NOAA Technical Memorandum NMFS-SEFSC-296

UTILIZATION OF THE *SARGASSUM* HABITAT BY MARINE INVERTEBRATES AND VERTEBRATES - A REVIEW

L. Coston-Clements, L.R. Settle, D.E. Hoss
and F.A. Cross

The Sargassum community

October 1991

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
Beaufort Laboratory
101 Pivers Island Road
Beaufort, N.C. 28516-9722

NOAA Technical Memorandum
NMFS-SEFSC-296

UTILIZATION OF THE *SARGASSUM* HABITAT BY MARINE INVERTEBRATES AND VERTEBRATES - A REVIEW

L. Coston-Clements, L.R. Settle, D.E. Hoss and F.A. Cross

October 1991

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
John A. Knauss, Administrator
NATIONAL MARINE FISHERIES SERVICE
William W. Fox, Jr. Assistant Administrator
for Fisheries

NOTICE:

This report should be cited as follows:

Coston-Clements, L., L.R. Settle, D.E. Hoss and F.A. Cross. 1991. Utilization of the *Sargassum* habitat by marine invertebrates and vertebrates - a review. NOAA Technical Memorandum NMFS-SEFSC-296, 32 p.

Copies may be obtained by writing:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

or

National Marine Fisheries Service, NOAA
Southeast Fisheries Science Center
Beaufort Laboratory
101 Pivers Island Road
Beaufort, NC 28516-9722

Cover illustration from Teal and Teal, 1975.

Introduction

Numerous species of brown algae (Class Cyclosporeae: Order Fucales: Family Fucaceae) of the genus *Sargassum* occur throughout the world's tropical and temperate oceans. The pelagic complex in the western North Atlantic is comprised primarily of *Sargassum natans* and *S. fluitans*. Both species are hyponeustonic and fully adapted to a pelagic existence (Parr, 1939). Known commonly as gulf-weed, sea holly, or sargassum, they are characterized by a brushy, highly branched thallus (stem) with numerous leaf-like blades and berry-like pneumatocysts (floats). These floating plants may be up to several meters in length but are typically much smaller. See Hoyt (1918), Winge (1923), Parr (1939), Taylor (1960), Prescott (1968), and Humm (1979) for detailed descriptions of the various species.

Sargassum floats contain mostly oxygen with some nitrogen and carbon dioxide, and are responsible for buoyancy. Oxygen content is dependent on the oxygen partial pressure of the surrounding medium and independent of photosynthetic activity (Hurka, 1971). Woodcock (1950) also found diurnal fluctuations in gas pressure within the floats, and attributed it to similar changes in oxygen partial pressure during daylight and darkness.

There is some debate as to whether sargassum found in the Gulf Stream, Gulf of Mexico, Caribbean Sea, and the North Atlantic Central Gyre is material detached from littoral plants in the Antilles and other tropical regions during storms (Peres, 1982) or whether the oceanic components are a separate species group independent of their coastal littoral relatives. Most researchers consider the pelagic forms a separate and distinct species group having evolved from benthic species (Winge, 1923; Parr, 1939; Friedrich, 1969; Butler et al., 1983; Stoner and Greening, 1984). Supporting evidence includes the lack of sexual reproduction characteristic of benthic forms, the loss of a basal holdfast, and the number of endemic organisms in the associated community (10 invertebrates and 2 vertebrates). Benthic forms, such as *S. filipendula*, occur in the open ocean in small quantities, but should be considered flotsam (Hoyt, 1918; Winge, 1923; Parr, 1939; Dooley, 1972).

Sargassum circulates between 20° and 40° N latitude and 30°W longitude and the western edge of the Florida Current/Gulf Stream, with an apparent center of distribution within the North Atlantic Central Gyre between 28° and 34°N latitude (Fig. 1) (Winge 1923; Ryther, 1956; Dooley, 1972; Butler et al. 1983). Large quantities also occur on the continental shelf. Some of this material is cast upon beaches along the eastern seaboard (Hoyt, 1918; Humm, 1979; Winston, 1982), while much of it remains on the shelf or is entrained into the Gulf Stream. Throughout the region, sargassum frequently aggregates into large windrows in response to wind forcing (Winge, 1923; Langmuir, 1938; Faller and Woodcock, 1964) or shear currents along frontal boundaries (Stommel, 1965). Woodcock (1950) demonstrated that sargassum can be downwelled along such convergence zones; the depth of descent being dependent on the buoyancy of individual algal clumps and the magnitude of the Langmuir circulation cell. Clumps that do not sink below a critical depth (≈ 100 m) can withstand the hydrostatic pressure and will ultimately rise to the surface. There is also, however, a time-at-depth relationship that can influence the true critical depth at which buoyancy is lost and the algae sink to the bottom (Johnson and Richardson, 1977). Peres (1982) questioned the ability of any sargassum to return to the surface after being downwelled. When buoyancy is lost, sargassum sinks slowly to the bottom (about 2 days to reach 5000 m) and provides a resource for bottom dwelling consumers (Schoener and Rowe, 1970).

The contribution of sargassum to total primary production in the western North Atlantic is variable and dependent on the region examined and on accumulated biomass. Carpenter and Cox (1974) estimated average production across the western Sargasso Sea at ≈1.0 mg C $m^{-2}d^{-1}$, with higher values frequently occurring at localities on the continental shelf and in the northern Sargasso Sea (above 30°N). Howard and Menzies (1969) found production highest in the Gulf Stream, lowest on the shelf, and intermediate in the Sargasso Sea. These authors estimate sargassum probably contributes about 0.5% of the total primary production in the region, but nearly 60% of the total in the upper 1 m of the water column (Howard and Menzies, 1969; Carpenter and Cox, 1974; Hanson, 1977; Peres, 1982). In addition, epiphytic cyanobacteria (*Dichothrix* and *Oscillatoria*) contribute significantly to overall production and nitrogen fixation within the immediate sargassum community (Carpenter, 1972; Carpenter and Cox, 1974; Phlips and Zeman, 1990). Both sargassum and its associated blue-green algae epiphytes are adapted to conditions of strong sunlight, that is, photosynthesis is not inhibited at high light intensities (Phlips, et al., 1986).

A survey conducted in the Sargasso Sea from 1933 to 1935 (Parr, 1939) estimated sargassum biomass at 524 to 1642 mg m^{-2}. Stoner's (1983) estimates in the Sargasso Sea from the years 1977 to 1981 were less than 6% of those earlier estimates. He suggested that the decline may have been anthropogenically influenced. Subsequent analysis of Stoner's data, however, concluded that there had been no significant change in the biomass of sargassum from 1933 to 1981, except in an area northeast of the Antilles. This apparent decline was attributed to seasonal variation in sargassum abundance or long-term current shifts, and apparently not to pollution (Butler et al. 1983; Butler and Stoner, 1984). Reliable estimates of total biomass are not available, however, as no directed statistical study encompassing the vast range of these species has been conducted.

Habitat Utilization

Pelagic sargassum supports a diverse community of marine organisms including micro- and macro-epiphytes (Carpenter, 1970; Carpenter and Cox, 1974; Mogelberg et al., 1983), fungi (Winge, 1923; Kohlmeyer, 1971), more than 100 species of invertebrates (Table 1), over 100 species of fishes (Table 2), and four species of sea turtles (Carr, 1987a; Manzella and Williams, 1991). Some inhabitants, unique to the sargassum habitat, have evolved unusual shapes and coloration affording them the additional advantage of camouflage among the floating plants. Others are less specialized and utilize the habitat for foraging or protection from predators. Community structure is variable; influenced by season, geographic location, and algal "age" (Weis, 1968; Fine, 1970; Butler et al. 1983; Stoner and Greening, 1984). Weis (1968) also noted differences in epibiont diversity between species of sargassum. An important factor in the structure of the community is related to compounds occurring in the exudate released by the algae during growth. Tannins produced on the distal growing tips of sargassum have an inhibitory effect on colonizing epibionts (Conover and Sieburth, 1964; Sieburth and Conover, 1965). This antifouling effect lasts a short time and a succession of bacteria, hydroids, bryozoans, and blue-green algae rapidly follow (Winge, 1923; Conover and Sieburth, 1964; Ryland, 1974). Carpenter and Cox (1974) also suggest that low epibiont density within some areas of the Sargasso Sea may be nutrient limited rather than limited by the antibiotic activity of sargassum exudates. Natural chemical compounds, including phenolic compounds, produced by algae may also serve as a deterrent to herbivores (Paul, 1987; Hay and Fenical, 1988; Hay et al., 1988; Steinberg, 1988).

For details of community metabolism, respiration, trophic web and chemistry, we refer the reader to the works of Culliney (1970), Burns and Teal (1973), Smith et al. (1973), Johnson and Braman (1975), Blake and Johnson (1976), Hanson, (1977), Geiselman (1983), Morris et al. (1976), and Trapnell et al. (1983).

Invertebrates

The invertebrate fauna consists of both sessile and motile forms (Table 1). Epizoans include colonial hydroids, encrusting bryozoans, the polychaete *Spirorbis*, barnacles, pycnogonids, and the tunicate *Diplosoma*. Older plants gradually become heavily encrusted with these organisms and ultimately sink. This biomass then gradually disintegrates, providing valuable nourishment for animals in deeper water (Parr, 1939; Weis, 1968; Schoener and Rowe, 1970; Butler et al. 1983). Conspicuous among the motile fauna are decapod crustaceans, particularly the *Portunus* crabs, and shrimps *Latreutes* and *Leander*, various molluscs, including the sargassum snail *Litiopa melanostoma*, polychaetes, flatworms, and nudibranchs. Fine (1970) found very high numbers of portunids in his late summer samples in the Gulf Stream and Sargasso Sea. Only *Portunus sayi* is commonly considered a resident of the community; the remaining megalopa and juveniles are transitory and utilize the habitat as a nursery.

Dooley (1972) examined stomach contents of the eight most abundant fish species yielding further insight into the invertebrate component of the sargassum community. These included hydroids, copepods, phylosoma larvae, shrimp zoea and postlarvae, crabs, pycnogonids, barnacles, tunicates, polychaetes, bivalves, gastropods, and platyhelminthes. The presence of two rather enigmatic members of the sargassum fauna were revealed by Morgan et al. (1985) through stomach content analysis of several large epipelagic predatory fishes. They found the large mysis of the penaeoids, *Cerataspis monstrosa* and *C. petiti*, frequently co-occurred with sargassum in the stomachs of surface feeding tuna (Scombridae) and dolphin *Coryphaena hippurus*. Nothing is known about the adult stage or life history of these rare crustaceans.

Vertebrates - Fishes

There is a well known assemblage of small fishes associated with sargassum rafts, many of which serve as forage for commercially or recreationally exploited species (Table 2). Dooley (1972) described 54 species from 23 families in the sargassum community of the Florida Current, while Bortone et al. (1977) reported 40 species from 15 families in the eastern Gulf of Mexico. Only 14 species from 11 families are known from the Sargasso Sea (Fedoryako, 1980; 1989).

Young jacks (Carangidae) live among the protective branches of sargassum and feed heavily on copepods and larval decapods. Apparently sargassum carries along a resident plankton population capable of sustaining these voracious predators (Yeatman, 1962). Sub-adult jacks range further from the rafts but dart in to feed on shrimp and young fishes living in the sargassum. The filefishes and triggerfishes (Balistidae) are also abundant and feed primarily on hydroids, encrusting bryozoans, and other invertebrates.
Another major predator is the voracious sargassumfish, *Histrio histrio*, which selectively preys upon shrimp and young fish (Adams, 1960).

Large predatory species associated with the sargassum habitat include jacks, dolphins (Coryphaenidae), barracudas (Sphyraenidae), mackerels and tunas (Scombridae), swordfish (Xiphiidae), and billfishes (Istiophoridae) (Gibbs and Collette, 1959; Stephens, 1965; Dooley, 1972; Fedoryako, 1980; Carr, 1986; C. Manooch, pers. comm.). It is believed that dolphin, a much sought after game and food fish, takes shelter under flatoam (including sargassum) because of the enhanced availability of prey (Dooley, 1972). Filefish, triggerfish, jacks, flyingfish (Exocoetidae), and puffers (Tetradontidae) are among the species identified in dolphin stomachs (Gibbs and Collette, 1959; Dooley, 1972; Manooch et al., 1984). Fragments of sargassum were also commonly found. Manooch et al. (1984) stated "The close association (=dependence) of dolphin with fish and invertebrates that form the sargassum community is unmistakable". Manooch and Mason (1983) also reported finding sargassum fragments in 26% of yellowfin tuna, *Thunnus albacaras*, stomachs they examined as well as in 12% of blackfin tuna, *T. atlanticus*. They believed the material was ingested incidentally with normal prey.

There is less known about the ichthyoplankton associated with the habitat, but it seems likely that the same hydrodynamic mechanisms that drive the formation of sargassum rafts, i.e., convergence of surface water within shear zones or Langmuir cells, will also aggregate surface oriented organisms (Kingsford, 1990). There is some evidence that this is the case for swordfish, *Xiphias* *gladius*, larvae and cobia, *Rachycentron canadum*, eggs near the Gulf Stream frontal zone (Hassler and Rainville, 1975; J.J. Govoni, pers. comm.). In addition to feeding and shelter, adults of some oceanic pelagic fishes use sargassum as a spawning substrate (Dooley, 1972; Peres, 1982) or as a nursery area for larvae and juveniles. Most notable among these are the flyingfishes (Winge, 1923; Breder, 1938) which are a major component of the diet of large oceanic fishes.

Vertebrates-Sea Turtles

During the pelagic stage, hatchling loggerhead, *Caretta caretta*, green, *Chelonia mydas*, Kemp's ridley, *Lepidochelys kempi*, and hawksbill, *Eretmochelys imbricata*, sea turtles have been observed in sargassum off Florida, Georgia, North Carolina, and Texas (Smith, 1968; Fletemeyer, 1978; Carr and Meylan, 1980; Carr, 1986; 1987a; Schwartz, 1988; 1989; Manzella and Williams, 1991; Schwartz, pers. comm.). Hundreds of loggerhead hatchlings, both dead and alive, were found in the wrack of sargassum deposited on the shore at Cocoa Beach, Florida following a hurricane in September, 1979 (Carr and Meylan, 1980). Stomach contents of the dead hatchlings showed that almost all contained sargassum floats and leafy parts. Schwartz (1988) reported numerous loggerhead hatchlings captured during commercial trawling for sargassum. This observation constitutes the largest known aggregation of loggerhead hatchlings encountered off the North Carolina coast.

Hatchling turtles are thought to actively seek out frontal zones and hence sargassum rafts. These areas are then utilized for forage and protection during the "lost year" (Carr 1986; 1987a,b). Witham (1988) suggested an alternative hypothesis for this association. He noted that it remains untested as to whether sea turtles actually benefit from their association with sargassum or whether they are at increased risk from predation, entanglement, and stranding.

Summary

The pelagic sargassum habitat of the northwestern Atlantic consists of both truly pelagic forms and flotsom detached from coastal regions. While within the neuston it provides numerous species of invertebrates and vertebrates a source of food, shelter, and substrate. Community structure varies with season, location, and algal age.

While the relationship of many species within this habitat is well understood, others remain less well known. This is particularly true for egg and larval stages of fishes, some crustaceans, and juvenile sea turtles. Functional relationships between the animals and the habitat have not been elucidated (e.g., we do not know the effect of the loss of sargassum on fish or sea turtle populations). Because estimates of oceanic biomass of sargassum are variable and inadequate, we also do not have a clear understanding the population dynamics of the sargassum habitat, i.e., what is the standing crop, the productivity and the effect of harvesting on living marine resources?

Acknowledgments

We would like to express our thanks to Drs. J. J. Govoni and F. J. Schwartz for providing unpublished data, Drs. W. W. Kirby-Smith and R. E. Robbins for assistance with the invertebrate taxonomy, and to Dr. C. S. Manooch, III for review of the report.

Personal Communications

Dr. J. J. Govoni, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort Laboratory, Beaufort, North Carolina, 28516.

Dr. C. S. Manooch, III, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort Laboratory, Beaufort, North Carolina, 28516.

Dr. F. J. Schwartz, University of North Carolina, Institute of Marine Science, 3407 Arendell Street, Morehead City, North Carolina, 28557.

Literature Cited

Adams, J.A. 1960. A contribution to the biology and post-larval development of the sargassum fish, *Histrio histrio* (Linnaeus), with a discussion of the *Sargassum* complex. Bull. Mar. Sci. Gulf Carib. 10:55-82.

Beardsley, G.L., Jr. 1967. Age, growth, and reproduction of the dolphin, *Coryphaena hippurus*, in the Straits of Florida. Copeia 1967:441-451.

Beebe, W. and J. Vee-Van. 1928. The fishes of Port-Au-Prince Bay, Haiti. Zoologica 10:1-279.

Berry, F.H. 1959. Young jack crevalles (*Caranx* species) off the southeastern Atlantic coast of the United States. Fish. Bull., U.S. 59:417-535.

Berry, F.H. and L.E. Vogele. 1961. Filefishes (Monocanthidae) of the western north Atlantic. Fish. Bull., U.S. 61:61-109.

Blake, N.J. and D.L. Johnson. 1976. Oxygen production-consumption of the pelagic *Sargassum* community in a flow-through system with arsenic additions. Deep-Sea Res. 23:773-778.

Böhlke, J.E. and C.C.G. Chaplin. 1968. Fishes of the Bahamas and adjacent tropical waters. Livingston, Wynnewood, PA, 771 p.

Bortone, S.A., P.A. Hastings and S.B. Collard. 1977. The pelagic *Sargassum* ichthyofauna of the eastern Gulf of Mexico. Northeast Gulf Sci. 1:60-67.

Breder, C.M., Jr. 1938. A contribution to the life histories of Atlantic Ocean flyingfishes. Bull. Bingham Oceanogr. Coll., Yale Univ. 6(5):1-126.

Brusca, R.C. and G.J. Brusca. 1990. Invertebrates. Sinauer Associates, Inc., Sunderland, MA. 922 p.

Burns, K.A. and J.M. Teal. 1973. Hydrocarbons in the pelagic *Sargassum* community. Deep-Sea Res. 20:207-211.

Butler, J.N., B.F. Morris, J. Cadwaller and A.W. Stoner. 1983. Studies of *Sargassum* and the *Sargassum* community. Bermuda Biol. Sta. Spec. Publ. 22:1-85.

Butler, J.N. and A.W. Stoner. 1984. Pelagic *Sargassum*: has its biomass changed in the last 50 years? Deep-Sea Res. 31:1259-1264.

Caldwell, D.K. 1959. Observations on tropical marine fishes from the northeastern Gulf of Mexico. Quart. J. Fla. Acad. Sci. 22:69-74.

Carpenter, E.J. 1970. Diatoms attached to floating *Sargassum* in the western Sargasso Sea. Phycologia 9:271-274.

Carpenter, E.J. 1972. Nitrogen fixation by a blue-green epiphyte on pelagic *Sargassum*. Science 178:1207-1209.

Carpenter, E.J. and J.L. Cox. 1974. Production of pelagic *Sargassum* and a blue-green epiphyte in the western Sargasso Sea. Limnol. Oceanogr. 19:429-435.

Carr, A. 1986. Rips, FADS, and little loggerheads. BioScience 36(2):92-100.

Carr, A. 1987a. Perspective on the pelagic stage of sea turtle development. Conserv. Biol. 1(2):103-121.

Carr, A. 1987b. Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles. Mar. Pollut. Bull. 18:352-356.

Carr, A. and A.B. Meylan. 1980. Evidence of passive migration of green turtle hatchlings in *Sargassum*. Copeia 1980:366-368.

Conover, J.T. and J. McN. Sieburth. 1964. Effect of *Sargassum* distribution on its epibiota and antibacterial activity. Bot. Mar. 6:147-157.

Culliney, J.L. 1970. Measurements of reactive phosphorus associated with pelagic *Sargassum* in the northwest Sargasso Sea. Limnol. Oceanogr. 15:304-306.

Dawson, C.E. 1962. New records and notes on fishes from the north central Gulf of Mexico. Copeia 1962:442-444.

Deason, E. 1983. Meiofauna of pelagic *Sargassum*. Bermuda Biol. Sta. Spec. Publ. 22:102-113.

Dooley, J.K. 1972. Fishes associated with the pelagic sargassum complex, with a discussion of the sargassum community. Contrib. Mar. Sci. 16:1-32.

Faller, A.J. and A.H. Woodcock. 1964. The spacing of windrows of *Sargassum* in the ocean. J. Mar. Res. 22:22-29.

Fedoryako, B.I. 1980. The ichthyofauna of the surface waters of the Sargasso Sea southwest of Bermuda. J. Ichthyol. 20(4):1-9.

Fedoryako, B.I. 1989. A comparative characteristic of oceanic fish assemblages associated with floating debris. J. Ichthyol. 29(3):128-137.

Fine, M.L. 1970. Faunal variations on pelagic *Sargassum*. Mar. Biol. 7:112-122.

Fletemeyer, J.R. 1978. Underwater tracking evidence of neonate loggerhead sea turtles seeking shelter in drifting *Sargassum*. Copeia 1978:148-149.

Friedrich, M. 1969. Marine biology. (Translated from German by G. Vevers). Univ. Washington Press, Seattle, 474 p.

Geiselman, J. 1983. The food web of the *Sargassum* community. Bermuda Biol. Sta. Spec. Publ. 22:260-270.

Gibbs, R.M., Jr. and B.B. Collette. 1959. On the identification, distributions, and biology of the dolphins, *Coryphaena hippurus* and *C. equisetis*. Bull. Mar. Sci. Gulf and Carib. 9:117-152.

Hanson, R.B. 1977. Pelagic *Sargassum* community metabolism - carbon and nitrogen. J. Exp. Mar. Biol. Ecol. 29:107-118.

Hassler, W.W. and R.P. Rainville. 1975. Techniques for hatching and rearing cobia, *Rachycentron canadum*, through larval and juvenile stages. Univ. N.C., Sea Grant Publ. UNC-SG-75-30.

Hastings, P.A. and S.A. Bortone. 1976. Additional notes on tropical marine fishes in the northern Gulf of Mexico. Fla. Sci. 39:123-125.

Hay, M.E. and W. Fenical. 1988. Marine Plant - herbivore interactions: The ecology of chemical defense. Annu. Rev. Ecol. Syst. 19:111-145.

Hay, M.E., P.E. Renaud and W. Fenical. 1988. Large mobile versus small sedimentary herbivores and their resistance to seaweed chemical defenses. Oecologia 75:246-252.

Howard, K.L. and R.J. Menzies. 1969. Distribution and production of *Sargassum* in the waters off the Carolina coast. Bot. Mar. 12:244-254.

Hoyt, W.D. 1918. Marine algae of Beaufort, N.C., and adjacent regions. Bull. U.S. Bur. Fish. 36:367-560.

Humm, H.J. 1979. The marine algae of Virginia. Va. Inst. Mar. Sci., Spec. Pap. Mar. Sci. No. 3.

Hurka, M. 1971. Factors influencing the gas composition in the vesicles of *Sargassum*. Mar. Biol. 11:82-89.

Johnson, D.L. and R.S. Braman. 1975. The speciation of arsenic and the content of germanium and mercury in members of the pelagic *Sargassum* community. Deep-Sea Res. 22:503-507.

Johnson, D.L. and P.L. Richardson. 1977. On the wind-induced sinking of *Sargassum*. J. Exp. Mar. Biol. Ecol. 28:255-267.

Kingsford, M.J. 1990. Linear oceanographic features: a focus for research on recruitment processes. Aust. J. Ecol. 15:391-401.

Kohlmeyer, J. 1971. Fungi from the Sargasso Sea. Mar. Biol 8:344-350.

Langmuir, I. 1938. Surface motion of water induced by wind. Science 87:119-123.

Manooch, C.S., III and W.T. Hogarth. 1983. Stomach contents and giant trematodes from wahoo, *Acanthocybium solanderi*, collected along the south Atlantic and Gulf coasts of the United States. Bull. Mar. Sci. 33:227-238.

Manooch, C.S., III and D.L. Mason. 1983. Comparative food of yellowfin tuna, *Thunnus albacares*, and blackfin tuna, *Thunnus atlanticus*, (Pisces: Scombridae) from the southeastern and Gulf of Mexico coasts of the United States. Brimleyana 9:33-52.

Manooch, C.S., III, D.L. Mason and R.S. Nelson. 1984. Food and gastrointestinal parasites of dolphin *Coryphaena hippurus* collected along the southeastern and Gulf coasts of the United States. Bull. Jpn. Soc. Sci. Fish. 50:1511-1525.

Manooch, C.S., III, D.L. Mason and R.S. Nelson. 1985. Food of little tunny *Euthynnus alletteratus* collected along the southeastern and Gulf coasts of the United States. Bull. Jpn. Soc. Sci. Fish. 51:1207-1218.

Manzella, S. and J. Williams. 1991. Juvenile head-started Kemp's ridleys found in floating grass mats. Mar. Turtle Newsletter 52:5-6.

Minerals Management Service. 1990. Final environmental report on proposed exploratory drilling offshore North Carolina, Vol. 1. U.S. Department of the Interior, Minerals Management Service, Atlantic OCS Region. Environmental Assessment Section, Herndon, VA.

Mogelberg, D.D., B.F. Morris and J. Cadwaller. 1983. Sessile fauna and flora. Bermuda Biol. Sta. Spec. Publ. 22:225-234.

Morgan, S.G., C.S. Manooch, III, D.L. Mason and J.W. Goy. 1985. Pelagic fish predation on *Cerataspis*, a rare larval genus of ocenaic penaeoids. Bull. Mar. Sci. 36:249-259.

Morris, B.F., J. Cadwallader, J. Geiselman and J.N. Butler. 1976. Transfer of petroleum and biogenic hydrocarbons in the *Sargassum* community. Pages 235-259 in H.L. Windom and R.A. Duce (eds.), Marine Pollutant Transfer. D.C. Heath and Co. Lexington, MA.

Morris, B.F. and D.D. Mogelberg. 1973. Identification manual to the pelagic *Sargassum* fauna. Bermuda Biol. Sta. Spec. Publ. 11, 63 p.

Parr, A.D. 1939. Quantitative observations on the pelagic *Sargassum* vegetation of the western North Atlantic. Bull. Bingham Oceanogr. Coll., Yale Univ. 6(7):1-94.

Paul, V.J. 1987. Feeding deterrent effects of algal natural products. Bull. Mar. Sci. 41:514-522.

Peres, J.M. 1982. Specific pelagic assemblages. Pages 314-372 in O. Kinne (ed,), Marine Ecology, Vol. 5, pt. 1, John Wiley and Sons, New York.

Phlips, E.J., M. Willis, and A. Verchick. 1986. Aspects of nitrogen fixation in *Sargassum* communities off the coast of Florida. J. Exp. Mar. Biol. Ecol. 102:99-119.

Phlips, E.J. and C. Zeman. 1990. Photosynthesis, growth and nitrogen fixation by epiphytic forms of filamentous cyanobacteria from pelagic sargassum. Bull. Mar. Sci. 47:613-621.

Prescott, G.W. 1968. The algae: A review. Houghton Mifflin, Boston, Mass., 436 p.

Randall, J.E. 1968. Caribbean reef fishes. T.F.H. Publications, Inc., Jersey City, N.J. 318 p.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada, Fifth edition. Am. Fish. Soc. Spec. Publ. 20, 183 p.

Ryland, J.S. 1974. Observations on some epibionts of gulf-weed, *Sargassum natans* (L.) Meyen. J. Exp. Mar. Biol. Ecol. 14:17-25.

Ryther, J.M. 1956. The Sargasso Sea. Sci. Am. 194(1):98-104.

Schoener, A. and G.T. Rowe. 1970. Pelagic *Sargassum* and its presence among the deep-sea benthos. Deep-Sea Res. 17:923-925.

Schwartz, F.J. 1988. Aggregations of young hatchling loggerhead sea turtles in the sargassum off North Carolina. Mar. Turtle Newsletter 42:9-10.

Schwartz, F.J. 1989. Biology and ecology of sea turtles frequenting North Carolina. Pages 307-331, in R.Y. George and A.W. Hulbert (ed.), North Carolina Coastal Oceanography Symposium, NOAA-NURP Rep. 89-2.

Schwartz, F.J., W.T. Hogarth and M.P. Weinstein. 1982. Marine and freshwater fishes of the Cape Fear Estuary, North Carolina, and their distribution in relation to environmental factors. Brimleyana 7:17-37.

Sieburth, J. McN. and J.T. Conover. 1965. *Sargassum* tannin, an antibiotic which retards fouling. Nature 208:52-53.

Smith, K.L., Jr., K.A. Burns and E.J. Carpenter. 1973. Respiration of the pelagic *Sargassum* community. Deep-Sea Res. 20:213-217.

Smith, W.G. 1968. A neonate Atlantic loggerhead turtle, *Caretta caretta*, captured at sea. Copeia 1968:880-881.

Steinberg, P.D. 1988. Effects of quantitative and qualitative variation in phenolic compounds on feeding in three species of marine invertebrate herbivores. J. Exp. Biol. Ecol. 120:221-237.

Stephens, W.M. 1965. Summer cruise to the Sargasso Sea. Sea Frontiers 11:108-123.

Stommel, H. 1965. The Gulf Stream. Univ. Calif. Press, Berkeley, 248 p.

Stoner, A.W. 1983. Pelagic sargassum: evidence for a major decrease in biomass. Deep-Sea Res. 30(4A):469-474.

Stoner, A.W. and H.S. Greening. 1984. Geographic variation in the macrofaunal associates of pelagic *Sargassum* and some biogeographic implications. Mar. Ecol. Prog. Ser. 20:185-192.

Taylor, W.R. 1960. Marine algae of the eastern tropical and subtropical coasts of the Americas. Univ. Mich. Press, Ann Arbor, 870 p.

Teal, J. and M. Teal. 1975. The Sargasso Sea. Little, Brown, Boston, MA, 216 p.

Trapnell, D., A.H. Knap and J.N. Butler. 1983. Hydrocarbons in some fauna of the *Sargassum* community. Bermuda Biol. Sta. Spec. Publ. 22:271-296.

Weis, J.S. 1968. Fauna associated with pelagic sargassum in the Gulf Stream. Am. Midl. Nat. 80:554-558.

Winge, O. 1923. The Sargasso Sea, its boundaries and vegetation. Rep. Dan. Oceanogr. Exped. 1908-1910 3(2): 3-34.

Winston, J.E. 1982. Drift plastic - an expanding niche for a marine invertebrate? Mar. Pollut. Bull. 13:348-351.

Witham, R. 1988. Drifting Sargassum weed: safe haven or increased risk for hatchling sea turtles? NOAA Tech. Memo. NMFS-SEFC-214:129-130.

Woodcock, A.M. 1950. Subsurface pelagic *Sargassum*. J. Mar. Res. 9:77-92.

Yeatman, H.C. 1962. The problem of dispersal of marine littoral copepods in the Atlantic Ocean, including some redescriptions of species. Crustaceana 4:253-272.

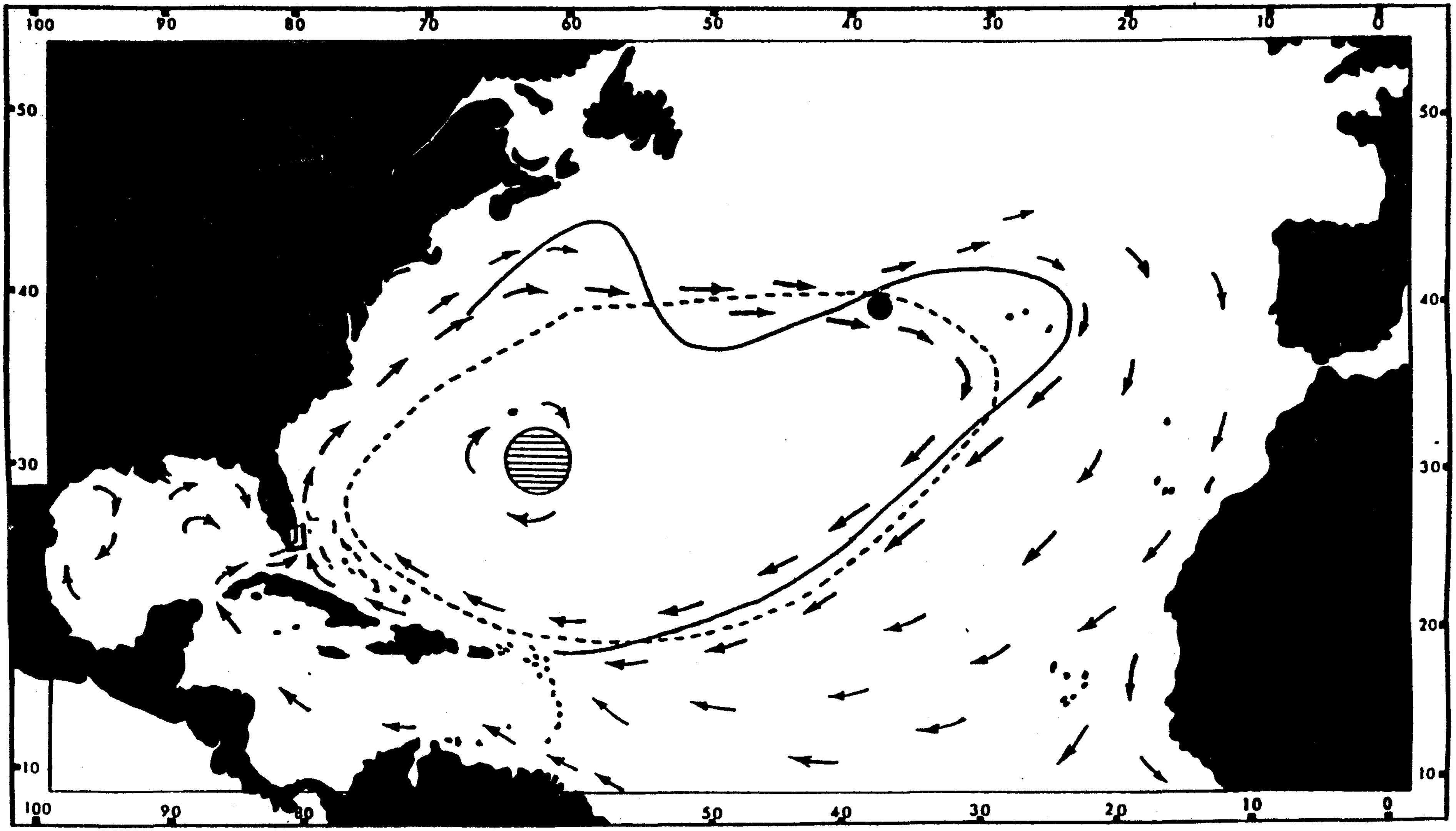

Figure 1. Distribution of pelagic Sargassum in the Northwest Atlantic. Solid line refers to the outer boundary of regular occurrence; dashed line refers to the area in which there is a > 5% probability of encounter within any 1° square; hatched circle represents possible center of distribution (From Dooley, 1972).

Table 1. Invertebrates and primitive chordates associated with pelagic *Sargassum*[a]. Taxonomy follows Brusca and Brusca (1990).

Phylum Sarcomastigophora
Class Granuloreticulosea
Order Foraminiferida
Planorbulina acervalis
Rosalina sp.

Phylum Cnidaria
Class Hydrozoa
Order Hydroida
Aglaeophenia latecarinata
A. minuta
A. perpusilla
A. rigida
Aglaeophenoides mammillata
Antenella secundaria
Campanularia volubilis
Cladocryne pelagica
Clytia bicophora
C. cylindrica
C. johnstoni
C. longicyatha
C. noliformis
C. raridentata
C. simplex
Desmocyphus pumilus
Dynamena quadridentata
Eucopella sargassicola
Gemmaria **sp.**
Gonothyraea gracilis
G. integra
Halecium nanum
Hebella calcarata
Laomedea sp.
Obelia bicuspidata
O. dichotoma
O. geniculata
O. hyalina
Plumularia catharina
P. corrugata
P. diaphana
P. floridana
P. margaretta
P. megalocephala
P. obligua
P. sargassi
P. setaceoides
P. strictocarpa
Scandia mutabilis
Setularia amplectens
S. brevicyathus
S. cornicina
S. exigua
S. flowersi
S. gracilis
S. inflata
S. mayeri
S. rathbuni
S. stookeyi
S. turbinata
S. versluysi
Syncoryne mirabilis
Zanclea costata
Z. gemmosa

Class Anthozoa
Order Actiniaria
Anemonia sargassensis

Table 1. Contd.

Phylum Platyhelminthes
  Class Turbellaria
    Order Acoela
      Amphiscolopus sargassi

    Order Polycladida
      Acerotisa notulata
      Holoplana grubei
      Stylochus mertensi
      S. pellucidus
      Gnescioceros sargassicola

Phylum Annelida
  Class Polychaeta
    Order Phyllodocida
      Alciope contrainii
      Harmothoe dearborni
      Platyneris coccinea
      P. dumerillii

    Order Sabellida
      Spirorbis corrugatus

    Order Amphinomida
      Amphinome rostrata

Phylum Arthropoda
  Class Pycnogonida
      Anoplodactylus petiolatus
      Endeis spinosa
      Tanystylum orbiculaire

  Class Branchiopoda
    Order Cladocera
      Evadne spinifera

  Class Maxillopoda
    Order Harpacticoida
      Amonardia phyllopus
      Dactylopodia tisboides
      Harpacticus gurneyi
      Paradactylopodia oculata
      Paralaophonte congenera
      Scutellidium longicauda

Table 1. Contd.

Order Cyclopoida
- *Macrochiron avirostrum*
- *M. hudsoni*
- *M. sargassi*
- *Copilia mediterranea*

Order Thoracica
- *Conchoderma virgatum*
- *Lepas anatifera*
- *L. anserifera*
- *L. australis*
- *L. fascicularis*
- *L. hilli*
- *L. pectinata*

Class Malacostraca

Order Decapoda
- *Alpheus* sp.
- *Cerataspis monstrosa*
- *C. petiti*
- *Hippolyte coerulescens*
- *H. ensiferus*
- *H. tenuirostris*
- *H. zoztericola*
- *Latreutes ensiferus*
- *L. fucorum*
- *Leander tenuicornis*
- *Palaemon natator*
- *P. pelagicus*
- *Planes minutus*
- *Portunus sayi*
- *P. spinimanus*
- *Sergestes oculatus*
- *Tozeuma carolinense*
- *Virbius acuminatus*

Order Isopoda
- *Anatanais normani*
- *Bagatus minutus*
- *Bopyroides latreuticola*
- *Bopyrus squillarum*
- *Idotea baltica*
- *I. metallica*
- *I. whymperi*

Table 1. Contd.

Janira minuta
Paradynamene benjamensis
Probopyrus latreuticola

Order Amphipoda
Ampithoe longimana
A. pelagica
Biancolina brassicaecephala
Caprella danilevskii
Hemiaegina minuta
Luconacia incerta
Sunampithoe pelagica
Vibilia pelagica

Phylum Tardigrada
Order Heterotardigrada
Styraconyx sargassi

Phylum Mollusca
Class Gastropoda
Order Mesogastropoda
Bittium sp.
Litiopa melanostoma
Rissoa sp.

Order Thecosomata
Creseis spinifera

Order Nudibranchia
Aeolidiella occidentalis
Corambella depressa
Cuthona pumilio
Doridella obscura
Doto pygmaea
Fiana pinnata
Glaucus atlanticus
Scyllaea pelagica
Spurilla sargassicola
S. neapolitana
Tethys protea

Class Cephalopoda
Order Teuthoida
Onychia caribaea

Table 1. Contd.

Phylum Ectoprocta
  Class Gymnolaemata
    Order Cheilostomata

Aetea anguina
Membranipora turberculata
Thalamoperella falcifera

Phylum Chordata
  Class Ascidiacea
    Order Aplousobranchia
Diplosoma gelatinosum

[a] List compiled from Winge,1923; Parr, 1939; Adams, 1960; Yeatman, 1962; Weis, 1968; Friedrich, 1969; Fine, 1970; Dooley, 1972; Morris and Mogelberg, 1973; Ryland, 1974; Teal and Teal, 1975; Peres, 1982; Butler et al., 1983; Deason, 1983; Stoner and Greening, 1984; and Morgan et al., 1985.

Table 2. Fishes associated with pelagic *Sargassum* in the North Atlantic and Gulf of Mexico.[a] * = early life stage present (i.e. egg, larvae or juvenile). Nomenclature follows Robins et al. (1991).

Family/Species		Common Name
Carcharhinidae		
Carcharhinus falciformis		silky shark
C. limbatus		blacktip shark
C. longimanus		oceanic whitetip shark
Clupeidae		
Sardinella aurita		Spanish sardine
Gadidae		
Urophycis earlli	*	Carolina hake
U. floridana	*	southern hake
Antennariidae		
Histrio histrio	*	sargassumfish
Exocoetidae		
Cypselurus furcatus		spotfin flyingfish
C. melanurus	*	Atlantic flyingfish
Exocoetus obtusirostris	*	oceanic two-wing flyingfish
Hemiramphus balao		balao
H. brasiliensis		ballyhoo
Hirundichthys affinis	*	fourwing flyingfish
Hyporhamphus unifasciatus		silverstripe halfbeak
Parexocoetus brachypterus	*	sailfin flyingfish
Belonidae		
Tylosurus acus	*	agujon
Fistulariidae		
Fistularia tabacaria	*	bluespotted cornetfish
Centriscidae		
Macroramphosus scolopax		longspine snipefish
Syngnathidae		
Hippocampus erectus	*	lined seahorse
H. reidi	*	longsnout seahorse
Microphis brachyurus	*	opposum pipefish
Syngnathus floridae	*	dusky pipefish
S. louisianae	*	chain pipefish
S. pelagicus	*	sargassum pipefish
S. springeri	*	bull pipefish

Table 2 (Contd).

Serranidae		
Epinephelus inermis	*	marbled grouper
Priacanthidae		
Pristigenys alta	*	short bigeye
Apogonidae		
Apogon maculatus	*	flamefish
Rachycentridae		
Rachycentron canadum	*	cobia
Echeneidae		
Phtheirichthys lineatus		slender suckerfish
Carangidae		
Caranx bartholomaei	*	yellow jack
C. crysos	*	blue runner
C. dentex	*	white trevally
C. hippos	*	crevalle jack
C. latus	*	horse-eye jack
C. ruber	*	bar jack
Chloroscombrus chrysurus	*	Atlantic bumper
Decapterus macerellus	*	mackerel scad
D. punctatus	*	round scad
D. tabl	*	redtail scad
Elagatis bipinnulata	*	rainbow runner
Naucrates ductor		pilotfish
Selar crumenophthalmus	*	bigeye scad
Seriola dumerili	*	greater amberjack
S. fasciata	*	lesser amberjack
S. rivoliana	*	almaco jack
S. zonata	*	banded rudderfish
Trachurus lathami	*	rough scad
Coryphaenidae		
Coryphaena hippurus	*	dolphin
Lutjanidae		
Rhomboplites aurorubens	*	vermilion snapper
Lobotidae		
Lobotes surinamensis	*	tripletail
Sparidae		
Pagrus pagrus	*	red porgy

Table 2 (Contd).

Mullidae		
Mullus auratus	*	red goatfish
Pseudupeneus maculatus	*	spotted goatfish
Upeneus parvus	*	dwarf goatfish
Kyphosidae		
Kyphosus incisor	*	yellow chub
K. sectatrix	*	Bermuda chub
Chaetodontidae		
Chaetodon ocellatus	*	spotfin butterflyfish
C. striatus	*	banded butterflyfish
Pomacentridae		
Abudefduf saxatilis	*	sergeant major
A. taurus	*	night sergent
Pomacentrus variabilis	*	cocoa damselfish
Mugilidae		
Mugil cephalus	*	striped mullet
M. curema	*	white mullet
Sphyraenidae		
Sphyraena barracuda		great barracuda
S. borealis	*	northern sennet
Polynemidae		
Polydactylus virginicus	*	barbu
Labridae		
Bodianus pulchellus	*	spotfin hogfish
Thalassoma bifasciatum	*	bluehead
Blenniidae		
unidentified	*	blenny
Acanthuridae		
Acanthurus randalli		gulf surgeonfish
Trichiuridae		
Unidentified	*	snake mackerel

Table 2 (Contd).

Scombridae		
Acanthocybium solandri	*	wahoo
Auxis thazard		frigate mackerel
Euthynnus alletteratus		little tunny
Katsuwonus pelamis		skipjack tuna
Scomber japonicus	*	chub mackerel
Scomberomorus cavalla		king mackerel
Thunnus albacares		yellowfin tuna
T. atlanticus		blackfin tuna
Xiphiidae		
Xiphias gladius	*	swordfish
Istiophoridae		
Istiophorus platypterus	*	sailfish
Makaira nigricans	*	blue marlin
Tetrapturus albidus	*	white marlin
Stromateidae		
Centrolophus sp.		ruff
Cubiceps pauciradiatus		bigeye cigarfish
Hyperoglyphe bythites		black driftfish
H. perciformis		barrelfish
Peprilus triacanthus	*	butterfish
Psenes cyanophrys	*	freckled driftfish
Balistidae		
Aluterus heudeloti	*	dotterel filefish
A. monoceros	*	unicorn filefish
A. schoepfi	*	orange filefish
A. scriptus	*	scrawled filefish
Balistes capriscus	*	gray triggerfish
Cantherhines macrocerus	*	whitespotted filefish
C. pullus	*	orangespotted filefish
Canthidermis maculata	*	rough triggerfish
C. sufflamen	*	ocean triggerfish
Monacanthus ciliatus	*	fringed filefish
M. hispidus	*	planehead filefish
M. setifer	*	slender filefish
M. tuckeri	*	pygmy filefish
Xanthichthys ringens	*	sargassum triggerfish
Ostraciidae		
Lactophrys sp.		boxfish

Table 2 (Contd).

Family/Species		Common Name
Tetraodontidae		
Chilomycterus antennatus		bridled burrfish
C. schoepfi		striped burrfish
Diodon holocanthus	*	ballonfish
D. hystric	*	porcupinefish
Sphoeroides spp.	*	puffers
Molidae		
Mola sp.		sunfish

[a] List compiled from: Beebe and Vee-Van, 1928; Breder, 1938; Berry, 1959; Caldwell, 1959; Gibbs and Collette, 1959; Adams, 1960; Berry and Vogele, 1961; Dawson, 1962; Stephens, 1965; Beardsley, 1967; Böhlke and Chaplin, 1968; Randall, 1968; Weis, 1968; Friedrich, 1969; Fine, 1970; Dooley, 1972; Hassler and Rainville, 1975; Teal and Teal, 1975; Hastings and Bortone, 1976; Bortone et al., 1977; Fedoryako, 1980; Schwartz et al., 1982; Manooch and Hogarth, 1983; Manooch and Mason, 1983; Manooch et al., 1984; Manooch et al., 1985; Carr, 1986; Fedoryako, 1989; Minerals Management Service, 1990; J. Govoni, pers. comm.; C. Manooch, pers. comm.; L. Settle, unpubl. data.