected by neuston nets (Austin & Stoops-Glas, 1977; Carpenter *et al.*, 1972; Carpenter & Smith, 1972; Colton *et al.*, 1974; Morris, 1980b; Van Dolah *et al.*, 1980). Only two shipboard studies refer to sightings of large pieces of plastic. Venrick *et al.* (1973) listed sightings of man-made objects (two-thirds of which were plastic) on the surface of the central north Pacific in an area 600 miles from the nearest landfall (Hawaii) and outside main shipping lanes, while Morris (1980a) found that in the Mediterranean, where pollution of this type could be expected to be high for both oceanographic and demographic reasons, 60–70% of objects over 1.5 cm in size appeared to be plastic debris such as bottles, sheets, cups, packing material, etc. In addition, beach studies of marine litter (including plastic containers and plastic fragments) have been carried out on British and West European beaches, where a large proportion of litter was found to originate from shipboard sources (Dixon & Dixon, 1981).

Table 1 shows plastic material obtained in one collection along the hightide line over approximately ½ mile of the North Beach, Fort Pierce, Florida, on 23 December 1980, after several days of onshore winds. This sample included only those items (76) encrusted by at least one bryozoan colony; the total number of items present was at least double that number. Most of this material (51 items) consisted of whole or parts of plastic containers or container tops. Most items (47) were semi-flexible, though some had become brittle apparently due to breakdown of the plasticizers with age (Carpenter & Smith, 1972). Composition included high density polyethylene, polystyrene and styrene butadiene rubber. Re-flotation in seawater showed that most pieces (62) had floated at or just below the water surface.

Probably many of these objects were swept into the *Sargassum* windrows which form along the borders of convection cells at the ocean surface (Faller & Woodcock, 1964), and, thus entangled, cast ashore with the *Sargassum* masses. Their origin for the most part is not in the Sargasso Sea. Labels or imprinting with the place of manufacture aided in identification of the origins of some of these objects (though of course it does not preclude their having been dumped far away at sea!). Sources for some may be similar to those reported for pelagic tar in these waters

TABLE 1

Characteristics of drift plastic encrusted by bryozoans.

Type of object	No. of items
Smaller bottles (bleach, detergent, etc.)	13
Container lids or caps (e.g. spray can tops)	14
Gallon jugs (e.g. milk jugs)	8
Bailers (gallon jugs cut in half	7
Other containers (e.g. ice cream, motor oil, baby formula)	9
Pails and buckets	9
Plates, cups, bowls	4
Sandals	3
Plastic lattice	2
Plant pot	1
Regulator exhaust port	1
Toy	1
Chemical toilet base	1
Paint brush handle	1
Boat rudder	1
Unidentifiable fragments	1
Total	76
Buoyancy in seawater	**No. of items**
Surface	62
Bottom	14
Flexibility	**No. of items**
Rigid	9
Semi-rigid	47
Flexible	20
Place of manufacture (stamped or labelled)	**No. of items**
No identifying mark	47
United States	20
Venezuela	4
Colombia	1
In Spanish – no other identification	2
England	1
Sweden	1
No. of bryozoan species encrusting	
1 species only	62
2 species	8
3 species	5
>3 species	1

could be identified as of US origin; it seems likely that these originated in southern Florida or in shipping traffic passing through the Straits of Florida, were carried through the Straits of Florida and entrained in the Florida Current–Gulf Stream system. It is possible that some US debris had a more distant source in the Gulf of Mexico and was carried by the Gulf Loop current to the Straits of Florida, but in view of the evidence on pelagic tar transport this is probably a less important source. Plastic items originating in Venezuela, Colombia, Guatemala and Jamaica were also found in the sample, indicating that the other major source of the plastic is the Caribbean. Material transported from the easternmost Caribbean and the northern coast of South America could reach the Atlantic coast of Florida via the Guiana and Antilles Currents. Material originating in the southern or southwest part of the Caribbean would be carried by the Caribbean Current, passing south of Jamaica and between the Yucatan Peninsula and the west coast of Cuba, through the Straits of Florida and into the Gulf Stream. Calculations based on July surface currents (as given in Wüst, 1964) indicate that an object could be transported by this route from Venezuela to the Atlantic coast of Florida in as little as four months, or from Jamaica to the Atlantic coast of Florida in as little as two months.

Like *Sargassum*, drifting plastic become a substratum for encrusting organisms, but while the *Sargassum* community consists of over 100 species, 10% of them endemic, and shows a high degree of biological integration, with specialized adaptations of form and behaviour that indicate a relatively long history (Friedrich, 1969), the fauna and flora of drift plastic is limited to a very few species (of bryozoans, serpulids, barnacles, *Millepora*, filamentous algae and Foraminifera), and at least in the area studied is dominated by the encrusting cheilostome bryozoan *Electra tenella* (Fig. 1). *Electra tenella* occurred on 56 of the objects sampled, and on 43 of them it was the only bryozoan present. The second most abundant species, *Membranipora tuberculata*, is the commonest bryozoan and one of the most abundant organisms on *Sargassum* (Friedrich, 1969; Ryland, 1974). Although larvae show settlement preferences on *Sargassum natans*, the species can occur on other algae (Winston & Eiseman, 1980), and it is not surprising to find some colonies on plastic substrata. *Electra tenella*, however, has not been found on *Sargassum*. It may be that settling larvae of *E. tenella* cannot attach to the *Sargassum* surface, or dislike the tannins it produces, or that the species cannot survive the competition for space in the densely populated *Sargassum* community. When *M. tuberculata* and *E. tenella* colonies came into contact with each other on plastic surfaces the *M. tuberculata* overgrew the *E. tenella*. The reason for the success of *Electra tenella* on plastic may lie in the lack of ability of most other organisms to colonize the smooth semi-flexible plastic surfaces, or to grow and persist without being sloughed or broken. There may also be far less predation occurring around floating plastic objects than in the *Sargassum* community where filefish, flatworms, pycnogonids and nudibranchs all feed on bryozoans.

Electra tenella was described by Hincks (1880) based on a specimen collected from Florida. Since then it has been re-described only by Marcus (1937) who found it on the coast of Brazil, and Weiss (1948) who reported it (as *Acanthodesia tenella*) from fouling panels in Biscayne Bay, Miami Beach, Florida. Osburn (1940) stated that he did not find the species in Puerto Rico, but examination of his specimens of '*Conopeum reticulum*' showed them to be *Electra tenella* and not the European species *Conopeum reticulum*. This report listed it as occurring on hard substrata, chiefly dead shells and barnacles in shallow water harbour areas, but it has only once been recorded as a fouling species (Weiss, 1948). Perhaps, like the closely related Indo-Pacific species *Electra angulata* (recorded from drifting wood, from shells, barnacles and sea-snakes), *Electra tenella* has specialized for an epipelagic mode of life.

In spite of its sparse record over the last hundred years, *Electra tenella* is now one of the most abundant bryozoans on the Atlantic coast of Florida (Winston, 1982), and its success appears to be due chiefly to the presence of large quantities of drift plastic in those waters. The increase in the amount of semi-rigid or non-algal epipelagic substratum provide by plastic trash may have been somewhat offset by a decrease in the available natural substratum (logs, non-finished wood, coconuts, sea beans), due to the clearing of coastal forests and development of coastal areas. But the total amount of plastic substratum is probably increasing rapidly and will continue to do so, at least in the near

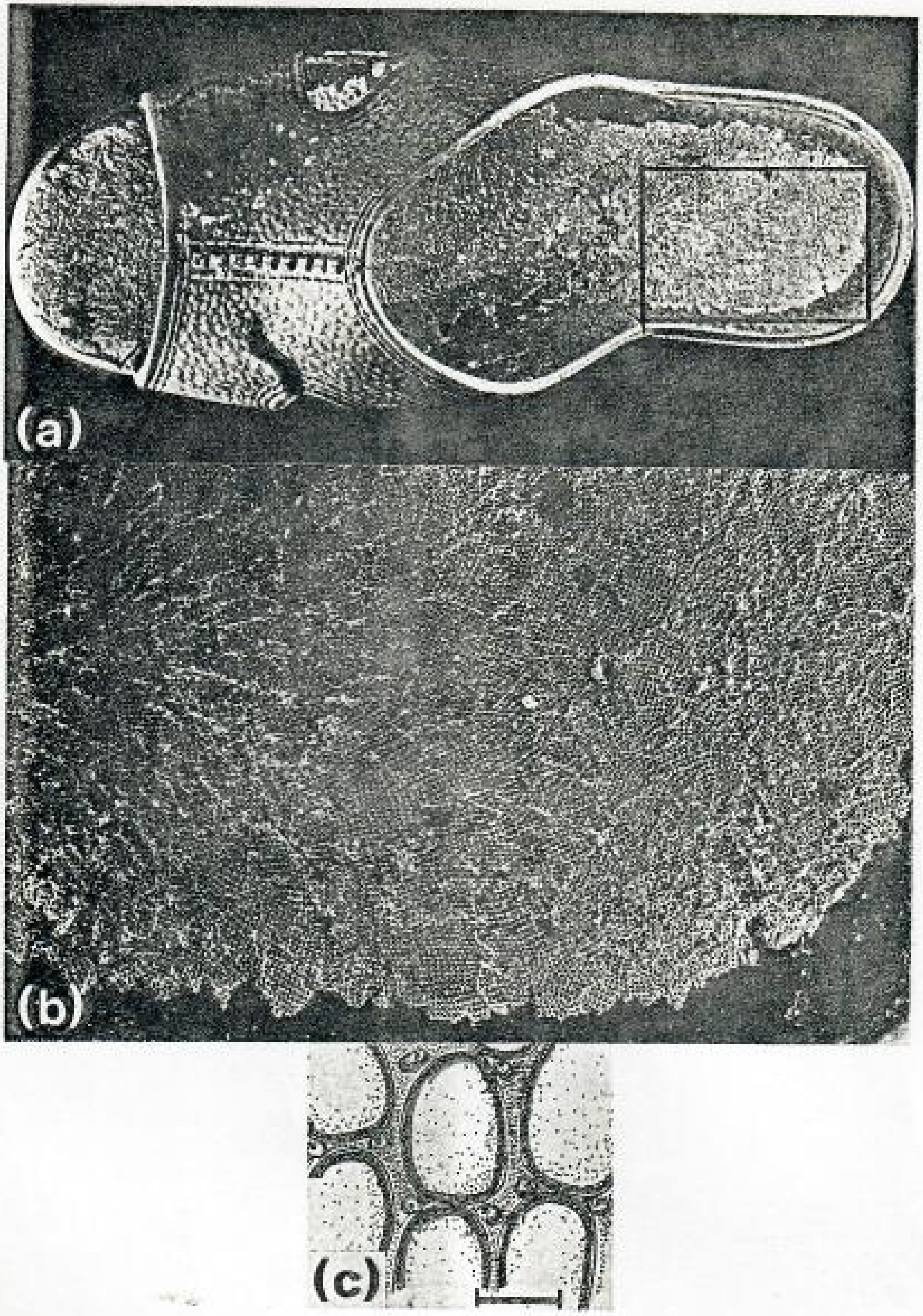

Fig. 1 (A) Sandal of Colombian manufacture encrusted by colonies of the chielostome bryozoan *Electra tenella*. 4×6 cm area enclosed in black rectangle is enlarged in Fig. 1B.
(B) Portions of two colonies of *Electra tenella*.
(C) Several zooids of *Electra tenella* (scale = 200 μm).

future, as Caribbean countries increase production and distribution of plastics. Like other organisms able to thrive in the border of manmade and natural environments (e.g. wild turkeys, cattle egrets, armadillos) this marine invertebrate may be actively expanding its abundance and range.

Thanks to C. Baker and R. A. Winston for field assistance, to M. E. Rice and N. P. Smith for aid with oceanographic calculations, and to W. Lee for chemical analyses of plastic objects. Thanks also to A. H. Cheetham (U.S.N.M.) for allowing examination of Osburn's material and to P. L. Cook (British Museum – Nat. Hist.) for permitting examination of the type of *Electra tenella*.

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Correlation of Dispersant Effectiveness and Toxicity of Oil Dispersants Towards the Alga *Chlamydomonas reinhardti*

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Using synchronous cultures of the unicellular green alga *Chlamydomonas reinhardti*, the toxicities of mixtures of Ekofisk crude oil and oil dispersants were measured. Sixteen so-called concentrates and 10 solvent-based dispersants were tested. The dispersing effectiveness of these compounds with respect to the Ekofisk crude oil was also measured. The concentrates were tested undiluted as well as diluted using algal growth medium (2‰ salinity) and artificial sea water (33‰ salinity) as dispersing liquid. The solvent-based compounds were tested in algal medium. For all compounds we found significant correlations between their toxicity and their effectiveness in dispersing the Ekofisk oil, such that the more effective the compound, the more toxic it was.

To control the use of chemical oil dispersants in Norwegian waters, the Norwegian authorities have put forward regulations including toxicity testing with the green alga *Chlamydomonas reinhardti* (Anon., 1980). For several years we have been testing the toxicity of dispersants, both water-soluble concentrates and solvent-based types, with this alga and its close relative, the marine flagellate *Dunaliella bioculata*. During these studies we have noticed that the most toxic compounds seemed to be those which were the most effective in dispersing oil. This impression stems from visual observations of their effectiveness as seen in the algal cultures during testing, and from the observations that the mixture of oil and dispersant was usually more toxic than the two tested alone.

We here report the results of experiments undertaken to test whether or not such a correlation exists between toxicity and effectiveness.

Methods

The test oil was Ekofisk crude oil, and the dispersants were commercially available ones obtained from the manufacturers. In this report they are not identified.

Toxicity tests were performed with synchronous cultures of *Chlamydomonas reinhardti*, as described previously (Heldal *et al.*, 1977). In short, appropriate amounts of oil/dispersant mixture were added to the algal cultures contained in 25 ml test tubes, to give a concentration series. These cultures consisted of zoospores at a density of *ca* 1.5 million cells ml^{-1}, and they were cultivated in parallel with control cultures at 35°C and at 20,000 lux, with intermittent

SYNTHETIC DEBRIS OBSERVED ON A HAWAIIAN MONK SEAL

by George H. Balazs

Injury and mortality to northern fur seals (*Callorhinus ursinus*) resulting from entanglement in scraps of net and other synthetic debris have been well documented and appear to be on the increase in recent years (Fiscus and Kozloff 1972, Kajimura 1976, Roppel et al. 1978). Kenyon and Rauzon (1977) and Fiscus et al. (1978) have suggested that such entanglement may represent a significant threat to the endangered Hawaiian monk seal (*Monachus schauinslandi*), particularly with the advent of greater commercial fishing activity in the animal's breeding and foraging habitat of the Northwestern Hawaiian Islands. Although Kenyon and Rauzon (1977) recorded two monk seals at French Frigate Shoals with long narrow scars suggestive of extended contact with lines, no direct observations have been reported of lines or other synthetic items actually tangled around a seal in the Northwestern Hawaiian Islands. The purpose of this paper is to document such a case, which I have observed during the course of field studies of the Hawaiian green turtle (*Chelonia mydas*).

On 3 October 1974 a subadult monk seal with synthetic debris wrapped around the base of its neck was observed on Whale-Skate Island at French Frigate Shoals (Fig. 1). The material was approximately 1.5 cm wide and consisted of a continuous band into which the seal had apparently placed its head. The predominant forward motion of the animal while swimming undoubtedly served to slide the band to a tight position. Except for the presence of this band, the seal appeared to be in good condition with no signs of respiratory distress or emaciation. It was not possible to determine how long the band had been on the seal; however signs of fraying and deterioration indicated that it would probably eventually break and fall off.

On a number of occasions I have observed debris of this type along the shorelines at French Frigate Shoals, Lisianski and Kure Atoll. According to McMaster and Carr (1975), these bands are manufactured from polypropylene for use in securing crates and other cargo. The boxes of frozen bait carried by Japanese longline fishing vessels are known to be secured with bands of this type. Although some of these boats operate in off-

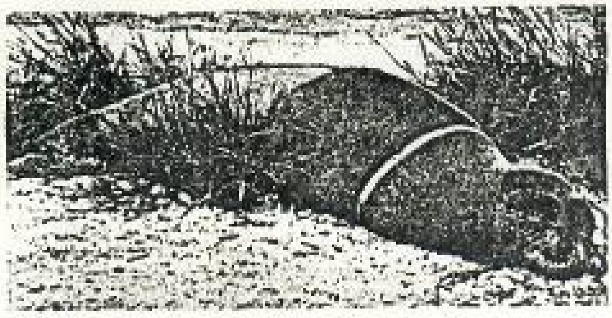

Fig. 1. Seal on Whale-Skate Is., with polypropylene banding around its neck.
Photo by George H. Balazs

shore waters of the Northwestern Hawaiian Islands, the bands could conceivably have drifted from any of numerous locations throughout the North Pacific where they were discarded.

The seal observed on Whale-Skate Island has not been recorded during subsequent trips to French Frigate Shoals. However, if the band fell off and did not leave a scar, there would be no way of recognizing this particular animal. Since the initiation of my research at French Frigate Shoals in June of 1973, I have recorded two seals with deep distinctive scars which probably resulted from lines or other entangling debris (Figs. 2 and 3). Photographs presented by Kenyon and Rauzon (1977) reveal that one of the animals that I observed was the same individual seen during the course of their field work.

Acknowledgements

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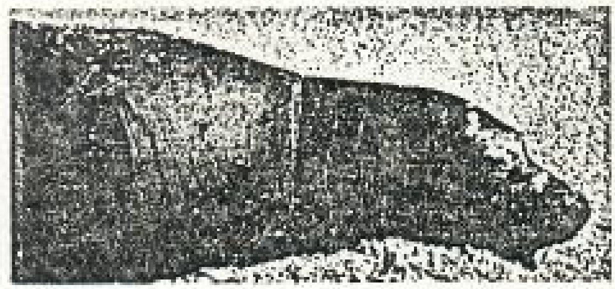

Fig. 2. Seal at East Island, Sept. 1977. A narrow scar extends around the animal's neck. *Photo by George H. Balazs*

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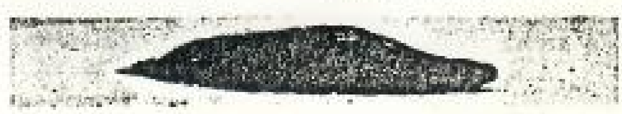

Fig. 3. Seal on Trig Is. with abdominal scar. *Photo by George H. Balazs*

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The Amount of Garbage Pollution from Merchant Ships

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The content of ships' waste was analysed on two merchant vessels. The results show a large amount of unnecessary garbage pollution by ships. The disposal at sea of plastic materials, and of all garbage except food waste in certain special areas, is against the Inter-Governmental Marine Consultative Organization (IMCO) 1973 regulations. Ships are ignoring these regulations. The garbage can be a hazard to man and wildlife, apart from being aesthetically displeasing. It is recommended that more responsibility be put with the shipping companies, owners and suppliers to stop this pollution.

The origin of litter on British beaches is world-wide (Dixon & Cooke, 1977; Dixon & Hawksley, 1980). This suggests that disposal from shipping is the major source. There is an increasing number of records of man-made debris in the marine environment from all parts of the world (Carpenter & Smith, 1972; Feder *et al.*, 1978; Morris 1980; Van Dolah *et al.*, 1980).

The Inter-Governmental Marine Consultative Organization (IMCO) conference on marine pollution in 1973 produced regulations for preventing pollution by garbage from ships. Annex V, Regulation 3, from the final act of this conference prohibits the disposal at sea of all plastic materials. There is a limit of 25 nautical miles from the nearest land for the disposal of floating material, and 12 nautical miles for food waste and other garbage. The disposal of all garbage except food waste is prohibited in the Mediterranean Sea, the Baltic Sea, the Black Sea, the Red Sea, the region of the Persian Gulf and around the Great Barrier Reef, Australia. Food waste may not be dumped less than 12 nautical miles from the nearest land in these areas.

This report presents evidence that these regulations are ignored. It is believed that this is the first time that a systematic count of the garbage dumped from merchant ships has been carried out.

Methods

Investigation of the stores

All the cases, wrappings, containers, packages, bottles and jars taken on board a ship are ultimately disposed of at sea. Provisions usually last for 2, 4 or 6 months. Hence one method of obtaining a measure of litter dumped at sea is to count the items in the stores.

Two merchant ships were investigated. The amount of metal, glass and plastic containers was counted from the lists of stores. The period the stores were to last was noted, and the figures worked out to a daily consumption per person.

The first ship took stores on 25 and 30 September 1980, scheduled to last 2 months. The results are shown in Table 1. The second ship took major stores on 4 September 1980, and between 11 and 19 December 1980. These lists showed goods consumed in 98 days. Minor provisions were taken on 26 January and 27 March 1981. The results are shown in Table 2.

TABLE 1

The use of materials from a stores list scheduled to last for 60 days (ship's company, 30).

	Metal			Glass		Plastic	
Use	Food & domestic	Drink	Aerosols	Food	Drink	Food & domestic	Garbage bags
Number of containers	580	7680* 135 tins tobacco	79	160	660	5721 lb frozen foods † 96 bots. cleaner	600
Daily usage per person	0.3	4.3 (drink)	0.4	0.1	0.4	0.05 (bots.)	0.3
Total		5.0			0.5		0.4

*The canned drink was supplemented with 30 kegs of lager.
†Frozen food was listed in weight not number of packages.

TABLE 2

The use of materials from a stores list over 98 days (ship's company, 46).

	Metal			Glass		Plastic	
Use	Food & domestic	Drink	Aerosols	Food	Drink	Food & domestic	Garbage bags
Number of containers	2515	24480	108	617	1514	N.A. 26/1/81 27/3/81	2000* 360 † 960 ‡
Daily usage per person	0.6	5.6	0.02	0.14	0.3	0.3 (90 days)	
Total		6.2			0.4		0.3

N.A. – Not available.
*The bags were not used much because they were the wrong size. They have been excluded from the calculations.
†360 packets of crisps – stores taken in Los Angeles, 26 January 1981.
‡960 packets of crisps – stores taken in Cairns, Australia, 27 March 1981.

Food and domestic waste includes containers of food stuffs, sanitary cleansers, detergents and various disinfectants. Aerosols include polish, fly spray, fresh air sprays and oven cleaners. The lists do not include personal items like toiletries, toothpaste, deodorant sprays, aftershaves, etc.

Most of the provisions are packed in boxes or crates and wrapped in plastic. Some food stuffs are in sacks, some plastic, others natural fibre. There are other sundry items in the stores such as mops, crockery, cutlery (metal and plastic), plastic cups and kitchen utensils which are not included in the calculations.

Subjective assessment of the content of ship's waste

A chart was prepared with the following column headings: Time, Container, Cardboard/Paper, Wood, Plastic, Glass, Tin, Food Waste, and Other. When rubbish was dumped, the person assessed what it consisted of. He represented this assessment in the chart as a number of X's. For instance, if it was entirely food waste, there would be X's in that column only; if there were equal amounts of plastic, glass and tin then there were the same number of X's in each of these columns, and so on. The time of dumping and the type of container were also noted. Containers were usually a dustbin, a 10 l. bucket or a plastic garbage bag. Often the number of items in each category was recorded if they were large and easy to count, e.g. drums, or if they were unusual like crockery, fluorescent tubes and sacks (listed under 'other' – see Table 4).

From the data the position of the ship at the times of dumping could be worked out. The X's in each column were converted to percentages of the total waste, and the average calculated for each day.

This assessment was continued during three sea passages:

(1) Los Angeles to Canton (Guangzchou), southern China – 26 days.

(2) Southern China to Cairns, North Queensland, Australia – 12 days.

(3) Australia to the Gulf of Panama – 28 days.

The average daily percentage of each category was worked out for the entire voyage – 65 days at sea. The results are shown in Table 3.

Amount of waste

It is arguable whether analysing the stores list accurately shows how much is dumped at sea. Not all the stores may be used up in the time planned: some, a very small amount, may be dumped ashore. The assessment only gives a subjective percentage content. To obtain a true picture, the amount of litter in each category was counted over a period of 44 days.

The contents of 102 dustbins of waste were counted prior to being dumped. This represents 54% of the total bin waste over the whole voyage (the total number of bins was 188). The figures were calculated to the average daily total per man. The results are shown in Table 4. The contents of 312 buckets of waste were not counted.

TABLE 3

The average daily percentage content of ship's waste.

	Cardboard/ paper	Wood	Plastic	Glass	Metal	Food
L.A. to China (25 days)	24.4	0.4	1.5	2.0	20.2	46.5
China to Australia (12 days)	26.4	–	1.4	2.6	23.5	42.8
Australia to Panama (28 days)	23.9	–	1.6	2.6	22.3	48.6
Mean	24.9	0.1	1.5	2.6	22.0	46.0

Results and Discussion

The stores

The results from the stores lists (see Tables 1 and 2) gives an estimation of the maximum number of containers it is possible to dump at sea. There is little difference between the two ships in the usage per person for glass and plastic materials. On neither ship was it possible to calculate the amount of plastic food containers, e.g. frozen food packets. The numbers of metal containers are significantly different: 4.4 and 6.2. The explanation is that the first vessel supplemented the canned drinks with 30 kegs of lager. These were returned to port and refilled when empty. The use of keg beer therefore meant 30% fewer cans disposed of at sea.

Content of ship's waste

There was little difference in the percentage content of the ship's waste during the three sea passages (Table 3). The average figures for the whole voyage show that over a quarter of the material (26.1%) is non-biodegradable; that is plastic, glass and metal (aluminium, tin and bimetallic aluminium/tin cans). If the figures for the sundry other items were available it is probable that the non-biodegradable material is nearer 30% of the total ship's waste.

TABLE 4

The amount of waste dumped at sea (ship's company, 46).

	Cardboard/ paper	Plastic	Glass	Metal
Total counted over 44 days	320 boxes	370 holders* 165 crisp packets 19 bags 2 drums	245 bottles† 5 glasses 29 fluorescent tubes 2 bulbs	5176 cans 2 drums
Average daily amount	7.3 boxes	8.4 holders 3.8 crisp packets 0.4 bags	5.6 bottles 0.1 glasses 0.6 tubes	117.6 cans
Average daily amount per person	0.2 boxes	0.3 materials	0.2 bottles	3.2 cans

*370 holders account for 43% of the cans.

†245 bottles includes 107 small 'Schweppes' bottles and caps, and 138 large spirit bottles and caps.

Other items included: 25 plates, 1 cup, 35 potato sacks (natural fibre), 4 onion sacks (man-made fibre), 1 mop, 2 plastic ashtrays, 1 tupperware container, 1 air filter, 1 rubber mat, 6 plastic bags and 1 bucket of oily rags and engine-room waste, 14 boxes of wafers (wrapped in plastic), 4 heavy duty plastic crates, 1 cassette tape and 1 plastic ice-bucket lid.

The results in Table 4 show that more cans are dumped at sea than any other containers. The majority of the counted plastic material were the can holders. More plastic was dumped which it was not possible to count. For example the majority of the boxes were wrapped in plastic. Frozen food packets were disposed of in the 312 buckets of waste that were not counted.

Using the figures from Tables 2 and 4: every day each person afloat dumps between 3.2 and 6.2 metal, between 0.2 and 0.3 glass, and 0.3 plastic containers in the sea. Lloyd's register in 1979 lists 71 000 merchant ships in the principal fleets of the world. Assuming 30 people per ship, the 6 816 000 metal, 426 000 glass and 639 000 plastic con

Not all 71 000 ships are afloat at the same time, but there are many ships that are not included in the Lloyd's register, for instance, naval vessels which carry large numbers of people. Thirty people per ship is a conservative number when considering the passenger ships and the number of 'conventional' ships still operating with old-style large numbers of crew.

Each of six British merchant ships during their voyages ignored or did not know about the IMCO regulations regarding the dumping of garbage. The 12 and 25 nautical miles limits were constantly disregarded. On three occasions sailing through the Mediterranean Sea, the vessels continued to dump garbage. Another ship dumped 348 cans, 54 plastic materials and 33 bottles in three days sailing between the North Queensland coast and the Great Barrier Reef. This is against the IMCO regulations which defines this area as 'nearest land' (IMCO, 1973).

Hazards

Apart from the aesthetic point that garbage dumped from ships is spoiling beaches (Dixon & Cooke, 1977), and coral reefs (personal observation on the Barrier Reef), there are hazards to man and wildlife. The tear-off lids from metal cans are a common cause of cut feet amongst bathers (Dixon, 1978). These lids could damage fish, which have also been reported to have swallowed plastic cups (Anon, 1975). Fragments of nylon netting have proved fatal to seabirds which become entangled (Bourne, 1977). It is feasible that the plastic can holders and man-made fibre loose sacking could pose a similar problem. I have observed large sheets of plastic being dumped at sea. Turtles have been observed swimming with plastic sheeting wrapped around their shells (Morris, 1980; personal data from the marine archives at Bracknell).

Conclusions

It appears that the IMCO regulations are not enough to stop this form of pollution. Ships generally do not have disposal units so the people on board have no choice but to dump rubbish at sea. The regulations should require:

(a) that shipping companies, owners and suppliers ensure that the vessels do not take on board any material which IMCO regulations prohibit dumping at sea; i.e. plastic.

(b) that ships be supplied with efficient disposal units. These do not usually deal with metal containers (Perry, 1981). Supplying ships with keg beer, and/or bulk containers of other drink, e.g. soft drinks, will go a long way to reducing can waste. Recycling depots at ports should be provided to take the rest. It would be a relatively simple matter to store crushed cans on board until the ship reaches port.

Regulation 7 of the IMCO conference report in 1973 states:

"(1) The Government of each party to the Convention undertakes to ensure the provision of facilities at ports and terminals for the reception of garbage, without causing undue delay to ships, and according to the needs of the ships using them.

(2) The Government of each party shall notify the Organization for transmission to the Parties concerned of all cases where the facilities are alleged to be inadequate."

At 26 ports in 15 countries these facilities were not provided adequately. In several ports the only facility is a barge which when full is towed out to sea where the rubbish is dumped.

The responsibility should be with shipping companies, owners and suppliers to ensure that ships stop this needless pollution of the sea.

My thanks to the officers and crews of several merchant ships for assisting me with this work.

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Man-made Objects on the Surface of the Central North Pacific Ocean

IN August 1972, on the Scripps Institution of Oceanography's expedition C'BOG 1 in the Central North Pacific, there was a rare combination of clear warm weather and calm seas which tempted the scientific personnel to spend their leisure time on the bow of the ship. From this vantage point it was obvious that the sea surface is littered with a startling array of man-made objects, even 600 miles from the nearest major civilization (Hawaii) and outside the major shipping lanes.

A junk log was established and maintained (not continuously) for four days, during which time the ship travelled from 34° 29′ N, 145° 36′ W to 35° 00′ N, 155° 00′ W, and then south to 31° 00′ N, 155° 00′ W. Record was kept of the duration of watch, ship's speed and viewing conditions, and an effort was made to categorize each object, even though exact identification was often uncertain.

The results of this log are presented in Table 1. During 8.2 viewing hours during which time the ship travelled 156 km, and in approximately 12.5 km², a total of 53 man-made objects was recorded. Twelve of these were glass fishing floats, approximately 5 to 14 inches in diameter, which may claim some historic or aesthetic place on the sea surface. The remaining 41 objects were encountered with an average frequency of one every 12 minutes. At least two-thirds of these were plastic.

Succumbing to the temptation to extrapolate from our sample of six plastic bottles, we have calculated an average concentration of 0.5 bottle km^{-2} (95% confidence interval, assuming a Poisson distribution: 0.2–1.0 bottle km^{-2}) and a total of 35.4 million plastic bottles (14.2×10^6–70.8×10^6) currently adrift in the North Pacific Ocean (as well as 5.9 million red rubber sandals). A more conservative estimate may be derived from the observed ratio of plastic bottles to fishing floats, of which there are an estimated ten million afloat in the Pacific Ocean[1]. Our ratio predicts five million plastic bottles.

Table 1 Tentative Identification of Man-made Objects adrift in the Central North Pacific Ocean

Plastic		Glass		Miscellaneous	
Bottles	6	Fishing floats	12	Rope	1
Fragments	22	Bottles	4	Old balloon	1
Total	28	Total	16	Finished wood	1
				Shoebrush	1
				Rubber sandal (red)	1
				Paper items	3
				Coffee can	1
				Total	9

On two of the plastic bottles, algal growth was evident. A third was covered with gooseneck barnacles. Floating plastic, like a glass fishing float, provides a long-lived substrate for transport of sessile animal species as well as algal and bacterial growth; whether the increased availability of such "micro-arks" might alter distributional patterns or attract local concentrations of associated pelagic organisms is an open question.

In the growing concern over global pollution, the accumulation of plastic products has received little attention. Widespread concentrations of plastic pellets have been reported in the Sargasso Sea[2]. Although plastic objects may directly injure wildlife[3], the inert nature of plastic means that it is unlikely to enter the food chain and threaten human welfare. As a pollutant, its effect is chiefly aesthetic, which is difficult to evaluate and easy to ignore. We find it alarming that "disposable" items now litter even the most remote surfaces of the oceans.

The production of plastics has evolved rapidly during the past twenty years—annual production of plastic bottles now exceeds 3×10^9. The development of degradable plastics may bring some relief[4], but unless we find adequate means of disposing of our plastic products soon, we can anticipate that the "Wynkin, Blynkin and Nod" of our children will set sail into a plastic sea, accompanied by all the "no-deposit—no-return" products of our technology.

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Induced Nucleophilic Substitution in Benzo[a]pyrene

Cavalieri and Calvin have proposed[1,2] that the carcinogenic action of benzo[a]pyrene (BaP) may arise from aryl hydroxylase induced binding to nucleophilic cellular components. Their theory proposes that attack by electrophilic oxygen, produced in the hydroxylase system, occurs at the 6 position of the hydrocarbon to give a carbonium ion, localized primarily at the 1 and 3 positions, which can undergo attack with nucleophilic cellular components. Alternatively, initial attack could occur at 1 or 3, followed by nucleophilic reaction at 6.

Some evidence for the theory has been obtained by using iodonium ion as a model for the hydroxylase system. Benzo[a]pyrene and iodine dipyridine nitrate react to give either the 6-iodo or 6-pyridinium derivative or a mixture depending upon reaction conditions. Effects of solvent, concentrations and ratios of reactants were investigated and are summarized in Table 1. Equimolar quantities of the reagents react within 10 min in chloroform to give 6-iodo-benzo[a]pyrene in nearly quantitative yield. All other reactions listed required up to 24 h to reach completion. Formation of the pyridinium derivative requires a 2 : 1 molar ratio of iodonium reagent to BaP.

Table 1 Effect of Reaction Variables on Product Formation

Concentration of BaP	Molar ratios py/BaP*	Molar ratios (py-I-py)†/BaP	Solvent	Yield, % I-BaP	Yield, % py-BaP
		1	$CHCl_3$	99	Trace
		1	MeOH	95	
		1	DMF	95	
			Pyridine	No reaction	
1 mg $ml.^{-1}$	32	2	1% py/$CHCl_3$	50†	50†
0.5 mg $ml.^{-1}$	64	2	1% py/$CHCl_3$		95
5 mg $ml.^{-1}$	30	2	5% py/$CHCl_3$		95
5 mg $ml.^{-1}$	30	1	5% py/$CHCl_3$		50
1 mg $ml.^{-1}$		2	CH_3CN		10

* Added pyridine.
† Approximate yields.

The formation of the 6-pyridinium derivative may be interpreted as arising *via* the proposed ionic mechanism with initial electrophilic attack occurring at position 1 or 3 rather than at position 6 as occurs in the formation of 6-iodobenzo[a]pyrene. The position of attack might change for steric reasons because different reagents could be involved as indicated by the following equilibria:

$$(py\text{-}I\text{-}py)^+ \rightleftharpoons (py\text{-}I)^+ + py \rightleftharpoons I^+ + 2\,py$$

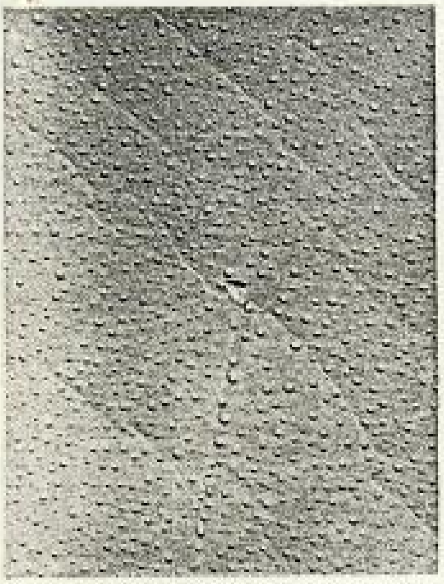

Fig. 2. Electron micrograph of wax particles generated from a pine needle at 20 kv (the torn area in the center is 0.7 μm long).

from the cuticle only while a leaf is growing (*5*), and, because of the lack of seasonal variation in wax composition (*6*), the wax coating apparently is not further affected by the plant metabolism (*7*). Although the wax layer on the tips of some pine needles is relatively smooth, other needles of comparable age from the same or from another pine tree may exhibit shapes similar to those shown in Fig. 1 (*Pinus echinata*). Wax fingers are also found on other species of trees. The tips exhibiting the elongated wax fingers tend to be in exposed areas such as on the tops of trees, on the outside of a lone tree, or on the margin of a stand. Melting of the wax cannot be invoked as an explanation for the observed configuration for several reasons, chief among which is that the tips point upward.

It is suggested that the wax fingers represent the preserved record of a conduction path which became molten during the atmospheric phenomenon usually referred to as brush discharge. To test that hypothesis, pine needle specimens were mounted on one of a pair of electrodes in a closed system and subjected to various electrical gradients in the laboratory. In each case carbon-coated disks were attached to the opposite electrodes, and the collected particulates were replicated and examined with an electron microscope. Particles collected when the pine needle was raised to a potential of 20 kv with respect to a flat plate 20 cm away are shown in the electron micrograph (Fig. 2). At lower potentials the particles were similar in size but less concentrated, whereas at 30 kv the wax fingers began to shatter and irregular strips and chunks were collected. The small wax particles released under low to moderately high potential gradients have diameters in the size range < 0.6 μm; particles in this size range may be a major factor in the production of blue haze.

Chalmers (*8*) has measured a significant conduction current passing through a small tree. The local, flat-field potential gradient easily can reach several thousand volts per meter as electrified clouds pass overhead; in an electrical storm gradients much higher than this may be recorded. These observations suggest that discrete wax particles in the appropriate size range to produce blue haze are generated by natural forces in the environment. Other types of vegetation, including grasses, could, in principle, emit wax particles under similar conditions. In the brush discharge phenomenon, high potential gradients occur at the sharp edges and tips of leaves, producing a blue glow at night. Undoubtedly, such factors as the dielectric strength of the wax, its melting point, the ambient temperature, the radius of curvature of the underlying conductive surface, and the exposure of the plant all have some bearing on the rate of production of wax aerosols. Other extrinsic factors, such as gaseous or particulate air pollutants, may affect the properties of the wax so as to reduce or enhance the rate of wax attrition, possibly leading to the denudation of the needle tip and the eventual loss of the needle because of excessive drying.

Went (*2*) has suggested that the blue haze aerosols, returned to the ground by various natural processes, may be a source of the petroleum formed in earlier geological periods. The presence of significant quantities of waxes in crude oil and the observation of a mechanism for the generation of wax aerosols in the environment suggest that the wax particles, which may serve as condensation nuclei for terpenes and other organic gases, may be a complementary factor in the phenomena described by Went. Another implication is that radioactive fallout collected on the sharp edges and tips of vegetation may be reemitted to the atmosphere during the next thunderstorm after its initial deposition. In this same connection, particulate silver iodide from cloud-seeding operations may be retained locally for a period of time and be reentrained into an unseeded cloud, producing the "memory effect" that has been observed by some atmospheric scientists (*9*).

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22 November 1971

Plastics on the Sargasso Sea Surface

Abstract. *Plastic particles, in concentrations averaging 3500 pieces and 290 grams per square kilometer, are widespread in the western Sargasso Sea. Pieces are brittle, apparently due to the weathering of the plasticizers, and many are in a pellet shape about 0.25 to 0.5 centimeters in diameter. The particles are surfaces for the attachment of diatoms and hydroids. Increasing production of plastics, combined with present waste-disposal practices, will undoubtedly lead to increases in the concentration of these particles. Plastics could be a source of some of the polychlorinated biphenyls recently observed in oceanic organisms.*

While sampling the pelagic *Sargassum* community in the western Sargasso Sea, we encountered plastic particles in our neuston (surface) nets. The occurrence of these particles on the sea surface has not yet been noted in the literature [we also collected petroleum lumps which have received attention (*1, 2*)].

The plastics were collected with a neuston net (3), 1 m in diameter with 0.33-μm meshes, towed at 2 knots (1 knot = 1.85 km/hour) on cruise 62 of the *Atlantis II* (27 September to 18 October 1971). The particles of plastic were manually sorted from the contents of the neuston tows; they were counted and their weights were determined on shore with a Mettler H 15 balance. Plastics were present in all 11 neuston tows (Table 1). Their occurrence was widespread, since the distance from the southernmost to the northernmost tow was 1300 km.

There were, on the average, about 3500 plastic particles per square kilometer (the range was from 50 to 12,000). This density gives a mean of one particle per 280 m^2 and a maximum of one particle per 80 m^2. The weight per square kilometer was from 1 to 1800 g and averaged about 290 g. The lowest concentrations were observed at stations 10 and 11, as we began to enter the Gulf Stream.

Most of the pieces were hard, white cylindrical pellets, about 0.25 to 0.5 cm in diameter, with rounded ends (Fig. 1). Chemical weathering and wave action may have produced the pellet shape. Many pieces were brittle, which suggests that the plasticizers had been lost by weathering. Some had sharp edges, which indicates either recent introduction into the sea or the recent breaking up of larger pieces. A few particles (6 percent by number) were colored green, blue, or red, and there were also a small number of clear sheet plastics. Several larger pieces could be identified as a syringe needle shield, a cigar holder, jewelry, and a button snap. From the variety of identifiable objects, it was evident that many types of plastics were present. Solvent assays and burning properties of some of the white pellets indicated that they were not polystyrenes, acrylics, or polyvinyl chlorides.

Most plastics had populations of hydroids and diatoms attached to their surfaces. We noted the hydroids *Clytia cylindrica* and *Gonothyraea hyalina* and the diatoms *Mastogloia angulata*, *M. pusilla*, *M. hulburti*, *Cyclotella meneghiniana*, and *Pleurosigma* sp. With the exception of the last, these species have previously been observed on pelagic *Sargassum* (4). Hydroids and diatoms have not been reported on petroleum lumps, whereas goose barnacles *(Lepas)* and isopods *(Idotea)* have (1).

The source of the particles may have been the dumping of waste from cities or by cargo and passenger ships. However, no metropolitan dumping occurs in the areas sampled, although some of the southernmost sample areas are within major shipping lanes from Europe to Central America and the Panama Canal. The station closest to land, station 6, was 240 km northeast of Bermuda. Stations 10 and 11, the closest to the continent, were about 900 km southeast of New York City.

Plastics have been produced in large quantities only since the end of World War II. The increasing production of plastics, combined with present waste-disposal practices, will probably lead to greater concentrations on the sea surface. At present, the only known biological effect of these particles is that they act as a surface for the growth of hydroids, diatoms, and probably bacteria.

Many plastics contain considerable concentrations of polychlorinated biphenyls (PCB's) as plasticizers. If the plasticizers have been lost to seawater, as suggested above, the incorporation of PCB's by marine organisms is possible. Polychlorinated biphenyls have recently been observed in pelagic *Sargassum* and oceanic animals (5).

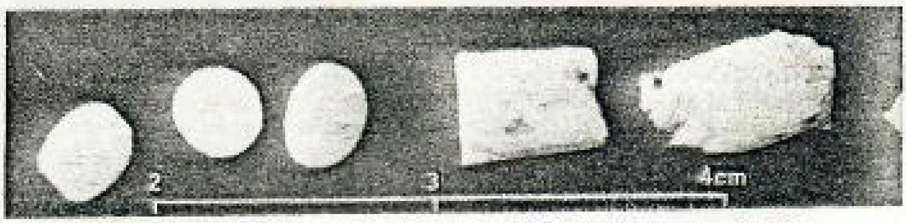

Fig. 1. Typical plastic particles from tow 2. White pellets are on the left.

Table 1. Neuston tow data.

Tow number	Date (October 1971)	Towing time (hours)	Location at start	Number collected	Weight collected (g)	Concentration Number/km^2	Concentration g/km^2
1	12	2.25	30° 10.5'N 60° 02.5'W	5	0.31	601	37.7
2	12	2.66	30° 19.4'N 60° 00.9'W	48	2.48	4,877	251.9
3	12	4.08	30° 55.6'N 59° 57.1'W	22	1.06	1,457	70.2
4	13	1.00	31° 51.7'N 60° 37.8'W	4	0.22	1,081	60.0
5	13	0.50	32° 25.2'N 61° 14.6'W	8	0.73	4,324	395.1
6	14	6.50	33° 32.5'N 62° 30.9'W	62	2.48	2,579	103.3
7	14	0.85	34° 21.8'N 62° 53.0'W	38	5.57	12,080	1,770.7
8	15	1.00	35° 15.4'N 63° 46.3'W	17	0.96	4,595	258.9
9	15	0.85	35° 37.4'N 64° 20.8'W	22	0.64	6,994	201.9
10	16	1.00	37° 02.0'N 65° 41.0'W	1	0.22	270	4.9
11	16	5.75	37° 00.5'N 65° 34.8'W	1	0.08	47	0.6
					Mean	3,537	286.8

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Star-Bulletin Monday, October 12, 1987 • B:1

TODAY Features and Entertainment

Marine debris is killing wildlife. It's time to ...

'GET THE DRIFT AND BAG IT!'

Seals die from becoming entangled in ocean debris, such as discarded fishing gear. A turtle, above, died as a result of starvation. The bottle to swallow food.

By Susan Manuel
Star-Bulletin writer

MANY people who love or live off the ocean act as though it's a bottomless pit as they blithely toss beer cans, damaged nets and ice bags overboard.

These same people may be horrified at pictures of northwestern seal kills, where herds of pups are bludgeoned to bloody pulps.

But the two scenes aren't that far apart.

Endangered sea turtles mistake plastic ice bags for jellyfish and eat them. The bags get caught in the turtles' throats or lodge in their stomachs.

"They either die from suffocation or from a false feeling of being full. They die of starvation," says Pacific Whale Foundation spokeswoman Kristy Kaufman.

Monofilament line cuts through turtle flippers. Emaciated sea animals, tangled in trawl netting and lines, are brought to Sea Life Park to recover. Hawaiian sea birds carry stomachloads of strange plastic objects.

According to a U.S. House subcommittee report, about 1 million sea birds and 100,000 marine mammals are killed annually by choking on or wrapping in plastic debris.

The fishing industry is the major culprit, but in Hawaii, residents who spend happy days relaxing on the ocean are casting out garbage that kills and doesn't degrade.

"We're a civilized world. It's just boggling," says Clyde Morita, coordinator for the Community Work Day Program's "Get the Drift and Bag It." The cleanup takes place on beaches on the four major islands Saturday.

Hawaiian monk seals, of which only 1,000 to 1,500 exist in the Northwest Hawaiian Islands, get trapped in lost or abandoned fish nets carried here by currents from the north Pacific and settling in clumps on reefs.

An agent stationed on the islands has released nearly 30 entangled seals since 1982 when the fisheries agency became aware of the problem. Three seals have been found dead in nets, one in 1986, two this year. More are seen scarred. Other seals are necklaced with plastic packing bands or muzzled with plastic rings. One was wandering around in a life jacket.

Young seals who've just finished their five-week nursing seem most susceptible. They get into the garbage while weaning in the shallows, learning to feed and explore their environment.

Whales get hung up, too. A humpback recently dragged a buoy through the Hawaiian islands; and gray whales off Southern California have pulled similar handicaps from Alaska.

Small pieces of Styrofoam, plastic packing pellets, plastic beebees used as ball bearings on ships are turning up on Hawaii shores and in the stomachs of sea birds and turtles.

Tourists are becoming disenchanted particularly on the East Coast, where beaches are strewn with plastic junk.

"You see a plastic milk bottle float by or a beer can on a scuba dive — this is something that reduces the qualities we have out here, for tourists and the rest of us," says Terry O'Halloran, president of the Ocean Recreational Council of Hawaii.

The detritus isn't always deadly. Hawaiian sea birds can eat an incredible assortment of plastic objects and thrive in spite of them, according to a study soon to be published by the National Wildlife Health Research Center in Madison, Wisc.

BIC cigarette lighters, and toy poodles, guns and soldiers were regurgitated after investigators pumped water into the stomachs of 16 species of captured sea birds during field studies last year in the Northwest Hawaiian Islands. They found plastic things in 14 species and in every albatross chick examined.

"We're a civilized world. It's just boggling."

— Clyde Morita, project coordinator

Plan to go?

Volunteers are needed **Saturday, from 8:30 a.m. to noon,** to meet at various beaches and **collect debris as part of the 22-coastal state "Get the Drift And Bag It" campaign.**

Data from the cleanups will be sent to the National Marine Fisheries Service as evidence to promote national and international anti-marine pollution legislation.

Participants are urged to call ahead to register and determine time and location from their county coordinators.

For more information:

- **On Oahu,** call the Community Work Day Program, 548-6444 or State Litter Control Office, 548-3400.
- **In Hilo,** call the Department of Parks and Recreation, 961-8311.
- In Kona, BIORTA/TORCH, 329-7585.
- **On Maui,** the Pacific Whale Foundation, 879-8811.
- **On Kauai,** the Mayor's Beautification Task Force, 742-9142.

Photos courtesy of Community Work Day Program

rim encircling his neck became too tight for it

The plastic that chicks swallowed came from adult birds who feed their young by regurgitating food. The stuff stays in the chick's stomachs for months, until the chicks are strong enough to throw up boluses full of toys.

A few birds were killed by objects puncturing or filling their stomachs, "but we have no significant mortality," said the study's field investigator Paul Sievert. "They're amazingly resilient."

"Aesthetically, it's a problem. All these remote islands, the shores are littered with plastic. It's really a sad statement on how man treats the environment."

National Marine Fisheries agents at Kure Atoll found over 2,000 pounds of netting in a single summer. Eighty percent is from trawlers; 15 percent are monofilament gill nets.

"We don't know how much is lost and how much is intentional," says marine biologist John Henderson of the National Marine Fisheries Service.

The fishing industry is both supportive of controls and dubious of their enforcement.

"The public's under the impression fishermen throw away huge amounts of fishing gear," says Jim Cook, owner of Pacific Ocean Producers on Pier 35. "No one can afford to throw away fishing gear. Some gets lost. Most of it is plastic."

Fisheries officials realize that if commercial boats were required to bring home all the nets and garbage they throw off, small ports would be inundated.

But a partial solution will soon be mandated by international law, after the United States signs a treaty banning the dumping of plastic in the ocean. Half the nations representing the world's shipping tonnage must sign Annex V of the MARPOL convention for it to become law. MARPOL, or the International Convention for the Prevention of Pollution from Ships, administered by the London-based International Maritime Organization, already bans dumping oil and bulk chemicals at sea.

See DEBRIS, Page B-3

"This is something that reduces the qualities we have out here, for tourists and the rest of us."

— Terry O'Halloran, Ocean Recreational Council of Hawaii

DEBRIS: It's time to 'Get the drift and bag it!'

Continued from Page B-1

The Soviet Union signed Annex V in July, leaving the United States the only roadblock. But plastic pollution on East Coast beaches is so bad, threats to tourism helped convince members of Congress to press for passage, and the Senate Foreign Relations Committee approved a bill Sept. 25.

Annex V is a "step in the right direction, but not a panacea," says Alan Reichman, ocean ecology coordinator for Greenpeace International in Seattle.

Enforcement will be the problem. Some U.S. officials want ships to use a "garbage logbook" showing how and where garbage was disposed. But one fishing supplier here said fishermen see the ocean as a daily battleground, to which they owe little respect.

"I don't think they'd have a problem bringing it back," he said. "Whether they will bring it back is another question."

"I don't think they're gonna (comply)," agreed fisherman Fritz Amtsberg, skipper of the Ipokai, docked last week at Kewalo Basin.

Amtsberg was to join commercial fishing representatives from Japan, Taiwan, South Korea, Canada and the United States in Kona this week (Oct. 13-16) at the National Conference on Marine Debris. The fishing industry will be creating guidelines to keep plastic out of the water and to help ports get rid of it.

The industry is taking the lead in cleaning the northern Pacific, partly for reasons of self-interest.

"I don't like anything that will kill sea life, and I don't like anything that will jeopardize my goal," says Amstberg. "I don't like gill nets (which kill everything they engulf) and I don't like big pieces of webbing that will get caught in my propellor."

But Amstberg, in the middle of unloading a 17,000-pound ono catch, says he has "mixed emotions" on the pollution issue. He caught much of that record haul close to a large section of Japanese gill net that was acting as a refuge for live bait.

He also uses fish aggregate buoys, bundles of garbage that draw in fish: "One man's trash," Amstberg says "is another man's treasure."

"I just drove 2,000 miles. I think I saw one plastic soap thing and one to two Styrofoam cups. I don't advocate peppering the ocean with Styrofoam cups. The problem with nets is they're an indiscriminate way of fishing. You can't confuse that with ocean pollution."