A SURVEY OF THE FISH RESOURCES OF SAIPAN LAGOON

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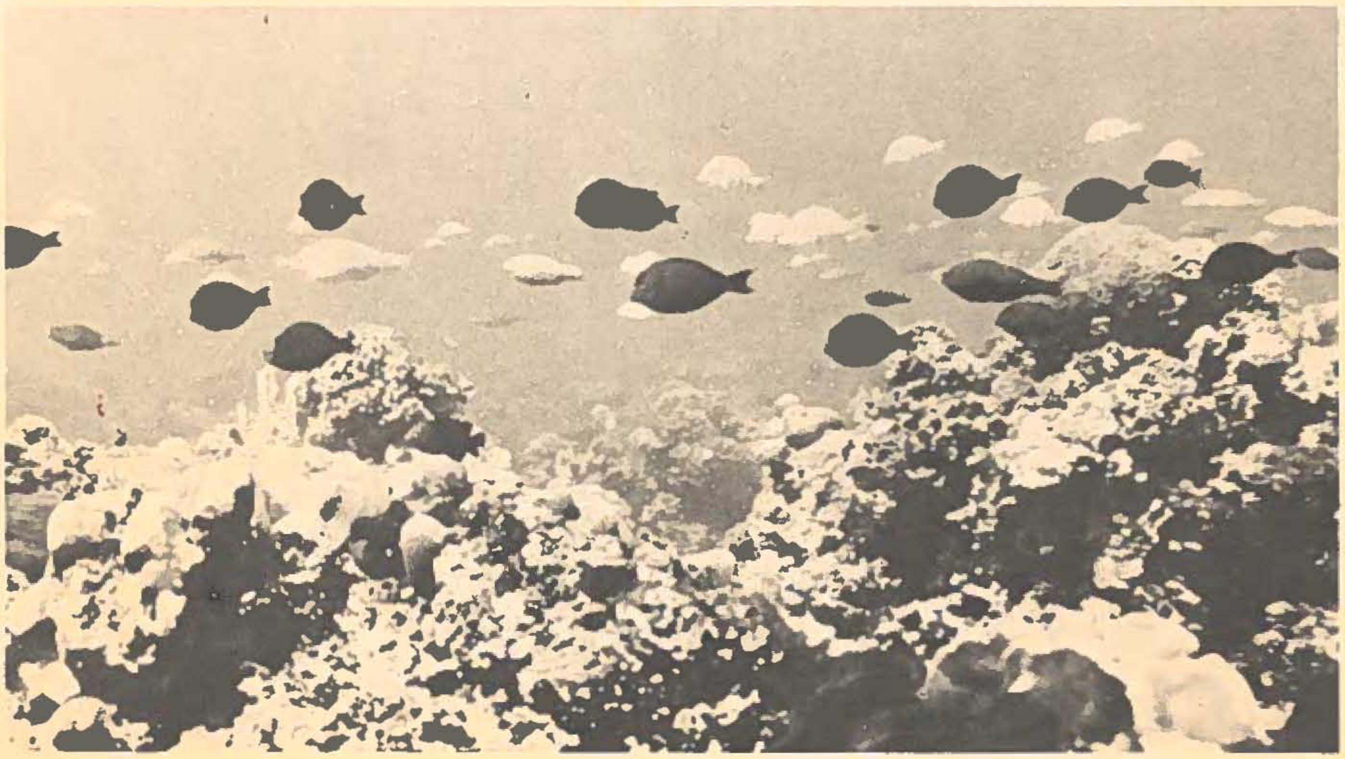

UNIVERSITY OF GUAM MARINE LABORATORY

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A SURVEY OF THE FISH RESOURCES

OF SAIPAN LAGOON

By

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INTRODUCTION

PURPOSE

The fish resources of tropical island reefs have historically provided island inhabitants with much of their protein food supply. As island economies undergo a process of westernization, and imported foodstuffs become more available and more heavily utilized, the importance of reef fish resources is often overlooked. Shoreline developments which involve release of effluent materials onto the reef or dredging and filling of marine habitats are frequently designed and undertaken without sufficient understanding of their potential impacts on reef fish populations. Recently there has developed a greater appreciation of the importance of reef fishery potential among planners and administrators of many tropical island communities, and the need for information upon which informed decisions can be made has been felt.

One of the major difficulties in understanding the dynamics of reef fish populations and in developing effective management policies has been the great variety of fish species present in tropical reefs, and the variety of habitats for fish which reefs provide. Classical approaches to fishery management have been developed over many years in temperate and boreal continental shelf environments where habitats are more or less uniform over great expanses and where a relatively small number of species are exploited. The long periods of time and the considerable financial investment that have gone into research on these temperate and boreal fish stocks is not available to fisheries management in tropical islands. Johannes (in press) has articulated the need for rapid and inexpensive methods of fish stock assessment in the tropics and has pioneered some methodology for achieving these goals. The research described in this report is another approach to the problem of fisheries management in tropical islands.

Saipan Lagoon is a typical high-island barrier reef lagoon. It covers an area of approximately 35 million m^2 and contains a variety of habitat types. A study of the geology and sediment distribution within the lagoon was prepared by Cloud (1959). Doty and Marsh (1977) carried out a detailed, year-long environmental study of the area surrounding the power barge Impedence. Fish distributions within their study area were investigated, but management of fishery stocks was not addressed.

The approach of the present study has been to determine the distribution and abundance of resource fishes among the various habitats within Saipan Lagoon. The average "turn-over time" for the various fish groups has been estimated from published studies, and this information is used to estimate annual harvest potential for the lagoon as a whole. Plankton tows have been used to dtermine areas of fish egg and larvae concentrations, indications of fish breeding and nursery grounds.

Planners can use the information in this report to aid them in locating potentially deleterious activities, such as dredging, filling, and waste disposal, in areas where damage to highly productive or unique environments will be minimized. Fisheries managers can use the estimates of harvest potential to make best use of underutilized resources and, if necessary, to take steps to protect overharvested fish resources.

SCOPE OF WORK

The investigations reported herein were carried out under contract no. S79-02 with the Coastal Zone Management Program of the Government of the Northern Mariana Islands. We were requested to provide the following services:

A. Conduct surveys of the lagoon to count and identify fish species and populations. To the extent possible, the fish surveys should be coordinated with other studies on algae, marine invertebrates, and corals in the lagoon.

B. Prepare a list of species found, their locations, relative abundance, and any other relevant factors.

C. Provide a map showing survey locations and generalized distribution of fishes.

D. Conduct a field survey of the abundance and distribution of the eggs and larvae of fishes to identify areas of possible importance as breeding grounds and nursery areas.

E. Conduct fish surveys and areas which have been damaged through destructive fishing practices (e.g. chlorox, dynamite) and other areas of particular concern identified by the CZM coordinator.

F. Insofar as is possible, provide information on the potential fish yield of the various areas surveyed and recommendations for protection of habitats and endangered species at all stages of their life cycles.

ACKNOWLEDGEMENTS

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METHODS

The Saipan Lagoon surveys were carried out from January 2 to 8 and January 24 to 29, 1979. Fish censuses were performed in the following manner. Twenty-four habitats within the lagoon and on the seaward side of the lagoon barrier reef were censused. At each location, three investigators swam through the water with snorkeling or scuba gear, as appropriate, making two 10-minute counts of 22 categories of potentially economically important fishes (see Results Section for categories). After the two 10-minute counts, another 10 to 20 minutes were spent by each investigator in making as complete a list as possible of all fish species in the habitat. The six 10-minute counts from each habitat were averaged. By swimming a measured line at approximately the same speed that the censuses had been swum, and estimating the distance over which the various categories of fishes could be recognized, we determined the average area covered by a 10-minute census to be 2,000 m^2. From these data we were able to estimate the density per m^2 of each category of fish in each habitat type. By examining aerial photographs of the lagoon, consulting the map produced by Cloud (1959), and using our own field information and photographs, we mapped the 24 lagoon habitats. A planimeter (Keoffel and Esser Company) was used to measure the area of each habitat on the map, and this was converted to actual area in m^2. With this data we were able to compute the estimated total number of fish of each category in each habitat. Summing all the habitats gave us an estimate of the total number of fishes in each category for the whole lagoon study area.

In order to locate areas of fish spawning and nursery areas for larval fishes, we made 17 horizontal surface tows in various parts of the lagoon (Figure 1) with a 50 cm diameter conical zooplankton net with mesh size of .35 mm. Tows were 5 minutes in duration (Table 4). and were made at a speed of approximately 1 m/sec. Each tow, then, sampled about 59 m^3 of water. All tows were made in the daytime. Samples were preserved in 5-10% formalin and returned to the laboratory where counts were made of the various planktonic organisms in the samples (subsampling was done on some large samples). From these data we were able to calculate density per m^3 of fish eggs, fish larvae, and other zooplankters in the lagoon waters.

RESULTS AND DISCUSSION

FISH HABITATS IN THE SAIPAN LAGOON STUDY AREA

Twenty four habitats were designated within the study area (Maps 1a-e). In the listing below, the habitats are described and the occurrence of economically valuable fishes within them is summarized. Detailed density estimates for fish categories within each habitat are given in Table 1.

Habitat 1 -- (Plate 1A) This consisted of a single small embayment east of Charlie Dock which was surrounded by mangrove trees, the only area of mangrove growth in the lagoon. The water was shallow, approximately 0.5 m, and the substrate was fine silt. An inflow of fresh water could be detected, and visibility was poor, less than two m. Few fishes of any kind were seen here, but it was the only area where mullets were seen during the censuses counts, although there were incidental sighting of mullet in habitats 3 and 23. Habitat 1 was also the area of highest leiognathid density.

Habitat 2 -- (Plate 1B) This habitat was dominated by stands of the seagrass *Enhalus acoroides*, sometimes with admixtures of other seagrasses and algae. The substrate was fine sand. Depths ranged from 1.0-1.5 m. This habitat only occurred in inshore areas. Rabbitfish were the most abundant food fishes in this habitat, and goatfish and snappers were relatively abundant.

Habitat 3 -- (Plate 1C) This habitat was characterized by heavy stands of the seagrass *Halodule uninervis* which provided virtually complete coverage of the sand substrate. This was a relatively shallow (1.0-3.0 m) habitat, occurring predominantly inshore. The largest counts of snappers occurred in this habitat although most of these snappers were small juveniles. The greatest abundance of rabbitfish was also found in this habitat, and goatfish, primarily *Parupeneus barberinus*, were relatively abundant. Sparids, which were seldom seen anywhere, reached their highest densities in this habitat.

Habitat 4 -- This habitat was also dominated by *Halodule*, but in patches rather than continuous stands. Dead coral and algae including a diverse assemblage of *Caulpera*, also occurred here. The highest counts of silversides occurred in this habitat but even these were in rather low abundance. No other economically important fishes were particularly abundant in this habitat.

Habitat 5 -- The only occurrence of this habitat was at the north end of the lagoon. It was shallow (0.5-1.5 m) and characterized by a sandy substrate with a variety of algae, including *Boergesenia forbesii* and the red alga *Gracilaria edulis*, and scattered small corals. No economically important fishes were abundant here, although it was one of only two habitats where silversides were seen and one of only three habitats where leiognathids were seen.

Habitat 6 -- (Plate 1D) This sandy habitat contained scattered patches of Sargassum polycystum and a large number of small black sea cucumbers. Depths were 0.8-2.0 m. Goatfish (mainly Parupeneus barberinus and Mulloidichthys flavolineatus) were the most abundant food fish in this habitat and cardinalfish were found in their second-highest density here. A few medium-sized high-bodied jacks were also seen.

Habitat 7 -- This habitat was found mid-lagoon at a depth of 1.5-3.0 m. The substrate was composed of sand and rubble supporting growths of Padina, Caulerpa, Dictyota and other algae. A moderate diversity of fishes was found here but no economically important fishes were seen in particularly high abundance. A small species of barracuda was seen only in this habitat.

Habitat 8 -- (Plate 1E, F) This habitat consisted of mid-lagoon patch reef areas characterized by living and dead corals and reef-building coralline algae. Depths were 0.5 to 2.0 m. Fish diversity was rather high in this habitat. Juvenile parrotfish were at their highest density in this habitat, and rabbitfish were fairly common.

Habitat 9 -- (Plate 1G) This habitat was found in inshore dredged areas from Charlie Dock to Puntan Muchot. The substrate was silt with rubble, wreckage, and some coral growth. The water was rather turbid. Despite the poor visibility, the greatest density of high-bodied jacks was seen in this habitat. These were rather small subadult fishes swimming in schools.

Habitat 10 -- (Plate 1H, 2A, B) This was the main harbor area and extended to depths of 12 m. Extensive stretches of sand dominated this habitat, but isolated outcrops of coral were not uncommon. There was a moderate diversity of fishes seen in this habitat. The highest density of edible-sized snappers (principally Lutjanus kasmira) occurred in this habitat (the higher count of snappers from habitat 3 reflects the abundance of juvenile snappers there). Adult parrotfish and surgeonfish were also fairly common in this habitat. Among the potential baitfish, cardinalfish were at their greatest density and blue Chromis at their second greatest density in this area.

Habitat 11 -- This habitat consisted of extensive stretches of sand with occasional small patches of Halodule. Depths ranged down to 2.5 m. Few fishes of any kind were seen in this habitat. It was the only area where milkfish were seen, although these were in very low abundance. A large stingray, Taeniura melanospilus, was seen here.

Habitat 12 -- (Plate 2C, D) This area was characterized by uninterrupted stretches of sand covered with the blue-green alga

Microcoleus lyngbyaceus. It was approximately 3 m deep. Few fishes occurred here, but the density of slender-bodied jacks was greatest in this habitat.

Habitat 13 -- (Plate 2E, F) This sandy-bottomed habitat supported a rather extensive cover of the small seagrass Halophila minor as well as other algae and numerous sea cucumbers. The depth was approximately 1.2-2.5 m. Fish diversity was rather low. No economically important fishes were abundant in this habitat, although there was a moderate density of cardinalfish in small holes.

Habitat 14 -- (Plate 2G, H) This mid-lagoon habitat was characterized by a sandy substrate with fairly numerous clusters of Acropora scattered throughout. The depth was approximately 1.5 m. Species diversity was rather high here. Goatfish, primarily Mulloidichthys flavolineatus, were at their highest density in this habitat, and juvenile parrotfish were at their second-highest density. Blue Chromis were moderately abundant.

Habitat 15 -- (Plate 3A, B) This was an area of well-developed Acropora formosa colonies near a reef channel. Depths ranged from 0.5 to 3.5 m. Many species of fish were seen in this habitat. Large squirrelfish, primarily Flammeo spp., were at their greatest density. Several other economically important fishes were seen in moderate to high densities in this habitat, including goatfish (Mulloidichthys flavolineatus), snappers (Lutjanus kasmira), juvenile parrotfish, and blue Chromis.

Habitat 16 -- This consisted of the lagoon fringing reef south and east of Managaha Island. It was an area of fairly rich coral growth and some algae. Depths ranged from 0.5 to 4.5 m. Species diversity was high. Edible-sized groupers, which were nowhere very abundant, were at their highest density here. Large wrasses, surgeonfish, and adult parrotfish were also fairly abundant in this area.

Habitat 17 -- (Plate 3C, D) This was an area of numerous patch reef west of Managaha Island. Coral growth was luxurient on these patch reefs. Depths ranged from 0.5 to 5.0 m. Species diversity was rather high. Surgeonfishes and large wrasses were fairly abundant in this habitat.

Habitat 18 -- (Plate 3E, F) This habitat occurred near the barrier reef in the northern part of the lagoon. It was characterized by sand, rubble, scattered Acropora, Padina, and other algae. Depths were 1.0-4.0 m. A moderate diversity of fish occurred in these areas. No economically important fishes were abundant in this habitat.

Habitat 19 -- The lagoonward fringe of the barrier reef at the southern part of the lagoon comprises this habitat. Depths were 0.2-2.0 m. The substrate was predominantly coralline algae, with sand and some coral growth. Fish diversity was rather high in this habitat. Juvenile parrotfish, rabbitfish, and surgeonfish were moderately abundant.

Habitat 20 -- (Plate 3G, 4A) This was a band of rich coral growth near the northern lagoon barrier reef. Depths were 0.5-1.5 m. Species diversity was rather high in this habitat. Goatfish, juvenile parrotfish, and surgeonfish were relatively abundant in this habitat. This was one of the few places where sharks were seen in the lagoon.

Habitat 21 -- (Plate 4B) This habitat occurred at the lagoonward fringe of the barrier reef at the northern and western margins of the lagoon. Depths ranged from 0.5 to 2.0 m. Coral growth was rich in these areas, and fish species diversity was rather high. Blue *Chromis* were at their highest densities in this habitat. Large wrasses, rabbitfish, and juvenile parrotfish were moderately abundant.

Habitat 22 -- (Plate 4C, D) This habitat was a highly dissected, submerged barrier reef with coral, sand and algae. Growth of the alga *Chlorodesmis* was lush. Depths ranged from 0.5 to 5.0 m. Fish species diversity was relatively high. Surgeonfish (primarily *Acanthurus lineatus*) were quite abundant in this habitat. Juvenile and adult parrotfish occurred in moderate abundance.

Habitat 23 -- (Plate 4E, F) This was a zone of spur and groove topography seaward of the barrier reef. Depths ranged from 1.0-4.0 m. The habitat was subject to heavy surge. Greatest fish diversity was recorded in this habitat. It was among the two habitats of highest surgeonfish abundance (primarily *Acanthurus lineatus*) and was the area highest in abundance for adult parrotfish, large wrasses, and large groupers. Some very large needlefish were also seen in this zone.

Habitat 24 -- (Plate 4G, H) This was a deeper (6.0-10.0 m) zone seaward of the western barrier reef. It was an area of coralline algae mounds with deep holes and sand channels. A relatively high diversity of fishes occurred in this habitat. The highest density of surgeonfish was seen here, as well as a reasonably large number of adult parrotfish. This was the only habitat where rudderfish and fusiliers were censused.

DISTRIBUTION AND ABUNDANCE OF FISHES OF POTENTIAL ECONOMIC IMPORTANCE

The twenty-two categories of economically valuable fishes censused in Saipan Lagoon are characterized in the following listing. A summary of their general distribution and an evaluation of their economic potential are given for each category. More detailed data on the distribution of each fish category are given in Table 1.

Sharks (Carcharhinidae and Orectolobidae) -- The estimate of 277 sharks in Saipan Lagoon is based on a rather small number of actually observed sharks and is probably not a very accurate figure. Two species were seen, the blacktip shark Carcharhinus melanopterus and the nurse shark Nebrius ferrugineum. Considering the densities observed, there is little economic potential in shark fishing in lagoon waters.

Milkfish (Chanidae; Agua) -- Again, the estimated abundance of these fish is based on few actual observations and is not likely to be an accurate assessment. Milkfish do not appear to have any economic potential in Saipan Lagoon.

Large Squirrelfish (Holocentridae; Sesiok, Chalak) -- (Plate 5A) These were quite numerous in habitat 15 where the large masses of Acropora provide these fishes with cover during the daytime. The most abundant of these squirrelfish were ones belonging to the genus Flammeo and these are not as highly regarded as some of the large species of Adioryx (e.g. A. spinifer). As our censusing was carried out during the daytime and squirrelfish are predominantly nocturnal, we have quite likely underestimated their true abundance.

Mullets (Mugilidae; Laiguan) -- (Plate 5B) Adults were seen in the small mangrove-lined embayment east of Charlie Dock (Habitat 1). They were not especially numerous. Other adult mullet were seen in habitats 3 and 23, but not during the census counts. Some juveniles of baitfish size were collected in the small boat harbor east of Puntan Muchot, but these were not abundant enough to be a valuable baitfish resource. There seems to be no economic potential for mullets in the lagoon.

Barracuda (Spyraenidae; Alu) -- (Plate 5C) The only sighting within the lagoon was of a single school of approximately 200 individuals of a relatively small species tentatively identified as Sphyraena chinensia. Some large barracuda were seen off the northeast coast of Saipan near the seaward opening of the Grotto.

Large Groupers (Serranidae; Gadao) -- (Plate 5E) This category included all groupers large enought to eat. These fishes are sometimes hard to see as they are often rather cryptically colored and wait motionless on the bottom or in holes to ambush their prey. We may have underestimated their true abundance, but it appears that fishing for large groupers in the lagoon would offer little yield. Epinephelus merra was the dominant lagoon species.

Slender-bodied Jacks (Carangidae; Hagi) -- (Plate 6A) In this category are carangid fishes of the genera Scomberoides, Decapterus, Trachurops, and others with this general body shape. Although the atulai, Trachurops crumenopthalmus, is seasonally very abundant, none were seen during our surveys. Very few jacks of this type were seen in the lagoon.

High-bodied Jacks (Carangidae; Ee, Tarakito) -- (Plate 5H) This category includes carangids of the genera Caranx, Carangoides, and others. Small Caranx melampygus were quite abundant in the inshore areas of habitat 9, but large ones were only seen in zones near the barrier reef in areas of heavy surge.

Snappers (Lutjanidae and Lethrinidae, in part; Funai, Kakaka, Tagafi, Mafute) -- (Plate 6B, C, D, F) Included in this category are species in the genera Lutjanus and Lethrinus. The highest abundance of these fishes was recorded in the Halodule stands of habitat 3, but most of those counted were juvenile Lethrinus. In the harbor area of habitat 10, Lutjanus kasmira dominated an abundant snapper assemblage. Some very large Lutjanus bohar were seen in habitat 24. The population of snappers in Saipan Lagoon is large, estimated at some 120,000 individuals, and represents a significant food resource. Snappers in inshore areas could best be harvested with nets, while those of the deeper and more offshore areas would be more effectively taken with spears and handlines.

Leiognathids (Guaguas) -- (Plate 6H) These silvery fishes are related to snappers. They are characteristically found in brackish and inshore areas, which is also the case in Saipan Lagoon. They were nowhere numerous enough nor dense enough to be an important fishery resource.

Sparids (Salagai, Matanhagon, Sihig) -- (Plate 6G) This category contains a variety of snapper-like fishes in the genera Monotaxis, Scolopsis, and Gnathodentex. Although locally abundant in various areas in Micronesia, no important concentrations of them were seen in Saipan Lagoon.

Rudderfish (Kyphosidae; Guili) -- (Plate 5G) No rudderfish were seen inside Saipan Lagoon. The only ones seen on this survey were on the outer reef terrace, and even here they were in low abundance. Several large rudderfish were seen outside the Grotto on the northeast coast of Saipan.

Goatfish (Mullidae; Salmonete) -- (Plate 7A) Goatfishes are one of the major fish resources of Saipan Lagoon. The high density of goatfish in the mid-lagoon habitat 14 reflects the great numbers of the schooling Mulloidichthys flavolineatus in the area. Parupereus barberinus was also present, but in lesser abundance, in this habitat.

Rather large schools of M. flavolineatus were also seen at the Acropora-dominated habitat 15. The coral-rich habitat 20 also supported a substantial number of goatfish of the species P. trifasciatus, P. barberinus, and M. flavolineatus. Other habitats with high densities of goatfish are 3, 6, and 18. Goatfish are most effectively taken by nets of various sorts.

Large Wrasses (Labridae; Aaga, Tanguisson) -- (Plate 7D, E) This category contains primarily large individuals of the genera Cheilinus, Coris, Epibulus, Hemigymnus, and Thalassoma. They were most abundant in areas of rich reef development in habitats 8, 16, 17, 21, 23, and 24. In these habitats they are most effectively taken with spears. Outside the reef these fishes can also be captured by handlining and traps. Standing stocks are great enough for these fishes to comprise a valuable resource.

Parrotfish (Scaridae; Palagsi) -- (Plate 7G) Although some juvenile parrotfish may be harvested for food, most people prefer to take the larger adult individuals. However, in order to assure the continued production of larger parrotfish, the habitats of the juveniles must be maintained. Juvenile parrotfish are most numerous in relatively coral-rich habitats inside the lagoon, in particular habitats 8, 14, 15, 19, and 21. Adult parrotfish prefer more exposed locations on or outside the barrier reef such as habitats 22, 23, and 24. They are also moderately abundant in the deep harbor area of habitat 10. Parrotfish are one of the most important reef fish resources of Saipan Lagoon.

Surgeonfishes (Acanthuridae; Hijuc, Hugopau, Kicho, Hangon, Tataga) -- (Plate 7F) Our counts of surgeonfishes included some forms which are not generally harvested for food such as juveniles and members of the genus Zebrasoma. However, the great majority of surgeonfish censused were edible-sized Acanthurus, Ctenochaetus, and Naso. The greatest concentrations of surgeonfishes were in barrier reef habitats 23 and 24. Acanthurus lineatus dominated the surgeonfish counts in these habitats. Coral-rich habitats 16, 17, and 22 also had high surgeonfish densities. A. lineatus dominated in habitat 22, while in habitats 16 and 17 other species such as A. triostegus, A. glaucopareius, Ctenochaetus striatus, and Naso literatus were also common. Lesser, but significant, concentrations of surgeonfish were seen in habitats 9, 10, 15, 19, 20, and 21. Surgeonfish are the most abundant food fish resource in Saipan Lagoon.

Rabbitfish (Siganidae; Sesjun) -- (Plate 7H) Large numbers of rabbitfish were seen during the surveys, and all were of edible size or close to it. No juveniles (manahac, dage) were seen. Rabbitfish were most abundant in the seagrass dominated habitats 2 and 3. They were also moderately abundant in habitats 8 and 19. Rabbitfish can most effectively be taken with nets in the seagrass areas and with spears in the more coralliferous habitats. They are a major food fish resource in Saipan Lagoon.

Other Food Fish -- Although not enumerated during the censuses, some other potential food fish were seen in very low abundances in or near the study area. Flagtails (Family Kuhliidae; Atingyet; Plate 5F) were seen in a tide pool at Puntan Aginjan and at the Grotto. Several very large needlefish (Family Belonidae; Pulus) were seen off the barrier reef in habitat 23. Occasional Flatfish (Family Bothidae; Tampat) were seen in habitats 4, 6, and 13. None of these fishes were abundant enough to be considered as valuable food fish resources.

The fish groups considered below are evaluated in terms of their potential as skipjack tuna baitfish. They have all been used at one time or another as baitfish in the Western Pacific (Wilson, 1971; Baldwin and Hida, unpublished).

Silversides (Atherimidae; Ginyo) -- Small schools of these silvery fishes were seen in habitats 4 and 5. Concentrations are insufficient for use ás baitfish.

Cardinalfish (Apogonidae; Lansi) -- (Plate 5D) Not all cardinalfish make good baitfish and some of the cardinalfish we censused fall into this category. Greatest concentrations were found in habitats 6, 7 and 10 clustered around coral outcrops or cables and other man-made objects in the water. The rather low densities and the difficulties involved in collecting enough of these fishes to use in baiting suggests that these fishes are not likely to be a useful baitfish resource. However, these fishes are primarily nocturnal and secretive during the day and we have quite likely underestimated their abundance.

Fusiliers (Caesionidae; Bonita) -- (Plate 6E) These fishes are schooling, plankton-feeding fishes related to the snappers. They were only seen outside the barrier reef in habitat 24. These fishes are quite abundant in Truk Lagoon and have been used as tuna bait in that area, but they are not abundant enough in the Saipan Lagoon area to be used as a baitfish.

Blue Chromis (Pomacentridae. in part) -- (Plate 7B, C) Two species, Chromis caerulea and C. atripectoralis, are included in this category. These fishes are extremely abundant in Saipan Lagoon (with an estimated total abundance in excess of 4 million). Greatest densities were in habitats 10, 15, and 21, with reasonably high densities in habitats 7, 8, 9, 14, 18, and 20. C. caerulea typically occurs in large aggregations around coral heads, while C. atripectoralis tends to occur further out in the water column, less closely associated with the coral substrate. While Chromis is not considered an ideal tuna baitfish, it is adequate in the absence of any better choices. Its great abundance in the lagoon indicates that there is a baitfish potential in these fishes. The major difficulty is in collecting enough of them without damaging the corals in which they live.

None of the more highly regarded clupeoid-type baitfishes (Families Clupeidae, Dussumieridae, and Engraulidae) were seen in Saipan Lagoon.

EQUILIBRIUM YIELDS OF EXPLOITABLE FISH POPULATIONS

For a fish population to remain in equilibrium, that is, for population size to remain more or less constant over a long period of time, the number of fish removed from the population through harvesting or natural death must not exceed the rate at which young fishes of the same kind (recruits) can replace the loss. It is also necessary, of course, that the amount of appropriate habitat available to the fish population remain constant. A given fish population can exist at a variety of equilibrium abundance levels. The particular equilibrium population size and the particular equilibrium yield which can be harvested will depend, to a great extent, on the rate at which the harvesting takes place. With no harvesting, the population can achieve its greatest equilibrium abundance while the equilibrium yield will be zero. At very high levels of fishing, the population will become smaller and smaller, eventually becoming fished out so that the yield is so low that it is no longer worthwhile to fish for that type of fish. Under these conditions, the equilibrium population size is very low (or zero) and the equilibrium yield is also very low (or zero). Between the two extremes of no fishing and very heavy fishing exists a level of harvesting which produces the maximum equilibrium (or maximum sustainable) yield. The equilibrium population size at this level of fishing is generally somewhere around half of the maximum population size when there is no fishing at all.

Sale (1977) has argued that the population size of many reef fishes depends primarily on the amount of living space available. Fishes produce large numbers of eggs and larvae. When these larvae develop and reach the stage at which they are ready to recruit to the adult population, they can only recruit if they encounter appropriate living space. Those that don't find living space die and do not become part of the adult population. If this is indeed the case, then reef fish populations should remain fairly constant under a rather large range of harvesting pressures as long as sufficient numbers of reproductive adults remain in the population to produce enough offspring to recruit to all available appropriate living space.

"Turnover time" can be defined as the average time it takes for a newly spawned fish egg to grow to maturity and become a reproductive adult fish. Turnover time is basically the same as generation time, but will be used in the following discussion to mean the time duration from newly spawned egg to median harvestable size. Turnover time can be visualized as the time it would take a batch of newly spawned eggs to replace its parent population if that parent population were completely harvested (assuming that the parent population wasn't harvested before it reached reproductive maturity). As an example, if a particular species of fish took one year to develop from egg to median adult size, it would be possible to harvest all the adults in one year's time and they would be replaced by their offspring. If the turnover time of a particular population was two years, the whole adult population could be harvested every two years (or half of it could be harvested every year) and the population would still be able to replace itself; in other words, the population would remain in equilibrium. This rather simplistic model of fish population dynamics, which ignores natural mortality, interspecific competition, variations in growth rates, and variations in egg and larval survival, is used here to provide preliminary estimates of maximum rates of harvesting which will leave the populations in equilibrium.

A major difficulty in this approach is obtaining accurate values of turnover time for the various groups of economically important fishes. Most of the categories which were censused are made up of several species which may have different turnover times. Few studies on rates of growth and maturation of reef fishes of any kind have been done, and few of any of the available studies have been done in the western Pacific. In Table 2 we have presented estimates of equilibrium annual harvesting rates for some economic fish categories. We were unable to obtain age and growth information for many of the categories, however, and harvest estimates are not given for these. Even for those categories for which annual equilibrium harvest estimates are given, it is important to stress that the turnover time estimates are very tentative and often based on species which are not important (or do not occur) in Saipan Lagoon. These annual harvest estimates should not be used as a basis for fishery management until validated by further studies.

FISH SPECIES DIVERSITY

Two hundred forty nine species of fish were seen in the twenty four surveyed lagoon habitats (Table 3). An additional three species, Adioryx lacteoguttatus (Cuvier and Valenciennes), Apogonichthys ocellatus (Weber), and Plesiops caeruleolineatus Ruppell., were seen in a man-altered rubble area near habitat 3. Habitats richest in fish species were those associated with the barrier reef, coral rich habitats near Managaha Island, and the rich growth of Acropora of habitat 15 (Map 24). Few species were seen in the mangrove-lined embayment of habitat 1 or the blue green algae covered sand of habitat 12.

A fish resource with potential economic importance is salt-water aquarium fish. Although the present study did not address itself particularly to this resource, the map of species richness (Map 24) is a good guide to areas where the diversity of possible aquarium fish is highest, and Table 3 gives the specific habitat locations of many fish species which could be harvested for the aquarium trade.

DISTRIBUTION OF FISH LARVAE AND EGGS

The maintenance of reproductively viable population levels is essential to the management of any potential fisheries resource. The production of offspring by fishes is usually by the release of sperm and eggs into the water column where the fertilized egg floats freely as a temporary "member" of the zooplankton community. There are certain fishes whose eggs are not planktonic. Of the twenty-two listed groups of fishes counted in this survey, those with non-planktonic eggs include the blue Chromis with demersal attached eggs (Sale, 1977), the apogonids, many of which are mouth brooders (Breder and Rosen, 1966)and the sharks which are live-bearers. Upon hatching, however, most demersal eggs release pelagic larval stages. The eventual destination of these eggs and larvae is largely dependent upon the circulation pattens of the particular area and upon the time required for larval development. This lag time in fishes may be as little as 12 hours or as long as several weeks. The site of larval rearing and egg development is often quite separate from the area of concentration of the exploitable resource. Identification and protection of these areas is an integral part of population maintenance and a necessary step in the planning of resource management.

The zooplankton community of Saipan Lagoon as a whole was found to be rather sparse, averaging only 66.2 (n=17, s=151.7) individuals per cubic meter. This is considerably lower than densities found in a similar survey of the zooplankton community of Yap Lagoon of 257.7 per m^3 (Lassuy, 1978) and far lower than was found near Ebeye in Kwajalein Atoll of $617/m^3$ (Amesbury et al., 1975). Densities similar to those found in Saipan Lagoon have been recorded from Arakabesan (Randall et al., 1978) and Malakal Islands (Birkeland et al., 1976) in Palau. Densities for individual tows ranged from 1.7 per m^3 for tow no. 14 near the reef margin at the proposed site of the fishery complex to a high of 631.6 per m^3 for two no. 12 in the vicinity of the mangrove channel just north of Charlie Dock. The densities of individual taxa of zooplankters are detailed in Table 4.

The distribution of fish eggs and larvae appears to be widespread in Saipan Lagoon as eggs were observed in all 17 and larvae in 14 of the 17 tows. The only other taxon recorded in all tows was the ubiquitous copepods. Other consistent contributors to the zooplankton community included brachyuran crab zoeae and foraminifera which both occurred in 15 of the 17 tows and shrimp larvae which were counted in all but three of the tows. Together these six taxa form the bulk of all tows averaging 92% (n=17, s=6.5) of the total density and ranging to as high as 98.8%. Occasionally numerous in the counts were the chaetognaths and larvaeceans which were observed in 10 and eight tows, respectively. Both of these reached their highest proportions in the inner harbor areas of tows no. 11 and 12. Doty and Marsh (1977) report particularly slow and sometimes eddying water movements in this area which seems to represent an area of generally enriched plankton abundance.

As an individual taxon, the fish eggs were by far the most consistently important contributors to zooplankton abundance averaging 54.0% (n=17, s=28.3) and ranging to as high as 96.2% of the total density. The density of fish eggs was generally from about one to 25 eggs per m^3 with a mean of 14.3 per m^3 (n=17, s=19.5). There were two tows with sharply higher values than the remaining 15 tows. These were tows no. 1 and 4 which had egg densities of 54.8 per m^3 and 66.4 per m^3, respectively. Both tows were made in proximity to areas of habitat-type no. 3, rich _Halodule_ seagrass beds. Tow no. 1 was directly over a thick _Halodule_ bed to the north of the harbor area. The density of larval fish appears quite low (Table 4). However, the maximum density of 3.1 larvae per m^3 in the area of habitat no. 1, the mangrove channel, is similar to some of the higher densities found in the Yap Lagoon survey (Lassuy, 1978). Their consistently high representation in the zooplankton communities of the mangrove canals of Yap suggested these areas to represent significant nursery grounds for the rearing of larval fish.

In general, then, while the abundance of zooplankton in Saipan Lagoon as a whole seemed relatively low, the contribution of fish eggs and larvae was particularly pronounced. Habitat 3, richly developed seagrass beds primarily composed of _Halodule uninervis_, seemed to be exceptionally productive areas in terms of the production of fish eggs. While no water movement studies were carried out during this survey, it was apparent that flow was quite rapid and generally in the direction of the harbor. The report of irregular and slow water movements in the area of the inner harbor suggest this may represent an area of convergence for water masses from the north and south extensions of the lagoon. The additional factor of freshwater being introduced into the system, as was mentioned for habitat no. 1, makes the inner harbor area an especially likely location for the accumulation of nutrients and the possible development of an enriched plankton community. After exhausting the food reserves of its egg sac, it would obviously be advantageous for a larval fish to be in an area of enriched food supply to support its rapid development and growth. Should the suggested water movement pattern be indeed the case, the tows seemed to reveal a possible strategy for the successful production of offspring by the fishes of Saipan Lagoon. With egg production occurring in the north and south extensions of the lagoon and with allowance for the mentioned lag time in larval development during transit to the harbor area, the hatched larvae would then be in the richest area of food production within the lagoon, i.e., the mangrove channel and inner harbor areas.

The results of the zooplankton analysis thus suggest that the protection and management of the rich _Halodule_ beds of habitat no. 3, the mangrove channel of habitat no. 1 and adjacent areas are integral to the maintenance and development of a viable fishery in Saipan Lagoon.

CONCLUSIONS AND RECOMMENDATIONS

PLANNING AND HABITAT PROTECTION

Because reef environments surrounding Micronesian islands are almost always beautiful and rich in marine life, it is difficult for planners to locate shoreline developments in areas where environmental impacts will not be felt. At the same time, most Micronesian reef systems are relatively limited in extent, and even small-scale impacts may have important consequences. Among the many considerations that go into selecting a site for future development, an important one is the possible effect of environmental modification on the habitats of economically important fishes.

In making these recommendations, we are guided by the following principles:

1) Because relatively little is known about the specific habitat requirements of the great majority of reef fishes throughout their entire life cycle, and many fishes may reside in different habitats during their early life than they do as adults, it is important that a significant amount of each distinct kind of lagoon habitat be maintained in a relatively unmodified condition.

2) Habitats where economically important fishes are abundant should be preserved to the greatest extent possible so that the maximum economic benefit can be derived from the harvesting of these fishes.

3) Habitats in which spawning or nursery grounds for fish are suspected, because of the occurrence of high densities of fish eggs and larvae in the water, should be protected.

4) Habitats in which fish species diversity is high should be protected.

Needless to say, there are many other grounds for protecting various lagoon areas, such as the presence of economically important organisms other than fish, areas of easy access for tourists and sport divers, habitats of endangered species, etc.

Recommendations

Habitats 1 and 15 should be protected in their entirety because of their uniqueness and limited extent. Habitat 1 also contained the highest density of mullets and leiognathids. Habitat 15 had the highest density of large squirrelfish, rather high densities of several other economically important fish groups, and a high diversity of fish species.

Because of high densities of economically valuable fish species, as large an extent as possible of the following habitats should be preserved intacts:

Habitats	Important resources fishes
2	rabbitfish
3	snappers, rabbitfish, goatfish
4	juvenile parrotfish
6	goatfish
7	juvenile parrotfish, barracuda
8	large wrasses, juvenile parrotfish, rabbitfish
9	high-bodied jacks, surgeonfish
10	snappers, adult parrotfish, surgeonfish, blue *Chromis*
12	slender jacks
14	goatfish, juvenile parrotfish, blue *Chromis*
15	squirrelfish, goatfish, juvenile parrotfish, surgeonfish, blue *Chromis*
16	large groupers, large wrasses, adult parrotfish, surgeon-fish
17	large wrasses, surgeonfish
18	goatfish, juvenile parrotfish, blue *Chromis*
19	juvenile parrotfish, surgeonfish, rabbitfish
20	goatfish, juvenile parrotfish, surgeonfish
21	large wrasses, juvenile parrotfish, surgeonfish, rabbitfish, blue *Chromis*
22	juvenile and adult parrotfish, surgeonfish
23	large groupers, large wrasses, adult parrotfish, surgeonfish
24	large wrasses, adult parrotfish, surgeonfish

The egg and larvae surveys indicated that habitats 1 and 3 are important areas for the early developmental stages of many fish. However, because we were not able to identify the fish eggs and larvae, it is quite possible that many fish species have their spawning and nursery ground in other parts of the lagoon. Many fish may be spawning and undergoing larval development during other times of the year.

Habitats in which fish species diversity was particularly high are habitats 8, 14, 15, 16, 17, 19, 20, 21, 22, 23, and 24. Major portions of these habitats should be protected.

The above recommendations are made on the basis of the surveys performed in January 1979. At other times of the year, fish populations in Saipan Lagoon may be more or less abundant than they were during this study and may be distributed somewhat differently. Further information on the dynamics of the fish populations in Saipan Lagoon could require modification of these recommendations.

ESTIMATES OF EQUILIBRIUM YIELDS

The equilibrium yield estimates given in Table 2 have been calculated according to the following formula:

$$Y_i = \sum_j (A_j \times \bar{N}_{i,j}/C)/T_i$$

where Y_i = annual equilibrium harvest of fish category i

A_j = area of habitat j (m^2)

$\bar{N}_{i,j}$ = average number of members of fish category i seen in habitat j in 10 minutes

C = area covered by census in 10 minutes (m^2)

T_i = estimated turnover time of fishes in category i (years)

The accuracy of the equilibrium yield estimates depends upon the accuracy of each of the parameters used to calculate it. More accuracy could be achieved by the following means:

1) additional censusing within each habitat type to obtain better estimates of the mean abundance of each fish category within each habitat;

2) subdivision of the habitats into a larger number of smaller habitats to take into account the variation of fish distribution within habitats;

3) more precise measurements of the area covered by each habitat;

4) more precise determination of the area covered during the 10-minute censuses;

5) censusing during other times of the year to take into account seasonal variations in fish abundance in different habitats;

6) better estimates of turnover time of fish categories based on the particular species which dominate in Saipan Lagoon;

7) a finer breakdown of fish categories to take into account variations in turnover time among different species which have been lumped into a single category.

Fundamental to the value of estimating equilibrium yields is the need for accurate catch data for fishes taken from the lagoon. Unless there is a way to know how many fishes of the various categories are being harvested annually, it is not possible to determine whether particular categories are overharvested or underharvested and so there is no effective means for managing the stocks.

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Table 1. Density (no./1000 m^2) and estimated total abundance of economically important fish groups in various habitats of Saipan Lagoon.

Habitat	Total Area (m)	Sharks Density	Sharks Total Abundance	Milkfish Density	Milkfish Total Abundance
1	8,813	-	-	-	-
2	2,215,101	-	-	-	-
3	1,844,938	-	-	-	-
4	1,166,307	-	-	-	-
5	290,842	-	-	-	-
6	778,517	-	-	-	-
7	1,222,125	-	-	-	-
8	1,010,603	-	-	-	-
9	240,900	-	-	-	-
10	6,045,992	-	-	-	-
11	3,246,269	-	-	.085	[1]129
12	749,139	-	-	-	-
13	831,397	-	-	-	-
14	1,695,111	-	-	-	-
15	91,072	-	-	-	-
16	496,488	-	-	-	-
17	951,847	-	-	-	-
18	2,273,857	-	-	-	-
19	531,742	-	-	-	-
20	1,633,417	.085	139	-	-
21	2,743,905	-	-	-	-
22	637,503	-	-	-	-
23	2,834,977	-	-	-	-
24	1,624,603	.085	138	-	-
Total	35,165,466		277		129

[1] only part of habitat 11 considered appropriate for milkfish

Table 1. (continued)

Habitat	Large Squirrelfish Density	Large Squirrelfish Total Abundance	Mullets Density	Mullets Total Abundance	Barracuda Density	Barracuda Total Abundance	Large Groupers Density	Large Groupers Total Abundance
1	-	-	8.165	72	-	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	.085	157
4	.750	875	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-
7	-	-	-	-	16.665	20,367	-	-
8	-	-	-	-	-	-	.085	86
9	-	-	-	-	-	-	-	-
10	.915	5,532	-	-	-	-	.085	514
11	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-
15	14.250	1,298	-	-	-	-	.085	8
16	.085	42	-	-	-	-	.250	124
17	.165	157	-	-	-	-	.085	81
18	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-
21	.085	233	-	-	-	-	-	-
22	-	-	-	-	-	-	.085	54
23	.085	241	-	-	-	-	.250	709
24	.335	544	-	-	-	-	.085	138
Total		8,922		72		20,367		1,871

Table 1. (continued)

Habitat	Slender Jacks Density	Slender Jacks Total Abundance	High-Bodied Jacks Density	High-Bodied Jacks Total Abundance	Snappers Density	Snappers Total Abundance	Leiognathids Density	Leiognathids Total Abundance
1	-	-	-	-	.085	1	.750	7
2	-	-	-	-	3.250	7,199	.415	919
3	-	-	-	-	18.500	34,131	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	.250	73
6	-	-	.250	195	.415	323	-	-
7	-	-	-	-	-	-	-	-
8	-	-	.085	86	2.250	2,274	-	-
9	-	-	12.415	2,991	2.085	502	-	-
10	-	-	-	-	10.415	62,969	-	-
11	.085	276	-	-	.085	276	-	-
12	.585	438	-	-	.335	251	-	-
13	-	-	-	-	-	-	-	-
14	-	-	-	-	1.585	2,687	-	-
15	-	-	-	-	3.500	319	-	-
16	-	-	-	-	.750	372	-	-
17	-	-	-	-	.665	633	-	-
18	-	-	-	-	.585	1,330	-	-
19	-	-	-	-	2.585	1,375	-	-
20	-	-	-	-	.335	547	-	-
21	-	-	-	-	.500	1,372	-	-
22	-	-	.085	54	1.415	902	-	-
23	-	-	.085	241	.500	1,417	-	-
24	.085	138	-	-	1.000	1,625	-	-
Total		852		3,567		120,505		999

Table 1. (continued)

Habitat	Sparids Density	Sparids Total Abundance	Rudderfish Density	Rudderfish Total Abundance	Goatfish Density	Goatfish Total Abundance	Large Wrasses Density	Large Wrasses Total Abundance
1	-	-	-	-	.165	2	-	-
2	-	-	-	-	4.915	10,887	-	-
3	.250	461	-	-	15.085	27,831	.165	304
4	-	-	-	-	1.165	1,359	.085	99
5	-	-	-	-	.335	97	-	-
6	-	-	-	-	17.085	13,301	.085	66
7	-	-	-	-	.585	715	.165	202
8	-	-	-	-	5.165	5,220	1.000	1,011
9	-	-	-	-	5.250	1,265	.250	60
10	-	-	-	-	8.835	53,416	.585	3,540
11	-	-	-	-	-	-	-	-
12	-	-	-	-	.335	251	-	-
13	-	-	-	-	.915	761	-	-
14	-	-	-	-	42.585	72,186	.165	280
15	.085	8	-	-	25.335	2,307	.165	15
16	.085	42	-	-	6.000	2,979	2.250	1,117
17	-	-	-	-	9.665	9,200	1.250	1,190
18	-	-	-	-	16.500	37,519	.165	375
19	-	-	-	-	5.665	3,012	.335	178
20	-	-	-	-	23.085	37,707	.335	547
21	.085	233	-	-	1.585	4,349	2.085	5,721
22	-	-	-	-	9.250	5,897	.665	424
23	-	-	-	-	2.835	8,037	2.585	7,328
24	-	-	.250	406	3.915	6,360	1.085	1,763
Total		744		406		304,658		24,220

Table 1. (continued)

Habitat	Juvenile Parrotfish Density	Juvenile Parrotfish Total Abundance	Adult Parrotfish Density	Adult Parrotfish Total Abundance	Surgeonfish Density	Surgeonfish Total Abundance
1	-	-	-	-	.500	4
2	.250	554	.165	365	1.335	2,957
3	10.250	18,911	.085	157	2.835	5,230
4	22.415	26,143	-	-	1.585	1,849
5	2.000	582	-	-	1.165	339
6	1.585	1,234	-	-	.415	323
7	21.915	26,783	.085	104	3.665	4,479
8	70.415	71,162	.165	167	7.250	7,327
9	12.500	3,011	1.165	281	20.750	4,999
10	6.000	36,276	9.415	56,923	28.500	172,311
11	-	-	-	-	.915	2,970
12	-	-	-	-	-	-
13	.085	71	-	-	.665	553
14	55.335	93,799	.415	703	3.915	6,636
15	30.750	2,800	.335	31	18.415	1,677
16	9.915	4,923	8.835	4,386	36.415	18,080
17	11.165	10,627	4.335	4,126	42.335	40,296
18	20.415	46,421	.165	375	6.250	14,212
19	31.835	16,928	.665	354	17.085	9,085
20	33.500	54,719	.665	1,086	29.415	48,047
21	28.915	79,340	1.250	3,430	17.500	48,018
22	22.835	14,557	10.585	6,748	47.835	30,495
23	1.415	4,011	45.415	128,750	81.585	231,292
24	2.335	3,793	10.250	16,652	81.665	132,673
Total		516,645		224,638		783,852

Table 1. (continued)

Habitat	Rabbitfish Density	Rabbitfish Total Abundance	Silversides Density	Silversides Total Abundance	Cardinalfish Density	Cardinalfish Total Abundance
1	-	-	-	-	-	-
2	19.835	43,937	-	-	1.000	2,215
3	28.835	53,199	-	-	.165	304
4	2.835	3,306	3.335	3,890	2.250	2,624
5	1.750	509	2.500	727	-	-
6	.165	128	-	-	3.415	2,659
7	.665	813	-	-	2.915	3,562
8	12.415	12,547	-	-	1.165	1,177
9	1.935	442	-	-	-	-
10	.585	3,540	-	-	4.335	26,209
11	.085	276	-	-	1.250	4,058
12	-	-	-	-	-	-
13	.085	71	-	-	2.085	1,733
14	5.915	10,027	-	-	1.750	2,966
15	7.415	675	-	-	.085	8
16	5.665	2,813	-	-	-	-
17	1.000	952	-	-	.250	238
18	2.665	6,060	-	-	-	-
19	13.915	7,399	-	-	.500	266
20	3.000	4,900	-	-	-	-
21	9.750	26,753	-	-	-	-
22	3.165	2,018	-	-	-	-
23	1.915	5,429	-	-	-	-
24	.250	406	-	-	.165	268
Total		186,200		4,617		48,287

Table 1. (continued)

Habitat	Fusiliers Density	Fusiliers Total Abundance	Blue Chromis Density	Blue Chromis Total Abundance
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	-	-	-	-
7	-	-	67.585	82,597
8	-	-	70.085	70,828
9	-	-	64.250	15,478
10	-	-	335.415	2,027,917
11	-	-	-	-
12	-	-	-	-
13	-	-	5.000	4,157
14	-	-	132.165	224,034
15	-	-	269.165	24,513
16	-	-	2.915	1,447
17	-	-	73.000	69,485
18	-	-	105.415	239,699
19	-	-	1.250	665
20	-	-	49.690	81,164
21	-	-	574.165	1,575,454
22	-	-	8.835	5,632
23	-	-	-	-
24	2.500	4,062	-	-
Total		4,062		4,423,070

Table 2. Equilibrium harvesting rates for fishes of potential economic importance in Saipan Lagoon.

	A estimated abundance in Saipan Lagoon	B estimated turnover time (years)	source of turnover time	C=A/B estimated yearly equilibrium harvest
sharks	277	12	Randall, 1977	23
milkfish	129			
large squirrelfish	8,922			
mullets	72			
barracuda	20,367	1.5	DeSylva, 1963	13,578
large groupers	1,871	1.5	Thompson and Munro, 1976	1,247
slender jacks	852			
high-bodied jacks	3,567	2.0	Watari, 1973	1,784
snappers	120,505			
leiognathids	999			
sparids	744			
rudderfish	406			
goatfish	304,658			
large wrasses	24,220	2.0	Roede, 1972	12,110
adult parrotfish	224,638			
surgeonfish	783,852	1.5	Randall, 1961	522,568
rabbitfish	186,200	1.5	Tsuda et al, 1976; Hasse et al, 1977	124,133
silversides	4,617			
cardinalfish	48,287			
fusiliers	4,062			
blue *Chromis*	4,423,070	1.0	Swerdloff, 1970	4,423,070

Table 3. Fish species observed in various habitats of Saipan Lagoon, January 1979.

SPECIES	HABITATS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CARCHARHINIDAE																								
Carcharhinus melanopterus (Quoy & Gaimard)								+												+				+
ORECTOLOBIDAE																								
Nebrius ferrugineum (Lesson)														+										
MYLIOBATIDAE																								
Aetobatus narinari (Euphrasen)												+												
DASYATIDAE																								
Taeniura melanospila Bleeker											+													
CHANIDAE																								
Chanos chanos (Forsskal)											+													
MURAENIDAE																								
Echidna nebulosa (Ahl)			+			+																		
Gymnothorax flavimarginatus (Ruppell)																						+		
G. javanicus (Bleeker)																								+
G. meleagris (Shaw and Nedder)																+								
G. undulatus (Lacepede)		+	+	+									+											
1 Gymnothorax sp.			+	+																				
OPHICHTHIDAE																								
Myrichthys colubrinus (Boddaert)			+																					
SYNODONTIDAE																								
Saurida gracilis (Quoy and Gaimard)				+							+			+	+									

Table 3. (continued)

SPECIES	HABITATS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BELONIDAE																								
species A (large; Strongylura?)																							+	
species B (small)												+				+								
HEMIRAMPHIDAE																								
unidentified halfbeaks			+	+																		+	+	
HOLOCENTRIDAE																								
Adioryx diadema (Lacepede)			+		+										+		+							
A. spinifer (Forsskal)					+									+										+
Adioryx sp.																+							+	
Flammeo laevis (Gunther)														+										
F. opercularis (Valenciennes)														+	+						+			
F. sammara (Forsskal)		+	+	+	+			+						+	+	+		+		+	+			
Myripristis adustus Bleeker				+																				
M. amaenus (Castlenau)				+				+						+										
M. murdjan (Forsskal)		+						+	+						+	+		+			+			
M. violaceus Bleeker														+										
AULOSTOMIDAE																								
Aulostomus chinensis (Linnaeus)															+					+			+	
FISTULARIIDAE																								
Fistularia commersoni Ruppell			+	+									+		+	+							+	
SYNGNATHIDAE																								
Corythoichthys intestinalis (Ramsay)			+	+		+								+					+					
Doryramphus melanopleura (Bleeker)			+	+															+					
ATHERINIDAE																								
unidentified silversides				+	+																			
MUGILIDAE																								
unidentified mullet	+		+																				+	

Table 3. (continued)

SPECIES	HABITATS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
[2]SPHYRAENIDAE																								
Sphyraena barracuda (Walbaum)																								+
S. chinensis Lacepede							+																	
SCORPAENIDAE																								
Dendrochirus brachipterus (Cuvier)						+					+													
Scorpaenodes guamensis (Quoy and Gaimard)			+	+										+										
Scorpaenopsis diabolus (Cuvier)				+																				
APOGONIDAE																								
Apogon coccineus Ruppell			+	+																				
A. exostigma Jordan and Starks														+										
A. kallopterus Bleeker								+																
A. novemfasciatus Cuvier & Valenciennes	+	+	+	+	+	+	+	+					+	+					+		+			
A. nubilis Garman		+	+											+										
A. saipanensis Fowler			+																					
[3]*Apogon* sp. A (yellow)					+		+	+		+				+										
Apogon spp.		+		+							+					+	+	+						
Cheilodipterus macrodon (Lacepede)															+									+
Paramia quinquelineata (Cuvier & Valenciennes)		+	+		+		+	+						+	+			+	+					
Siphamia sp.							+																	
SERRANIDAE																								
Epinephelus merra (Bloch)								+		+						+	+			+		+		
LUTJANIDAE																								
Aphareus furcatus (Lacepede)																							+	
Aprion virescens Cuvier and Valenciennes										+														
Lutjanus bohar (Forsskal)																								+
L. fulvus (Schneider)		+		+				+	+						+	+	+		+				+	+
L. kasmira (Forsskal)		+								+					+									
L. monostigmus (Cuvier and Valenciennes)			+			+														+	+			+
Lutjanus sp.		+				+		+		+	+				+									

Table 3. (continued)

SPECIES	HABITATS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
LETHRINIDAE																								
Gnathodentex aureolineatus (Lacepede)															+									
Lethrinus harak (Forsskal)		+						+	+	+		+		+		+		+	+			+		
L. miniatus (Bloch and Schneider)																						+		
L. ramak (Forsskal)						+									+		+					+		
Lethrinus sp.		+		+					+	+	+			+			+	+						
Lethrinus juveniles			+																					
Macolor niger (Forsskal)								+																
Monotaxis grandoculis (Cuvier and Valenciennes)										+					+									+
NEMIPTERIDAE																								
Scolopsis cancellatus (Cuvier and Valenciennes)																+							+	
CAESIONIDAE																								
Caesio caerulaureus Lacepede																								+
CARANGIDAE																								
Caranx melampygus Cuvier		+				+		+															+	
Decapterus pinnulatus (Eydoux and Souleyet)																								+
Scomberoides lysan (Forsskal)							+				+	+												
Trachinotus bailloni (Lacepede)		+																						
KYPHOSIDAE																								
Kyphosus cinerascens (Forsskal)																+							+	+
MULLIDAE																								
Mulloidichthys flavolineatus (Lacepede)	+	+	+			+		+					+	+	+		+	+	+	+	+			+
M. vanicolensis (Valenciennes)									+						+						+			
Parupeneus barberinus (Lacepede)		+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+
P. bifasciatus (Lacepede)																			+			+	+	
P. cyclostomus (Lacepede)								+	+							+		+	+				+	+
P. pleurostigma (Bennett)										+					+	+	+	+	+	+				+
P. trifasciatus (Lacepede)								+	+	+					+	+	+	+	+	+	+	+	+	+
[4]*P. spilurus* (Bleeker)															+						+			

Table 3. (continued)

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	HABITATS																							
CIRRHITIDAE																								
Cirrhitus pinnulatus (Schneider)																							+	
Neocirrhites armatus (Castlenau)																								+
Paracirrhites arcatus (Cuvier)																	+						+	+
P. forsteri (Schneider)																	+				+		+	+
LEIOGNATHIDAE																								
Gerres argyreus Cuvier and Valenciennes	+	+	+		+											+								
CHAETODONTIDAE																								
Chaetodon auriga Forsskal		+	+		+	+	+	+	+	+				+	+	+	+	+	+	+	+	+	+	+
C. bennetti Cuvier and Valenciennes									+						+									+
C. citrinellus Cuvier and Valenciennes															+	+	+	+	+	+	+	+	+	
C. ephippium Cuvier and Valenciennes		+	+				+	+						+	+	+			+	+	+	+	+	+
C. kleini Bloch																+								
C. lunula Lacepede			+		+		+	+		+				+	+	+	+	+	+	+	+	+	+	+
C. melannotus Bloch and Schneider															+	+					+			+
C. mertensii Cuvier										+														
C. ornatissimus Solander																+	+	+				+	+	+
C. punctatofasciatus Cuvier																							+	+
C. quadrimaculatus Gray																							+	+
C. reticulatus Cuvier																	+			+	+		+	+
C. trifasciatus Mungo Park								+	+	+				+	+	+	+	+		+	+	+	+	+
C. ulietensis Cuvier and Valenciennes							+	+	+					+	+					+		+	+	+
C. unimaculatus Bloch																+	+						+	+
Forcipiger flavissimus Jordan and McGregor																							+	
Heniochus chrysostomus Cuvier							+	+	+	+				+	+	+	+	+	+	+	+			+
Megaprotodon trifascialis (Gmelin)															+		+			+	+			+
POMACANTHIDAE																								
Centropyge flavissimus (Cuvier and Valenciennes)																	+				+		+	+
Pomacanthus imperator (Bloch)											+						+		+			+	+	

Table 3. (continued)

SPECIES	HABITATS																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
POMACENTRIDAE																								
Abudefduf vaigiensis (Quoy and Gaimard)																+			+			+	+	+
A. septemfasciatus (Cuvier)															+									
A. sexfasciatus (Lacepede)							+	+	+					+	+	+			+		+			
A. sordidus (Forsskal)																+								
Amphiprion clarkii (Bennett)										+														
A. melanopus Bleeker						+		+						+	+	+			+	+	+			+
Chromis atripectoralis Welander and Schultz														+	+		+	+		+	+	+		
C. caerulea (Cuvier)						+	+	+	+	+				+	+	+	+	+	+	+	+	+		
C. margaritifer Fowler																	+							
Chromis xanthura (Bleeker)										+														
Dascyllus aruanus (Linnaeus)			+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+			
D. reticulatus (Richardson)										+													+	
D. trimaculatus (Ruppell)		+				+		+		+	+			+		+			+		+			
Eupomacentrus albifasciatus (Schlegel and Muller)		+	+	+	+	+	+	+					+	+	+	+	+		+	+	+	+		
E. fasciolatus (Ogilby)				+												+	+							
E. lividus (Bloch and Schneider)			+					+						+	+					+	+			
E. nigricans (Lacepede)							+	+	+					+	+	+	+	+	+	+	+	+		
Glyphidodontops glaucus (Cuiver and Valenciennes)								+								+			+		+			
G. leucopomus (Lesson)		+					+	+					+			+			+		+	+	+	
Plectroglyphidodon dickii (Lienard)																	+	+		+	+	+	+	
P. imparipennis (Vaillant and Sauvage)																							+	
P. johnstonianus Fowler and Ball																+	+	+			+			
P. lachrymatus (Quoy and Gaimard)																+	+				+			+
P. leucozona (Bleeker)		+								+														
P. phoenixensis (Schultz)																							+	
Pomacentrus pavo (Bloch)		+	+			+	+	+		+	+			+				+	+					
P. vaiuli Jordan and Seale							+	+		+	+			+	+	+	+	+	+	+	+	+		+
unidentified pomacentrid			+																					
LABRIDAE																								
Anampses caeruleopunctatus Ruppell																+								
A. twisti Bleeker																	+							+
Bodianus axillaris (Bennett)																								+
Cheilinus chlorurus (Bloch)					+		+			+						+	+	+	+	+			+	+

Table 3. (continued)

SPECIES	HABITATS																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
C. oxycephalus Bleeker								+						+			+		+					
C. rhodochrous Gunther									+	+				+						+				+
C. trilobatus Lacepede		+	+				+	+		+				+	+	+	+		+	+	+	+	+	+
C. undulatus Ruppell								+						+	+	+				+	+			+
Cheilinus sp.		+	+		+			+											+		+			
Cheilio inermis (Forsskal)		+	+	+	+		+				+				+	+	+	+	+	+	+			+
[5]Cirrhilabrus sp.										+														
Coris aygula Lacepede																+							+	
C. gaimardi (Quoy and Gaimard)																+	+			+	+			
Cymolutes praetextatus (Quoy and Gaimard)				+	+						+	+	+											
Epibulus insidiator (Pallas)															+		+			+	+	+	+	+
Gomphosus varius Lacepede								+							+	+	+	+		+	+		+	+
Halichoeres centriquadrus (Lacepede)															+	+	+			+	+	+	+	+
H. hartzfeldi (Bleeker)										+														
H. margaritaceous (Cuvier and Valenciennes)			+				+	+								+	+				+	+		
H. marginatus Ruppell																+	+				+	+		
H. trimaculatus (Quoy and Gaimard)		+	+	+	+	+	+	+		+	+		+	+	+	+	+	+	+	+	+	+		
Hemigymnus fasciatus (Bloch)														+		+				+	+	+		+
H. melapterus (Bloch)							+	+						+	+	+		+		+	+	+	+	
Labrichthys unilineatus (Guichenot)															+					+	+			
Labroides bicolor Fowler and Bean								+													+			
L. dimidiatus Cuvier & Valenciennes							+	+	+	+				+	+	+	+	+	+	+	+	+	+	+
Macropharyngodon meleagris (Cuvier and Valenciennes)																+					+			+
Pseudocheilinus evanidus Jordan and Evermann										+														
Pseudojuloides cerasinus (Snyder)																								+
Stethojulis bandanensis (Bleeker)			+	+		+	+	+		+			+	+	+	+	+	+	+	+	+	+	+	
S. strigiventer (Bennett)		+	+	+																		+		
Stethojulis juveniles		+	+		+									+										
Thalassoma amblycephala (Bleeker)																+				+	+		+	
T. fuscum (Lacepede)																+	+						+	
T. hardwicke (Bennett)								+						+	+	+	+			+	+	+	+	
T. lutescens (Lay and Bennett)								+		+					+	+	+	+	+	+	+		+	+
T. purpureum (Forsskal)																+					+	+	+	
T. quinquevittata (Lay and Bennett)																+	+				+	+	+	
Xyrichtys macrolepidotus (Bloch)											+													

Table 3. (continued)

	HABITATS																						
SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
X. taeniourus (Lacepede)			+					+			+		+		+	+	+	+	+	+	+			
unidentified labrid A							+																	
unidentified labrid B																	+							
unidentified labrid C																								+
SCARIDAE																								
Calotomus spinidens (Quoy and Gaimard)																	+					+		+
Cetoscarus bicolor (Ruppell)																						+		+
Scarus chlorodon Jenyns								+	+	+					+		+					+	+	
S. forsteri Cuvier and Valenciennes										+					+	+								+
S. sexvittatus Ruppell																							+	
S. ghobban Forsskal		+						+	+	+				+	+	+	+		+	+	+	+		+
S. globiceps Cuvier and Valenciennes																							+	+
S. harid Forsskal															+									
S. jonesi Streets																							+	
S. rubroviolaceus (Bleeker)																							+	+
S. sordidus Forsskal		+	+	+			+	+	+	+				+	+	+	+	+	+	+	+	+	+	+
S. venosus Cuvier and Valenciennes										+													+	+
Scarus sp.								+						+	+	+			+				+	
juvenile scarids		+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+
MUGILOIDIDAE																								
Parapercis cephalopunctata (Seale)																		+	+				+	
P. clathrata Ogilby																		+						
ACANTHURIDAE																								
Acanthurus achilles Shaw																						+		
A. glaucopareius Cuvier															+	+	+		+	+	+	+	+	+
A. guttatus Bloch and Schneider																							+	
A. lineatus (Linnaeus)								+							+	+	+				+	+	+	+
A. mata Cuvier and Valenciennes	+			+			+	+		+					+	+	+							+
[6]A. nigricaudus										+				+	+		+							+
A. nigrofuscus Forsskal								+									+					+	+	+
A. olivaceous Bloch and Schneider					+					+	+						+		+					+
A. pyroferus Kittlitz																							+	

Table 3. (continued)

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A. triostegus (Linnaeus)				+	+		+	+	+							+	+	+	+	+	+	+	+	+
A. xanthopterus Cuvier and Valenciennes		+	+	+			+	+	+	+				+	+	+		+	+	+				
Ctenochaetus striatus Cuvier and Valenciennes							+	+	+						+	+	+		+	+	+	+	+	+
Naso brevirostris Valenciennes								+		+	+			+	+		+	+	+					
N. literatus (Bloch and Schneider)						+	+	+		+				+	+	+	+	+	+	+	+	+	+	+
N. tuberosus (Lacepede)																							+	
N. unicornis (Forsskal)							+	+	+	+	+			+		+	+	+	+		+	+	+	
Naso juveniles					+																			
Zebrasoma flavescens (Bennett)							+	+	+	+				+	+	+	+	+		+	+	+		+
Z. veliferum (Bloch)							+	+	+					+	+		+			+				+
ZANCLIDAE																								
Zanclus cornutus (Linnaeus)							+	+	+	+				+	+	+	+	+	+	+	+	+	+	+
SIGANIDAE																								
Siganus argenteus (Quoy and Gaimard)		+		+	+		+	+	+					+	+	+	+		+	+	+			
S. punctatus (Bloch and Schneider)																	+							
S. spinus (Linnaeus)		+	+	+	+		+	+	+	+	+		+	+	+	+		+	+	+	+	+	+	
Siganus sp.							+																+	
MICRODESMIDAE																								
Gunnelichthys monostigma Smith											+	+	+											
BLENNIIDAE																								
Exallias brevis (Kner)																								+
Meiacanthus atrodorsalis (Gunther)								+		+				+	+	+				+				+
Petroscirtes breviceps (Bleeker)													+											
P. mitratus Ruppell													+											
Plagiotremus tapeinosoma (Bleeker)							+			+										+	+			
Salarias fasciatus (Bloch)							+	+							+	+	+		+	+	+			
CALLIONYMIDAE																								
Diplogrammus goramensis (Bleeker)											+													

Table 3. (continued)

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	HABITATS																							
GOBIIDAE																								
Acentrogobius ornatus (Ruppell)			+				+								+									
Amblygobius albimaculatus (Ruppell)		+					+	+		+			+		+									
Fusigobius neophytus (Gunther)										+	+			+	+									
Gnatholepis sp.				+							+								+					
Paragobiodon echinocephalus (Ruppell)			+																					
unidentified gobiids	+																	+						
ELEOTRIDAE																								
Asterropteryx semipunctatus Ruppell			+	+			+																	
Pogonoculius zebra Fowler																							+	
Ptereleotris evides (Jordan and Hubbs)																							+	
P. microlepis (Bleeker)							+			+			+	+										
Valenciennes strigatus Broussonnet					+						+					+		+		+				
BOTHIDAE																								
Bothus mancus (Broussonnet)				+		+							+											
SOLEIDAE																								
Aseraggodes melanostictus (Peters)											+													
BALISTIDAE																								
Balistoides viridescens (Bloch and Schneider)											+			+									+	
Melichthys vidua (Solander)																							+	
Rhinecanthus aculeatus Linnaeus		+	+	+	+	+	+	+		+	+		+	+	+	+		+	+					
R. rectangulus (Bloch and Schneider)				+										+		+			+	+		+	+	
Sufflamen bursa (Bloch and Schneider)																							+	
S. chrysoptera (Bloch and Schneider)																							+	
MONACANTHIDAE																								
Alutera scripta (Osbeck)																							+	
Amanses scopas (Cuvier)																								+
Cantherines dumerilli (Hollard)																								+
C. pardalis (Ruppell)																	+						+	
Oxymonacanthus longirostris (Bloch and Schneider)								+						+	+		+	+		+	+	+		+

Table 3. (continued)

SPECIES	HABITATS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
OSTRACIONTIDAE																								
Lactoris fornasini (Bianconi)					+	+																	+	
Ostracion cubicus Linnaeus		+													+	+						+		
O. meleagris Shaw										+														
TETRAODONTIDAE																								
Arothron hispidus (Linnaeus)			+	+	+	+	+				+													
A. immaculatus (Bloch and Schneider)				+																				
A. nigropunctatus (Bloch and Schneider)							+								+	+					+	+		+
[7]Arothron sp.												+												
Canthigaster solandri (Richardson)	+	+	+	+	+	+	+	+	+				+	+	+	+		+	+	+	+	+	+	+
Total Species in Habitat (excluding unidentified juveniles in habitats where appropriate adult forms were seen)	7	37	47	41	30	26	52	74	31	56	31	8	22	68	84	90	77	50	60	65	77	61	86	81

[1]This species has often been erroneously identified by recent authors as Gymnothorax thyrsoideus (Richardson). Randall (1973) stated that it may be undescribed. Two specimens were collected and will be deposited in the University of Guam Marine Laboratory (UGML) Fish Collection.

[2]Identifications of barracudas are tentative. The species identified as Sphyraena chinensis Lacepede has been collected on Guam and deposited in the University of Guam Marine Laboratory (UGML) Fish Collection.

[3]This species was tentatively identified by Lachner in Schultz et al. (1953) as Apogon novaeguineae Valenciennes but may be undescribed.

[4]Identification is tentative.

[5]This species will be described by John Shepard.

[6]Randall and Mange (1978) provided this name for this Indo-Pacific surgeonfish which has been erroneously known as Acanthurus gahhm (Forsskal) or A. nigricans (Lacepede) in recent literature. No author designation was given.

[7]This individual was seen momentarily and is probably one of the above three species. It is not counted in the total species tally for Saipan Lagoon.

Table 4. Individual and total zooplankton densities for horizontal surface tows in Saipan Lagoon in January, 1979.

Taxon	Density (Individuals/m^3)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Fish eggs	54.8	1.2	26.0	66.4	15.7	2.1	3.5	1.3	3.0	18.5	1.0	5.1	10.3	0.7	26.5	6.6	0.9
Fish larvae	<0.1		0.1	0.2	0.1	<0.1		<0.1	<0.1	0.4	0.3	3.1	0.1	<0.1	0.1	0.3	
Copepods	0.1	0.1	2.1	13.9	0.4	0.3	0.7	1.0	0.8	1.1	117.6	485.1	2.4	0.4	0.6	2.0	0.1
Brachyuran zoeae	1.1	0.4	0.9	0.3	1.3		0.5	0.1	0.4	4.8	1.0	15.8	0.7	0.2	0.3	12.2	
Shrimp larvae	0.2	0.1		1.4	0.1		0.2	0.1	0.1	4.2	6.1	32.5	1.7	0.2	0.2	2.5	
Chaetognaths			0.1	0.5	0.1		<0.1	0.1	<0.1	2.2	13.6	52.4		<0.1			
Larvaceans		<0.1		0.3			0.1		0.1	0.3	30.2	25.4		<0.1			
Foraminifera	0.1	0.2	2.5	0.3	0.5	1.0	0.2	0.7	1.2	0.4	0.7	1.0			1.3	1.2	1.2
Gastropod larvae	0.6			0.2	0.4	0.2	<0.1	0.1	<0.1	1.4		9.2	0.2		1.1	0.2	0.1
Bivalve larvae						<0.1											<0.1
Medusae							<0.1				0.3						
Pagurid megalopas							<0.1										
Lucifer											0.3	1.5					
Insects		<0.1			0.1				<0.1				0.1				
Mysids								<0.1				0.5		0.1	0.1		0.1
Ascidian tadpoles							<0.1	<0.1					0.2	<0.1			
Radiolaria	<0.1				0.1	<0.1			<0.1				0.1	<0.1	0.2		<0.1
Polychaetes	<0.1					<0.1		<0.1	<0.1							0.2	<0.1
Heteropods						<0.1											
Isopods	<0.1		0.1		0.1	<0.1											<0.1
Egg case						<0.1	<0.1	<0.1								0.2	
Amphipods										0.1					0.1		<0.1
Stomatopod larvae										0.5							
Nauplii									<0.1								
Cumaceans									<0.1								
Misc. worms						<0.1								<0.1			
Misc. unknowns	<0.1	<0.1	0.2		0.1	0.1	<0.1	0.1	<0.1				0.2		0.2	0.2	
TOTAL	57.0	2.1	32.0	83.5	19.0	3.8	5.4	3.6	5.8	33.9	171.1	631.6	16.0	1.7	30.7	25.6	2.5

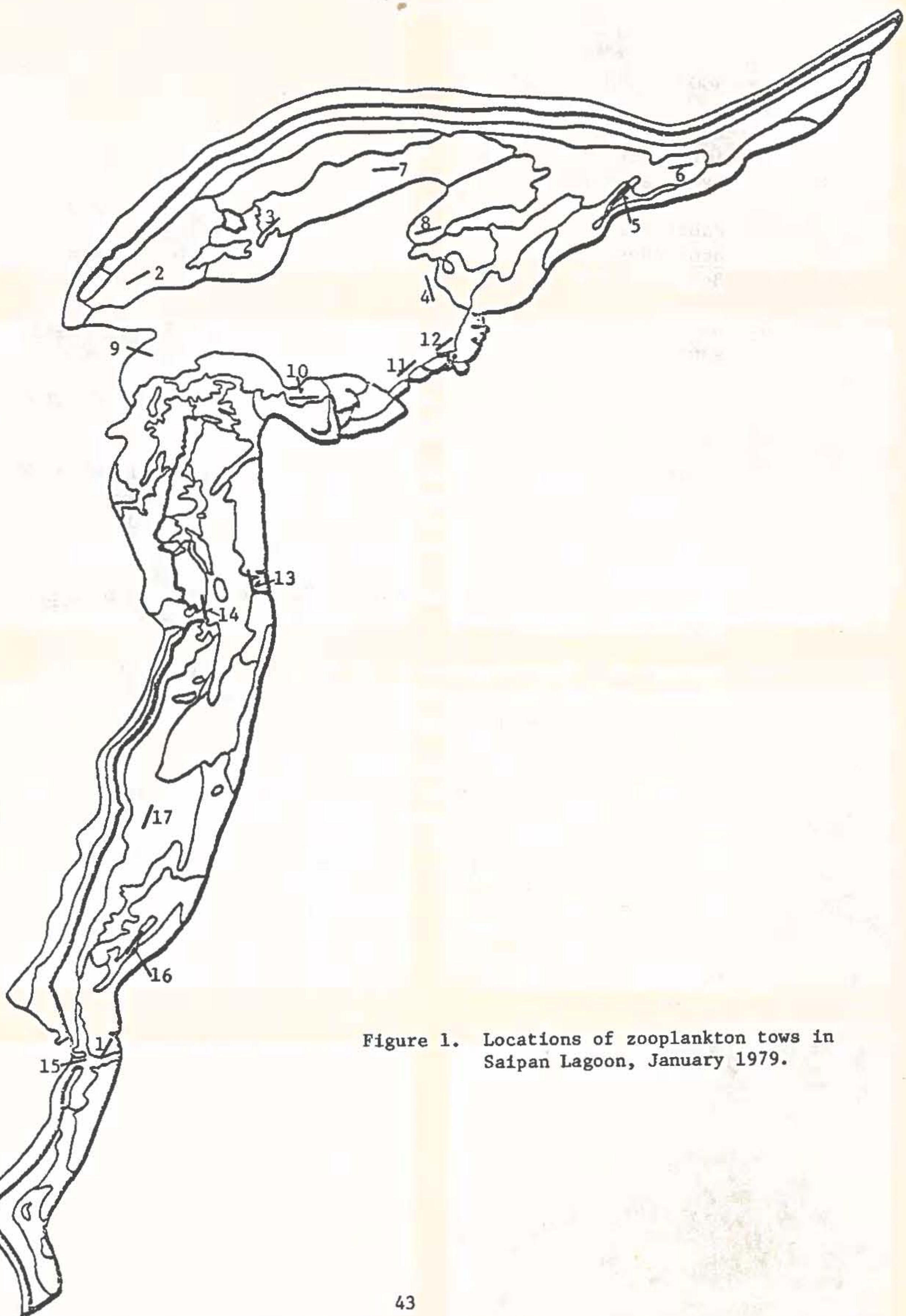

Figure 1. Locations of zooplankton tows in Saipan Lagoon, January 1979.

PLATE I

SAIPAN LAGOON FISH HABITATS

A. Habitat 1. Silty inlet lined with mangroves and under influence of freshwater runoff, north of Charlie Dock. Average Depth, 0.5 m.

B. Habitat 2. Thick patches of the seagrass, _Enhalus acoroides_ surrounded by fine sand, adjacent to Achugau Beach, 1.3 m.

C. Habitat 3. Vast expanse of the seagrass _Halodule uninervis_ south of Susupe Point, 1.3 m.

D. Habitat 6. Coarse sand with scattered rocks covered with the alga _Sargassum polycystum_, Susupe Point, 1.5 m.

E. Habitat 8. Extensive patch reef consisting mainly of dead coral covered with _Caulpera racemosa_ and other algae and scattered living heads of the coral _Pocillopora damicornis_. About 800 m north of Flores Point. 1 m.

F. Habitat 8. Some large examples of the soft coral _Sarcophyton tracheiliophorum_, 1 m.

G. Habitat 9. Shoreline south of the power barge with substrate consisting of rocks and scrap metal overgrown with the coral, _Pocillopora damicornis_, 3 m.

H. Habitat 10. Tanapag Harbor in the vicinity of the northeast mooring buoy. Substrate consists of fine sand with scattered living coral patches, primarily _Pocillopora damicornis_, 12 m. The fish in the center is the goatfish, _Parupeneus trifasciatus_.

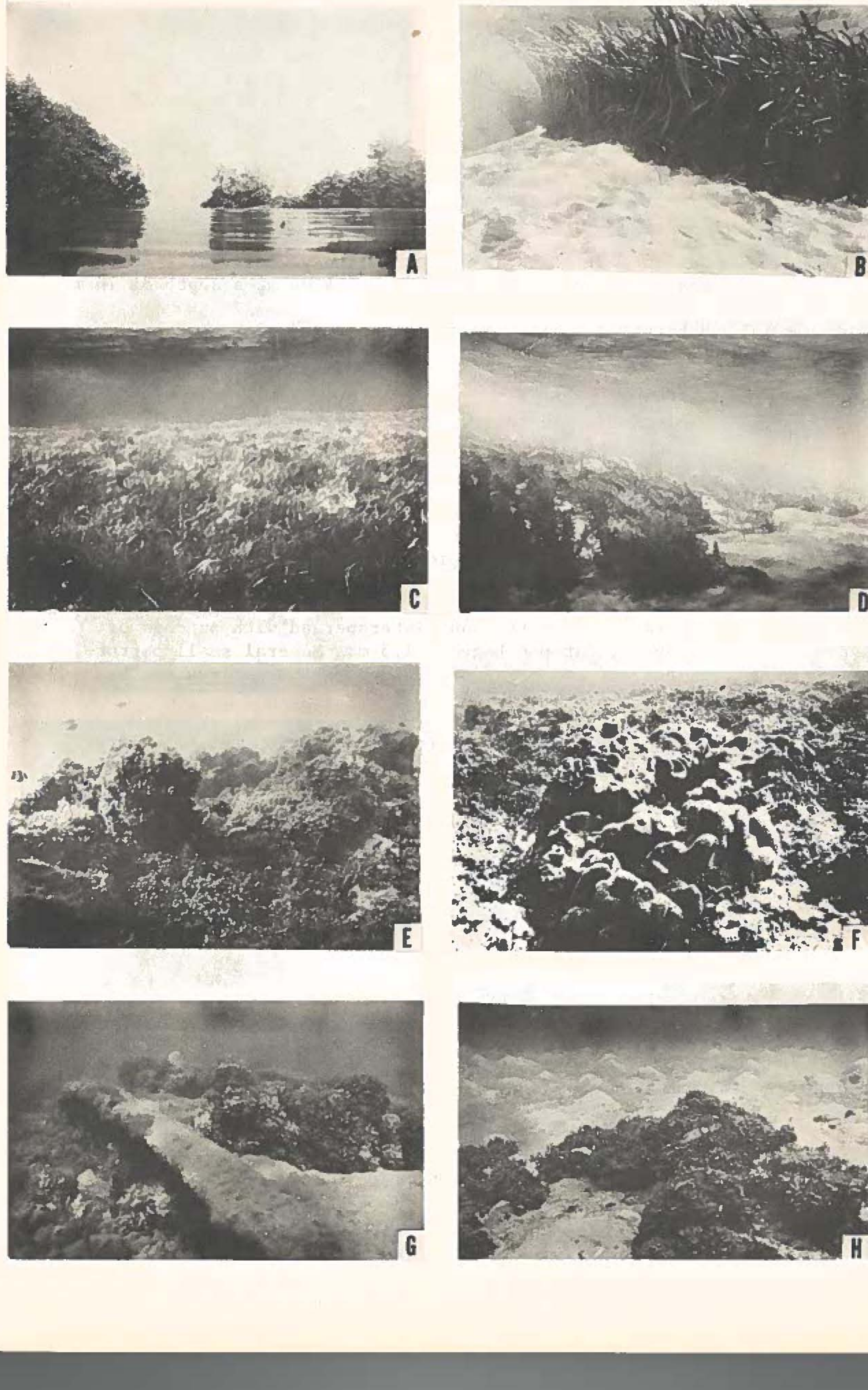
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PLATE II

SAIPAN LAGOON FISH HABITATS

A. Habitat 10. Tanapag Harbor in the vicinity of the northeast mooring buoy. A vast sandy plain at 12 m.

B. Habitat 10. Tanapag Harbor in the vicinity of the northeast mooring buoy. A patch reef area at a depth of 10 m.

C. Habitat 12. Flat sandy plain covered with a mat of the blue-green alga, *Microcoleus lyngbyaceus*, 1.1 km west of Dogas Point, northern Tanapag Lagoon, 3 m.

D. Habitat 12. Another view of the area shown in C.

E. Habitat 13. Coarse sand with scattered algae and holothurians, central Garapan Lagoon, 2.5 m.

F. Habitat 13. Coarse sand with scattered holothurians and several goatfish, *Mulloidichthys flavolineatus*, central Garapan Lagoon, 2.5 m.

G. Habitat 14. Coarse sand interspersed with patches of *Acropora*, Garapan Lagoon, 1.5 m. Several small parrotfishes and two goatfish, *Parupeneus barberinus* can be seen.

H. Habitat 14. Patches of the corals *Acropora* and *Porites*, Garapan Lagoon, 1.5 m.


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PLATE III

SAIPAN LAGOON FISH HABITATS

A. Habitat 15. Large patches of the coral *Acropora formosa* near the proposed fisheries complex, northern Garapan Lagoon, 2 m. The fish at left are squirrelfish, *Flammeo sammara*.

B. Habitat 15. Large patch of the coral *Acropora formosa* nearly 2 m thick, northern Garapan Lagoon, 2.5 m. The fishes are the goatfish, *Parupeneus spilurus* and the snapper *Lutjanus kasmira*.

C. Habitat 17. Patch reef on the west side of Managaha Island, 2.5 m.

D. Habitat 17. Edge of a patch reef on the west side of Managaha Island, 3.5 m.

E. Habitat 18. Area of coarse sand, rubble and small pieces of living *Acropora* corals about 300 m north of Dogas Point, northern Tanapag Lagoon, 1.5 m.

F. Habitat 18. Coarse sand with large scattered mounds of dead and living coral adjacent to the area shown in E.

G. Habitat 20. Large expanses of *Acropora* spp. and other corals interspersed with sand and rubble patches, immediately inshore of the exposed reef flat, northern Tanapag Lagoon.

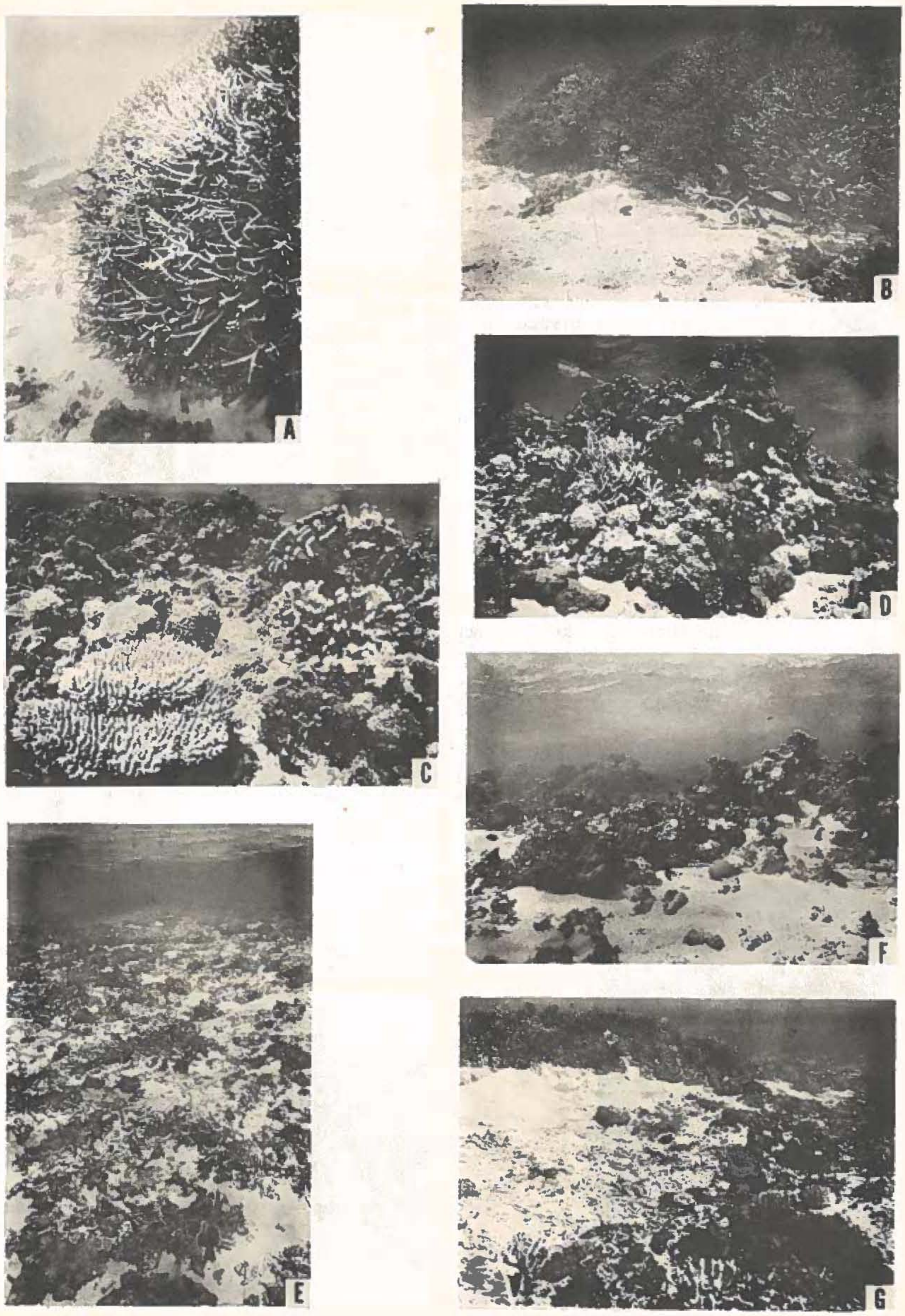
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PLATE IV

SAIPAN LAGOON FISH HABITATS

A. Habitat 20. Large expanses of coral, mainly Acropora spp., immediately inshore of the exposed reef flat, northern Tanapag Lagoon, 0.7 m. The tops of these corals are exposed during the lowest tides.

B. Habitat 21. Large expanses of Acropora spp. and other corals with scattered patches of rubble and coarse sand, outer edge of Garapan Lagoon, 1 m.

C. Habitat 22. Submerged reef crest of eroded limestone dissected by sand channels, northeast edge of Garapan Lagoon, 1.5 m.

D. Habitat 22. Area adjacent to that shown in C.

E. Habitat 23. Surge zone at extreme upper portion of spur and groove zone at the reef margin immediately north of Afetna Point, 1 m.

F. Habitat 23. Reef margin at the lower portion of the spur and groove zone immediately north of Afetna Point, 4 m. Fishes seen are the surgeonfish Acanthurus guttatus, A. glaucopareius, and Naso unicornis and the parrotfish, Scarus sordidus.

G. Habitat 24. Reef margin off the northern end of Garapan Lagoon, 3 m. Several species of surgeonfish and parrotfish can be seen.

H. Habitat 24. Coralline algal reef dissected by deep, cavernous sand channels and holes, outside the northern end of Garapan Lagoon, 10 m. The fish in the upper portion of the photo are the parrotfish, Scarus sordidus.

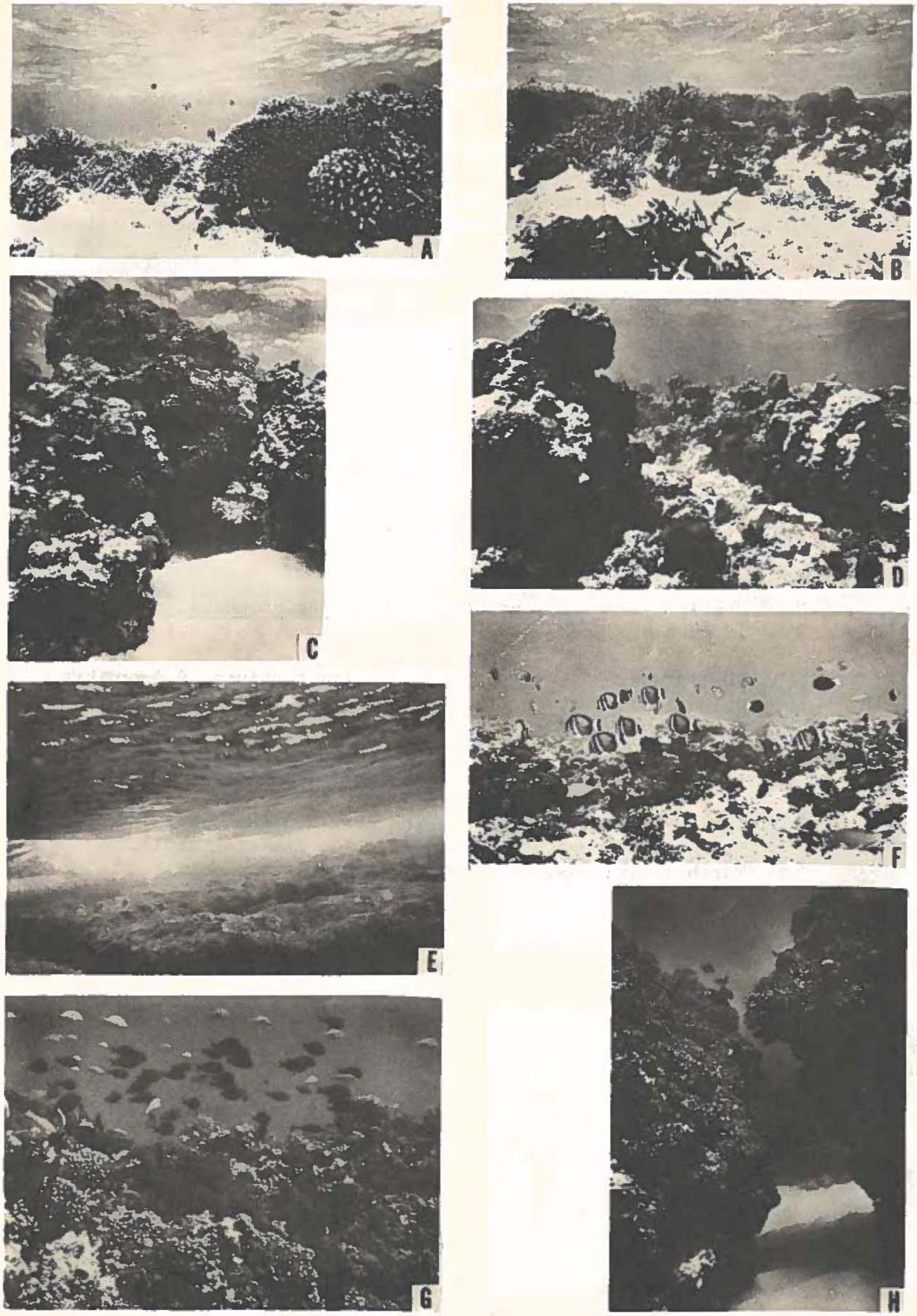
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PLATE V

REEF FISHES OF POTENTIAL ECONOMIC IMPORTANCE

A. Family Holocentridae, squirrelfish. Flammeo opercularis, about 16 cm standard length, outer Garapan Lagoon, habitat 21, 1.6 m.

B. Family Mugilidae, mullets. Plicomugil lobiosus about 13 cm s.l., Enewetak Atoll, Marshall Islands. Large mullet, similar to these were seen only in very shallow water adjacent to the shoreline in habitats 1 and 3 or in the surf zone of habitat 23.

C. Family Sphyraenidae, barracudas. Sphyraena helleri, about 35 cm s.l., Kawaihae, Hawaii, a small species possibly identical with those seen in habitat 7.

D. Family Apogonidae, cardinalfish. Apogon sp., about 3 cm s.l., 2.5 m, habitat 13.

E. Family Serranidae, groupers. Epinephelus merra, about 18 cm s.l., Guam.

F. Family Kuhliidae, flagtails. Kuhlia taeniura, 9.4 cm s.l., from a tide pool at Afetna Point.

G. Family Kyphosidae, rudderfish. Kyphosus cinerascens, about 18 cm s.l., Kona Coast, Hawaii.

H. Family Carangidae, jacks. The common high-bodied jack, Caranx melampygus, about 60 cm s.l., Enewetak Atoll, Marshall Islands.

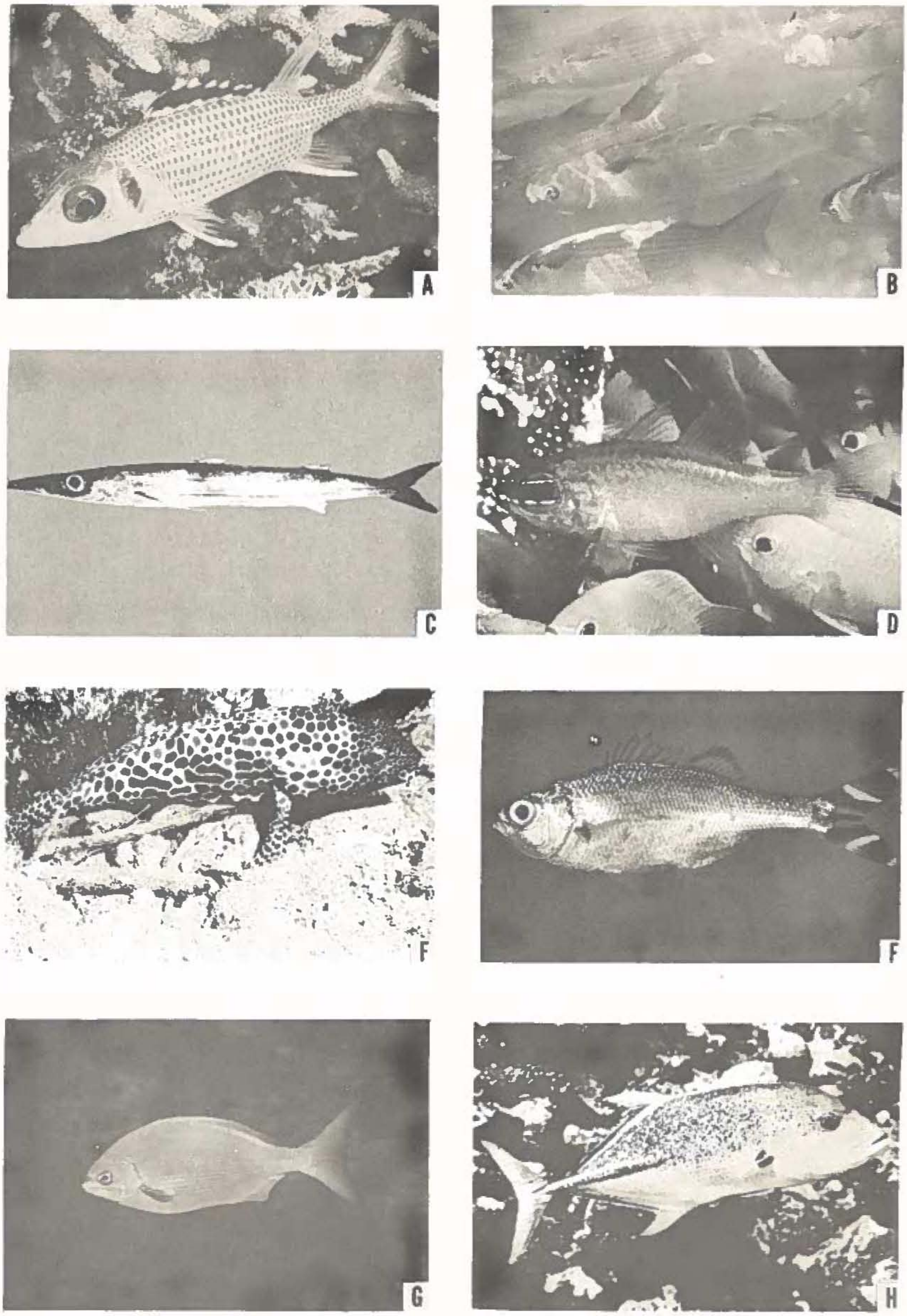
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PLATE VI

REEF FISHES OF POTENTIAL ECONOMIC IMPORTANCE

A. Family Carangidae, jacks. One of the slender jacks, the leatherback, Scomberoides lysan, about 25 cm s.l., Guam.

B. Family Lutjanidae, snappers. The red-snapper, Lutjanus bohar, about 58 cm s.l., in a fish trap off Guam. This, one of the largest species of reef snappers, was observed only outside the lagoon, in habitat 24. Large specimens may be responsible for ciguatera poisoning.

C. Family Lutjanidae, snappers. Lutjanus sp., about 10 cm s.l., 12 m, Tanapag Harbor, Habitat 10.

D. Family Lutjanidae, snappers. Aprion virescens, about 25 cm s.l., Oahu, Hawaiian Islands. This highly prized food fish reaches a length of 1 m and was seen only in the deepest part of Tanapag Harbor, habitat 10.

E. Family Caesionidae, fusiliers. Caesio xanthonotus, about 16 cm s.l., Enewetak Atoll, Marshall Islands.

F. Family Lethrinidae. Lethrinus harak, a juvenile about 10 cm s.l., over the seagrass, Halodule uninervis, 1.5 m, habitat 2.

G. Sparid, Monotaxis grandoculis, a juvenile about 10 cm s.l., Oahu, Hawaiian Islands.

H. Family Leiognathidae, Mojarras. Gerres argyreus?, 19.0 cm s.l., Guam.

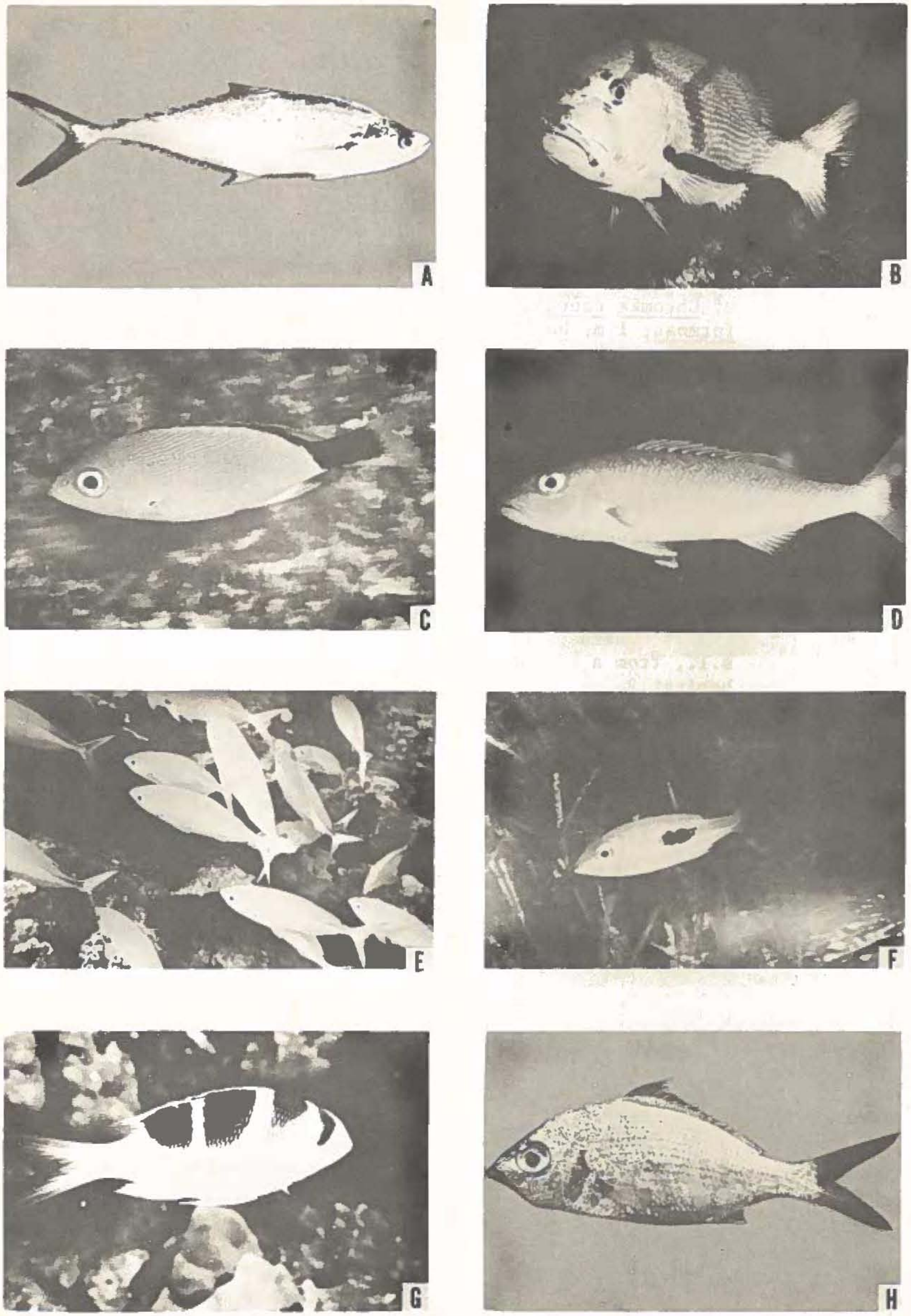
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PLATE VII

REEF FISHES OF POTENTIAL ECONOMIC IMPORTANCE

A. Family Mullidae, goatfish. Parupeneus barberinus, about 11 cm s.l., 1.5 m, Susupe Point, habitat 6.

B. Family Pomacentridae, damselfish. A typical aggregation of Chromis caerulea, above staghorn coral, Acropora formosa, 1 m, habitat 15.

C. Family Pomacentridae, damselfish. Chromis caerulea, about 4 cm t.l., 2.5 m, habitat 13.

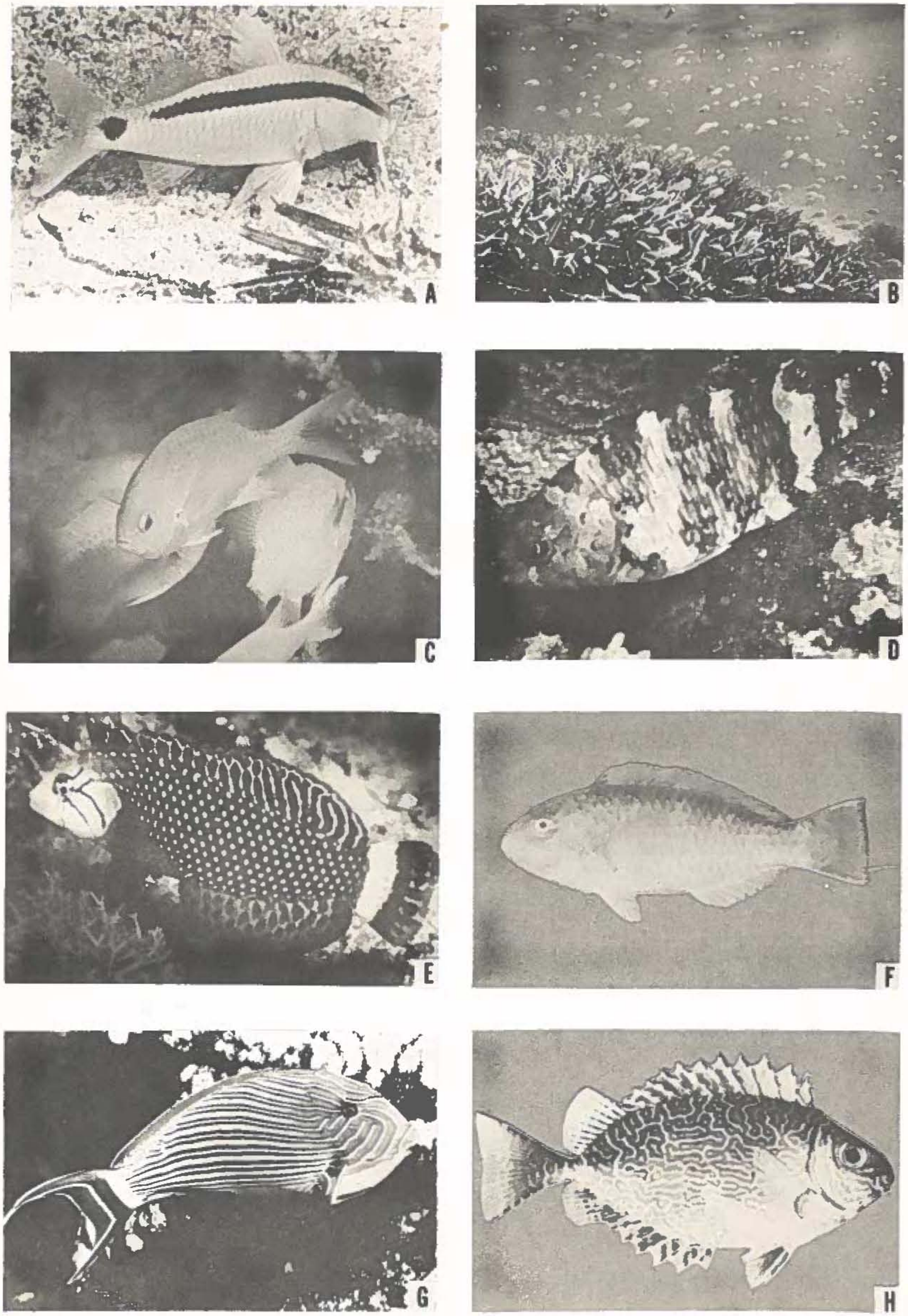
D. Family Labridae, wrasse. Cheilinus trilobatus, about 10 cm t.l., 1.5 m, Managaha Island, habitat 16. This species reaches a total length of 35 cm.

E. Family Labridae, wrasse. Xyrichtys taeniourus, about 10 cm s.l., 1.5 m, Managaha Island, habitat 16. This species reaches a total length of 25 cm.

F. Family Scaridae, parrotfish. Scarus ghobban, 7.8 cm s.l., from a seagrass (Enhalus acoroides) bed, 1.5 m, habitat 2.

G. Family Acanthuridae, surgeonfish. Acanthurus lineatus, about 20 cm s.l., Enewetak Atoll, Marshall Islands. This is the most abundant surgeonfish along the upper edge of the reef margin of Saipan Lagoon.

H. Family Siganidae, rabbitfish. Siganus spinus, 12.0 cm s.l., from a seagrass (Enhalus acoroides) bed, 1.5 m, habitat 2.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Key to Color Maps

B = Blue, G = Green, Y = Yellow, O = Orange, R = Red
Densities in number per 1000 m^2

1. Habitats: B = Habitat 1, G = Habitat 2, Y = Habitat 3, O = Habitat 4, R = Habitat 5
2. Habitats: B = Habitat 6, G = Habitat 7, Y = Habitat 8, O = Habitat 9, R = Habitat 10
3. Habitats: B = Habitat 11, G = Habitat 12, Y = Habitat 13, O = Habitat 14, R = Habitat 15
4. Habitats: B = Habitat 16, G = Habitat 17, Y = Habitat 18, O = Habitat 19, R = Habitat 20
5. Habitats: B = Habitat 21, G = Habitat 22, Y = Habitat 23, O = Habitat 24
6. Sharks: R = >.068-.085
7. Large Squirrelfish: B = >0-3, R = >12-15
8. Large Groupers: G = >.05-.10, R = >.20-.25
9. Slender Jacks: B = >0-.12, R = >.48-60
10. High-bodied Jacks: B = >0-2.5, R = >10.0-12.5
11. Snappers: B = >0-4, Y = >8-12, R = >16-20
12. Leiognathids: G = >.15-.30, Y = >.30-.45, R = >.60-75
13. Sparids: G = >.05-.10, R = >.20-.25
14. Goatfish: B = >0-9, G = >9-18, Y = >18-27, R = >36-45
15. Large Wrasses: B = >0-.6, G = >.6-1.2, Y = >1.2-1.8, O = >1.8-2.4, R = >2.4-3.0
16. Juvenile Parrotfish: B = >0-15, G = >15-30, Y = >30-45, O = >45-60, R = >60-75
17. Adult Parrotfish: B = >0-10, G = >10-20, R = >40-50
18. Surgeonfish: B = >0-17, G = >17-34, Y = >34-51, R = >68-85
19. Rabbitfish: B = >0-6, G = >6-12, Y = >12-18, O = >18-24, R = >24-30
20. Silversides: O = >2.1-2.8, R = >2.8-3.5
21. Cardinalfish: B = >0-.9, G = >.9-1.8, Y = >1.8-2.7, O = >2.7-3.6, R = >3.6-4.5
22. Blue Chromis: B = >0-120, G = >120-240, Y = >240-350, R = >480-600
23. Number of Fish Species: B = >0-20, G = >20-40, Y = >40-60, O = >60-80, R = >80-100