ASSOCIATION OF FISHES WITH FLOTSAM IN THE OFFSHORE WATERS OF CENTRAL AMERICA

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ABSTRACT

During April, May, June, and October, 1963, a total of 70 purse seine collections were made of the fishes associated with floating objects. Nearly all of these collections were from the offshore waters of Costa Rica. Twelve families of fishes (Lobotidae, Carangidae, Coryphaenidae, Mullidae, Kyphosidae, Pomacentridae, Scombridae, Blenniidae, Stromateidae, Mugilidae, Polynemidae, and Balistidae) and 32 species were represented in the collections. Most of the species were present during both spring and fall, and nearly all of the fishes were juveniles.

Nine of the 32 species, including the 2 most abundant ones, *Caranx caballus* Günther and *Selar crumenophthalmus* (Bloch), were carangids. The lengths of two species, *Abudefduf saxatilis* (Linnaeus) and *Seriola* sp. were greater the farther an object was located from shore. Some species such as *C. caballus, Psenes pacificus* Meek and Hildebrand, and *Canthidermis maculatus* (Bloch) were present in almost a complete series of juvenile stages; others as *Chromis atrilobata* Gill, *Pseudupeneus grandisquamis* (Gill), and *Agonostomus monticola* (Bancroft) were represented by only a single juvenile stage. More fishes were collected under large objects than under small objects. The total number of individuals present near moored objects after 5 days did not differ from the numbers present after 20 or more days. The coloration of fishes was related to their association behavior. Silvery colored fishes did not remain as close to the object as did the more darkly colored species. Most adult fishes, which did not remain as near the object as did juveniles, appeared beneath an object only intermittently. *Canthidermis maculatus,* however, maintained close contact with drifting objects both as adults and juveniles.

Observations of the behavior of species are discussed in relation to the mechanisms for the association of fish with flotsam that have been postulated by other authors. None of their hypotheses was supported by our data. Additional mechanisms were postulated.

The association of fishes with floating objects has been exploited by a number of fisheries. Japanese pole-and-line fisheries and American purse seine and live-bait fisheries take advantage of the association of yellowfin tuna, *Thunnus albacares* (Bonnaterre), and oceanic skipjack, *Katsuwonus pelamis* (Linnaeus), with algae, logs, and other flotsam (Uda, 1933; McNeely, 1961). Uda and Tsukushi (1934), and Yabe and Mori (1950) reported that log-associated schools of tuna provide a consistently higher yield per unit fishing effort than unassociated schools.

Moored rafts of bamboo or palm fronds are used to attract dolphin-fish, *Coryphaena hippurus* (Linnaeus), in seine fisheries of Japan (Kojima, 1955, 1956, 1960a, 1960b, and 1961). Moored cork-slabs serve the same purpose for Maltese fishermen (Galea, 1961). Two types of palm-frond rafts are used by Indonesian fishermen to attract various clupeids, scombrids, *Decapterus* spp., and other carangids (Hardenberg, 1950; Soemarto, 1960). In addition to these commercially important species, many others of lesser or no commercial value are also encountered (Murray and Hjort (1912), Yabe and Mori (1950), Uchida and Shojima (1958), Besednov (1960), Kojima (1960a), Mansueti (1963), and Gooding and Magnuson[1]).

Note: Approved for publication March 8, 1966.

[1] Reginald M. Gooding and John J. Magnuson—Observations on the ecology and behavior of fishes around a drifting raft near Hawaii during the first 48 hours adrift. Manuscript, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii.

Gooding and Magnuson reviewed the hypotheses that have been advanced to explain this habit: (1) attraction by food (smaller fish, algae, decaying palm fronds, and plankton made more visible by the shade of the object); (2) negative phototaxis in response to the shadow cast by the object; (3) shelter from predators; and (4) use of the object as a spawning substrate. They also suggested an additional hypothesis that floating objects are cleaning stations where pelagic fishes go to have their parasites removed by other fish.

This paper provides information on the ecology and behavior of fishes associated with floating objects in the offshore waters of Central America. Special attention is given to the frequency, abundance, and size of the species which compose flotsam-associated aggregations and how these characteristics are related to the location and size of the object. These studies are the framework upon which future behavior investigations will be based. The aim of our program is to determine whether a device can be designed that will be maximally efficient in aggregating tuna and skipjack. The potential value to the tuna fishery of establishing such devices has been discussed by Alverson and Wilimovsky (1963).

PROCEDURES

Nearly all of our studies were in the offshore waters of Costa Rica (fig. 1) because yellowfin tuna and skipjack are often associated with the flotsam in this region (logbook records obtained through the courtesy of the Inter-American Tropical Tuna Commission). Several collections were near the coast of southern Mexico and 1 near Cocos Island. Samples were collected by encircling flotsam and its associated fauna with a small 7/16-inch (11 mm.) stretch-mesh purse seine, 12 feet deep (3.7 m.) and 110 feet (33.5 m.) long (Aasted, MS.)[2]. An average of 66 percent of the fishes observed beneath an object were captured in the seine. Fish larger than 100 mm. standard length may have escaped the net, and fish smaller than 15 mm. occasionally swam through the webbing. When the net was set, fish tended to stay near the flotsam or even swim upward. Thus, fish swimming at a depth greater than the maximum depth of the seine also may have been caught. Sampling errors due to fish escaping from or entering the seined cylinder of water were probably small.

[2] Donald C. Aasted. A miniature purse seine for capturing small pelagic fishes. Manuscript. Bureau of Commercial Fisheries Tuna Resources Laboratory, La Jolla, Calif.

Twenty-three purse seine collections of fishes were made during April, May, and June, 1963, and 47 during October. Of these samples, 62 were of fishes associated with naturally occurring flotsam, and 8 were of fishes collected beneath moored logs, buoys, and other objects.

After a collection was made, the success of the set was estimated, the object was described and measured, and motile and attached organisms were preserved. In the October studies, to determine the rate and direction of movement of drifting materials, all objects were tagged and marked with a small flag prior to release. Underwater observations and cinematic photographs were used to describe the behavior and estimate the abundance of fishes.

CHARACTERISTICS AND DISTRIBUTION OF FLOTSAM

Far more drifting materials were in the study area in October than in the spring. The Gulf of Nicoya was littered with floating logs and other plant debris. The greater abundance of flotsam in October was not surprising because rainfalls are usually heaviest during this period (Peterson, 1960).

Fish were not seen beneath the flotsam in the Gulf and were only rarely associated with inshore logs between Cape Blanco and Piedra Blanca (fig. 1). Northwest of this area, however, nearly every drifting object encountered had its own associated fish population. Most often these objects were aggregated in areas of current convergence.

During April, May, and June, currents in the area usually set northwest at an estimated 2 knots; currents also set northwest during October but were not as strong. Three logs tagged in October and later recovered had drifted northwest at 0.28, 0.45, and 0.33 knot.

Only one of the drifting objects sampled had attached invertebrates—goose barnacles, *Conchoderma virgatum* (Spengler). This species and other goose barnacles of the genus *Lepas* were found in quantity on moored objects after 14 or more days.

Adult and megalops grapsoid crabs of the genus *Plagusia* were numerous on nearly all logs. Individuals in the megalops stage frequently were swimming near drifting objects.

SEASONAL VARIATION IN OCCURRENCE OF FISH

Over 12,000 fishes were captured beneath floating objects in this study; 12 families and 32 species were

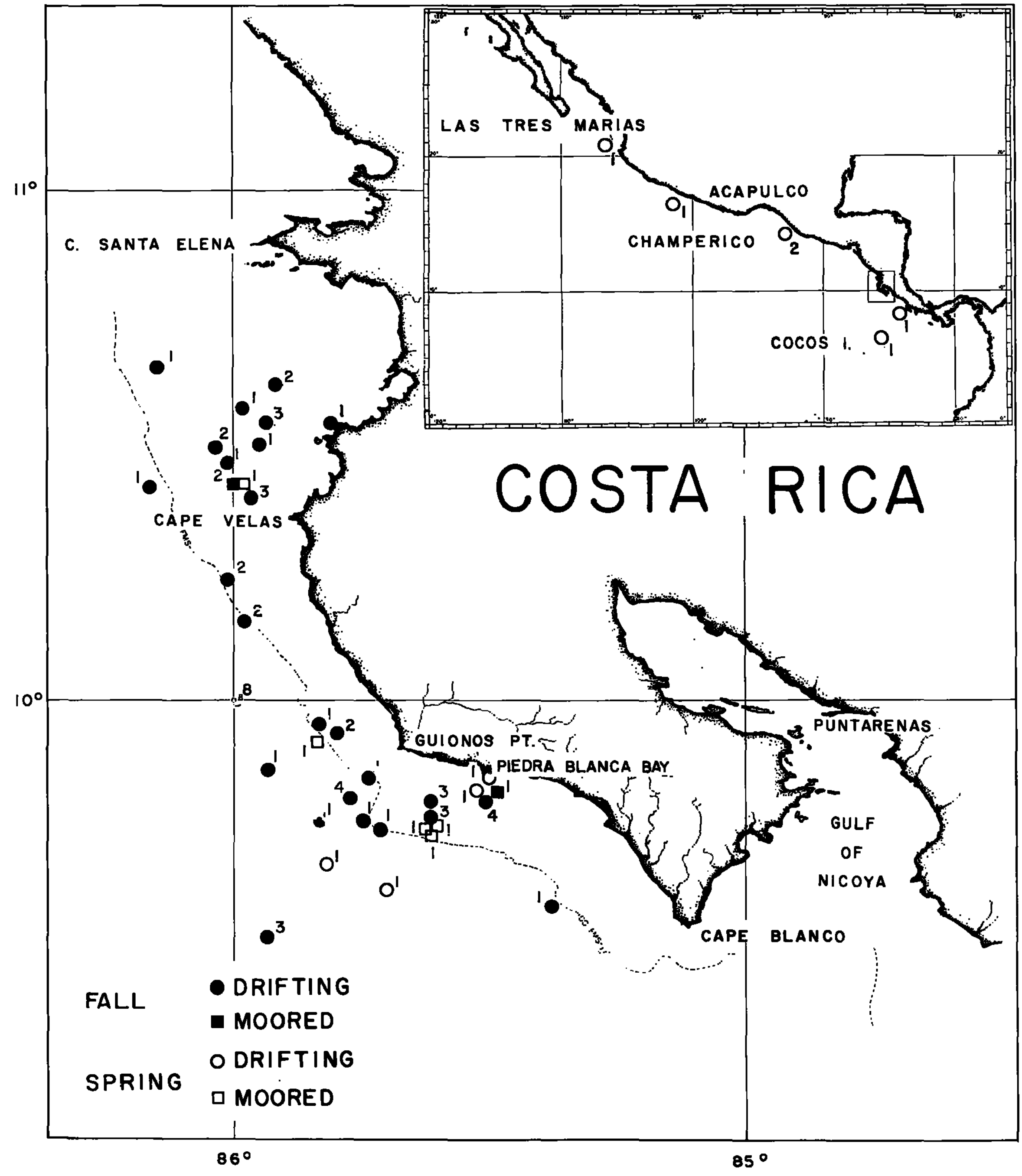

FIGURE 1.—Positions of collections made of fishes beneath flotsam in April, May, and June 1963 (spring) and October 1963 (fall). Numerals indicate number of collections made in each locality. Inset at top shows location of study area and position of the six collections made outside this area.

represented. The scientific name, family, and season of occurrence of these species are presented in table 1. Abbreviated names are used in the text and subsequent tables.

There was little seasonal variation in the occurrence of species. Twenty-four of the total of 32 species were captured or observed during both spring and fall. The seasonal occurrence of adult

TABLE 1.—*Length, life stage, and seasonal occurrence of species collected beneath flotsam in the offshore waters of Central America*[1] *in 1963*

Species	Life stage: Adult	Life stage: Juvenile	Total captured	Range of standard length	Season: Spring	Season: Fall
			Number	*Mm.*		
Lobotidae (tripletails)						
Lobotes pacificus Gilbert	–	x	3	72–246	–	x
Carangidae (jacks and scads)						
Caranx caballus Günther	x[2]	x	6,215	9–212	x	x
Caranx hippos (Linnaeus)	–	x	105	16–85	x	x
Caranx marginatus (Gill)	–	x	44	17–101	x	x
Decapterus sp.[3]	–	x	298	17–100	x	x
Elagatis bipinnulatus (Quoy and Gaimard)	–	x	218	11–263	x	x
Naucrates ductor (Linnaeus)	–	x	43	29–143	x	x
Selar crumenophthalmus (Bloch)	x[2]	x	1,348	15–108	x	x
Seriola colburni (Evermann and Clark)	–	x	5	103–154	x	–
Seriola sp.[3]	–	x	315	10–163	x	x
Coryphaenidae (dolphins)						
Coryphaena equiselis Linnaeus	–	x	5	35–68	x	–
Coryphaena hippurus Linnaeus	x[2]	x	2	34–42	x	x
Mullidae (goatfishes)						
Pseudupeneus grandisquamis (Gill)	–	x	339	26–54	x	x
Kyphosidae (sea chubs)						
Kyphosus analogus (Gill)	–	x	3	63–137	x	x
Kyphosus elegans (Peters)	–	x	22	32–103	x	x
Kyphosus sp.[3]	–	x	2	18–59	x	x
Sectator ocyurus (Jordan and Gilbert)	x[4]	x	248	17–253	x	x
Pomacentridae (damselfishes)						
Abudefduf saxatilis (Linnaeus)	–	x	437	8–46	x	x
Chromis atrilobata Gill	–	x	1,449	21–32	x	x
Scombridae (mackerels and tunas)						
Auxis thazard (Lacépède)	–	x	1	48	x	–
Euthynnus lineatus Kishinouye	x[4]	x	7	37-477[5]	x	x
Katsuwonus pelamis (Linnaeus)	x[4]	–	435	230-597[5]	–	x
Thunnus albacares (Bonnaterre)	x[4]	–	149	500-750[5]	x	–
Blenniidae (combtooth blennies)						
Blenniolus brevipinnis (Günther)	x	x	39	13–31	x	x
Stromateidae (butterfishes)						
Psenes pacificus Meek and Hildebrand	–	x	822	10–133	x	x
Mugilidae (mullets)						
Agonostomus monticola (Bancroft)	–	x	38	11–30	–	x
Mugil curema Valenciennes	–	x	6	18–47	x	x
Polynemidae (threadfins)						
Polydactylus approximans (Lay and Bennett)	–	x	30	23–47	x	x
Polydactylus opercularis (Gill)	–	x	1	40	–	x
Monacanthidae (filefishes)						
Alutera monoceros (Linnaeus)	x[2]	x	1	107	–	x
Alutera scripta (Osbeck)	x[2]	x	1	72	–	x
Balistidae (triggerfishes)						
Balistes polylepis Steindachner	–	x	9	28–184	x	x
Canthidermis maculatus (Bloch)	x	x	178	30–236	x	x

[1] Specimens cataloged in Marine Vertebrates collection, Scripps Institution of Oceanography.
[2] Adults observed but not captured.
[3] Specific name unknown.
[4] Adults collected by method other than small purse seine.
[5] Fork length.

scombrids can be ascribed to variation in collection methods rather than to seasonal differences. Adult frigate mackerel, *Auxis thazard*, black skipjack, *Euthynnus lineatus*, oceanic skipjack, and yellowfin tuna were present during both seasons, and all are known to associate with flotsam.

The mountain mullet, *Agonostomus monticola*, was not in the spring collections but occurred in 10 of the 47 fall collections. This species inhabits marine waters only as a prejuvenile (Ebeling, 1961). Thus its occurrence in only the fall collections could be due to a seasonal difference in reproductive activities.

The remainder of the species that were taken during only 1 season were relatively uncommon in the collections. Their absence during 1 season could be due to chance alone.

LIFE STAGE OF FISHES ASSOCIATED WITH FLOTSAM

Nearly all of the fishes observed and captured beneath drifting objects were juveniles; however, adult sharks, *Carcharhinus limbatus* (Müller and Henle) and *Carcharhinus azureus* (Gilbert and Starks), and schools of adult *Caranx caballus*, *Selar crumenophthalmus*, *Coryphaena hippurus*, *Sectator ocyurus*, and *Euthynnus lineatus* were observed. With the exception of *S. ocyurus*, these adults did not swim as close to the object as did the smaller fishes, and they remained near it only for short periods. None of these adults were captured by the small purse seine. Some were captured, however, by other methods. Owing to the infrequent capture of these adults and to the difficulty of ascertaining whether or not they were in fact associated with a particular object, our presentation is limited to the fishes captured by the small seine. *Canthidermis maculatus* was the only species that frequently occurred both as adult and juvenile; both stages were captured in the seine.

To determine if the size of the fishes was related to the distance of an object from shore, the shortest distance to the shore from the location of each collection was measured to the nearest nautical mile. The length measurements of species from different collections captured at the same distance from shore were combined, and a mean and range were established (figs. 2, 3, and 4).

The mean and minimum length of *Abudefduf saxatilis* and *Seriola* sp. increased with the distance of an object from shore (chi-square test for two independent samples, $p < .01$)—figs. 2 and 3. The maximum size of these two species did not show this change. The mean length of *Selar crumenophthalmus* also increased with distance, but this change was not as marked as in the other two species (fig. 4).

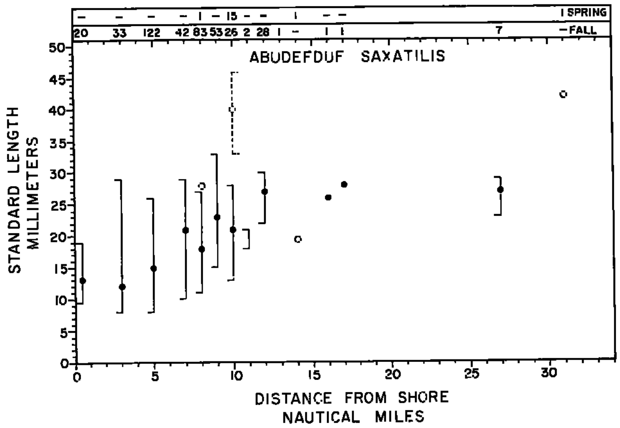

FIGURE 2.—Range and mean standard length of *Abudefduf saxatilis* collected beneath flotsam in the offshore waters of Central America at various distances from shore. Broken lines indicate range for spring collection, solid lines, range for fall collections. Open circles indicate mean for spring, filled circles, mean for fall; circles without bars indicate single fish. Upper numerals are total number of *Abudefduf* captured in spring of 1963, lower numerals, fall 1963.

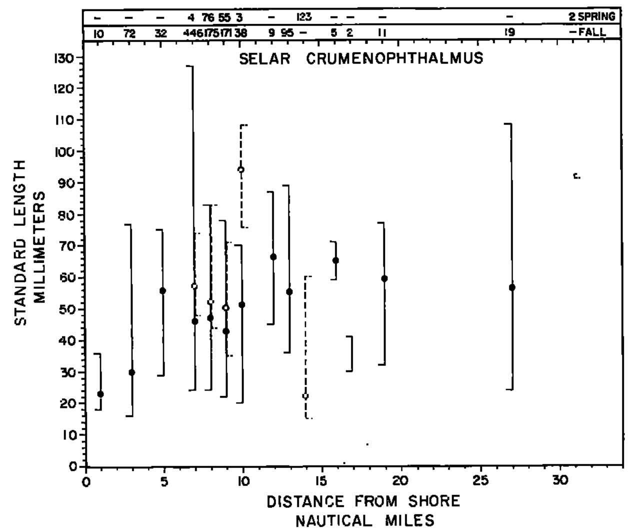

FIGURE 4.—Range and mean standard length of *Selar crumenophthalmus* collected beneath flotsam in the offshore waters of Central America at various distances from shore. Broken lines indicate range for spring collections, solid lines, range for fall collections. Open circles indicate mean for spring, filled circles, mean for fall. Upper numerals are total number of *Selar* captured in spring of 1963, lower numerals, fall of 1963.

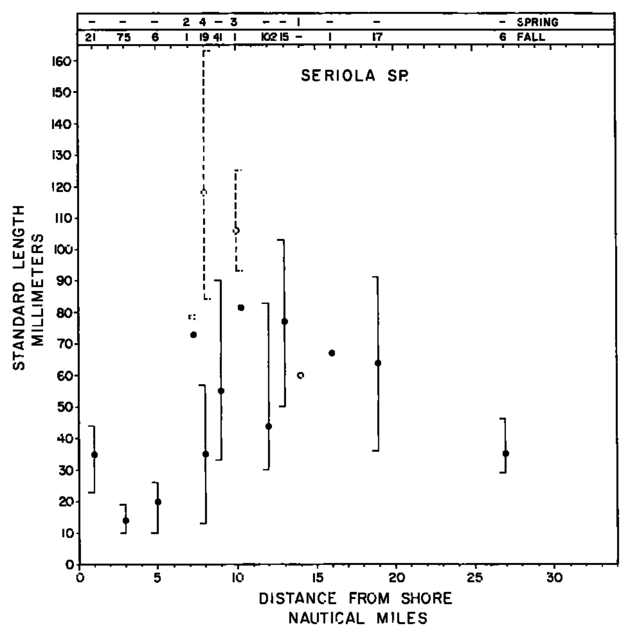

FIGURE 3.—Range and mean standard length of *Seriola* sp. collected beneath flotsam in the offshore waters of Central America at various distances from shore. Broken lines indicate range for spring collections, solid lines range for fall collections. Open circles indicate mean for spring, filled circles, mean for fall; circles without bars indicate single fish. Upper numerals are total number of *Seriola* sp. captured in spring of 1963, lower numerals, fall of 1963.

Abudefduf saxatilis spawns inshore on rocks or reefs, and the males defend the clutch of eggs (R. Rosenblatt, personal communication); thus, larvae and juveniles of this species may be more abundant inshore. It seems possible that individuals captured offshore were originally recruited to the object inshore and accompanied it as it drifted away from land. The larger size of the offshore specimens could be attributed to growth while the fish were associated with the object.

In the remainder of the fishes no obvious relation was evident between the distance from shore and the minimum or mean length; however, the ranges of sizes at which these fishes were associated with flotsam differed widely. Some species were represented by almost a complete series of juvenile stages. *Caranx caballus* and *Psenes pacificus* are good examples of this group (fig. 5). Less abundant species in this group were *Elagatis bipinnulatus*, *Kyphosus elegans*, *Sectator ocyurus*, and *Canthidermis maculatus*

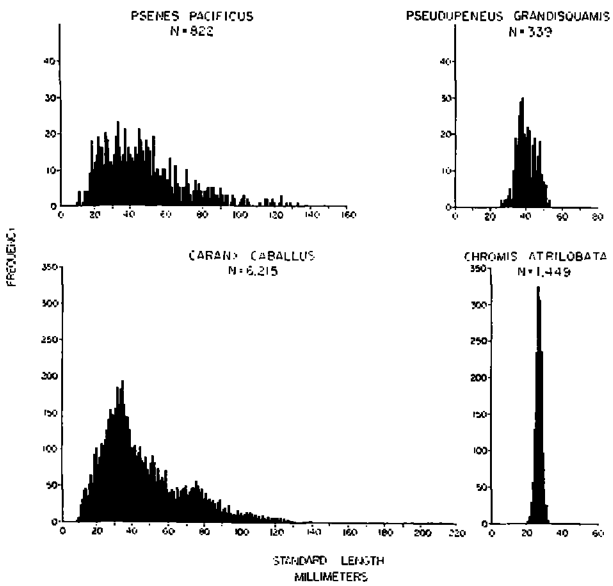

FIGURE 5.—Length frequency for *Psenes pacificus*, *Pseudupeneus grandisquamis*, *Caranx caballus*, and *Chromis atrilobata*. Numbers are totals for combined spring and fall collections.

(table 1). The size range of juveniles of other species was extremely restricted. *Chromis atrilobata* and *Pseudupeneus grandisquamis* had this compact type of size distribution (fig. 5). Other species, not figured, which also had a limited size range included *Agonostomus monticola*, *Polydactylus approximans*, and *Blenniolus brevipinnis*. *Pseudupeneus*, *Chromis*, *Agonostomus*, and *Polydactylus* have pelagic juvenile stages but as adults inhabit other areas. The upper size limit of these species in our collections probably was determined by the size at which they end the pelagic phase of their lives.

Blenniolus brevipinnis is a small species; females 19.5 mm. long can be sexually mature (Krejsa, 1960). Adults and juveniles have been found near drifting logs as well as among rocks and coral heads in inshore areas (Krejsa, 1960). Apparently for both adults and juveniles of this species, drifting objects are a suitable pelagic substitute for inshore habitats.

FREQUENCY, ABUNDANCE, AND DOMINANCE OF FISHES COLLECTED BENEATH FLOTSAM

The characters used by Fager and McGowan (1963) for the analysis of zooplankton populations were used to describe the structure of the flotsam-associated aggregations of fish: (1) frequency—the total number of collections in which a species occurred; (2) abundance—the range and median of the numbers of individuals per collection in which the species was found; and (3) dominance—the number of samples in which a particular species or a group including this species comprised 50 percent or more of the total number of individuals in a given collection. As the structure of the populations in the spring was similar to that in the fall, the two series of collections were combined to calculate these statistics.

Fifteen of the 32 species had frequencies greater than 10. These were ranked from 1 to 15 on the basis of their frequency, median abundance, and dominance. Tied values were given the average of the ranks (table 2 and fig. 6). The remainder of the species was ranked only by frequency (table 3).

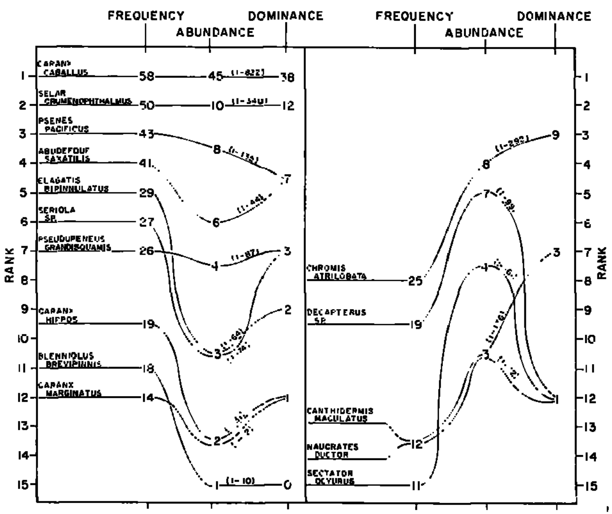

FIGURE 6.—Ecological characters of the 15 species most frequently captured beneath flotsam in the offshore waters of Central America in 1963. Each species was ranked separately by: *frequency*, the total number of collections in which the species occurred; *abundance*, median of the numbers of individuals per collection in which the species was found; and *dominance*, the number of collections in which a species was among those making up 50 percent of the individuals. Lines indicate the rank held by each species in the three rankings. Values upon which ranks were based are shown in each column. In the second column, parentheses enclose the range of the number of individuals per collection of occurrence. For clarity, we separated the 15 species into 2 groups: left half of figure, species whose ranked abundance was the same as or lower than the ranked frequency; and right half, species whose ranked abundance was higher than the ranked frequency. The total number of collections was 70.

TABLE 2.—*Ecological characters of the 15 most frequently captured species collected beneath flotsam in the offshore waters of Central America in 1963*[1]

Species	Frequency[2]	Rank[3]	Abundance		Rank[3]	Dominance[4]	Rank[3]
			Range[5]	Median[6]			
Caranx caballus	58	1	(1-822)	45	1	38	1
Caranx hippos	19	9.5	(1-31)	2	13.5	1	12
Caranx marginatus	14	12	(1-12)	2	13.5	1	12
Decapterus sp.	19	9.5	(1-99)	7	5	1	12
Elagatis bipinnulatis	29	5	(1-64)	3	10.5	2	9
Naucrates ductor	12	13.5	(1-12)	3	10.5	1	12
Selar crumenophthalmus	50	2	(1-340)	10	2	12	2
Seriola sp.	27	6	(1-74)	3	10.5	3	7
Pseudupeneus grandisquamis	26	7	(1-87)	4	7.5	3	7
Sectator ocyurus	11	15	(1-161)	4	7.5	1	12
Abudefduf saxatilis	41	4	(1-44)	6	6	7	4.5
Chromis atrilobata	25	8	(1-292)	8	4	9	3
Blenniolus brevipinnis	18	11	(1-10)	1	15	0	15
Psenes pacificus	43	3	(1-135)	8	3.5	7	4.5
Canthidermis maculatus	12	13.5	(1-176)	3	10.5	3	7

[1] The total number of collections was 70.
[2] The total number of collections in which the species occurred.
[3] Rank based on figures in adjacent columns.
[4] The number of samples in which a particular species or a group including this species comprised 50 percent or more of the total number of individuals in a given collection.
[5] Range of the numbers of individuals per collection in which species was found.
[6] Median of the numbers of individuals per collection in which species was found.

TABLE 3.—*Frequency, abundance, and dominance of species occurring in 10 or fewer collections made in the offshore waters of Central America in 1963. Listed in order of frequency*

Species	Frequency	Abundance[1]	Dominance
Agonostomus monticola	10	1 (1-11)	0
Polydactylus approximans	9	1 (1-12)	0
Kyphosus elegans	8	1 (1-12)	0
Mugil curema	5	1 (1-2)	0
Balistes polylepis	5	1 (1-4)	0
Kyphosus analogus	3	1 (1)	0
Lobotes pacificus	3	1 (1)	0
Seriola colburni	2	– (2-3)	0
Coryphaena hippurus	2	– (1)	0
Coryphaena equiselis	2	– (2-3)	2
Kyphosus sp.	2	– (1)	0
Polydactylus opercularis	1	– (1)	0
Auxis thazard	1	– (1)	0
Euthynnus lineatus	1	– (1)	0
Alutera monoceros	1	– (1)	0
Alutera scripta	1	– (1)	0

[1] Figures in parentheses show range in number of individuals per collection of occurrence.

Nine of the 32 species were carangids, and all but 1 of these, *Seriola colburni*, were among the 15 most frequent species. The carangid, *C. caballus* was by far the most frequent, abundant, and dominant species collected. This fish contributed 50 percent or more of the individuals in more than half of the collections. *Selar crumenophthalmus*, also a carangid, ranked second in frequency, abundance, and dominance. No other family was represented as frequently in the collections. The family Kyphosidae was represented by four species but only one, *Sectator ocyurus*, occurred in more than 10 collections.

On the basis of their rank by frequency, abundance, and dominance, the 15 most frequent species can be divided into three groups: (1) species that occupied about the same rank in all three categories; (2) species that were captured frequently but were not abundant in the collections in which they occurred; and (3) species captured less frequently that were abundant in the collections in which they occurred. The three highest ranking species, *C. caballus*, *Selar crumenophthalmus*, and *Psenes pacificus* were in the first group. *Abudefduf saxatilis* and *Blenniolus brevipinnis* exemplify the second group, and *Chromis atrilobata* and *Canthidermis maculatus* the third.

The factors responsible for the differences in frequency and abundance of species are unknown. For some species, evidence suggested that schooling was a significant factor. All of the 15 most frequently captured species, except *Abudefduf* and *Blenniolus*, schooled either with their own or other species beneath flotsam. *Abudefduf* remained near the object and appeared to defend small territories; *Blenniolus* maintained contact with the surface of the object and were not aggregated. Possibly the solitary or individual habits of these species were responsible for their lower abundance. Juvenile *Chromis* school at the stage at which they associate with flotsam. This species was dominant in seven of eight collections made in the same area on the same day. The median number of individuals in these seven collections was 199. *Chromis* was dominant only once in the remainder of the collections, and the median number of fish per collection was two. The irregular abundance of *Chromis* could be ascribed to a tendency toward the recruitment of an entire school.

Canthidermis maculatus also was a schooling species and tended to be abundant in the collections in which it occurred. This species did not show the limited temporal and regional abundance described for juvenile *Chromis*, but the distribution of *Canthidermis* appeared to extend farther to sea than other species. The collection farthest from shore (200 nautical miles) contained 87 *Canthidermis* and 4 *Balistes polylepis*. Only *Canthidermis* was observed beneath other drifting material in the same area. The four *B. polylepis* were located inside the cavity of a large bamboo stem and probably did not represent a usual component of high-seas aggregations. Had we taken more collections from flotsam drifting 100 or more nautical miles from shore we feel the frequencies for *Canthidermis* would have increased proportionately.

Decapterus sp. ranked fifth in abundance but only once dominated a collection. This species nearly always schooled with *Selar crumenophthalmus* but was less abundant in the mixed schools. *Decapterus* was captured without *Selar* in only 7 of 19 collections. Thus whenever a large number of *Decapterus* was taken, the number of *Selar* was usually larger. Hence, *Decapterus* rarely dominated a collection.

The use of only the numbers of individuals for the determination of dominance instead of numbers and weights obscured some of the relations among species. Had weights as well as numbers been used, *Canthidermis* and *Psenes* probably would have dominated more collections and *Chromis*, *Pseudupeneus*, and *Abudefduf* fewer. Owing to their large size range and abundance, little difference would be expected in the values for *C. caballus* and *Selar*.

OBJECT SIZE

To determine if the length or the number of fishes was related to the size of the object, we recorded for each collection the volume of the object in cubic centimeters, the total number of fishes captured, and the mean length of all fishes in the collection. Of the two variables only the number of individuals in the collection was obviously related to the volume of the object. Collections made beneath large objects tended to be larger than those taken beneath smaller objects (table 4).

Field observations indicated that the frequency of occurrence of larger fishes may be related to the size of the object. The largest object studied, an entire tree, was too large to be encompassed by the purse seine. The tree was 1 m. in diameter at the root section, had a trunk diameter of 0.3 m. and was over 10 m. long. Associated with the tree was the largest aggregation of adult fishes seen during the study. There were large schools of adult *Sectator ocyurus*, *Canthidermis maculatus*, *Coryphaena hippurus*, and *Euthynnus lineatus* in addition to numerous juvenile fishes. A portion of the school of adult *Sectator* is shown in figure 7A, and in 7B some of the adult *Canthidermis* are shown among the branches of the tree. For comparison, two groups of juvenile fishes that were associated with two smaller objects are pictured in 7C and 7D. Yabe

TABLE 4.—*Number of collections made of fishes associated with objects of three size classes and the number of fishes these collections contained*

[Collections were made in the offshore waters of Central America in 1963]

Fish in collection	Collections from objects of different volume (cubic centimeters)			Total
	101–5,000	5,001–100,000	100,001–5,000,000	
Number	Number	Number	Number	Number
1–10	5	3	0	8
11–100	2	14	6	22
101–1000	0	19	19	38
Total	7	36	25	68[1]

[1] Two collections omitted owing to lack of volume measurements.

and Mori (1950) captured, by hook and line, fishes associated with a tree of similar dimensions (1 m. in diameter at the butt and 15 m. long). The lengths of the fish of the species they captured exceeded the lengths of the fish in our purse seine collections by about a factor of 10. In our study, the juvenile fishes that were associated with the tree were of the same species and about the same size as those collected beneath smaller objects. Thus the size of the object appeared to be related to the presence or absence of large or adult fishes rather than differences among juveniles.

ARTIFICIAL MOORED OBJECTS

To study the rate of recruitment of fishes to floating materials, eight objects of various types were moored near the Costa Rican coast for periods of 15 hours to 46 days. Six objects were not visited from the time they were moored until the day the collection was made. Two balsa logs were moored in the same locality at the same time and were observed daily until collections were made on the fifth day.

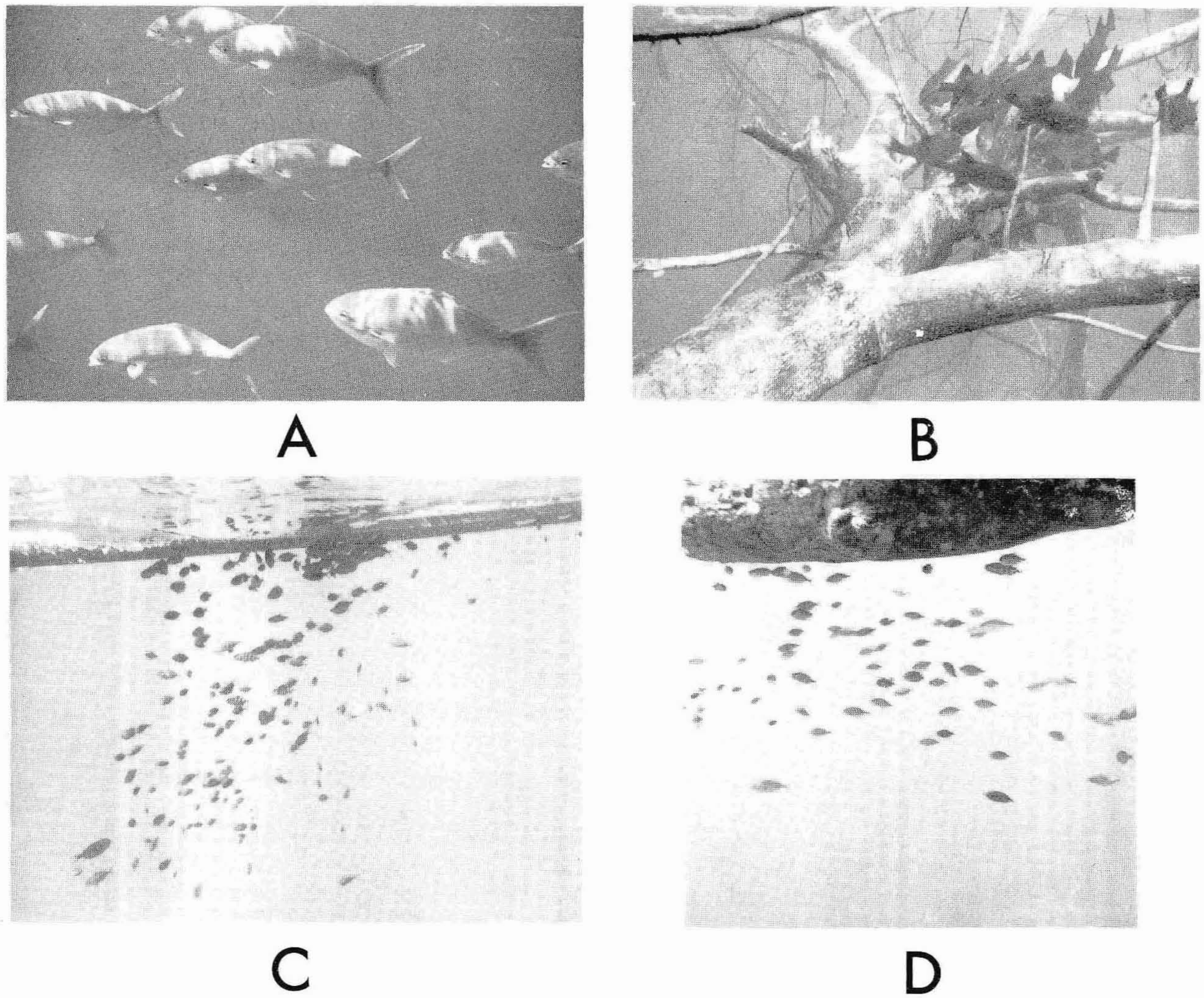

FIGURE 7.—Fishes associated with drifting objects in the offshore waters of Central America in 1963. A, a school of adult *Sectator ocyurus* associated with an entire tree; the small fish in background were juvenile *Selar crumenophthalmus*. B, an aggregation of adult *Canthidermis maculatus* in the branches of the same tree; all but three had a dark coloration. C, a group of juvenile *Psenes pacificus*, *Naucrates ductor*, and other carangids beneath a drifting plank; *Psenes* are in a dense clump directly below the plank, *Naucrates* can be recognized by the presence of dark vertical bars. D, juvenile *Canthidermis maculatus*, *Naucrates ductor*, and various juvenile carangids beneath a drifting log.

Divers made daily counts of the number of individuals of each species beneath each of the two logs. The volumes of the two balsa logs calculated from their measurements were 0.021 $m.^3$ (log A) and 0.065 $m.^3$ (log B).

Counts of the number of individuals beneath logs A and B were 20 and 96 for the second day and 121 and 80 for the third day. By the fourth day it was not possible to make an accurate tabulation because the number of fish under each log was well over 100. On the fifth day 198 individuals were captured under log A and 349 under log B. Prior to being moored log B was encountered 27 miles from shore and 236 fish representing 8 species were captured at that time. Thus more fish were captured after the log was moored 5 days than were collected when the log was drifting 27 miles from shore. Fewer species were represented, however. The larger number of individuals captured beneath log B may reflect the difference in volume of the logs.

Although logs A and B were moored only 100 m. apart, their associated fish populations differed in species composition, dominant species, and the time at which each species was first observed. No ordered recruitment of species was evident (table 5).

The number of fish collected beneath inflated truck inner tubes varied greatly (table 6). All the tubes were identical in size and shape with the exception of the tube that had 10 manila lines attached. After periods longer than 5 days the number of fish collected beneath the tubes did not increase substantially with time through 20 or more days. The number of fish appears to increase rapidly during the first few days and thereafter to remain at about the same level.

Because a drifting object passes through inshore spawning areas, juveniles of species that spawn inshore would be expected to be more abundant beneath a drifting object than beneath an object moored offshore. *Abudefduf saxatilis* and perhaps *Seriola* sp. spawned inshore. Both species showed a high frequency in the fall collections, but neither was found under the two balsa logs moored in the fall. With these two exceptions, no difference existed in the species composition or in the size of the individuals between populations of fishes associated with moored objects and those associated with drifting objects.

TABLE 5.—*Species recruited to two balsa logs,* A *(volume, 0.021 m.*^{3} *and* B *(volume, 0.065 m.*^{3}*) moored 100 m. apart 7 nautical miles from the Costa Rican coast in 1963*

Species	Log A		Log B	
	Day species first observed[1]	Fish captured on fifth day	Day species first observed[1]	Fish captured on fifth day
		Number		*Number*
Pseudupeneus grandisquamis	3	87	2	31
Selar crumenophthalmus	3	79	3	304
Caranx caballus	2	17	2	129
Chromis atrilobata	3	8	3	0
Elagatis bipinnulatus	5	6	4	6
Psenes pacificus	–	–	5	2
Blenniolus brevipinnis	5	1	–	–
Caranx marginatus	2	0	4	2
Polydactylus approximans	3	0	3	0
Alutera	–	–	4	0
Total		198		474

[1] No underwater observations were made on the day the log was moored (Day 1).

TABLE 6.—*Number of fish and species recruited to various objects moored near the Costa Rican coast in 1963*

Object	Time elapsed after establishment	Fish	Species	Distance from shore	Season
		Number	*Number*	*Nautical miles*	
Truck inner tube[1]	15 hours	203	6	31	Spring
Balsa log (A)	5 days[2]	198	7	7	Fall
Balsa log (B)	5 days[2]	474	6	7	Do.
Truck inner tube	6 days	263	8	8	Spring
3 feet by 3 feet by ¼ inch plywood	20 days	2	1	2	Fall
Truck inner tube	20 days	13	4	7	Spring
Truck inner tube	28 days	492	7	8	Do.
Truck inner tube	46 days	118	5	9	Do.

[1] Attached to this inner tube were ten ¾-inch (19 mm.) manila lines 10 m. long. All tubes had a volume of 0.286 m.^{3}
[2] Established at same time at same locality.

BEHAVIOR

DISTRIBUTION AND FRIGHT BEHAVIOR

When disturbed, nearly all species swam toward the drifting object and maintained a position much closer to it than when undisturbed. The fishes showed this behavior when a school of porpoise, *Stenella grafmani*, passed a log, when four porpoise, *Tursiops* sp., passed nearby, when a school of black skipjack approached a log, and when a shark, *Carcharhinus azureus*, swam beneath a log. The movements of a diver, skiff, and the research vessel also induced this response. The fishes rapidly habituated to the movement of the outboard skiff; after several passes of the skiff near the same log the fear reaction no longer could be evoked.

Most species showed a marked change in behavior when disturbed. *Abudefduf saxatilis* frequently entered holes or crevasses on the surface of the log. The kyphosids moved in and out of holes and swam back and forth rapidly over the log so close to it that their fins almost touched it. Schools of all species became more compact; sometimes individuals that were a part of a diffuse aggregation of several species separated into monotypic schools. For example, when only a few *Chromis atrilobata* were present under undisturbed conditions they remained with the carangids in a loose aggregation, but when frightened they formed a compact monotypic school.

The fear response produced a marked vertical stratification of species beneath the object. Species distributed at various distances from the log, or members of a common loose aggregation, separated into discrete compact groups. If large numbers of fishes were grouped in this manner the distribution usually resembled a cone, the apex of which was at the underside of the object. The base was usually formed by a large group of juvenile *Selar crumenophthalmus* and *Decapterus* sp. The fish were always in this position when the object was approached by the research vessel or the skiff. It was only after the skiff had been near the log for a half hour or longer that the fish lost these more rigid groupings and strayed from their position directly beneath the log.

When the fish were undisturbed, the conical distribution beneath the log was not apparent, owing to movements in the horizontal plane and the breaking up of groups. The mixed school of *C. caballus*, *C. hippos*, *C. marginatus*, *Elagatis bipinnulatus*, and *Psenes pacificus* broke up into smaller units, and these at times moved at least 15 m. away from the object. Juvenile kyphosids swam 1.5 to 3 m. away from the object but did not range as far as the juvenile carangids. Adult *Canthidermis maculatus* frequently swam beyond the limit of visibility—15 m.—and returned to the object. *Abudefduf saxatilis* and *Blenniolus brevipinnis*, on the other hand, always remained near the object.

The relative vertical position of species usually was maintained under both disturbed and undisturbed conditions. Those species that increased their horizontal range when undisturbed also increased, to a lesser extent, their vertical range of movements. The juvenile kyphosids swam as deep as 1.5 m. below the object; *Pseudupeneus*, *Decapterus*, and *Selar* were observed at a depth of 12 m. (limit of visibility from the surface). Adult *Canthidermis* was the only species whose relative vertical position changed markedly. Under disturbed conditions this species was often among those occupying a position close to the object, but after the disturbance had ceased they ranged from the surface to depths over 12 m. Juvenile *Canthidermis*, on the other hand, occupied the same relative vertical position under disturbed and undisturbed conditions.

Commonly the responses of juvenile fish to a drifting object differed from those of the adult. Adults swam deeper, ranged farther, and appeared beneath the object less frequently than did juveniles. With the exception of adult *Sectator* and *Canthidermis*, they did not always respond to movements of the skiff by moving toward the object as did all the juvenile fishes. It was not possible, therefore, to be certain that adult *Euthynnus lineatus*, *Coryphaena hippurus*, *Caranx caballus*, or *Selar crumenophthalmus* were truly associated with a particular object.

POSITION RELATIVE TO OBJECT AND LATERAL BODY COLORATION

The lateral coloration of the fishes and their position relative to the object were correlated. The species that remained closest to the log were darker than were those that maintained greater distances from the object or associated with the object only intermittently (table 7). For example, *Abudefduf saxatilis*, *Psenes pacificus*, all species of *Caranx*, the kyphosids, *Blenniolus brevipinnis*, and *Lobotes pacificus*, were yellow, brown, or black and remained near the log. On the other hand, *Chromis atrilobata*, brownish above, silvery below, occupied a deeper position, and *Selar crumenophthalmus* and *Decapterus* sp., which were silvery, regularly occupied the

TABLE 7.—*Lateral coloration (live), estimated vertical distribution and aggregation type of certain species associated with flotsam in the offshore waters of Central America in 1963*

Fishes[1]	Lateral coloration (live)	Estimated vertical distance from object[2]	Grouping
Juvenile:			
Blenniolus brevipinnis	Dark brown with black bars	0	Individual
Abudefduf saxatilis	Yellow with dusky bands	0–3	
Canthidermis maculatus	Blue with white spots to black	3	
Polydactylus approximans[3]	Silvery below, blue above	3	Pure school
Kyphosus analogus	Black with pale purple stripes and spots		
Kyphosus elegans	Black with pale purple stripes and spots	0–15	Individual
Sectator ocyurus	Yellow with brown stripes below, dark olive green above		
Caranx caballus	Yellow below, olive above		
Caranx hippos	Yellow with dark dusky bands		
Caranx marginatus	Yellow with dark dusky bands	15–150	Mixed school
Elagatis bipinnulatus	Yellow with two blue stripes below, dark bluegreen above		
Seriola sp.	Yellow with black bands below, dark olive above		
Psenes pacificus	Yellow with brown stripes below, olive above		
Chromis atrilobata	Silvery below, pale brown above	150–200	Pure school
Decapterus sp.	Silvery below, blue above		
Selar crumenophthalmus	Silvery below, blue above	150–600	Mixed school
Pseudupeneus grandisquamis	Silvery below, blue above		
Adult:			
Canthidermis maculatus	Blue with white spots to black	0–300	Pure school
Caranx caballus	Silvery below, blue above	600–1300	

[1] Only those species are included for which we have sufficient notes on vertical distribution.
[2] Estimate made under disturbed conditions.
[3] Did not school beneath log but to one side near the surface.

deepest position of all the permanently associated fishes. This relationship suggests a protective advantage afforded by the log other than the physical obstruction of predators. The dark brown, yellow, and black of the closely associated species was well adapted to the colors of the most commonly occurring flotsam. Thus, when associated with flotsam, the more darkly colored species were probably less conspicuous to predators than when isolated. From examination of fishes associated with flotsam in the Atlantic, Murray and Hjort (1912) made similar speculations. They also suggested that *Naucrates ductor*, blue with darker transverse bars, might occupy an intermediate position between the organisms strongly associated with flotsam and those which merely live near drifting objects.

Although both *Canthidermis maculatus* and *Polydactylus approximans* had a pelagic coloration, they were frequently near the object when frightened. The fright reaction of *Polydactylus* differed from that of other species. These fish formed a compact rapidly moving school a few centimeters below the water surface. The school moved about near the object but never below it. Adult *Canthidermis* when undisturbed swam deeper and ranged farther from the object than all the yellow, brown, and black species. When frightened they moved to 0 to 3 m. below the object. Thus, this species occupied a position in keeping with its pelagic coloration only under undisturbed conditions. *Canthidermis* has the ability to turn from the normal pelagic coloration, blue with white spots, to black. Juveniles and adults had intermediate color phases as well as pelagic and dark phases.

Within the same species, coloration appeared to reflect differences in the behavior of association. The silvery adult *C. caballus* did not maintain close contact with an object and appeared beneath it only intermittently. The yellowish juvenile *C. caballus*, on the other hand, maintained close contact with the object. Gooding and Magnuson (see footnote 1) reported that when *Psenes pacificus* was associated with their raft it was yellow, but unassociated individuals were silvery.

FEEDING BEHAVIOR

Adult *Canthidermis*, *Alutera*, and juvenile *Elagatis* frequently were seen feeding on colonial salps. Once we saw three *Canthidermis* nipping the base of the neck and legs of a green turtle. On no other occasion did we see this species engaged in activities that could be interpreted as parasite cleaning. Occasionally juvenile kyphosids were observed snapping at the surface of a log or branch. Juvenile *Abudefduf* showed this behavior more frequently.

Adult *Coryphaena hippurus* frequently pursued smaller fishes located beneath flotsam. We did not see them capture fish, but the stomach of an adult *Coryphaena* taken by hook and line contained a *Caranx caballus*. Frequently fishes with lateral lesions were seen beneath logs. These included *Caranx caballus*, *Canthidermis maculatus*, and *Elagatis bipinnulatus*.

Two schools of skipjack, and one of yellowfin tuna were associated with logs in the study area and were seined by American tuna fishermen. When the boats reached port, stomach contents of fish from each school were examined and the lengths of the fish determined. Euphausiids and myctophids were the dominant food organisms in the stomachs of skipjack, and the portunid crab, *Portunus affinis*, in the stomachs of yellowfin tuna. Only seven stomachs contained fishes—carangids and scombrids—that may have been associated with flotsam (table 8). Stomachs from each of the three schools contained debris of the kind usually found near drifting logs (pieces of wood, thorns, and bird feathers).

TABLE 8.—*Occurrence of flotsam-associated fishes in the stomachs of two schools of oceanic skipjack, and one school of yellowfin tuna associated with flotsam in offshore waters of Central America in 1963*

Stomach contents	*Skipjack* seined October 3, 1963 (222–48)[1]		*Skipjack* seined October 6, 1963 (213–61)[1]		*Yellowfin tuna* seined June 18–22, 1965 (149–107)[1]	
	Number	*Volume Ml.*	*Number*	*Volume Ml.*	*Number*	*Volume Ml.*
Fish						
Flotsam-associated species	0	0	1	77.0	6	575.0
Unassociated species	10	281.1	34	1448.5	7	206.0
Unidentified remains	3	0.3	0	0	44	790.0
Invertebrates	33	212.8	26	25.0	73	1579.0
Bird feathers and plant debris	5	—	2	—	3	—

[1] At left, number examined; at right, number with food.

COURTSHIP BEHAVIOR

No eggs of any kind were found attached to the flotsam. Some species observed near drifting objects were, however, in reproductive condition. Three ripe male black skipjack were captured from a school near a large drifting tree. Underwater observations of these fish revealed a high frequency of wobbling and chasing. This behavior was similar to that described by Magnuson and Prescott[3] for the reproductive behavior of Pacific bonito, *Sarda chiliensis* (Cuvier).

Nearly all the adult male and female *Canthidermis maculatus* captured in the fall were ripe. On one occasion these fish showed what may have been courtship behavior, but no spawning was observed.

TRANSFER OF FISHES TO OTHER OBJECTS AND HOMING

Some species were attracted to the skiff when it drifted alongside a floating object. Only the fishes that occupied upper positions in the aggregation, such as juvenile *Caranx caballus*, *Psenes pacificus*, *Elagatis bipinnulatus*, *Kyphosus elegans*, and *Sectator ocyurus*, showed this behavior. The more deeply positioned species, *Selar crumenophthalmus*, *Decapterus* sp., *Pseudupeneus grandisquamis*, and *Chromis atrilobata* did not transfer to the skiff. Those species most closely associated with the surface of the object, *Abudefduf saxatilis* and *Blenniolus brevipinnis*, did not transfer unless the original object was removed from the water. Transfers to the skiff were only temporary. The fishes swam beneath the skiff, remained there a few minutes, and then returned to the original object. Movements back and forth from the object to the skiff lasted no longer than 30 minutes; thereafter, the fish remained beneath the original object.

Two attempts were made to transfer the fish population of a log to a 4- by 8-foot (122 cm. by 243 cm.), 1/4-inch (6 mm.) thick plywood sheet. A log with a fish population was attached to the plywood sheet 24 hours; then the two objects were separated. During daylight, underwater observations were made while the two objects were attached and after they were parted. At no time did the fishes congregate beneath the plywood sheet. They remained beneath the original object during the 24 hours the objects were attached and after they were separated. The experiment was repeated; this time, 60-cm. sections of unraveled 1/2-inch (13 mm.) manila line were attached at 10-cm. intervals in three rows to the underside of the plywood. The rope produced a dense mass of filaments. After 2 1/2 hours none of the fishes had transferred from the original log to the plywood, but 1 hour after the plywood was freed from the original object, over 100 *C. caballus* had been recruited to the plywood.

The failure of fishes to form a permanent association with new objects, a skiff or plywood sheet, when already associated with another object suggests that a more familiar object may have a higher valence.

Ten adult *Canthidermis maculatus* were captured, tagged, and released separately; four were released 7.5 m. from their original log, four at 15 m. and two at 30.5 m. One hour and 30 minutes later, three of those released at 7.5 m. and three released at 15 m. had returned. Neither of the fish released at 30.5 m. returned. Conceivably the fish planted at the greatest distance could not see the log. The recapture of fish planted at lesser distances suggested that they may return to their log when it is within visual range.

RUBBING BEHAVIOR

Adults of *Coryphaena hippurus*, *Canthidermis maculatus*, and *Sectator ocyurus* frequently rubbed their dorsal surface or sides against the logs and the skiff. An entire school of adult *Sectator* showed this behavior.

SEA SNAKES

We frequently observed the sea snake, *Pelamis platurus*, swimming near the surface. Often a small school of fish of the genus *Polydactylus* was below a snake. On three occasions the snake was feeding. It began to swim backwards; the schooled fish reversed direction and began swimming with their heads oriented toward the tail of the snake. The snake then captured fish from the school by a rapid thrust of the head and anterior portion of the body, directed either to the side and posteriorly or downward and posteriorly.

Klauber (1935) also observed *P. platurus* feed on fish schooled beneath it.

Klawe (1964) examined the stomachs of 56 *P. platurus* from the eastern tropical Pacific. In the 22 which contained food, *Polydactylus approximans* was the most abundant food, *Pseudupeneus grandisquamis* was second, and Mugilidae third. One individual each of *Selar crumenophthalmus*, *Caranx hippos*, and *Fistularia corneta* also were found. Except for *F. corneta* we captured all of these species beneath flotsam, and there was no difference in size between the fishes we collected and those in the stomachs of sea snakes. Apparently *P. platurus* takes advantage of the habit of some species to congregate beneath flotsam.

[3] John J. Magnuson and John H. Prescott—Courtship, locomotion, feeding, and miscellaneous behavior of Pacific bonito (*Sarda chiliensis*). Manuscript, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii.

ECOLOGICAL INTERPRETATION

Fishes were recruited rapidly to moored objects. The number beneath objects moored 5 days and the number beneath those moored 20 or more days did not differ. Goose barnacles were attached to all four objects moored 14 days or longer, but they were found on only one drifting object. Thus, all but one of the drifting objects probably had been at sea not longer than 14 days. Rapid recruitment appears to be characteristic of the formation of flotsam-associated fish aggregations. Hardenberg (1950) reported that Indonesian fishermen harvest the fishes beneath their palm frond rafts at intervals of several days. Gooding and Magnuson (see footnote 1) stated that fishes were recruited to their raft minutes after it was set adrift.

Recruitment of fishes followed no particular sequence. Small collections containing only a few fish were not necessarily all of one species. The species composition and order of recruitment of fishes to two balsa logs moored 100 m. apart were dissimilar.

The same species dominated our collections in both fall and spring. Similarities were marked between the families and genera represented in our study area and those reported from other areas (Uchida and Shojima, 1958; Besednov, 1960; Kojima, 1960a; Mansueti, 1963). Juvenile carangids were by far the most important family in terms of abundance, number of species, and dominance. They were also by far the most frequently reported flotsam associate from other areas. Other families of fishes commonly encountered in this study and frequently reported by other authors included the Scombridae, Balistidae, Kyphosidae, and Stromateidae.

The presence of attached invertebrates on floating objects appeared not to influence the occurrence of fish species. The only drifting object that had goose barnacles attached did not have a species composition different from that of objects without the barnacles. Although barnacles were present on each of four objects moored 14 or more days, the species composition of the aggregations of fish did not differ from those of objects moored much shorter periods.

Many of the flotsam-associated fishes were schooling species. We believe that the habit of schooling and of association with drifting materials may be related. Two scombrids, *Katsuwonus pelamis* and *Thunnus albacares*, not only associate with inert materials but also with large sharks and whales, and *T. albacares* is a common associate of porpoise schools (Uda and Tsukushi, 1934; and unpublished logbook records of the Inter-American Tropical Tuna Commission). The carangid, *Naucrates ductor*, known for its association with sharks (Dales, 1957), also was found beneath flotsam in this and in other studies (Murray and Hjort, 1912; Galea, 1961). Many fishes school at times with fish other than their own species. *Katsuwonus pelamis* and *Thunnus albacares* school together (Orange, Schaefer, and Larmie, 1957), and juvenile *Selar crumenophthalmus* and *Decapterus* sp. were observed schooling together in this study. *Trachurus symmetricus* (Ayres), a carangid associate of flotsam in southern California waters, schools with *Scomber japonicus* Houttuyn and *Sardinops sagax* (Jenyns)[4] and associates with jellyfish (Limbaugh, 1955). The tendencies of fishes to associate with living animals other than their own species and to associate with inert drifting materials may be related. Atz (1953) suggested, among other possibilities that an aggregating companion for a schooling fish could represent merely "a simple point of reference for optical fixation". Flotsam could function in this capacity for schooling fishes.

A schooling mechanism cannot explain the presence of all the associated species. Some fishes did not school, and for others alternative mechanisms are equally plausible. Mechanisms postulated by other authors were: attraction to food, negative phototactic response to the shadow of the object, shelter from predators, presence of spawning substrate, and parasite-cleaning symbiosis.

Owing to the infrequent occurrence of flotsam-associated fishes in the stomachs of predators the food hypothesis probably can be eliminated for predacious adults.

For juveniles and nonpiscivorous adult fishes the food hypothesis would not apply, as the drifting materials were usually devoid of attached invertebrates and algae that would provide food. That fishes were attracted because plankton was more visible in the shadow cast by the object also seems unlikely, because the fishes did not remain in the shadow. Furthermore, plywood sheets that cast large shadows were less effective in attracting fish than were objects that produced smaller shadows.

That all the juvenile fishes and adult *Canthidermis maculatus* and *Sectator ocyurus* swam toward and beneath the object when predators appeared, sug-

[4] Unpublished data, Bureau of Commercial Fisheries, La Jolla, California.

gests the association has a selective advantage. This behavior was not, however, a mechanism for the association, because fishes remained near the object in the absence of predators.

Use of the object as a spawning substrate would apply only to adult fishes. Adults, however, represented only a small portion of the total individuals present. Adults of two species, *Euthynnus lineatus* and *Canthidermis maculatus*, were in reproductive condition. *Euthynnus* does not have attached eggs, however (Calkins and Klawe, 1963), and no eggs were found on any of the floating materials.

The cleaning-station hypothesis suggested by Gooding and Magnuson (see footnote 1) could apply only to some of the fishes. *Canthidermis maculatus* alone showed behavior that could possibly be interpreted as cleaning. This species was taken in only 14 of the 70 collections. Except in the collection made farthest from shore, where *Canthidermis* and *Balistes polylepis* were the only species present, no differences in the species composition were evident in the collections that contained *Canthidermis*. Thus, if *Canthidermis* regularly consumes parasites of other fishes the activity does not appear to influence the presence of these fishes.

Artificial reefs established in sandy locations rapidly attract groups of fishes that would not otherwise inhabit these areas (Carlisle et al., 1964). The artificial reef provides the habitat requirements for certain fishes in an otherwise unsuitable area. Similarly, a drifting object may provide a suitable habitat for inshore fishes that have pelagic juvenile stages or that have become displaced from shore. This explanation seems to be plausible for the presence of *Abudefduf saxatilis*, *Blenniolus brevipinnis*, *Balistes polylepis*, and other species. The very restricted size range of *Chromis atrilobata* and *Pseudupeneus grandisquamis* suggests that these species are available for association during a limited period. Many of the *Pseudupeneus* were near the size at which metamorphosis takes place. Approaching metamorphosis was indicated by the slight color changes in some of the individuals and by pronounced changes in coloration after the fish were kept in a shipboard aquarium 34 hours. Possibly large premetamorphic juveniles may be attracted to objects because of changes associated with metamorphosis; for these fish the object may represent an inshore or nonpelagic habitat.

In summary, we found little evidence to support the mechanisms postulated by other authors. We have suggested two mechanisms: (1) fishes are attracted to drifting materials because the object functions as a schooling companion, and (2) for species not adapted to a pelagic life and others undergoing a change from a pelagic to other modes of existence, drifting materials may function as a substitute for a reef or other substrate. In both situations the object may have the same function, that is, provide a visual stimulus in an optical void.

The occurrence of juvenile fishes beneath flotsam was much more frequent than that of adults. That some species, as *Chromis atrilobata*, *Pseudupeneus grandisquamis*, and *Agonostomus monticola*, are pelagic only as juveniles can explain the absence of the adults. Of the species that are pelagic as juveniles and adults, the juveniles were in the vicinity of an object for longer periods and remained closer to the object than did the adults. Owing to their larger size and faster swimming speed, adults are probably less susceptible to predation. Thus, for adult fishes the selective advantage of maintaining a close association with a drifting object may be small. It is also possible that development is accompanied by an increase in the specificity of the responses of schooling fishes to other schooling companions. The valence of flotsam as a schooling object would then be lowered and intermittent association with drifting objects might be expected.

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