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GUEST EDITORIAL

WHAT WILL AQUARIOLOGISTS DO?

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Five years have already elapsed since the first International Congress of Aquariology was held. This important meeting gathered in Monaco for an entire week in 1960, during which nearly 150 aquariologists from 25 different countries discussed almost every technical aspect of their profession in a most cordial way.

However, this very first congress could go no further than to create a necessary link between colleagues and to prepare very promising exchanges of views on the main subject areas. In this respect, the success was encouraging, and it made clear to every one of us how necessary it was to establish permanent relationships and also to organize new congresses in order to probe deeper into the subject. In spite of developing all this good will, nothing further happened. This is detrimental to the development of aquariology, which is altogether a science, an art, and a very complex profession.

Unquestionably aquariology has progressed noticeably. Still, a good deal of improvement remains to be thought of and applied. The results gathered should be coordinated, developed and generalized for the use of workers in the field. Research ought to be pushed. Notwithstanding our efforts, our public aquariums only produce but a remote impression of the living sea and the underwater world, often dramatic, sometimes frightful. Our dsplays remain rather conventional, and we should not take the chance of getting used to them and accepting them instead of trying to reconstruct the natural perspectives which we believe are as important as the display of the animals themselves.

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In short, a public aquarium has to be up to its purpose and to its time. In order to reach this level, it must solve collectively its problems of perspective, population, water movements, lighting, feeding, exchange and supply. It must also fight the basic reasons of its backwardness: the relative isolation of the different organizations, the difficulties of hiring and training high quality employees, and the stumbling blocks that force it to idleness. Consequently, it becomes quite plain that an intensive collaboration between aquariologists throughout the world is a must, and that it should be achieved without delay. Here we are, over 600 of us with the same feelings, who could congregate into an international organization aimed at creating and sustaining links between aquariologists. This task could be accomplished easily if the most dynamic and the freest among us would undertake to carry it out.

Over and above the usual necessities of mail, news, and transmission-after-translation of the most essential published data of bibliography, this organization would organize reciprocal congresses with a pre-estabished orientation. The subject matter would be prepared, and, generally speaking, the results would receive maximum diffusion. Furthermore, a serious technical magazine would consolidate exchanges of view, link together technically and sentimentally the big family of aquariologists, sometimes far away, and would keep us posted professionally.

Financially, this organization could be self sufficient: on the one hand many countries will want to help its goals, on the other hand the arquariologists themselves represent a large enough number to equilibrate the budget.

Many of us feel that this organization deserves to materialize and become an active reality soon. What will aquariologists do about it?

NIGHT HABITS OF FISHES OF ALLIGATOR REEF, FLORIDA[1]

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Since 1958 the senior author has been engaged in a continuing program of research on the fishes of Alligator Reef off the Florida Keys. As a part of this work over 100 night diving trips using SCUBA equipment were made in the period from February, 1962, to September, 1966. The present paper presents some of the observations on reef fishes made during these night dives. The junior author participated in the night diving activities from their inception through August, 1964.

Published information on nocturnal habits of fishes is limited, and, except for papers by Randall, Hobson, Schroeder and Starck, most available information has been obtained from aquarium observations or inferred from examination of stomach contents. Among the few papers which deal with nocturnal habits of various tropical marine fishes are Longley *et al.* (1925), Longley (1927), Longley and Hildebrand (1941), Townsend (1929), Breder (1948), Winn (1955), Hiatt and Strasburg (1960), Randall and Brock (1960), Randall (1961, 1963), Schroeder and Starck (1964), Starck and Schroeder (1965) and Hobson (1965).

Hobson (1965) is the most comprehensive study of nocturnal habits in fishes among these references. His work was carried out in the Gulf of California and a number of interesting parallels with the present study may be seen as well as several differences.

Schroeder and Starck (1964) and Starck and Schroeder (1965) are popular accounts, with numerous black and white and color photographs, of part of the present study.

The remaining citations mention nocturnal habits in relation to the biology of individual species.

METHODS USED FOR NIGHT OBSERVATIONS

Initially, observations were made through use of sealed-beam automobile headlights powered by a battery in a small plastic boat towed by the divers. Most observations, however, were made with the aid of 30-watt sealed-beam

[1] Contribution No. 755 from the Institute of Marine Science, University of Miami.

spotlights arranged as a headlight and powered by nickel-cadmium or lead-acid batteries carried by each diver.

Searching wide areas to determine the distribution of species which disperse at night was accomplished through transects made by swimming compass courses radiating from areas of diurnal concentrations of fishes for distances up to one-quarter mile. A towed sled equipped with a 230-watt floodlight and a two-man submarine were used for longer transects of up to three miles. On windy nights, transects were also made by permitting the boat to drift and swimming with it at the end of a line.

Most nocturnal species are either immobilized by a light or move slowly in a confused manner. There is a direct relationship between imobilizing effect and light intensity, with a light of greater intensity having a greater effect than a dimmer one. Occasionally individuals will dart away when struck by a light beam, but this response is not consistent within a species. We noted that a light caused the strongest flight response shortly after sunset when daylight was still slightly visible underwater.

Light of a full moon makes possible good observation in shallow water, without the disturbance of artificial lights, and penetrates well enough for more limited vision down to about 75 feet. White-sand bottom in shallow depths permits some observation by available light even on moonless nights. Although natural light observation is desirable in some instances we found that for general purposes much more information could be gained with the use of artificial lights.

THE STUDY AREA

Alligator Reef (Coast and Geodetic Survey, chart number 1250) is a shallow knoll on the Florida Reef chain lying about three and one-half miles southeast of Upper Matecumbe Key in the Florida Keys. The reef-top ranges in depth from five to twenty feet (1.5 to 6 m) and the bottom is composed of calcareous sand, coral rubble, and rock. Numerous alcyonarians, sponges, and scattered small coral heads are found in the areas of rocky bottom. The most important topographic features are a rocky outcropping in five to ten feet (1.5 to 3 m) of water around the lighthouse on the shallower part of the reef and a rock ledge, three to eight feet (1 to 2.5 m) high, facing inshore which starts about 200 yards (180 m) south of the lighthouse and extends about 300 yards (270 m) to the southwest. These rocky areas are important places of concentration for many species of reef fishes.

Offshore from the reef-top is a band of sand 100 to 200 yards (90 to 180 m) wide, gradually sloping to a depth of about 55 feet (16 m) where the deep reef begins. The deep reef is a rocky area 25 to 100 yards (25 to 90 m) wide, running parallel to the reef-top and 95 feet (28 m) deep at its outer edge. It is traversed by numerous gullies, which are probably the remnants of ancient surge channels or spur and groove formations (Shinn, 1963). Sponges, corals, and alcyonarians cover the bottom. Seaward of the deep

reef the bottom, consisting of silt, sand, and coral rubble, gently slopes to the deeper waters of the Florida Straits.

Inshore from the reef-top the back-reef consists of coral rubble and sand, which becomes finer in texture toward shore. Irregular patches of *Thalassia* and other marine grasses are scattered through this zone. Occasional rocky areas covered with sponges and alcyonarians occur. About a mile inshore from the reef-top the sandy back-reef ends and the lagoon, known as Hawk Channel, begins. Large beds of *Thalassia*, patch reefs, and flat rocky bottom supporting alcyonarians, sponges, and *Saragassum* dominate the lagoon floor.

Night dives were made in all of the reef zones described above to a depth of 135 feet (40 m) about one-half mile beyond the seaward edge of the deep reef. Alligator Reef is in the West Indian faunal region and most of the fishes observed are common to reefs throughout the tropical Western Atlantic. Alligator Reef has been extensively sampled by over 160 collections using rotenone preparations and by numerous other collecting methods. Some 517 species of fishes have been collected of which about 390 may be considered to be reef inhabitants. The remainder are pelagic forms and species from adjacent inshore and deeper water areas. Because the area and its fauna are well known to the observers, nocturnal changes were generally readily apparent.

OBSERVATIONS

Observations are presented in phylogenetic sequence by family.

Orectolobidae—nurse sharks:

Several small nurse sharks, *Ginglymostoma cirratum*, were found at night resting under rocks on the reef-top. They feed on demersal fishes and invertebrates during the day but may also be seen resting then. Nocturnal feeding was not observed.

Carcharhinidae—requiem sharks:

Shark fishing is most productive on the reef at night and large bull sharks, *Carcharhinus leucas*, have been seen at dusk entering the reef area from deep water. In spite of their greater abundance on the reef at night, only a very few sharks have been observed after dark. Occasional small carcharhinid sharks seen at night were moving about actively in midwater.

Only one large shark was encountered after dark. This individual, a bull shark, came up behind the senior author who was kneeling on the bottom unaware of its approach. Another diver, Alan Emery, saw it moving in, intercepted it and struck it on the nose with a camera housing. It whirled about and departed.

Lack of more numerous sightings of large sharks after dark is probably a result of their greater caution in shallow water coupled with some avoidance of the lights used. Attempts to approach a shark at dusk by boat or by

swimming while directed by an observer on the lighthouse resulted most often in the shark fleeing to deeper water.

Torpedinidae—electric rays:

Narcine brasiliensis has been seen frequently at night foraging in sandy areas of the back-reef. Submarine transects, with a visibility of about 25 feet on either side of the vehicle, made in the back-reef area reveal one to three of these rays per mile.

Dasyatidae—stingrays:

Dasyatis americana is occasionally found actively moving about at night on the reef. It feeds both in the day and at night. Stomach contents of specimens from inshore areas contain mostly penaeid shrimps and crabs.

The most abundant cartilaginous fish on the reef is *Urolophus jamaicensis*. They feed at night and are easily discerned because of the reflections from their eyes. One or more of these small rays can usually be seen within the range of a diver's light in any sandy area on the reef-top. During the day they characteristically rest covered with sand and are not as easily found. They occur less abundantly in the back-reef and lagoon and offshore to a depth of 95 feet (28 m). At night their mottled pattern is faded. The nocturnal pattern of this species is illustrated in figure 1 and Starck and Schroeder (1965: 78). In figure 1 the arched head attitude forming a tunnel into the mouth may be seen. Krumholz (personal communication) believes this may be a feeding posture for trapping small crustaceans.

Clupeidae—herrings:

Several species of herrings are active nocturnal plankton feeders. *Harengula pensacolae* and to a lesser extent *Harengula humeralis* are abundant and active in many reef areas at night. Large numbers of them concentrate to feed on plankton attracted by the night light. In the day they school over sandy bottom in the back-reef area.

Jenkinsia lamprotaenia is another species attracted in great numbers to a light. During the day they form dense schools around rocks, coral, or other cover. The rocky ledge on the reef-top and patch reefs in the lagoon are favored schooling locations. At night the schools break up into smaller more loosely associated feeding groups and are found over much of the reef area.

Jenkinsia majua behaves similarly to the preceding species but schools chiefly on the deep reef in the day. Often it forms mixed schools with *Sardinella anchovia*. At night it ranges up over the reef as well as at least one-half mile beyond at a depth of 135 feet (40 m).

Sardinella anchovia is an active night feeder from the outer edge of the reef to several miles beyond the reef into the Florida Current. They are common in the day along the outer reef edge at a depth of 75 to 90 feet (22 to 26 m). Several specimens have also been taken in trawl and rotenone collections during the day at a depth of 150 feet (45 m). Longley and Hildebrand (1941: 7) report *Sardinella anchovia* as commonly occurring

at the surface about a night light over 10 to 20 fathom depths at the Tortugas, Florida.

Synodontidae—lizardfishes:

Two synodontids, *Synodus synodus* and *Trachinocephalus myops*, have occasionally been observed at night in several reef zones. Both species are typically found partially buried in sandy areas and respond to a light by erratic movements in a manner characteristic of nocturnally active animals. Synodontids also feed actively in the day by erupting from their resting position on the bottom to strike their prey as it passes over.

Muraenidae—morays:

Enchelycore nigricans, *Gymnothorax funebris* and *Gymnothorax moringa* are commonly seen at night. Morays are active nocturnal feeders (Hiatt and Strasburg 1960: 74) often emerging completely from rocky crevices where they are found in the day. The species listed are principally fish eaters. On one occasion a *Gymnothorax moringa* about 60 cm long bit off an arm from an octopus with an arm spread as long as the length of the moray. The octopus had backed into the moray as it was retreating from a diver. A violent struggle ensued for about 10 seconds until the moray broke free, devouring an arm of the octopus.

Ophichthidae—snake eels:

All of the eleven species of snake eels collected at Alligator Reef are to a greater or lesser extent burrowing forms. *Echiopsis mordax*, *Myrichthys aceninatus* and *Myrichthys oculatus* have well developed eyes and fins and display striking color patterns. At night eels which appeared to belong to this group have occasionally been seen with their heads extended from the sand of the reef-top and back-reef areas. On several occasions one species, *Myrichthys oculatus*, has been found completely in the open so that specific identification was possible. Though they may rarely be seen in the day the much greater frequency of sightings after dark together with the emergence from the sand of invertebrates which are their food is indicative of nocturnal feeding habits.

Other ophichthids of the genera *Ahlia*, *Carolephia*, *Myrophis*, *Sphagebranchus* and *Verma* are smaller species and have poorly developed eyes, fins, and pigment patterns. Though they are more common than the larger species in rotenone collections they are very rarely seen in the open. Presumably they subsist on the interstitial fauna and seldom emerge completely from the substrate.

Congridae—conger eels:

Garden eels, *Nystactichthys halis*, are common just beyond the outer edge of the deep reef in depths of 95 to 100 feet (28 to 30 m) and to a lesser extent in the sand band just inshore of the deep reef at a depth of about 60 feet (18 m). They feed actively in the day, picking plankton as it drifts past their

burrows. Night dives in these areas have failed to reveal any garden eels, and we believe that they are inactive at night.

Belonidae—needlefishes:

Platybelone argalus is common and active over the reef both night and day. Schools of up to 100 or more individuals of about 30 cm standard length are sometimes seen around the lighthouse at night.

Houndfish, *Tylosurus crocodilus*, a meter or more in length, are frequently seen over all areas of Alligator Reef. They also appear to be active both night and day. Most frequently they are seen individually or in small groups and do not form the large schools of the preceding species.

Hemiramphidae—halfbeaks:

Hemiramphus brasiliensis is present over the reef in great numbers, especially in the fall and winter, with schools of from tens to thousands of individuals. They may be in any reef zone, but are most prevalent over the reef-top and fore-reef. The schools move about actively at night as well as diurnally. An underwater nightlight suddenly turned on results in hundreds of these fish showering the surface around the boat. They feed largely on floating blades of marine grasses but will also take small animals (Randall 1965: 258). Feeding occurs in the day and probably also at night.

Fistulariidae—cornetfishes:

Fistularia tabacaria has been seen a number of times at night. It occurs in back-reef or lagoon areas and both over sandy bottom and over alcyonarian, *Spheciospongia*, and *Thalassia* bottom in Hawk Channel. Eight specimens were seen in a one-mile night transect in Hawk Channel. They are solitary predators on medium-sized reef fishes.

Only once has a cornetfish been seen at Alligator Reef in the day.

Syngnathidae—pipefishes and seahorses:

Syngnathus louisianae has been seen, and collected, partially buried in sand of the back-reef area at night.

Hippocampus reidi has been observed in a grass patch of the back-reef at night, apparently inactive as it clung to the grass by its prehensile tail.

The small number of sightings, feeding habits, and small eyes are not indicative of general nocturnal feeding among Syngnathids.

Holocentridae—squirrelfishes and soldierfishes:

Five species of squirrelfishes are common at Alligator Reef. All have been observed at night. *Holocentrus ascensionis* and *Holocentrus rufus* live individually in rocky holes on the reef-top and on the deep reef. *Holocentrus vexillarius* and *Holocentrus coruscus* are usually found in numbers in coral crevices or under ledges from the reef-top shoreward. All emerge at night to forage in adjacent areas of mixed rubble, sand, rock and grass bottom. *Myripristis jacobus* is found in groups under rocky ledges on the reef top and emerges after dark. It does not range as far as do the species of *Holocentrus* and tends to forage over the reef-top. It has not been observed at the

Fig. 1—**Urolophus jamaicensis** in frontal view showing the arched head attitude commonly observed at night.

surface as reported by Hobson (1965: 297) for *M. occidentalis*.

Several references refer to nocturnal habits in this group. Hiatt and Strasburg (1960: 76) and Randall (1963: 44) classify the family as nocturnal, and Hobson describes nocturnal habits in two Gulf of California squirrelfishes. Longley and Hildebrand (1941: 53–54) state that *Holocentrus ascensionis*, *Holocentrus coruscus* and *Holocentrus vexillarius* feed by night and lie hidden by day. No distinct nocturnal color changes were seen in holocentrids at Alligator Reef, though Breder (1949: 92) reports that *Holocentrus ascensionis* becomes much paler, almost white, at night in aquaria. This change was probably related to being held over a white substrate in an aquarium.

Serranidae—sea basses:

Groupers appear in the same rocky areas and behave in a similar manner day and night. *Epinephelus striatus*, *Mycteroperca bonaci*, *Mycteroperca microlepis*, *Mycteroperca phenax*, and *Petrometopon cruentatum* are among those frequently observed at night. *Petrometopon cruentatum*, the smallest species, is found in rocky crevices and stays among the rocks both day and night. The other species are more free-moving but still do not usually go far from cover. Groupers probably have peaks of feeding activity around sunrise and sunset but, in common with most larger predaceous fishes, feed

any time food is available. Hobson (1965: 293) found this feeding pattern in *Mycteroperca rosacea*, which he classified as diurnal but for which he described intense feeding periods around sunrise and sunset. Other references are not inconsistent with such a pattern. Randall and Brock (1960: 11) found that the stomach contents of 11 species of groupers they examined in the Society Islands had the majority of full stomachs in the morning. Longley and Hildebrand (1941: 96) report that *Epinephelus morio* feeds both day and night but do not indicate peak periods. Randall (1965: 13) examined stomach contents of 250 specimens of *Epinephelus striatus* and found largely fishes and crustaceans were eaten. Food organisms were characteristic of rocky or coral areas, but no feeding time was determined other than that the specimens were collected in the day and that 100 of them had empty stomachs. Forty percent empty stomachs does not indicate peak feeding in the day.

Diplectrum bivittatum was seen resting at night on sand and rubble bottom about one-half mile beyond the deep reef at a depth of 135 feet (40 m). It exhibited a blotched color pattern similar to that of some grunts (*Haemulon* spp.) at night.

Diplectrum formosum has been observed in the sandy back-reef area at night and after dawn among the blades in sparser areas of *Thalassia* growth. Neither species of *Diplectrum* appeared to be active at night.

Other small serranids of the genera *Hypoplectrus* and *Serranus* also appear to be inactive at night. *Serranus tabacarius* is seen resting on the bottom in surge channels on the deep reef in depths of 50 to 90 feet (15 to 27 m) and *S. tortugarum* behaves similarly on the rubble bottom just beyond the deep-reef. *Hypoplectrus unicolor* and *H. gemma* have been found resting close to the bottom in rocky areas on the deep-reef. In some individuals of *H. gemma* a pattern of pale blotches was observed. Other species of *Serranus* and *Hypoplectrus*, although commonly seen in the day, have not been observed at night and are presumably inactive. Stomachs of these species, taken in the day, usually contain food. Stomach contents of species of *Serranus* from Alligator Reef are reported in Robins and Starck (1961).

Grammistidae—soapfishes:

Rypticus subbifrenatus is a smaller species commonly taken in rotenone collections in rocky and coral areas. It has not been observed in the day but at night is occasionally seen among the rocks and coral in the same locations where it is collected in the day.

Rypticus bistrispinus is found primarily around isolated small rocks or sponges on level bottom beyond the deep reef. It is often in pairs. One night a specimen was seen moving about on open sandy bottom in an area of scattered large sponges in 135 feet (40 m) of water.

Solitary individuals of *Rypticus saponaceus* are usually found among rocks in the day. At night it emerges but remains in the vicinity of the rocks.

The Eastern Pacific soapfish, *Rypticus bicolor*, is also reported to be a nocturnal feeder (Hobson, 1965: 297).

Lutjanidae—snappers:

Lutjanids are primarily nocturnal feeders though they also feed in the day to varying extents depending upon the species and the availability of food. *Lutjanus apodus* and *Lutjanus griseus* form schools (sometimes mixed) of several hundred to several thousand individuals over rocky bottom at certain locations on the reef-top (fig. 2). These species also occur in other inshore locations. At sunset the schools grow increasingly restless, and about 30 to 45 minutes after sunset they disperse.

After dark *Lutjanus apodus* forages individually in rocky areas on the reef-top. They feed primarily on crustaceans and small fishes, including resting diurnal species such as pomacentrids. The Eastern Pacific cognate of *Lutjanus apodus*, *L. argentiventris*, is reported by Hobson (1965: 297) to feed nocturnally in rocky areas near shore.

Lutjanus griseus feeds in more open areas of the reef-top and back-reef. They frequent mixed rubble, grass, and sand bottom, and broken bottom of sponges and alcyonarians on a flat rocky substrate. Gray or mangrove snapper commonly range as much as a mile from their daytime resting places. They prey largely on crustaceans and fishes. The most important

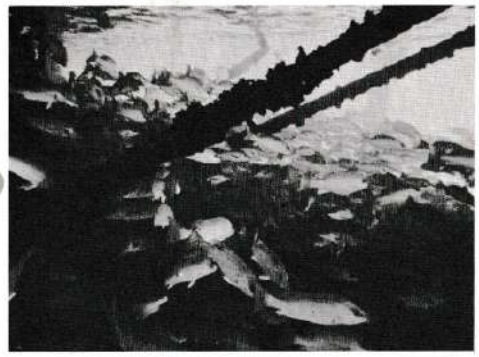

Fig. 2—A large diurnal school of gray snapper (Lutjanus griseus) with a few Haemulon sciurus and L. apodus beneath Alligator Lighthouse.

of the fishes eaten are species of grunts of the genus *Haemulon* which are nocturnal feeders in the same areas.

Lutjanus jocu is similar to *Lutjanus apodus* in body form and color and it also feeds in rocky areas. *Lutjanus jocu* is more solitary in habits, however, and tends to be found under ledges and in caves during the day. It is a fish and crustacean eater as is *Lutjanus apodus*, but its larger size permits it to consume larger prey. Competition may thus be reduced between these two similar species which feed in the same areas and on the same type of prey.

Lutjanus synagris occurs in the sandy back-reef area where it forms small schools close to the bottom in the cover of alcyonarian and sponge patches. At night it is usually seen around the scattered grass patches and over sandy rubble bottom of the back-reef. Its food is largely the small invertebrates which emerge in these areas after dark.

Juveniles of *Lutjanus buccanella* were observed on two occasions wandering about over the silty sand and rubble along the outer edge of the deep-reef. Small resting schools have been occasionally seen on the deep-reef during the day. The adults of this species are found commonly in depths of 50 to 100 fathoms (85 to 180 m). The young of several other deeper water serranids and lutjanids also occur in shallower water than the adults.

Ocyurus chrysurus is a semi-pelagic snapper which ranges throughout the reef habitat. It is most often found in loosely associated schools over rocky areas and it feeds actively both day and night. It is most successfully caught by commercial hook and line fishermen at night. Food of this species consists mainly of larger planktonic and smaller nektonic organisms together with some benthic crustaceans and worms. Crustaceans and small fishes from the drifting *Saragassum* community are also eaten.

The biology of lutjanids occupying West Indian coral reefs has been studied by the senior author, especially with reference to *Lutjanus griseus* (Starck, in press). Longley *et al.* (1925: 232); Longley (1927: 70); and Longley and Hildebrand (1941: 115–121) also give notes on the biology of several Florida lutjanids and indicate nocturnal feeding for the species discussed.

Priacanthidae—bigeyes:

Priacanthus cruentatus occupies holes and ledges on the reef-top during the day. At night it emerges but remains in the same rocky areas and bears a mottled color pattern faintly seen in the day (figs. 3 and 4). Hiatt and Strasburg (1960: 81) suggest that this species feeds in caves during the day in the Marshall Islands, but may also feed nocturnally. Longley and Hildebrand (1941: 112) state that feeding occurs chiefly at night and our observations lead us to the same conclusion.

Apogonidae—cardinalfishes:

Cardinalfishes of the genus *Apogon* are abundant nocturnal predators at Alligator Reef. *Apogon aurolineatus, Apogon binotatus, Apogon maculatus,*

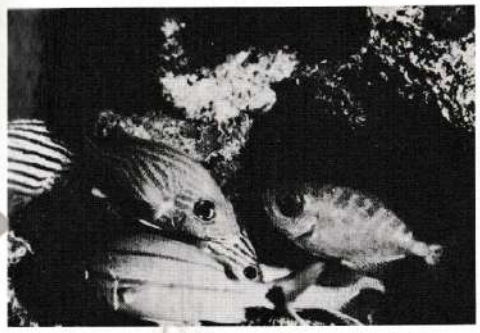

Fig. 3—The faint traces of a mottled pigment pattern as seen in the daytime on **Priacanthus cruentatus** (on the right). Also resting beneath the same rock ledge are **Haemulon flavolineatum** (above center) and **H. aurolineatum** below and **Equetus pulcher** partially visible (on the left).

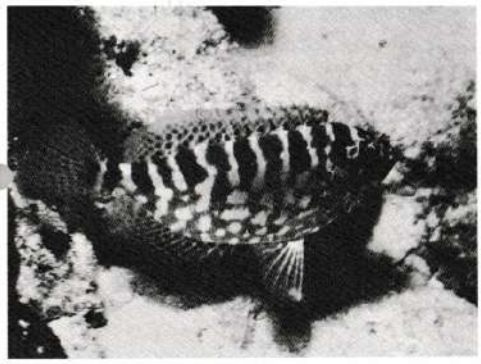

Fig. 4—The heavily mottled nocturnal pattern of **Priacanthus cruentatus.**

Apogon pseudomaculatus, *Apogon planifrons* and *Apogon conklini* spend the day in caves and crevices on the reef where they are found individually or in small aggregations. After dark they emerge and, except for *Apogon conklini*, feed near bottom in areas adjacent to their daytime retreats. All but *A. conklini* are predominantly reddish in color diurnally. At night most of them fade to pink but become darker when held in the beam of a light. (This change is illustrated in Schroeder and Starck (1964: 149)).

Apogon conklini is a dusky species which rises in midwater to feed on plankton. It is often found individually or in small groups around the top of an alcyonarian or the outstretched arms of a basket-starfish, *Astrophyton muricatum* (fig. 5).

Apogon stellatus is a commensal, living with the queen conch, *Strombus gigas*. It has been seen on several occasions at night roaming in the back-reef area adjacent to the reef-top. This area supports a considerable population of *Strombus* in which *Apogon stellatus* spends the day. In the day this species is quite dusky in coloration. At night it is paler with a metallic greenish sheen. This change in color has been commented on by Breder (1949: 91), who also suggests (1948: 307–308) that it emerges from its host and prowls about at night for food.

Hobson (1965: 298) reports nocturnal plankton feeding habits in an Eastern Pacific apogonid and cites other references to nocturnal habits in the family. Longley and Hildebrand (1941: 87–90) indicate nocturnal habits for these fish and describe paler color at night for several species.

Carangidae—jacks, scads, and pompanos:

Jacks are most often seen around the nightlight, where they congregate to feed on plankton attracted by the light (fig. 7). The individuals involved are small, usually less than 250 mm long. *Caranx ruber* is by far the most abundant species attracted in this way (see Starck and Schroeder, 1965: 77) and more than 100 individuals may be present. They are often mixed with schools of clupeids drawn in at the same time. Occasionally small specimens of *Caranx bartholomaei* and *Caranx crysos* are also attracted. Larger *Caranx bartholomaei* have been seen swimming in midwater at night. All of these species are active diurnal feeders as well.

Decapterus punctatus schools in the back-reef area in the day and on occasion has gathered in the fringes of the lighted area around a diver to feed on plankton. At the Tortugas *Decapterus punctatus* was reported by Longley and Hildebrand (1941: 75) to be taken around a submerged light. Stomachs examined by Longley contained copepods. Hobson (1965: 299) reports nocturnal feeding over sand by another scad *Selar crumenophthalmus* in the Eastern Pacific.

Gerridae—mojarras:

Eucinostomus argenteus is common in sandy areas of the back-reef and between the reef-top and deep-reef in depths of 10 to 40 feet (3 to 12 m).

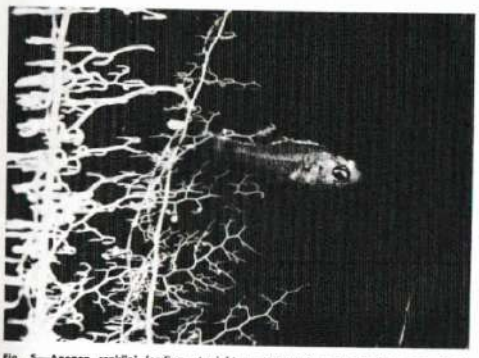

Fig. 5—Apogon conklini feeding at night up current from the feeding arms of the basketstarfish (Astrophyton muricatum).

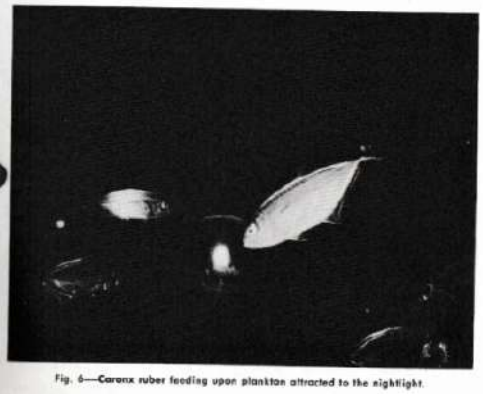

Fig. 6—Caranx ruber feeding upon plankton attracted to the nightlight.

It occurs individually or in small loosely associated groups and appears to be quite active at night. Breder (1948: 295) reported that *Eucinostomus gula* in an aquarium rested quietly in open water well up from the bottom at night in about the same place in which it spent the day. In an enclosed space it could probably do little else.

Pomadasyidae—grunts:

Grunts of the genus *Haemulon* are among the most abundant of West Indian reef fishes. They make up a significant proportion of the biomass of most shallow water reefs. Eleven species of *Haemulon* and two of *Anisotremus* occur at Alligator Reef. For this reason as well as the occurrence of several closely related species in a limited area they were chosen as the subject for a dissertation by the junior author.

All but two of the eleven species are normally nocturnal feeders as adults. *Haemulon album*, one of the exceptions, is the largest species and as an adult feeds actively in the day either individually or in small groups. Its large size frees it from many of the predators on other species of *Haemulon* and its pale gray color blends well with the general shade of the open areas adjacent to the reef where it commonly feeds by day. The relatively small eye of this species is probably also related to diurnal feeding. Whether or not large

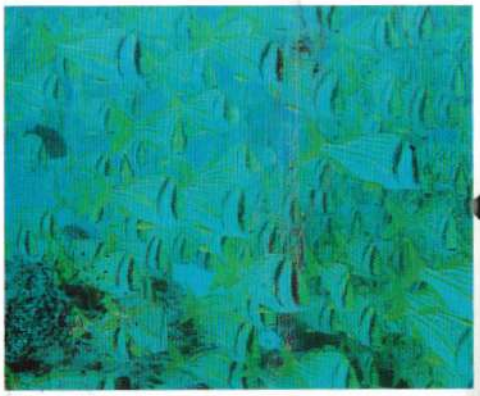

Fig. 7—A daytime school of parkfish (Anisotremus virginicus).

Fig. 8—Portion of a diurnal school of grunts, principally Haemulon sciurus at Alligator Reef. Abudefduf saxatilis, Lutjanus griseus, and Mulloidichthys martinicus are also intermingled in this group.

adults feed at night as well is unknown, but the few observations made saw them quiescent. Juveniles up to a size of about 300 mm S.L. school in back-reef areas during the day. Their schools are located in areas with moderate cover such as alcyonarians and sponge patches. At night they disperse throughout the sandy back-reef area. At this stage they are similar in size and habits to the other species of *Haemulon*.

Active diurnal feeding is also observed in *Haemulon striatum*. This is the smallest species as an adult and is a particulate plankton feeder. Color pattern, behavior and body form are reminiscent of small juveniles of the other species which also feed diurnally on plankton. It is commonly found in schools two to six feet above the bottom and is most abundant on the deep reef at depths of 60 to 95 feet (18 to 28 m). At night the large diurnal schools of *H. striatum* disperse, but their behavior does not suggest active feeding. Its schooling behavior is most similar to that of *Haemulon chrysargyreum*, which is found in much shallower waters.

All of the remaining species are primarily nocturnal feeders and all occur to a greater or lesser extent on the reef-top at Alligator Reef. These species feed on invertebrates, the most important of which are annelids, echinoderms, crustaceans, and mollusks. They form dense schools (often mixed) in the day (figs. 7 and 8), with the exception of *Anistroemus surinamensis*

which stays under ledges and in caves. Around sunset the schools become increasingly restless; individuals mill about and the species become difficult to distinguish unless a silhouette is presented. If a strong light is turned on a school at this time it will "explode" as the individuals flee in all directions. About 30 to 45 minutes after sunset the fish disperse, and thereafter an artificial light produces only immobilization or slight and confused movements.

Pigment patterns seem to be closely related to the nocturnal and diurnal behavior of each species, and adult diurnal color patterns are distinct. The species involved can be divided into two principal groups on the basis of diurnal behavior and colors. One group, *Haemulon aurolineatum*, *Haemulon melanurum*, *Haemulon parrai*, and *Haemulon plumieri* consist of species which are pale tending to greyish in overall appearance. These species school in more open areas, and would include *Haemulon album* and *Haemulon striatum* discussed above.

Haemulon melanurum is uncommon on Alligator Reef and its nocturnal behavior is not well known, since it has only been observed on limited occasions at night. The other pale species are seen in open areas of sand and rubble at night.

Haemulon aurolineatum occurs in all reef zones in the day and has been observed most commonly at night in the sandy back-reef area. It has also been seen at night at a depth of about 135 feet (40 m) on silty sand bottom up to one-half mile beyond where it schools in the day along the outer edge of the deep reef.

Haemulon parrai schools in the day over rubble and rock bottom near Alligator Lighthouse, often in company with *Lutjanus griseus*. At night it has been seen most frequently over sandy bottom in the immediate vicinity of its diurnal location.

Haemulon plumieri is found by day over broken bottom consisting primarily of alcyonarians and sponges on a flat rock substrate in all reef zones. At night is occupies the same areas and is a typical species in adjacent grass patches.

The remaining species consist of a series of forms dark in color at one extreme and showing an increasing predominance of yellowish pigments in contrast shading through the series. These species are most commonly associated with rocky or coral areas during the day. The darkest species are most shadow-loving, whereas the predominantly yellow species school more in the open where bright light on corals, alcyonarians, and algae give an overall yellowish appearance to the reef.

Anisotremus surinamensis is the darkest species of this series. It stays in caves and under ledges on the reef top and deep reef in the day and emerges to feed in rocky areas at night. It feeds on rock-dwelling species of echinoderms, especially *Diadema antillarum* (Randall *et al.*, 1964: 429) and crustaceans (largely majid and porcellanid crabs).

Another dark species is *Haemulon macrostomum* which is dark dorsally, fading to silvery-white ventrally, and shows traces of dark mid-lateral stripes. A yellow stripe is present immediately adjacent to the base of the dorsal fin on each side. The yellow stripes terminate in a yellow saddle on top of the caudal peduncle. This species occurs on the reef-top in areas of coral or rock with strong relief. It usually rests in shaded locations. At night it feeds in the same areas. The main item of its diet is the sea urchin, *Diadema antillarum* (Randall *et al.*, 1964: 429), which emerges from crevices at night.

Haemulon carbonarium is a moderately dark species. It is dusky dorsally and has a series of bronze stripes along the sides of the body on a blue-gray background. It is found in coral and rocky areas of strong to moderate relief, and schools in shaded locations or close to the reef-top in irregular areas. At night it feeds in the same areas and in immediately adjacent regions of rock and rubble.

Haemulon sciurus (fig. 9) is somewhat similar in size and appearance to *Haemulon carbonarium* but is paler than the above species. It is not dusky dorsally and the lateral stripes are yellow alternating with pale blue. It is abundant on the reef-top and also in various inshore locations. It occurs in areas of moderate cover and rests near or just above the bottom. At night it migrates to adjacent areas of mixed sand, rubble, and grass, and the flat rocky bottom dominated by alcyonarians and sponges. It is frequently seen as much as one-fourth mile from the nearest point of daytime concentration, and has even been observed on the deep-reef, where it does not occur in the day.

Haemulon flavolineatum is a smaller species, predominantly yellow in appearance (figs. 9, 10 and 11). Its pattern consists of yellow stripes on a pale blue background. It schools on the reef-top in brightly lit areas where coral, alcyonarians, and brown algae produce a dominantly yellow background. It also occurs in numerous inshore locations. Often it schools two to three feet above the substrate. At night it scatters throughout adjacent areas and is common in the sandy back-reef zone one-half to one mile from the nearest point of diurnal concentration.

Haemulon chrysargyreum is the smallest and most terete species of this series. Yellow-orange stripes on a silver-white background give it an overall yellow appearance. It is common on the reef-top in the same areas as the preceding species, but tends to school higher above the reef than the former species. At night it is most abundantly seen in the sandy back-reef zone, and it will gather to feed on plankton attracted to the nightlight. Similar feeding behavior in large juvenile (to 250 mm) *Haemulon album* has been

Fig. 9—Haemulon flavolineatum (french grunt) in typical daytime pattern.

Fig. 10—Haemulon flavolineatum showing the pale nocturnal pattern found on individuals over open sand bottom.

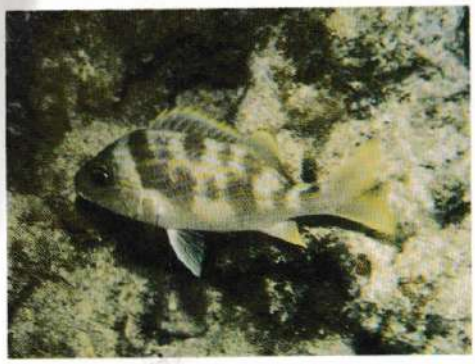

Fig. 11—The mottled pattern seen on specimens of H. flavolineatum foraging over variegated background or rocky bottom areas.

observed by the junior author around the lights of an underwater television installation in Bimini, Bahamas.

Anisotremus virginicus (figs. 7 and 12) is more difficult to place in the above series, but would probably fit in close to *Haemulon sciurus* and *Haemulon carbonarium*. Its dominantly yellow appearance is produced by yellow fins and head. Its body is pale with blue lines and two broad prominent black bars occur on the head. It schools from one to five feet above the bottom, usually in open areas between coral heads or rocks (fig. 7). It is seen at night in locations similar to those described for *Haemulon carbonarium*. It also ventures more into the open rubble and alcyonarian areas frequented by *Haemulon sciurus* and *Haemulon flavolineatum*. It may be an ecological intermediate between the dark rock feeding species and the paler back-reef foragers.

It can be seen that the darkest species (*Anisotremus surinamensis*, *Haemulon macrostomum*, and *Haemulon carbonarium*) tend to feed in rocky areas at night, as well as staying closer to rocks in the day. Though paler at night, they do not become as pale as the other species in this group. The first and second are also the largest species of the series, which probably endows them with more protection from snappers, groupers, morays, and other nocturnal predators which abound in rocky areas.

In all species of *Haemulon* the degree of paleness at night varies between individuals within a species. In the extreme it may almost completely obliterate the distinctive diurnal pattern, as commonly happens in *Haemulon chrysargyreum* or *Haemulon flavolineatum* over open sandy bottom.

A second pattern has also been observed in *Haemulon flavolineatum*, *Haemulon plumieri*, *Haemulon sciurus*, *Haemulon carbonarium*, and *Haemulon macrostomum*, which probably can occur in all the species of *Haemulon*. This pattern, consisting of large, irregular, dark and pale blotches, is associated with rocky areas and grass patches (fig. 12). A similar pattern has also been observed in *Lutjanus griseus* at night.

Nocturnal color patterns of grunts are illustrated by Schroeder and Starck (1964: 130), and Starck and Schroeder (1965: 69). Townsend (1929: 348, 364, 365) also shows these patterns, but does not identify them as nocturnal. Various patterns, light or mottled, have been produced by hormone injections (Rasquin, 1958: 46–48).

Hobson (1965: 298) describes nocturnal activities similar to those observed at Alligator Reef in several species of pomadasyids from the Gulf of California, and cites other references. He also describes behavior of a diurnal pomadasyid school in the presence of a predator where the grunts involved rapidly formed a very tight school. Hobson points out the protective function of such a school and the work of Mantcifel and Radakov (1961), which indicates that a predator must direct his attack on one individual to achieve any degree of success.

Observations at Alligator Reef further elucidate this behavior. On numerous occasions, usually late in the afternoon, large jacks, *Caranx bartholomaei*, have been seen to prey on schools of grunts. When the jacks first appear the grunts form tight groups as described by Hobson and the maze of contrasting lines of the milling, closely packed fish make singling out one individual especially difficult. One or more jacks will then rush into and scatter the tightly packed school. Individual grunts are then pursued and seek shelter in the reef. Thus suitable cover nearby also becomes an important factor for the location of the diurnal school.

Longley and Hildebrand (1941: 22–130) treat all of the species mentioned here, and give some biological data for most. They indicate nocturnal feeding for the family. Randall (1963: 44) also characterizes the family as night feeders, and points out the ecological significance of their nocturnal foraging in adjacent areas.

Sciaenidae—drums:

Two species of sciaenids are abundant on the reef-top at Alligator Reef. *Equetus pulcher* and *Odontoscion dentex* spend the day in holes in the reef, usually in groups of up to 20 individuals. At night they forage individually over the bottom in the immediate vicinity. The diurnal color pattern of

Equetus pulcher consists of sharply contrasting black and white stripes which often fade to pale gray at night.

Occasional specimens of *Equetus punctatus* are also seen at night in rocky areas on the reef-top. They rest during the day within the rocks. Longley and Hildebrand (1941: 144) on *Eques acuminatus* (=*Equetus pulcher*, as used here) state that it usually ventures little beyond the shadow of its shelter by day but moves out at dusk. Hobson (1965: 300) reports nocturnal habits in an Eastern Pacific species of *Pareques*.

Mullidae—goatfishes:

Two species of goatfishes, *Mulloidichthys martinicus* and *Pseudupenus maculatus*, occur at Alligator Reef. *Mulloidichthys* schools in the day on the reef-top, and often mixes with schools of pomadasyids (fig. 8) or lutjanids which also show a predominantly yellow pattern. At night it is seen on the bottom in sandy patches of the reef-top and responds actively to a light. It probably feeds at that time. Longley and Hildebrand (1941: 141) report examination of stomachs of this species in morning and afternoon and conclude that it is a nocturnal feeder. It appears to be somewhat paler at night.

Pseudupenus maculatus feeds diurnally in small groups. It occurs in all reef zones and feeds usually in sandy areas adjacent to cover of coral, rocks, or alcyonarians. At night it rests individually on the bottom in the same sandy areas. At that time it is much paler than in the day and the dark lateral blotches are almost absent. Diurnal and nocturnal color patterns of this species are illustrated by Schroeder and Starck (1964: 135). Longley and Hildebrand (1941: 142) describe it as diurnal.

Pempheridae—sweepers:

Pempheris schomburgki is found during the day on the reef-top. It forms large schools in crevices, under ledges and among rocks. At night they emerge to feed on plankton in midwater above the reef. They move about either individually or in loose aggregations.

Sparidae—porgies:

Calamus proridens is most abundant in the lagoon area and feeds actively in the day. A submarine transect at night through the same area revealed scattered but numerous individuals just above the grassy bottoms. Most individuals appeared more mottled than in the day and though their activities were not determined they were not resting on the bottom. *Calamus calamus* and *C. arctifrons* also move about at night.

Kyphosidae—sea chubs:

During the day schools of *Kyphosus incisor* are active over the reef-top. They spend much of their time in mid-water and feed largely on drifting *Sargassum* at the surface. After dark they rest in sheltered, though not confined, locations on the reef-top. At night some large individuals exhibit

white spots on a dark background, a feature that is also characteristic of juveniles.

Chaetodontidae—butterflyfishes:

All chaetodontids observed are active diurnal browsers and all are more or less inactive at night. *Chaetodon capistratus, Chaetodon ocellatus, Chaetodon tedentarius,* and *Chaetodon striatus,* have all been observed at night resting in rocky areas. Though inactive they respond to the presence of a diver, and often start to move away. On one occasion a large *Chaetodon ocellatus* was seen by moonlight to be moving about over a patch of rock, but its activity was not further ascertainable. It is the only chaetodontid observed to undergo a substantial color change. At night it acquires a large dark smudge on the side and a distinct black spot, sometimes present in the day, at the base of the soft dorsal fin. Diurnal and nocturnal patterns in this species are illustrated in Schroeder and Starck (1964: 131). Longley and Hildebrand (1941: 147–149) describe the nocturnal pattern of *C. ocellatus* and a nocturnal pattern for *C. capistratus* which was not seen in specimens observed at Alligator Reef.

Holacanthus bermudensis, Holacanthus ciliaris, and *Holacanthus tricolor* rest in holes and under ledges at night. They are inactive and respond sluggishly to the close presence of a diver. *Pomacanthus paru* and *Pomacanthus arcuatus* are darkly colored species which rest in more open locations at night. Usually they are seen next to a rock or large sponge. They feed to a considerable extent on sponges, and it is possible that while resting next to a sponge at night they might also feed on it. They are more responsive to the presence of a diver than are the species of *Holacanthus.*

Henry A. Feddern, of the Institute of Marine Science, Miami, is presently investigating the comparative ecology of the angelfishes of this region and a more thorough report will be published. Hobson (1965: 295) described similar diurnal feeding and nocturnal resting in three species of chaetodontids from the Gulf of California.

Pomacentridae—damselfishes:

All pomacentrids observed are diurnal feeders and all seek individual shelter at night in sponges, rocks, coral, or other close cover. They respond to the presence of a diver and his light by moving slowly about within the confines of their shelter. The species observed at night are *Abudefduf saxatilis, Chromis marginatus, Chromis cyanea, Chromis insolatus, Chromis* sp., *Pomacentrus dorsopunicans, Pomacentrus variabilis, Pomacentrus partitus, Pomacentrus planifrons,* and *Microspathodon chrysurus.* All but *Abudefduf* and *Microspathodon* occur on both the reef-top and deep-reef. *Abudefduf* is found from the reef-top shoreward and *Microspathodon* on the reef-top and patch reefs. *Abudefduf, Chromis* and *Pomacentrus partitus* are to a large extent particulate plankton feeders. The remaining species of *Pomacentrus*

Fig. 12—*Anisotremus virginicus* showing the dark areas in the spinous dorsal and lateral stripes which form at night.

feed chiefly on small demersal invertebrates and algae. *Microspathodon* is principally a herbivore.

Abudefduf saxatilis becomes much darker at night, specially on moonless nights, and the yellow lateral bars almost disappear (fig. 13). This coloration has also been observed during the day in egg-guarding individuals in the shadow of the reef. Nests of this species are found throughout the year, though summer is the peak season at Alligator Reef. Nest sites are located on flat rock immediately adjacent to the reef and in holes in the reef itself. Nests are formed by clearing away silt, sand, and rubble, over a patch about 10 to 20 cm in diameter, exposing the rocky substrate. The eggs, about 1 mm in greatest diameter and purplish in color, are attached to the substrate in a single layer. Nests have often been seen on several successive days, and hatching occurs in about a week. An adult fish usually guards the nest (fig. 14) and continues this activity even at night. An unguarded nest is quickly eaten by swarms of labrids in the day. Pomadasyids and lutjanids also prey on *Abudefduf* eggs in the day (fig. 15). At night small shrimp have been seen among the eggs and nocturnal fishes would undoubtedly take a greater toll were it not for around-the-clock nest guarding.

In the remaining species the most common color change noted at night was a general darkening, but pale bars and other markings have been observed in some cases.

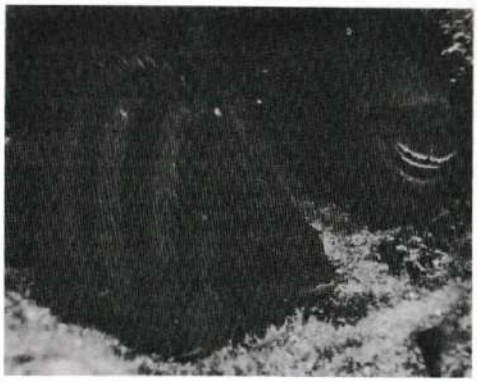

Fig. 13—Abudefduf saxatilis exhibiting the dark pattern observed on dark nights.

Hobson (1965: 293) also reports diurnal feeding and nocturnal resting in three Gulf of California pomacentrids. He points out Breder's (1948: 294–295) aquarium observations on nocturnal resting in *Abudefduf saxatilis* and *Pomacentrus leucosticus*.

Alan R. Emery, of the Institute of Marine Science Miami, is engaged in a study of the comparative biology of species of the family Pomacentridae at Alligator Reef and a more detailed report is planned.

Labridae—wrasses:

All wrasses observed are active diurnally. Seventeen species have been collected at Alligator Reef. At night these abundant and conspicuous fishes disappear. Four species have been found resting after dark. The remainder presumably also rest at night.

Bodianus rufus, one of the larger labrids at Alligator Reef, occurs in rocky areas during the day. It is a non-schooling species. Small individuals can usually be found along rocky ledges on the reef-top. They often remove ectoparasites from other fishes, especially the bar jack, *Caranx ruber*. Randall (1962: 44) reported such cleaning behavior in *Bodianus rufus* from the Caribbean, and Hobson (1965: 294) mentions cleaning by *Bodianus diplotaenia* in the Gulf of California. At night medium to large-sized specimens of *Bodianus rufus* have been found resting in rock crevices. No

mucous envelopes were observed as reported by Hobson in juvenile *Bodianus diplotaenia*. Perhaps smaller individuals than the ones we observed would produce such envelopes.

Over the deep-reef *Clepticus parrai* schools to feed on plankton during the day. This species feeds in midwater, often rising 20 to 40 feet above the bottom. At night a few individuals have been seen resting in crevices of the deep-reef.

The various species of *Halichoeres*, and *Hemipteronotus*, though very common in the day, have not been observed at night. In aquaria they often bury themselves beneath the sand for considerable periods. At night on the reef they probably bury in sandy areas or secret themselves among rocks. Breder (1951) mentions nocturnal burrowing in sand in *Halichoeres*, *Thalassoma* and *Hemipteronotus*.

The hogfish, *Lachnolaimus maximus*, is the largest West Indian labrid. In the day it feeds individually or in small groups on demersal invertebrates of open bottom in all reef zones. At night they rest in the shelter of rocks, coral heads, and alcyonarians (fig. 16).

Thalassoma bifasciatum (fig. 15) is the most abundant wrasse of West Indian coral reefs. In the day it occurs over and around the reef in loosely aggregated groups of several to 20 or 30 individuals. They feed by picking small benthic organisms from the substrate. They also often feed over the reef on plankton and to a lesser extent by cleaning ectoparasites from other fishes. At dusk they have been seen to enter crevices or rock holes, and a rotenone collection made in a rocky area at night resulted in a number of affected *Thalassoma* emerging from the rocks. Breder (1948: 295) stated that *Thalassoma bifasciatum* either disappeared into shells or burrowed in sand on the coming of darkness in aquaria.

Longley and Hildebrand (1941: 197) also reported this species to bury itself in sand at night. In aquaria or reef situations where suitable rocky shelter is unavailable sand burrowing is apparently an alternate means of acquiring nocturnal shelter. Feddern (1965) treats in detail several aspects of the biology of *Thalassoma bifasciatum* at Alligator Reef and discusses nocturnal habits. Hobson's (1965: 294) description of diurnal and nocturnal behavior in *Thalassoma lucasanum* in the Gulf of California is similar to that of *Thalassoma bifasciatum*.

Scaridae—parrotfishes:

Parrotfishes are diurnal grazers on algae and marine grasses. They wander over and around the reef, usually in small schools. The schools may consist of one species or of two or more species mixed. At night parrotfishes are inactive. Most species rest in rocky crevices, or in grass patches.

Scarus coelestinus (figs. 17 and 19), *Scarus coeruleus*, and *Scarus guacamaia* (fig. 18) are the largest West Indian scarids. They often form mixed schools (fig. 19). *Scarus vetula* is a smaller species, less abundant at Alligator Reef.

Scarus croicensis and *Scarus taeniopterus* are the smallest species of *Scarus*, and also often form mixed schools. These species all rest at night in caves and crevices (fig. 17). A particular crevice will frequently be found to shelter what appears to be the same individual of *S. guacamaia* or *S. coelestinus* (see Winn and Bardach (1960: 32) on home caves).

Mucous envelopes have been observed about smaller specimens of *Scarus guacamaia* and *Scarus vetula* and around the adults of the smallest species, *Scarus croicensis* (fig. 20). If disturbed by touch a fish in the mucous envelope will usually explode from it with a sudden burst of activity. Juveniles of other species of *Scarus* have not been observed. Winn and Bardach (1959) suggest a protective function for the mucous envelope from results of experiments on predation by *Gymnothorax moringa* on *Scarus croicensis* and *Sparisoma rubripinne*, of which the latter does not form a mucous envelope. Winn (1955: 145–147) and Winn and Bardach (1960: 30–31) also discuss mucous envelope formation.

Three species of the genus *Sparisoma* have frequently been found at night. Adults of *Sparisoma viride*, the largest species, rests in rocky areas but usually in more open locations than do the species of *Scarus*. *Sparisoma rubripinne* has been observed lying among the blades of *Thalassia* in grass

Fig. 14—Abudefduf saxatilis guarding a nest by day. The flat granulated surface beneath the fish is a layer of eggs.

Fig. 15—Thalassoma bifasciatum raiding the eggs from a disturbed nest of A. saxatilis during daytime. Several of the various pigment patterns of Thalassoma are evident.

patches of the back reef. *Sparisoma chrysopterum* has been found on numerous occasions lying on its side in open sandy patches. In some cases it is lying in the center of a shallow depression slightly greater in diameter than the length of the fish and apparently made by the fish. Its colors and pattern closely approximate the sand bottom on which it lies. None of the species of *Sparisoma* has been observed to form a mucous envelope (Winn and Bardach, 1960: 31).

The above observations suggest an explanation for the apparent absence of a mucous envelope in *Sparisoma*. Morays are abundant nocturnal predators in rocky areas where species of *Scarus* rest at night. Morays, in contrast to most other nocturnally active fishes, have relaively small eyes and probably rely primarily on olfactory and possibly tactile senses to find their prey. If the mucous envelope serves to hinder olfactory or tactile detection of the enclosed fish or functions as an early warning system then it could afford considerable advantage to smaller individuals of the genus *Scarus* who rest in rocky areas. Adults of the larger species of *Scarus* who form no cocoon are too big to serve as prey for morays. Species of *Sparisoma* rest in the open, well away from the rocks, except for adults of *Sparisoma viride* which are also too large for morays to feed upon. In such open areas, the most important nocturnal predators on fishes of this size are lutjanids and serranids which have large eyes and appear to find their prey visually, hence the transparent mucous envelope would have little effect. *Scarus* and

Sparisoma have both been found in the stomach contents of gray snapper collected early in the morning.

Parrotfishes, though difficult to approach in the day, are completely inert at night and can even be picked up if care is taken. If sufficiently disturbed they depart suddenly in a flurry of audible caudal oscillations and may be heard colliding with rocks or other obstacles.

In general scarids do not exhibit distinctive nocturnal color patterns, though *Sparisoma chrysopterum* tends to match the shade of its background and some individuals of other species show irregular pale blotches or bars (fig. 18).

Resting parrotfishes and parrotfishes with mucous cocoons are illustrated in Schroeder and Starck (1964: 136–137, 146–147), and Starck and Schroeder (1965: 71).

Acanthuridae—surgeonfishes:

Three species of surgeonfishes occur on Alligator Reef. They are all diurnal browsers on algae. At night they are inactive. *Acanthurus bahianus* and *Acanthurus chirurgus* are most often seen in schools of three or more individuals. At night they usually rest in loosely associated groups among alcyonarians, near rocks, or other open shelter. These species appear slightly paler at night, but do not undergo a striking color change.

Juveniles of *Acanthurus coeruleus* are found in the day as solitary individuals grazing about the reef. The adults occur both individually and in schools of up to 30 or more. These schools are often seen mixed with schools of *Scarus coelestinus* (fig. 19).

At night juveniles and adults are found alone close to rocks or under ledges, in more confined locations than the previous two species. This species undergoes a significant nocturnal color change, developing a distinct series of pale bars on the sides (Schroeder and Starck, 1964: 134). The color change has been observed on both the blue adults and yellow juveniles. The bars are apparent on young, one to two days after the acronurus larvae enter the reef habitat and begin to transform.

Randall (1961) in Hawaii and Hobson (1965: 296) in the Gulf of California also observed nocturnal resting in surgeonfishes. Randall (1961: 265) reported a color change in the form of dark lateral blotches in *A. triostegus* at night.

Scombridae—mackerels and tunas:

Scomberomorus regalis has been seen on several occasions at night swimming about in midwater and behaving much as in the day.

Gobiidae—gobies

Of the many gobies which occur on Alligator Reef only one has been seen after dark. It was inactive and presumably the others are also. The species seen at night, *Elacatinus oceanops*, occurs in the day (fig. 21) in small groups on the exposed surfaces of rocks or coral heads. It is a parasite cleaner and is

probably more specialized in this respect than any other West Indian fish. Its color pattern is strikingly similar to that of the parasite-picking wrasse of the Indo-West Pacific, *Labroides dimidiatus* (Randall, 1958: 333). At night it had been found resting among the expanded polyps of a brain coral (Schroeder and Starck 1964: 142, 143) and beneath the tentacular crown of a serpulid worm (fig. 22).

Scorpaenidae—scorpionfishes and rockfishes:

Three species of scorpionfishes have been seen at night. *Scorpaena grandicornis* has been found in a grass patch in the back-reef zone and *Scorpaena plumieri* has been observed in rocky and coral areas on the reef-top and lagoon. Both species were resting on the bottom as they do in the day and their activity could not be ascertained. Their mode of feeding is by resting camouflaged on the bottom until prey approaches close enough, and their relatively large eyes suggest nocturnal feeding. This, however, does not preclude diurnal feeding, as it has been observed.

Scorpaenodes caribbaeus, a small species common in rocky areas, is often taken in rotenone collections, but not seen in the day. At night it has been found on several occasions in the same rocky areas. Apparently it emerges to feed around the rocks.

Opisthognathidae—jawfishes:

Opisthognathus aurifrons is commonly observed in the day hovering above its burrow and feeding on plankton. At night it has never been found, and is apparently inactive.

Opisthognathus lonchurus occurs on rubble bottom in depths of 135 to 150 feet (40 to 45 m) one-quarter to one-half mile beyond the outer edge of the deep-reef. At night it has been found half emerged from its burrow and even in one case resting on the open bottom. This behavior, in view of the reluctance of jawfishes to stray from their burrows in the day, is highly indicative of nocturnal activity of some type.

Clinidae—clinids:

The many species of blennies, like the gobies, are not usually seen at night. Several clinids and no blenniids have been observed after sunset. Once, while diving without artificial light, a pea-sized spot of bioluminescence appeared on a small rock protruding from the sand. After moving to within two feet of the glowing spot it remained, but its source was not discernable. A light was directed at the spot and turned on. The beam revealed the head of a small emblemariid blenny, *Acanthemblemaria aspera*, protruding from a small hole in the otherwise rather smooth surface of the rock. As no other animal was visible and the blenny appeared at the exact spot where the luminescence was located, it is probable that this fish is luminescent. Unfortunately, after several seconds in the light, it retreated and did not re-emerge after the light was extinguished.

Several other clinids seen at night were all resting on the bottom and apparently inactive.

Brotulidae—brotulas:

Petrotyx sanguineus has been found swimming along the sand beneath the ledge on the reef-top at night. Though taken in rotenone collections, it is concealed in crevices and caves among the rocks during the day. Like many creatures that live among the rocks in the day it is apparently active at night.

Ophidiidae—cusk-eels:

Though commonly taken in rotenone collections, cusk-eels have not been seen in the day, and are probably nocturnal. Two species have been found at night. *Ophidion holbrooki* has been observed in the sandy back-reef area. After several seconds in the light they burrow slowly, tail first, into the sand. Several individuals of the other species, *Ophidion selenops*, were seen swimming eel-like near the bottom at a depth of 40 to 100 feet (12 to 30 m). They were probing the fine sand with their pelvic filaments as they swam along.

Carapidae—pearlfishes:

Pearlfish, *Carapus bermudensis*, were seen at night having head downward one to four feet above the bottom (fig. 23). Possibly they are feeding on plankton. In the day they may be found in the respiratory tree of holothurians of several species. Smith (1964: 38–39) also reported seeing *Carapus homei* at Guam hovering above the bottom at night, away from their normal daytime holothurian host.

Fig. 16—Lachnolaimus maximus resting among the branches of alcyonarians at night.

Fig. 17—Two of the many Scarus coelestinus found at night in the holes and crevices of the rock ledge.

Sphyraenidae—barracudas:

Large barracuda, *Sphyraena barracuda*, are found in the day individually and in schools of up to 20 or 30 individuals in many reef areas. They especially frequent the area around the ledge on the reef-top and around Alligator Lighthouse. They become increasingly active at dusk. After dark they have been seen individually and in schools near the Lighthouse and along the ledge as in the day. They frequently dart through the lighted area beneath the boat, possibly striking at carangids or clupeids feeding there. In one instance at the end of a night sled transect, two of the three strands of a white nylon tow-rope were found to be cleanly cut near the middle of the rope. A barracuda is the most likely explanation for such a clean cut in midwater. Perhaps the beam of a diver's light crossing the rope created a flash of white, which attracted the barracuda's strike. As in the case of other large predators, barracuda are probably primarily crepuscular, but will feed at any time food is available.

Barracuda can be approached quite easily at night when blinded by a light, but are best left alone as they tend to dart about erratically when one gets too close. Colliding with this fish would be serious, for even if the mouth were closed its pointed snout would inflict injury.

In one instance a barracuda that was approached closely spun around and darted blindly off, striking the reef face a few feet away at top speed. Its snout was splintered by the impact and it sank to the bottom dead.

Sphyraena borealis has been seen during both day and night in small groups over alcyonarian patches in the back-reef. At night it has also been found over sandy bottom beyond the outer edge of the deep-reef in a depth of 125 feet (37 m). Like most piscivorous predators it probably feeds to some extent at any time, with peaks of activity at dawn and dusk.

Atherinidae—silversides:

Allanetta harringtonensis is similar in habits to *Jenkinsia majua* previously discussed. It schools along the deep reef in certain areas during the day. At night it is commonly found feeding over the reef-top, the back-reef, and even beyond the reef for at least one-half mile.

Bothidae—lefteye flounders:

Bothus ocellatus occurs in sandy areas of all reef zones. At night it is seen resting, uncovered, on the sand. It probably feeds then on the various small invertebrates which emerge and prowl about the sand.

Balistidae—triggerfishes and filefishes:

Alutera scripta has been seen at night on the deep-reef hovering above the bottom. Its activity was not ascertained, but it was completely in the open. *Alutera schoepfi* has also been observed on a number of occasions at night. It usually is found in open areas of alcyonarians and sponges on a rocky substrate. Often two individuals are found hanging head down, one or two feet apart. Their dorsal spines are erected and face one another. What such behavior is associated with is unknown; possibly courtship is involved. A nocturnal pattern of pale blotches on a dark background is commonly seen. This species frequently rises to the surface to feed among drifting *Sargassum* in the day.

Catherines pullus has been found resting at night wedged in rocky holes in the reef. Clark (1950: 164–165) described a nocturnal resting pattern of brown mottling on a tan background in this species in an aquarium.

Ostraciidae—trunkfishes:

Acanthostracion quadricornis is common at night in several reef zones. They move about in the open much as in the day and probably are nocturnal feeders, though they also feed in the day. During a two mile submarine transect of the lagoon area at night over 100 adult *A. quadricornis* were seen scattered along the route. A large specimen when picked up by hand made

a loud honking sound. A pattern of large irregular pale blotches over the normal bluish background is usually observed at night.

Lactophrys trigonus also occurs chiefly in the lagoon area, but is much less abundant than the preceding species. It behaves at night much like that species, and exhibits a similar pattern of pale blotches over its normal olivaceous background.

Lactophrys triqueter is frequently seen at night moving about in the open. It feeds in the day by picking small organisms off the bottom and by blowing into the sand to uncover small invertebrates. Like many other fishes, it can be easily handled when blinded by a light at night; however, it can and will bite if opportunity arises. It occurs most commonly on the reef-top and deep-reef. Like the above species it may also show a pattern of pale blotches at night.

Tetradontidae—puffers:

Canthigaster rostrata is often observed among the rocks and coral of the reef at night and in the immediately adjacent sandy areas. It appears to be nocturnally active, at least in some instances. It is probably the commonest plectognath fish at Alligator Reef and is also active in the day. One individual resting in a crevice at night exhibited a strongly mottled pattern, though more typically they appear the same both day and night.

Diodontidae—porcupinefishes:

Reef-dwelling porcupinefishes usually stay under ledges and in holes during the day. At night *Chilomycterus antillarum, Diodon holacanthus,* and *Diodon hystrix* have been seen in the open along the reef-top. They feed on various invertebrates, particularly larger shelled forms, which emerge during the hours of darkness.

Chilomycterus schoepfi is occasionally seen at night in the Hawk Channel grassbeds and is active nocturnally.

DISCUSSION

On coral reefs, as elsewhere, animals tend to exhibit distinct patterns of nocturnal and diurnal behavior (figs. 24 and 25). In the coral reef community, which is dominantly an animal community, such changes alter the whole character of the reef. The absence of great numbers of pomadasyids, lutjanids, labrids, pomacentrids, scarids, and acanthurids, gives the nocturnal reef a deserted appearance. It is easy, therefore, to begin to think of reef fishes as either diurnal or nocturnal and although certain species and groups may be properly described by these terms, the activity of significant numbers is best characterized as crepuscular. In all three groups there are varying degrees of adherence to a particular time of activity so that even the use of three terms tends to oversimplify the actual situation.

The herbivores, Kyphosidae, Scaridae, Acanthuridae and certain members of the Pomacentridae, Clinidae, and Blenniidae, are apparently truly

Fig. 18—**Scarus guacamaia** wedged beneath a ledge at night and showing traces of a faint barred pattern.

Fig. 19—A mixed school of large adult **Scarus coelestinus** and **Acanthurus coeruleus** browsing over a patch reef during the day. The water becomes cloudy with debris as the parrotfish take up mouthfuls of material scraped off the rock surfaces and expell the grindings.

diurnal. At night their behavior ranges from the completely inert scarids to the alert but inactive acanthurids.

Omnivores of the families Hemiramphidae, Chaetodontidae, Balistidae, and Ostraciidae, all feed in the day. Their nocturnal habits vary from certain chaetodontids which rest under ledges at night to the balistids and ostraciids which are active and in the open at night and probably feed at that time, also.

Species which pick small animals from the substrate, such as certain pomacentrids, labrids, and chaetodontids and plankton feeders of the families Serranidae, Pomacentridae, and Labridae, are diurnal and rest at night. Several other families have species which feed on plankton at night; these include the Apogonidae, Pempheridae, Pomadasyidae, Clupiidae, and Atherinidae. All but the first and second also have species which feed to some extent on plankton in the day.

Various members of the families Dasyatidae, Holocentridae, Serranidae, Lutjanidae, Pomadasyidae, Sciaenidae, and Diodontidae, feed to a large extent on invertebrates. It is among these families that we find many of the active nocturnal feeders. All of these nocturnal feeders, however, will feed in the day when food is readily available and frequently do so under natural conditions. Also, certain species of some of these families normally feed in the day, but the diurnal feeders usually differ in their food from their nocturnal relatives.

Fig. 20—Rear view of a **Scarus croicensis** juvenile in its nocturnal mucous envelope.

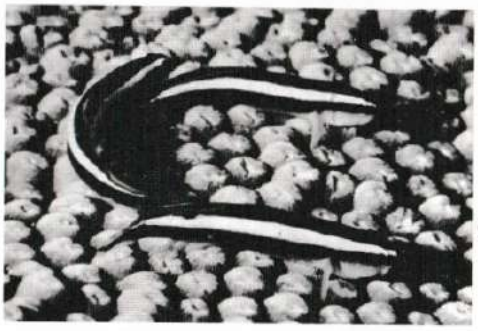

Fig. 21—Three **Elacatinus oceanops** on a coral head parasite cleaning station in the day.

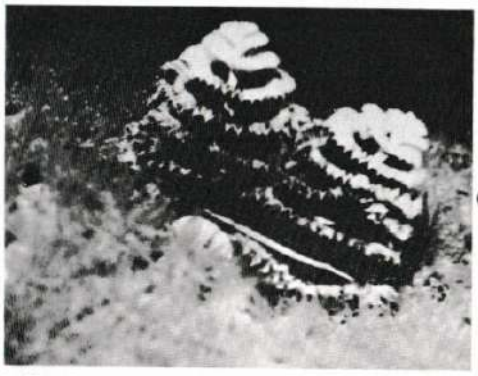

Fig. 22—An **Elacatinus oceanops** sleeping at night on the same coral head beneath the crown of a serpulid worm.

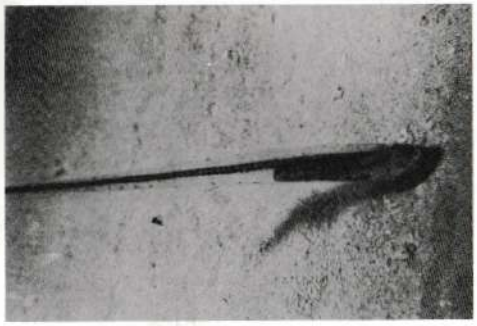

Fig. 23—A pearlfish, **Carapus bermudensis**, at night. In this case the specimen sank closer to the bottom once in the diver's headlamp.

The larger piscivorous fishes seem to have peaks of activity at dawn and dusk, but appear to be active both day and night, and they also feed anytime that food is available. This group includes various sharks, muraenids, groupers, carangids, and barracudas.

Time of feeding in reef fishes is generally related to one of four types of food: sessile organisms, plankton, non-sessile invertebrates, and fishes. Reef plants, epizoites, and larger fixed animals form a source of food which cannot hide and which can easily be harvested in the day. The fishes which feed on this food are largely diurnal. Plankton is a food source constantly passing over the reef and if not eaten passes on and is lost to the reef community. Plankton feeders are, accordingly, both diurnal and nocturnal, but different species are involved between day and night, indicating different requirements for day and night plankton feeding. Most non-sessile reef invertebrates are nocturnal. The mobile species hide in the day and emerge only at night; thus, this source of food largely requires nocturnal feeding. Exceptions to this generalization are certain fishes which have developed mechanisms whereby they can get at hidden invertebrates in the day. *Dasyatis americana*, *Pseudupeneus maculatus*, and *Lactophrys triqueter* are examples. They excavate buried prey and feed in the day. Larger piscivorous fishes tend to feed at any time, but are especially active at dawn and dusk, probably to take advantage of the confusion and concentration of fishes during this time of change-over of shifts.

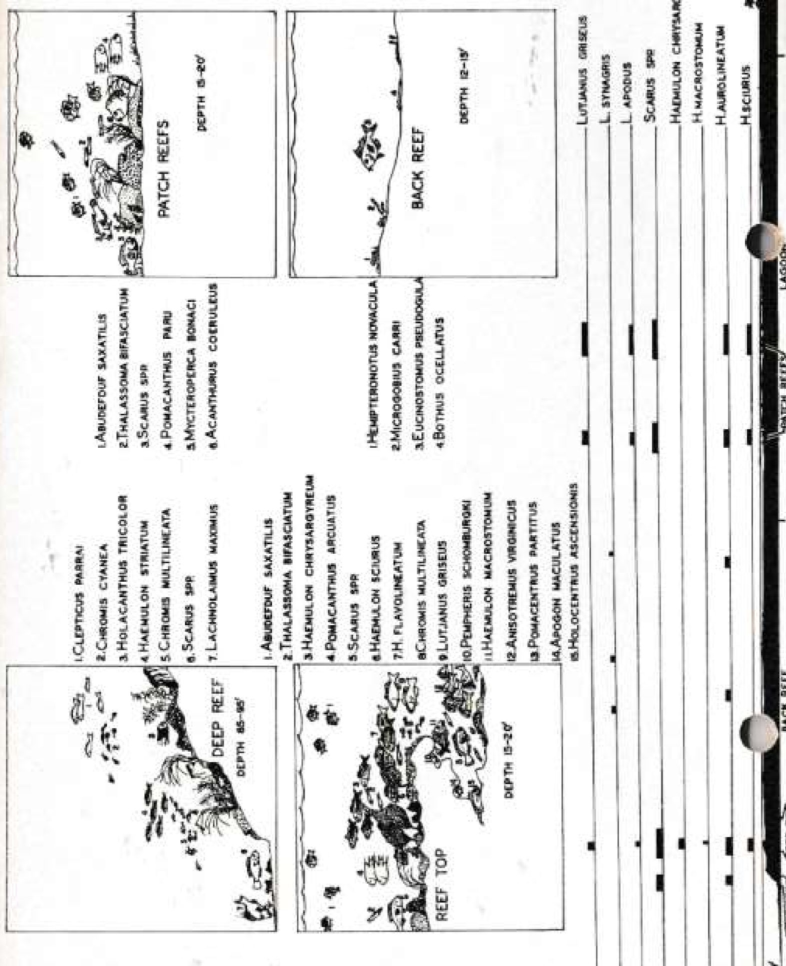

Fig. 24—Typical areas with associated species and their distributions on the Alligator Reef-Lower Matecumbe transect during diurnal hours.

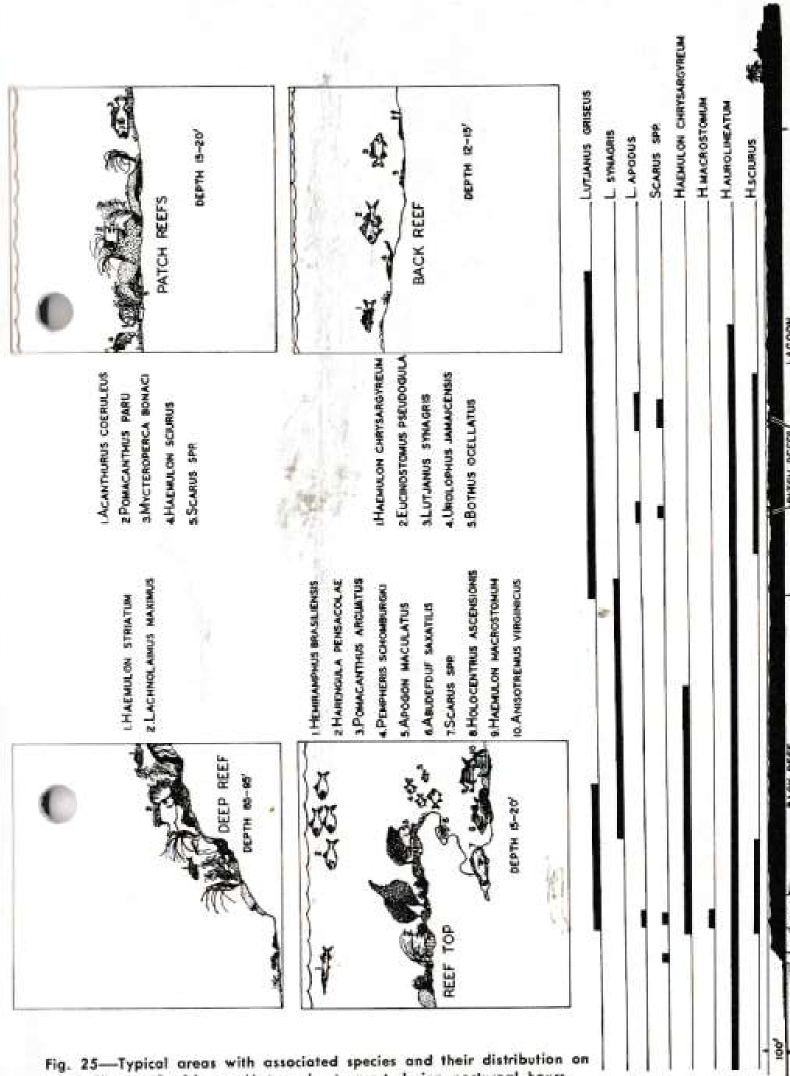

Fig. 25—Typical areas with associated species and their distribution on the Alligator Reef-Lower Matecumbe transect during nocturnal hours.

It should be emphasized that these generalizations, while useful in understanding the ecological situation involved, cannot be applied to individual species in all cases. In addition to exceptions within categories, there are species which broadly overlap different categories and others which change feeding habits with growth. In such cases, however, differences in morphology, color, and behavior, reflect the difference in habits.

Nocturnal foraging of many species, especially pomadasyids and lutjanids, and nocturnal plankton feeding, have some additional important ecological considerations, involving coral reef trophic structure. The disproportionately large amount of animal biomass in coral reef communities has long been recognized as an interesting ecological problem. Odum and Odum (1955) in a widely cited paper have attempted to explain this apparent anomaly chiefly by considering an additional source of plant biomass in the form of boring algae in the skeleton of living corals and in the substrate. However, their methods of estimating biomass at this and other levels are questionable. They fail to explain by what manner this material can get into the food chain. They erroneously consider corals to be herbivores because of the presence of plant material. They underestimate the importance of plankton feeding in reef animals, and are apparently unaware of the foraging of reef fishes in areas other than where they are evident in the day.

There is no *a priori* reason why a coral reef community must have a preponderance of plant material or of herbivores over carnivores. Some deep water rocky reefs below the zone of effective plant growth support dense populations of fishes and invertebrates dependent entirely upon imported food. Plankton feeders and foragers in adjacent areas are significant importers of food into the coral reef community.

Later studies reported by Bardach (1959), Hiatt and Strasburg (1960), Randall (1963), and Talbot (1965), also give estimates of the trophic composition of reef fish populations at different locations, but only Randall's work, which is very general in this respect, classifies species in a manner consistent with actual feeding habits. Before a realistic concept of reef or even reef fish trophic structure is possible it will be necessary to consider not only what is eaten but also how and where the food was obtained. When this is done, as is now in progress for the fishes of Alligator Reef, a picture of trophic structure emerges that is quite different from what has been previously proposed.

The requirement of most pomadasyid and several lutjanid species for back-reef forage area also has other ecological effects. The almost complete absence of these fishes from certain islands in the Caribbean which have fringing reefs with only a narrow shelf and very limited back-reef areas is understandable in terms of this requirement. Likewise these species are also excluded from many suitable forage areas by the absence of sheltered locations for daytime schooling. Dense schools of snappers and grunts around wrecks and other debris in forage areas devoid of natural cover indicate the potential of artificial reefs in such situations.

If nocturnally active fishes are compared to the diurnal species, several external differences become apparent. Eyes of diurnal species, for example, labrids, scarids, acanthurids, and pomacentrids, tend to be smaller than those of nocturnal species, e.g., pomadasyids, lutjanids, apogonids, holocentrids, and some serranids. Important exceptions are the muraenids, and brotulids, which instead have well developed olfactory and lateralis systems to supplement their sensory mechanisms.

Fishes active at night tend to be colored drably. Grays, browns, and dull shades of other colors predominate. Bright red fishes such as holocentrids, apogonids, and priacanthids, are apparent exceptions to this trend. Red fishes are almost wholly nocturnal on the reef-top in depths less than 30 feet. In deeper water, a number of red fishes are diurnal, but, at the depths which they live red does not appear as such. Usually it serves as grey or brown. It is interesting to note also that a number of fishes, both nocturnally active and diurnal species, have red phases in deeper water. These include such diverse species as *Mycteroperca venenosa*, *Serranus baldwini*, *Petrometopon cruentatum*, *Lutjanus analis*, and *Bodianus rufus*, to name but a few. In shallow water at night the level and quality of light is such that to a human observer (and probably to fishes), reddish hues appear as grays or browns.

The brilliant yellow, blue, and green fishes which dominate the reef in the day are with some exceptions largely diurnal species. Bright yellow species of pomadasyids which school over the reefs in the day lose much and sometimes all of this color when they leave the reef at night.

NIGHT DIVING

Because night diving has proven so useful for certain studies a few comments are here appended.

After a number of years of daylight work at Alligator Reef curiosity led to a logical extension from daylight to night diving. The first dive made it apparent that striking and significant changes in the nature of the reef community occurred at night. Much of the subsequent night diving was therefore related to specific research projects.

Differences in nocturnal and diurnal behavior of reef animals are such that attempting to study the ecology and behavior of many species, especially the nocturnal ones, only in the day would be comparable to studying most birds at night.

In addition to observing behavior, night diving also affords unique opportunities for collecting many animals. Most invertebrates are nocturnal and many areas which appear relatively barren in the day support large populations which emerge only after dark. Many species thought to be quite rare were found to be very common at night. Also, several new records

of occurrence have been made, and at least two new species have been found. One, a shrimp, which was found on resting parrotfishes at night. Probably it is a parasite cleaner and its habits suggest a manner in which this interesting behavior may have come about.

Certain fishes, such as scarids and labrids, are difficult to collect in the day with conventional techniques. At night when they are resting rotenone preparations are quite effective. A hand net is also surprisingly useful on fishes at night because of the blinding effect of a diver's light.

Night diving presents no great problems of equipment or technique; however, a few points are worth mentioning. Except for a headlamp, the equipment is that of daylight diving. Waterproof flashlights and the 3-watt sealed beam lights sold as divers' lights have been found to be inadequate for most work. Lights powered by wires to a power source on the surface are adequate but cumbersome. The most useful arrangement we have found is a 30-watt sealed-beam spotlight powered by a nickel-cadmium or lead-acid motorcycle battery carried by the diver. The light is arranged as a headlight, miner fashion, to leave the hands free. A plastic football helmet is ideal headgear to which to attach a headlight.

A submerged light hung beneath the boat and a light on the boat visible from 360 degrees is important for enabling divers to find their way back to the boat.

Locating specific areas after dark can be difficult. In addition to standard pilotage techniques a lighted or reflective buoy placed during the day at the proper location can be useful. The simplest and most certain approach is to find the desired area before sundown.

The danger of shark attack is difficult to assess, but appears to not be especially great. The number of large sharks seen coming onto the reef at dusk, the ease with which they can be caught at night over the reef, the fact that only a few small carcharhinid sharks have been seen at night while diving, and the behavior of these indicate that for some reason sharks are avoiding divers at night. The stimuli emitted by divers with lights moving slowly about near the bottom are perhaps not of a nature to trigger an attack. Collecting large fish, extended diving without lights, or considerable swimming on the surface might produce different results.

A submersible firearm detonated by contact, was constructed and carried on many night dives, but as yet has not been needed. Tests on numerous sharks and rays (including a 14-foot tiger shark) in the day indicate that it is capable of killing the largest shark instantly if properly used.

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