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.

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

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

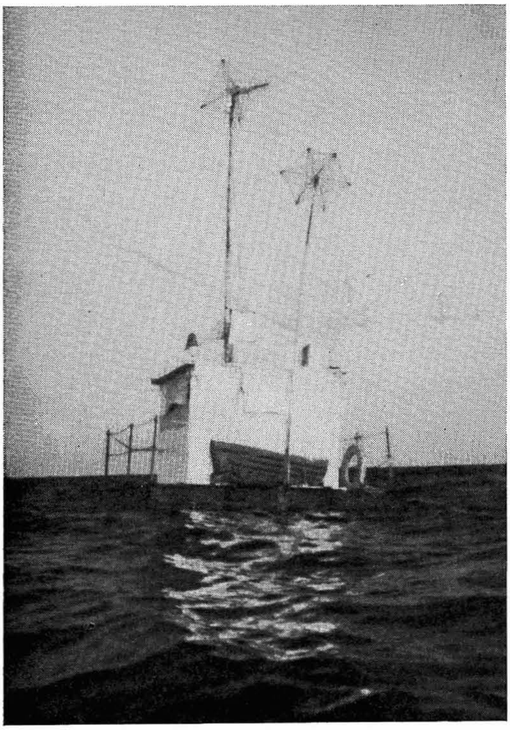

FIG. 1. The observation raft used in study.

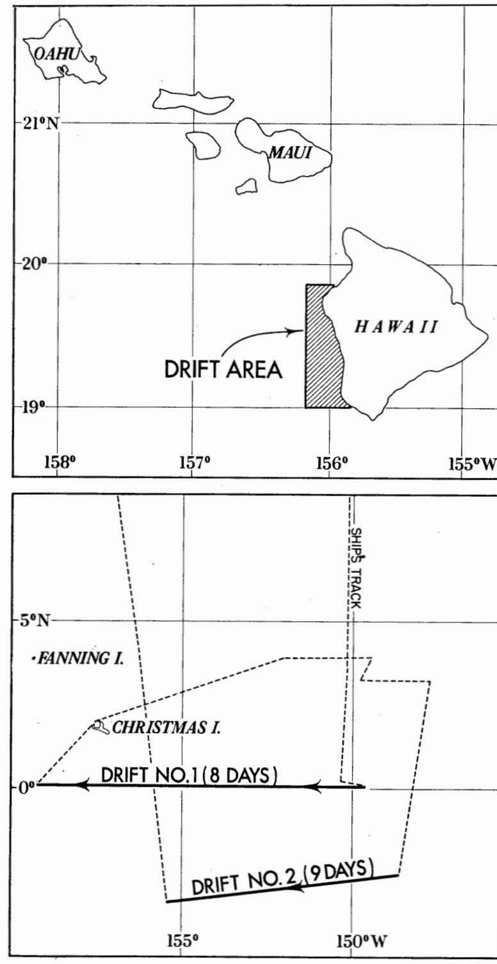

FIG. 2. Areas in which drifts were made with the observation raft, off Hawaii (*upper panel*) and near the Equator (*lower panel*).

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.

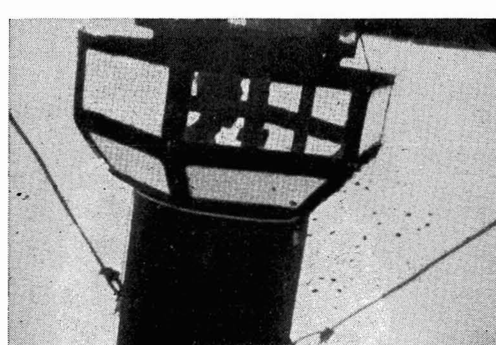

FIG. 3. The observation chamber of the raft. Dark specks to right of chamber are small fish. The white object behind the chamber is the parachute drogue.

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 *4a–f*) were broadly

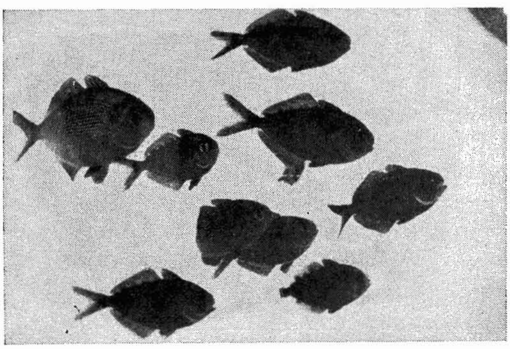

FIG. *4a*. Freckled driftfish.

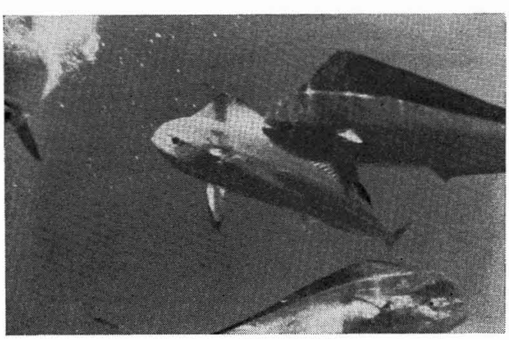

FIG. *4b*. Adult dolphin.

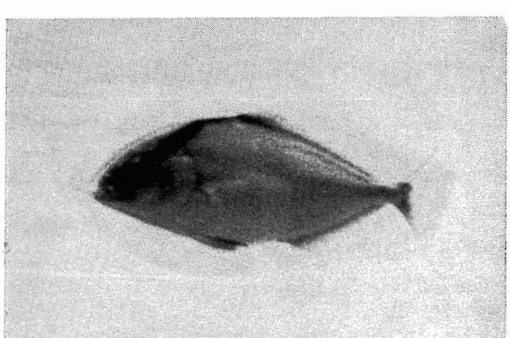

FIG. *4c*. Amberjack.

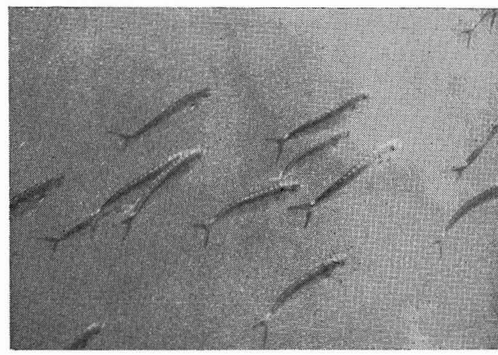

FIG. *4d*. Juvenile dolphin.

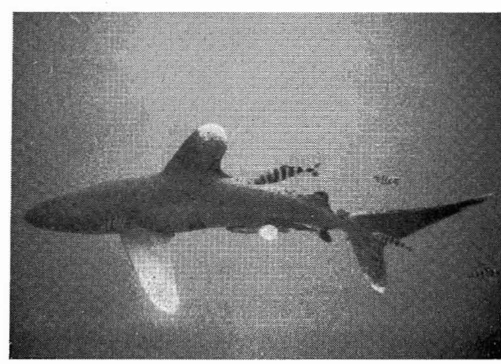

FIG. *4e*. Whitetip shark accompanied by pilotfish and remora.

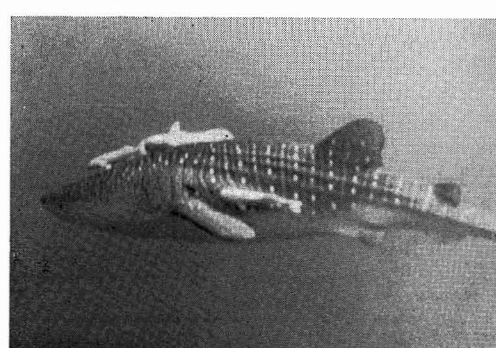

FIG. *4f*. Whale shark accompanied by remora.

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 cinerascens* (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	2.9–5.3†	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 1965 Day (8.5)	HAWAII AUGUST 1965 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

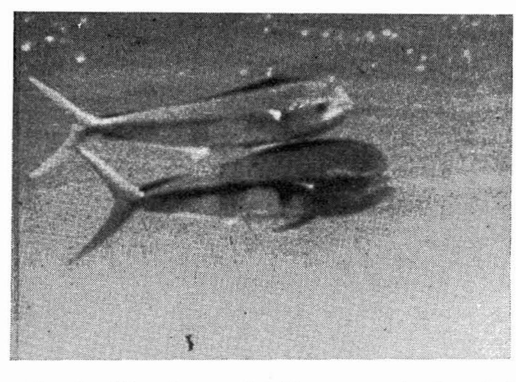

FIG. 5. The lower dolphin assumed the dark coloration when one of the observers entered the water.

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

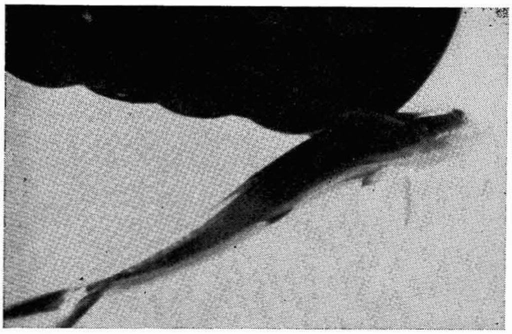

FIG. 6. Adult dolphin chafing against a 55-gallon drum beneath the raft.

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.

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