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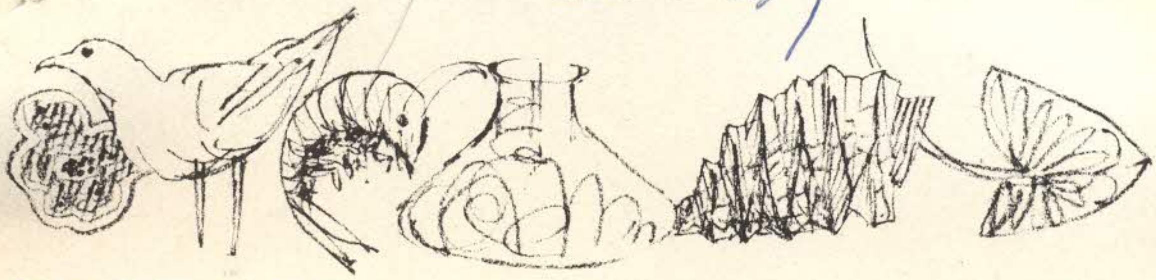

# CONTRIBUTIONS IN MARINE SCIENCE

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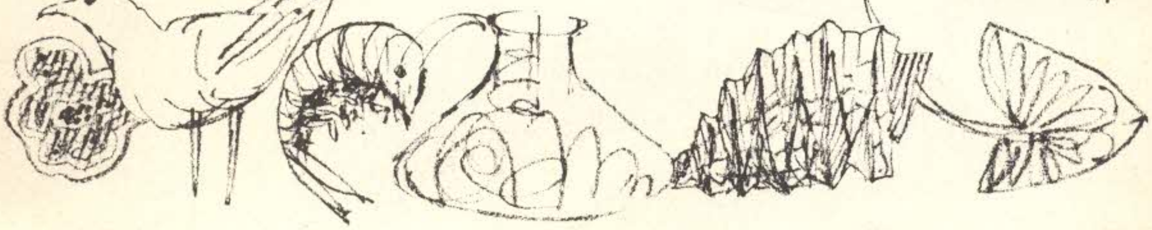

# FISHES ASSSOCIATED WITH THE PELAGIC SARGASSUM COMPLEX, WITH A DISCUSSION OF THE SARGASSUM COMMUNITY[1]

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## ABSTRACT

From April 1966 through May 1967, some 3,200 kgm (3.5 tons) of sargassum were collected in the Florida Current. Analysis revealed approximately 8,400 fishes belonging to 8 orders, 23 families, 36 genera and 54 species. The families Carangidae (14 species), Monacanthidae (10 species), Balistidae (4 species) and Antennariidae (1 species) numerically comprised 90% of all fishes collected. Sargassum was present in very low quantities in spring and winter, while tremendous quantities were available in summer and fall. Summer and fall were marked by fewer, larger fishes than winter and spring. As a consequence of surface current patterns, sargassum acts as a vehicle for dispersal of some of its inhabitants. The sargassum community appears to be important in the life histories of many species of pelagic, littoral and benthic fishes, providing them with a substratum, protection against predation and concentration of food in the open sea.

## INTRODUCTION

This study concerns the fishes of the pelagic sargassum complex in the Florida Current, including their seasonal occurrence, relative abundance and ecological relationships. The role of sargassum during the ontogeny of the fifty-four species collected in this study is also discussed. In addition, a brief consideration of the North Atlantic sargassum community and its biogeographical distribution is included.

Columbus referred to the drifting weed encountered during his voyage of 1492 and since then the pelagic sargassum complex has been known but not throughly studied. Kuntze (1881) and Krummel (1891) quantitatively surveyed the weed in the Sargasso Sea; Winge (1923) and Parr (1939) studied the distribution of sargassum in the North Atlantic; Deacon (1942) generally discussed the Sargasso Sea; Woodcock (1950) described the buoyancy of sargassum weed; Faller and Woodcock (1964) studied the spacing of sargassum windrows; and Lang-

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muir (1938) discovered that sargassum windrows were oriented along the convergencies of circulation cells of the sea surface.

The invertebrate fauna of the sargassum has been examined to some extent. Timmermann (1932) studied the zoogeographical distribution of the invertebrates; Conover and Sieburth (1964) examined the effect of sargassum distribution on its epibiota; Prat (1935), Ekman (1967) and Hedgpeth (1953, 1957) discussed the sargassum community; Burkenroad (1939) studied the hydroids; several epizoic flatworms were described by Hyman (1939); Hackett (1963) compiled a checklist of sargassum fauna and flora; Weis (1968) wrote a brief note on several previously unreported gastropods; and Fine (1970) although hampered by limited sampling examined the diversity and affinity of sargassum fauna off North Carolina.

The Pacific Ocean sargassum complex has been studied extensively by Japanese workers. Kojima (1955, 1956, 1957, 1960, 1960a, 1961, 1966) has written prolifically on the dolphin and its reaction to flotsam. Hirosaki (1960, 1960a, 1963, 1963a, 1964, 1965) studied the ecology and behavior of fishes found under sargassum and other flotsam off Japan. Ida, Hiyama and Kusaka (1967, 1967a) examined weed associated fishes including their behavior and food habits. Imamura, et al. (1965) discussed a raft used to attract dolphins; Senta (1962, 1965, 1966, 1966a, 1966b) attempted to explain factors that caused fishes to associate with floating weed. Shojima and Ueki (1964) and Uchida and Shojima (1958) discussed larval and juvenile fishes found in sargassum; and Yabe and Mori (1950) described the association of tuna and flotsam. Mukai (1971) studied the invertebrates associated with beds of sessile sargassum in the Inland Sea of Japan; and Besednov (1960) collected fishes under central Pacific sargassum patches.

Little work has been done on the relationships of North Atlantic fishes with sargassum weed. However, many of the fishes found with sargassum have been studied such as: Collette (1962) a new halfbeak, Bruun (1935) and Breder (1938) on the flying fishes, Herald (1965) the American pipefishes, Nichols (1937), McKenney, et al. (1958) and Berry (1959) the crevalle jacks (*Caranx*), Mather (1958) the amberjacks (*Seriola*) of the western North Atlantic and Berry (1968) described a new species of Jack (*Decapterus tabl*) found in this study. Gibbs and Collette (1959) and Beardsley (1967) studied the dolphins (*Coryphaena*), Lewis (1967) the food habits of the yellowfin tuna and dolphin, Caldwell (1962) larval and juvenile goatfishes, Moore (1962) the kyphosids, Matsui (1967) the mackeral (*Scomber*), Taning (1961) and Arata (1954) examined the life history of the swordfish (*Xiphias*), Legaspi (1956) and Mckenney (1961) the driftfish (*Psenes*), Anderson (1957) the early development of the silver mullet (*Mugil curema*), Berry and Vogele (1961) the filefishes, Moore (1967) the triggerfishes and Adams (1960) on the life history of the sargassum fish (*Histrio histrio*). Longley and Hildebrand (1941) surveyed the fishes of Tortugas, Florida and mentioned some fishes found with sargassum.

## SARGASSUM COMMUNITY

The sargassum community is a world-wide circumtropical phenomenon comprised of a rather unique and diverse association of organisms. Although the community has faunal affinities with littoral areas and contains some transients from inshore waters the complex is holopelagic. Pelagic sargassum may have evolved from a benthic form in littoral areas of the Caribbean Sea, but age of the community can only be conjectured because of the lack of fossil evidence. The relative age of the community may be estimated by the fact that the only two species of endemic fishes belong to phylogenetically advanced forms.

The sargassum community is a concentration of food in the epipelagia in the area outlined in Figure 1. Upon sinking, pelagic sargassum adds organic carbon to the ocean bottom over broad areas of the North Atlantic and is a source of food for a major constituent of the deep-sea benthos (Schoener and Rowe, 1970). The invertebrate fauna is comprised of approximately 100 species, nearly 10% endemic; major groups include: hydroids, anthozoans, flatworms, bryozoans, polychaetes, gastropods, nudibranchs, bivalves, cephalopods, pycnogonids, isopods, amphipods, copepods, decapod crustaceans, insects and tunicates. Shrimp and crabs comprise the bulk of the invertebrates and a major source of food for sargassum associated fishes. The importance of sargassum in the development of many pelagic fishes and fishes with pelagic stages will be discused in detail.

## DISTRIBUTION

Pelagic sargassum occurs in the Atlantic, Pacific and Indian Oceans and the Red Sea (Markkaveeva, 1965). Krummel (1891) estimated that in the North Atlantic, sargassum covered nearly two million square miles; Parr (1939) measured the density of the weed at from two to five tons per square mile (2.6 $km^2$) of sea surface.

The sargassum complex in the Florida Current study area is comprised of about 80% *Sargassum natans*, 10% *S. fluitans* and 10% detached sessile *S. filapendula.* Fragments of aquatic vascular plants and other debris are ofen found interspersed with sargassum. The two formerly mentioned holopelagic species of sargassum are sterile, reproducing vegetatively by fragmentation. The weed maintains its buoyancy by a large number of gas filled vesicles (Woodcock, 1950) and can probably remain afloat idefinitely unless killed by cold temperature (below 18°C), sunk by great wave action or submerged by excessive epibiotic growth (Parr, 1939).

Sargassum circulates between 20° and 40° N. latitude and between 30° W. longitude and the western edge of the Gulf Stream (Timmermann, 1932). Parr (1939) and Conover and Sieburth (1964) found a paucity of weed in the central Caribbean Sea. Some weed occurs in the Gulf of Mexico, apparently carried out of the northern Caribbean between Yucatan and Cuba. Whether the weed is self-sustaining is not known, but the sargassum carried into the Gulf of Mexico is probably lost to the North Atlantic community. Considerable qualities of sargassum are carried between the Bahaman Bank and Cuba, channeled northward through the Straits of Florida by the Florida Current and either remain in the Gulf Stream drift, sink or are blown ashore by strong onshore winds.

The center of distribution of pelagic sargassum appears to be in the vicinity of the North Atlantic gyre southeast of Bermuda between 28° and 34° N. lati-

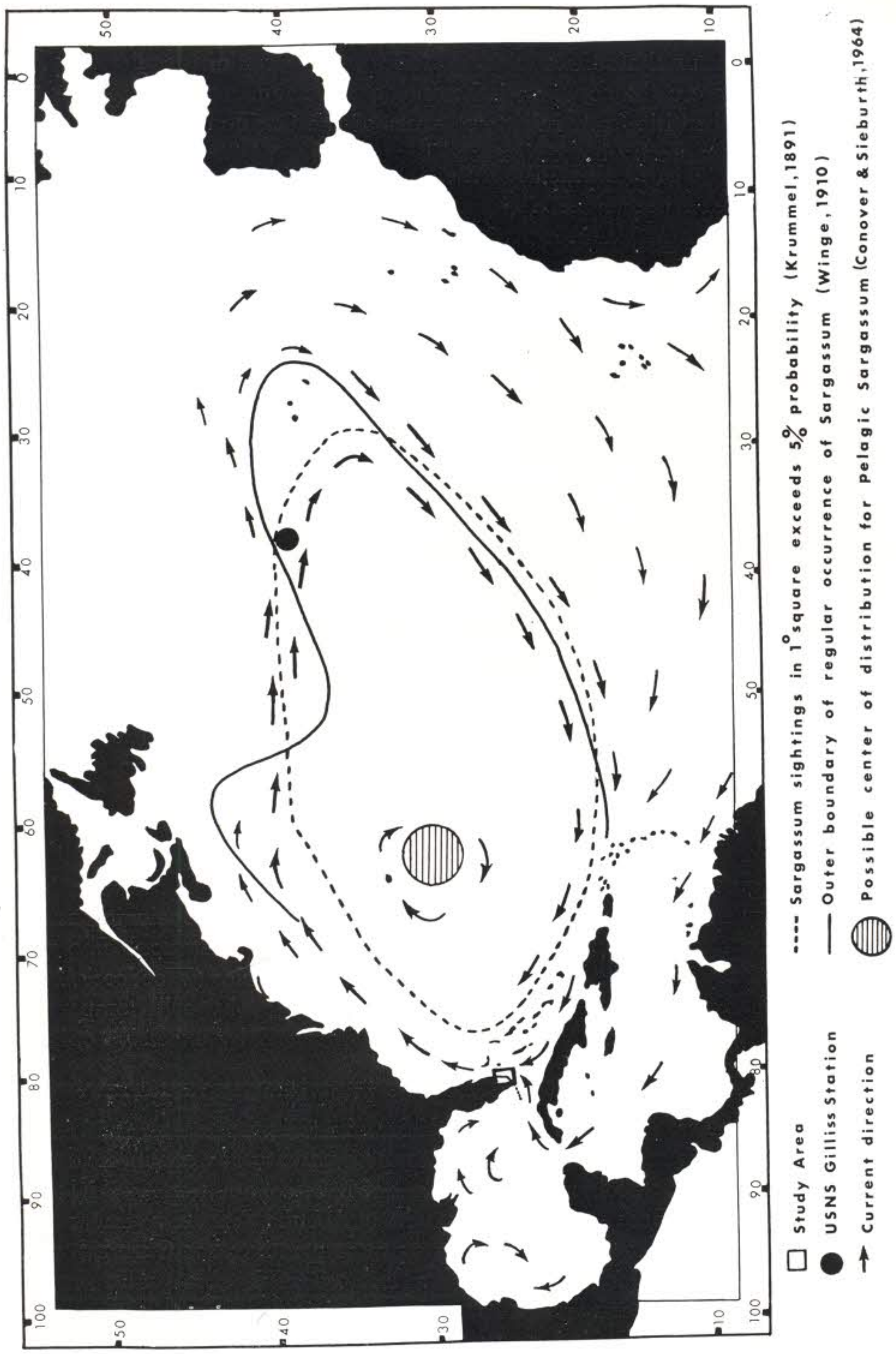


FIG. 1. Outer boundary of regularly occurring pelagic sargassum weed in the North Atlantic, including the possible center of distribution, area of study, and a collection station near the Azores from the vessel USNS Gilliss.

tude and 65° W. longitude (Conover and Sieburth, 1964; Sieburth and Conover, 1965; Fig. 1). According to Winge (1932) the 18° isocryme limited sargassum distribution and Parr (1939) believed that cold winds upon the exposed shoots was a critical factor.

## MATERIALS AND METHODS

Sargassum samples were taken within the Florida Current semi-monthly from April 1966 through May 1967. The stations were generally located in an area within a 16 km circle approximately 11 km east southeast off the southern tip of Key Biscayne, Florida (Fig. 2). Several stations were up to 40 km offshore, and two stations were inshore of the Florida Current. The current edge was usually from 1 to 2 km east of the 20 m bottom contour (Fig. 2). The availability and proximity of the sargassum determined the precise sampling location. The amount of weed and the number of stations taken per trip was determined by the time required to sort each sample. Most samples were collected using a miniature purse seine, although a hook and line was used when large fishes were observed near sargassum. A dip net was occasionally used when the seas were rough and the weed very scattered.

A miniature purse seine was modified from a design by Hunter, Aasted and Mitchell (1966). The net used was rectangular and measured 30.5 m by 5.2 m. The body of the net was constructed from two 61.5 m by 2.6 m panels of blue nylon 12.5 mm stretch mesh sewn together. Two meters of netting were hung on each meter of head rope. The additional netting rendered "bag" to the net and decreased the tendency for the lead line to ascend during pursing operations. The net was lighter and cost less to construct than the seine designed by Hunter, Aasted and Mtichell (1966).

### Sampling Technique

A sargassum patch that could be entirely encircled with the seine was selected. The patch was approached from the vessel's starboard side from downwind. A drougue chute was deployed and the net played out. The boat circled the patch in a clockwise direction so that upon completion of the circle the vessel would lie downwind of the net to prevent drifting over the catch. The net was closed and pursed as quickly as possible The entire operation generally took from 30 to 45 minutes.

The sargassum sample was rinsed thoroughly in large tubs and the rinse water strained through a 1mm mesh sieve. The weed was wet weighed to the nearest ½ kg. on a machete beam balance; a one gallon sample of weed was preserved for epibiotic analysis and the remainder discarded. The term sargassum biomass discussed later refers to the fresh wet weight.

Samples were sorted and identified and the numbers and kinds of fishes were recorded. Standard lengths were measured to the nearest mm with dial calipers or dividers. The preserved wet weight of each fish species was determined to the nearest gram with a triple beam balance within a week of its capture. The term fish biomass used later refers to the weight formerly discussed. Only superficial examination of the food habits of some sargassum associated fishes was attempted. Stomach analyses were conducted on preserved specimens of the ten most numerous species of fishes from a range of sizes and from each season of occurrence. Details of the food habits of these fishes will be discussed later. Specimens collected were entered into the museum of N.O.A.A., Tropical Atlantic Biological Laboratory, Miami, Florida.

The location of the sampling station was fixed with a radio directional finder. Field data included the determination of surface salinity (with an optical densitometer), surface and air temperatures, sea state, cloud cover, approximate wind velocity, time of day and characteristics of the sargassum patches.

## RESULTS AND DISCUSSION

During the course of this study 3,200 kgm (3.5 tons) of sargassum were collected containing approximately 8,400 fishes belonging to 8 orders, 23 families,

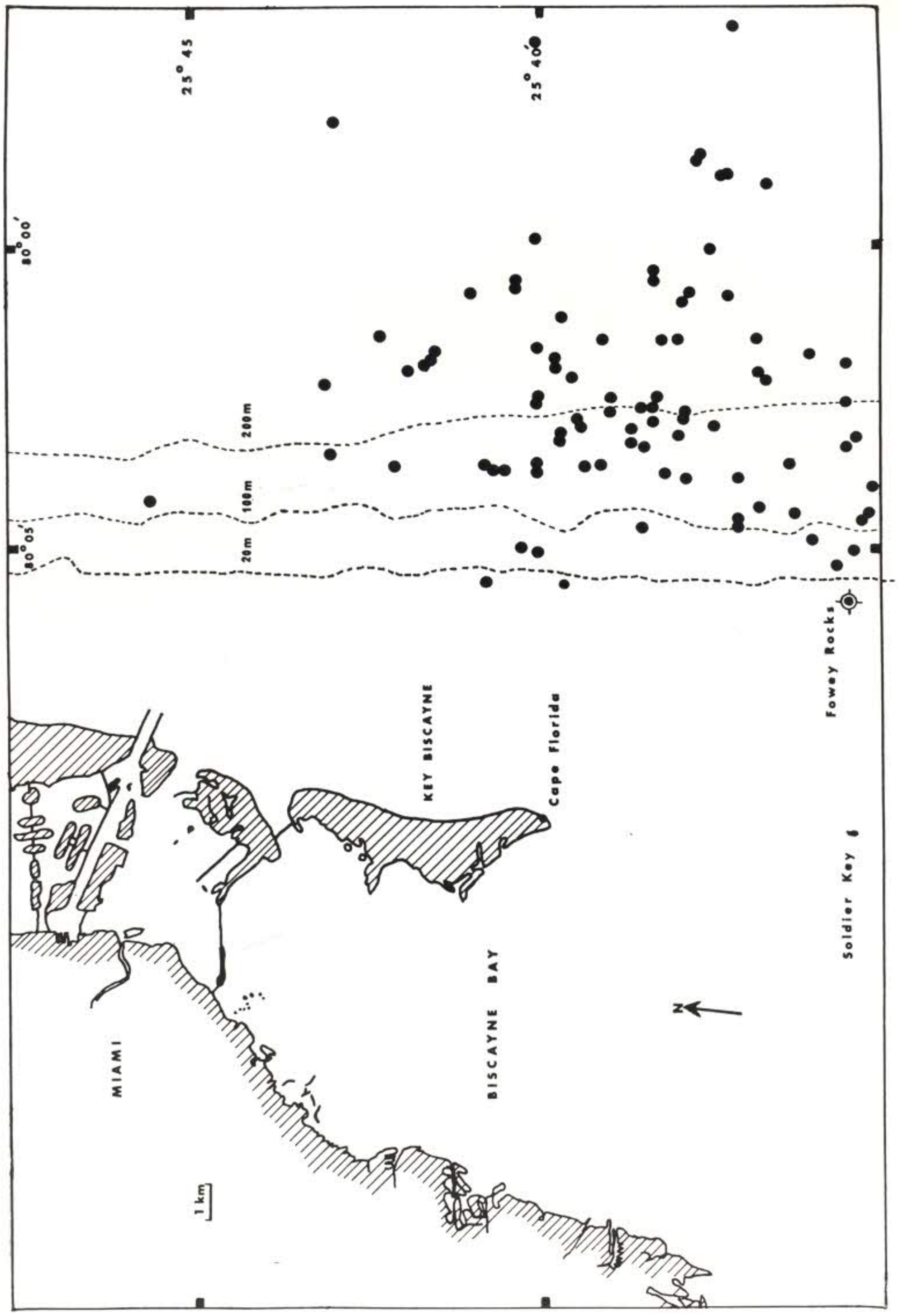


FIG. 2. Area of study and sampling locations. Dots denote station locations. Enclosed dot is Fowey Rocks lighthouse. Dashed lines are approximate bottom contours.

36 genera and 54 species. Statistical analyses revealed a positive correlation between weed biomass and the numbers of the two most numerous species of fishes found in sargassum. The correlation coefficient for *Histrio histrio* was $r = 0.31$ and significantly different from 0 (completely random) at the 0.1% level; for *Stephanolepis hispidus* $r = 0.21$ and significantly different from 0 at the 10% level. Analyses of several other less numerous species of fishes failed to reveal any significant correlation. In addition, no significant correlation was found between the total biomass of fishes and weed, probably due to the high degree of variance introduced by the less numerous species (Fig. 3). June through October was marked by more numerous and larger fishes than the period from November through May (Fig. 4).

Hydrographic conditions in the Florida Current proved to be remarkably stable throughout the year. Surface temperature varied from a low of 23.5°C in

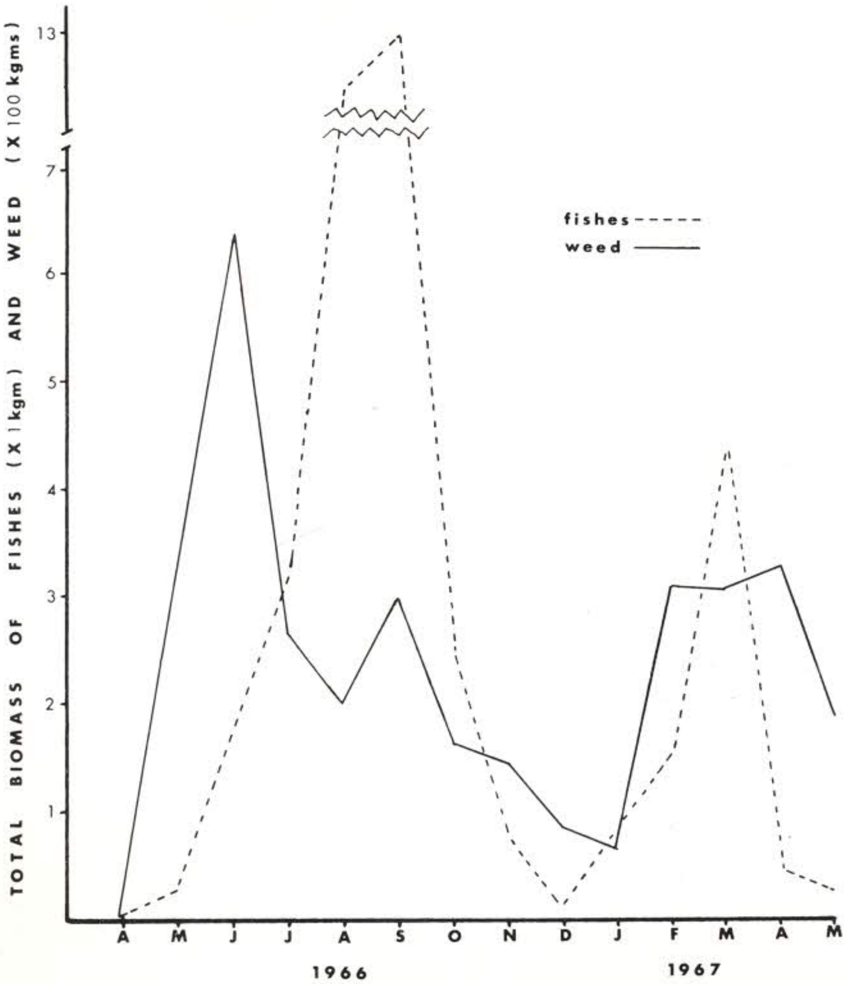


FIG. 3. A comparison of the total biomass of sargassum with the total biomass of associated fishes.

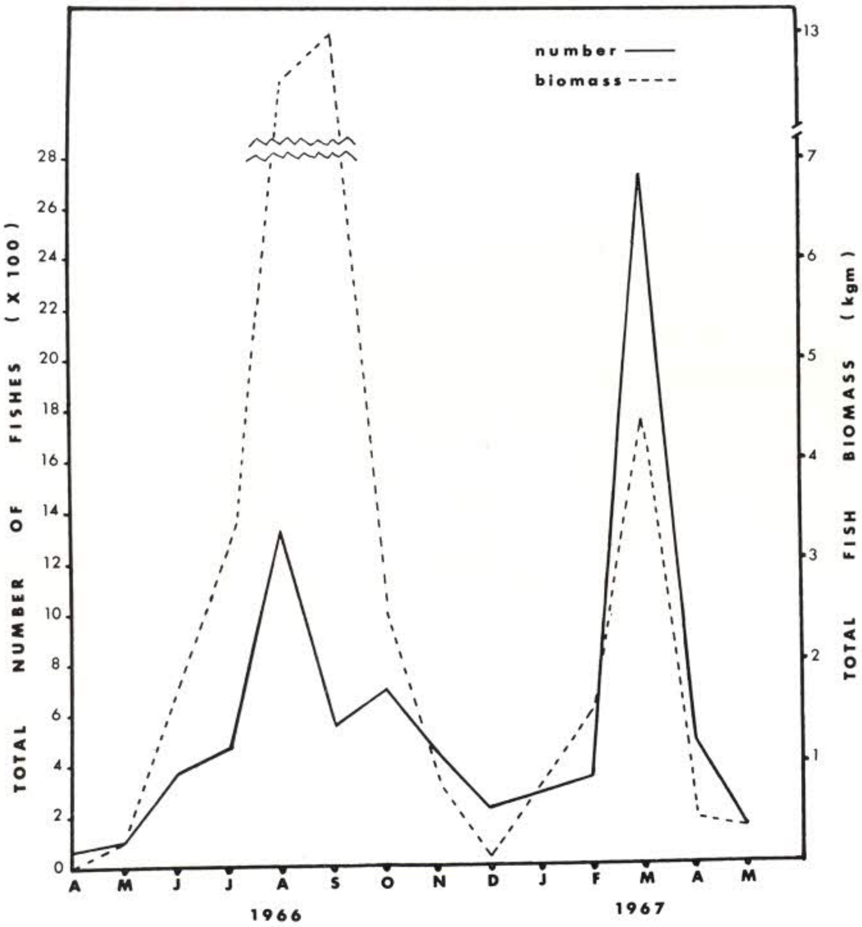


FIG. 4. A comparison of total numbers and total biomass of sargassum associated fishes.

December to a high of 30.1°C in August. Surface salinity ranged from a low of 35.3‰ in May to a high of 37.0‰ in June. There did not appear to be any relationship between numbers of fishes found in sargassum and hydrographic conditions in the Florida Current.

The only night station taken during the study did not reveal a fauna unlike that collected earlier during the day. Likewise, there were no apparent differences between two samples taken slightly inshore of the Florida Current and those taken several hundred meters to the east within the current.

The sargassum fishes have been separated into four categories based on their relative abundance, frequency of occurrence and ecological relationship to the weed. The first group has been designated coincidentally associated fishes based on their rare occurrence, less than 20 specimens. The second group has been defined as moderately associated fishes. These fishes were rare, less than 20 specimens, but based on previous reports they were thought to be associated with sargassum either for a source of food or shelter. Because of the paucity of specimens, fishes belonging to the two previously mentioned groups will only be listed and not discussed (Table 1). The third category has been designated as seasonally occurring sargassum fishes. These fishes were found in relative high numbers, but occurred during less than 6 months of the study (Table 2) and will be discussed briefly. The last and most important catagory has been listed as fishes closely associated with sargassum. These fishes were found in numbers greater than 20 specimens and occurred during 6 months or more of the study.

## SEASONALLY OCCURRING FISHES

### Hemiramphidae

*Hemiramphus balao* LeSueur

The balao was present in March through June, and November through February, reaching its peak abundance in the latter period (Table 2). This species is probably a predator on the members of the sargassum community.

### Exocoetidae

*Cypselurus heterurus* (Rafinesque)

Adults of this flyingfish have been reported to use sargassum and other flotsam as a substratum for their eggs, the young use the weed as a refuge (Breder, 1938). Both adults and young of this species were taken under sargassum in May and November through February.

TABLE 1

A list of the coincidental and moderately associated sargassum fishes found in the Florida Current
Coincidental = (C), Moderately associated = (M)

| | | | |
|---|---|---|---|
| Carcharhinidae | | Mullidae | |
| *Cacharhinus falciformis* | (C) | *Upeneus parvus* | (C) |
| Clupeidae | | Xiphiidae | |
| *Sardinella anchovia* | (C) | *Xiphias gladius* | (C) |
| Belonidae | | Monacanthidae | |
| *Tylosurus acus* | (M) | *Alutera monoceros* | (M) |
| Exocoetidae | | *A. schoepfi* | (M) |
| *Parexocoetus brachypterus* | (C) | *A. heudelotii* | (M) |
| *Exocoetus obtusirostris* | (C) | *Cantherhines macrocerus* | (M) |
| *Hirundichthys affinis* | (M) | *Monacanthus tuckeri* | (M) |
| Centriscidae | | Balistidae | |
| *Macrorhamphosus* sp. | (C) | *Canthidermis maculatus* | (M) |
| Syngnathidae | | *C. sufflamen* | (M) |
| *Syngnathus louisianae* | (C) | *Xanthichthys ringens* | (M) |
| Carangidae | | Tetraodontidae | |
| *Caranx hippos* | (M) | *Sphaeroides sp.* | (C) |
| *Decapterus macarellus* | (M) | Diodontidae | |
| *D. tabl* | (M) | *Diodon holacanthus* | (M) |
| *Elagatis bipinnulatus* | (M) | *D. hystrix* | (M) |
| *Seriola fasciata* | (M) | | |
| *S. zonata* | (M) | | |

TABLE 2

The number, relative abundance, seasonal occurrence, mean size and size ranges of seasonally occurring sargassum fishes found in the Florida Current

| Species | March–June Number | March–June Number per hundred kgm of weed | March–June Mean size (mm) | March–June Size range (mm) | July–October Number | July–October Number per hundred kgm of weed | July–October Mean size (mm) | July–October Size range (mm) | November–February Number | November–February Number per hundred kgm of weed | November–February Mean size (mm) | November–February Size range (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hemiramphidae | | | | | | | | | | | | |
| *Hemiramphus balao* | 16 | 0.89 | 80 | 37–98 | 0 | — | — | — | 31 | 5.00 | 87 | 47–110 |
| Exocoetidae | | | | | | | | | | | | |
| *Cypselurus heterurus* | 3 | 0.16 | 27 | 12–51 | 0 | — | — | — | 60 | 9.70 | — | larvae–90 |
| Carangidae | | | | | | | | | | | | |
| *Trachurus lathami* | 1,889 | 105.0 | 48 | 12–62 | 0 | — | — | — | 0 | — | — | — |
| Scombridae | | | | | | | | | | | | |
| *Scomber japonicus* | 240 | 13.40 | 57 | 37–78 | 0 | — | — | — | 0 | — | — | — |
| Mugilidae | | | | | | | | | | | | |
| *Mugil curema* | 0 | — | — | — | 0 | — | — | — | 159 | 25.80 | — | larvae |

## Carangidae

*Trachurus lathami* Nichols

The rough scad was collected with *Scomber* and *Decapterus* in very large schools and only in March. Stomach analysis of 14 specimens are shown in Table 3. Much of the material was not identifiable, but sargassum crustaceans and many copepods were evident.

TABLE 3

Stomach analysis of the eight most abundant sargassum fishes. Stomach contents listed in percent of occurrence. Number in parentheses is number of specimens examined. A = *Trachurus lathami*, B = *Caranx crysos*, C = *C. ruber*, D = *Seriola rivoliana*, E = *Stephanolepis hispidus*, F = *S. setifer*, G = *Balistes capriscus*, and H = *Histrio histrio*

| Stomach contents | Fish species | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A (14) | B (42) | C (28) | D (8) | E (75) | F (66) | G (26) | H (77) |
| Sargassum fragments | .. | 10 | .. | 75 | 73 | 76 | 31 | 3 |
| Empty | 40 | 5 | 4 | .. | .. | .. | 19 | 12 |
| Invertebrates | | | | | | | | |
| Unidentified | 26 | 38 | 4 | .. | .. | .. | 31 | 25 |
| Hydroids | .. | .. | .. | .. | 84 | 48 | 15 | .. |
| Copepods | 26 | 31 | 96 | .. | 25 | 8 | 31 | .. |
| Phylosoma larvae | .. | 14 | .. | .. | .. | .. | .. | .. |
| Shrimp | | | | | | | | |
| *Leander tenuicornis* | .. | 40 | 7 | 50 | .. | 11 | 23 | 14 |
| *Latrudes fucorum* | .. | .. | .. | .. | 4 | 6 | .. | 19 |
| Zoea, post larvae | .. | .. | 21 | .. | .. | .. | .. | .. |
| Crabs | | | | | | | | |
| *Portunus sayi* | .. | .. | .. | .. | 3 | 11 | 8 | .. |
| Pycnogonid | .. | .. | 4 | .. | 11 | 2 | 4 | .. |
| Barnacles | .. | .. | .. | .. | 32 | 29 | 27 | .. |
| Tunicates | .. | . | .. | .. | 1 | 23 | .. | .. |
| Polychaetes | .. | .. | .. | .. | 12 | .. | 12 | .. |
| Bivalvia | .. | .. | .. | .. | 1 | .. | .. | .. |
| Gastropods | .. | .. | .. | .. | .. | 5 | 12 | .. |
| Platyhelminthes | .. | .. | .. | .. | .. | 3 | .. | .. |
| Vertebrates | | | | | | | | |
| Fishes | | | | | | | | |
| Unidentified | 8 | 2 | 4 | 38 | .. | .. | .. | 27 |
| *Synodus* (larvae) | .. | 5 | .. | .. | .. | .. | .. | .. |
| *Coryphaena sp.* | .. | .. | .. | 13 | .. | .. | .. | .. |
| *Syngnathus* sp. | .. | .. | .. | 25 | .. | .. | .. | .. |
| Carangid | .. | .. | .. | .. | .. | .. | .. | 10 |
| *Trachurus lathami* | .. | .. | .. | .. | .. | .. | .. | 4 |
| *Caranx* sp. | .. | .. | .. | 25 | .. | .. | .. | 1 |
| *C. crysos* | .. | .. | .. | 25 | .. | .. | .. | .. |
| *Scomber japonicus* | .. | .. | .. | .. | .. | .. | .. | 1 |
| *Cantherhines pullus* | .. | .. | .. | 25 | .. | .. | .. | 1 |
| Balistid | .. | .. | .. | 38 | .. | .. | .. | .. |
| *Canthidermis* sp. | .. | .. | .. | 25 | .. | .. | .. | .. |
| *Stephanolepis* sp. | .. | .. | .. | .. | .. | .. | .. | 6 |
| *Histrio histrio* | .. | .. | .. | .. | .. | .. | .. | 1 |
| Fish eggs | .. | .. | .. | .. | .. | 2 | .. | .. |

### Scombridae

*Scomber japonicus* Houttuyn

The Pacific mackerel was found only during March, always schooling with *Trachurus* and *Decapterus*. *Scomber* probably uses sargassum fauna as a supplemental source of food much like *Trachurus*.

### Mugilidae

*Mugil curema* Valenciennes

Numerous schools of larval silver mullet (8–20 mm) were observed and captured near or among sargassum from December through February. Larval mullet probably use sargassum as a refuge to avoid predation.

## FISHES CLOSELY ASSOCIATED WITH SARGASSUM

### Syngnathidae

*Syngnathus floridae mckayi* (Jordan and Gilbert)

Male brood pouches of this pipefish contained eggs from May through December. The smallest mean size and the greatest abundance occurred from July through October (Table 4). *S. floridae mckayi* apparently use sargassum as a shelter. Several specimens were taken among sargassum off the Azores from the USNS Gilliss and will be discussed later.

*Syngnathus pelagicus* Linnaeus

The sargassum pipefish is endemic to the pelagic sargassum community and was found throughout the year. Males of this species were found with eggs in their brood pouches in November and May. Böhlke and Chaplin (1968) observed eggs in July in the Bahamas.

### Lobotidae

*Lobotes surinamensis* (Bloch)

Young specimens of the triple tail were taken from summer through winter, with a peak in abundance occurring in early fall (Table 4). Young taken from sargassum were discussed by Böhlke and Chaplin (1968), who believed that young *Lobotes* were not established in sargassum. The tendency of *Lobotes* to float on their side at the surface and also the presence of rough scales and sharp opercular spines appears to ideally suit *Lobotes* for life in sargassum (Breder, 1949). A small specimen was found in sargassum off the Tortugas by Longley and Hildebrand (1941). The sargassum weed seems to be an important habitat for the young triple tail, while the more independent adults probably use the faunal complex as an occasional source of food.

### Carangidae

The family carangidae is one of the most numerous and diverse groups found among sargassum. According to Böhlke and Chaplin (1968) most, if not all of the carangids are probably pelagic spawners. Many species have apparently adopted the sargassum as a nursery. The very young jacks (below 20 mm) were

TABLE 4

The number, relative abundance, seasonal occurrence, mean size and size ranges of fishes closely associated with sargassum found in the Florida Current

| Species | March–June Number | March–June Number per hundred kgm of weed | March–June Mean size (mm) | March–June Size range (mm) | July–October Number | July–October Number per hundred kgm of weed | July–October Mean size (mm) | July–October Size range (mm) | November–February Number | November–February Number per hundred kgm of weed | November–February Mean size (mm) | November–February Size range (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Syngnathidae | | | | | | | | | | | | |
| *Syngnathus floridae mckayi* | 5 | 0.28 | 123 | 87–145 | 46 | 4.90 | 94 | 48–166 | 17 | 2.80 | 101 | 68–163 |
| *S. pelagicus* | 5 | 0.28 | 134 | 110–167 | 9 | 0.96 | 129 | 88–178 | 9 | 1.50 | 108 | 98–124 |
| Lobotidae | | | | | | | | | | | | |
| *Lobotes surinamensis* | 1 | 0.06 | 68 | 68 | 27 | 2.90 | 159 | 18–250 | 2 | 0.32 | 149 | 115–183 |
| Carangidae | | | | | | | | | | | | |
| *Caranx crysos* | 135 | 7.50 | 41 | 12–111 | 330 | 35.30 | 70 | 17–136 | 4 | 0.65 | 49 | 36–65 |
| *C. ruber* | 170 | 9.50 | 37 | 18–87 | 137 | 14.60 | 40 | 14–89 | 3 | 0.49 | 33 | 27–43 |
| *C. bartholomaei* | 49 | 2.70 | 29 | 10–77 | 61 | 6.50 | 23 | 15–72 | 39 | 6.30 | 26 | 19–35 |
| *Seriola rivoliana* | 14 | 0.78 | 37 | 12–107 | 25 | 2.70 | 137 | 21–295 | 13 | 2.10 | 47 | 26–81 |
| *S. dumerili* | 15 | 0.84 | 24 | 13–108 | 9 | 0.96 | 118 | 62–245 | 7 | 1.10 | 110 | 52–164 |
| *Selar crumenophthalmus* | 17 | 0.95 | 48 | 37–76 | 37 | 4.00 | 96 | 54–145 | 31 | 5.00 | 52 | 36–92 |
| *Decapterus punctatus* | 159 | 8.90 | 50 | 39–54 | 4 | 0.43 | 56 | 53–60 | 119 | 19.30 | 59 | 35–78 |
| Coryphaenidae | | | | | | | | | | | | |
| *Coryphaena hippurus* | 8 | 0.45 | 96 | 18–170 | 0 | . . . | . . | . . . . | 14 | 2.30 | 65 | 15–158 |
| Kyphosidae | | | | | | | | | | | | |
| *Kyphosus sectatrix* | 9 | 0.50 | 23 | 10–69 | 20 | 2.10 | 71 | 11–132 | 9 | 1.50 | 45 | 24–72 |
| Pomacentridae | | | | | | | | | | | | |
| *Abudefduf saxatilis* | 22 | 1.20 | 12 | 8–25 | 31 | 3.30 | 19 | 11–39 | 12 | 1.90 | 16 | 12–25 |
| Stromateidae | | | | | | | | | | | | |
| *Psenes cyanophrys* | 124 | 6.90 | 30 | 11–79 | 8 | 0.85 | 54 | 23–89 | 12 | 1.90 | 33 | 20–78 |

TABLE 4 (Continued)

| Species | March–June | | | | July–October | | | | November–February | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Number per hundred kgm of weed | Mean size (mm) | Size range (mm) | Number | Number per hundred kgm ofweed | Mean size (mm) | Size range (mm) | Number | Number per hundred kgm of weed | Mean size (mm) | Size range (mm) |
| Monacanthidae | | | | | | | | | | | | |
| *Stephanolepis hispidus* | 132 | 7.40 | 24 | 8–57 | 1,383 | 148.0 | 51 | 12–74 | 442 | 71.6 | 30 | 7–83 |
| *S. setifer* | 132 | 7.40 | 30 | 9–69 | 87 | 9.30 | 38 | 25–68 | 27 | 4.40 | 20 | 11–38 |
| *Alutera scripta* | 12 | 0.67 | 88 | 46–128 | 33 | 3.50 | 108 | 46–162 | 5 | 0.81 | 92 | 43–143 |
| *Monacanthus ciliatus* | 12 | 0.67 | 21 | 14–26 | 6 | 0.64 | 19 | 18–19 | 2 | 0.32 | 19 | 19 |
| *Cantherhines pullus* | 26 | 1.50 | 44 | 33–67 | 17 | 1.80 | 57 | 47–76 | 2 | 0.32 | 54 | 50–59 |
| Balistidae | | | | | | | | | | | | |
| *Balistes capriscus* | 1 | 0.06 | 30 | 30 | 480 | 51.3 | 67 | 13–132 | 12 | 1.90 | 89 | 35–175 |
| Antennariidae | | | | | | | | | | | | |
| *Histrio histrio* | 844 | 47.0 | 16 | 7–115 | 218 | 23.3 | 17 | 6–58 | 238 | 38.6 | 15 | 7–58 |

found within the protection of the weed, while the larger jacks were found progressively further below and away from the weed.

*Caranx crysos* (Mitchill)

The peak abundance of the blue runner was in June and July (Fig. 5). Based on the mean sizes and modes, and in agreement with Berry (1959), spawning probably takes place principally in early September. *C. crysos* probably migrates inshore between the sizes of 100 and 140 mm (Table 4). The largest specimen I captured in the sargassum was 136 mm, while Berry (1959) had no record of this species inshore smaller than 100 mm. Stomach analysis of 42 specimens appears in Table 2. Phylosoma larvae and copepods were the dominant food in August, while zoea and copepods were the primary food in July.

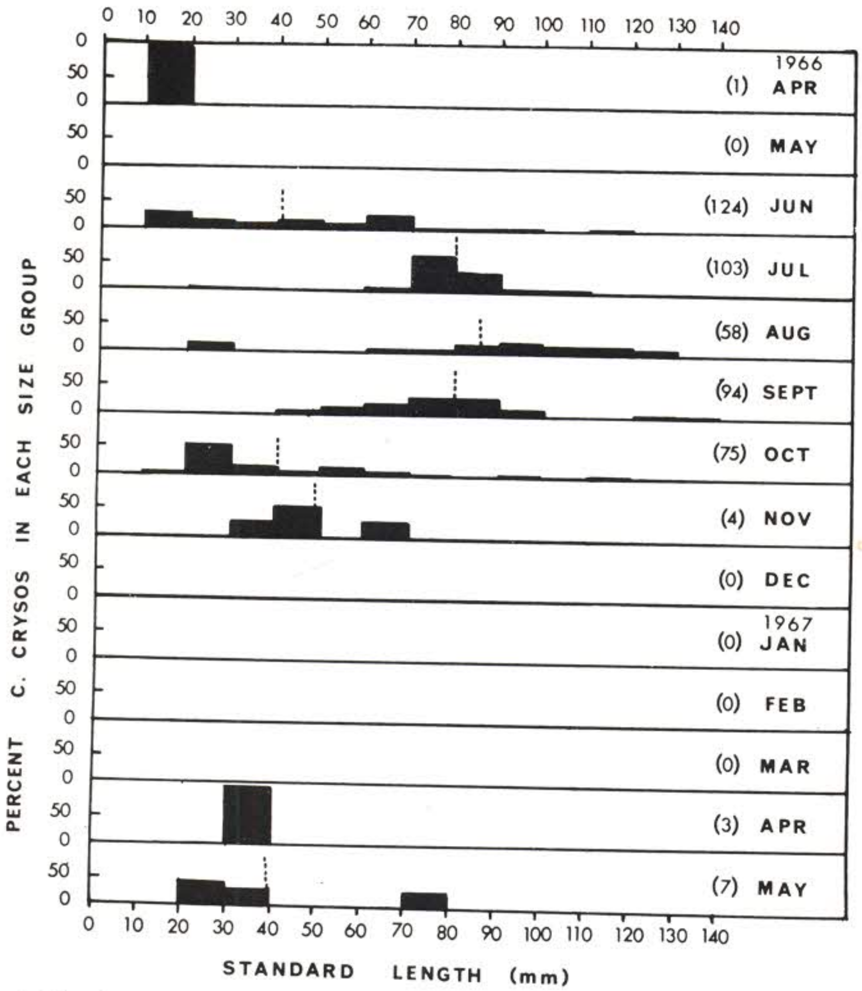


Fig. 5. Size frequency distribution of *Caranx crysos* collected under sargassum in the Florida Current during 1966 and 1967. Dashed lines are mean sizes, numbers in parenthesis are numbers of specimens.

*Caranx ruber* (Bloch)

The bar jack was found from April through October. Based on size frequency data, spawning probably occurs in July and August (Fig. 6). Based on small specimens, Berry (1959) believed spawning took place from mid February through mid August. He also found *C. ruber* rare inshore north of Jupiter, Florida. Stomach analysis of 28 specimens appears in Table 2. No seasonal differences in feeding were noted.

*Caranx bartholomaei* Cuvier

Based on small specimens captured the yellow jack probably spawns from February through October; Berry (1959) believed spawning took place from mid February to mid September. Inshore migration of *C. bartholomaei* probably occurs before 75 mm is attained. Berry (1959) found that a 38 mm-specimen

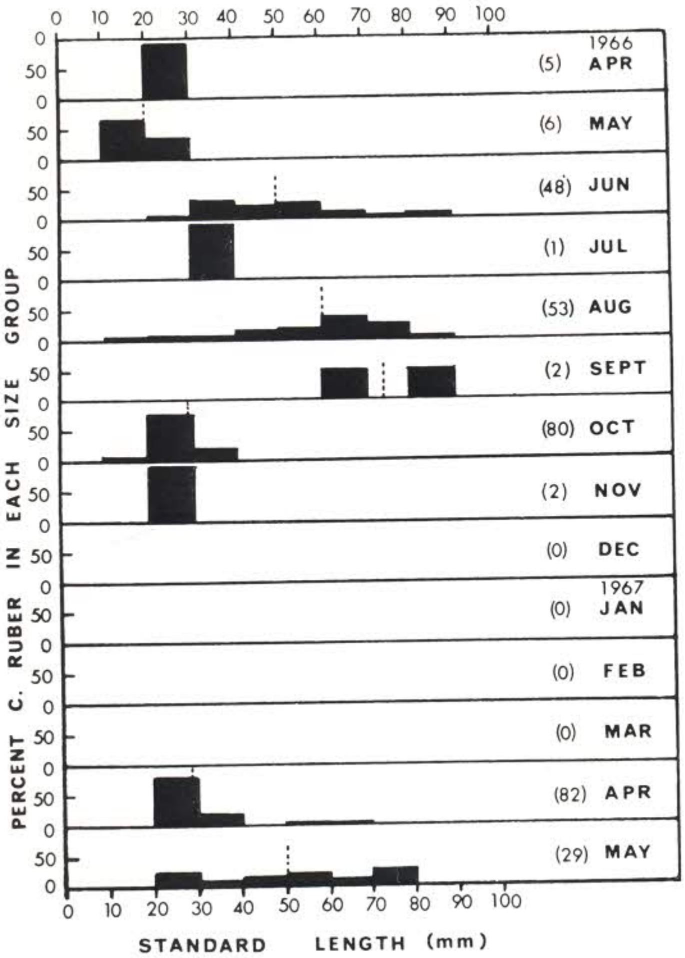


FIG. 6. Size frequency distribution of *Caranx ruber* collected under sargassum in the Florida Current during 1966 and 1967. Dashed lines are mean sizes, numbers in parenthesis are number of specimens.

was the smallest inshore specimen on record. Often onshore winds and currents will drive sargassum and accompanying fishes to inshore areas, particularly at places like south Florida and Cape Hatteras where the Florida Current is close to shore. Roessler (1970) occasionally found small *Caranx*, *Histrio histrio*, and other sargassum associated fishes within the estuary of the Everglades National Park.

*Seriola rivoliana* Valenciennes and *S. dumerili* (Risso)

Young amberjacks (below 50 mm) appear to use sargassum as a refuge, while larger amberjacks apparently are major predators of the sargassum complex. Stomach analysis of eight specimens of *S. rivoliana* (177–295 mm) can be seen in Table 2. Based on small specimens captured, spawning probably occurs in the spring for both species.

*Selar crumenophthalmus* (Bloch)

The bigeye scad was found throughout the year with a peak in both abundance and size occurring in summer and fall (Table 4). Stomach analysis of a single 147 mm-specimen of *Selar* revealed carangids, balistids, and sargassum fragments.

*Decapterus punctatus* (Agassiz)

The round scad was found from November through May with a peak in March. This species probably uses sargassum as a refuge and not as a source of food. Examination of the stomach contents of 10 specimens revealed only copepods. Whether these copepods were residents of the sargassum community or not is not known.

*Coryphaena hippurus* Linnaeus

The dolphin is one of the most sought after game and food fish and nearly always found in or near sargassum weed. Kojima (1956) believed dolphin take shelter under flotsam (including sargassum) because of a great availability of food. Gibbs and Collette (1959) reported finding filefishes, triggerfishes, jacks, sargassum fragments and sargassum crabs in the stomachs of dolphins. Lewis (1967) found dolphin stomachs contained flyingfishes, filefishes, triggerfishes, puffers and swellfishes.

The present study has yielded an entire ontogenetic series of *C. hippurus*, but curiously not a single specimen of *C. equisetis*; this cannot be explained. Based on the smallest specimens captured, *C. hippurus* may spawn in late November and late March. Based on fecundity studies, Beardsley (1967) believed that peak spawning occurred from January through March, with possible spawning year-around.

Kyphosidae

*Kyphosus sectatrix* (Linnaeus)

The Bermuda chub was found throughout the year, with the smallest individuals occurring in spring and fall. The young fish appear to be closely associated with sargassum (Moore, 1962), while the adults prefer rocky reef areas

(Böhlke and Chaplin, 1968). It is not known why *K. incisor,* the other species found in the western Atlantic was not found in sargassum.

### Pomacentridae

*Abudefduf saxatilis* (Linnaeus)

Young (below 39 mm) sergeant majors occurred year-around. Perhaps sargassum is a nursery for these littoral fishes. The sergeant major is a circumtropical species, and its young have been found associated with sargassum in other oceans. Besednov (1960) recorded juveniles from sargassum northeast of New Guinea.

### Stromateidae

*Psenes cyanophrys* Culver

The freckled driftfish were most numerous and smallest in the spring (Table 4). According to Böhlke and Chaplin (1968), the adults probably inhabit deeper waters. The young *Psenes* are colored so that they appear well hidden among sargassum.

### Monacanthidae

The filefishes, triggerfishes and jacks comprised 74% of all fishes I found in sargassum. The filefishes and triggerfishes make up an important part of the pelagic forage fish fauna as well (Berry and Vogele, 1961). The importance of monacanthids and balistids in the diets of dolphins and tuna have been shown by Gibbs and Collette (1959) and Lewis (1967).

*Stephanolepis hispidus* (Linnaeus)

The planehead filefish was the most numerous fish found in sargassum (Table 4). *S. hispidus* outnumbered its sibling species *S. setifer* by 5 to 1. *S. hispidus* was in peak abundance in July and August with spawning probably occurring from September through April, based on mean and modal sizes (Fig. 7). Females with immature eggs were observed in December. It is interesting to note that the young of two species of *Stephanolepis* coinhabit the sargassum, while the adults appear to be disjunct; *S. hispidus* a continental species as an adult, and the smaller *S. setifer*, an insular species (F. H. Berry, personal communication). Ida, Hiyama and Kusaka (1967a) have shown that in *S. cirrhifer*, a species found in association with sargassum off Japan, the feeding habits changed with growth. Based on stomach analysis of the young of *S. hispidus* and *S. setifer*, it is evident that their diverse food habits are such that they are compatable, while it is possible that the food habits of the adults make *S. hispidus* and *S. setifer* competitive. Stomach analysis of 75 young *S. hispidus* appears in Table 3. The principal foods from winter through spring were sargassum fragments, hydroids and barnacles; summer foods were sargassum fragments, hydroids and copeopods *Stephanolepis setifer* (Bennett).

The pigmy filefish was most abundant during the summer (Table 4). Based on mean and modal sizes, spawning appears to occur, as with *S. hispidus*, from September through April (Fig. 8). The results of examination of the food habits

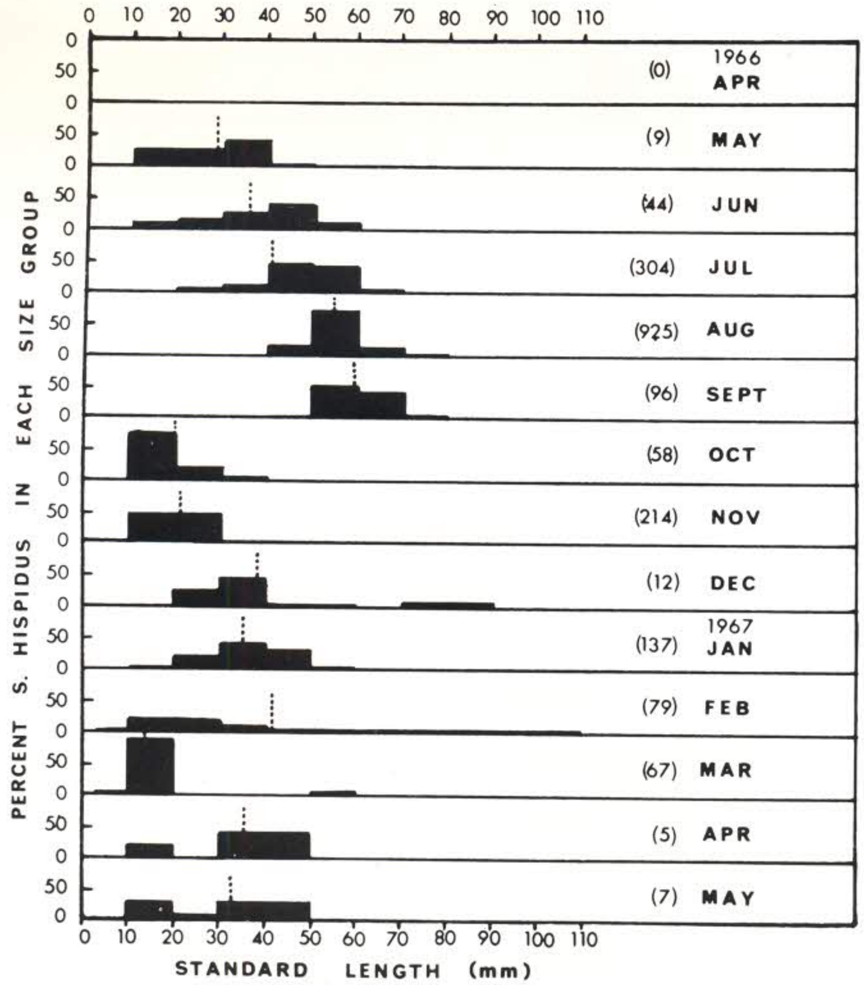


FIG. 7. Size frequency distribution of *Stephanolepis hispidus* collected under sargassum in the Florida Current during 1966 and 1967. Dashed lines are mean sizes, numbers in parenthesis are numbers of specimens.

of 66 young *S. setifer* is shown in Table 3. There was little seasonal variation in feeding other than polychaetes being the dominant food during the summer.

*Alutera scripta* (Osbeck)

The scrawled filefish was collected throughout the year, with the smallest specimens in August. Young *A. scripta* probably use sargassum as a nursery then migrate inshore at approximately 160 mm.

*Monacanthus ciliatus* (Mitchell)

The fringed filefish is a common inhabitant of *Thalassia* beds as juveniles and adults. Young specimens (below 27 mm) of *M. ciliatus* were collected in sargassum year-round. Spawning appears to occur year-round because of the nearly constant small mean size and size ranges (Table 4).

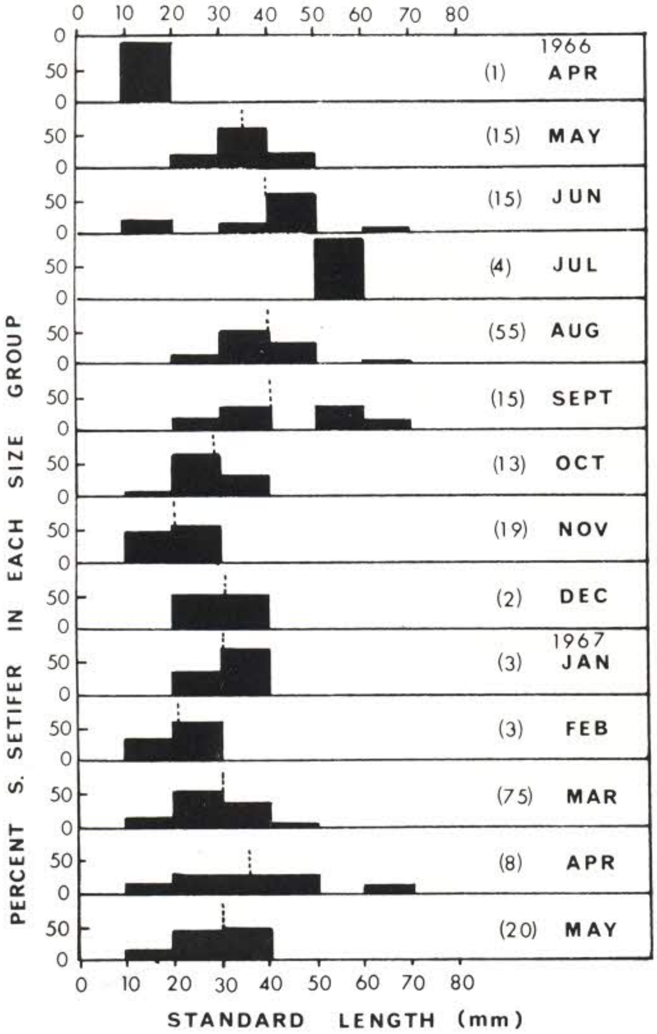


FIG. 8. Size frequency distribution of *Stephanolepis setifer* collected under sargassum in the Florida Current during 1966 and 1967. Dashed lines are mean sizes, numbers in parenthesis are numbers of specimens.

*Cantherhines pullus* (Ranzani)

The orangespotted filefish is a fairly common sargassum inhabitant along with its rare sibling species *C. macrocerus* (Dooley, 1968). *C. pullus* was in peak abundance in June, and found in low numbers in winter (Table 4). According to Randall (1964), ripe females were found in the Virgin Islands and Puerto Rico from February to June. *C. pullus* apparently spawn in late winter to late spring. The pelagic young inhabit sargassum to approximately 76 mm or less, then migrate to inshore reefs.

### Balistidae

*Balistes capriscus* Gemlin

The gray triggerfish was caught in high numbers from August through October, with very few caught in subsequent months (Fig. 9). Based on the smallest specimens captured, spawning probably occurs from July through October. Stomach analysis of 26 specimens revealed that *B. capriscus* relies heavily on the sargassum complex for food (Table 3).

### Antennariidae

*Histrio histrio* (Linnaeus)

The endemic sargassum fish appeared in 87 of the 102 samples collected in the Florida Current. Length frequency analysis showed an increase in mean size from April through September followed by a sudden influx of 6–15 mm individauls in October (Fig. 10). There was apparently subsequent recruitment of the

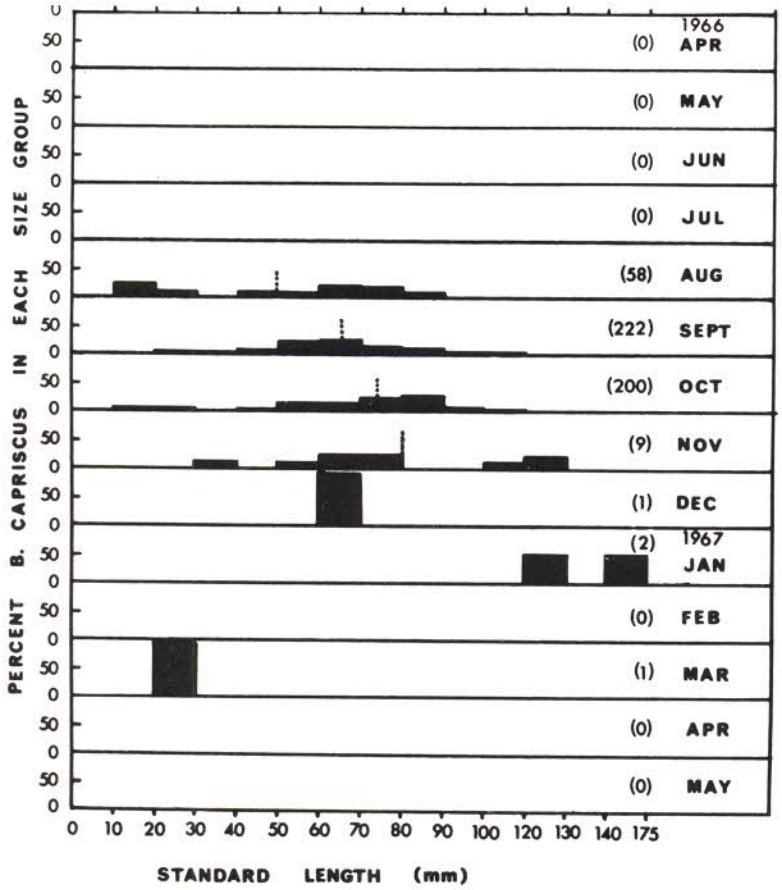


FIG. 9. Size frequency distribution of *Balistes capriscus* collected under sargassum in the Florida Current during 1966 and 1967. Dashed lines are mean sizes, numbers in parentheses are numbers of specimens.

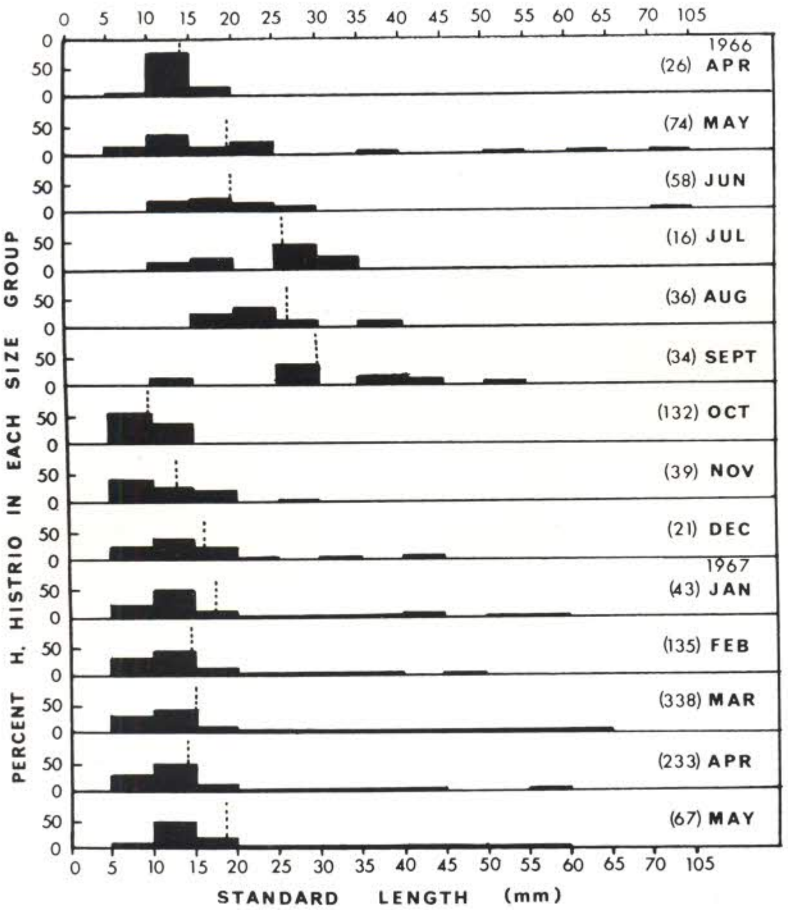


FIG. 10. Size frequency distribution of *Histrio histrio* collected under sargassum in the Florida Current during 1966 and 1967. Dashed lines are mean sizes, numbers in parentheses are numbers of specimens.

smallest size groups (5–10 mm), and emmigration or high mortality of the larger fishes from October through April. Spawning occurred at least from late August through April based on mean and modal sizes (Fig. 10). Adams (1960) suggested that spawning might be year-round. She also found that larval and post-larval *Histrio* (up to 4 mm) occurred at depths from 50 to 600 m. Adams (1960) did not find any *Histrio* larger than 4 mm below a depth of 50 m, and I did not recover any specimen smaller than 6 mm in sargassum. *Histrio* has an enormus mouth and distensible stomach and is a voracious predator within the sargassum community. Adams (1960) found even the larval *Histrio* were carnivorous. It was found in my study that small *Histrio* (below 20 mm) generally fed on sargassum shrimps (carideans), while larger specimens fed mostly on fishes. Stomach analysis of 77 *Histrio* appears in Table 3.

## FISH—SARGASSUM RELATIONSHIP

Age of the sargassum community is conjectural because no fossil record for Sargassum is known (C. J. Dawes, personal communication), and only three specimens of a fossil antennariid *Histonotophorus bassani*, a relative of *Histrio histrio*, are known from the Upper Eocene (Eastman, 1911). However old the sargassum community, the complex appears to be well established as evidence by its nearly cosmoplitan occurrence in world oceans, the high degree of faunal adaptive coloration, form and behavior (Cott, 1957) and the numerous examples of endemism (10 invertebrates and 2 fishes).

Many hypotheses have been proposed for the causative factors for the fish—sargassum relationships. Prat (1935) suggested the weed offered fishes a source of food, protection from predators, a substratum, a shelter for eggs and larvae, and a mechanical protection from waves. Mitchell and Hunter (1970) demonstrated by laboratory experimentation that fishes associated with drifting kelp were pursued less often, for shorter periods, and captured less frequently by predators. Ida, Hiyama and Kusaka (1967b) clearly showed that most weed associated fishes were dependent upon sargassum for both food and shelter. The present study shows sargassum fishes feed on the sargassum community (Table 3). Damant (1921) believed that fishes were attracted to flotsam because the shade made zooplankton more visible for capture. Senta (1966) found that the kinds of material used in artificial weed experiments seemed to make little difference in the gathering of juvenile fishes. Kojima (1957) found a sargassum filefish reacted positively to shade, while Senta (1966a) found some juvenile fishes were attracted to light. Hunter and Mitchell (1968) discovered fishes seemed to aggregate around three dimentional objects more than two dimentional ones. Factors such as optical fixation (Senta, 1966b; Hunter and Mitchell, 1967), thigmotrophism (Breeder and Nigrelli, 1938), and the use of flotsam as a cleaning station (Gooding and Magnuson, 1967) have been suggested as causing fish to aggregate around floating objects.

It seems probable that sargassum primarily offers protection, as can be seen by adaptive behavior and coloration of the fishes, and a concentration of food in the somewhat barren upper meter of the open sea. Langmuir (1938) first noticed that *Sargassum* aggregated into windows that were oriented along convergencies of sea surface circulatory cells induced by the wind. Sutcliffe, Baylor and Menzel (1963) demonstrated that organo-phosphates concentrate as surface slicks along the convergencies of these "Langmuir Cells." Particulate organics and phosphates from these slicks are broken up and carried by downwelling and would appear to be readily available as a source of nutrients for planktonic organisms (Sutcliffe, Baylor and Menzel, 1963). The high concentrations of plankton found in windows lend support to this hypothesis and would seem to form the basic food source necessary to the sargassum community.

In addition to this allocthonous source of plankton, the sargassum community apparently carries along a resident planktonic population. Yeatman (1962) found six species of littoral copepods clinging to or swimming close to sargassum collected in the North Atlantic. These copepods reproduce while being transported with sargassum as shown by egg-sacs, numerous nauplii and various immature stages present. Stomach analysis of a 25-mm flyingfish revealed a number of these littoral copepods and led Yeatman (1962) to conclude "*Sargassum* inhibiting copepods furnish food for some fishes as well as for coelenterates, etc. in the Sargasso Sea." Table 3 shows that sargassum jacks, filefishes and triggerfish frequently feed on copepods.

Young jacks live within or close to the protective branches of sargassum and feed heavily on copepods and larval decapod crustaceans. Sub-adult jacks such as *Seriola*, range further from the community and occasionally dart in to feed on shrimp and young fishes that inhabit the weed.

The filefishes and triggerfishes form a second major predatory component of the sargassum community. Filefishes feed manly on hydroids and encrusting bryozoans, injesting large quantities of sargassum leaves in the process; secondarily, filefishes feed on other sargassum invertebrates (Table 3). Triggerfishes depend less on encrusting bryozoans, but otherwise feed similarly to the filefishes.

The third major predator of the sargassum complex is the voracious sargassum fish *Histrio histrio*. *Histrio* is a skillful predator consuming very little superflous weed while selectively feeding on shrimp and young fishes (Table 3).

Fishes that associate with sargassum seem to derive principal benefit from the food and protection offered by the weed. Additional factors such as those discussed probably play a less important role in the gathering of fishes around floating sargassum. Whatever the reasons for the association, it seems probable that these causitive factors would serve to reinforce both innate and acquired aggregation behavior in many of the closely associated fishes. Breder and Halpern (1946) have suggested that such a phenomenon was instrumental in developing schooling behavior in fishes.

## ZOOGEOGRAPHIC DISTRIBUTION

Sargassum is transported via major ocean currents and apparently acts as a vehicle for the dispersal of some of its associated organisms. Sargassum—ocean current dispersal is seemingly an active mechanism within the North Atlantic and Pacific Oceans, but probably is very restricted between these systems.

Fell (1967) emphasized the role of ocean currents in the dispersal of marine organisms and theorized that species gradients reflected the direction of successful migration as supported by the distribution of the molluscan genus *Voluta* and other groups. Briggs (1967) disagreed and contended that data from shore fishes suggested that the degree of biological competion was a more important factor in the dispersal of shore animals than the direction of major ocean currents. Briggs further believed that species gradients do not indicate the direction of dispersal, possibly only the success. Scheltema (1966, 1968) has shown impressive evidence for the dispersal of coelenterate, echinoderm, arthropod, annelid and molluscan larvae via ocean currents and its importance to the zoogeography of shallow water tropical species. Yeatman (1962) gave evidence based on plankton samples taken across the North Atlantic, that six species of littoral harpacticoid copepods probably owe their European and Mediterranean distributions to sargassum association.

Of the fifty-two sargassum fishes identified to species in my study, twenty (38%) are circumtropical, or nearly so; most of these have been recorded from world-wide sargassum communities; eighteen species (35%) have been reported from both sides of the North Atlantic; fourteen species (27%) have been found only in the western North Atlantic. According to drift-bottle data, the minimum time required for surface transport from the Bahamas and Florida to Cape Hatteras, North Carolina (25°–34°N) to the Azores is 145 days (Scheltema, 1966). Sargassum fishes collected off Miami from June through August have been compared to the corresponding species taken from Gulf Stream sargassum off Cape Lookout, North Carolina in July and off the Azores in September (Table 5).

TABLE 5

Comparison of the species composition of sargassum fishes taken from three stations in the North Atlantic. Measurements listed in mm, N = number, $\bar{X}$ = mean size

| | MIAMI (June–August) | | | CAPE LOOKOUT, N.C. (July 29–31) | | | AZORES (September 6) | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | N | $\bar{X}$ | Range | N | $\bar{X}$ | Range | N | $\bar{X}$ | Range |
| *Cypselurus furcatus* | .. | .. | .. | 6 | 24 | 20–33 | .. | .. | .. |
| *Syngnathus floridae mckayi* | 38 | 97 | 48–166 | .. | .. | .. | 2 | 150 | 146–154 |
| *Caranx crysos* | 285 | 64 | 12–124 | 30 | 26 | 13–55 | .. | .. | .. |
| *C. dentex* | .. | .. | .. | 27 | 23 | 14–27 | .. | .. | .. |
| *C. latus* | .. | .. | .. | 2 | 21 | 19–23 | .. | .. | .. |
| *C. hippos* | 1 | 24 | 24 | 3 | 30 | 29–32 | .. | .. | .. |
| *C. ruber* | 103 | 55 | 14–89 | 6 | 37 | 18–50 | .. | .. | .. |
| *C. bartholomaei* | 6 | 42 | 16–71 | 8 | 17 | 12–23 | .. | .. | .. |
| *Seriola rivoliana* | 5 | 81 | 21–132 | 6 | 35 | 24–56 | .. | .. | .. |
| *S. dumerili* | 8 | 93 | 62–121 | .. | .. | .. | 1 | 88 | 88 |
| *Trachurus lathami* | 9 | 29 | 15–51 | 4 | 17 | 14–19 | .. | .. | .. |
| *Elagatis bipinnulatus* | 4 | 63 | 35–123 | 1 | 30 | 30 | .. | .. | .. |
| *Kyphosus sectatrix* | 5 | 73 | 17–108 | 2 | 24 | 18–29 | .. | .. | .. |
| *Psenes cyanophrys* | 23 | 47 | 30–79 | 10 | 41 | 12–65 | .. | .. | .. |
| *Abudefduf saxatilis* | 11 | 20 | 8–39 | 2 | 18 | 15–20 | .. | .. | .. |
| *Pseudopriacanthus altus* | .. | .. | .. | 8 | 19 | 16–22 | .. | .. | .. |
| *Coryphaena hippurus* | .. | .. | .. | 4 | 30 | 13–54 | 1 | 42 | 42 |
| *Stephanolepis hispidus* | 1273 | 52 | 10–70 | 194 | 20 | 9–50 | 5 | 67 | 54–86 |
| *S. setifer* | 72 | 38 | 7–68 | 1 | 31 | 31 | .. | .. | .. |
| *Stephanolepis* sp. | .. | .. | .. | 185 | 14 | 10–17 | .. | .. | .. |
| *Monacanthus ciliatus* | 6 | 18 | 14–19 | 2 | 20 | 19–20 | .. | .. | .. |
| *M. tuckeri* | .. | .. | .. | 1 | 16 | 16 | .. | .. | .. |
| *Alutera scripta* | 34 | 100 | 46–162 | 5 | 50 | 34–93 | .. | .. | .. |
| *A. heudelotii* | 1 | 70 | 70 | 1 | 43 | 43 | .. | .. | .. |
| *Cantherhines pullus* | 31 | 48 | 33–67 | 5 | 47 | 40–53 | .. | .. | .. |
| *Canthidermis maculatus* | 2 | 59 | 51–67 | 1 | 8 | 8 | .. | .. | .. |
| *C. sufflamen* | 8 | 63 | 12–94 | 4 | 39 | 32–57 | .. | .. | .. |
| *Balistes capriscus* | 58 | 50 | 13–99 | 34 | 22 | 11–67 | 2 | 77 | 74–80 |
| *Xanthichthys ringens* | .. | .. | .. | 1 | 27 | 27 | .. | .. | .. |
| *Diodon holacanthus* | .. | .. | .. | 2 | 36 | 34–37 | .. | .. | .. |
| *Histrio histrio* | 110 | 22 | 10–73 | 2 | 12 | 10–14 | 6 | 19 | 10–38 |

These data from North Carolina and the Azores are based on limited sampling, but probably are indicative of the relative diversity and size composition of sargassum fishes found in these areas. A progressive decrease in the numbers of species can be noted from Miami (54) to Cape Lookout (33) and the Azores (6) (Table 6). Some Caribbean sargassum fishes have ranges that include the Azores, Portugal, Madeira and northern West Africa and can be explained by examination of the North Atlantic surface current pattern. The Florida and Gulf Stream currents carry sargassum associated fishes northward; they are carried eastward to the Azores via the North Atlantic drift, and finally the Canary current carries these expatriates southward to the coasts of Madeira, Portugal and northern West Africa (Fig. 1).

Examples of unsuccessful dispersal are apparent; Fish (1966) reported the occurrence of sargassum and tropical fishes (jacks and filefishes) between Rhode Island and Cape Cod in summer and early fall; Dawson (1962) reported a similar situation in the northern Gulf of Mexico.

Extensive collections by the Japanese show a dimunition of numbers of sargassum fishes as one moves away from the influence of the Kuroshio current. Species numbers decline from a peak of 63 off Sagami Bay and vicinity where the Kuroshio current swins east, to 40 species off Fukuoka in the East China Sea, to a low of 15 species off the Oki Islands in the southern Sea of Japan. Besednov (1960) found 18 species of sargassum fishes off the Fiji Islands far to the south of the principal North Pacific current system.

The North Atlantic and Pacific have analogous but distinct palagic sargassum systems, with approximately 30% of their fishes in common. Both systems show centers of high fish diversity marked by a progressive decrease in numbers of species as one moves away from these areas (Table 6).

The successful dispersal of sargassum associated fishes and invertebrates is undoubtedly brought about by the enhancement of survival offered by sargassum

TABLE 6

Zoogeographic distribution of numbers of species of sargassum associated fishes. The number in brackets is the number of species not represented in area of highest diversity

| | |
|---|---|
| ATLANTIC | |
| Miami, Florida (25° 40′ N; 80° 00′ W) | 54 species |
| *Cape Lookout, North Carolina (34° 04′ N; 76° 14′ W) | 33 species [4] |
| †Azores (38° 04′ N; 39° 52′ W) | 6 species [0] |
| Total Atlantic species recorded‡ | 72 species |
| §PACIFIC | |
| Sagami Bay, Japan (35° 00′ N; 139° 00′ E) | 63 species |
| Fukuoka, Japan (33° 50′ N; 130° 30′ E) | 40 species [11] |
| Oki Islands, Japan (36° 00′ N; 133° 00′ E) | 15 species [3] |
| Fiji Islands (20° 00′ S; 170° 00′ E) | 18 species [6] |
| Total Pacific species recorded | 77 species |

* R/V Eastward cruise E-19-70, July 29–31, 1970.
† USNS Gilliss, cruise 402, 6 September 1967.
‡ Recorded from stations and literature.
§ After (Hirosaki, 1960; Shojima and Ueki, 1964; Ida, Hiyama and Kusaka, 1967a; Uchida and Shojima, 1958; Senta, 1962; Besednov, 1960).

association through food and shelter from predation. Pelagic sargassum in conjunction with major ocean currents appears to be a method whereby some marine organisms have successfully bridged faunal barriers.

## ADDENDUM

Since completion of this study the following systematic changes have been made: Monacanthidae was incorporated into Balistidae, Hemiramphidae was placed in Exocoetidae, *Alutera* = (*Aluterus*), *A. heudelotii* = (*heudeloti*), *A. scripta* = (*scriptus*), *Sphaeroides* = *Sphoeroides*, *Diodon holacanthus* = *D.* (*holocanthus*), *Caranx crysos* = *C.* (*fusus*), *Elagatus bipinnulatus* = *E.* (*bipinnulata*). The author of *Psenes cyanophyrs* has been changed from Cuvier to Valenciennes; *Stephanolepis* = (*Monacanthus*).

The following citations should also be included: Hentschel (1922) examined sargassun invertebrates; Germain (1935) summarized much of the early knowledge of the Sargasso Sea; Culliney (1970) found (PO-P) phosphate concentrations two to three times greater in water in floating sargassum than in surrounding water; Carpenter (1970) found the number of species of diatoms attached to pelagic sargassum fewer and also smaller than those found ashore on marine and fresh water plants; Hurka (1971) discussed factors that influenced the gas composition in sargassum vesicles; and Kohlmeyer (1971) described sargassum fungi.

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