A Study of the Nocturnal - Diurnal Transition Periods of Tropical Reef Fishes on a Jamaican Fore - Reef.

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ABSTRACT: A site gently sloping from 25 to 35 feet in depth was chosen on the West Fore Reef of Discovery Bay to monitor the morning and evening transition periods between day and night. The first and last times when an individual fish and fish species were judged active were recorded, along with behavioral observations, during 4 morning and 4 evening observations (2 short observations were also done during midday). Times of observation were generally from 3/4 hour before sunrise to 1/4 hour after, and 1/2 hour before sunset to 3/4 hour after. These were roughly the periods of greater activity found by earlier workers (Hobson 1972, Collette and Talbot 1972). Light meter readings were taken on 2 mornings and 3 evenings. These light levels are graphed with the average changeover times of diurnal and nocturnal fish in the morning and evening (Figs 2,3). For the morning transition, the mean last active sighting for nocturnal species is 13 minutes before sunrise, the most quiet period is roughly from 11 to 6 min before sunrise, and the mean first active sighting of diurnal species is 7 min. after sunrise. In the evening, the mean time diurnals go inactive is one minute before sunset, the period with least activity is around 7 min. to 8 min. after sunset, and the mean emergence time for nocturnal species is 18 min. after sunset. This general pattern matches that described in Hawaii (Hobson 1972), but the "quiet" or interim periods at Discovery Bay are much shorter and less distinct. The sequence of emergence and coverseeking of diurnal and nocturnal species and families at Discovery Bay is similar to the sequence in the Virgin Islands (Collette and Talbott 1972), although fish here are generally active longer in the evening. Although some piscivorous predators were observed, it was not possible to test Hobson's (1965, 1968, 1972, 1975) hypothesis that a historic threat from predators overrides the local situation, causing an interim period, but our and Collette and Talbott's observations suggest this idea may have been overstated.

A section on taxonomy and behavioral observations is included. Interesting observations include a marked morning creole wrasse migration eastward, reversing in the evening, and hamlet territoriality and mating, observed at dusk.

INTRODUCTION: It has been well substantiated that the majority of tropical reef fish are active either by day or by night with the diurnal species generally inactive at night and the nocturnal species quiet during the day.[1] (Hobson 1965, 1968, 1974, Starck and Davis 1966, Colette and Talbot 1972; Vivien 1973). The diurnal fish are a highly diverse and abundant group of colorful fish with a variety of feeding specializations and behaviors while the more inconspicuous nocturnal fish exhibit limited diversity, are usually drab colors (shades of red) and are characterized by large eyes and mouths. The changeover between these two groups follows a definite sequence during specific time periods around sunrise and sunset.

To date, the transition sequence has been described in four reefs; the Gulf of California (Hobson 1965, 1968), Kona, Hawaii (Hobson 1972), Alligator Reef, Florida (Starck and Davis 1966) and the Virgin Islands (Colette and Talbot 1972). All of the studies outline the same general sequence of events during changeover. Hobson (1972) describes the following pattern: In the morning transition, there are 3 major periods: one, the disappearance of the nocturnal fish; two, an interim period where there are few active fish in the water column; and three, the appearance of the diurnal fish, usually in a rather abrupt manner. The evening changeover has three periods also; the disappearance of the diurnals, a quiet period, and finally, the emergence of the nocturnal fish. The transition sequence in the morning tends to cover a time span of 45 minutes prior to sunrise to 15 minutes after. The evening sequence usually begins 15 minutes before sunset and concludes 45 minutes after sunset.

The general patterns of each transition period are comparable among the various reefs surveyed. We begin with the night to day turnover. The cover seeking by the nocturnals starts about 45 minutes before sunrise with the soldierfish and squirrelfish all moving towards the shelter sites and then going under cover by a half hour before sunrise. At this time there are only a few cardinalfish left in the water column and they are slowly migrating down to shelter. This is also the start of the interim period. It begins to get light, and at first, there are few fish active. Then, 20 minutes before sunrise, the earliest rising diurnals (damselfishes, butterflyfish, goatfish, and small serranids) begin feeding low in the coral. Activity among the diurnals increases until, approximately 10 minutes before sunrise, there is an explosion of fish into the water column. This emergence involves the parrotfishes, some pomacentrids and the surgeonfish. The last fish to make their appearance are the wrasses and the sedentary fish, such as the blennies.

The day to night transition begins about 30 minutes before sunset as the chromis and the small wrasses in the water column begin their descent. By sunset, the small wrasses,

[1] Hobson 1975, p. 382.

the chromis and the juveniles of the pomacentrids have taken shelter in the coral. Schools of some larger wrasses and parrotfish begin assembling and migrating towards shelters located elsewhere on the reef. By 10 minutes after sunset, the water column is empty and the interim period begins. At the beginning of this period some surgeonfish, damselfish, and serranids are still active low in the coral. Then, 20 minutes after sunset, the smaller cardinalfish begin their vertical migration up into the water column, and 30-35 minutes after sunset, the squirrelfish and soldierfish make their abrupt appearance. By 45 minutes after sunset, the nocturnal situation is set.

The times of the beginning and end of each transition are variable among each reef surveyed, yet what is important to note is that the general patterns are the same. Comparing two reefs, you will find that congeners will have similar appearance and disappearance times relative to sunrise and sunset. (ie. damselfish are early risers on all reefs.) What causes the well-defined sequence of events, during each transition, to occur? Why is a similar pattern found on reefs in both the Atlantic and the Pacific Oceans? Hobson (1972) has put forth a plausible explanation. He states that the crepuscular period (coinciding with the interim period) before sunrise and sunset is a time of high activity by the piscivorous predators. The defensive mechanisms of the diurnal fish against predation (aposymatic coloring and schooling) become ineffective as light diminishes, and the fish are left defenseless. For this reason the diurnals must take shelter in the coral before the onset of this period. Since the larger diurnals have less to worry about, they are usually the last to take cover sometime after the juveniles and smaller diurnals are gone. The piscivorous fish are visual feeders and by approximately 30 minutes after sunset, they can no longer see to feed and cease their activity. Now the nocturnals emerge. During the morning crepuscular period, the nocturnals must take shelter and then for 20 minutes the piscivorous predators are active until approximately 10 minutes before sunrise. At this time light is sufficient for the defensive mechanisms of the diurnals to be effective. Once again the larger diurnals have less predation pressure and they are out before the smaller and juvenile diurnals. Hobson, in explaining why patterns of changeover should be similar in all reefs, states, "similar patterns of events in widely separated areas indicates a long evolution that in any one locality transcends the existing situation, even the existing species. Fish behavior reflects a historic threat from predators." (pp. 738, 739 1972).

By monitoring a fore-reef site at Discovery Bay, Jamaica, we can compare activity patterns here, with those of congeners studied by Hobson (1972) and Colette (1972) in Hawaii and the Virgin Islands. In this way we can test Hobson's hypothesis that the historic threat from predators transcends the local situation, leading to a pronounced sequence of cover seeking, interim period, and emergence. A qualitative picture of predation pressure can be achieved by observations. Finally, we can get some description of aspects of fish behavior related to the transition periods (ie. intrareef migration, vertical migration, courtship and mating of certain species.)

METHODS: Site selection was an important aspect of this project, and had to be determined before the start of the survey. The site had to be in an area of unobstructed view (e.g. a level topography), of reasonable depth to monitor vertical migration of planktiverous fish (> 18 ft) but not so deep that we would by limited by air supply and the decompression tables (< 30 ft), and finally, the site had to be of relatively easy accessibility.

We chose mooring 1 on the West Fore Reef as being the easiest to locate at night. By diving one afternoon off of Mooring 1, we came upon a suitable site (see figure 1) in the A. cervicornis zone at a depth of approximately 30 ft. The site was located about 60 feet southwest of the mooring. Using metered string attached to bottles we set up three markers on our site, one to the north, one to the west, and one to the east. Each meter on these markers was tied with a piece of marking tape, so that we could make quick estimates of height in the water column. In order to facilitate locating the site in the dark, we attached one end of a long rope to the base of the mooring and the other end was tied off to a coral, in the direction of our site, some 40 ft away from the mooring. By having a well-marked site to which we could return each observation period, we were able to become familiar with the "resident" species (see figure 1) and their locations. Knowing where each fish could be found allowed us to be precise on changeover times, at least fore these "residents." The drawback of continued observations at a single site is that we lose some of the species that are restricted in their distribution across the reef. We determined that the advantages of a single site outweighed the disadvantages, especially considering the limited time available for conducting this project.

It was also necessary to clarify the hours that our survey would be taken. Considering the limitations of underwater observation with SCUBA, we needed to select the times which would incorporate the extent of the transition periods both morning and evening. Referring to the work of Hobson (1972), we decided to set up our observations as a 1-hour period encompassing sunrise and a 1-hour period encompassing sunset. We would start 45 minutes before sunrise and end 15 minutes after sunrise. In the evening we started 15 minutes before sunset and ended 45 minutes after it. (sunrise and sunset times taken from the local paper.) According to Hobson these are the periods of active changeover. Our observations were all at least an hour in length, but they did not all conform to the aforementioned time schedule (See Table 1). We were, however, able to get a complete picture of the changeover by combining all our observations for the various survey periods.

The surveys were conducted as follows. In the boat, on the way to the mooring we would note weather conditions (wind, surf, and cloudiness). Once in the water, we

recorded entry and exit times to and from our survey site. On a couple of occasions we were unable to locate our survey site, and on these days we noted entry [and] and exit time in and out of the water. At our site we would achieve neutral buoyancy and float around at various heights in the water column. Using underwater notebooks, we noted the common names of the fish seen, the time seen, whether or not it was active or schooling, its height in the water column (mainly for the species which migrate vertically) or its location if it appeared to be a "resident" fish, and finally, any unusual behavior it might exhibit (mating or cleaning). Fish which we were unable to identify in the field we drew pictures of or described, so that we could work on the taxonomy back in the lab. Flashlights were carried so that we could find the site in the dark, and identify the fish seen during the dark periods of our survey. It must be noted that the use of flashlights could have the effect of scaring off the fish which are negatively phototactic. We were unable to do anything about this situation and the number of fish we missed as a result is not known. Night observation techniques of earlier observers are not described in the literature — we assume that they also used flashlights and had similar observational biases. We carried a Sekonic Auto lumi photographic light meter, enclosed in a watertight casing, to the study site, and periodically took light meter readings with the meter pointed at the surface. Using ASA 400, shutter speeds of 1/4, 1/125, and 1/250 we recorded the corresponding f-stops. To supplement the light meter readings, which were very crude at low light levels, we made qualitative statements in our notes referring to the time in the morning when we were first able to see to read without the use of our flashlights and the time in the evening when we could no longer read.

After completing our survey, we would return to the lab and transcribe all our observations chronologically into one notebook and phylogenetically into another notebook. In the phylogenetic listing, we recorded family, common name, last or first time seen, whether or not the fish was schooling and its height in the water column. The advantage of transcribing the notes immediately upon return is that you have images of the different fish you saw fresh in mind, which is helpful when it comes to identifying unknown species and describing behavior.

At the conclusion of all our survey periods we compiled our data to make up a master listing for both the morning and evening transition periods (see Tables 2+3). For each of the fish that exhibited a changeover, we determined a mean disappearance or emergence time from all the surveys combined. A mean changeover time for the diurnal fish and a mean changeover time for the nocturnal fish were determined for the morning and evening transitions. By converting all our light meter readings to those that corresponded with a shutter speed of 1/25 second, we were able to make a graph of light level vs. time (see Figures 2+3). Our qualitative remarks on ability or inability to read were used as constants for extrapolating the light level curves. We could then correlate mean changeover times for the diurnals and nocturnals to the light levels during the morning and evening transition period. (see figures 2+3)

The concluding step was to compare our general trends with those found in previous studies available to us. (Hobson 1972, Colette 1972).

SUMMARY AND
DISCUSSION: the transition periods can be summarized as follows:

Night to Day Transition

1) **Coverseeking of the nocturnals** - About 40 minutes before sunrise the cardinalfish begin descending down to the corals. By the time they reach a hieght of approximately a foot off of the coral most of the squirrelfish are gone, and by 15 minutes before sunrise there is little activity in the water column.

2) **Interim** - the quiet period only lasts for a short while (~5 minutes), for soon the early rising diurnals became active in the Acropora cervicornis. The serranids and the pomacentrids are the early risers active some 10 & 14 minutes before sunrise. The blue chromis and creole wrasse begin their rapid ascent into the water column about 5 minutes before sunrise.

3) **Emergence of the diurnals** - beginning with the schooling chromis and creoles, the diurnal fish become progressively more active, until soon after sunrise the hamlets, acanthurids, chaetodontids, juvenile pomacentrids, and the scarids all are active. The late risers among the diurnal fish are the wrasses, the blennies, the gobies, and the fairy basslet.

Day to Night Transition

1) **Coverseeking of diurnals** - the first diurnals to take shelter are the blennies some 20 minutes before sunset. The chromis begin to descend into the corals, as light becomes insufficient to maintain schools. Some of the hamlets begin to take cover and the juvenile wrasses and damselfishes take refuge. By sunset only the adult damselfish, the barred hamlet and the parrotfish are still active. The damselfish remain low in the coral and the parrots and hamlets are gone by 5 minutes after sunset.

2) **Interim** - activity is continued throughout this period by damselfish low in the coral until 20 minutes after sunset when the cardinalfish begin their ascent into the water column.

3) **Emergence of the nocturnals** - by 25 minutes after sunset the cardinalfish have reached 1 to 2 meters. Other nocturnal fish (squirrelfish, bigeyes, and croakers) begin to increase in visibility and activity. The squirrelfish are the most conspicuous of these other nocturnals; the other fish are more cryptic and easily missed.

The general nature of these trends should be kept in mind. Not all individuals of a species become active at once, with some species showing more variation than others.

These general trends compare well as far as which fish appear first and which appear last, and their order of appearence. It is easiest to compare our times of changeover with those found in the Tektite project (Collette and Talbott 1972), because they have many of the same species of fish (see Table 4). Considering the limited time span of our project and our unfamiliarity with the behavior patterns of some of the fish (especially the nocturnal ones); the similarity between our results and those of Collette and Talbott is striking. The morning transition is remarkably similar, with three notable exceptions: 1) our squirrelfish reduce activity by 15 min before sunrise, while in the Virgin Islands they are active until 35 min. after sunrise; 2) our yellowhead wrasses become active just before sunrise, while theirs waited till 40 to 50 minutes after sunrise; and 3) harlequin basses were active 20 minutes earlier at Discovery Bay. On the evening transition, diurnal fish as a whole tend to stay active ~10 min. longer than in the Virgin Islands. Even the bluehead, one of our earliest cover-seekers, stays out 20 minutes longer than bluehead observed by Collette and Talbot. This extended activity of the diurnal fish could be a reflection of reduced predation pressure here, indicating the local situation may not be dominated by historical evolutionary pressures as strongly as proposed by Hobson (1972, and others). Our interim periods are not as distinct as those described by Hobson, lasting about 5 minutes in the morning, and being rather hard to define in the evening, due to some activity overlap by diurnals and nocturnals (mean changeover times do differ by 20 minutes). It is worthwhile to note the Tektite project does not even mention an interim in the morning, although they did note it in the evening. Hobson also describes a "mass emergence of diurnals" in the morning and a "mass emergence of nocturnals" in the evening. The morning emergence was readily apparent in our observations, but the evening emergence was a more gradual process than that described by Hobson.

Other general trends which should be mentioned include longer activity of adults compared to juveniles. This held true for all the damselfish and wrasses except the bluehead, whose juveniles emerged with the laterising adults.

A number of fish were consistently seen at the same spot, indicating they had taken up temporary or permanent residence. Earlier authors (Lockhurst 1978) have said this may reflect competition for space, or high predation pressure. Notable residents included a pair of Yangs, a fairy basslet, a juvenile spanish hogfish, and a glasseye (see taxonomy section and map of site).

TAXONOMY + OBSERVATIONS

The following is a list, of all species seen, in phylogenetic order, with the guidelines followed for identification or lumping of difficult groups. This is followed by a short statement on abundance, behavior, and other interesting observations. A few species which are notably missing from our survey site are listed at the end of this section. Information on feeding habits is drawn from Randall 1968.

F. Dasyatidae

Yellowspotted stingray (Urolophus jamaicensis) Two of these rays were seen on our site. Their size was about 3 feet.

F. Torpedinidae

Lesser Electric ray (Narcine brasiliensis) The two individuals that we saw were distinguished by their round disk-like bodies with dark blotches and prominent side fins.

F. Synodontidae

Sand diver or lizardfish (Synodus intermedius) Two-three of these were seen on the sediment both day and night.

F. Muraenidae

Green moray (Gymnothorax funebris) One small individual was seen at the NW corner of our site (see Figure 1). A juvenile Bicolor damselfish was seen swimming right by the open jaws of this moray one morning. No morays were seen at night.

F. Holocentridae

This is a confusing family. The Blackbar soldierfish (Myripristis jacobus) is easily distinguished; a few small ones (3-5") were observed. The treatment of the genera Holocentrus, Flammeo, and Adioryx varies from author to author, and common names are sometimes switched. The so-called Longspine squirrelfish (Flammeo marianus in Randall 1968) is not listed in Chaplin and Scott 1972, and is most common "from 100-200 ft." (Randall p.50). So, aside from one Cardinal soldierfish (Plectrypops retrospinis) we lumped all others under the term squirrelfish.

The group as a whole is one of the most abundant nocturnal families. Squirrelfish may occasionally be seen during the day, but their activity starts increasing around sunset. At night we observed that they would venture further from their resting spots but rarely rise up higher than half a meter from the bottom. Activity was hard to gauge, as we were not familiar with this group's feeding behavior. (They feed mainly on crustaceans, according to Randall). As a result, our observed time of changeover for this group is probably later than it should be.

F. Holocentridae (cont.)

We found some evidence that squirrelfish occupy hiding spots in the day that are used by diurnal fish at night. One squirrelfish used a spot vacated by a Red hind, another went into a hole vacated by 3 striped parrots, after waiting at the opening for several minutes. Yellowtail damselfish and squirrelfish were often seen together in Millepora or Dendrogyra heads.

F. Fistulariidae

Blue spotted cornetfish (Fistularia tabacaria) Distinguished from the trumpetfish by a thin filament extending from tail. One 3.5 foot fish was seen in the morning. This fish is thought to be mainly piscivorous.

F. Aulostomidae

Trumpetfish (Aulostomus maculatus) Solitary individuals were regularly seen morning and evening, sometimes hanging vertically in the water. Seem to be active all the time.

F. Bothidae

Peacock flounder (Bothus lunatus) A one foot individual swam through the sand channel at our site one morning. It changed from its regular brown and blue spotted coloration to white with brown spots just seconds after touching the sand.

F. Apogonidae

We did not distinguish between the 20-odd species of cardinalfish shown in Boike and Chaplin. These are another major group of nocturnal fish, We noted the vertical migration of these fish up into the water column replacing the chromis as a plankton feeder. (fig. 4) We noted the appearance of small fish (1") and larger fish (2-3").

Cardinalfish were seen mainly over heads of M. annularis and other massive corals. Very few cardinals were noted rising out of the A. cervicornis which was in greater abundance at our site (see figure 1)

F. Emmelichthyidae

Boga (Inermia vittata) This identification is somewhat tentative. This fish most closely resembles the schools of silvery bluish thin fusiform fish observed often in the morning and the evening, but not in the day. Solitary fish were quite common before the morning transition. As these fish avoid light, a clear view was hard to come by.

F. Serranidae

Coney (Cephalopholis fulva)
Graysby (Petrometopon cruentatum)
Harlequin bass (Serranus tabacarius)
Red Hind (Epinephelus guttatus)

F. Serranidae

Tiger grouper (*Mycteroperca tigris*)
Barred hamlet (*Hypoplectrus puella*)
Indigo hamlet (" *indigo*)
Black hamlet (" *nigricans*)
Butter hamlet (" *unicolor*)
Shy hamlet (" *guttavarius*)

The sea basses and hamlets are diurnal and carnivorous. The hamlets will be given special attention as many interesting observations were made on this little known genus. The first 5 species listed above are generally cryptic and unobtrusive. For this reason, their first and last recorded times sighted may differ somewhat from when they were active. They are generally single, although pairs of Coney were seen and the Harlequins were often in pairs. One morning, a Red Hind was observed to be completely motionless hugging the side of a coral hole 17 minutes before sunrise. A squirrelfish was in the vicinity in the open. Five minutes later, the squirrelfish was exactly where the Hind had been. However, after sunrise, the squirrelfish was also gone, perhaps because the spot was too exposed.

Five species of hamlets were seen on the site. While densities are hard to calculate, it was clear that our site had hamlet densities several orders of magnitude higher than those observed by Barlow (1975. Barred hamlet density 1 per 166 m^2, Black & Yellowtail hamlet density 1/500 m^2, no Indigo hamlets observed). Our site was roughly 200 m^2, and as many as 6-12 Barred hamlets, 3-7 Black hamlets and 3-5 Indigo hamlets were seen in one observation period.

Interactions observed:

Morning — A Barred hamlet was seen chasing an Indigo
a Butter
a Shy

No aggression was seen between a Butter and an Indigo which were 1.5 ft apart
No aggression was seen when a Barred confronted a 3-spot damsel. A Shy, Barred, and Black hamlet were all seen exhibiting territorial twitching behavior.

Evening — A Barred hamlet was seen chasing a Barred and an Indigo was seen to exhibit territorial behavior towards observer.

F. Serranidae (cont.)

These observations support Barlow's statement that territorial spacing is achieved by interspecific aggression, but the occurrence of a Butter and an Indigo hamlet in close proximity show that such aggression does not always occur.

Reproduction: Pairs of Barred, Black, and Indigo hamlets were observed mainly occuring during the evening. Five matings of the Barred Hamlets were observed all in the evening. Barred hamlet was not seen by Barlow so we describe an interesting observation. Mating began with a pair of hamlets coming together at dusk. In this pairing, one individual was of a darker banding than the other. Courtship began with a synchronous dance of the pair. Both fish would make exactly the same waving and twisting motions. Copulation was initiated by the darker individual as it rose above the coral surface where the dance took place. The lighter individual would rise up and the pair would intertwine in coitus. This position was held for only a few seconds then both fish would drop back to the coral. At this point the two fish depart, or, as was once observed, the banding pattern is shifted between individuals and once again the courtship dance is begun this time though, the other individual (the new dark one) initiates coitus.

This mating pattern was first described by (Clark 1956, 1965) for another synchronously hermaphroditic serranid, Serranus subligarius. This mating has probably been described for Hypoplectrus puella, although we have not found any such description in the available literature.

Some comments on Thresher's (1978) hypothesis are pertinent. According to his theory on hamlet mimicry, hamlets gain a selective advantage by mimicking non predaceous fish (aggressive mimicry). His proposed models are Black hamlet ⇔ Dusky damselfish, Shy Hamlet ⇔ Rock beauty, and another possible one is Butter hamlet ⇔ 4-eye Butterflyfish. At our site the mimics do parallel their models in proportional abundance, but occur in nearly equal numbers. While our qualitative data is too weak to substantiate or refute Thresher's hypothesis, a more obvious factor controlling relative densities among hamlets is the greater aggressiveness of the Barred hamlet, which was the most abundant species on our site.

F. Grammistidae

Spotted soapfish (Rypticus subbifrenatus) One individual was seen. It is recognized by its peculiar body shape.

F. Grammidae

Fairy basslet (Gramma loreto) One individual was regularly seen under a rock near the northmarker (see figure 1).

F. Priacanthidae

Glasseye or Glasseye snapper (Priacanthus cruentatus) brownish barred or dull red
Bigeye (Priacanthus arenatus) bright red
The Glasseye is a large (6-7") nocturnal fish that was infrequently seen. They would usually appear at predictable resting sites (see figure 1). These fish were not seen during the day.

F. Carangidae

Bar jack (Caranx ruber)
Horse-eye jack (Caranx latus)
Rainbow runner (Elegatis bipinnulatus)
These large piscivorous predators were seen from well before the transition throughout the day into early evening. Small individuals were seen weaving slowly through the Blue chromis schools at dusk. Others were observed waiting to be cleaned by a juvenile Spanish hogfish (midday). Of these three jacks, the Bar jack was by far, the most common with the identification of the Horse-eye jack being tenuous.

F. Lutjanidae

Yellowtail snapper (Ocyrus chrysurus). A few of these predators were seen, usually in the dim lighting of the crepuscular period.

F. Pomadysidae

French grunt (Haemulon flavolineatum) Two of these fish were seen in an inactive school of Yellow goatfish.

F. Sparidae

Porgy (Calanus sp.) Several large (2-3 ft) individuals were seen passing through our site. (These fish feed on large invertebrates such as urchins).

F. Sciaenidae

Reef croaker (Odontoscion dentex) This inconspicuous brown fish was seen more often after familiarity with the site was achieved by the observers. It is nocturnal and of medium size (6-10"), with a prominent black spot at the base of the pectoral fin.
Spotted drum (Equetus punctatus) One juvenile was seen in the evening.

F. Mullidae

Spotted goatfish (Pseudupeneus maculatus) Only occassionally seen, bottom feeding.
Yellow goatfish (Mulloidichthys martinicus) The fish was commonly seen, often in feeding groups at certain sites (see Figure 1) and sometimes in large inactive schools.

F. Chaetodontidae

Rock beauty (Holacanthus tricolor) One individual was seen, not at our site.
Four-eye butterflyfish (Chaetodon capistratus) This fish was regularly seen at our site (see Figure 1) possibly the same one or two fish.

F. Pomacentridae

Three-spot damselfish	(Eupomacentrus planifrons)
Bicolor damsel	(" partitus)
Dusky damsel	(" fuscus)
Cocoa damsel	(" variabilis)
Beaugregory	(" leucostictus)
Yellowtail damsel	(Microspathodon chrysurus)
Blue chromis	(Chromis cyanea)
Brown chromis	(Chromis multilineata)

These abundant early-rising small diurnal fish are not without their taxonomic difficulties. Completely dark fish are called Duskies; they usually have a purple-rimmed anal fin. These fish are hard to distinguish, in poor light, from 3 spots, Cocoas, and Beaugregories, so their periods of activity may be overestimated. Three-spots are generally lighter around the head, with a yellow eye ring; some individuals have a dark "mask" through the eye region (this may be a color change). Three-spots are one of the most common damsels and are by far the most aggressive. One was observed chasing a 2½ foot trumpetfish and they commonly confront 6 foot divers. This aggressiveness wanes with diminishing light levels. Juvenile 3-spots come out later and go in earlier than the adults and they are not territorial.

Yellowtails are easily identified by their tail; they are larger than other damsels, and may have light or dark bodies. One light individual was seen courting a darker individual. No juvenile yellowtails were seen.

Bicolor damsels are another common damsel that's easily identified. They remained low in the A. cervicornis throughout the day. The juveniles of this species were out almost as early as the adults and a good deal of time before the juveniles of other damsels.

Cocoas and Beaugregories were often lumped in our notes. The marks we used to separate them were the black saddle on the dorsal pedunele of the Cocoa and the thinner body of the Beaugregory.

The chromis are planktivorous and schooled high in the water column throughout the day. The two species were usually lumped, as Chaplin and Scott show forms of C. cyanea that are very similar to C. multilineata in color. A white spot at the base of the dorsal

F. Pomacentridae (cont,)

fin was used to identify C. multilineata.

The chromis began to emerge from the A. cervicornis and coral mounds around 10 minutes before sunrise. Small schools of 8-25 individuals gradually formed and moved ~3 feet off the bottom, picking up individuals as they went. At this time, a school would sink back down into the coral when approached by an observer. By 5-8 minutes after sunrise, schools of 50 or more chromis would start to migrate vertically up to 6-9 ft in the water. By 15 minutes after sunrise hundreds of fish were in the schools, with some stragglers still emerging from the coral.

In the evening, the schools descended and broke up at higher light intensities than those during which the schools were formed. Around an half hour before sunrise the schools began descending and shrinking in number. By 20 minutes before sunset, schools of 20-40 individuals were about 3 feet up in the water column. By 10 minutes before sunset, the schools had diffused and only a few individuals were still visible just above the coral.

Schools of juvenile chromis were observed to restrict their movements to the immediate area of their shelter site, a massive coral head (see figure 1).

F. Labridae

Yellowhead wrasse (Halichoeres garnoti)
Blufhead " (Thalassoma bifasciatum)
Creole " (Clepticus parrai)
Clown " (Halichoeres maculipinna) red bands on head
Spanish hogfish (Bodianus rufus)

This familiar group includes some rather interesting behavior. The young are more difficult to identify than the adults. Yellowhead juveniles are yellow with a blue lateral line and varying shades of purple above it. As they mature, the blue stripe may be lost. Bluehead juveniles are yellow with varying amounts of black striping, but they always have a black dot on the dorsal fin. Both the adult and juvenile bluehead were late risers, and both went under cover early in the evening.

Creole wrasses are notable for their pronounced intrareef migrations. These fish would form large schools heading east in the morning and going west in the evening.

A few Clown wrasses were seen, others were probably not identified.

A juvenile Spanish hogfish was observed several times on the southern border of our site (see figure 1). It operated as a cleaning fish and was seen cleaning several Bar Jack during one survey.

F. Scaridae

Striped parrotfish (Scarus croicensus)
Redband parrotfish (Sparisoma aurofrenatum)
Stoplight parrot (" viride)
Queen " (Scarus vetula)
Princess " (Scarus taeniopterus)
Blue " (Scarus coeruleus)

These common herbivores were not always identified to species. Many juveniles and females are similar to the Striped parrot; so its numbers may be overestimated. Even so, this was the most common scarid.

Redbands have a white saddle at the base of the dorsal fin. (common)

Queen and Princess parrots are differentiated by the greater degree of bifurcation of the Queen parrot's caudal fin. Both of these were rare at our site.

Stoplights are distinctive and quite common.

Blue parrots were at first confused with the Creole wrasses. It was finally determined that only one blue parrot had been seen; a supermale with the blunt forehead.

Juvenile parrotfish were only noted during the day.

F. Blennidae

The Redlip Blenny (Ophioblennius atlanticus) This was the only blenny positively identified. Others ranging from 1-3.5 inches, probably in the family Clinidae, were often seen on massive corals.

F. Scombridae

Cero (Scomberomorus regalis?) A few mackerals were seen near the site. None were positively identified but this species is the most common one seen on tropical reefs.

F. Gobiidae

Gobies Another very difficult group, vastly oversimplified in the underwater guides. Bolke and Chaplin list 43 species. We commonly saw small (1") yellow and black striped gobies on brain corals. These fish were also seen cleaning chromis and parrotfish (see figure 1).

F. Acanthuridae

Ocean surgeon (Acanthurus bahianus) A lack of barring distinguishes this fish from the related Doctorfish. A couple of these fish were seen at our site.

Blue tang (Acanthurus coeruleus) A pair of Blue tangs were seen in or around a large hole in a M. annularis mound every observational period (see figure 1). It might be worthwhile to mention that no other tangs were seen in the area during our surveys.

F. Balistidae

Black durgon (Melichthys niger) A pair of these fish was seen once during the survey

F. Monocanthidae

Tail-light or orange spotted filefish (Cantherhines pullus) One 4" individual was seen. The swimming pattern and white spot at the base of the dorsal fin are distinctive.

F. Ostraciidae (= Ostracionidae)

Smooth trunkfish (Lactophrys triqueter) one individual seen low in coral.
Spotted trunkfish (Lactophrys bicaudalis) two individuals seen
These peculiar little fish were seen several times. The Smooth trunkfish has larger more irregular spots than the Spotted. These fish are triangular in cross-section and swim quite slowly near the coral surface.

F. Tetraodontidae

Bandtail puffer (Sphaeroides spengleri) This fish was seen twice and was distinguished from the sharpnose puffer by its flatter profile and ventral row of spots.

F. Canthigasteridae

Sharpnose puffer (Canthigaster rostrata) This very common fish was seen very early in the morning until late in the evening. According to Randall, they may eat anything from algae to polychaetes, crustaceans, and urchins. We observed these fish being chased by Three-spot damsels.

Species of Fish Notably Missing from our Survey Site.

F. Serranidae

Tobaccofish (Serranus tabacarius). Although none of these colorful fish were present at our site a pair was seen about 100 feet from the site one morning.

F. Pomacentridae

Sergeant major (Abudefduf saxatilis) This fish species has been noted for its patchy distribution along this reef (Bill Carlsen, personal communication).
Yellowtail damselfish juveniles none of these distinctive purple fish were found, although juveniles of all the other pomacentrids and labrids were observed.

F. Labridae

Slippery Dick (Halichoeres bivittatus) The juveniles of this species may have been missed due to its resemblance to striped parrots, but this is unlikely for the more colorful adults.

OBSERVED FISH TOTALS

FAMILIES - 33 SPECIES - 66

Damselfish (excluding chromis) and serranids didn't move about, as did the adult wrasses and the parrotfish, neither of which were observed holding territories.

A few instances of nocturnal and diurnal fish sharing hiding places were observed (see Taxonomy-squirrelfish, red hind), but we have no solid measure of this overlap.

In conclusion, we have seen that our observations share many trends with previous surveys. We have shown in a limited manner the sequence of events which make up the morning and evening transitions between diurnal and nocturnal fish for a Jamaican reef, and we have provided a detailed phylogenetic analysis of all the fish seen noting identification marks, interesting behavior and movements. Hobson's statement about the predictability of sequential turnover was borne out, but the effect of a historic predation threat on this transition isn't as evident as Hobson has indicated (1972, p 738). Examination of other reefs (or fish communities which might be isolated from predation, like the mangrove area west of the Marine Lab dock), with some quantification of predation pressure, would test this hypothesis more fully.

MORNING CHANGEOVER

Sunrise = 0625

TABLE 2

CHANGEOVER TIMES

FISH by common name	SATURDAY 2/23	TUESDAY 2/26	WEDNESDAY 2/27	THURSDAY 2/28	$\bar{x}$ time
NOCTURNAL					
Squirrelfish	0615 ✓	0612	0613	0618	0614
Cardinalfish	0605 ✓	0608	0612	0615	0610
Reef croaker	—	—	—	0616	0616
Glass eye snapper	—	—	0613	0620	0617
DIURNAL					
Bar jack	0620	0624	0602	0636	0621
Harlequin bass	0640 ✓	0635	0629	0646	0637
Coney	0640	0624	0632	—	0632
Graysby	0700	0612	0645	0600	0629
Red hind	—	—	0618	0618	0618
Indigo hamlet	0701	0612	0640	0624	0634
Barred hamlet	0622 ✓	0613	0618	0615	0617
Butter hamlet	—	0617	—	0657	0637
Shy hamlet	—	—	0648	—	0648
Black hamlet	—	0629	0637	0628	0631
Fairy Basslet	—	0650	0644	0643	0646
Boga	—	0553	0605	0553	0557
Porgy	—	0620	0611	0650	0627
Rock beauty	—	—	0656	—	0656
Four eye butterflyfish	0633 ✓	0623	0638	0625	0630
Blue chromis adult	0627 ✓	0623	0624	0620	0623
juvenile	—	—	—	0629	0629
Bicolor damsel adult	0622	0613	0611	0618	0616
juvenile	—	—	—	0618	0618
3-spot damsel adult	0621 ✓	0612	0612	0616	0615
juvenile	—	0616	0644	0637	0632
Dusky damsel adult	0620	0617	0616	0611	0616
Yellowtail damsel adult	0620	0606	0611	0616	0612
Beaugregory	—	0634	0649	0617	0633
Cocoa	0635	—	0700	—	0647
Bluehead wrasse adult	0702 ✓	—	0642	0642	0642
juvenile	0645	0640	0642	0637	0641
Yellowhead wrasse adult	0627	0630	0630	0626	0628
juvenile	—	0634	0640	0643	0639
Creole wrasse	0625	0623	0624	0621	0623
Clown wrasse	—	—	0659	0700	0700
Spanish hogfish	—	—	—	0649	0649
Stoplight parrotfish	0636	0616	0622	0615	0622
Striped parrotfish	0632	0627	0624	0627	0628
Redband parrotfish	0640	0626	0629	0641	0634
Blennies	—	0650	0647	0630	0642
Cleaning goby	—	0630	0645	0641	0638
Blue tang	0627	0623	0640	0634	0631
Ocean surgeon	—	0650	0706	—	0658

Mean Appearance time of all diurnals 0634 ± 12 min.

Mean Disappearance time of all nocturnals 0614 ± 3 min.

Sunset = 6:13

TABLE 3

EVENING CHANGEOVER

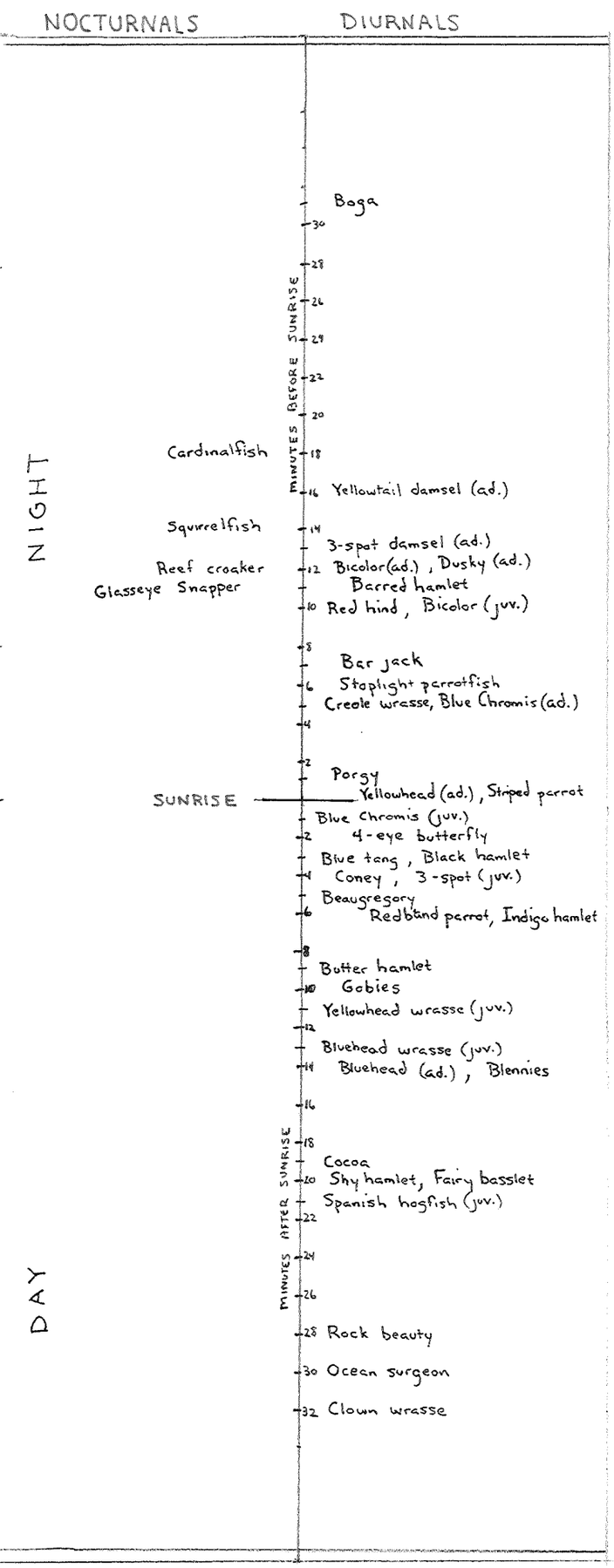
CHANGEOVER TIMES

FISH by common name		SATURDAY 2/23	SUNDAY 2/24	TUESDAY 2/26	WEDNESDAY 2/27	$\bar{x}$ time
NOCTURNAL						
Black-bar soldierfish		—	1841	—	1748	1815
Squirrelfish		1829 ✓	1835	1827	1826	1829
Cardinalfish		1823 ✓	1842	1839	1833	1831
Glasseye snapper		1827	—	1831	1829	1829
Yellowtail snapper		1812	1816	1816	1735	1815
Reef croaker		—	1840	—	1813	1826
Spotted drum		—	1830	—	—	1830
Bigeye		1847	—	—	—	1847
Boga		1838	1841	1834	—	1838
DIURNAL						
Bar jack		1809 ✓	1810	1752	1820	1807
Harlequin bass		—	1810	1821	1747	1806
Tiger grouper		1847	—	—	1818	1832
Coney		1805	1809	1810	1750	1804
Graysby		—	—	—	1754	1754
Black hamlet		—	—	—	1759	1759
Barred hamlet		—	1823	1817	1810	1817
Indigo hamlet		—	1745	1755	1814	1758
Butter hamlet		—	—	1803	—	1803
French grunt		—	—	—	1737	1737
Porgy		—	—	613	—	1813
Four-eye butterflyfish		1809 ✓	1808	1816	1809	1809
Blue chromis	adult	1812 ✓	1811	1808	1759	1807
	juvenile	—	—	—	1800	1800
Bicolor damsel	adult	1821	1828	1825	1824	1824
	juvenile	—	—	—	1808	1808
Yellowtail damsel	adult	1818	1828	1825	1830	1825
Three-spot damsel	adult	1828	1838	1833	1830	1832
	juvenile	—	1752	—	1754	1753
Dusky damsel	adult	1822	1830	1807	1800	1820
Beaugregory		—	—	—	1748	1748
Cocoa damsel		1805	—	—	1807	1806
Bluehead wrasse	adult	—	1801	—	1800	1801
	juvenile	—	1757	—	1758	1758
Yellowhead wrasse	adult	1812	1813	1821	1812	1814
	juvenile	—	1800	—	1755	1758
Creole wrasse		1812	1816	1810	1759	1809
Stoplight parrotfish		1818	1819	1835	1814	1821
Striped parrotfish		—	1811	1820	1819	1817
Redband parrotfish		1800	1806	1821	1746	1809
Blennies		—	—	—	1749	1749
Cleaning gobies		—	—	—	1759	1759
Blue tang		1817 ✓	1827	1817	1807	1817
Black durgon		—	—	—	1741	1741
Cero		—	—	—	1737	1737

mean disappearance time for all diurnals 1809 ± 11 min.

mean appearance time for all nocturnals 1829 ± 10 min.

Changeover times of Individual Fish with Respect to Sunrise and Sunset
Summary of Tables 2 and 3.



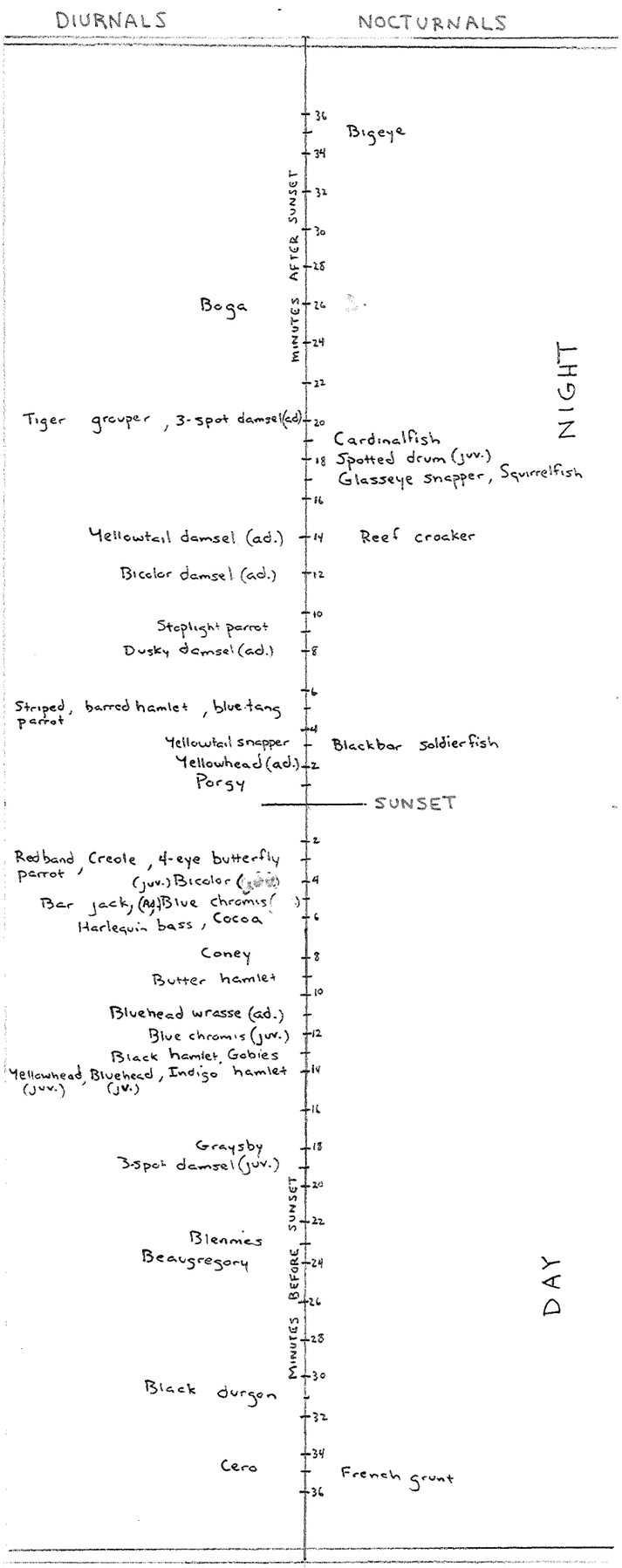


TABLE 4

CHANGEOVER TIMES

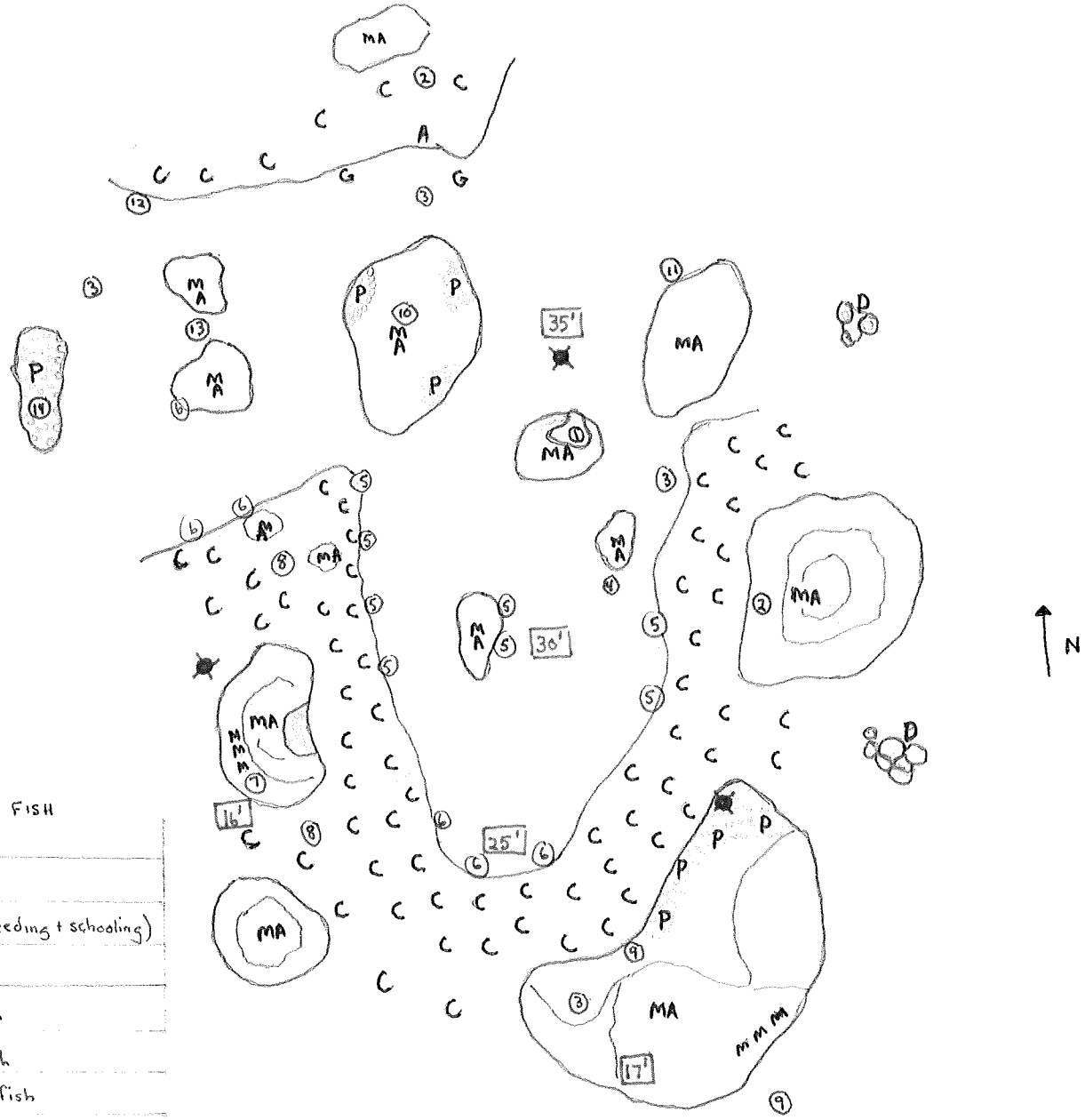
Common Fish Observed	Tektite Morning		Woessner+Hunt Morning	Tektite Evening		Woessner+Hunt Evening
Squirrelfish	0645		0614	1810		1829
Barred hamlet	0555	*	0617	1716-1815	*	1817
Bluehead wrasse	0605-0635	*	0642	1715-1745		1801
Yellowhead wrasse	0650-0700		0628	not seen		1814
Blue tang	0600-0610	*	0631	1750-1815	*	1817
Harlequin bass	0646		0637	1745		1806
4-eye butterflyfish	0540-0610	*	0630	1720-1815	*	1809
Coney	0555-0615	*	0632	1810		1804
Graysby	0555	*(?)	0629	1820		1754
3-spot damselfish	0545-0605	*	0615	1730-1815		1832
Cocoa damselfish	0540-0625	*	0647	1725-1740		1806
Bicolor damselfish	0550-0605	*	0616	1745-1815	*	1824
Yellowtail damselfish	0540-0610	*	0612	1730-1800		1825
Blue chromis	0550-0605	*	0623	1700-1745		1807
Bar jack	0604	*	0621	1746		1807
Striped parrotfish	0600-0635	*	0628	1720-1800	*	1817
Redband parrotfish	0600-0635	*	0634	1745-1800	*	1809
Stoplight parrotfish	0555-0620	*	0622	1729		1821
	Sunrise 0610		Sunrise 0629	Sunset 1805		Sunset 1812

* indicates similar changeover times with respect to sunrise and sunset.

Figure 1

Map of Survey Site

Location: ~60 ft. S.W. of mooring 1 West Fore Reef



Locations of resident fish

1. Pair of Blue tangs
2. Glasseye Snapper
3. Yellow goatfish (feeding + schooling)
4. Black hamlet
5. 3 spot damselfish
6. Bicolor damselfish
7. Yellowtail damselfish
8. Cleaning gobies station
9. Spanish hogfish
10. Barred hamlet
11. Fairy basslet
12. 4-eye butterflyfish
13. Juveniles of Bluehead + Yellowhead
14. Green moray

Key to corals

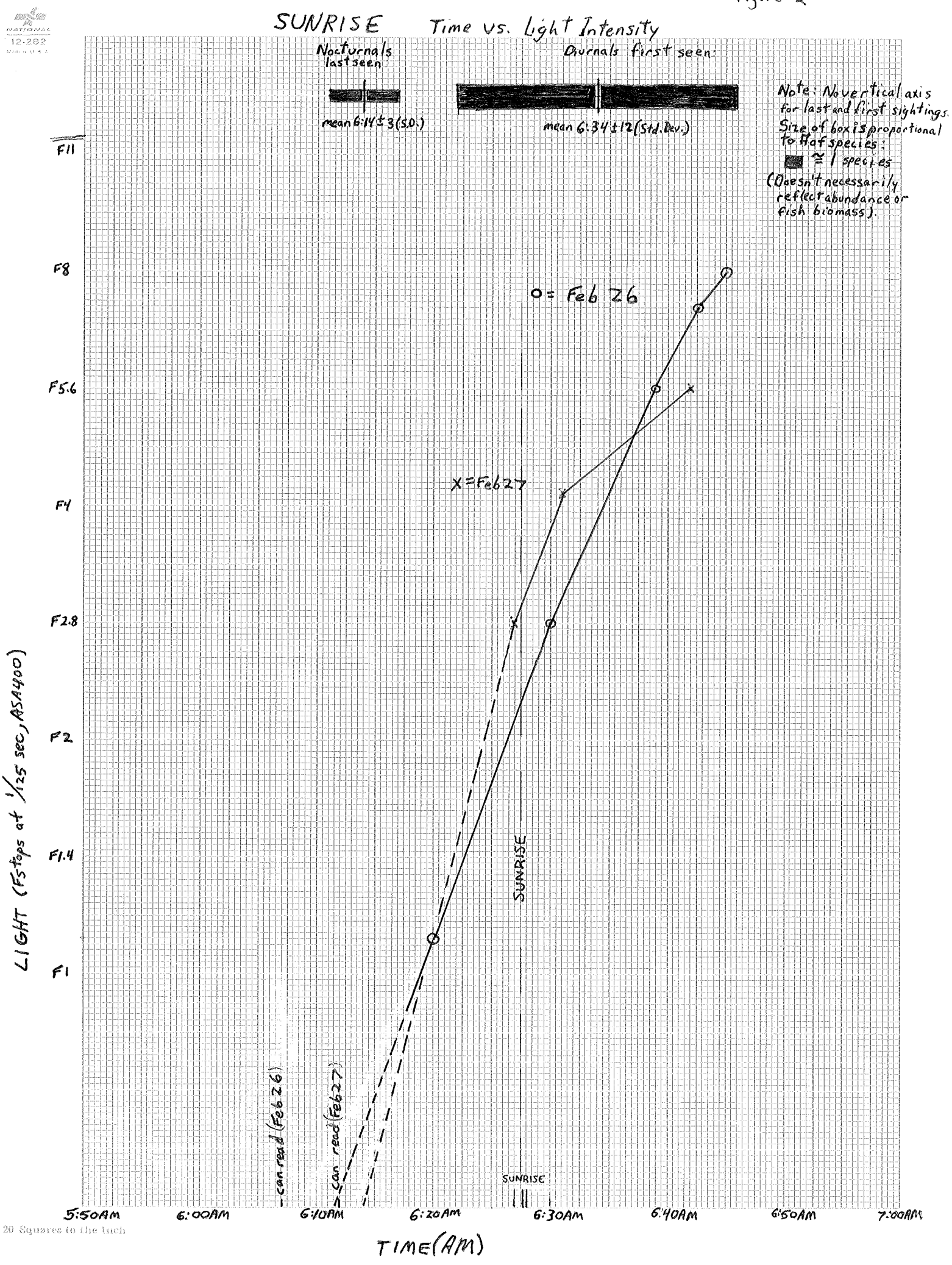
- A - Agaricia
- C - Acropora cervicornis
- D - Dendrosyra
- G - Gorgonia
- MA - Montastrea annularis
- M - Millepora
- P - Porites porites

GENERAL INFORMATION

TABLE 1

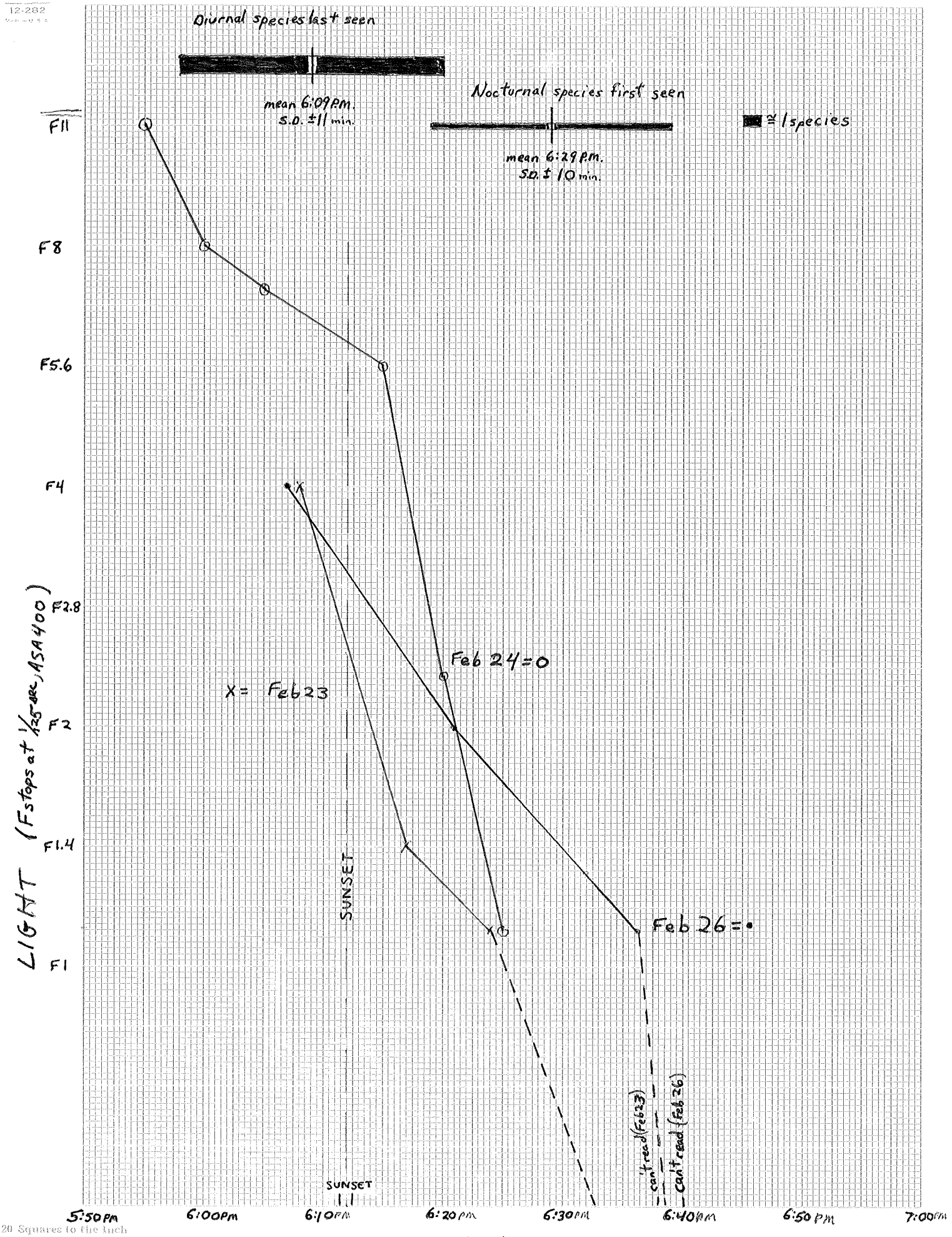
DAYS OF OBSERVATION		HOURS OF OBSERVATION	TIME OF SUNRISE	TIME OF SUNSET	WEATHER CONDITIONS
SATURDAY	A.M.	0600-0705	0630		calm water clear skies
2/23	P.M.	1800-1853		1811	turbid water cloudy skies
SUNDAY	A.M.	———	0629		———
2/24	P.M.	1745-1845		1812	Clear skies windy
TUESDAY	A.M.	0550-0655	0628		calm clear starry night
2/26	P.M.	1737-1845		1812	Choppy surf clear skies
WEDNESDAY	A.M.	0600-0703	0628		Pouring rain
2/27	P.M.	1733-1838		1812	Choppy surf Partly Cloudy
THURSDAY	A.M.	0550-0701	0627		stars out little wind big swells
2/28	P.M.	———		1812	———

Figure 2



SUNSET Time vs. Light Intensity

Figure 3



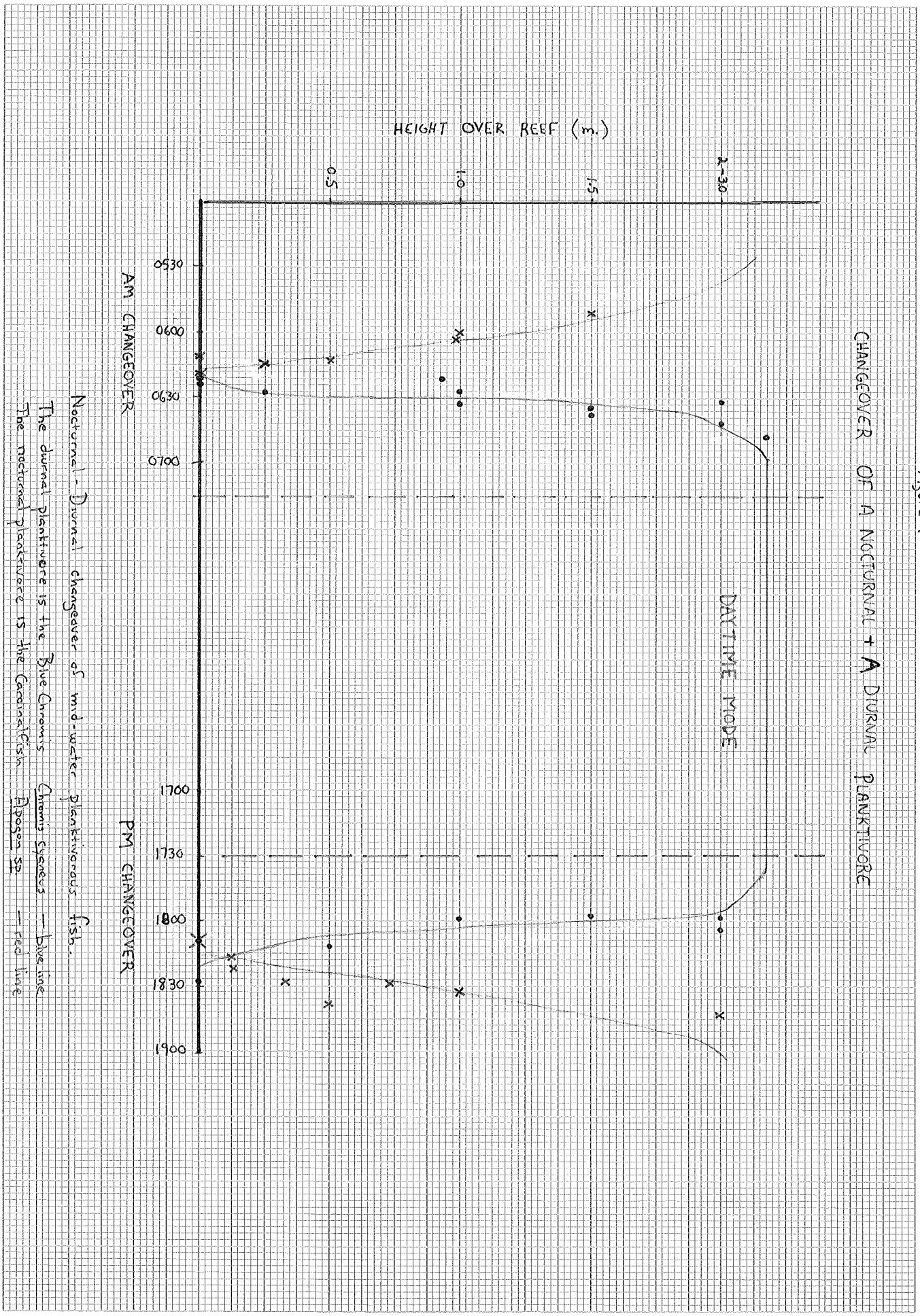


Figure 4

CHANGEOVER OF A NOCTURNAL + A DIURNAL PLANKTIVORE

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* These articles weren't available to us.