OBSERVATIONS ON COLORATION IN REFERENCE TO BEHAVIOR IN TIDE-POOL AND OTHER MARINE SHORE FISHES

C. M. BREDER, JR.

BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY
VOLUME 92 : ARTICLE 5 NEW YORK : 1948

OBSERVATIONS ON COLORATION IN REFERENCE TO BEHAVIOR IN TIDE-POOL AND OTHER MARINE SHORE FISHES

OBSERVATIONS ON COLORATION IN REFERENCE TO BEHAVIOR IN TIDE-POOL AND OTHER MARINE SHORE FISHES

C. M. BREDER, JR.
The American Museum of Natural History

BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY
VOLUME 92 : ARTICLE 5 NEW YORK : 1948

BULLETIN OF THE AMERICAN MUSEUM OF NATURAL HISTOR Y

Volume 92, article 5, pages 281–312, text figures
1–5, plates 20–23, tables 1–3

Issued November 22, 1948

Price: $.55 a copy

OBSERVATIONS ON COLORATION IN REFERENCE TO BEHAVIOR IN TIDE-POOL AND OTHER MARINE SHORE FISHES

C. M. BREDER, JR.
The American Museum of Natural History

BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY
VOLUME 92 : ARTICLE 5 NEW YORK : 1948

BULLETIN OF THE AMERICAN MUSEUM OF NATURAL HISTORY
Volume 92, article 5, pages 281–312, text figures
1–5, plates 20–23, tables 1–3

Issued November 22, 1948

Price: $.55 a copy

CONTENTS

INTRODUCTION

IT HAS LONG BEEN KNOWN that tide pools in many parts of the world are characteristically inhabited by definite types of small fishes, some of which are mature while others are the young of species that spend their adulthood elsewhere. In addition to the characteristic faunas of such locations there are also found occasional individuals of species that are typical of other habitats and can only be looked upon as casuals or accidentals in tide-pool environments. The briefest observation of the behavior of the, generally, several species demonstrates that the attitudes of the various forms differ considerably and that evidently there is some interspecific hierarchy in existence.

The opportunity to make some preliminary observations on the subject presented itself, and these are here presented. They are suggestive of the desirability of making more extensive studies from both an observational and an experimental approach.

In addition to these tide-pool observations related phenomena in other environments were given some attention. They consisted chiefly of observations of the behavior of certain fishes on the sandy beaches that interrupt the outcropping rocks, forming the basis of the tide pools. Fishes in more protected places and sandy tidal flats were also the subjects of further correlated observation. All are compared and considered in the light of the present general knowledge of behavior and pigmentary reactions and serve to form a basis for further studies on the ecology of the environments concerned.

The opportunity alluded to above occurred between July 15 and August 28, 1947, during the construction operations of the Lerner Marine Laboratory on the island of North Bimini, Bahamas, British West Indies. It was necessary for the author to give rather close attention to building details but there were intervals when it was possible to give some attention to biological matters. The establishment of the Lerner Marine Laboratory is a field operation of the Department of Fishes and Aquatic Biology of the American Museum and is intended primarily to expedite the researches of that department and to serve as a permanent base for studies in marine ecology and related matters which require long continued or often repeated observations in a single locality under more satisfactory working conditions than can be usually found in less than permanent field stations.

Most of the incidental collecting was undertaken by Mr. Benjamin Dontzin to whom credit is due. Dr. R. F. Nigrelli, although occupied with other studies, also gave useful help in regard to some collecting matters. Thanks are due to Miss Francesca LaMonte and Mr. John Armstrong for notes on the fate of the aquarium and the tide pools subsequent to August. The author is also grateful to Mr. J. T. Nichols for advice on certain taxonomic matters and to Miss Priscilla Rasquin and Mr. James W. Atz for reading the manuscript and for giving various helpful suggestions.

TIDE-POOL CONTENTS

THE TIDE POOLS on North Bimini from Entrance Point to Paradise Point along the western shore were examined from time to time, especially at the lower of the low tides. Certain of these tide pools are shown in plate 20. From these pools the following species were collected. Nomenclatural usage is discussed with other matters under the later consideration of the individual species.

Jenkinsia lamprotaenia (Gosse)
Mugil trichodon Poey
Eucinostomus gula (Cuvier and Valenciennes)
Eques pulcher Steindachner
Pomacanthus aureus (Bloch)
Acanthurus hepatus (Linnaeus)
Eupomacentrus leucostictus (Müller and Troschel)
Eupomacentrus adustus (Troschel)
Abudefduf saxatilis (Linnaeus)
Abudefduf analogus (Gill)
Thalassoma bifasciatum (Bloch)
Bathygobius soporator (Cuvier and Valenciennes)
Salarichthys textilis (Quoy and Gaimard)

No pool was found to contain more than three or four species, and many of them were completely empty of fish life, especially those higher up the beach.

The fishes fell clearly into three categories: the typical, with evident specializations associated with the peculiarities of such environments; the casual, with no obvious specializations directed towards responses to such a habitat; and the accidental, which were seldom encountered and which gave evidences of not being well suited to the tide-pool environment and were typically found in much larger numbers elsewhere. This division, which is purely a classification convenience, places the individual species together with pertinent notes as follows.

TYPICAL SPECIES

Bathygobius soporator (Cuvier and Valenciennes)

The scale counts were characteristic of this form as discussed by Longley and Hildebrand (1941). None was seen with the higher scale count ascribed to *B. curacao* (Metzelaar). Ginsburg (1947), in a revision of the American species of *Bathygobius*, has attempted the very formidable undertaking of dividing them into subspecies. As only one of his forms of *B. soporator*, *Bathygobius soporator soporator* (Cuvier and Valenciennes), is from the Bahamas, evidently the present material should be referable to that subspecies. It would, moreover, be pointless, in present connections, to attempt to work out such a subspecific analysis. In any case many investigators would prefer to consider such a condition a matter of local populations not suitable for formal recognition in trinomial nomenclature. The present author, at least, before undertaking a detailed study of the matter, would want to find out experimentally how much of the observed variations in proportions and merestic counts is referable to genetic constitution and how much is environmentally superimposed by incidental differences in temperature to which individual clutches of eggs are undoubtedly exposed.

Individuals in the tide pools ranged from 15 to 45 mm. in standard length. They were ubiquitous and much more numerous in the tide pools than any other species. Some were mature, but none were as large as the breeding fish discussed by Breder (1943). No evidence of reproduction was encountered, but it may be that less "difficult" environments are resorted to for this purpose or it may have been too late in the season. The large numbers of very small fish would tend to support the latter view. In agreement with Beebe (1931), it was found that this species could be induced to wave its free pectoral rays under slightly suffocating conditions. The respiratory advantage this evidently provides is probably one of the factors which make this species so free ranging in these tide pools, which vary widely as to temperature, salinity, and oxygen content.

Salarichthys textilis (Quoy and Gaimard)

Individuals ranged from about 15 to 30

mm. in standard length. Since the species attains about twice the size of the largest found here, it is probable that all were immature. This blenny, the only other species here designated as typical, parallels the goby in a large number of ways, including general over-all pattern and coloration as well as behavior. One item which evidently has not been previously reported is that its upper pectoral rays, although not free but merely widely spread, are used similarly to those of *Bathygobius*. It differs in the use of them, however, in that at all times noted they were seen to be in regular and rapid motion. The two species when kept in a single aquarium showed this difference nicely. Under these conditions at no time was the goby noted to wave its free rays while the blenny kept the equivalent ones in incessant motion. The physical differences between the pectoral fins of the two species are shown in plate 21. Evidently the blenny has, in any case, higher oxygen requirements since it was never found so far up the beach as the goby. It showed no hesitancy in leaping out of any uncovered aquarium and about the tide pools it was notably more active and more prone to move overland. While the goby tended to seek shelter in holes and under shells on attempts at capture, the blenny was much more apt to leave the pool and make off overland down beach, individuals often reaching open water.

CASUAL SPECIES

Eupomacentrus leucostictus
(Müller and Troschel)

The most prominent of the brightly colored casuals were the young of what is evidently this species. Individuals ranged from about 10 to 30 mm. in standard length. They were mostly in their vivid blue and yellow phase, the larger individuals generally not being quite so bright as the smaller.

Eupomacentrus adustus Troschel

This form with the brick red back is what Beebe and Hollister (1931) called *E. rubridorsalis* and what Longley and Hildebrand (1941) considered the young of *E. adustus*. Individuals ranged from about 20 to 30 mm. in standard length and were much less common than *E. leucostictus*. Both species were confined to the lower pools.

Abudefduf analogus (Gill)

This was the most common species of the casuals. It reached higher up the beach than any other of this category. Individuals ranged from about 10 to 25 mm. in standard length. This species was previously found at Bimini by Dr. W. Beebe and reported by Breder (1933).

Abudefduf saxatilis (Linnaeus)

Next to the preceding, this species was the most abundant of the casuals, which form it followed closely as to numbers, although it did not reach so far up the beach. Individuals ranged from about 10 to 20 mm. in standard length.

ACCIDENTAL SPECIES

Jenkinsia lamprotaenia (Gosse)

This species was found in only one pool. Evidently a small portion of a school became accidentally trapped in one of the larger basins. Individuals ranged from about 35 to 40 mm. in standard length.

Mugil trichodon Poey

A school of about one dozen fish, of about 55 to 60 mm. in standard length, was found in a large sandy depression which could hardly be called a tide pool as herein discussed. This is evidently an accidental trapping. The fishes seemed ill at ease and dashed about in what seemed to be an excited state most of the time.

Eucinostomus gula (Cuvier and Valenciennes)

Three individuals of about 30 mm. in standard length were taken from one tide pool. This is evidently an accidental trapping.

Eques pulcher Steindachner

A single specimen about 10 mm. in standard length was found in one pool. It is shown in plate 23. This is evidently an accidental trapping. This illustration shows what appears to be the smallest size on record, about 10 mm. in standard length. Longley and Hildebrand (1941) describe the patterns of young up to 50 mm. without specifying their smallest. Their description agrees quite well with the present individual, the dark pattern of which was jet black. Fowler (1947) figures a drawing of one of about 23 mm. in standard length which also agrees, showing only slight differences that are apparently referable to size. The only other species with which this form might be confused at these small sizes is *E. lanceolatus* (Linnaeus). A description of a 15-mm. specimen by Longley and Hildebrand (1941) indicates that it is very different, closely resembling its adult pattern.

Pomacanthus aureus (Bloch)

In the lower pools, exposed only on very low tides, young specimens of about 15 to 20 mm. in standard length were notably conspicuous because of their intensely black bodies crossed by brilliant yellow bars. This form is here called *P. aureus* on the authority of Longley and Hildebrand (1941), which equals *P. arcuatus* (Linnaeus) of authors and not of Longley and Hildebrand. The present specimens agree closely with the color description of the very young of this species given by the above students except that the fifth (peduncular) bar is missing. Presumably our material is yet to develop that mark. Jordan and Evermann (1896) give an almost identical description for the young of *P. paru* (Bloch), which equals *P. arcuatus* (Linnaeus) of Longley and Hildebrand. Either the young of these two forms are almost indistinguishable on a color and pattern basis or the two descriptions actually refer to a single species. Our specimens are referable to the species indicated on a basis of dorsal spines and the rather difficult but recognizable scale counts.

Acanthurus hepatus (Linnaeus)

A very few individuals of this species were found in pools exposed only at the extreme low tides. They ranged from about 10 to 20 mm. in standard length. While it is impossible to be absolutely certain, these fish could hardly represent *A. caeruleus* Bloch and Schneider. They are clearly not *A. bahianus* Castelnau on a basis of both Breder (1925) and Longley and Hildebrand (1941). This material raises some doubt on the synonymization of *A. pawnee* (Breder) with *A. hepatus* as has been done by Longley and Hildebrand (1941). The present material should be in the "*pawnee*" stage on a basis of size, but it is not, and resembles larger *hepatus* out of that size range. Either *hepatus* shows remarkable variation in its size at the time of this transformation or there are two forms confused. Further study of this problem is being held in abeyance pending the accumulation of more material.

Thalassoma bifasciatum (Bloch)

This species was found in small numbers in pools which harbored either of the preceding two species. All were of very small size, ranging from about 10 to 15 mm. in standard length.

GENERAL REMARKS

The tide pools of Bimini are typical of many localities in the West Indies, as to both formation and contents. Those especially studied were located at such a level as to be emptied of water at each spring tide. That is to say, any populations contained therein were either destroyed or escaped in each complete tidal cycle. The pools themselves, cavities in the old uplifted coral rock which is variously eroded, often have a sand bottom, some algal growth, and a few invertebrates (generally a few gastropods, chitons, and small crabs, with an occasional echinoderm) and little else of macroscopic size.

When undisturbed, a given single pool would usually show the same contents tide after tide, except as to the forms indicated under the listing of accidental species. When

a pool had been relieved of its contents, it did not become refilled with fishes on the next tide, and many went on to the drying of the following spring tide without reëstablishment of a new population. Thus it follows that the fishes of these tide pools are not merely accidentally trapped but are in regular residence, not ordinarily interrupted for one tidal cycle. This appears to be true for both the blennies and the gobies despite the fact that they travel easily overland when disturbed, and is in agreement with Beebe (1931) who found that individuals of *Bathygobius* removed from one pool to another generally returned to the original pool.

In this connection it is notable that the species here considered typical of the tide pools studied, in addition to their respiratory specializations and ability to leave the pools and travel overland, are able to and do match the bottom to a remarkable degree. Their pattern and pigmentation are changed rapidly, but, in addition, when engaged in combat or other social behavior, their coloration may run counter to the background and render them for the time very conspicuous. The casuals on the other hand show no color matching ability at all, and with their frequently bright colors are usually conspicuous objects. The least colorful of them, *Abudefduf analogus* with its dark brown and light pattern, is distinctly conspicuous when swimming freely over most of the tide-pool backgrounds, but when alarmed it often hugs closely to a rock or shell and rests quietly. At these times it becomes fairly inconspicuous. This is not true of the other species listed in this category. It should be noted in this connection that *A. analogus*, except for the typical tide-pool forms, is the most abundant species that was encountered.

Another point in connection with the typical species is that they could spend their entire lives in these environments on a size basis, while the casuals are all young of species sufficiently large when adult to prevent their permanent residence in these small bodies of waters.

The typical residents are strictly carnivorous. Their diet includes a few casuals but seems to be based chiefly on very small invertebrates. That typicals and casuals were found in continued residence in certain tide pools for long periods and that their return to emptied pools was slow would indicate that casuals are not an important part of the diet of the typical forms. Beebe and Tee-Van (1928) examined the stomach contents of *Bathygobius* and found only small blennies. On the other hand, the casuals are all nonpredatory, and feed almost exclusively by picking minute bits of whatever animal and vegetable matter becomes available. This method of feeding is true of the accidentals with the exception of *Eucinostomus* and *Mugil* which grub in the sand for food to a marked extent.

Because the behavior of the fishes in the pools could be studied only during the brief intertidal periods and because only the lower pools contained any assortment of fishes (the upper pools usually had none), some individuals were transferred to an aquarium.

The hurricane that passed close to Bimini on September 16, 1947, stripped the tide pools of all fish life, except for *Bathygobius*, and considerably modified other shore environments.

TRANSFER TO AQUARIA

FOR THE FURTHER STUDY of these fishes an aquarium 2 feet by 1 foot by 1 foot was employed. It was fitted with the local light-colored coral sand and six shells of various kinds and sizes, one of which was that of a young *Strombus gigas* well covered with a growth of *Batophora* (see pl. 22). Standing water was used which was refreshed by changing a single bucket full, usually every third day. The aquarium was placed on a veranda in such a position that it received direct sunlight in the early morning and late evening but not in the middle of the day. Nevertheless the temperature rose on occasion to as high as 36° C. without any evident interference with the activity of the specimens. This should be expected because of the vast temperature changes to which small tide pools are subjected and to which the fishes found within them are evidently well accommodated.

After the aquarium was well established the following fishes were placed within it:

Abudefduf saxatilis	3 examples
Eupomacentrus leucostictus	2 examples
Abudefduf analogus	3 examples

Almost immediately a peck-order was established. The two largest fish were about the same size: one *A. analogus* and the other *E. leucostictus*. The latter quickly dominated the former, which became clearly the "number two" fish. The rest, all considerably smaller, were not clearly recognized as to peck-order, and there was evidently no "omega" fish. All clearly showed a close association with the shells, except *A. saxatilis* which was evidently only "half" in the peck-order system and kept relatively up from the bottom. The rest were all given to hiding in the various shells. The dominant fish took over all of the shells, busily circulating from one to another and rooting out any possible occupants. The arrangement of the sand at the entrance to one shell was modified from time to time by vigorous fanning with the tail, just as the adults arrange their home sites.

To this population was added two very tiny postlarval *Atherina stipes* Müller and Troschel, not from the tide pools but from the sea surface over a clean sand bottom. The tide-pool fish paid no attention to them whatever, and they remained near the surface of the water.

The following day the peck-order was found to be the same, but there was much less evident friction between the various individuals. Later the same day the following fishes were added to the aquarium:

Eucinostomus gula	1 example
Eupomacentrus adustus	1 example
Thalassoma bifasciatus	2 very small examples

The red-backed *Eupomacentrus* was barely smaller than the dominant fish and immediately took issue with the dominance of the first, and the order was challenged for a time, but eventually the newcomer took second place, relegating the former second fish to third place.

Although the *Thalassoma* were very much smaller than the others, they were little bothered and seemed to be outside the peck-order hierarchy.

The *Eucinostomus* held to open water and was picked on chiefly by the semi-open-water *A. saxatilis*. By the next morning both its caudal tips had been removed, and the fish was taken out of the aquarium in order to avoid its destruction. The other fishes, principally the *A. saxatilis*, had risen high in the water in order to attack it, the most vigorous attackers being not over half its length. It is to be especially noted that at this time not one other fish showed the slightest caudal or other damage and that at no time was the *Eucinostomus* seen to attempt to defend itself. Although the *Eucinostomus* was actually taken from a tide pool, this species is not typical of such places and must, as previously noted, be looked upon as accidental. This species is more nearly typical of white sand flats, and its behavior in such localities is discussed farther on.

It is notable that the peck-order in this aquarium was nicely graded, in addition to the usual size order, not as to pattern but as to darkness of pigmentation. Under the same conditions of illumination and background, the order of the various species, arranged according to darkness of coloration,

becomes identical with the peck-order as established by observation of behavior. The largest fish of each kind—and all these were very nearly the same size—may be arranged in the order of both peck relationship and darkness of pigmentation, as follows:

Eupomacentrus leucostictus	Darkest
Eupomacentrus adustus	Nearly as dark
Abudefduf analogus	Large dark blotches
Abudefduf saxatilis	Narrow vertical lines
Eucinostomus gula	Light and nearly unmarked

The *Thalassoma*, which were quite dark, the very small but brilliantly yellow *Eupomacentrus*, and the transparent and tiny atherinids were evidently not exactly included in the peck-order on a basis of insignificance of size. If a larger fish approached they simply "scampered" out of the way, but there never seemed to be any attempt to peck them on the part of the larger fish.

Three days later six *Bathygobius soporator* were added to the aquarium. Two of the gobies were a little over twice as long as the prior residents, two about as long, and two about half as long. The pomacentrids took considerable notice of this new introduction. The red-backed one caught one of the smaller and shook it as a dog might shake a rat, but it escaped, evidently unharmed. This same pomacentrid later backed up to one of the larger fishes and attempted to "fan" it away in very much the fashion that this species moves sand in modifying its retreats.

From here on the *Bathygobius* took charge of the situation. The two atherinids and the small *Thalassoma* quickly disappeared, presumably being eaten by the gobies. The peck-order previously described for the free-swimming species, while still in some evidence if looked for critically, was all but destroyed by the presence and interruptional activities of the dominating gobies.

Seven days later a medium-sized *Salarichthys textilis* and a small *Acanthurus hepatus* were added to the aquarium. The latter was about the size of the largest *Pomacentrus*. Although it was not much bothered by the others it seemed to be low or lowest on the peck-order, that is to say, it was never noted to pursue any other fish and was only occasionally pecked by others.

Fourteen days later the peck-order among the free-swimming fishes had become modified so that the *Acanthurus* was definitely number one, but there was little fighting, and all kept clear of this tang which "showed" its peduncular spine to the more timorous. The blue yellow *Pomacentrus* was number two and the red-back was number three. The latter had lost its red back and was a general washed-out gray. It was clearly not sickly, and this is evidently a normal pigmentary change.

The sequence of the events in this aquarium is given in table 1 together with the moon phases which during this period had twice emptied the majority of the natural tide pools from which the fishes came.

The fish were fed every day on bits of fish, craw-fish, or similar material, which all took freely, the gobies bolting great chunks of meat and the others picking it apart in small bits. By this time a considerable growth of algae had accumulated on the shells, and the rear glass was purposely never cleaned. The free-swimming fish all spent considerable time picking on this algae so that it clearly showed their tooth marks. Although they fed freely on the animal matter offered, they spent most of the day working on this algae and their excrement became largely a bright green. Simultaneously, the largest blue yellow pomacentrid became much more intensely yellow, and it is suggested that this type of food is directly connected with the intensity of the yellow shown by these fishes. Such yellow as is displayed by the other forms remained brilliant, a condition which generally rapidly disappears in aquaria where only animal foods are available. Longley and Hildebrand (1941) indicate that *Acanthurus* ". . . is almost entirely herbivorous," while Beebe and Tee-Van (1928) wrote, "The powerful gizzard-like stomach contained un-

identifiable vegetable and animal matter." The latter wrote, in reference to *P. aureus*, "Alimentary canal crammed with algae, hydroids, etc.," while the former indicated that "The diet includes algae and a great variety of sedentary animals."

A sharp differential was noted in the night behavior of the fishes in this aquarium, nearly every night that it was in maintenance. The following observations were made well after night. Some individuals would be in their closest sand-matching pattern while others would be conspicuously dark, in some cases nearly black. Since at least four of these fish were not sexually mature, this is evidently something not directly connected with sex or sex behavior. The night patterns were notably bolder, with a considerable amount of black-and-white, checkerboard effects in bold blotches, while the daytime patterns ran more

TABLE 1

CHRONOLOGY OF THE TIDE-POOL AQUARIUM

1947 Date	Species and Data		Moon Phase
July 24			First quarter
28	Aquarium established with		
	Abudefduf analogus	3	
	Abudefduf saxatilis	3	
	Eupomacentrus leucostictus	2	
	Atherina stipes	2	
30	Added the following:		
	Eucinostomus gula	1	
	Thalassoma bivittatus	2	
	Eupomacentrus adustus	1	
31	Removed *Eucinostomus*		
Aug. 1			Full moon
3	Added the following:		
	Bathygobius soporator	6	
9	Added the following:		Last quarter
	Acanthurus hepatus	1	
	Salarichthys textilis	1	
16			New Moon
23	Last observation		First quarter
	Acanthurus no. 1		

dark when a flashlight was played suddenly on the aquarium.

Bathygobius soporator was in and out of shells both by night and by day, apparently indifferently. The color pattern which they showed is difficult of interpretation and cannot be clearly defined without further detailed study. At any one time a variety of patterns would be noted, both day and to fine pepper-and-salt effects. The darker fish tended to dominate the bottom-matching light-colored fish in the daylight. These patterns were in general agreement with the notes of Beebe (1931), but they are evidently much more complicated than he indicated.

Both species of *Abudefduf* and the *Acanthurus* rested quietly near the proximity of shells for the most part after dark but in no

case did they hide in the cavity of a shell itself.

After dark both species of *Eupomacentrus* disappeared completely within the deep recesses of the shells, and only on one occasion was one even seen, and this one was well within a shell cavity. Although by day these fish will retreat deep into a shell when alarmed, they spend most of their time in the open, but evidently at night they rest completely hidden.

The *Thalassoma* either disappeared into shells or buried in the sand on the coming of darkness. The *Eucinostomus* rested quietly in open water well up from the bottom at night in about the same place in which it spent the day. The atherinids spent all their time at the surface of the aquarium, both night and day. The *Salarichthys* was both in and out of shells, day or night.

At no time were any respiratory difficulties noticed in any of the fishes in this tide-pool aquarium. *Bathygobius*, which waves the free pectoral rays in water of low oxygen content as an evidently accessory respiratory mechanism, was never noted to have recourse to this behavior, while the blenny was seen to wave its upper pectoral rays at all times.

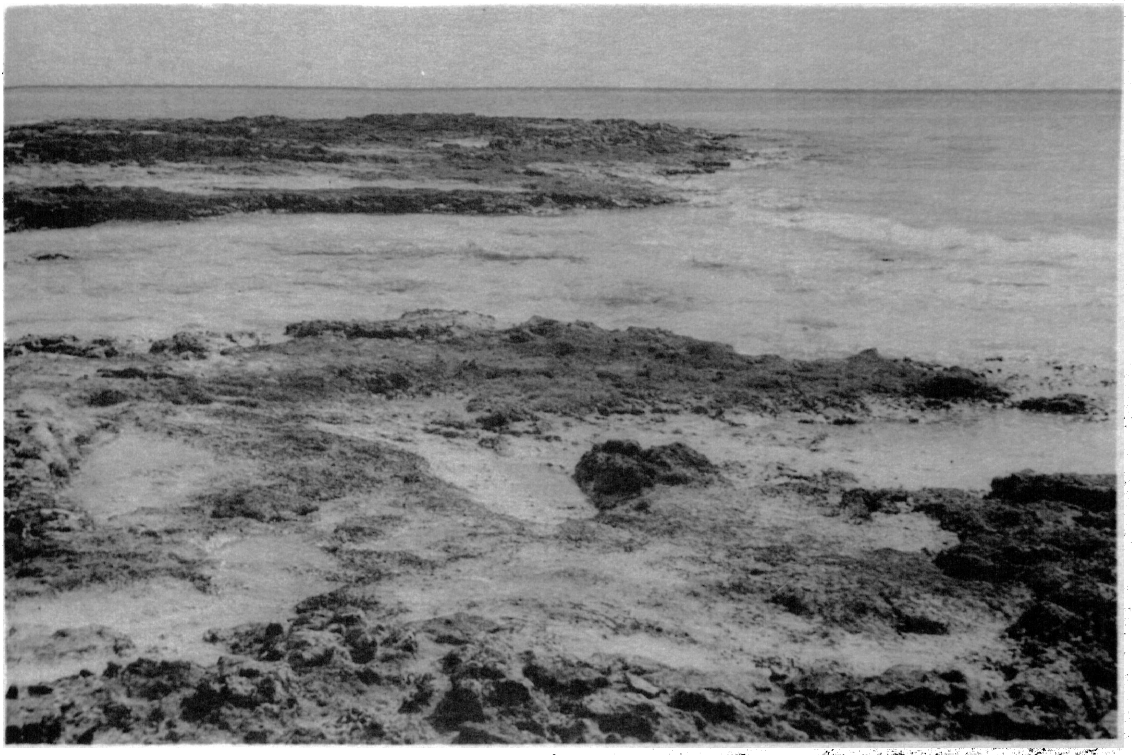
The arrangement of the aquarium used in these studies is shown in plate 22. This aquarium was maintained for a period after the departure of the author. Little by little the fishes disappeared until, about the middle of October, the largest *Bathygobius* was the sole survivor. Just how the loss of each fish occurred cannot be determined, but it is suspected that with the growth of the fishes the largest goby either harried or directly ate the rest. At least it was seen eating some of the individuals.

FISHES OF OPEN BEACHES

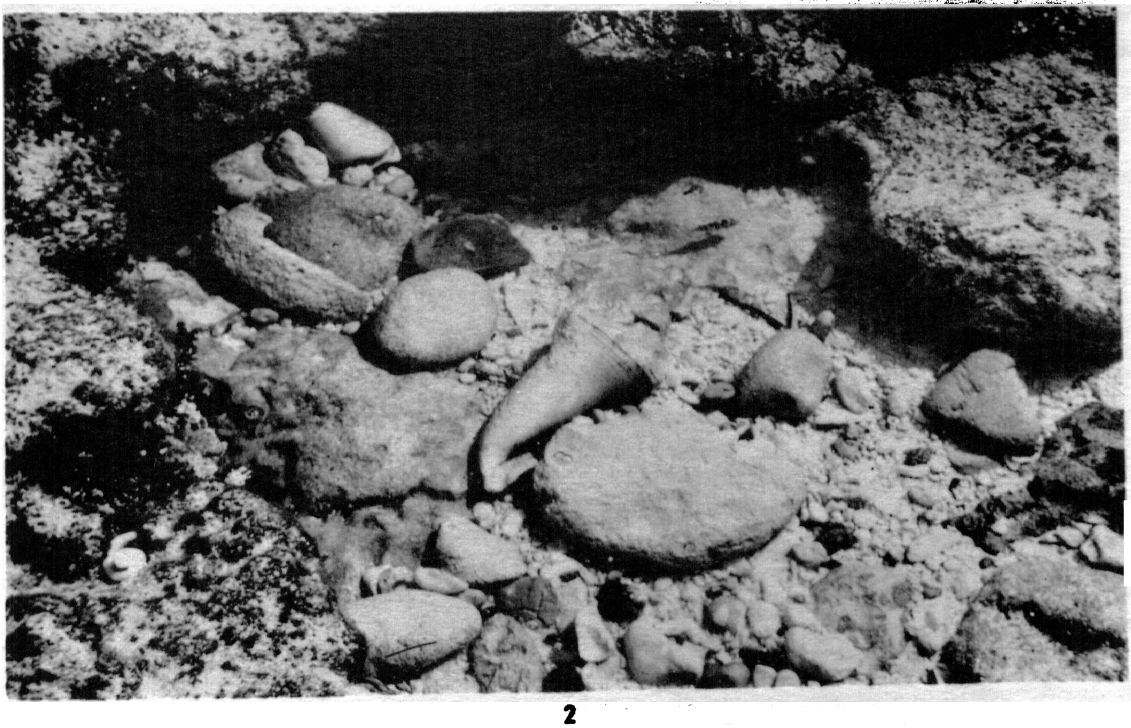
REFERENCE HAS ALREADY BEEN MADE to the behavior of *Eucinostomus gula* in tide pools and of its more typical occurrence on the open sandy beaches. Here great numbers in more or less loose aggregations of various sizes are common. Fishes of like size are usually found together and range all the way from large, fully mature individuals to the smallest juveniles. The bottoms over which they are most frequently encountered are either mottled, owing to the presence of trash, shells, or other objects darker than the nearly white sand, or large patches of perfectly clean, light-colored sand. In the former localities the fish show a mottling which renders them very inconspicuous. Over the clean sand they lose this mottling and become equally inconspicuous in a silvery vesture which takes on the color of the bottom itself. The only markings noticeable are the black pupil and a black tip to the dorsal fin.

Many if not all of the members of the family Gerridae root out invertebrate organisms from such sandy places and they may be frequently seen in such activity. Of *E. havana* (Nichols), Longley and Hildebrand (1941) had the following to say: "Nothing more is required to bring together such as are near than to wade out into the water a little more than waist deep and stir up sand, which calls them to feed. With them comes *Eucinostomus lefroyi.*" In this connection it is noted that with the species here under discussion more or less numerous individuals would be found to be staying rather near a bather or a group of bathers on the outside beach. On August 27 the following note was made in reference to a bathing party late in the day: "An eight-inch *Eucinostomus* became curious about our feet and followed us about for the entire time we were in the water. It was evidently interested in the materials our feet scuffed up and was entirely fearless." It is well known that many species of fishes will follow the rooting behavior of other species. The above-noted behavior clearly places *Eucinostomus* among these, although its protrusile premaxillaries and observed behavior show that it can and does forage independently.

Young *Sphyraena barracuda* are found in the same places and show a similar considerable ability to change their mottling or replace it entirely with a silvery vesture. This species acts almost exactly like *Eucinostomus* over a plain sand bottom in respect to pigmentation. Both show a black tip to the first dorsal and in addition *Sphyraena* shows a black tip to the second and to either caudal lobe (see fig. 1). These two species present a remarkably similar effect, in an over-all sense. From above the surface both are much more conspicuous than when viewed laterally through goggles. Since the water in which this phenomenon takes place is 3 feet or less in depth, such a view is possible if one swims in towards the shore and "walks" along on one's fingertips while floating face downward. Under such conditions it is not easy to associate the black markings with a fish. It would seem that these dark marks make up some kind of recognition pattern for the *Eucinostomus* since they are a well-marked, aggregating form, groups frequently showing themselves as indicated in figure 2. This kind of recognition could operate similarly for the solitary *Sphyraena* in a negative sense. Since, however, the latter preys to a considerable extent on the former and may be seen stalking them over these open sandy beaches, where there is nothing to hide behind, it is not inconceivable that the general similarity of these markings may be a deception practiced on the *Eucinostomus*. In fact a lone barracuda could look not unlike a small group of *Eucinostomus* of a size appropriate for the *Sphyraena* to prey upon. The way in which this conceivably could work out is indicated in figure 3. The only disruption would be the tip of the lower caudal lobe. Groups of fishes about as shown in figure 2 must be frequently in the visual field of solitary individuals that have become separated from their companions. To a human observer it is possible to see such separation at virtually any time. It is to be especially noted that a group of three as shown in the diagram have only one eye looking outward on the side resembling a barracuda and three on the side in which this resemblance is modified by the very presence

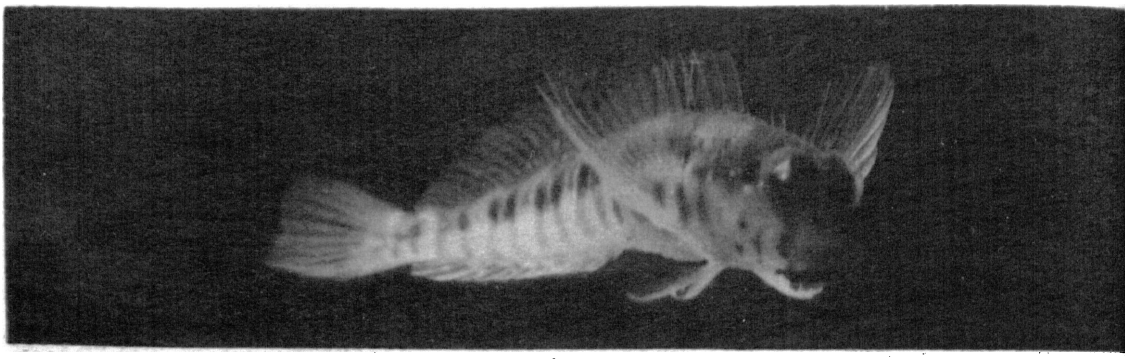


1

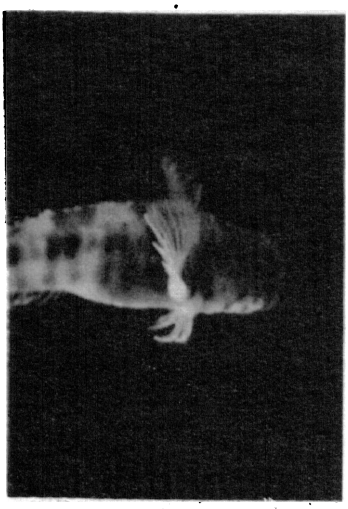


2

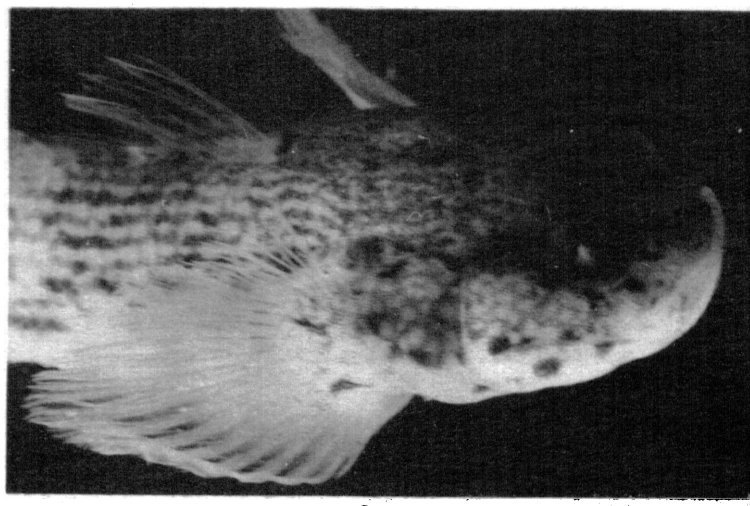
1. The tide-pools at Entrance Point, North Bimini, Bahamas. 2. A typical tide-pool at Entrance Point, showing one *Abudefduf analogus*



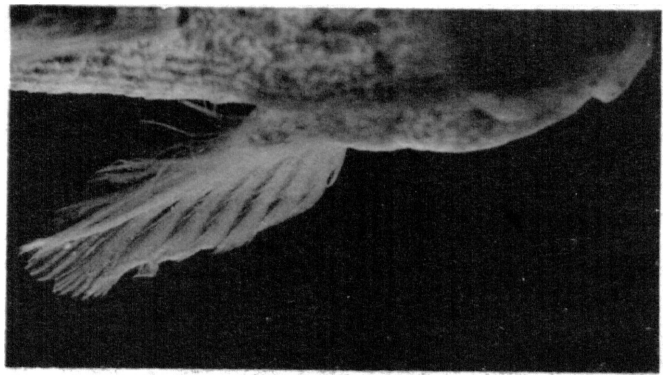
1



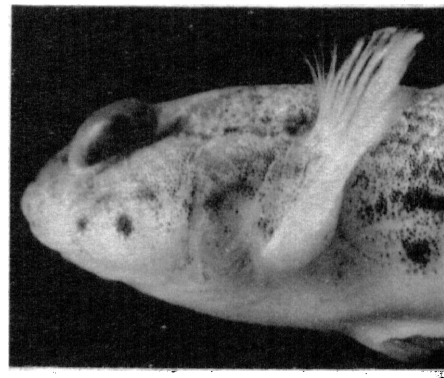
2



3

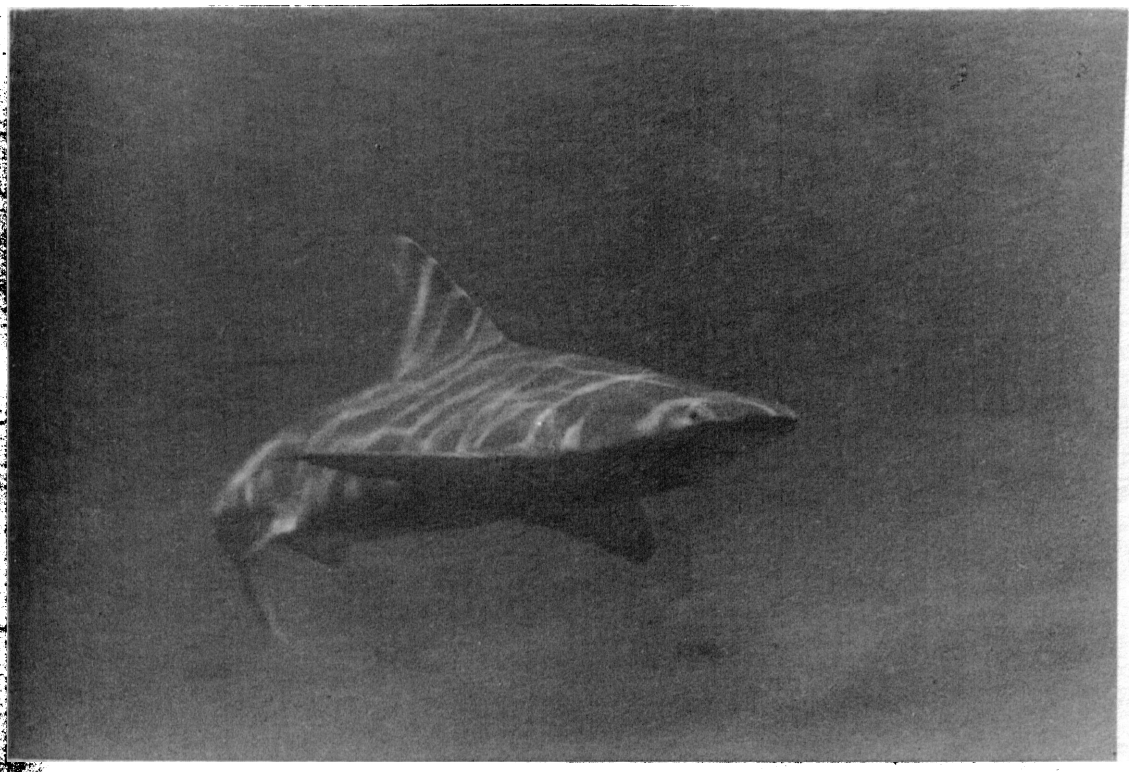


4

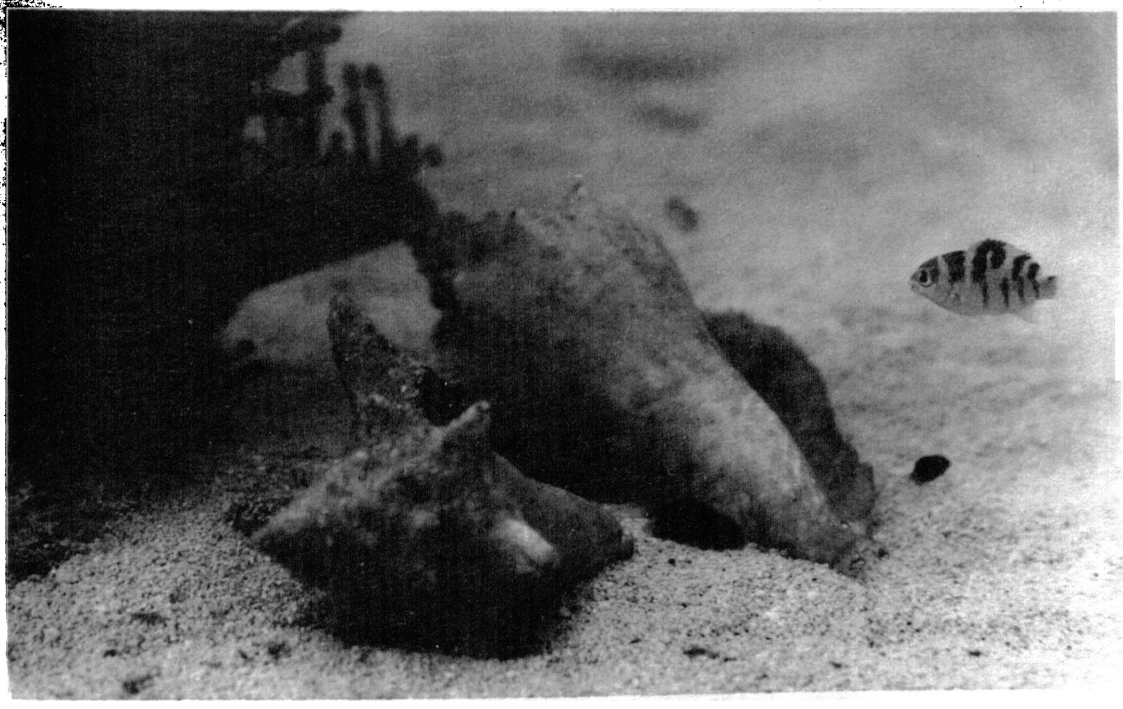


5

1. Quartering view of *Salarichthys textilis*, showing membrane connecting upper pectoral rays and position in which held when used for apparently supplementary respiratory efforts. 2. Lateral view of pose of *Salarichthys textilis*. 3. Semi-lateral view of *Bathygobius soporator*, showing upper free pectoral rays which are apparently used for supplementary respiration. 4. Dorsal view of right pectoral of *Bathygobius soporator*. 5. Anterior quartering view of left pectoral of *Bathygobius soporator*

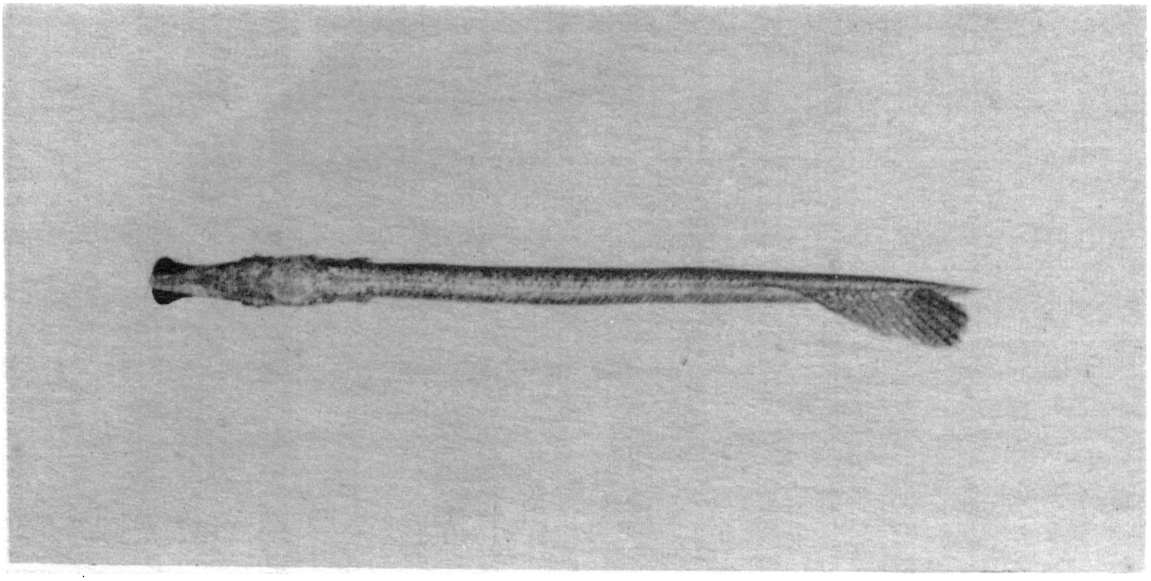


1



2

1. *Carcharhinus*, showing the pattern formed by wave-focused light rays on its back. 2. The "tide-pool" aquarium, showing *Abudefduf analogus* (upper right) and *Pomacentrus leucostictus*



1

2

1. Young *Tylosurus raphidoma*, showing dark mandibular lappets and a dark dorsal, 150 mm. in standard length. This photograph is of a living fish as it rests near the surface of the water. 2. Young *Eques pulcher* resting in the protection of shells. About 10 mm. in standard length

of the two additional eyes. The larger *Gerres cinereus* (Walbaum), also present on these beaches and too large for the little barracuda to eat, shows no such markings, while its young of comparable size were not found in these localities. Barracuda of a size appropriate to feed on these larger fish have moved off into deeper water, evidently for natatorial reasons.

In any case it is thought that the pigmentary conditions found over these light sandy bottoms are associated with the impossibility of having the dark pupil fade with the rest of the exposed surfaces for basic visual reasons. Walls (1942) gives an especially pertinent discussion of the difficulties involved in an attempt to "hide" the pupil, particularly in the case of silvery fishes, and Cott (1940) gives an extended discussion of the entire problem.

In the strong light usual over these places a shadow is cast on the bottom which in shallow water is nearly as distinct and dark as an equivalent one in air. As viewed from above, it is a very distinct mark and often serves to betray the presence of a fish before it is actually seen itself. In deeper water the shadow lightens and becomes more diffuse and is usually too remote from the fish to seem to have much significance. Viewed from under water, laterally, such shadows are not nearly so conspicuous as might be thought from an above-the-surface view. When the fish is close enough to be seen distinctly, the shadow is likewise distinct, but when the fish is at such a distance as to show only the markings herein discussed the shadow is impossible to detect. It would be difficult, if not impossible, to imagine how a fish by some chromatic adjustment could do anything tending to obliterate such a shadow, in any case, and there has been apparently no adjustment in such a direction.

Another detail of this environment is the result of bright, direct sunlight playing through the often only lightly rippled surface. Under these conditions, which may occur daily for long periods of time, the tiny wavelets so focus the sun's rays as to produce a pattern of bright lines at a certain distance below the surface. When this focal distance approximates the depth of the water, the bottom is seen to be covered with a moving, mesh-like network of brilliant lines which usually are attended by spectral colors at their edges. Under certain conditions this effect can make an object peculiarly distinct, but in present connections it is evidently of minor or no importance to the conspicuousness of the small fishes under consideration. This is because of their small size in reference to the usual sizes of the "mesh" of bright lines and the slight distance between the fish and the bottom. The meandering lines move over fishes and bottom alike without, in any evident way, making the fish more prominent than they are under cloudy conditions when no mesh of bright lines is present.

However, under different conditions and with larger fishes swimming in deeper water this effect can make the fish exceedingly prominent. For example, a shark such as *Carcharhinus* swimming in deep water remote from the bottom and in the focal plane of these bright, actually golden lines stands out prominently as far off as it can be seen. The all-over gray appearance produced by the exquisite countershading of these sharks, which otherwise renders them so inconspicuous, is completely nullified. A shark made prominent by these bright lines is shown in plate 22. This photograph was taken at the Marine Studios near St. Augustine, Florida (Breder, 1938). In a state of nature sharks are not usually seen under such conditions, and it would seem, on a basis of general field observation, that they avoid depths in which the phenomenon is possible. Most usually large sharks are to be found in water too deep to be in the focal plane of these bright lines or very close to the surface in water too shallow for the effect to be seen. On the sandy shores under consideration sharks are seldom seen in the daytime in any case, but as soon as night falls they come in from deeper water and spend the night cruising over these areas for feeding purposes. On every moonlit night their shadowy forms could be seen in numbers from the laboratory dock.

The ability of barracuda to change color is much more marked than is generally realized. The large adults of 3 or more feet in length are usually seen in the daytime to have a very dark, greenish black dorsal surface and a silvery under surface. However, after nightfall this dark back is replaced by

one nearly as light as the ventrum. A considerable number of these fish kept in a large enclosure 25 by 75 feet showed this diurnal change very clearly. Large flood lights thrown on them at night frequently caused anglers, quite familiar with the species, to suppose at first sight that the fish were dead and floating belly up. A few minutes of exposure to the floodlights brought back the dark back of fish usually swims or rests high above the bottom. In this phase the green above passes gradually to silver on the side, and this more abruptly to plain white upon the belly. In this phase the fish is readily seen from above, but if viewed at even a short distance by a diver working at its own or lower level it seems gray, and is readily lost in the blue-gray haze of the water. In the banded phase

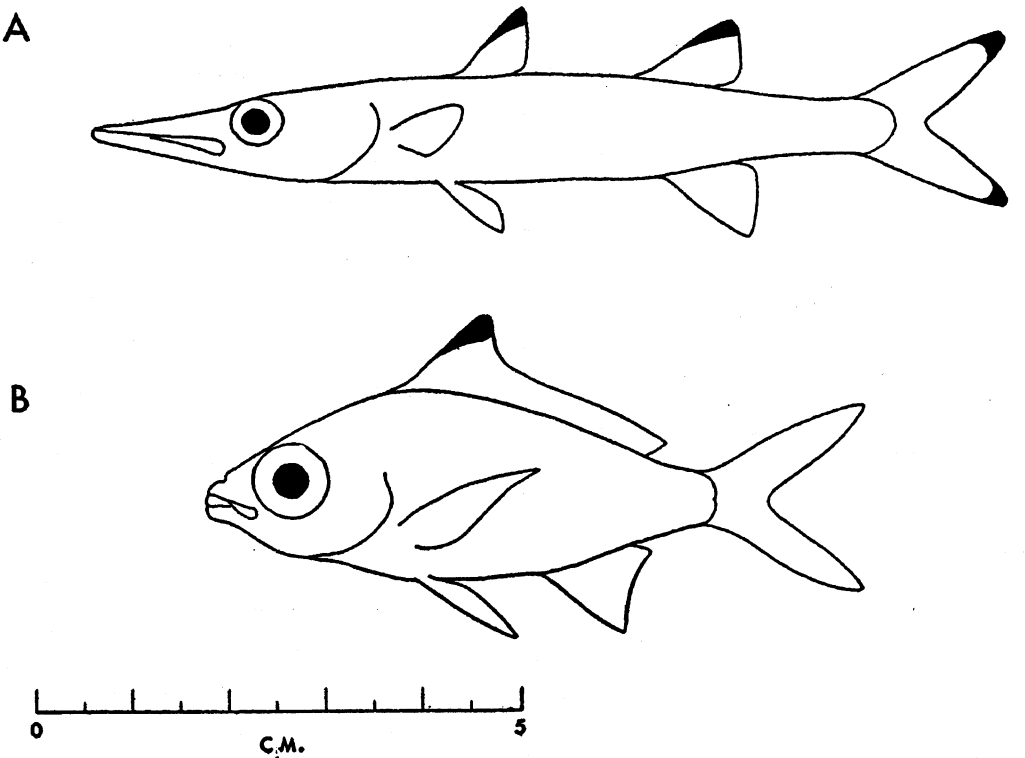


FIG. 1. Diagram of pattern assumed by certain fishes over a clear sand bottom, free of litter. A. *Sphyraena barracuda*. B. *Eucinostomus gula*.

daytime. Longley and Hildebrand (1941) seem to have been the only students to have previously discussed at length the extent of the pattern-changing capacity of this species. Their remarks, which are in essential agreement with present observations, are as follows: "The color is changeable in high degree. The young fish from one to several inches in length have a dark lateral stripe. The larger fish show a banded pattern that appears also in the young, as well as a plain one, countershaded and marked only by a number of black spots along the lateral line.

"The plain pattern is that in which the the body is crossed by seven distinct bars. This pattern is displayed when the fish rests over dark or variegated bottom. For example, of two 375-mm. fish seen at once at a dock at Fort Jefferson, one lay in the shadow of a cluster of piles, and the other was in bright sunlight over light-colored sand. The first was dark and conspicuously banded; the second, pale and uniform in coloration except for its countershading. Another observation was made upon a group of young barracudas, about 125 mm. long, at the Laboratory dock. Some were over light-colored sandy bottom, and were light and uniform in

color. Others were over bottom littered with brown algae, black sea-urchin spines, and dark-colored waste, and these were darker and plainly banded."

basking near the surface of the water in the neighborhood of a coral head, a buoy or a channel stake, appears much as a ghost fish, a shadowy wraith. Another lying near the

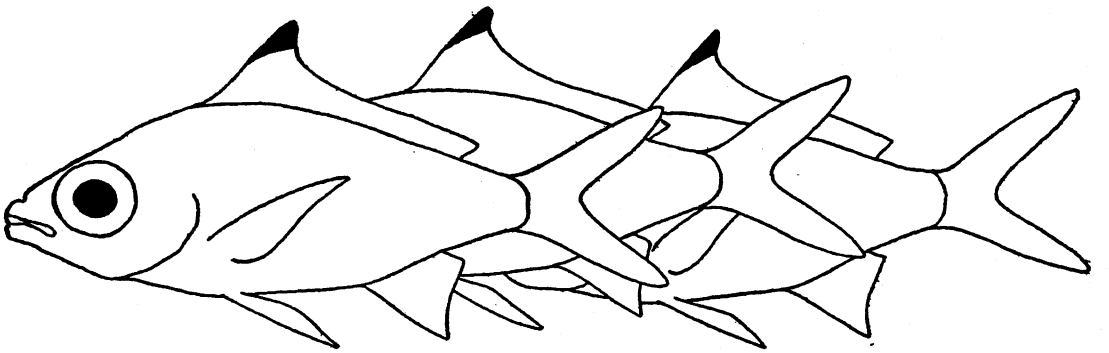


FIG. 2. A group of three *Eucinostomus* as they frequently arrange themselves when resting quietly over a clear sand bottom. Scale same as in figure 1.

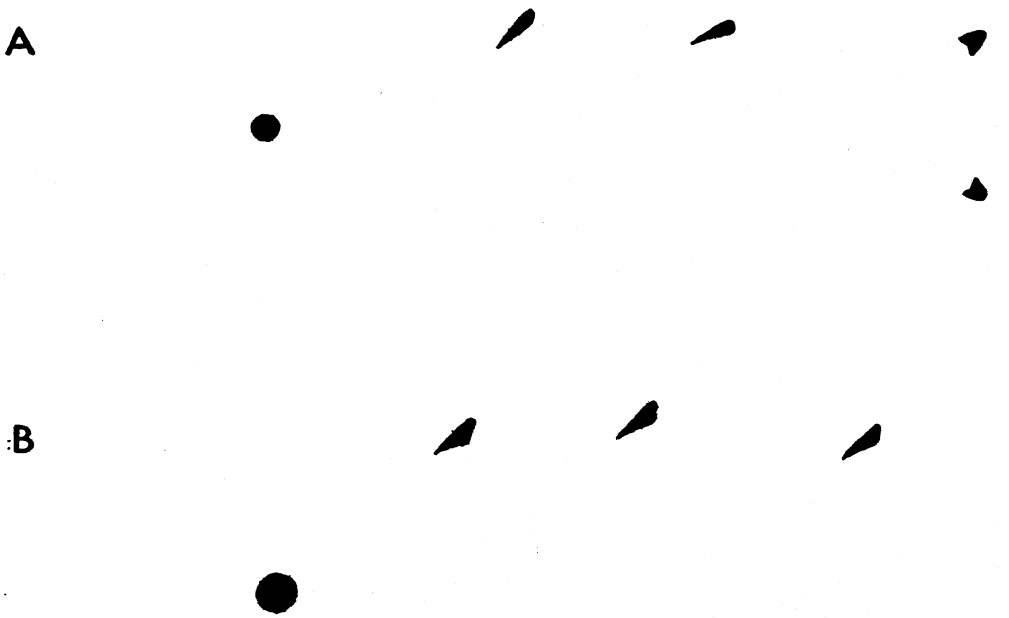


FIG. 3. Appearance of certain fishes over clear sand bottom as seen horizontally from diving equipment. A. *Sphyraena barracuda*. B. Three *Eucinostomus* grouped as in figure 2. This illustration is a tracing of figure 1 and figure 2, omitting the structural details not visible under the conditions in which the living fish are seen. Scale same as in figure 1.

Gudger (1918), after describing the pattern of various specimens in death or as preserved, made the following observations: "In life the color of the fish readily accommodates itself to its surroundings. A large barracuda

bottom over coral sand will so accommodate itself to its environment as to be almost unnoticeable so long as it remains quiet. Wood-Jones (1912) says that it is the hardest of all sea fish to see."

The only other species noted to participate in this general sandy beach complex of showing a black-and-white effect was *Mugil trichodon*, found in occasional small groups of generally from three to five individuals. These would have the sand color already described for the former two forms and would show the black pupil and a black edging to the caudal. All those seen were clearly too large for the little barracuda to bother. It was further noted that there were two types of black edging, as shown in figure 4, one about twice as wide as the other. It proved impossible to catch any, but it is suspected that the differences may be sexual, as the fish were all large enough to be sexually mature, and groups were not infrequently seen in which only one had a narrow band while the rest, one to four, had the wide band.

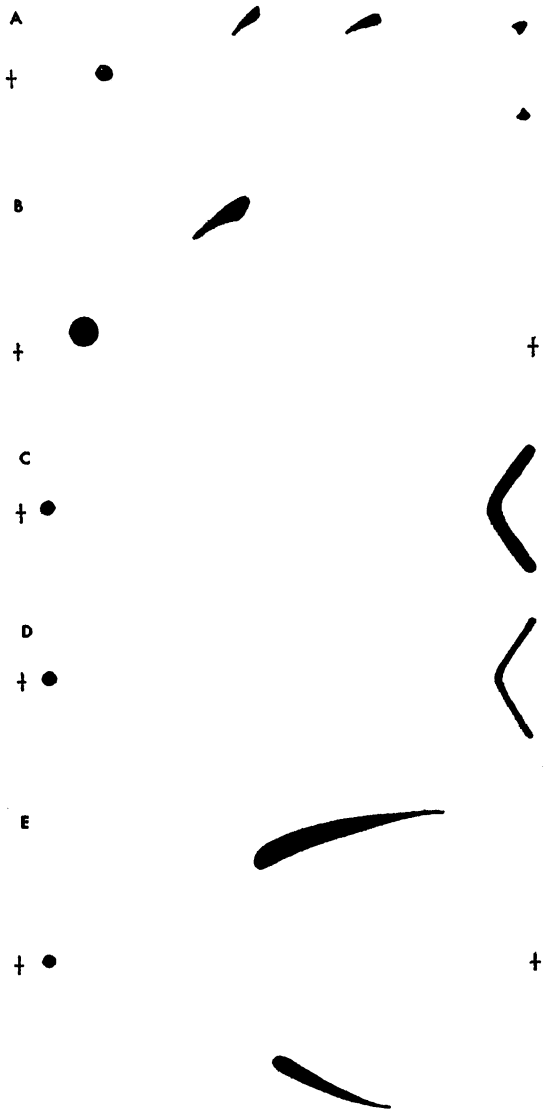


FIG. 4. Comparison of various black marks on fishes as seen over a clear sand bottom, all reduced to a common scale. The light crosses indicate the total lengths where pigment is absent. A. *Sphyraena barracuda*, young. B. *Eucinostomus gula*, young. C. *Mugil trichodon* (mature male?). D. *Mugil trichodon* (mature female?). E. *Trachinotus palometa*, young.

Along the outside beaches, actually in the light surf, not more than a few feet from shore the young of *Trachinotus palometa* Regan ran singly or in small groups, especially towards evening. Viewed from the seaward side, as from diving equipment, they show two strong diagonal black marks which indicate their long dorsal and anal, as indicated in figure 4. Thus they evidently belong to this group of clean sand fishes which are mostly black and white.

In slightly deeper water a few feet farther off shore species of *Tylosurus* abounded, which when viewed laterally from diving equipment were similarly not at all easy to see distinctly. The young of some of these have a dark dorsal and dark mandibular lappets as described by Breder (1932). Just what connection this may have with the presently discussed complex, if any, is not clear but could be made the subject of further study. A photograph taken of a living fish on the west coast of Florida (pl. 23) shows this condition in young *T. raphidoma* (Ranzani) as seen dorsally.

The very dark young of *Chaetodipterus faber* (Broussonet) and their behavior over light sand bottoms have been discussed in considerable detail by Breder (1946). The phenomenon involved was that of black fishes scattered on a light ground together with other dark objects (infertile mangrove seed pods) which they so closely resembled that it was extremely difficult to distinguish fish from inert items. As soon as these fish reached a size too large to be easily confused with the inert objects, they moved off into deeper water and took on aggregating or schooling habits and developed the typical banded coloration of the adults. At this place

on the Florida west coast the water is notably turbid, owing chiefly to the abundance of plankton organisms, so that the phenomenon above noted could take place successfully only in very shallow water of a few inches at most.

On the other hand, at Bimini, where the water is remarkably clear and vision is excellent even at considerable depths, the behavior of medium- and large-sized *Chaetodipterus* over clean sand bottoms was found to be notably different. Although none of the sizes resembling small mangrove seed pods was encountered, specimens were secured that were considerably larger, and comparable in size to those on the Florida coast that schooled and showed the banded coloration typical of adults. The smallest specimen taken, 58 mm. in standard length, looks very like the illustration of a 50-mm. specimen in Hildebrand and Cable (1938, fig. 29) except that the pattern and blotching are barely evident, even in the preserved specimen from Bimini, because of the much heavier over-all pigmentation. These at Bimini, moreover, were maintaining a solitary life, similar to that of the very small ones on the Florida coast, were as black as they, and displayed similar hyaline pectorals and caudals. Furthermore, their behavior on the sandy shores where they were found can only be described as similar to those smaller seed-pod resemblers from Florida. Although there was nothing in particular on the Bimini beaches that they resembled in any great detail, they nevertheless reclined and drifted about so that they looked like some bit of trash amid other more or less dark objects of greater or smaller size of a jetsam nature. They were not readily recognizable as fishes. Large adults were also seen in small numbers but always as solitary individuals. These presented themselves in one of two manners. They could be found lying as inert objects in clear places on light sand and just as black as the above-mentioned smaller sizes. Evidently this type of behavior carries on into the adult size in extremely clear water. Those seen behaving in this fashion were found in water from about 6 to 10 feet deep. Other individuals could be found under docks, and these were in a normal vertical position and showed the most contrasting black-and-white coloration of which they are capable, evidently to some extent matching the small piles that support the docks. One individual was first noted about 30 feet off the end of the laboratory dock, reclining on its side with virtually no perceptible motion. Little by little it inched towards the dock, an operation which took nearly an entire afternoon. It then righted itself and rapidly took on the strongly banded pattern. Evidently this same fish lived under the dock for the rest of our stay, a matter of 38 days. During this time it always showed the contrasting black-and-white pattern, in daylight or at night.

FISHES OF THE CONCH FLATS

EXTENSIVE SANDY FLATS form the eastern margin of the harbor at Bimini, and parts of them become dry at very low water. These flats are populated by large numbers of mollusks and other invertebrates of various sorts, typical of such protected places in the Bahamas. The fishes associated with them are also typical, but overlap in species those already discussed under both Tide-Pool Contents and Fishes of Open Beaches. One species is largely, if not entirely, confined to close association with these conch beds.

The inquiline association of this species, *Astrapogon stellatus* (Cope), within the gastropod *Strombus gigas* Linnaeus is well known (Plate, 1908; Hildebrand and Ginsburg, 1926; Gudger, 1927, 1929), but there appears to be no data on its frequency of occurrence, or on its variation as associated with habitat. Consequently when it became necessary to handle a considerable number of conchs, note was made of the number of individuals that contained such a fish. When the conchs were taken and placed in a boat they naturally withdrew within their shells, and any *Astrapogon* that they were harboring were securely trapped therein. As they relaxed the fish dropped out and it was a simple matter to count the number of conchs and fish to obtain the ratio of fish to mollusk. These counts were made on material taken on the flats east of the laboratory dock and are given in table 2.

In contrast to this ratio of one fish to fewer than 12 conchs, a collection of *Strombus samba* Clench made outside the harbor a little east of Turtle Rock August 25, consisting of 319 conchs, was found to contain not a single fish. If the same ratio of conch to fish existed here as in the harbor about 20 fish should have been recovered. Evidently either this association is chiefly, if not entirely, characteristic of the inside banks at this place, or it is a matter of specificity.

During this time of year, at least, one may expect from every sixth to every twentieth conch to contain an *Astrapogon*, with a mean at a little over 11. An examination of the tabulation of numbers indicates that there is a constant ratio of conchs to fish. This is shown more clearly in figure 5. There was no particular system to the collection of these conchs, which were taken for use as human food and as bait. Various parts of the banks were collected over, and this constant ratio in number of conchs per fish would seem to

TABLE 2

COMPARISON OF THE NUMBER OF *Strombus* COLLECTED WITH THE NUMBER OF *Astrapogon* FOUND

Date	No. of *Strombus*	No. of *Astrapogon*	No. of Conchs per Fish
	From harbor flats		
July 26	20	1	20.00
Aug. 1	61	6	10.17−
6	41	3	13.66+
7	21	2	10.50
9	211	7	30.43−
12	103	16	6.44+
19	18	3	6.00
20	48	8	6.00
All	523	46	11.15+
	From near Turtle Rock		
Aug. 25	319	0	—

indicate that the "infestation" of these inquilines is not dependent on the concentration of conchs. The collector simply picked up more of the mollusks when he found a denser concentration at whichever low tide he happened to work.

The reason for the absence of the fish in outside waters is not clear, and it may be that these shelter-seeking fishes merely avoid the open ocean and confine themselves to sheltered areas, a possibility that could be made the subject of further study.

Determination of sex was not made in the earlier collections, but all fish were examined for the presence of eggs in the mouth, since the species is known to be an oral incubator. As time went on, more of the females were noted to be heavily gravid. On August 12 the collection consisted of nine gravid females, six males, and one immature fish. On August 20 two males were carrying eggs in their mouths. Evidently, then, the fish were just coming into their spawning season, towards the end of August.

There appears to be a slight decrease in the ratio of fish to mollusk with the passage of time, as is indicated, but this shows no statistical significance. As the spawning season approaches, it nevertheless suggests that there may be a tendency for the fish to stay more within, or closer to, their retreats in the conch. Thus more would be apt to be trapped when the conchs were taken, but more collections should be made for purposes of statistical study.

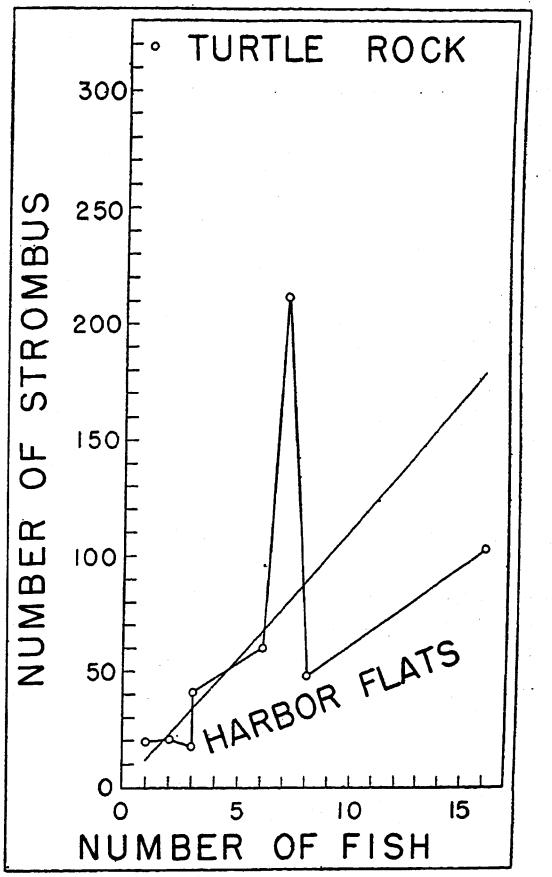


FIG. 5. Comparison of number of *Strombus* collected with number of *Astrapogon* found, at the harbor flats and outside the harbor, at Turtle Rock. From data of table 2.

DISCUSSION

ALTHOUGH VIRTUALLY nothing has been done, except in the most casual way, on the subject of the mutual relationships of behavior, environment, and pigmentation of marine shore fishes, the author has long believed that a study of their evident interactions would prove exceptionally useful in any attempt to evaluate the relative significance of physical status and behavior in relation to survival and selection. In fact so little is known about the general manner of life of any considerable number of fishes which might be so studied that much basic work must first be undertaken in order to provide a satisfactory foundation for procedure. This paper is to be considered a first move in this direction. The very fact that so many items of pertinence to the subject could be uncovered by the simple procedures indicated in the body of this contribution is indicative of the truth of the above statement. These, and many more as yet undescribed details together with rigorous experimental procedures, should go far to explaining the many superficially inexplicable variations of structure and behavior displayed by such fishes.

Because these three specialized environments abut one another, yet can hardly be said to intergrade, such a region becomes one of peculiar interest. In addition to the three particular environments mentioned specifically herein are others that bear a similar relationship to the whole, although it was impossible specifically to investigate them at this time. They include beds of *Thalassia*, which have rather abrupt meetings with the open sandy bottoms, and mangrove stands, which likewise meet the others with abruptness, to mention only the conspicuous chief ecological shore conditions.

Another abrupt and specialized environment, which must be considered as "artificial," is the shelter of docks and wharves which harbors a large variety of fishes not typical of any of the three environments here discussed. Many of these are associated with rocky places in deeper water. For example, the following species were noted to be habitually under the laboratory dock:

Lutianus griseus (Linnaeus)	Mature
Lutianus apodus (Walbaum)	Mature
Ocyurus chrysurus (Bloch)	Half grown
Haemulon sciurus (Shaw)	Mature
Haemulon plumieri (Lacépède)	Mature
Upeneus martinicus Cuvier and Valenciennes	Mature
Chaetodipterus faber (Broussonet)	Mature
Chaetodon striatus Linnaeus	Mature
Pomacanthus arcuatus (Linnaeus)	Half grown
Pomacanthus aureus (Bloch)	Half grown
Holocanthus tricolor (Bloch)	Mature
Angelichthys ciliaris (Linnaeus)	Mature
Acanthurus caeruleus Bloch and Schneider	Mature
Acanthurus hepatus (Linnaeus)	Mature
Eupomacentrus leucostictus (Müller and Troschel)	Mature
Abudefduf saxatilis (Linnaeus)	Mature
Iridio bivittata (Bloch)	Mature and half grown
Thalassoma bifasciatum (Bloch)	Mature and half grown

Many of the species above listed could also be found among the mangrove roots, which these docks, from a fish's point of view, must more or less resemble, and to which is added the attraction that human beings not infrequently drop or dump ovberboard things that are edible.

On the *Thalassia* beds visible from the dock the prominent fishes identifiable mostly at sight included the following:

Pomacentrus leucostictus (Müller and Troschel)	Mature
Iridio bivittatus (Bloch)	Half grown
Sparisoma flavescens (Bloch and Schneider)	Mature
Lactophrys triqueter (Linnaeus)	Mature and half grown
Lactophrys tricornis (Linnaeus)	Mature
Spheroides dorsalis Longley?	Mature
Chilomycterus schoepfi (Walbaum)?	Mature

The truly schooling species, *sensu stricto*, found in these environments wander more or less freely in and out of all of them except the tide pools, where only rarely are any of them trapped and then seemingly by the merest accident. All may be taken in much deeper water and apparently are only casuals close to shore. The species observed here include the following:

Jenkinsia lamprotaenia (Gosse)
Harengula macrophthalma (Ranzani)
Trachurops crumenophthalma (Bloch)

The second-listed species usually shows a dark humeral spot and the last a dark opercular spot, while the very small, first-listed form shows no such distinctive mark recognizable at any distance. These fish always travel in groups of numerous, often very large numbers of, individuals and because of their close packing in the tight schools can show no such "recognition" marks as the resident sandy-bottom forms. This lack of distinct marking and their particular social behavior mark them as apart from the latter-mentioned type, in addition to their wide ranging habits and only occasional appearance on these sandy shoals.

A considerable amount of work has been done on the relationships of various, mostly fresh-water fishes, including learning, social behavior, pattern, and color recognition, under captive conditions, but there has been scant attempt to correlate the results of these studies with the actual interplay of the various phenomena under feral conditions. Breder and Halpern (1946) attempted to bring together the data on the various influences at work on the aggregating behavior of the goldfish and other species, while Breder and Rasquin (1947) indicated how a fine structural difference may greatly influence the behavior of closely related forms and discussed the relationships between such features and a very specialized type of environment.

Although the tide pools are cut off from the sea only at certain tidal stages, the fish in them remain essentially the same for at least long periods of time and very definite hierarchies are set up. These are dominated by the species specialized in the direction towards making them thoroughly accommodated to this type of environment, while those not so obviously accommodated to it are in an inferior position but among themselves set up their own hierarchy, which is superior to the fishes that are not suited to such environments. An exception to this is the final dominance of the young *Acanthurus*, which, while generally resembling the form of the other competing fishes, is provided with a particularly vigorous defensive mechanism in its peduncular lancet that it uses freely. Since these tide pools are to all intents and purposes naturally constituted "aquaria," it is not surprising that all such forms thrive in man-made aquaria, or that those accidentally trapped do not thrive especially well in small aquaria. As a case in point, at the old New York Aquarium all the "typical" and "casual" species thrive very well if not too crowded, but none of the "accidental" species in the sizes here found were ever brought alive from the south, with the exception of *Eques* which proved to be exceptionally hardy. This form, although not regularly in tide pools, is typically found amid shell piles and similar places. Plate 23 shows an *Eques* resting in the shelter of some shells. *Pomacanthus*, *Acanthurus*, and *Thalassoma* all do fairly well under such conditions of captivity in their larger sizes which are never found in tide pools. *Jenkinsia* like most herrings is almost impossible to handle alive, and *Eucinostomus* never survived the trip north.

One of the more interesting points in this connection was that in the tide-pool aquarium both size and darkness of coloration were associated with peck-order, the darkest being

at the top and the lightest, and non-suited to tide-pool environments, at the bottom. The lightest, *Eucinostomus*, moreover fitted very well into the environment of open beaches where its coloration evidently had very special significance.

If consideration be given to the systematic position of the fishes found in these tide pools, it is at once apparent that only the more advanced acanthopterygians have representatives in the categories listed as casual and typical. This point, which is probably more than accidental, is brought out clearly in table 3 in which the orders and families are listed at the left in the usual systematic order. Here it becomes at once apparent that six of the seven genera listed as accidental have been considered by authors as, at least, not more advanced than those four listed as casual and typical. Although each may be specialized in its own particular direction, only the very advanced Gobioidea and Jugulares, in this region at least, have been able to establish themselves sufficiently in tide-pool environments to be considered as typical. It is to be noted in this connection that both are heavy fishes, sinking to the bottom when not actively swimming, while the others are all "floating" fish. Furthermore, the goby has developed an excellent hold-fast formed of its united ventral fins, while the blenny has developed marked ability to hop about in water or on land. Of the "floating" fish only one family, the Pomacentridae, with four species represented, has reached a point where it is possible to consider its representatives as other than accidental. The one genus, *Eupomacentrus*, has taken to living about and within empty shells and evidently always nests in them (see, for example, Brinley, 1939; Coonfield, 1940; and Longley and Hildebrand, 1941). The other, *Abudefduf*, nests in more exposed places. This is known for *A. saxatilis*, Longley and Hildebrand (1941), and in the absence of knowledge to the contrary may be assumed for *A. analogus*. As a result of this manner of activity, these fishes have considerable to do directly with the solids in their environment. On the other hand, all the species listed as accidentals either are known to

TABLE 3

SYSTEMATIC ARRANGEMENT OF TIDE-POOL REPRESENTATIVES

Order and Family	Genera		
	Accidental	Casual	Typical
Isospondyli			
Clupediae	*Jenkinsia*	—	—
Percesoces			
Mugilidae	*Mugil*	—	—
Percoidea			
Gerridae	*Eucinostomus*	—	—
Sciaenidae	*Eques*	—	—
Squamipinnes			
Chaetodontidae	*Pomacanthus*	—	—
Acanthuridae	*Acanthurus*	—	—
Chromides			
Pomacentridae	—	*Eupomacentrus*, 2 *Abudefduf*, 2	—
Pharyngognathi			
Labridae	*Thalassoma*	—	—
Gobioidea			
Gobiidae	—	—	*Bathygobius*
Jugulares			
Blennidae	—	—	*Salarichthys*

shed pelagic eggs which receive no parental attention, or there is good reason to suppose that they do.

The markings of the fishes typical of the light, clean, sandy bottoms present an item of considerable interest in the remarkably clear water of this area. The same species in less transparent water do not show the peculiar disappearing lightness marked only by a few dark points as seen at this place. The prominent forms, already discussed, are shown comparatively in figure 4, all reduced to a common length. The precise significance of these various marks, which are specifically distinct and in one case evidently sexually distinctive, is not clear at this writing. This should be, however, amenable to an experimental approach. While it is evident that there is a general resemblance in all, it is also clear that each has a definite character of its own. Thus, so far as a human in goggles is concerned, these five patterns may be recognized as soon as they emerge from the general blue gray haze and long before the fish itself can be distinguished. It would probably be pointless to speculate further at this time on the presumed significance of these "hieroglyphics" to their owners or those who view them. It would seem, however, at the very least, that they do tend to increase the distance perception of these fishes, for, although this water is remarkably clear when viewed from above, the horizontal view under water in all such places is sharply restricted by a bluish gray haze. To assume that these are all simple ruptive markings, *a priori*, would seem to be an unwarranted oversimplification for, as in many such cases, it would not be surprising to find that each fish is solving some special problem by this means under the restrictions of its particular environment.

Bearing on the above concepts is the relation between the behavior and pigmentation of *Chaetodipterus*, in which a fish instead of matching the background and thus "disappearing" does just exactly the reverse and becomes "lost" amid other bits of truly inert trash which it resembles to a greater or lesser degree of perfection. All background-matching fishes studied in sufficient detail have been shown to vary their pigmentation according to the albedo and not according to the amount of incident light (see, for example, Sumner, 1939, 1940, 1943; and Sumner and Wells, 1933). Also it has been shown that there are both direct and optically mediated elements, which are antagonistic in their action controlling the dispersal and production of melanin. Thus only blind individuals, of the various species studied, are able to show a truly dark phase, in the presence of light and a light background, as is indicated by Hogben (1942), Odiorne (1937), and Rasquin (1946). However this may be for the fishes so studied, it is evident that in the case of *Chaetodipterus* some different form of control must have the ascendancy, for these individuals, although clearly not blind, perform as though they were sightless. Furthermore, they do this only when over a relatively clean, light bottom, reverting to what is evidently a more usual type of chromatic reaction when in a different environment, such as described for the fish which took up its abode under the laboratory dock and henceforth showed a strongly barred pattern.

The darkening of the back of *Sphyraena* may have some bearing on this, since it is evidently done in the presence of light and quickly reversed on the coming of nightfall. This dark back clearly helps in its countershading, as an underwater view will attest, but what utility the lightening of the back on a dark night may have, if any, is far from evident.

The whole question of the bearing of the pineal on this general question, as suggested by Breder and Rasquin (1947) in their study of cave fish, leads to a general speculation on these fishes. In the small fishes such as *Atherina* and *Eucinostomus*, it might be imagined that some light penetrates to that area, which in the terms of the cave fish studies should tend to keep them in open water and away from shelters. This they do, and, contrariwise, the relatively heavily pigmented pomacentrids of the genus *Eupomacentrus* tend to hover in and about the shelter of shells, while *Abudefduf*, less heavily pigmented, would seem to be a stage away from such a habit. In both *Sphyraena* and *Chaetodipterus*, the heavy pigment and thick tissues must protect the pineal to a considerable degree, but neither genus is in the least lucifugous. The facts that *Astrapogon* is heavily

pigmented and hovers closely to its protecting mollusk, presumably prowling about at night for food, are also suggestive, but that *Eupomacentrus* retreats completely hidden within an empty shell at night suggests still some other mechanism of control. An experimental and morphologic study of the conditions in any or all of these should be illuminating and should form a firm step towards a better understanding of the vagaries of behavior displayed by these fishes.

SUMMARY

1. REGULAR INHABITANTS of Bahama tide pools maintain their residence for long periods, extending at least between drying on successive spring tides.

2. Peck-order hierarchies of some stability are established in these tide pools which are interspecific and evidently depend to a considerable extent on size and darkness of coloration.

3. The contents of such tide pools may be divided into *typical species* which are dominant and show specializations associated with tide-pool life, *casual species* which are less abundant and show no obvious tide-pool specialization but are well accommodated to them, and *accidental species* which are rare and evidently not suited to such places in which they are apparently occasionally trapped.

4. Species in the area studied which are here considered as typical include *Bathygobius soporator* and *Salarichthys textilis*; those considered as casual include the young of *Eupomacentrus leucostictus*, *E. adustus*, *Abudefduf analogus*, and *A. saxatilis*; while those considered as accidental include *Jenkinsia lamprotaenia*, the young of *Mugil trichodon*, *Eucinostomus gula*, *Eques pulcher*, *Pomacanthus aureus*, *Acanthurus hepatus*, and *Thalassoma bifasciatum*.

5. In addition to respiratory specializations and the ability to leave a given pool and move overland, the typical species are able to and do match the bottom on which they rest to a remarkable degree, while the casuals in no case show such adjustments, their bright colors making them conspicuous to a notable extent.

6. The typical species are strictly carnivorous and prey to some slight extent on the casuals, but the latter as well as the accidentals are all non-predatory, subsisting on such vegetable and animal matter as they may obtain by picking at growths on the substrate or grubbing in the sand.

7. The typical tide-pool species, and *Eupomacentrus* among the casuals, spend much time going in and out of cavities such as empty shells, the former both day and night while the latter spend the entire night hidden in such places. All the rest spend the night resting in open places, with the exception of *Thalassoma* which evidently spends the night under cover.

8. Both *Eucinostomus gula* and young *Sphyraena barracuda* inhabit open, shallow, sandy beaches and show a bottom-matching mottling over mottled bottom, but become plain and also bottom matching over clean sand with the exception of certain fin tips which become intensely black.

9. The fact that the black pupil of the eye cannot be faded suggests that the fin tip is in some way connected with this fact in reference to recognition or confusion.

10. Other fishes of these same clean beach areas that show similar black-and-white patterns, involving only the fin tips, include, besides the above, adult *Mugil trichodon* and young *Trachinotus palometa*.

11. Both young and adult of *Chaetodipterus faber*, in the very clear water of this region (in contrast to their chromatic behavior in places of greater turbidity), when on clear stretches of sand show their blackest phase and recline on one side, resembling a piece of inert trash, but when in the area of a dock right themselves and hide among the piles with their boldest pattern of black-and-white vertical bars.

12. Since the more usual background-matching behavior of other fishes makes it possible only for blind fish to show their darkest phase when in light on a light background, it follows that the visual-hormonal control of melanophores in *Chaetodipterus* must operate in a different manner.

13. The fish *Astrapogon*, inquiline in *Strombus gigas*, shows an approximately equal infestation of this mollusk irrespective of the concentration of the latter, but only in inside sheltered waters, and it is evidently absent from the relatively unsheltered *Strombus samba*. About one *Strombus* in 12 was found to be inhabited by an *Astrapogon* in sheltered places.

14. The spawning season of *Astrapogon* begins in August in this region.

LITERATURE CITED

BEEBE, W.
1931. Notes on the gill-finned goby, *Bathygobius soporator* (Cuvier and Valenciennes). Zoologica, New York, vol. 12, no. 5, pp. 55–66.

BEEBE, W., AND G. HOLLISTER
1933. New species of fish from the West Indies. Zoologica, New York, vol. 12, no. 9, pp. 83–88.

BEEBE, W., AND J. TEE-VAN
1928. The fishes of Port-au-Prince Bay, Haiti. Zoologica, New York, vol. 10, no. 1, pp. 1–279.

BREDER, C. M., JR.
1925. Scientific results of the first oceanographic expedition of the "Pawnee" 1925. Fishes. Bull. Bingham Oceanogr. Coll., vol. 1, no. 1, pp. 1–90.
1932. On the habits and development of certain Atlantic Synentognathi. Carnegie Inst. Washington Publ., no. 435, Papers Tortugas Lab., vol. 28, no. 1, pp. 1–35.
1933. New locality records of *Abudefduf analogus* including one from the United States. Copeia, no. 4, pp. 191–193.
1938. Observations at the Marine Studios. Bull. New York Zool. Soc., vol. 41, no. 4, pp. 123–129.
1943. The eggs of *Bathygobius soporator* (Cuvier and Valenciennes) with a discussion of other nonspherical teleost eggs. Bull. Bingham Oceanogr. Coll., vol. 8, no. 3, pp. 1–49.
1946. An analysis of the deceptive resemblances of fishes to plant parts, with critical remarks on protective coloration, mimicry and adaptation. *Ibid.*, vol. 10, no. 2, pp. 1–49.

BREDER, C. M., JR., AND F. HALPERN
1946. Innate and acquired behavior affecting the aggregation of fishes. Physiol. Zool., vol. 19, no. 2, pp. 154–190.

BREDER, C. M., JR., AND P. RASQUIN
1947. Comparative studies in the light sensitivity of blind characins from a series of Mexican caves. Bull. Amer. Mus. Nat. Hist., vol. 89, no. 5, pp. 319–352.

BRINLEY, F. J.
1939. Spawning habits and development of beau-gregory (*Pomacentrus leucostictus*). Copeia, no. 4, pp. 185–188.

COONFIELD, B. R.
1940. Chromatophore reactions of embryos and larvae of *Pomacentrus leucostictus*. Carnegie Inst. Washington Publ., no. 517, Papers Tortugas Lab., vol. 32, no. 12, pp. 169–178.

COTT, H. B.
1940. Adaptive coloration in animals. London, Methuen and Co., Ltd., xxxii+508 pp.

FOWLER, H. W.
1947 Notes on Bahama fishes obtained by Mr. Charles G. Chaplin in 1947 with descriptions of two new species. Notulae Naturae, no. 199, pp. 1–14.

GINSBURG, I.
1947. American species and subspecies of *Bathygobius*, with a demonstration of a suggested modified system of nomenclature. Jour. Washington Acad. Sci., vol. 37, no. 8, pp. 275–284.

GUDGER, E. W.
1918. *Sphyraena barracuda;* its morphology, habits, and history. Carnegie Inst. Washington Publ., no. 252, Papers Dept. Marine Biol., vol. 12, pp. 53–108.
1927. Inquilinism between the cheilodipterid fish, *Apogonichthys puncticulatus*, and the univalve mollusk, *Strombus bituberculatus*. Zoologica, New York, vol. 9, no. 2, pp. 193–200.
1929. On the morphology, coloration and behavior of seventy teleostean fishes of Tortugas, Florida. Carnegie Inst. Washington Publ., no. 391, Papers Tortugas Lab., vol. 26, pp. 149–204.

HILDEBRAND, S. F., AND L. E. CABLE
1938. Further notes on the development and life history of some teleosts at Beaufort, N. C. Bull. U. S. Bur. Fisheries, vol. 48, pp. 505–642.

HILDEBRAND, S. F., AND I. GINSBURG
1926. Descriptions of two new species of fishes from Key West, Fla., with notes on nine other species collected in the same locality. Bull. U. S. Bur. Fisheries, vol. 42, pp. 207–215.

HOGBEN, L.
1942. Chromatic behavior. Proc. Roy. Soc. London, ser. B, vol. 131, pp. 111–136.

JORDAN, D. S., AND W. B. EVERMANN
1896. The fishes of North and Middle America. Bull. U. S. Natl. Mus., no. 47, pp. i–lx, 1–3313.

LONGLEY, W. H., AND S. F. HILDEBRAND
1941. Systematic catalogue of the fishes of Tortugas, Florida, with observations on color, habits, and local distribution. Carnegie Inst. Washington Publ., no.

535, Papers Tortugas Lab., vol. 34, pp. i–xiii, 1–331.

ODIORNE, J. M.
1937. Morphological color changes in fishes. Jour. Exp. Zool., vol. 76, no. 3, pp. 441–465.

PLATE, L.
1908. *Apogonichthys strombi* n. sp., ein symbiotisch lebender Fisch von den Bahamas. Zool. Anz., vol. 33, no. 12, pp. 393–399.

RASQUIN, P.
1946. On the reappearance of melanophores in blind goldfish. Copeia, no. 2, pp. 85–91.

SUMNER, F. B.
1939. Quantitative effects of visual stimuli upon pigmentation. Amer. Nat., vol. 73, no. 746, pp. 219–234.
1940. Further experiments on the relations between optic stimuli and the increase or decrease of pigment in fishes. Jour. Exp. Zool., vol. 83, no. 2, pp. 327–343.
1943. A further report upon the effects of visual environment on the melanin content of fishes. Biol. Bull., vol. 84, no. 2, pp. 195–205.

SUMNER, F. B., AND N. A. WELLS
1933. The effects of optic stimuli upon the formation and destruction of melanin pigment in fishes. Jour. Exp. Zool., vol. 64, no. 3, pp. 377–394.

WALLS, G.
1942. The vertebrate eye. Bull. Cranbrook Inst. Sci., no. 19, pp. i–xiv, 1–785.

WOOD-JONES, F.
1912. Corals and atolls. London, Lovell Reeve and Co., xxiii + 329 pp.