SOUTHWEST FISHERIES CENTER

HONOLULU LABORATORY

2570 DOLE STREET

HONOLULU, HAWAII 96822-2396

NATIONAL MARINE FISHERIES SERVICE

November 1987

AN EXPERIMENTAL STUDY OF DERELICT GILL NETS IN THE CENTRAL PACIFIC OCEAN

Tim Gerrodette, Barry K. Choy, and Lisa M. Hiruki
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96822-2396

NOT FOR PUBLICATION

ADMINISTRATIVE REPORT H-87-18

This report is used to insure prompt dissemination of preliminary results, interim reports, and special studies to the scientific community. Contact the authors if you wish to cite or reproduce this material.

Southwest Fisheries Center Administrative Report H-87-18

AN EXPERIMENTAL STUDY OF DERELICT GILL NETS IN THE CENTRAL PACIFIC OCEAN

Tim Gerrodette, Barry K. Choy, and Lisa M. Hiruki
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, HI 96822-2396

November 1987

NOT FOR PUBLICATION

INTRODUCTION

The amount of debris in the world ocean is a matter of increasing concern. Several conferences (Shomura and Yoshida 1985) have been held in recent years to address the problem, and the National Marine Fisheries Service (NMFS) has established a program (Coe and Bunn 1987) to coordinate research, public awareness, and mitigation efforts.

One source of marine debris is fishing operations. The amount of fishing gear in use is staggering. For example, considering only gill nets in the North Pacific, at least 180,000 km of net is available to the various gill-net fisheries (Chen 1985; Gong 1985; Shima 1985; Uchida 1985), an amount that would stretch 4 1/2 times around the Earth. (This figure is conservative; it does not include gill net in the coastal fisheries of Korea and Taiwan.) Even if only a small percentage, e.g., 0.05% (Komatsu[1]), is lost in the course of these fishing operations, 90 km of gill net would enter the North Pacific Ocean every time these nets are used. Gill nets may be lost as a result of storms, cut adrift by a ship crossing the float line, or discarded overboard after being damaged. Such derelict gill nets are a cause for concern because they may 1) continue to catch fish, leading to waste of marine resources and inaccurate estimates of fishing mortality; 2) present a hazard to navigation by fouling ships' propellers; and 3) ensnare and kill such nontarget species as seals, dolphins, whales, turtles, and seabirds.

The impact a piece of derelict gill net will have depends on its size, shape, location, and length of time in the ocean. This paper reports the results of experiments designed to investigate some of these questions. Specifically, the objectives of the study were to measure the change in shape of derelict gill-net fragments of various sizes over time, to determine the fishing ability of derelict gill nets of known age, and to track the movement of drifting net fragments for periods up to 1 yr.

METHODS

Thirty sections ("tans") of used, 113-mm monofilament gill net of the type used in the Japanese high-seas squid fishery were purchased from Kyoei Unyu Company, Ltd., of Hakodate, Japan. Each section measured 50 m long and 9 m deep, with floats at 1-m intervals. Sections were joined together to make four nets of lengths 50, 100, 350, and 1,000 m.

---

[1]M. Komatsu. Statement of Masayuki Komatsu, International Affairs Division, Ministry of Agriculture, Japan Fisheries Agency. [Presented at the public hearings before the National Marine Fisheries Service on the take of marine mammals incidental to commercial salmon fisheries operation, MMPAH-1986-01, 7 p.]

Attached to each of the four nets was a small, dual-frequency, radio-satellite transmitter buoy (Fig. 1), designed by Telonics of Mesa, Arizona. The buoy, 90 cm in length and 9 cm in diameter, allowed tracking and potential recovery of each net. The UHF satellite transmitter portion of each buoy used the Argos system (Argos 1984) to give a location on the Earth's surface, accurate to within several hundred meters. The satellite transmitter broadcasted on a schedule of 24 h on, 72 h off; a series of locations was, therefore, available once every 4 d. The VHF radio transmitter portion of each buoy allowed close-range directional tracking and recovery within a radius of approximately 10 km. The radio transmitter broadcasted once a second without interruption. The combination of long- and short-range location systems was designed to allow physical recovery of the buoy and net after drifting freely in the ocean for up to 18 mo.

To reduce windage and to avoid accidental discovery by fishermen or others, the buoy also was designed to be as inconspicuous, both visually and electronically, as possible. The buoy projected only 25 cm above the ocean's surface. Further, the megahertz frequencies transmitted by the buoy's location systems were beyond the kilohertz frequencies commonly used in ships' radio direction finders (RDF's) for locating buoys.

The nets and their associated buoys were deployed on 12 August 1986 about 10 km east of Southeast Hancock Seamount, northwest of the Hawaiian Archipelago, from the NOAA ship Townsend Cromwell (Table 1). The nets were deployed by letting the ship drift downwind; hence, all nets were initially set parallel to the wind with the transmitter buoy at the downwind end. Measurements of net heading, length, and catch were made three times a day for 3 d from an inflatable boat. A temporary buoy was attached to one end of the net to serve as a visual target; from the other end, heading was then measured with a hand-held bearing compass, and length with an optical range finder. The configuration of each net was sketched. The longest (1,000-m) net was surveyed in a similar way, except that several visual targets were placed along its length, and measurements made in sections. Catch and fish aggregation around the nets were monitored by snorkel or scuba diving and documented photographically with video and 35-mm cameras.

Observations and measurements of the nets were confined to daylight hours. To track the nets during the night, larger buoy systems were attached to some nets each night and removed the next morning. Such a system consisted of a large RDF transmitter buoy; a long bamboo pole buoy with strobe light on top and large inflatable float; and a small, round, plastic buoy at the end of a tag line. The whole system had considerable windage. Because such a system probably affected a net's dynamics, the periods during which a large transmitter buoy system was attached to a net were considered in the interpretation of the results. The small radio-satellite transmitter buoys (Fig. 1), which were attached to the nets at all times, were considered to have negligible effects.

On the 10th day after deployment, the Cromwell returned and relocated all four nets. Rough seas, however, prevented launching a small boat, and the nets had to be observed from the deck of the Cromwell. After the cruise, the buoys were tracked by satellite until each buoy was either recovered or the signal from the satellite transmitter was lost. Positions were determined from monthly reports of Service Argos, Toulouse, France.

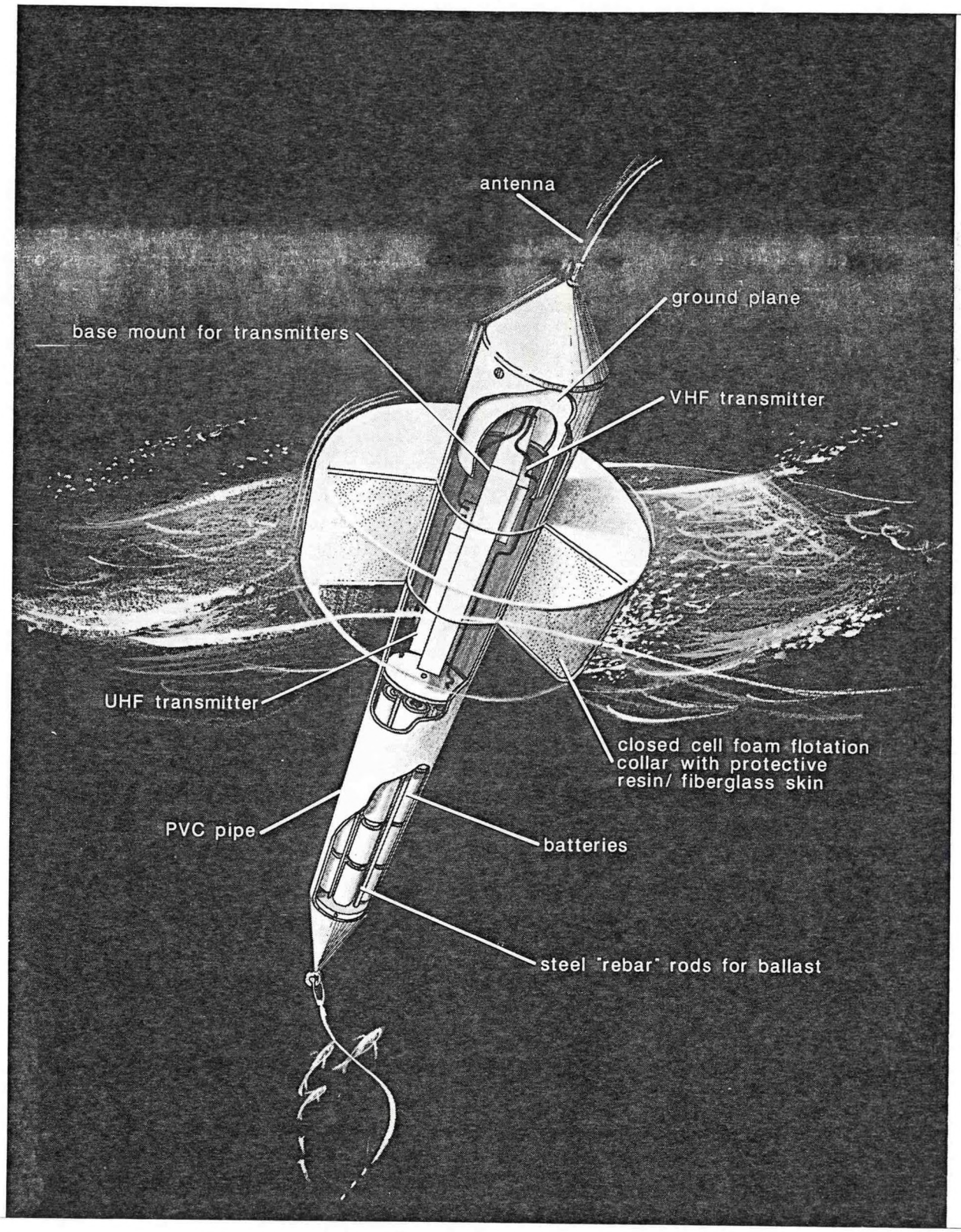

Figure 1.--Dual-frequency transmitter buoy used to track and recover experimental gill nets.

Table 1.--Experimental gill-net deployment on 12 August 1986 and tracking in the central Pacific Ocean. Dates and times are Midway standard time.

Buoy No.	Net length (m)	Deployment			Recovery			Days tracked
		Time (h)	Latitude	Longitude	Date	Latitude	Longitude	
10013	50	0841	29°46.7'N	179°10.3'E	3 Nov 86	28°48.9'N	176°57.6'W	83
10010[a]	100	0945	29°46.8'N	179°09.8'E	7 Jan 87	28°14.2'N	178°13.2'W	148
10011[a]	350	1226	29°47.0'N	179°08.6'E	8 Oct 86	29°35.2'N	176°18.9'W	57
10012	1,000	1330	29°47.6'N	179°08.0'E	17 Jun 87	23°00.1'N	178°00.0'E	309

[a]Buoy was not recovered; recovery data reflect time and location at which the signal was lost.

RESULTS

Shape and Heading

During the first 3 d, fair weather and calm seas greatly aided tracking and observation of the nets. Wind was east-southeast during this initial period, but shifted to east-northeast on the second and third days and rose slightly in strength (Table 2). The nets first drifted north-northwest, then north-northeast, traveling about 9 km/d.

Table 2.--Summary of wind and swell observations on 12-14 August 1986, the first 3 d of the gill-net experiment. Data are means calculated from the ship's hourly weather log.

Date	Time (h)	Wind		Swell	
		Speed (kn)	Heading	Height (ft)	Heading
12 August	0100-1200	9	116°	3	121°
	1300-2400	11	115°	3	116°
13 August	0100-1200	10	100°	3	118°
	1300-2400	14	70°	4	98°
14 August	0100-1200	13	74°	3	88°
	1300-2400	13	68°	4	83°

The 50- and 100-m nets shortened soon after deployment (Fig. 2). The 50-m net, in fact, had already collapsed by the time of the first observation, 30 min after deployment. "Collapsed" means that the net was folded like an accordion and all floats were close together. The net, however, was still hanging freely in the water; it was not tangled with itself.

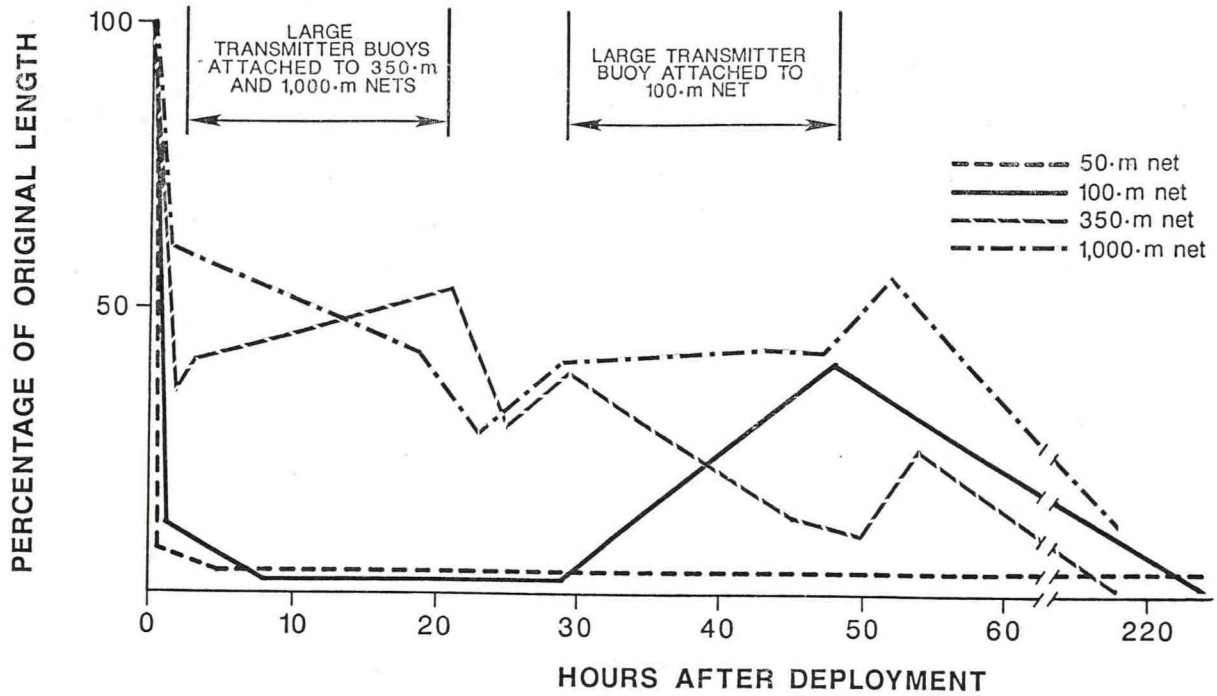

Figure 2.--Percentage of original lengths of four experimental derelict gill nets over time. By the 10th day after deployment, all experimental nets except the longest were collapsed. During the first and second nights of observation, large transmitter buoys attached to certain nets may have affected net lengths.

The 350-m net contracted to about 40% of its original length during the first few hours, but then contracted more slowly (Fig. 2). By the 10th day, it had collapsed completely. The rate of collapse of this net may have been affected by the large transmitter buoy attached to the downwind end during the first night. The net was slightly longer the next morning (observation at 21 h). After removal of the large buoy system, the net further contracted (25 h) but was longer in the evening (29 h). The next day, the net followed a similar pattern, contracting between morning and afternoon and lengthening by evening. Greater detail of the changes in configuration of this net is shown in Figure 3A. Interestingly, the net rotated so that its heading 50 h after deployment was approximately 140° from its original heading.

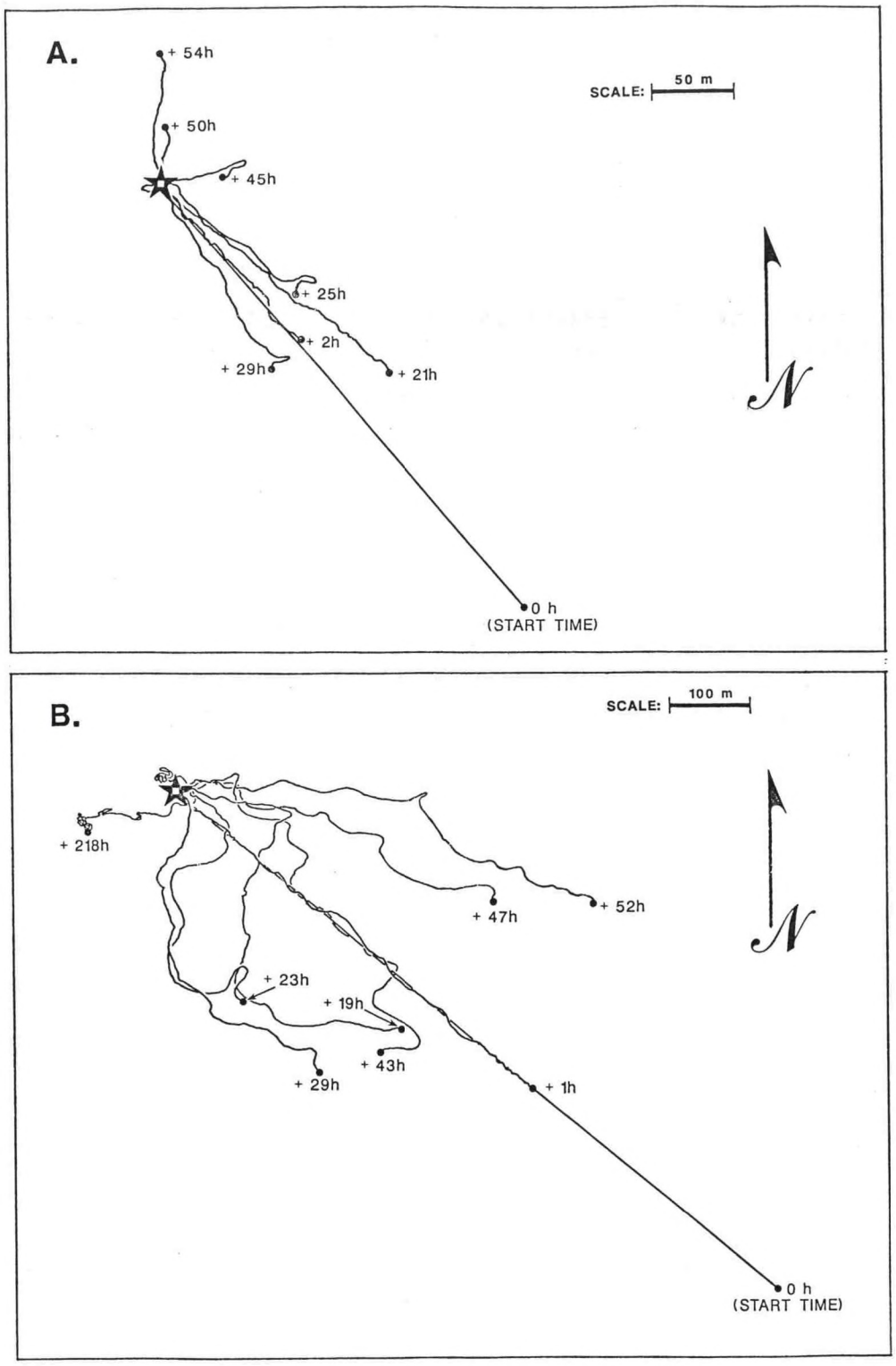

Figure 3.--Shape and heading of two experimental derelict gill nets at various points in time after deployment. The original windward end of the net (without the transmitter buoy) was placed at the origin (☆) of each sketch. A) 350-m net. B) 1,000-m net.

The 1,000-m net followed a pattern of contraction and expansion similar to the 350-m net, except that its relative size 52 h after deployment was twice as big (i.e., about 50% of original length instead of 25%) (Fig. 2). The 1,000-m net also rotated in the same direction as the 350-m net, but only by about 30° during the same period. By the 10th day (218 h), its heading had changed completely (Fig. 3B).

Catch

Very little was caught in any of the gill nets during the initial 3 d of observation. On the morning of the second day, a small marlin (Makaira sp.), about 1 m total length, was entangled in the 1,000-m net at the surface. On the third day, a large flyingfish (Exocetidae) was similarly caught in the same net. None of the other nets had any animals entangled in them by the end of the third day. Three small kahala (Seriola sp.) were observed swimming around the 350-m net on the second day, and one opelu (Decapterus sp.) and three small kahala, possibly the same three, were seen around the 1,000-m net on the third day. Soon after the nets were deployed, several albatross (Diomedea sp.) landed on the water near the float line, but each left after a short investigation.

After 10 d, nothing was visible in the 50-, 100-, or 1,000-m nets, although one mahimahi, Coryphaena hippurus, was swimming near the latter. The floats of the 350-m net were in a tight group with numerous small kahala swimming nearby. A rotting, 2-m shark of undetermined species was entangled in the net, together with several bony fish too rotten to identify.

Location

The location of each net during the entire course of the study, plotted once every 4 d, is shown in Figure 4. The number of days the buoys were tracked ranged from 57 to 309 (Table 1). The buoys and nets stayed in the general vicinity of the northwestern end of the Hawaiian Archipelago. For several months they remained north of Midway, then moved south. After 83 d at sea, the 50-m net and buoy 10013 were recovered by the Townsend Cromwell. Several species of fish were swimming near the net, and two pilotfish, Naucrates ductor, were caught in it (Table 3). No large animals were entangled in the net.

Buoy 10012, which was tracked the longest, traveled as far south as lat. 17°37.8'N, then returned north and west (Fig. 4). It was recovered after 309 d at sea by the chartered fishing vessel Feresa. The 1,000-m net was no longer attached to the buoy at that time. It is not known when the net became separated from the buoy, but the absence of barnacles, together with damage to the buoy, suggested that separation may have occurred only a short time before recovery. The buoy failed to transmit a position on 8 June 1987, 9 d before recovery (Fig. 4). The buoy was possibly entangled in the net at that time.

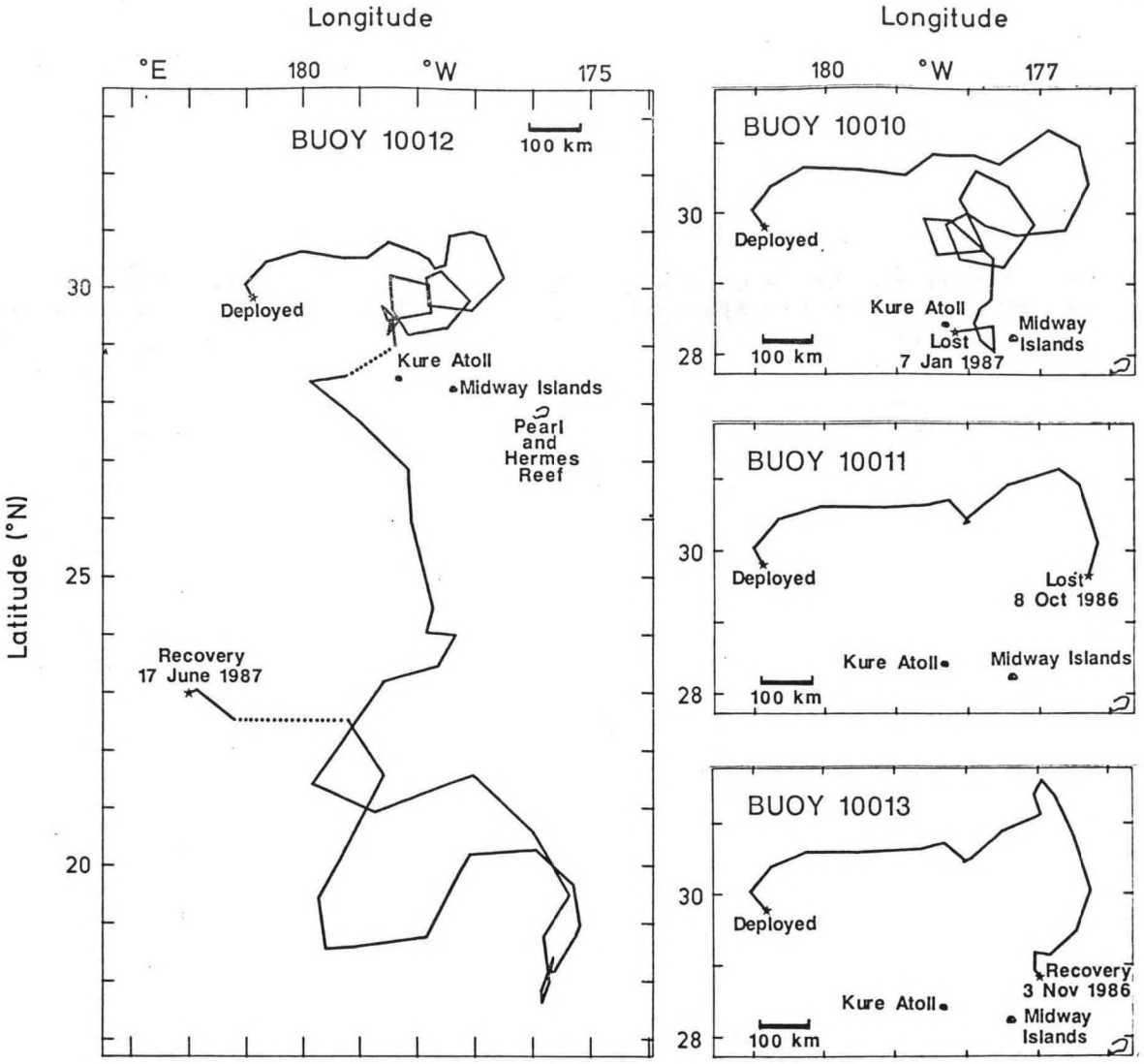

Figure 4.--Positions of four experimental derelict gill nets in the central Pacific Ocean, plotted at 4-d intervals. Plotted positions more than 4 d apart are shown as dotted lines.

Table 3.--Biological observations near the 50-m gill net recovered on 3 November 1986 north of Midway. The net had been drifting for 83 d. N = number of individuals sighted.

Species sighted	N	Sighting location
Pilotfish, *Naucrates ductor*	2	Caught in net.
Barracuda, *Sphyraena helleri*	20	Swimming near net.
Mahimahi, *Coryphaena hippurus*	2	Swimming near net.
Alutera scripta	11	Swimming near net.
Naucrates ductor juveniles	14	Swimming near net.
Unidentified fish, possibly *Kyphosus* sp.	7-12	Swimming near net.
Black-footed albatross, *Diomedea nigripes*	7	On surface near net.

The two remaining nets and buoys were not recovered because their signals were lost. Signals were no longer received from the buoy on the 350-m net after 57 d nor the 100-m net after 148 d (Table 1). The reason for signal loss is not known, but the most likely explanation is that the buoys became entangled in the nets and submerged. Buoy 10010 on the 100-m net stopped transmitting about 15 km southeast of Kure Atoll (Fig. 4). Possibly the net became caught on the reef, but searches by plane and boat in August 1987 failed to find it.

DISCUSSION

The amount of gill net that becomes lost, detached, or discarded in the course of gill-net fishing operations is not known with any precision. Based on fishing activity, however, the total amount is undoubtedly large. The loss rate of 0.05%, mentioned earlier, is an unsubstantiated estimate given by a Japanese Government official (i.e., footnote 1) during public hearings on the incidental catch of marine mammals during high-seas drift-net salmon fishing. Eisenbud (1985), citing a 1982 letter from Richard B. Roe, NMFS, mentions an estimate of 0.06% loss rate for the same fishery. Such a low loss rate, even if accurate for this fishery, is unlikely to apply to other types of gill-net fishing. For example, coastal gill-netting operations are likely to have a higher rate of net loss because of more boat traffic and a greater chance of the net's becoming hung up on the bottom. Even so, applying this minimum loss rate to the total amount of available gill net means that thousands of kilometers of derelict gill net enter the North Pacific every year.

The fishing ability of a net depends on its size and configuration in the water. Left alone, a drifting gill net will eventually collapse and become entangled with itself. The rate at which this happens depends, among other things, on the original length of the net. Rapid collapse of short sections of net is expected because of the weight of the leadline. Our study showed that nets less than 100 m long should collapse in less

than a day, those several hundred meters long in several days, and those 1 km or more long in several weeks (Fig. 2). These rates give a first approximation of the length of time an intact derelict gill net would remain in an active fishing configuration.

The rate of collapse may also depend on other factors. If a large animal such as a shark or seal is caught in a net, its struggling could hasten the collapse of the net. If a buoy is attached to one end of the net, the force of wind on the buoy could keep the net open much longer, as demonstrated by the effect of the large transmitter buoy system on the 100-m net in this study. After 1 d, the net was completely collapsed, but after the large buoy system was attached to it overnight, the net lengthened (Fig. 2). The nearby 50-m net, which did not have a large buoy system attached to it, did not lengthen during the same period. The force of the wind on the large buoy, which was at the downwind end of the net, caused a constant pull on one end of the net and was the likely cause of its lengthening.

Once collapsed, a gill net is still capable of catching fish, though much less effectively. The rapid collapse of the nets in this study suggests that the catch rate of a lost or discarded gill net would, for the target species, decline rapidly. Whether the hazard of a derelict gill net also declines rapidly for nontarget species, however, is not resolved by this study. A floating mass of net will attract fish that may, in turn, attract predators like birds, sharks, seals, and dolphins. Furthermore, the multiple folds of a collapsed net might be more effective in ensnaring an animal like a seal that is too large to be "gilled" in the normal fishing action of the net.

The movement of debris on the ocean's surface is controlled by a combination of wind and surface currents. The gill nets used in this study have a large surface area in the water and little above it. Hence, their movement over a period of months (Fig. 4) reflects mainly the movement of the upper 10 m of water rather than wind drift. Currents in the Hawaiian Archipelago are complex and irregular (Wyrtki et al. 1969). Eddies of various sizes are common in Hawaiian waters (Seckel 1955; Patzert 1969); the loops executed by buoys 10010 and 10012 may indicate such eddies. The abrupt changes in direction and speed reveal that predicting the drift of marine debris is a difficult problem and requires detailed knowledge of surface circulation.

ACKNOWLEDGMENTS

Thanks to the captains and crews of the NOAA ship Townsend Cromwell and fishing vessel Feresa for their assistance in gill-net deployment and recovery efforts. Michael Seki, NMFS, Honolulu, contributed the observations in Table 3. Alan Reichman, Greenpeace, Seattle, provided several references on gill-net entanglement.

LITERATURE CITED

Argos.
1984. Location and data collection satellite system user's guide. Service Argos Inc., Landover, MD 20785, 36 p.

Chen, T. F.
1985. High sea gill net fisheries of Taiwan. In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, Hawaii, p. 253-256. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Coe, J. M., and A. R. Bunn.
1987. Description and status of tasks in the National Oceanic and Atmospheric Administration's Marine Entanglement Research Program for fiscal years 1985-1987. Northwest Alaska Fish. Cent., Processed Rep. 87-15, 39 p. Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98115.

Eisenbud, R.
1985. Problems and prospects for the pelagic driftnet. Boston Coll. Environ. Aff. Law Rev. 12:473-490.

Gong, Y.
1985. Distribution and migration of flying squid, Ommastrephes bartrami (Lesueur), in the North Pacific. In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, Hawaii, p. 109-129. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Patzert, W. C.
1969. Eddies in Hawaiian waters. Hawaii Inst. Geophys. HIG-69-8, 57 p.

Seckel, G. R.
1955. Mid-Pacific oceanography, Part VII, Hawaiian offshore waters, September 1952-August 1953. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 164, 250 p.

Shima, K.
1985. Summary of Japanese net fisheries in the North Pacific Ocean. In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, Hawaii, p. 252. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Shomura, R. S., and H. O. Yoshida (editors).
1985. Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54, 579 p.

Uchida, R. N.
1985. The types and estimated amounts of fish net deployed in the North Pacific. In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27-29 November 1984, Honolulu, Hawaii, p. 37-108. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Wyrtki, K., V. Graefe, and W. Patzert.
1969. Current observations in the Hawaiian Archipelago. Hawaii Inst. Geophys. HIG-69-15, 97 p.