A SURVEY OF CIGUATERA AT ENEWETAK AND BIKINI, MARSHALL ISLANDS, WITH NOTES ON THE SYSTEMATICS AND FOOD HABITS OF CIGUATOXIC FISHES[1]

JOHN E. RANDALL[2]

ABSTRACT

A total of 551 specimens of 48 species of potentially ciguatoxic fishes from Enewetak and 256 specimens of 23 species from Bikini, Marshall Islands, were tested for ciguatoxin by feeding liver or liver and viscera from these fishes to mongooses at 10% body weight (except for sharks, when only muscle tissue was used.) The fishes are representatives of the following families: Orectolobidae, Carcharhinidae, Dasyatidae, Muraenidae, Holocentridae, Sphyraenidae, Mugilidae, Serranidae, Lutjanidae, Lethrinidae, Carangidae, Scombridae, Labridae, Scaridae, Acanthuridae, and Balistidae. The species selected were all ones for which toxicity can be expected, including the worst offenders from reports of ciguatera throughout Oceania; only moderate to large-sized adults were tested. In all, 37.3% of the fishes from Enewetak and 19.7% from Bikini gave a positive reaction for ciguatoxin. Because liver and other viscera are more toxic than muscle, the percentage of positive reactions at the level which might cause illness in humans eating only the flesh of these fishes collectively would drop to 16.2 for Enewetak and 1.4 for Bikini. This level of toxicity is not regarded as high for Pacific islands, in general.

Because ciguatoxin is acquired through feeding, the food habits of these fishes were investigated. Most of the highly toxic species, including seven of the eight causing severe illness or death in the test animals (*Lycodontis javanicus*, *Cephalopholis argus*, *Epinephelus hoedtii*, *E. microdon*, *Plectropomus leopardus*, *Aprion virescens*, and *Lutjanus bohar*) are primarily piscivorous. Some such as *Lethrinus kallopterus* (which also produced a mongoose death) feed mainly on echinoids and mollusks. Among the larger herbivorous fishes that were tested, only one individual of *Kyphosus* and two of *Scarus* caused a weak reaction in the test animals.

In view of the importance of correct identification of the ciguatoxic fishes, diagnostic remarks and an illustration are provided for each of the species tested. Some alteration in scientific names was necessary for a few of the fishes.

The Marshall Islands are the easternmost islands of Micronesia and of the Trust Territory of the Pacific Islands. They consist of 34 low islands, most of which are atolls, and numerous reefs which occur between lat. 4°30′ and 15°N and long. 161° and 173° E. They lie in two parallel groups in a northeast-southwest direction, the easternmost being the Ratak ("Sunrise") Chain and the westernmost the Ralik ("Sunset") Chain.

Two types of fish poisoning are known from the Marshall Islands: tetraodontid (puffer) poisoning (Hiyama 1943; Yudkin 1944; Halstead 1967) and ciguatera. This paper is restricted to the latter toxemia. It results from the ingestion of a great variety of tropical reef and semipelagic fishes. Ciguatoxin is thermostable, hence unaffected by cooking or freezing of the fishes. It is not the result of decomposition but is present to a varying degree in the different tissues of fishes when entirely fresh. The severity of the illness and the symptomatology depend upon the concentration of the toxin and the amount of fish eaten; fatalities are rare. Symptoms appear about 1-10 h after a toxic fish is consumed; those most commonly given are: weakness or prostration; diarrhea; tingling or numbness of the lips, hands, and feet; confusion of the sensations heat and cold; nausea; joint and muscular pain; inability to coordinate voluntary muscular movements; difficulty in breathing; burning urination; and itching. Probably the most common diagnostic symptoms are unpleasant tingling sensations of the palms of the hands and soles of the feet on contact with cool materials and the feeling of heat when cold objects are touched or cold liquids taken into the mouth. Light cases may not exhibit these sensations, however.

The Marshall Islands have long been known to harbor ciguatoxic fishes. The earliest report from these islands seems to be that of Steinbach (1895) who wrote of fishes being toxic on the west side of

[1]Contribution of the Mid-Pacific Research Laboratory.

[2]Bernice P. Bishop Museum, Box 19000-A, Honolulu, HI 96819.

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the lagoon at Jaluit. Becke (1901) recorded poisonous fishes from Ralik (Ebon), the southernmost atoll in the Marshalls (reference from Halstead 1967). With the takeover of the Marshalls by Japan at the start of World War I (1914), the documentation of ciguatera at these islands shifted to the Japanese. Hishikari (1921), Matsuo (1934), and Hiyama (1943) published on poisonous fishes at Jaluit. Some fishes in the vicinity of Utirik Island, Utirik Atoll, have been reported as poisonous (Hydrographic Office, U.S. Navy 1945).

Historically, Jaluit was the principal atoll of the Marshalls. It was the center of government, had the greatest shipping activity, and the highest population (1,683 in 1933). As a result of military activity during World War II, Kwajalein (the largest atoll in the world) and Majuro became more important. Majuro is the District Administrative Center of the islands. By 1958 the population was 3,336 (compared with 783 in 1935), whereas the population at Jaluit had declined to 1,112 in 1958 (Robson 1959).

Concurrent with the buildup in population and commerce at Majuro and Kwajalein was the appearance of ciguatera (or at least the first records in the literature of its incidence). Halstead and Lively (1954) reported one death and five persons seriously ill from the consumption of a moray eel at Kwajalein. Bartsch et al. (1959, table 2) documented the marked increase in cases of fish poisoning at the hospital at Majuro; there were 22 in 1955 (all in the last half of the year), 100 in 1956, and 211 in 1957. Banner and Helfrich (1964) stated that the atolls in the Marshall Islands where poisonous fishes are most commonly found are Kwajalein, Mille, Ailinglaplap, Jaluit, and Majuro. They tested numerous fishes of many species from Enewetak (formerly spelled Eniwetok) collected in 1958, but none were found to be toxic. Balaz,[3] on the other hand, interviewed Chief Johannes, the last remaining traditional chief of the Enewetak people, at Majuro on 15 March 1974. Johannes stated that poisonous fishes were known at the atoll at the time of his departure in 1946 from the islands of the eastern side between the deep passage and the northern end. It should be pointed out, however, that a short-term field survey of ciguatera at an atoll, such as that carried out by Banner and Helfrich, is difficult to equate to the continuous human bioassay of a population of native people dependent on fishes as their principal source of protein. One should also emphasize that even in highly toxic sectors, the percentage of poisonous fishes that will cause ciguatera when eaten is small. Nevertheless, only a few cases in an area may be needed to prevent residents from fishing in that area.

The atolls of Enewetak and Bikini are located at the northern end of the Ratak Chain 165 mi apart between lat. 11° and 12° N. The native people of Bikini were moved from their island to Rongerik Atoll and later to Kili Island when a series of nuclear explosion tests were carried out by the United States beginning in 1946. The people of Enewetak were transferrred to Ujelang Atoll in 1947 for the same reason. When repatriation of these Micronesian people was contemplated, a question arose as to the current level of toxicity of the food fishes of Bikini and Enewetak.

Fluctuation in the toxicity of fishes in reef ecosystems has long been recognized (Banner and Helfrich 1964; Cooper 1964; Halstead 1967; and Helfrich and Banner 1968). Furthermore, Randall (1958) hypothesized that disruptions of the marine environment resulting in the creation of new surfaces (particularly the repetitive formation of new surfaces) in potentially ciguatoxic areas may be linked to outbreaks of the toxemia. This hypothesis has received support from Cooper (1964) who related toxic sectors in the Gilbert Islands to the locations of wrecks and anchorages, by Helfrich et al. (1968) who documented the first outbreak of ciguatera at Washington Island, Line Islands, following the wreck of the MS *Southbank* in late 1964, and by Bagnis (1969) who reported numerous cases of ciguatera at the previously nontoxic atoll of Hao in the Tuamotu Archipelago after the atoll was altered as a staging area for nuclear testing at Mururoa.

de Sylva (1963) misinterpreted this hypothesis. He stated that Randall found poisonous fishes in estuarine areas. On the contrary, Randall reported toxic fishes in the Society Islands from certain areas of slight or intermittent freshwater drainage which are ordinarily flushed with clear water from the open sea. During periods of heavy rain the freshwater runoff to a normally marine habitat may cause death of stenohaline sessile marine animals, thus forming a new surface for benthic growth.

After stating that the basic toxic organism must be benthic, Randall (1958) wrote, "Since obligately herbivorous fishes and detritus-feeding

[3]George H. Balaz, Research Associate, Hawaii Institute of Marine Biology, pers. commun. 1974.

fishes may be poisonous, the toxic organism would most likely be an alga, a fungus, a protozoan, or a bacterium." He added that if it were an alga it must be fine because certain potentially toxic surgeonfishes are unable to feed on coarse types. Of the algae, he wrote that blue-greens were the most probable source of ciguatoxin.

Yasumoto et al. (1977), however, have shown that the "likely culprit" of ciguatera is a dinoflagellate which lives attached to dead coral or benthic algae. Though identified initially as a new species of *Diplopsalis*, it was later shown (Taylor 1979) to be a new genus as well. Subsequently, Adachi and Fukuyo (1979) named it *Gambierdiscus toxicus*. Although a fat-soluble toxin, later identified as ciguatoxin, was isolated from wild dinoflagellates of this species, this organism produced "... only meager amounts of ciguatoxin, if any,..." under culture conditions (Yasumoto et al. 1979).

The author first visited Enewetak in 1967, then in use as the terminus of a missile range by the United States. The resident personnel had been informed of the hazard of ciguatera, and local reef fishes were not served in the mess. In spite of the warning, some cases of ciguatera still occur, especially with the crews on supply ships to the island who sometimes catch and eat fishes, particularly red snapper, *Lutjanus bohar*, from the vessels before they could be informed of the danger. The most recent case was reported by Roth.[4]

In 1968 six residents of the atoll ate a large reddish brown grouper with small blue spots (probably *Plectropomus leopardus*) that one of them had caught off the garbage pier at the southwest end of Enewetak Island. They had asked a cook in the mess hall to prepare the fish for a meal. The cook refused, explaining that the species was one which could make them sick. Disbelieving, the men took the fish to their quarters and cooked it themselves. They all contracted ciguatera and were hospitalized (Spillman).[5]

These cases of fish poisoning and the knowledge that the marine environments of both Enewetak and Bikini have indeed been disrupted underlined the need for a survey of ciguatera at the two atolls.

The survey was supported by the U.S. Energy Research and Development Administration (now Department of Energy). The field work at Enewetak was based at the Mid-Pacific Marine Laboratory, and the fishing at Bikini was carried out from the RV *Liktañur*.[6] The testing of fishes for ciguatoxin was done at the Hawaii Institute of Marine Biology, University of Hawaii, under the supervision of A. H. Banner.

Six fishing expeditions of 2 to 4 wk duration were dispatched from Hawaii to Enewetak within the period September 1974-May 1978. There were four fishing cruises to Bikini (fishing periods of 3-7 days at the atoll) from December 1974 to July 1976. In addition, 12 potentially toxic *L. bohar* were caught from the *Liktañur* at the atoll of Rongelap in November 1975.

Fishes were collected by spearing, hook and line, trolling lures, explosives, and the ichthyocide rotenone. The specimens were held in chests of crushed ice until they were returned either to the Mid-Pacific Marine Laboratory or the *Liktañur*. They were then measured and weighed, tagged with a metal tag, and a sample taken for testing which included the liver, other viscera, and muscle. A data sheet was filled out for each specimen; the upper half of each sheet was used for field data and the lower half to record the testing for toxicity. A chart of the atoll was printed on the back of each data sheet (separate sets of sheets were maintained for Enewetak and Bikini) so that the locality of capture could be recorded. At Enewetak the entire fish was frozen after the sample was taken for testing. Aboard the *Liktañur* only the samples were retained. The Enewetak specimens, which proved to be highly toxic (rated 4 or 5, see below), were transported frozen to the University of Hawaii for use in biochemical and pharmacological research on ciguatoxin; the remaining fishes were either discarded or used as bait or chum.

For the testing, the samples of fish were fed to mongooses (*Herpestes mungo*) in single meals at 10% body weight. The mongoose is a good animal for the bioassay of ciguatoxin (Banner et al. 1960) because it has a symptomology similar to humans suffering from ciguatera, it retains a meal of toxic fishes (in contrast to cats which are prone to regurgitate fish when it is very poisonous), and because of its availability in Hawaii (where it is regarded as a pest). The mongoose symptoms were

[4]Robert M. Roth, Capt. USAF, MC., Command Surgeon, Joint Task Group, Enewetak, described the illness (symptoms typical of ciguatera) of Francisco Romolor, age 28, a civilian deckhand on the cargo ship *Muskingum*, following ingestion of a red snapper caught in the lagoon (pers. commun. 2 June 1978).

[5]Louis C. Spillman, Jr., Chief Medical Officer, Enewetak, pers. commun. 1968.

[6]The RV *Liktañur* is a converted U.S. Navy LCM, 115 ft in length, operated then by the U.S. Energy Research and Development Administration as a research and supply vessel.

divided into five progressive categories from 1 (diarrhea, slight weakness, and flexion of the forelimbs) to 5 (death within 48 h). The lack of symptoms was recorded as 0. The tests which resulted in a reaction of 4 or 5 were repeated on other mongooses if sufficient material was available. Also any questionable or unexpected tests were repeated.

Two tests were run on most of the fishes, one based on the feeding of liver or liver and viscera to the mongooses and one on muscle tissue. The liver of a toxic fish invariably gave a stronger reaction than muscle. A reaction of 3 to liver feeding would generally elicit a reaction of 1 with flesh. Helfrich et al. (1968) found liver more than 50 times as toxic as the muscle tissue of *L. bohar*. The remaining viscera are also more toxic than somatic muscle. Since the liver alone was often insufficient in mass to provide a meal to a mongoose at 10% body weight, it was usually necessary to combine it with other viscera (generally alimentary tract tissue).

The level of toxicity reported herein is from the liver-viscera feeding, with the exception of sharks. Shark liver may cause a toxemia from the high level of vitamin A. Furthermore, it was noted that mongooses will either not eat shark liver or will not consume enough to equal 10% of their body weight. Thus the toxicity data on sharks are based on muscle tissue alone.

Once a mongoose exhibited symptoms of ciguatera, it was not used again for testing. If it showed no symptoms at all, it was used a second time, but only after a period of at least 1 wk had elapsed. No mongooses were fed potentially toxic fish more than three times even when no symptoms were elicited. The reason for this is the known tendency for ciguatoxin to accumulate in a test animal. Though a fish may cause no illness when eaten, it may still have some toxin at the subsymptomatic level. Eating several such fishes in succession might result in a positive test for the last one, even though there was insufficient toxin to produce illness in a mongoose consuming such a fish for the first time.

The results of our first sampling of potentially toxic fishes at Enewetak and Bikini did not indicate a high level of toxicity. Only the larger individuals of the usual offending species were poisonous. Most of these species are carnivores, in particular those feeding heavily on fishes (Randall 1958). Therefore, subsequent fishing was concentrated on the larger fishes of these species. Because of this selectivity, both for species and size, more fishing effort was spent per fish caught; however, this meant less effort expended later in useless testing.

Prior to the present study, information on the food habits of ciguatoxic fishes was insufficient for most species. When a trained marine biologist familiar with the Marshallese marine biota was present, an analysis was made of the stomach contents of the fishes that were caught. Since ciguatoxin is known to pass through food chains to the larger fishes, where it is concentrated, analyses of the stomach contents of these fishes are needed for an understanding of the feeding interrelationships.

Some previously unpublished stomach-content

TABLE 1.—Summary of mongoose feeding tests (liver-viscera, sharks excepted) of fishes collected at Enewetak (0 = nontoxic; 5 = death of test animal).

	Intensity of reaction					
Species	0	1	2	3	4	5
Nebrius ferrugineus	2					
Carcharhinus albimarginatus	4					
C. amblyrhynchos	11		1			
C. galapagensis	1					
C. limbatus			1			
Galeocerdo cuvier	2					
Triaenodon obesus	8					
Taeniura melanospilos	1					
Lycodontis javanicus			2	1	3	3
Adioryx spinifer	6					
Sphyraena barracuda	3	1	2	1		
Cephalophalis argus	2	3	3		1	
Epinephelus fuscoguttatus	2		4	1		
E. hoedtii	6	3	1		1	
E. maculatus	8	3				
E. microdon	8	3	8	13	5	2
E. socialis	2					
E. tauvina	4	1	1			
Plectropomus leopardus	12	6	8	4		1
P. melanoleucus			1			
P. truncatus			1			
Variola louti	13	4		2		
Aprion virescens	8	1		1	1	
Lutjanus bohar	56	22	11	5		1
L. fulvus	2					
L. gibbus	21	5	2	3		
L. monostigmus	1	1	1			
Macolor niger	23	2				
Lethrinus amboinensis	24					
L. kallopterus	14	2	2			1
L. miniatus	6			3		
L. xanthochilus	2					
Monotaxis grandoculis	4	1				
Kyphosus cinerascens	1	1				
Caranx ignobilis	3	2				
C. lugubris	11	2	1	1		
C. melampygus	24	4	1	1		
C. sexfasciatus	2					
Gymnosarda unicolor	7	4	1	1		
Cheilinus undulatus	6		1			
Coris aygula	4	1				
Epibulus insidiator	5					
Hipposcarus harid	3	1				
Scarus gibbus	18	1				
S. rubroviolaceus	3					
Acanthurus xanthopterus	2					
Balistoides viridescens	1					
Totals	346	74	53	37	11	8

analyses obtained by the author from localities other than the Marshall Islands have been included in this report. The food habit data are presented in the species accounts following the assay of toxicity.

The length measurement most often used for bony fishes was standard length (SL). This was taken from the front of the snout to the end of the hypural plate (hence base of caudal fin). When the method of measuring length is not specified, standard length is intended. Fork length (FL) was used for carangids and scombrids because scutes or keels laterally on the caudal peduncle prevent the accurate external determination of the base of the caudal fin. Total length (TL) was employed for eels, nurse sharks, and some proportional measurements. The length usually given for requiem sharks is precaudal length (PCL).

Schultz and collaborators (1953-66) was the primary reference for the identification of ciguatoxic fishes and the fishes from their stomachs. Enewetak and Bikini were among the islands from which large collections of fishes were made for this systematic work. When names other than those given by Schultz and collaborators are used, an explantion is given in the species accounts.

The species of ciguatoxic fishes which were studied are discussed in approximate phylogenetic sequence below. The results of the mongoose feeding tests are summarized in Table 1 for Enewetak and Table 2 for Bikini.

TABLE 2.—Summary of mongoose feeding tests (liver-viscera, sharks excepted) of fishes collected at Bikini (0 = nontoxic; 5 = death of test animal).

	Intensity of reaction					
Species	0	1	2	3	4	5
Carcharhinus amblyrhynchos	1					
Galeocerdo cuvier	1					
Sphyraena barracuda	1	1	1			
S. forsteri			2			
Crenimugil crenilabis	3					
Epinephelus hoedtii	1					
E. maculatus	2					
E. microdon	2	1	4	1		1
E. tauvina	1		1			
Plectropomus leopardus	1					
Variola louti	2					
Aprion virescens	7	1				
Lutjanus bohar	112	15	8	6	2	
L. gibbus	32	3				
L. monostigmus	4	1				
Lethrinus amboinensis	9					
L. kallopterus	2					
L. miniatus	12					
L. xanthochilus	2					
Caranx ignobilis	2					
C. melampygus	6					
Gymnosarda unicolor	3					
Pseudobalistes flavimarginatus	2					
Totals	208	22	16	7	2	1

RESULTS

Orectolobidae (Nurse Sharks)

Nebrius ferrugineus (Lesson) (Figure 1): Like other orectolobids, this shark has a prominent nasal barbel, relatively small mouth, the fourth and fifth gill openings over the pectoral base, and the two dorsal fins set posteriorly on the body. The teeth, which are small and in numerous rows (the first three or four functional), have a large central cusp with four to six smaller cusps on each side (the teeth of the related genus *Ginglymostoma* have an even larger central cusp and only two small cusps on each side). The two dorsal fins are of nearly equal size, the first originating slightly anterior to the origin of the pelvic fins and the second distinctly anterior to the origin of the anal fin; the caudal fin is about 30% TL.

Nebrius concolor Rüppell appears to be a junior synonym. Bass et al. (1975b) employed this name,

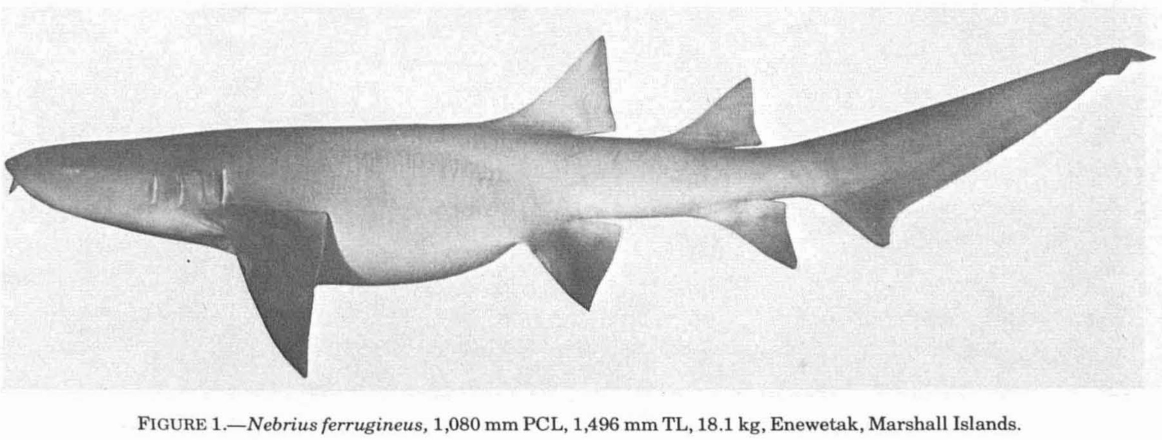

FIGURE 1.—*Nebrius ferrugineus*, 1,080 mm PCL, 1,496 mm TL, 18.1 kg, Enewetak, Marshall Islands.

but admitted that Lesson's *ferrugineus* might have priority.

This shark is a shallow-water species, usually seen at rest on the bottom during daylight hours. It is not common in the Marshall Islands. Two specimens were obtained from Enewetak, 1,400 and 1,487 mm TL, weighing 11.7 and 14.1 kg. The flesh of neither was toxic.

Fourmanoir (1961) stated that the principal food of this shark consists of octopuses and xanthid crabs. Gohar and Mazhar (1964) reported cephalopods, fishes, and parts of corals (*Stylophora*) from the stomachs of Red Sea specimens (the corals were probably accidentally ingested). Hiatt and Strasburg (1960) found a rabbitfish, *Siganus* sp., in the stomach of one of three specimens collected at Enewetak.

The stomach of the smaller of the two specimens taken during the present study contained a surgeonfish, *Acanthurus glaucopareius,* 95 mm SL. Three other Enewetak specimens and one from the Tuamotu Archipelago (to 1,615 mm TL, 20.9 kg) had empty stomachs.

Carcharhinidae (Requiem Sharks)

Carcharhinus albimarginatus (Rüppell) (Figure 2): The silvertip shark is one of three carcharhinid sharks with white on the tips of its fins; the others are the oceanic whitetip shark, *C. maou* (Lesson) (*C. longimanus* a junior synonym), and the whitetip reef shark, *Triaenodon obesus* (Rüppell). The name silvertip has been adopted by Kato et al. (1967) and others to avoid confusion with the other two species with white-tipped fins. The white on the silvertip's fins is not confined to the distal ends but continues along the posterior margins. The apex of the first dorsal fin is somewhat pointed (broadly rounded on *C. maou*); the origin of this fin is over the inner edge of the pectoral fin. The pectorals are about 18% TL (about 28% on *C. maou*). A median interdorsal ridge is present. There are usually 26 upper and 24 lower teeth. The precaudal vertebrae vary from 115 to 125.

Carcharhinus albimarginatus has not been reported as poisonous [Halstead (1967, pl. VI, fig. 3) illustrated it but misidentified the figure as *Triaenodon obesus*], but it would seem to have the potential for causing ciguatera because it preys in part on reef fishes. In the Marshall Islands it was usually seen on exposed outer reefs in water >30 m, though one individual was observed in the Enewetak lagoon in water only 2 m deep. Bass et al. (1973) summarized the depth distribution, noting records to 400 m. This species has attacked man.

The flesh of four silvertips, 933-1,650 mm PCL (15.0-73.5 kg), from Enewetak was nontoxic.

Fourmanoir (1961) reported the following wide variety of fishes from the stomachs of silvertips from Madagascar: *Promethichthys prometheus*, *Pristipomoides typus*, *Seriola songoro*, *Coris gaimard*, *Caesio coerulaureus*, *Acanthocybium solandri*, *Euthynnus pelamis*, and *Neothunnus al-*

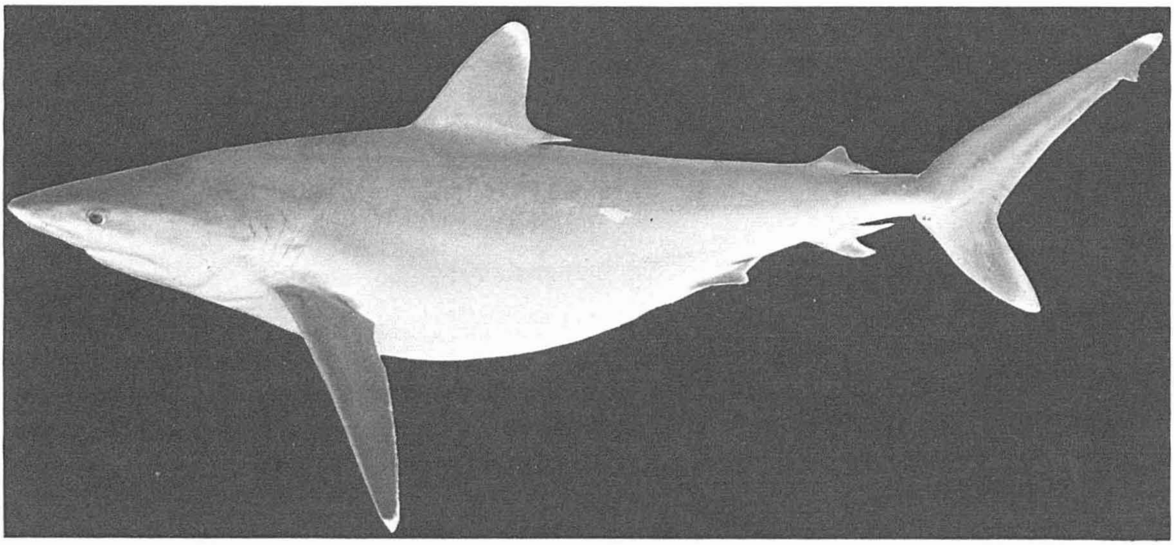

FIGURE 2.—*Carcharhinus albimarginatus,* 1,650 mm PCL, 2,154 mm TL, 73.5 kg, Enewetak, Marshall Islands.

bacora (= *Thunnus albacares*). Bass et al. (1973) examined the stomach contents of 10 specimens of *C. albimarginatus* from the western Indian Ocean. They found teleost fishes (exocoetid, myctophid, several soleids) in seven sharks; a spotted eagle ray, *Aetobatis narinari*, in one; and an octopus in one.

The stomach of one of the Enewetak silvertips (1,240 mm PCL, 1,650 mm TL) contained a gray reef shark, *Carcharhinus amblyrhynchos*, 483 mm PCL and 616 mm TL, as well as the dental plates and pharyngeal mills of three parrotfishes (*Scarus*). The stomachs of the other three sharks were empty.

Carcharhinus amblyrhynchos (Bleeker) Figure 3): This shark, now popularly known as the gray reef shark, was referred to by Schultz in Schultz and collaborators (1953) as *Carcharhinus menisorrah* (Müller and Henle). Bass et al. (1973) and Garrick (in press) are followed in the use of the name *C. amblyrhynchos* herein.

The gray reef shark lacks dark pigment distally on the first dorsal fin, but the tips of the other fins are broadly blackish, and there is a broad black margin posteriorly on the caudal fin. The dark markings on the fins are more evident on live than on dead specimens. The origin of the first dorsal fin is over the pectoral axil or anterior part of the inner edge of the pectoral fin. A short interdorsal ridge is present or absent. There are 26-28 upper teeth and 24-26 lower teeth; the precaudal vertebrae vary from 110 to 117 (two Enewetak specimens had 117).

This shark is abundant in the Marshall Islands. It occurs in many habitats from lagoons to ocean reefs, but it is most commonly encountered in deep channels and outer reef areas. It does not penetrate the shallows as readily as *C. melanopterus*.

The flesh of 11 specimens from Enewetak, 1,017-1,190 mm PCL (17.2-26.3 kg), and 1 from Bikini (3.6 kg, length not taken) was tested. All gave a zero reaction for ciguatoxin. The viscera of one of these, 1,158 mm PCL, from Enewetak produced a reaction of 2, however.

The stomachs of 74 individuals, 520-1,230 mm PCL (2.7-32.4 kg), from Enewetak, Fanning and Palmyra in the Line Islands, Marcus Island, Johnston Island, Palau Islands, and Ducie and Henderson in the Pitcairn Group, were examined for food. Forty-nine stomachs were empty or contained only bait. Three had eaten cephalopods (two octopus, one squid), and the rest contained the remains of fishes (in some cases only the lens of an eye or a few remnants of spines or bones). The fishes that could be identified to family or genus were the following: muraenid, belonid, exocoetid, *Fistularia*, *Decapterus*, *Trachinotus*, *Acanthurus*, and another acanthurid (either *Acanthurus* or *Ctenochaetus*).

In spite of its relatively small size, the gray reef shark constituted a hazard to the personnel of the survey program, particularly when divers were spearfishing or collecting with rotenone. Several

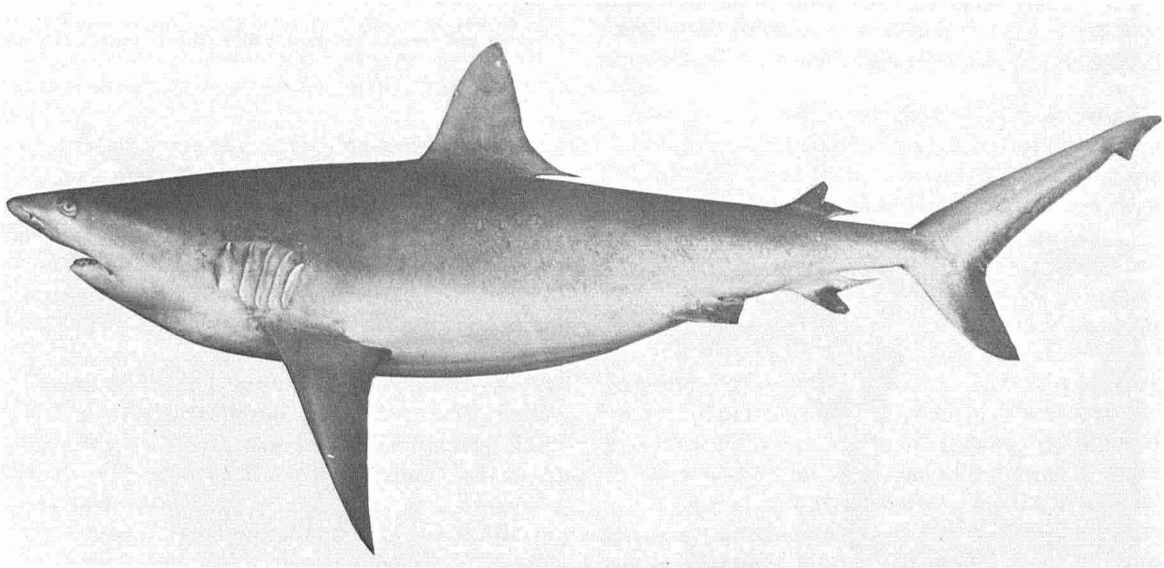

FIGURE 3.—*Carcharhinus amblyrhynchos*, 1,288 mm PCL, 1,640 mm TL, Tahiti, Society Islands.

of these sharks were killed by powerheads when their aggressive behavior and proximity warranted. On 12 July 1975 the companion diver of the author, Russell E. Miller, sustained 7 gashes in his head requiring 25 stitches as the result of an attack by a *C. amblyrhynchos* of about 1,500 mm TL. The shark first exhibited threat posturing (see Johnson and Nelson 1973) at the back of the author. Miller sounded a warning by rapping on his scuba tank with his powerhead handle. The shark immediately turned and swam toward him, repeating the exaggerated sinuous swimming of its threat behavior as it approached. Miller struck the shark with his powerhead but the shell misfired. The shark came on to slash his head (and cut the rubber strap of his face mask) with its upper jaw. On another occasion Gordon W. Tribble had the end of his speargun seized by a gray reef shark and vigorously shaken.

Richard C. Wass (1971) has made a comparative study of the biology of the gray reef shark and the sandbar shark in the Hawaiian Islands.

Carcharhinus galapagensis (Snodgrass and Heller) (Figure 4): This shark is circumtropical in distribution, but as noted by Garrick (1967), it shows a preference for the sea around oceanic islands.

The Galapagos shark has no distinctive markings; it is dark gray dorsally, pale ventrally. The origin of the first dorsal fin is anterior to the inner free corner of the pectoral fin. The second dorsal fin is relatively large for a *Carcharhinus*, its height 2.4-2.8% TL. A distinctive median interdorsal ridge is present on the back. There are 26-30 upper teeth (the anterior upper teeth broadly triangular) and 26-29 lower teeth. The precaudal vertebrae range from 103 to 109.

A single specimen, 1,831 mm PCL, 2,426 mm TL, 41.2 kg, was collected at Enewetak. Its flesh was nontoxic.

Tester[7] examined the stomach contents of 41 Galapagos sharks caught from the Hawaiian Islands; 51% were empty. Sixty percent of the sharks had eaten bony fishes, 35% cephalopods, 20% sharks and rays, and 10% crustaceans. He commented that the larger individuals (maximum length estimated as 10 ft or 3,048 mm) fed mostly on larger fishes which were torn into chunks. He regarded it as a dangerous species; Randall (1963) documented a fatal attack.

Bass et al. (1973) found food in 18 of 22 individuals of this species; 12 of the stomachs contained teleost fishes (serranid, *Platycephalus*, and a flatfish) and 10 had squids or octopuses (plus the shell of a bivalve mollusk).

The Enewetak specimen was empty as were three others 1,460-1,690 mm PCL from the Pitcairn Group. One of 1,580 mm PCL from Rapa contained the head of an unidentified eel.

Carcharhinus limbatus (Valenciennes) (Figure 5): The shark occurs in the Atlantic as well as the Indo-West Pacific. In the Atlantic it bears the common name of blacktip shark, a name which is poor for the species in the Pacific for two reasons.

[7]Tester, A. L. 1969. Final Report, Cooperative Shark Research and Control Program, University of Hawaii. Mimeogr. Rep., 47 + 36 append. p.

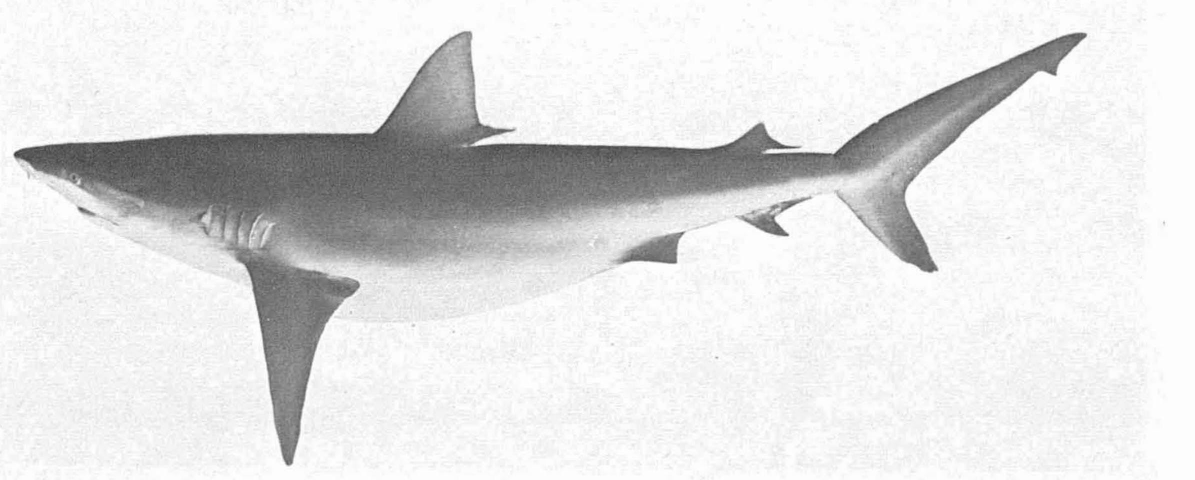

FIGURE 4.—*Carcharhinus galapagensis*, 1,831 mm PCL, 2,426 mm TL, 87 kg, Enewetak, Marshall Islands.

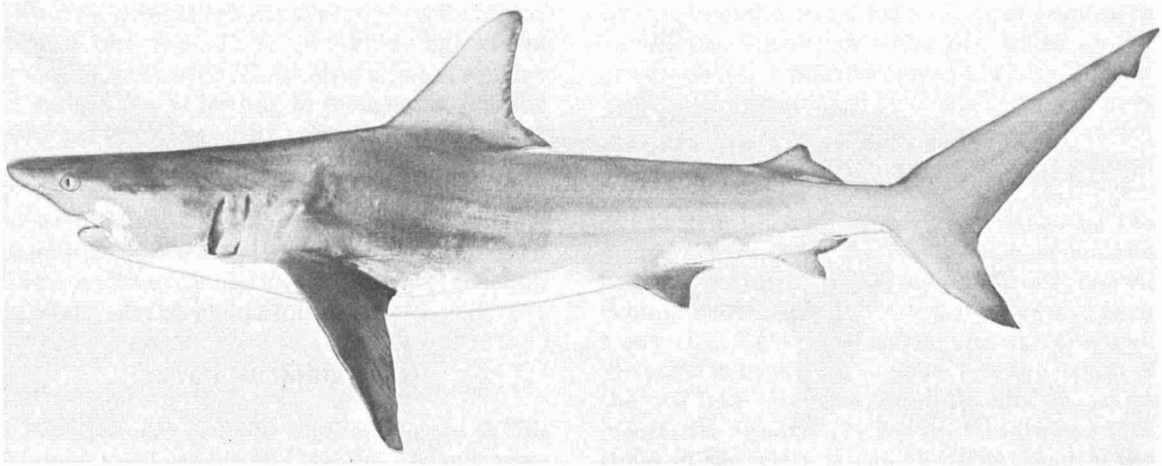

FIGURE 5.—*Carcharhinus limbatus,* 1,415 mm PCL, 1,910 mm TL, 38.2 kg, Enewetak, Marshall Islands.

The tips of the fins of Pacific individuals, particularly adults, are only slightly tipped or edged in black. Also the common Indo-West Pacific *C. melanopterus* has very pronounced black tips on its fins (see Randall and Helfman 1973, fig. 1, 2). To avoid confusion in common names, *C. melanopterus* has been referred to by many recent authors as the blacktip reef shark (though Bass et al. 1973, call it the blackfin reef shark).

Carcharhinus limbatus is distinctive in lacking a median ridge on the back between the dorsal fins, having a relatively long snout, and the cusp of its teeth notably narrow and erect. It has 29-32 upper, 28-32 lower teeth, and 88-102 precaudal vertebrae. The color is gray to bronze on the back, white below, with a long band of the dark dorsal color extending posteriorly from the last gill opening into the pale ventral color as far as the pelvic fins.

Two individuals of *C. limbatus* were caught at Enewetak during the ciguatera survey; these constitute the first records of the species from the Marshall Islands. The head of the illustrated specimen (which was 1,415 mm PCL, 1,910 mm TL, and weighed 38 kg) has been preserved in the Bernice P. Bishop Museum under catalog number 18074.

Only the second specimen, which was about 1,700 mm PCL (original data sheet with measurements was lost), was tested for toxicity. The viscera gave a reaction of 2 when fed to a mongoose.

Bass et al. (1973) reported on 55 of 101 sharks of this species with food in their stomachs. Fifty-one of the sharks had eaten teleost fishes, including: *Scomberomorus commerson*, *S. leopardus*, *Pomadasys* sp., *Sarpa salpa*, *Johnius hololepidosus*, *Leiognathus equula*, *Elops saurus*, *Tilapia mossambica*, and a soleid. Six contained elasmobranchs, including a small *C. obscurus* and a *Rhinobatus annulatus*. Two had eaten *Sepia* sp., and one a spiny lobster, *Panulirus homarus*.

The two Enewetak specimens had empty stomachs.

Galeocerdo cuvier (Peron and Lesueur) (Figure 6): The circumtropical tiger shark is readily identified by its broad bluntly rounded snout, distinctive teeth (heavily serrate, convex on the medial margin, and deeply notched on the lateral), low longitudinal keel on the side of the caudal peduncle, and dark bars (though these tend to fade with age).

The flesh of two tiger sharks from Enewetak, 1,770 and 2,410 PCL (72 and 174 kg), and one from Bikini, 1,498 mm PCL, was tested. None of these sharks were toxic. The Bikini specimen was caught at 4:30 a.m. in only 1.7 m of water.

Bigelow and Schroeder (1948) summarized the literature on food habits, danger to man, etc., of this shark. Other authors such as Clark and von Schmidt (1965), Bass et al. (1975a), and Tester (see footnote 7), have added to the list of the great variety of marine animals (mainly fishes) that this species will take as food, as well as sundry items of garbage and refuse discarded into the sea by man.

The stomach of the largest of the Marshall Islands specimens contained the scutes of a green turtle, *Chelonia mydas*, estimated to be 500 mm carapace length and the bait (a gray reef shark).

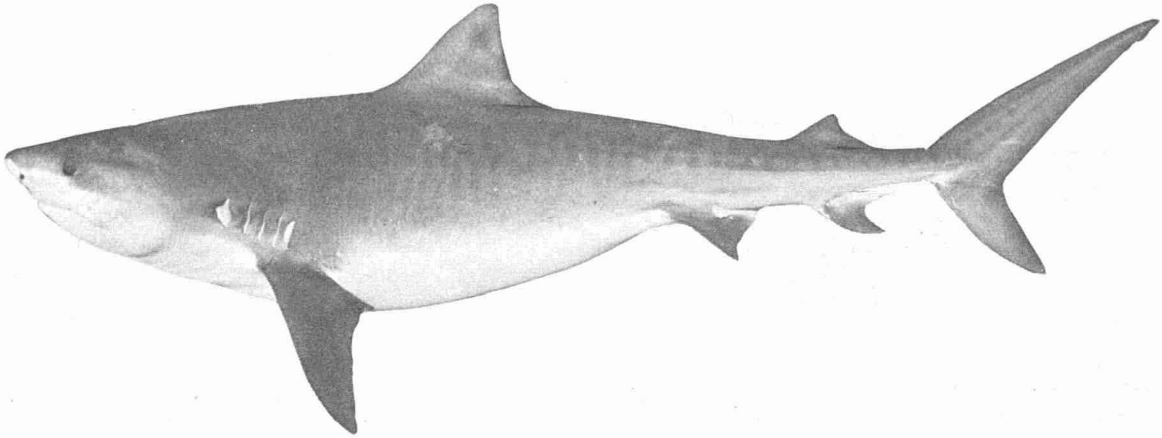

FIGURE 6.—*Galeocerdo cuvier,* 2,410 mm PCL, 3,055 mm TL, 175 kg, Enewetak, Marshall Islands.

The stomachs of the other two sharks were empty. Three other tiger sharks from Enewetak had food in their stomachs. One of 3,150 mm TL contained shark vertebrae. The second of 3,581 mm TL had the scutes of a green turtle and bird feathers. The third, 3,048 mm TL, was filled with pieces of a porpoise and the digested remains of shark fins.

A tiger shark of 3,327 mm TL from Ua Huka, Marquesas Islands, was empty, as was one of 2,895 mm TL from Oahu. Another from Oahu of 3,048 mm had an extremly distended stomach filled with heads of skipjack tuna (neatly cut by a knife, hence probably discarded from a fishing boat), plastic bags of garbage and aluminum foil, a cat, and two small reef fishes (one a balistid). It also contained the bait (the head of a calf). A 3,100 mm specimem weighing 174.6 kg taken by a set line at night at Rapa had eaten parts of a tiger shark larger than itself (probably from an individual caught on another hook), as well as a seabird.

Triaenodon obesus (Rüppell) (Figure 7): The whitetip reef shark, once classified by most ichthyologists in the family Triakidae, is now recorded as a carcharhinid (Compagno 1973). In spite of its scientific name, it is rather slender compared with most species of the family. Apart from its slim form and white-tipped first dorsal fin and upper caudal lobe, *T. obesus* is distinctive in its very blunt snout and teeth which bear a small cusp on each side of the main central one. It is widespread throughout the tropical and subtropical Indo-West Pacific region and ranges to the eastern Pacific as well. Banner and Helfrich (1964) and Brock et al. (1965) have reported this species as poisonous from Johnston Island.

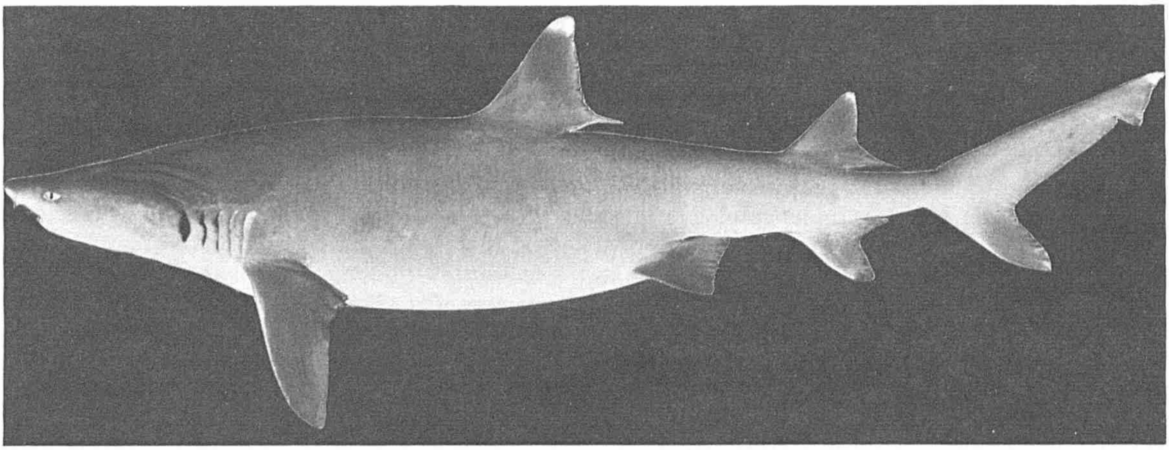

FIGURE 7.—*Triaenodon obesus*, 1,218 mm PCL, 1,520 mm TL, 23.5 kg, Tahiti, Society Islands.

The toxicity of eight whitetip reef sharks, 1,003-1,183 mm PCL (8.4-22.4 kg), from Enewetak was tested. The flesh of all was negative for ciguatoxin by feeding to mongooses, but the viscera of two gave positive reactions of 1.

Randall (1977) studied the biology of this species. He opened the stomachs of 56 specimens (24 of which were from Enewetak): 33 were empty, 6 had eaten octopuses (2 of these also contained fishes), and the rest had the remains of reef fishes, especially scarids and acanthurids.

Dasyatidae (Sting Rays)

Taeniura melanospilos Bleeker (Figure 8): The specimens collected in the Marshall Islands were initially called *Taeniura brocki* Schultz. However, it now seems more likely that they should be identified as *T. melanospilos* Bleeker. Schultz in Schultz and collaborators (1953) differentiated *T. brocki* by its having the venomous spine inserted "... at about half length of tail..." in contrast to a little behind the first third on *T. melanospilos*, in having the snout contained five times in the greatest width of the disc (given as six by Bleeker for *T. melanospilos*), and in having "...very numerous irregularly shaped small brownish to blackish spots and blotches speckling dorsal surface of disk ...," as opposed to "... numerous rounded black spots ..." for *T. melanospilos*. After noting the measurements of the position of the spine and the length of the tail of his only specimens of *T. brocki*, Schultz wrote, "... end of the tail may have been bitten off...." On the specimen illustrated herein, the spine is inserted at a point 41% the length of the tail from the base. From Schultz' measurements, the snout of *T. brocki* is contained 5.14 times in the width of the disc. The snout of the specimen illustrated herein is contained about 5.3 times in the disc width. Without knowledge of variation of this character and perhaps proportional differences with growth, the differentiation of species on this magnitude of snout length is questionable. Furthermore, Bleeker's (1853) de-

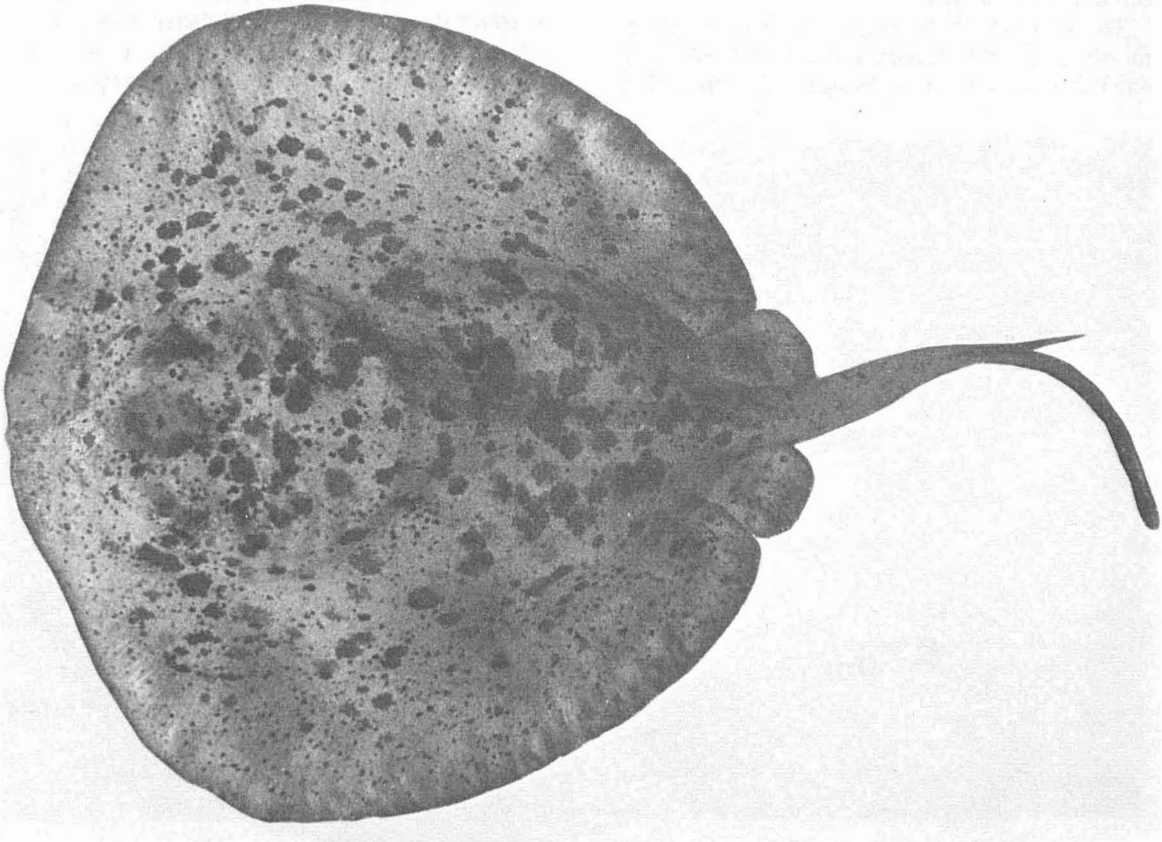

FIGURE 8.—*Taeniura melanospilos*, 1,255 mm disc length, 2,008 mm TL, 69 kg, Enewetak, Marshall Islands.

scription of the dark spots of *T. melanospilos* was not simply round as Schultz stated, but round and oblong and variably small, medium, and large.

One stingray of this species from Enewetak with a disc length of 870 mm (disc width 950 mm; tail length 950 mm), weighing 19.05 kg, was tested. It was not poisonous.

The stomach of this ray was empty. Another of 1,255 mm disc length weighing 68.9 kg collected by the author at Enewetak in 1968 had eaten two labrid fishes (*Xyrichtys*) and a parrotfish, *Scarus* sp. It was a female with seven embryos.

Muraenidae (Morays)

Lycodontis javanicus (Bleeker) (Figure 9): This moray is brown with large dark blotches and numerous small dark spots; the gill opening is in a large black spot; there are no pale margins on the fins. It is probably the species of eel reported by Khlentzos (1950) which poisoned 57 Filipino laborers at Saipan, Mariana Islands. In spite of prompt gastric lavage, 14 of these men became comatose and 2 died.

The severity of illness from the consumption of moray eels led Halstead and Lively (1954) to regard this as a distinct category of fish toxemia which they termed "Gymnothorax poisoning." However, it appears to be principally an acute form of ciguatera, though there is a possibility of involvement of one or more other toxins.

Lycodontis javanicus is not common in the Marshall Islands, but it is abundant (for a large carnivore) at Johnston Island; in recent years it has served as the primary source of ciguatoxin for biochemical and pharmacological study at the University of Hawaii by a team of scientists headed by A. H. Banner.

Nine specimens from Enewetak measuring 1,086-1,540 mm TL and weighing 3.6-13.0 kg were tested. All were toxic, two at the 2 level, one at 3, three at 4, and three at 5 from the feeding of liver and viscera to mongooses. The flesh of two of these eels with a mongoose reaction of 4 was tested; one was a 1 and the other a 2. One of the eels with a mongoose test of 5 for liver-viscera gave a reaction of 3 with flesh.

Brock (1972) studied some aspects of the biology of *L. javanicus*, including an analysis of the toxicity at Johnston Island. Of 1,074 specimens, only 158 (14.7%) contained food; 88.8% of the stomach-content material consisted of fishes (representing 17 different families, the Scaridae predominating). Among the more interesting prey species was

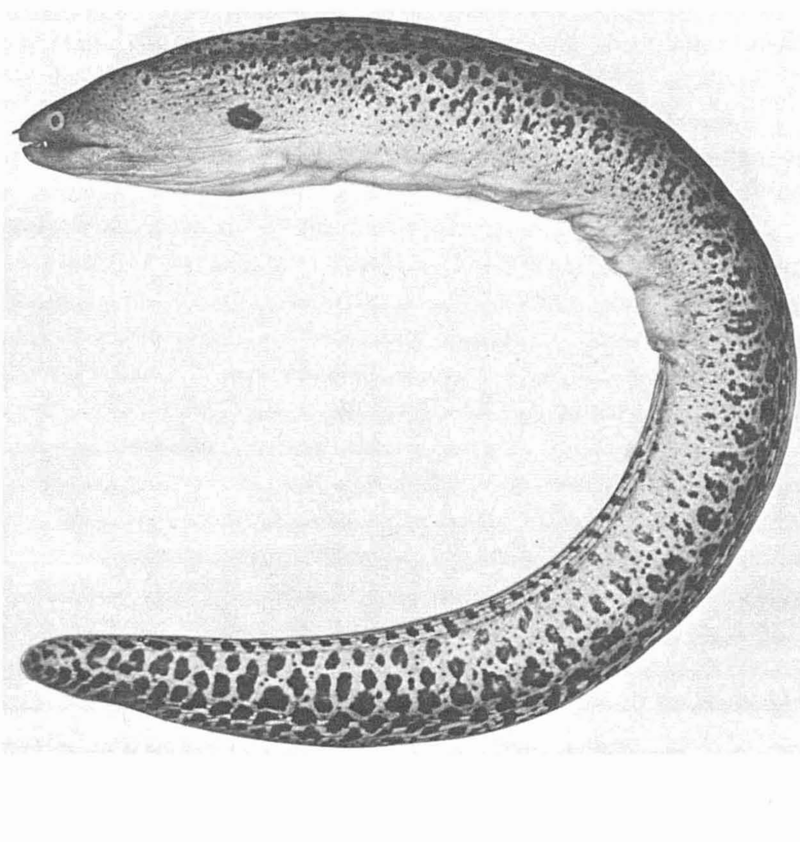

FIGURE 9.—*Lycodontis javanicus,* 732 mm TL, Enewetak, Marshall Islands.

a whitetip reef shark 465 mm PCL, taken from the stomach of a 1,422 mm moray. Octopus and spiny lobster were also eaten.

This is the largest species of moray in the Indo-Pacific region. Schultz (1949) attributed an attack on the late Vernon E. Brock at Johnston Island by a moray of about 10 ft (3,048 mm) in length to be *Enchelynassa canina*. Following a later interview with Brock, Randall (1969) reported that the eel was actually *L. javanicus* and the length 7-8 ft (2,134-2,438 mm). Stephens (1963) noted that the largest moray measured at Johnston during his stay at the island to be 7 ft 10 in (2,388 mm). The author tended to disbelieve occasional reports by divers of individual *L. javanicus* of 10-12 ft (3,048-3,658 mm) until he observed one of an estimated 3,000 mm long off Mafia Island, Tanzania, which was flushed from a cave with rotenone (the eel recovered from the affect of the rotenone and returned to its cave).

The stomach contents of 11 specimens 417-1,905 mm TL (the largest weighed 24.5 kg) were examined during the present study. Six of these eels were from Enewetak, the rest from Oeno, Pitcairn, Johnston, and Truk. Four had empty stomachs. The smallest contained a crab chela. The others had eaten fishes (two contained *Scarus* sp., one *Diodon* sp., and another *Thalassoma purpureum*). The stomach of a 1,540 mm, 13 kg specimen was distended with *Kyphosus cinerascens*, *Acanthurus nigricauda* (identified as *A. nigricans* by Schultz and Woods in Schultz and collaborators 1953, and as *A. gahhm* by Randall 1956), and *A. nigroris*, all of which totalled 1.5 kg. These fishes must be discounted as normal prey, however, as they were undoubtedly eaten as a result of a dynamite station at the Enewetak garbage pier. The eel was collected with a powerhead blast immediately after the dynamite explosion when it was discovered within the area in which many other fishes had just been killed.

Holocentridae (Squirrelfishes)

Adioryx spinifer (Forsskål) (Figure 10): The largest of the squirrelfishes, this species exceeds 300 mm SL. It has a deep body, the depth about 2.5-2.7 in SL, projecting lower jaw, 40-44 lateral line scales, and a well-developed venomous spine at the corner of the preopercle. The color is red and silvery with a deep red spot behind the eye and another on the pectoral axil; the fins are yellow except the spinous dorsal which is deep red. Described from the Red Sea, the species has since

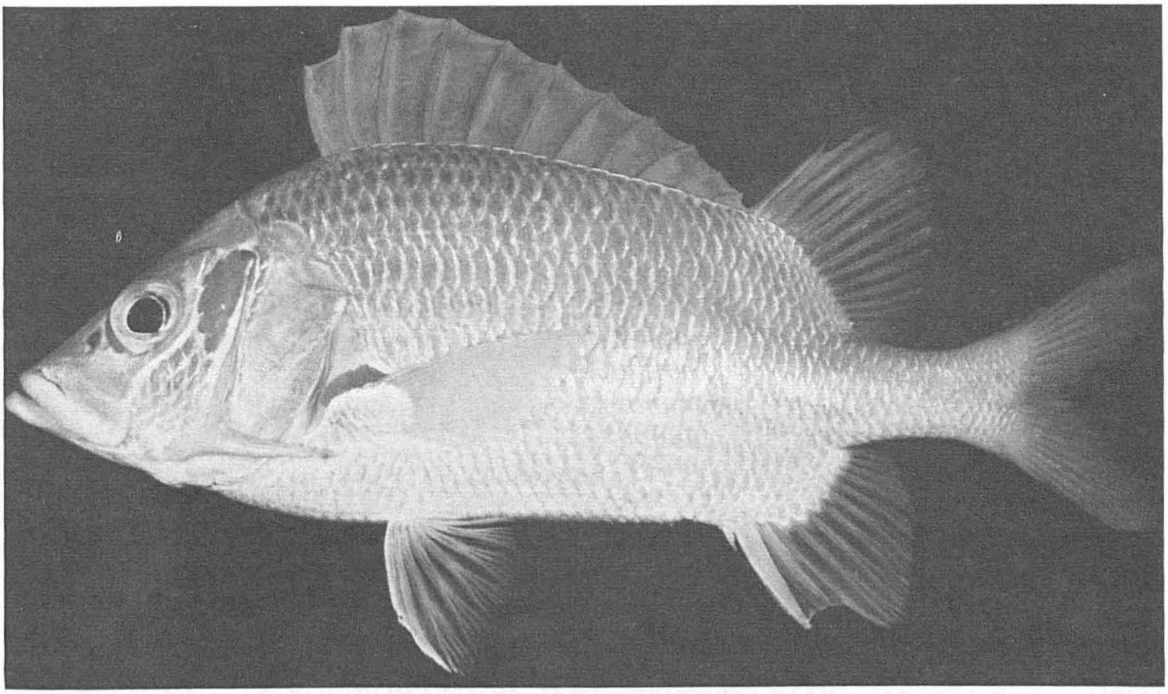

FIGURE 10.—*Adioryx spinifer*, 260 mm SL, Enewetak, Marshall Islands.

been recorded from throughout the tropical Indo-West Pacific. It is often found in caves.

Randall (1958) reported this species as occasionally toxic in Tahiti. In his review of ciguatoxic fishes, Halstead (1967) cited this and three other references.

Six specimens, 232-280 mm SL (0.35-0.66 kg), were collected for assay of toxicity from Enewetak. All were nontoxic.

Randall (1958) found fishes in the stomachs of two adults from Tahiti. Hiatt and Strasburg (1960) examined the stomachs of nine from Enewetak, one of which was empty. Crabs (especially xanthids) dominated the stomach contents of the other specimens: 12% contained stomatopods and 12% fishes. The stomachs of five specimens from Hawaii reported by Hobson (1974) contained crustaceans, mainly caridean shrimps, and xanthid crabs.

For this food-habit study a total of 31 specimens ranging from 182 to 280 mm SL were obtained, principally from Enewetak, but a few from the Red Sea, Society Islands, Hawaiian Islands, and American Samoa. Because this species is nocturnal, like other holocentrids in general, most specimens were collected in early morning hours. Twenty-eight of these fish had food in their stomachs; 82% by volume consisted of crabs, mostly xanthids, 5% fishes (including *Lycodontis rueppelliae* and a prejuvenile acanthurid), and the rest shrimps, a hermit crab, unidentified crustaceans (mostly larval), larval mollusks, and an unidentified worm.

Sphyraenidae (Barracudas)

Sphyraena barracudaa (Walbaum) (Figure 11): The great barracuda is distinctive in having a few blackish blotches on the side, especially posteriorly and ventrally, and the lowest lateral line scale count of the genus (76-85). It is the worst offender for causing ciguatera in the West Indies, due not only to the high level of toxicity of occasional individuals but also to its relative abundance there. The species is far less common in the Indo-West Pacific.

Seven specimens 563-1,182 mm SL (1.5-13.6 kg) from Enewetak were tested, and three from Bikini, 640-1,143 mm SL, the largest 15.0 kg. Three from Enewetak were nontoxic, one was toxic at the level of 1; two gave a reaction of 2; and one (1,050 mm, 12.7 kg) was a 3. The three from Bikini were tested at 0, 1, and 2.

de Sylva (1963) made a study of the systematics and life history of the great barracuda, principally from material from the western Atlantic. He reviewed previous papers which presented limited data on the food habits of this species. Among them was the report by Ommanney in Wheeler and Ommanney (1953) on the fishes found in the stomachs of 5 of 12 specimens of *S. commersoni* (now known to be a junior synonym of *S. barracuda*) from the Seychelles. One of the five contained an unidentified eel and another *Lethrinus ramak*. de Sylva mistakenly reported Ommanney's five barracuda as all having eaten *L. ramak*.

de Sylva opened the stomachs of 901 great barracuda, including juveniles, from various localities in the tropical western Atlantic. Of these, 529 (58.7%) contained food. Fishes were found in 82.2% of the stomachs, plant material in 2.8% (probably accidentally ingested with prey), invertebrates (notably squids and shrimps) in 2.6%, and unidentifiable material in 12.2%. The Hemiramphidae was the most common family of fishes found in the stomachs of 446 adult barracuda from Florida, whereas tetraodontid fishes predominated in the stomach contents of 132 adults from Bimini, Bahamas.

The stomachs of 13 specimens, 560-1,182 mm

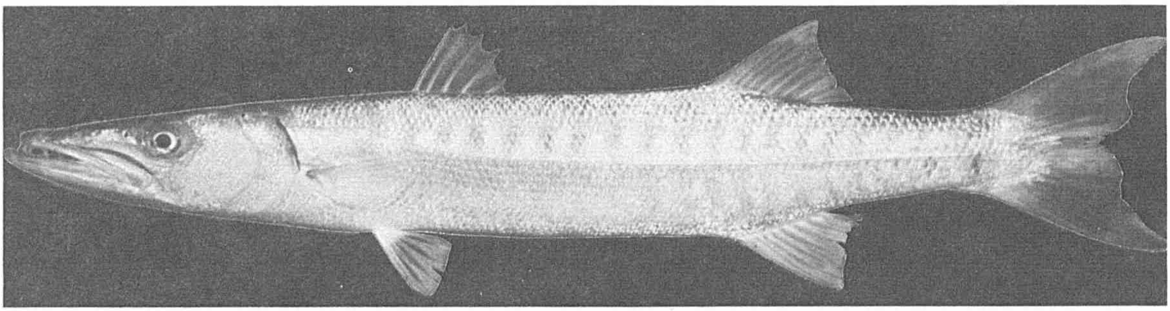

FIGURE 11.—*Sphyraena barracuda*, 524 mm SL, Palmyra, Line Islands.

SL, from the Marshall Islands and Line Islands were examined during the present study. Nine of these fishes had empty stomachs. The rest contained the remains of fishes.

Sphyraena forsteri Cuvier (Figure 12): This barracuda is readily distinguished from all others by its large eye, black blotch in the axil of the pectoral fins, and spiniferous plates on its first gill arch instead of gill rakers or no trace of rakers at all.

de Sylva (1973:18) wrote that this species of barracuda has been implicated in poisoning but added that the examples appear to be misidentifications of *S. barracuda*. Hiyama (1943, pl. 3, fig. 9), however, did not confuse his specimens with *S. barracuda*. He reported *S. forsteri* from the Marshall Islands as slightly poisonous from feeding flesh to cats and mice.

Only two individuals of this species were caught during the survey, both from Bikini and both the same size (610 mm SL, 1.8 kg). Each produced a toxic reaction of 2.

The stomach of one of these fish contained fish remains; the other was empty.

Mugilidae (Mullets)

Crenimugil crenilabis (Forsskål) (Figure 13): This large mullet has a deeply emarginate caudal fin, a black spot at upper pectoral base, and 37-39 rows of scales between the gill opening and the caudal base. Widespread in the tropical Indo-West Pacific region, it is usually seen in small aggregations in the shallows of lagoons and on outer reef flats. It appears to feed on fine algae and detritus from the substratum. After feeding on a sandy bottom it has been observed to expel sand from its gill openings. The spawning by a large school at the surface at night in the Enewetak lagoon was described by Helfrich and Allen (1975). *Crenimugil crenilabis* has been reported as poisonous by Randall (1958) from the Society Islands. It is probably the species of mullet that Ross (1947)

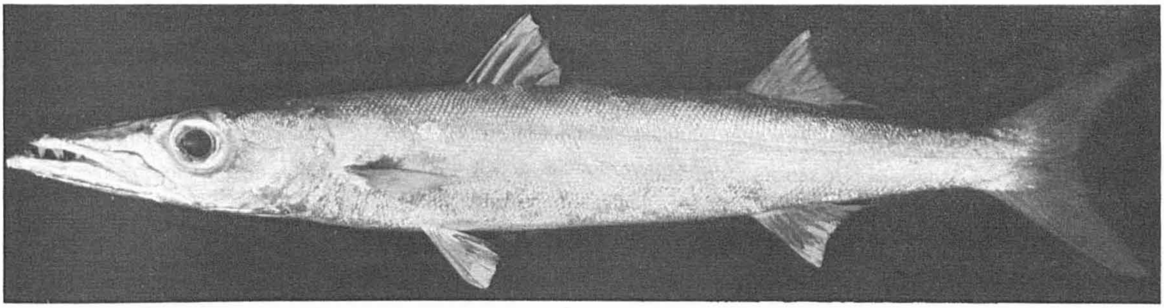

FIGURE 12.—*Sphyraena forsteri*, 540 mm SL, 1.2 kg, Enewetak, Marshall Islands.

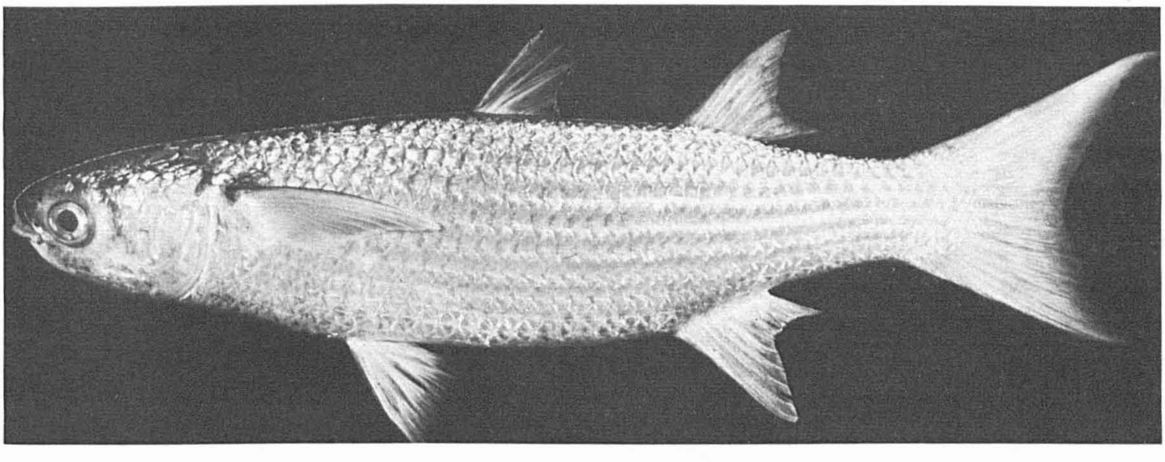

FIGURE 13.—*Crenimugil crenilabis*, 337 mm SL, Enewetak, Marshall Islands.

found toxic at Fanning, Line Islands (Randall 1958).

Three specimens, 248-406 mm (0.4-0.7 kg), were obtained for testing from Bikini. None were toxic.

Serranidae (Groupers)

Cephalopholis argus Bloch and Schneider (Figure 14): This common brown blue-spotted grouper has 9 dorsal spines (in contrast to 11 for the groupers of the genus *Epinephelus*). It does not reach large size, but is has occasionally been implicated in ciguatera. Although it is most abundant in outer reef areas, it also occurs on lagoon reefs.

A total of nine specimens from Enewetak were tested; these ranged from 278 to 390 SL (0.45-1.6 kg). Two were nontoxic, three gave a reaction of 1, three were recorded as 2, and the largest was a 4.

Randall (1955a) found 8 of 10 individuals of this grouper from the Gilbert Islands with empty stomachs; 1 had eaten a fish (probably from rotenone), and 1 a penaeid shrimp. Randall and Brock (1960) obtained 280 specimens for food-habit study, of which 182 were empty; 77.5% contained fishes and the rest crustaceans. Hiatt and Strasburg (1960) reported on food in five of eight stomachs from the Marshall Islands as crustaceans, fishes, and polychaetes. Helfrich et al. (1968) examined the stomachs of 51 from Palmyra; they found fishes in 89% of the stomachs and crustaceans. Harmelin-Vivien and Bouchon (1976) caught 43 *C. argus* for stomach-content analyses in Madagascar. They found fishes 95.7% by weight, shrimps 3.9%, and stomatopods 0.4% in the stomachs.

For the present study the stomachs of 39 specimens, 145-392 mm SL, from Enewetak, Society Islands, Samoa Islands, Palmyra, Marcus Island, and Pitcairn, were examined. Twenty-six were empty, one had eaten a stomatopod, and the rest contained fishes (two of these were the acronurus stage of Acanthuridae, one a labrid, one an antennariid, and one *Apogon kallopterus*).

Epinephelus fuscoguttatus (Forsskål) (Figure 15): The name *E. fuscoguttatus* was used by Schultz in Schultz and collaborators (1953) for the more common related species properly called *E. microdon* (Bleeker) (systematic clarification by Randall 1964). The two are similar in morphology and color. *Epinephelus fuscoguttatus* has higher pectoral ray counts (18 or 19, compared with 16 or 17 for *E. microdon*) and more lower limb gill rakers (18-21, including rudiments, compared with 16 or 17 for *E. microdon*).

This grouper is a large species; it is not common. Furthermore, it is the most wary of Marshall Islands groupers. Seven specimens (335-780 mm SL, 3.1-15.4 kg) were taken at Enewetak for testing, and none at Bikini. Four of the seven were toxic at the 2 level, and one (710 mm SL) was a 3.

Harmelin-Vivien and Bouchon (1976) caught four individuals of this species for food-habit study in Madagascar. The stomachs contained 94.2% fishes by weight and 5.8% brachyuran crabs.

The stomachs of seven specimens from

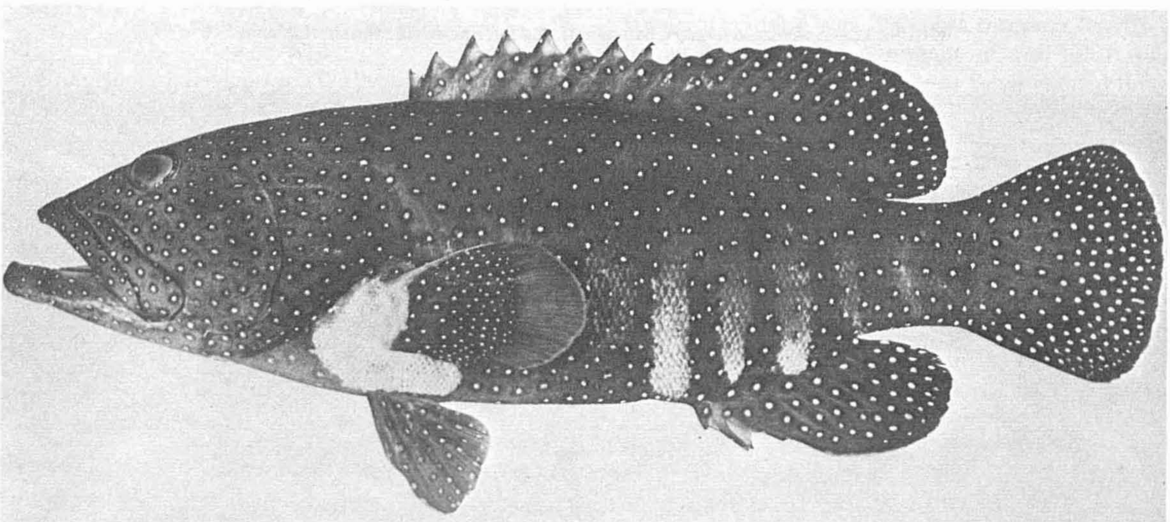

FIGURE 14.—*Cephalopholis argus*, 232 mm SL, Tahiti, Society Islands.

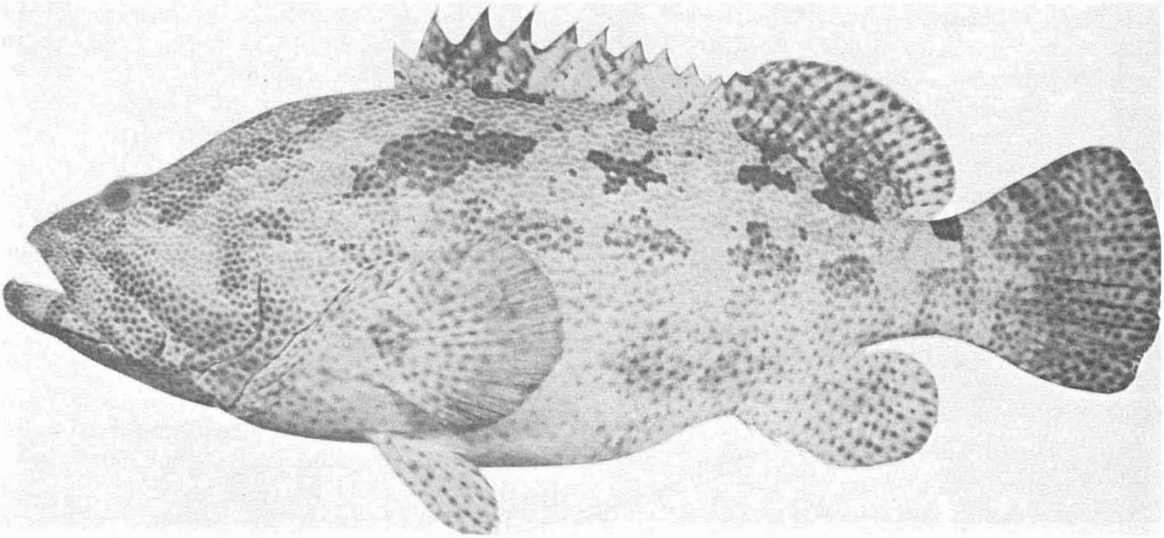

FIGURE 15.—*Epinephelus fuscoguttatus,* 551 mm SL, 5.9 kg, Gulf of Aqaba, Red Sea.

Enewetak were examined. Four were empty, one had an octopus, one had fish remains, and the last contained unidentified tissue which appeared to be cephalopod in origin. A specimen 408 mm SL from the Red Sea had crab remains in its stomach.

Epinephelus hoedtii (Bleeker) (Figure 16): Schultz in Schultz and collaborators (1953) described this fish as new from the Marshall Islands, naming it *E. kohleri*. It is relatively deep bodied and has a slightly emarginate to truncate caudal fin. He differentiated it from "... all of the 'varieties' of *flavocaeruleus* described by Boulenger in having the body spotted with dark blotches in addition to tiny dark specks." Although more study is needed of the complex of forms which Boulenger

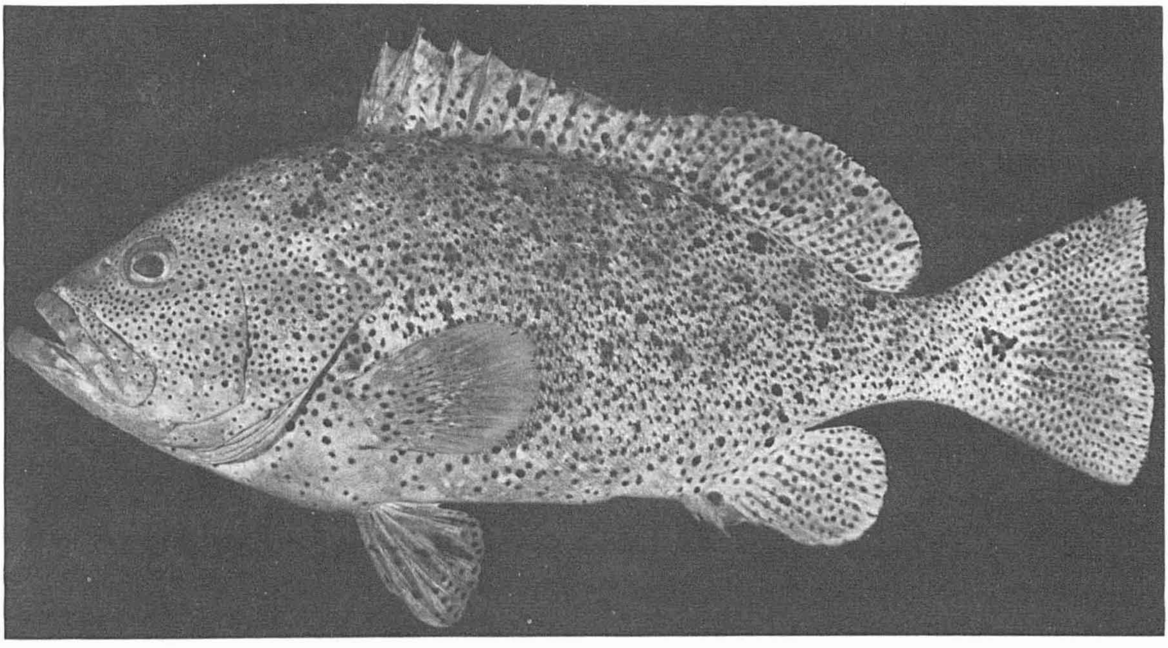

FIGURE 16.—*Epinephelus hoedtii,* 319 mm SL, Enewetak, Marshall Islands.

(1895) regarded as varieties of *flavocaeruleus*, I believe that the variety called *E. hoedtii* (Bleeker) is a valid species and that Schultz' *E. kohleri* is a junior synonym of it. Adult specimens, such as the type of *E. kohleri*, have the dark blotches, whereas smaller individuals, such as Bleeker's specimens, lack them. Hiyama (1943:81, pl. 18, fig. 49) identified it as *Serranus flavocaeruleus* (Lacepède).

This grouper was found around isolated coral heads in the lagoon of Enewetak. Eleven specimens, 348-429 mm SL, 1.36-2.72 kg, were tested. Six were nontoxic, three gave reactions of 1, one was a 2, and one (400 mm SL) a 4. A single specimen (2 kg) from Bikini was nontoxic.

Hiatt and Strasburg (1960) found fish fragments in the stomach of one of two specimens from the Marshall Islands.

The stomachs of the 11 Enewetak specimens were opened. Five were empty, one (429 mm SL) contained a 520 mm snake eel, *Leiuranus semicinctus*; two had eaten calappid crabs; and the remaining three contained the digested remains of fishes.

Epinephelus maculatus (Bloch) (Figure 17): This dark-spotted grouper was identified as *E. medurensis* (Günther) by Schultz in Schultz and collaborators (1953). It has also been called *E. fario* (Thunberg) by some authors. The oldest valid name, however, is *E. maculatus* (Bloch). Though the author ascertained that the type-specimen is no longer extant, Bloch's description and illustration match that of the juvenile of this species, particularly with reference to the large pale markings. Adults are distinctive in the rather elevated third and fourth dorsal spines; also there are two large dark areas on the dorsal fin and adjacent back which are separated by a pale area (both dark and light areas still have the profusion of small dark spots).

Like *E. hoedtii*, this species is found mainly around coral knolls in sandy stretches of atoll lagoons. Eleven specimens from Enewetak, 270-334 mm SL, 0.45-0.9 kg, were tested. Eight were nontoxic and three gave reactions of 1. Two from Bikini, 343 and 356 mm SL, were nontoxic.

The stomachs of 13 specimens from Enewetak and 2 from Bikini, 270-380 mm SL, were examined. One of 334 mm contained a portunid crab and unidentified fish remains; another of 345 mm had eaten a calappid crab (15% by volume), two microdesmid fish 78 and 86 mm SL (identified as *Gunnellichthys monostigma* by C. E. Dawson), and a digested fish; a third (308 mm SL) also contained *G. monostigma*; a fourth (288 mm SL) an octopus; and two others fish remains. The remaining nine stomachs were empty.

Epinephelus microdon (Bleeker) (Figure 18): This is a common species in the Marshall Islands for a grouper of moderate size. It is found on both

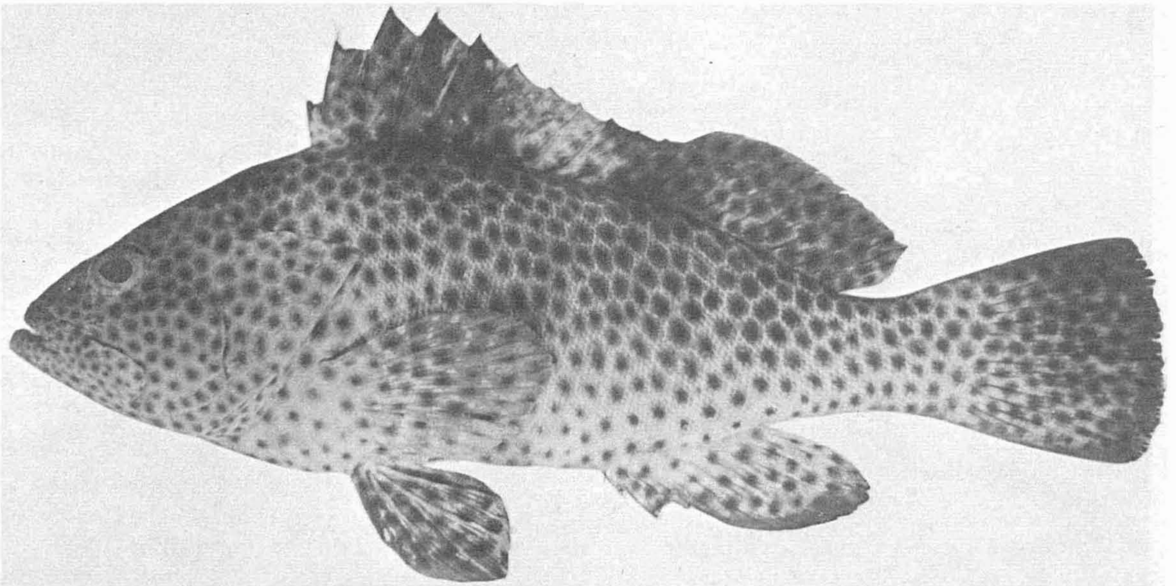

FIGURE 17.—*Epinephelus maculatus*, 280 mm SL, Enewetak, Marshall Islands.

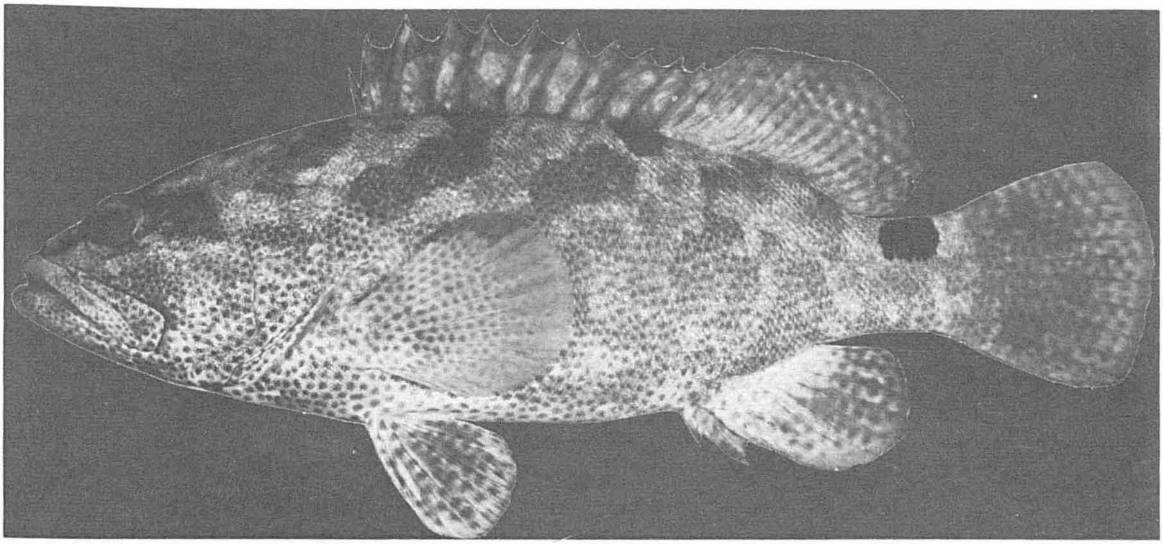

FIGURE 18.—*Epinephelus microdon,* 282 mm SL, Enewetak, Marshall Islands.

ocean and lagoon reefs. As mentioned in the account of *E. fuscoguttatus* above, it has been confused with this species by Schultz and other authors.

Thirty-nine specimens from Enewetak were tested for ciguatera toxin. These ranged from 310 to 470 mm SL and weighed 1.4-3.1 kg. Eight were nontoxic, 3 were toxic at the 1 level, 8 were 2, 13 were 3, 5 were 4, and 2 were 5 (caused death of test animals).

Nine specimens from Bikini, 279-508 mm SL, 0.9-4.1 kg, were tested. Two (279 and 342 mm) were nontoxic, one was poisonous at the 1 level, four were 2, one was 3, and one was 5 (460 mm SL).

Randall and Brock (1960) reported on the food habits of this species (as *E. fuscoguttatus*) from 33 specimens taken in the Society Islands and Tuamotu Archipelago. Of 10 with food in their stomachs, 5 had eaten crustaceans (mainly crabs) and 5 of them fishes. The eight specimens recorded by Hiatt and Strasburg (1960) as *E. fuscoguttatus* were probably *E. microdon*. Three fish had empty stomachs and the remaining five contained fishes and crustaceans.

Helfrich et al. (1968) examined the stomachs of 150 specimens from the Line Islands of which 81 contained food, mainly fishes and crustaceans. The latter accounted for 64% of the total by volume (portunid crabs and scyllarid lobsters were the most frequently recorded). A few of the groupers had eaten gastropods and cephalopods.

For the present food-habit study 44 specimens (210-610 mm SL) were examined, of which 28 were from Enewetak. The remaining 15 were from Palmyra, Tutuila, and Rapa (where the largest specimen was taken). Thirty of the 44 groupers had empty stomachs. Eight contained crabs (mainly porcellanids and portunids; one had eaten the xanthid *Carpilius convexus*), three contained fishes (one identified as *Scarus*), two had eaten octopus, and one a spiny lobster, *Panulirus*.

Epinephelus socialis (Günther) (Figure 19): This grouper has numerous small dark brown spots which tend to coalesce to form irregular longitudinal bands, especially posteriorly. The caudal fin and soft portions of the dorsal and anal fins have narrow pale margins and broad blackish submarginal zones. It is found mainly on the outer reef flat of the atoll environment, sometimes in surprisingly shallow and often turbulent water. Although fishes living entirely in this habitat would not be expected to be ciguatoxic, Halstead and Schall (1958) reported one specimen of this species as weakly toxic from Malden Island.

Two specimens, 354 and 360 mm SL, 1.1 and 1.6 kg, from Enewetak were tested. Both proved to be nontoxic.

The stomach contents of seven specimens from Enewetak, 235-360 mm SL, and one from Ducie Atoll, Pitcairn Group (420 mm SL, 2.3 kg) were examined. Three had eaten crabs (grapsids in two,

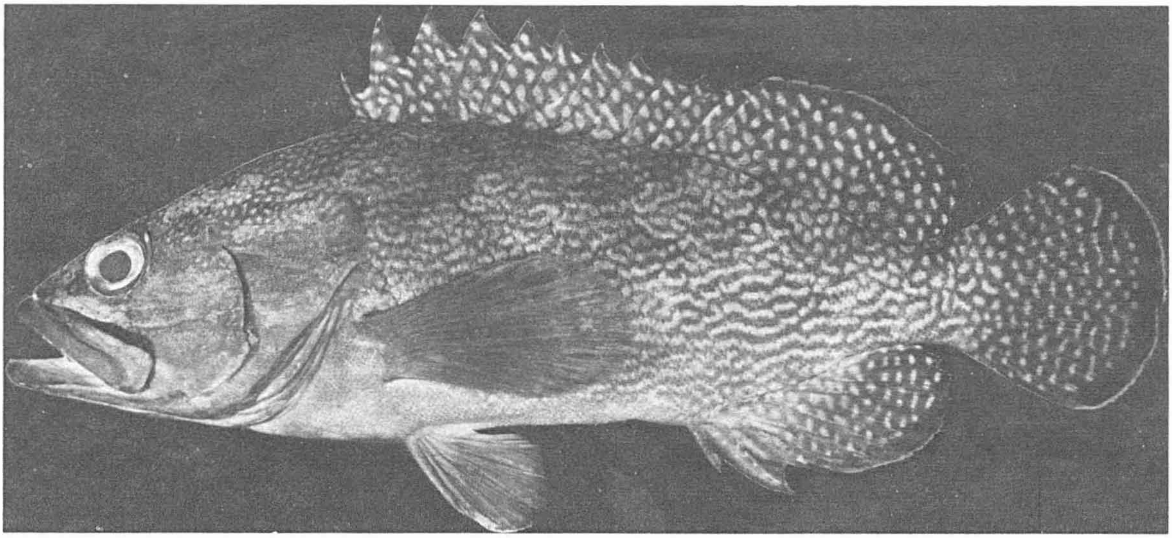

FIGURE 19.—*Epinephelus socialis,* 222 mm SL, Ponape, Caroline Islands.

including *Percnon*, and the xanthid crab *Eriphia sebana* was found in the third); one of 330 mm contained an octopus (60% by volume) and a prejuvenile acanthurid fish; one of 354 mm contained an acanthurid 165 mm SL. The remaining stomachs were empty.

Epinephelus tauvina (Forsskål) (Figure 20): The name *E. tauvina* has often been applied to a huge grouper for which the name *E. lanceolatus* seems correct. Though the true *E. tauvina* can attain moderately large size (to perhaps 800 mm SL or more), it is not a giant species. Schultz in Schultz and collaborators (1953) described this fish as *E. elongatus* from the Marshall Islands, Mariana Islands, Phoenix Islands, and Samoa Islands, and Smith and Smith (1963) named it *E. salonotus* from the Seychelles. Katayama (1960) and Randall (1964) showed that *E. tauvina*, described from the Red Sea, is the senior synonym. This species may be confused with other dark-spotted groupers such as *E. merra* Bloch and *E. hexagonus* (Bloch and Schneider), particularly when it is small. It is differentiated from them in having 15 instead of

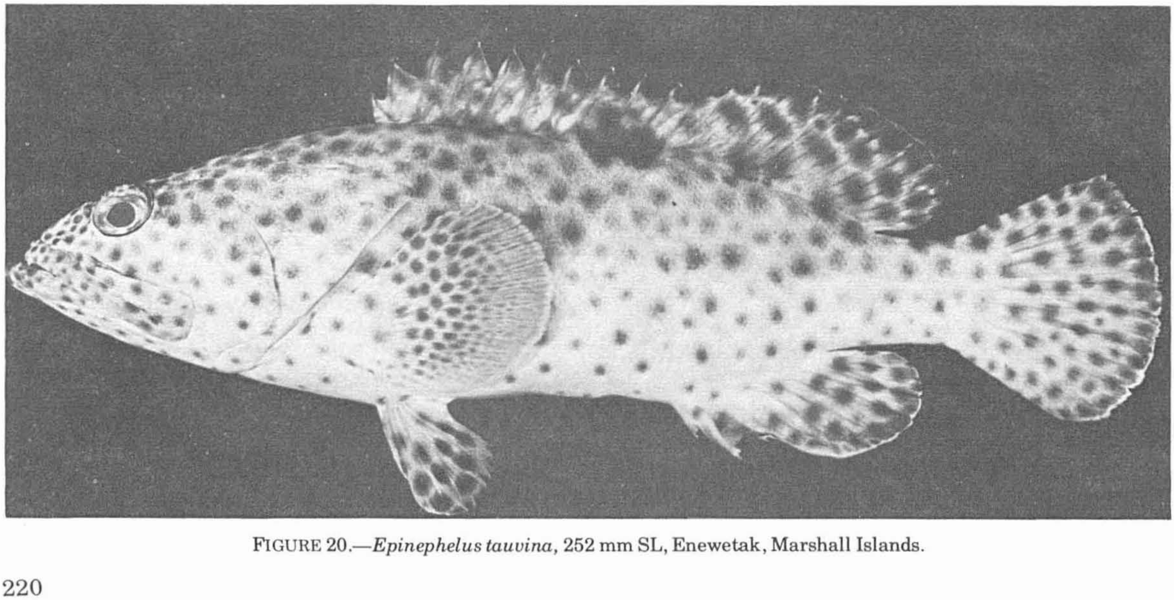

FIGURE 20.—*Epinephelus tauvina,* 252 mm SL, Enewetak, Marshall Islands.

16 soft rays in the dorsal fin, a total of 27-30 gill rakers, instead of 20-27, and a more elongate body.

Epinephelus tauvina is not very common in the Marshall Islands. It may be found in both lagoon and outer reef environments.

Six specimens from Enewetak, 324-434 mm SL, 0.45-2.54 kg, were tested. Four were nontoxic, and one each was poisonous at the 1 and 2 levels. One specimen from Bikini, 400 mm SL, was nontoxic, while a second, 450 mm SL (2.3 kg), gave a mongoose test of 3.

Randall and Brock (1960) found food in the stomachs of 3 of 12 specimens (identified as *E. elongatus*) collected in the Society Islands. All had eaten fishes; in addition, one stomach contained a crab chela.

Thirty-four specimens, 204-500 mm SL, from Enewetak, Society Islands, Line Islands, Cook Islands, Rapa, and the Red Sea were examined for food. Nineteen had empty stomachs, one contained a crab, and the rest had eaten fishes, of which one could be identified to species (*Adioryx lacteoguttatus*) and three to family (Pomacentridae, Holocentridae, and Mullidae).

Plectropomus leopardus (Lacepède) (Figure 21): This is the largest and most common of four groupers of the genus *Plectropomus* in the Marshall Islands. The genus is readily distinguished from other Micronesian serranid genera in having eight dorsal spines and large canine teeth in the jaws; also the body is more elongate than most other groupers. *Plectropomus leopardus* is reddish with small dark-edged blue spots and an emarginate caudal fin.

This species is among the worst offenders in Oceania for causing ciguatera. Halstead (1967) listed it as poisonous from Jaluit in the Marshall Islands and in the Tuamotus. He cited 10 papers that have reported on its toxicity in the Pacific, among them Randall (1958) who noted it as the most toxic of the groupers in Tahiti and reported his own poisoning from the Tuamotus.

Thirty-one specimens were collected at Enewetak for ciguatoxin content, mainly by spearing. The fish ranged from 426 to 790 mm SL and weighed from 1.8 to 11.8 kg. Twelve were nontoxic, six were poisonous at the 1 level, eight at 2, four at 3, and one (520 mm SL) was a 5. One specimen (8.2 kg) from Bikini was nontoxic.

Randall and Brock (1960) recorded the food of seven specimens from the Society Islands: four had empty stomachs and the rest had eaten fishes.

Thirty-seven specimens 426-790 mm SL were collected for food-habit study from Enewetak, Society Islands, and Okinawa. Fifteen had empty stomachs, and the rest contained fishes. Five had eaten parrotfishes (one grouper, 702 mm SL, contained a *Scarus gibbus* 313 mm SL). A 643 mm fish contained two acanthurids, one of which was a *Ctenochaetus striatus* 153 mm SL. A 705 mm grouper had eaten a labrid, *Cheilinus undulatus*, 270 mm SL. Two others had groupers in their stomachs, a 659 mm fish contained *E. tauvina* 267 mm SL, and a 790 mm fish contained a half-digested *Epinephelus* sp.

Plectropomus melanoleucus (Lacepède) (Figure 22): This distinctively colored grouper, white with

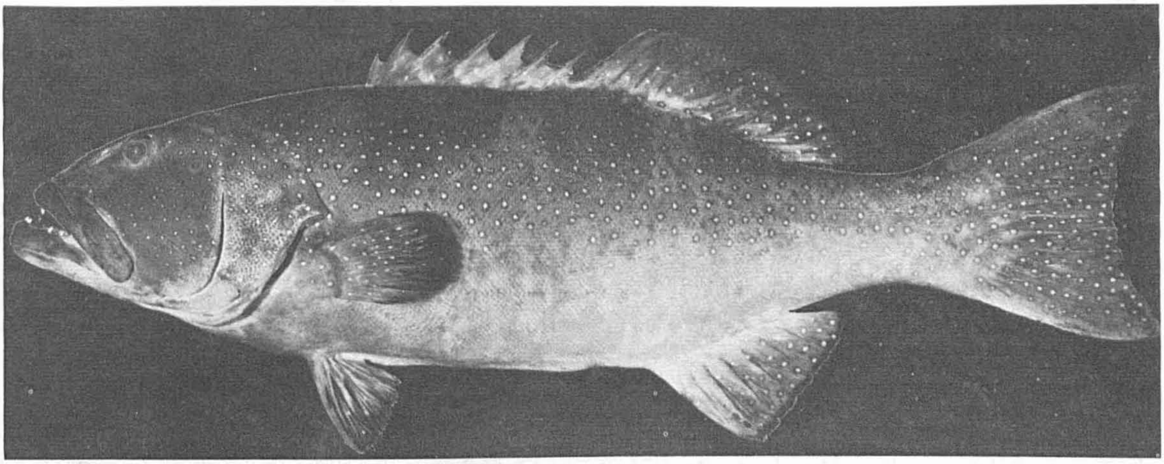

FIGURE 21.—*Plectropomus leopardus*, 513 mm SL, 3.4 kg, Enewetak, Marshall Islands.

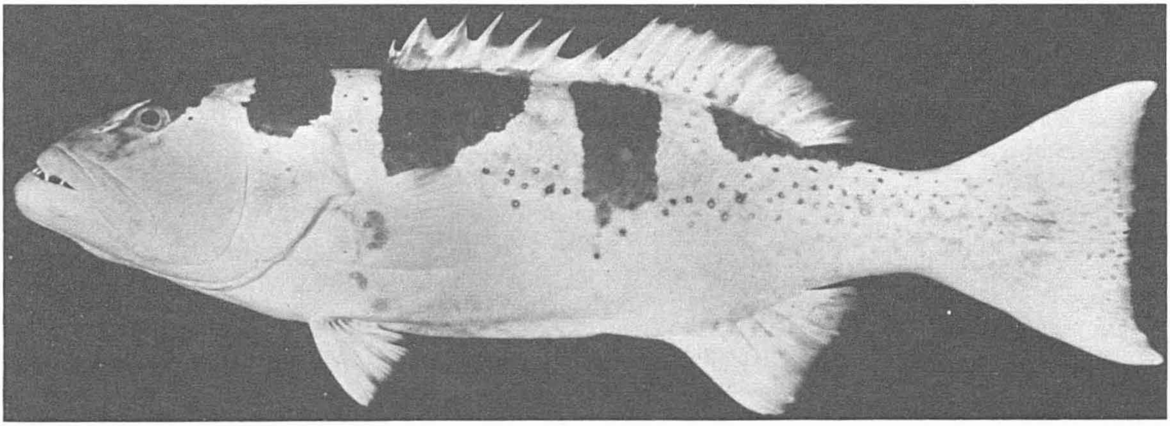

FIGURE 22.—*Plectropomus melanoleucus*, 492 mm SL, Enewetak, Marshall Islands.

black saddlelike bars, scattered small blue spots, and yellow fins has been regarded as a color phase of *P. maculatus* (Bloch) by a number of authors from Boulenger (1895) to Smith and Smith (1963). *Plectropomus melanoleucus*, however, is a valid species. In addition to color, it differs from *P. maculatus* (and *P. leopardus* and *truncatus*) by usually having 17 instead of 16 pectoral rays.

This species is rare in Oceania. Only a single specimen, 506 mm SL, 2.95 kg, was taken at Enewetak during the ciguatera survey. Its viscera produced a reaction of 2 when fed to a mongoose. Its stomach was empty.

Plectropomus truncatus Fowler (Figure 23): Like *P. leopardus,* this grouper has dark-edged blue spots, but the spots are larger in fishes of about the same size. The best field character to distinguish this species is its truncate caudal fin.

One specimen (384 mm SL, 1.45 kg) from Enewetak produced a ciguatoxic reaction of 2; its stomach was empty.

Hiatt and Strasburg (1960) reported one of three specimens of this grouper collected at Enewetak with a holocentrid fish in its stomach.

Variola louti (Forsskål) (Figure 24): This colorful grouper is yellowish brown to orange, profusely spotted with blue or pink (blue from shallow water, pink in deeper water), with broad zones of yellow posteriorly on the median and pectoral fins. Apart from color, it is readily distinguished by its deeply concave caudal fin. It is usually found on outer reefs at depths >15 or 20 m.

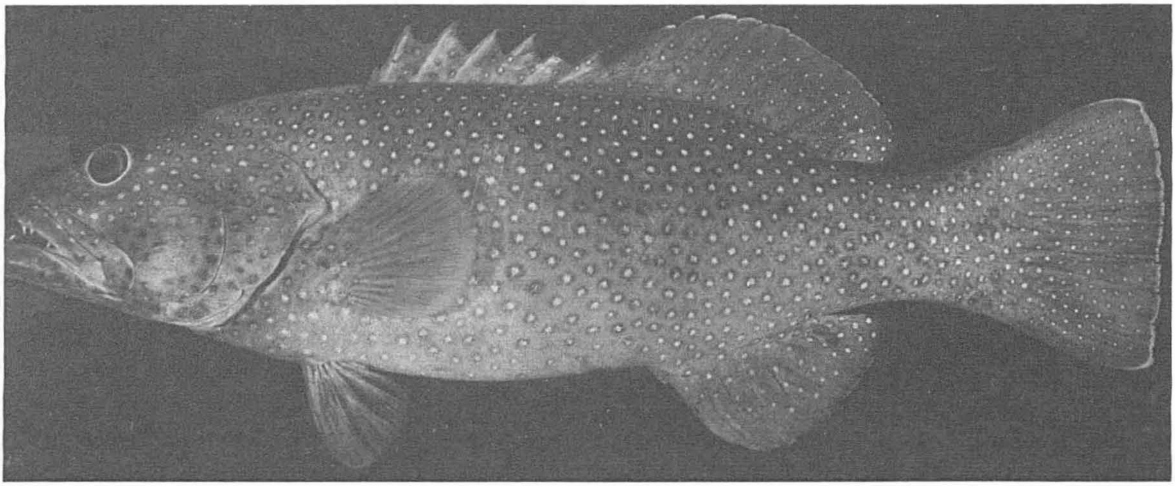

FIGURE 23.—*Plectropomus truncatus*, 350 mm SL, Enewetak, Marshall Islands.

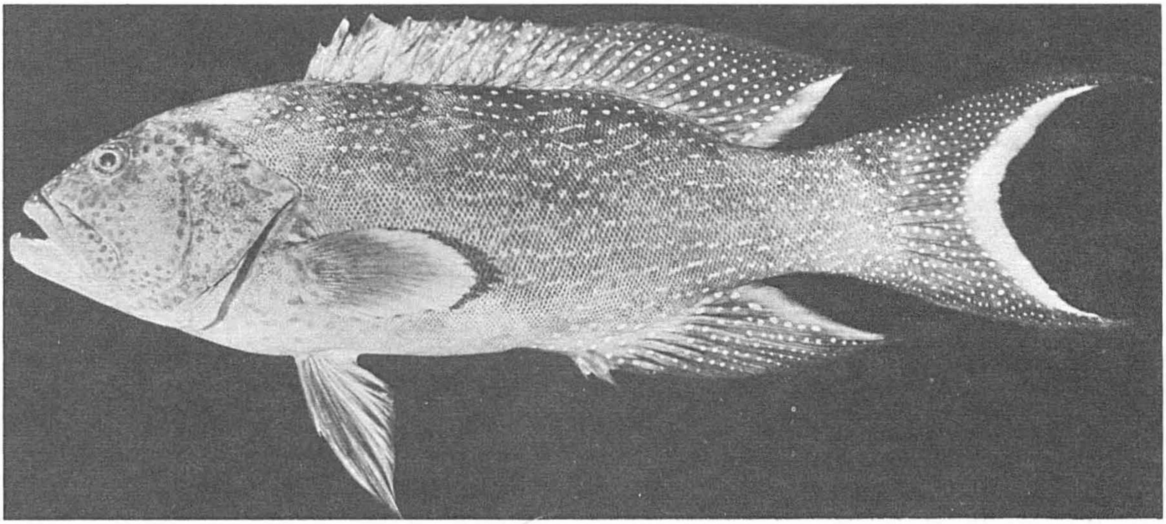

FIGURE 24.—*Variola louti*, 273 mm SL, Enewetak, Marshall Islands.

Variola louti is well known as a cause of ciguatera. In Mauritius it is prohibited from sale in fish markets. Toxicity there has been reported by Wheeler in Wheeler and Ommanney (1953).

Nineteen specimens were obtained for testing at Enewetak. They ranged from 352 to 418 mm SL and weighed from 1.1 to 2.2 kg. Thirteen were nontoxic, four gave a mongoose test of 1, and two a test of 3. Two from Bikini, 292 and 420 mm SL, were nontoxic.

Randall and Brock (1960) opened seven stomachs of the species from the Society Islands. Five were empty and two contained digested fishes. Hiatt and Strasburg (1960) found a juvenile unicornfish, *Naso* sp., in the stomach of one of two specimens from Bikini. Helfrich et al. (1968) examined the stomach contents of 44 specimens from the Line Islands. They found fishes, including acanthurids, balistids, and muraenids, in 80% of the stomachs, and crustaceans in 11%.

For the present food-habit study 44 specimens were examined. These ranged from 180 to 560 mm SL (largest weighed 5.45 kg). They were caught at Enewetak, Bikini, Line Islands, Tahiti, Rarotonga, Pitcairn Group, Rapa, and Tutuila. Twenty had empty stomachs. One contained a crab, one a spiny lobster, and the rest had eaten fishes, of which the following were identified at least to family: *Adioryx* sp. (120 mm specimen in a 295 mm grouper), *Scorpaena* sp. (28 mm specimen in a 235 mm grouper), *Parupeneus trifasciatus* (a 53 mm transforming specimen in a 470 mm grouper), juvenile *Chaetodon* sp., *Anampses caeruleopunctatus* (identified from scales), *Scarus sordidus* (140 mm specimen in a 375 mm grouper), and a pomacentrid.

Lutjanidae (Snappers)

Aprion virescens Valenciennes (Figure 25): This elongate snapper has been reported as poisonous from a number of Pacific localities, including the leeward Hawaiian Islands (Halstead 1967). Halstead did not list any Indian Ocean localities. It may therefore be worthy of note that the author incurred a mild case of ciguatera from eating a fish of this species at Mauritius. Also he was informed that poisoning is known from nearby Réunion.

Aprion virescens is a roving carnivore of open water but often found within or near reef areas, both in atoll lagoons and in outer reef zones. It is difficult to approach underwater; most of the specimens were obtained by hook and line, often while trolling.

Eleven specimens, 435-622 mm SL (1.6-5.2 kg), from Enewetak were tested. Eight were nontoxic, one (589 mm) gave a reaction of 1, one (622 mm) was a 3, and one (620 mm) a 4.

Eight were taken at Bikini ranging from 406 to 685 mm SL (1.8-5.4 kg). All, exept one of 457 mm SL which produced a mongoose reaction of 1, were nontoxic.

Ommanney in Wheeler and Ommanney (1953) reported on the analysis of stomach contents of 80 *A. virescens* from the Mauritius-Seychelles region. Forty-four of these were empty. The stomachs of

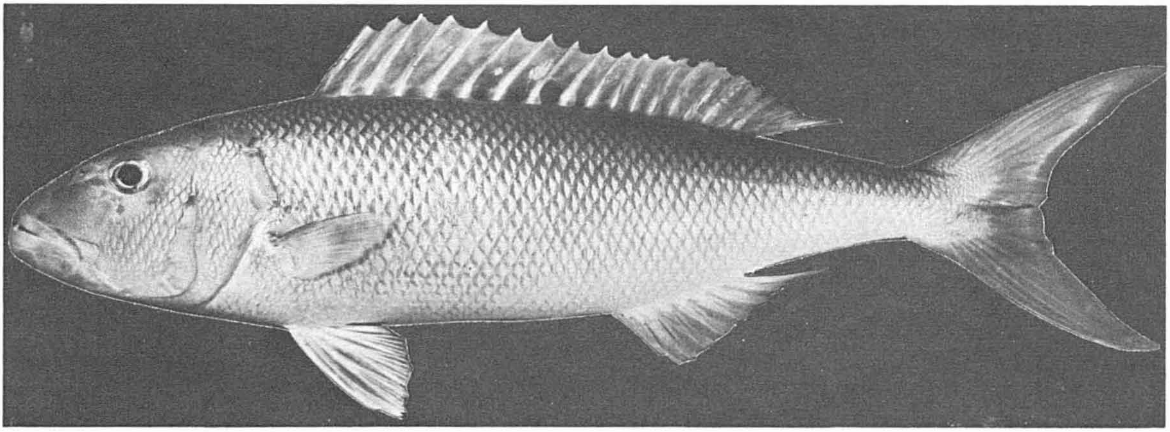

FIGURE 25.—*Aprion virescens*, 503 mm SL, 2.5 kg, Nuku Hiva, Marquesas Islands.

21 contained fishes; 6 had fishes and macroplankton; 5 had only macroplankton; and 4 contained cephalopods. Among the fishes taken from the stomachs were scarids, ostraciids, siganids, a bothid, and *Caesio coerulaureus*.

Talbot (1960) reported on 259 specimens caught by handline and surface lure on the east African coast which ranged from 202 to 800 mm SL (weight to 11.3 kg). He presented a diagram of the relative abundance of food organisms for this fish as follows: fishes 49%, plankton 17%, cephalopods 14%, and crustaceans exclusive of plankton (mainly portunid crabs) 12%. He did not indicate how many specimens had empty stomachs.

The stomachs of 15 specimens from the Marshall Islands and 1 from Hawaii were examined. Ten were empty. Four contained fishes; (one prey fish identified as *Scarus* sp.); one *A. virescens* (481 mm SL) had also eaten an octopus (one-third stomach volume). A 457 mm fish contained a 10 mm calappid crab, and one of 650 mm a stomatopod.

Lutjanus bohar (Forsskål) (Figure 26): This red snapper has been implicated more frequently in ciguatera than any fish of the Indo-Pacific region. It is probably the species which sickened the crew of Captain Cook in the New Hebrides in 1774 (Banner 1965). Its toxicity has also been reported under the junior synonym *Lutjanus coatesi* Whitley. This species occurs along seaward reefs and in passes. It is more common around atolls and low coral islands than high islands (Randall and Brock 1960). It is especially abundant in the Line Islands. Reef fishes became highly toxic there during and immediately after World War II; the toxicity declined in the early 1960's (Banner and Helfrich 1964). When the toxicity was high, *L. bohar* from these islands was used for the chemical and pharmacological work on ciguatoxin at the University of Hawaii (replaced by *Lycodontis javanicus* from Johnston Island in later years). It was the species used by Banner et al. (1966) to demonstrate the long periods of retention of ciguatoxin in the tissues of poisonous fishes when removed from the source of the toxin.

The toxicity of 95 specimens from Enewetak from 430 to 635 mm SL (2.5-7.5 kg) was tested. Fifty-six were nontoxic; 22 gave a mongoose test of 1; 11 were 2, 5 were 3, and 1 (533 mm) was a 5.

From Bikini 143 specimens which ranged from 330 to 760 mm SL were tested. Of these, 112 were nontoxic, 15 were 1, 8 were 2, 6 were 3, and 2 gave a mongoose test of 4.

From the atoll of Rongelap (lat. 11° N, long. 167° E) in the Marshall Islands we obtained 12 specimens of *L. bohar* which weighed from 3.2 to 9.1 kg. Eight of these were nontoxic, two gave a reaction of 2, one was a 3, and one a 5.

Hiatt and Strasburg (1960) found fragments of fish in one of two specimens of *L. bohar* from Bikini. Talbot (1960) examined 854 specimens from the East African coast; 58% had empty stomachs. Fishes composed 62% of the food material, crustaceans 24%, and mollusks 8%. Helfrich et al. (1968) determined the diet of 2,276 specimens from Palmyra and Christmas Islands in the Line Islands; 21.4% of these were empty. Fishes dominated the stomach contents (48.7% by volume at Palmyra and 65.4% at Christmas), of which acanthurids were the most common among those identified. Mollusks represented 19.1% by volume

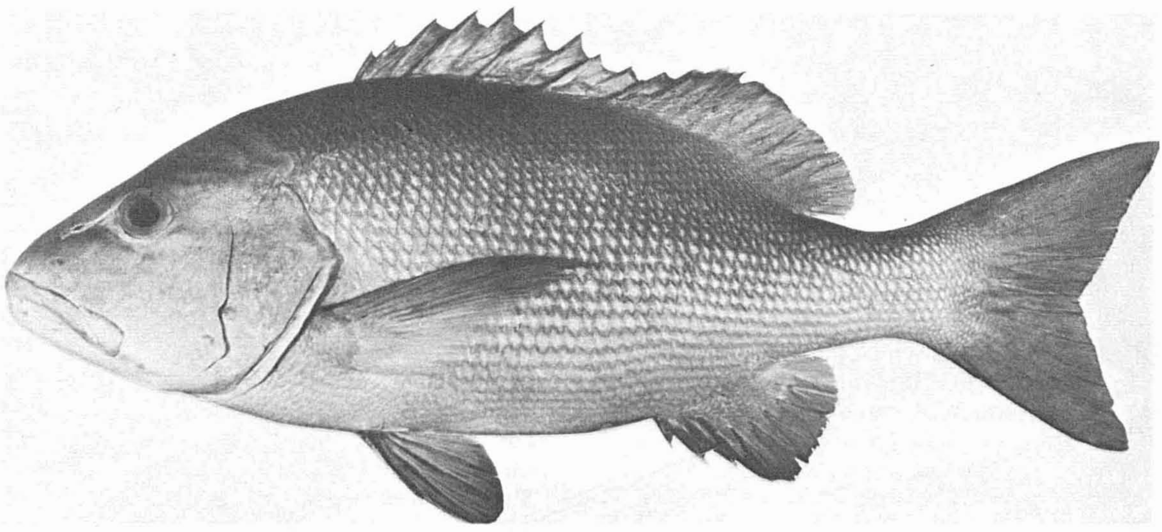

FIGURE 26.—*Lutjanus bohar,* 520 mm SL, 4.9 kg, Ulithi, Caroline Islands.

of the total food material at Palmyra and 18% at Christmas. Crustaceans (principally decapod megalops) composed 15.4% of the food among Palmyra fish and 13.3% of Christmas Island specimens.

The stomachs of 121 adult specimens of *L. bohar* from the Marshall Islands, 330-635 mm SL, most of which were taken by hook and line, were examined. Eighty-six were empty. Of those with identifiable food, 76.2% contained fishes (including *Lycodontis* sp., *Cephalopholis urodelus*, *Archamia* sp., *Lethrinus variegatus*, *Scarus* sp., and *Ostracion* sp.), 10.8% had eaten crabs (including portunids), 8.7% contained octopus, and 4.3% shrimps.

Lutjanus fulvus (Schneider) (Figure 27): The names *L. vaigiensis* (Quoy and Gaimard) and *L. marginatus* (Cuvier) are junior synonyms that have often been used for this snapper. It is yellowish on the body, the head gray, the caudal fin reddish black with a narrow white posterior border; the dorsal fin is reddish and the anal and pelvic fins yellow. It is a small inshore species, abundant throughout the Indo-West Pacific. It is found more often in sheltered than exposed environments. Hiyama (1943:48-49, pl. 6, fig. 17) reported that Marshallese natives informed him that this fish (which he identified as *L. flavipes* Valenciennes), rarely causes ciguatera; when it does, the cases are light. Halstead (1967:98, pl. 68, fig. 4) listed it among the ciguatoxic fishes [misidentified as *L. janthinuropterus* (Bleeker)].

Two specimens from Enewetak, 207 and 217 mm SL, were nontoxic.

Randall (1955a) examined the stomachs of six specimens taken with rotenone at Tarawa, Gilbert Islands. One had eaten a small holothurian, one a brachyuran crab, and two contained fishes that were probably prior victims of the ichthyocide. Hiatt and Strasburg (1960) analyzed the stomach contents of six juveniles from Arno, Marshall Islands; they reported the following food items: crabs, fishes, amphipods, shrimps, and stomatopods. Randall and Brock (1960) examined 50 specimens which had food in their stomachs; 54.3% of these contained crustaceans (mainly crabs) and 42.4% fishes. Helfrich et al. (1968) collected 51 specimens from Palmyra for food-habit study. The dominant food items were mugilid, mullid, and pomacentrid fishes; crustaceans made up the next most frequent organisms of the diet.

For the present study 44 specimens 182-250 mm SL were collected in the Marshall Islands, Mariana Islands, and Caroline Islands. Thirty-one of these had empty stomachs. Of those with food, 68.4% had eaten crustaceans (nearly all crabs, mainly calappids) and 31.6% fishes.

Lutjanus gibbus (Forsskål) (Figure 28): This snapper is also reddish like *L. bohar,* but it does not attain such large size. The dorsal profile of adults, beginning with the nape, is highly convex, which is the basis for the specific name. Schultz in Schultz and collaborators (1953) stated, "This species was taken only in moderately deep water.

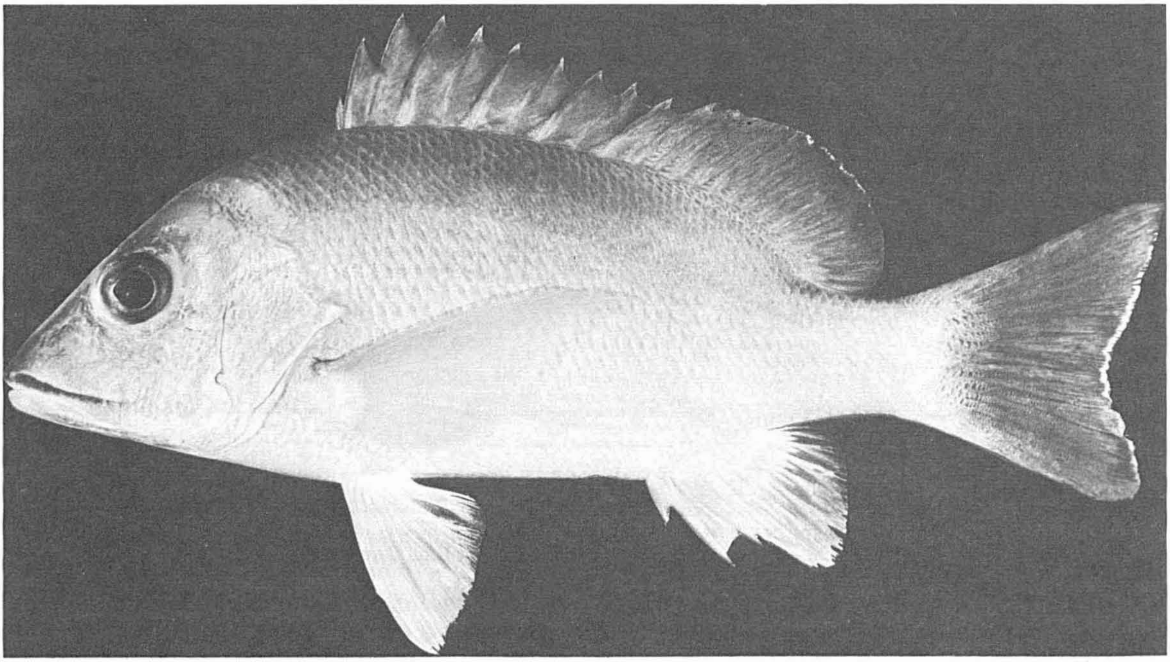

FIGURE 27.—*Lutjanus fulvus,* 215 mm SL, Enewetak, Marshall Islands.

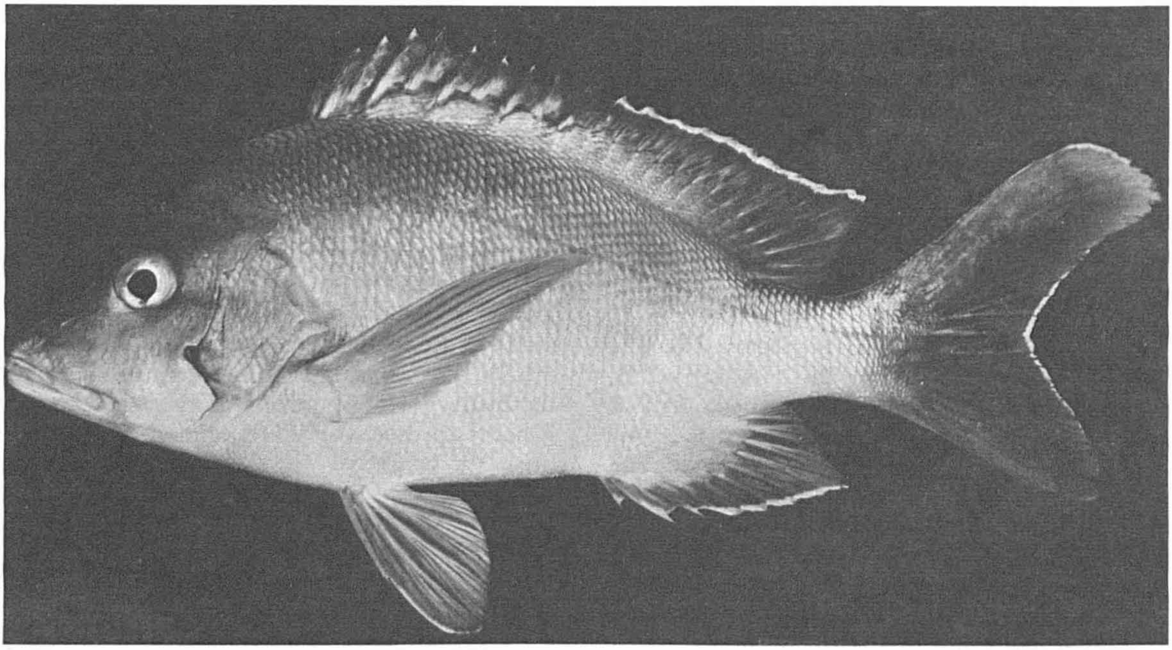

FIGURE 28.—*Lutjanus gibbus,* 291 mm SL, Palmyra, Line Islands.

It did not occur over the shallow parts of the reefs." Talbot (1960), on the other hand, wrote in reference to *L. gibbus* in east Africa, "It was only found in shallow water of from 3 to 8 fathoms." Actually, the species may occur either in the shallows or at moderate depths, but in the Marshall Islands, at least, it is usually encountered in water of 20 m or more. Though mainly found on the outside of sea reefs and in passes, it may also occur in lagoons. It is often observed in large aggregations.

Thirty-one specimens of *L. gibbus* from Enewetak 302-375 mm SL (largest 1.8 kg) were collected. Twenty-one of these fishes were nonpoisonous; five were rated as 1, two were 2, and three ranked 3 by the mongoose test.

Thirty-five specimens from Bikini, 279-385 mm SL, were tested. All but three were nontoxic; the three toxic fish produced a mongoose reaction of only 1.

Randall and Brock (1960) collected 23 specimens in the Society Islands of which only 9 had food in their stomachs (5 of these were juveniles). The four adults contained fishes, crabs, and unidentified crustaceans. Hiatt and Strasburg (1960) examined 43 specimens (175-260 mm SL) from the Marshall Islands of which 10 had empty stomachs. Crustaceans were the main food, especially crabs (60% contained xanthids and 17% portunids); Amphineura were found in 13% of the stomachs. *Octopus*, *Natica*, *Ptychodera*, small holothurians, polychaetes, sipunculids, and fish *Apogon* were all found in 4% of the stomachs. Talbot (1960) reported on the capture of 121 specimens. He wrote, "Foods eaten were mainly crustaceans, including crabs and Penaeid prawns. Small coral fishes were also occasionally taken." Helfrich et al. (1968) found food in 36 of 45 stomachs of adults from the Line Islands; fishes were the main item of diet, with crustaceans the second most abundant. [Fishes included unidentified eels, acanthurids, and *Pomacentrus nigricans* (= *Stegastes nigricans*).] Most crustaceans were brachyuran crabs, but there were also alpheid shrimps and slipper lobster. Mollusk remains were mainly prosobranchs, but opisthobranchs and cephalopods were also found. Sea urchins were the most common of the miscellaneous invertebrates composing the rest of the stomach contents.

During the present study the stomachs of 51 specimens from the Marshall Islands, 260-419 mm SL, were examined. Twenty-seven were empty. Of those with food, 40% had eaten crabs, 26% fishes (including *Pseudocheilinus* sp. and *Adioryx microstomus*), 17% echinoids (including *Eucidaris* sp. and *Heterocentrotus mamillatus*), 12% ophiuroids (including *Ophiocoma erinaceus*), 2.1% alpheid shrimps, 2.1% octopus, and 0.3% gastropods.

Lutjanus monostigmus (Cuvier) (Figure 29): This species, named from the blackish spot usually present on its side (on lateral line), is capable of causing severe cases of ciguatera. Belotte (1955) gave the case history of an American who was in a coma 3 days after eating this snapper in Tahiti; the author also interviewed this man. The sale of this species in Tahiti, where it is called "taivaiva," (Randall 1972) is forbidden. It is found in reef environments from shallow water to moderate

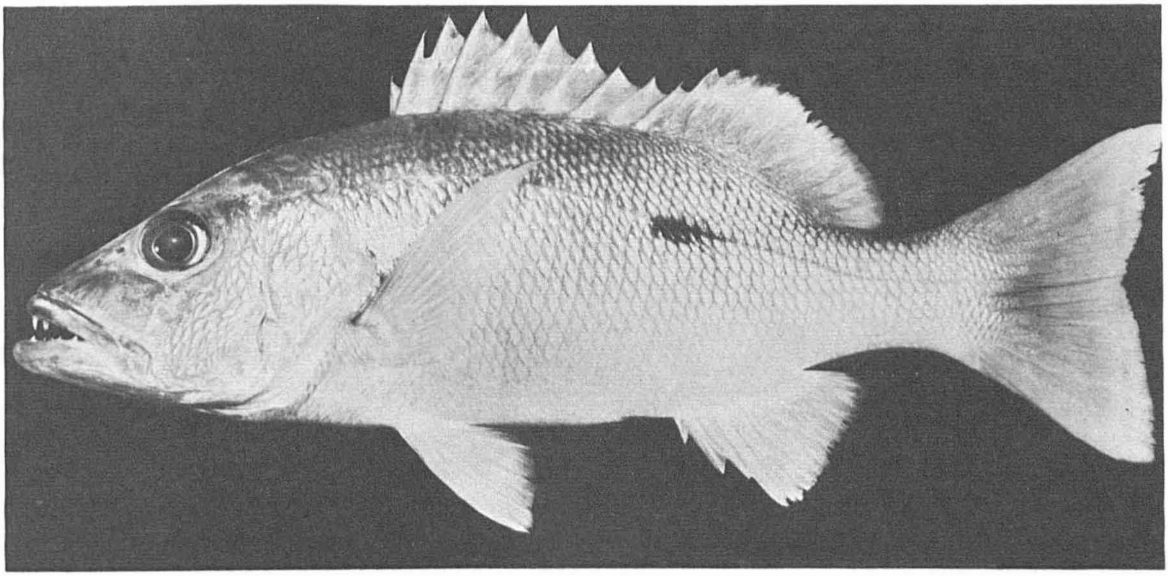

FIGURE 29.—*Lutjanus monostigmus*, 249 mm SL, Florida Island, Solomon Islands.

depths, especially where there is deep shelter. Not infrequently it is encountered in small aggregations. Adults are wary, hence difficult to spear.

Only three specimens were obtained from Enewetak, 310-420 mm SL (0.8-1.6 kg), for testing of toxicity. One was nontoxic, one was 1, and one a 2.

Five specimens, 400-445 mm SL, were collected in Bikini. Four were nontoxic; the largest gave a mongoose reaction of 1.

Randall and Brock (1960) opened 32 stomachs of adults of this species, of which 18 were empty. Those with full stomachs all contained fishes, among them *Decapterus pinnulatus*, *Selar crumenophthalmus*, and *Ctenochaetus striatus*. Hiatt and Strasburg (1960) found a goatfish in the stomach of one of three specimens from Enewetak; the other two were empty. Talbot (1960) collected 18 specimens off east Africa. He reported fish remains (including a mullid and a labrid) in most stomachs; penaeid prawn remains were also found. Helfrich et al. (1968) examined 29 specimens from the Line Islands. They found fishes in 92% of the stomachs and crustaceans (stomatopod larvae and one slipper lobster) in 23%.

For the present food-habit study 41 specimens of *L. monostigmus* were examined from the Marshall Islands, Society Islands, Line Islands, and Samoa Islands. Twenty-three had empty stomachs. Of those with food, 92% by volume had eaten fishes (including the holocentrid *Adioryx microstomus*, acanthurids, and a balistid), and 8% crabs (including a portunid).

Macolor niger (Forsskål) (Figure 30): Although not previously reported as poisonous, this lutjanid fish attains moderate size, is a reef-dweller, and carnivorous; this would seem to have the potential for causing ciguatera. A total of 25 adults, 403-445 mm SL (2.3-2.95 kg), were taken, all from Enewetak, and mainly from explosive stations in the lagoon. Twenty-three were nontoxic and two gave a reaction of 1 on the feeding of liver and viscera to mongooses.

The stomachs of eight adult specimens taken at 9:00 a.m. at Enewetak were examined. All were empty. The large eyes of this species is suggestive of nocturnal habits, and the numerous (about 72) long gill rakers would seem to indicate at least some feeding on zooplankton (perhaps more important in smaller individuals than large adults). Some of the specimens were caught by hook and line baited with fish. Hiatt and Strasburg (1960) also reported that this species can be caught on a baited hook.

Lethrinidae (Emperors)

Lethrinus amboinensis Bleeker (Figure 31): Following Sato (1978), this emperor is identified as *L. amboinensis*. It lacks characteristic color markings, being light brownish to greenish dorsally

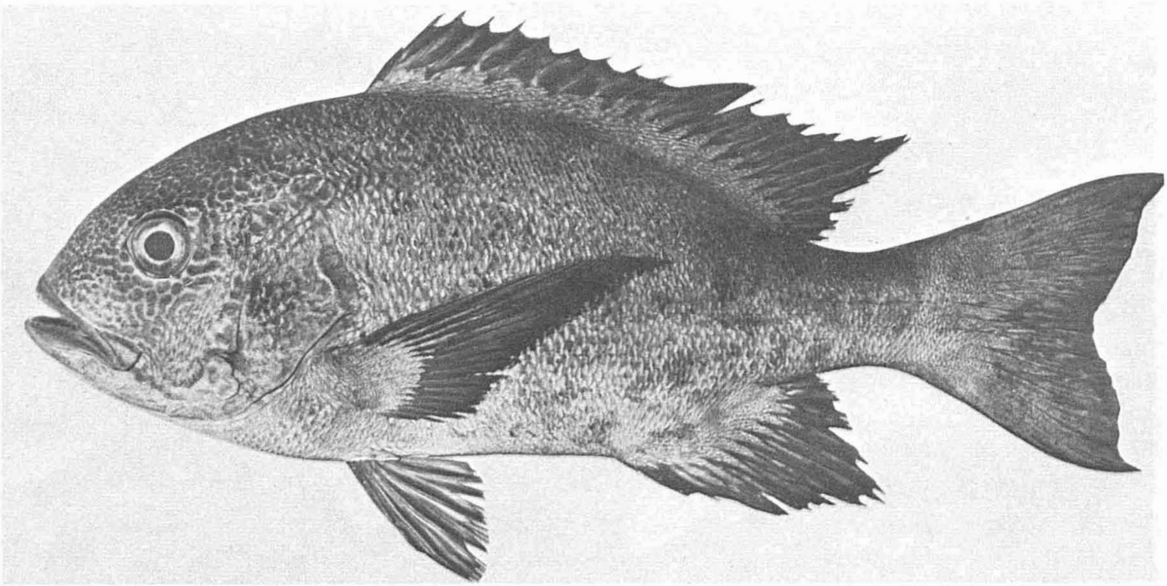

FIGURE 30.—*Macolor niger*, 378 mm SL, Enewetak, Marshall Islands.

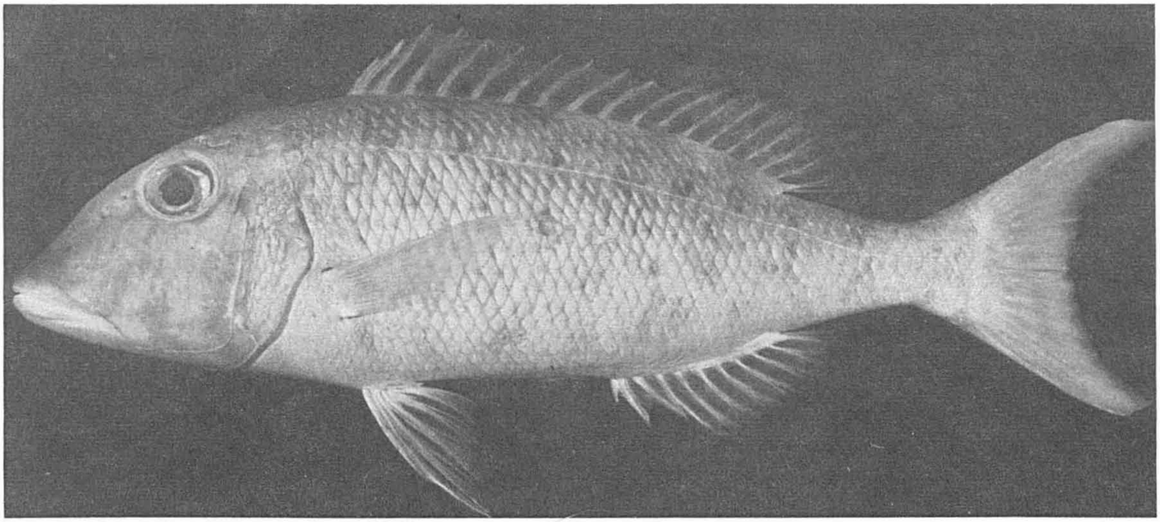

FIGURE 31.—*Lethrinus amboinensis,* 294 mm SL, Enewetak, Marshall Islands.

with small dark brown spots and blotches, shading to white ventrally. It is somewhat elongate, the head length greater than the depth; the snout is moderate, its length in adults 1.8-1.0 in head length; the maxilla reaches a vertical a little posterior to the anterior nostril. The teeth along the sides of the jaws are conical.

Twenty-four specimens were taken at Enewetak and nine at Bikini, the largest 310 mm SL. All were nontoxic.

Helfrich et al. (1968) determined the food of 14 specimens of *L. amboinensis* from Palmyra, Line Islands. Fishes were found in 75% of the stomachs, mollusks in 25%, and crustaceans in 17%; all specimens had some sea urchin fragments.

Fish remains were found in one of two stomachs examined at Bikini.

Lethrinus kallopterus Bleeker (Figure 32): This *Lethrinus* is distinctive in having orange fins and blackish spots over occasional scales; the snout is short, the maxilla reaching a vertical at anterior edge of eye. The teeth at the sides of the jaws are nodular (i.e., neither conical nor well-developed molars). It was most often seen in the deeper parts of the atoll lagoons.

A total of 19 specimens were collected at Enewetak for the testing of toxicity. These ranged from 337 to 443 mm SL (1.1-2.7 kg). Fourteen were nontoxic, two produced a reaction of 1, two were 2, and one (368 mm SL) was a 5.

Two specimens, 330 and 457 mm SL, were procured from Bikini; neither was toxic.

The stomachs and intestines of 13 specimens, 330-443 mm SL, from the Marshall Islands were opened. Five of the fish were empty. Four had eaten only echinoids (including *Echinometra mathaei*); one contained mostly echinoids but also the cowrie *Cypraea carneola*; another (the largest) had eaten just the cowrie *C. vitella*; still another had a cowrie in its gut (20% by volume of the food material), and the rest of the food material consisted of crinoids; one specimen contained only a starfish arm.

Lethrinus miniatus (Forster in Bloch and Schneider) (Figure 33): This emperor has an especially long snout (1.6-1.8 in head length of adults). It is primarily gray in color, but can alter its pattern, like many other *Lethrinus*, to one of dark irregular bars and blotches. Often there are two or three bluish streaks on the snout passing anteriorly and diagonally downward from the eye. The teeth on the sides of the jaws are conical. This species was seen in both lagoon and outer reef environments, but mainly in lagoons. It is among the largest of the emperors, reported to attain 1 m.

Of nine adults, 435-530 mm SL (1.8-3.6 kg), which were caught at Enewetak, six were nontoxic, and three gave a reaction of 3.

Twelve specimens from Bikini, 381-635 mm SL, 1.4-7.3 kg, were nontoxic.

Eight of 14 specimens from Enewetak and Bikini had food in their stomachs. Three contained fish remains, one of which (456 mm SL) included a

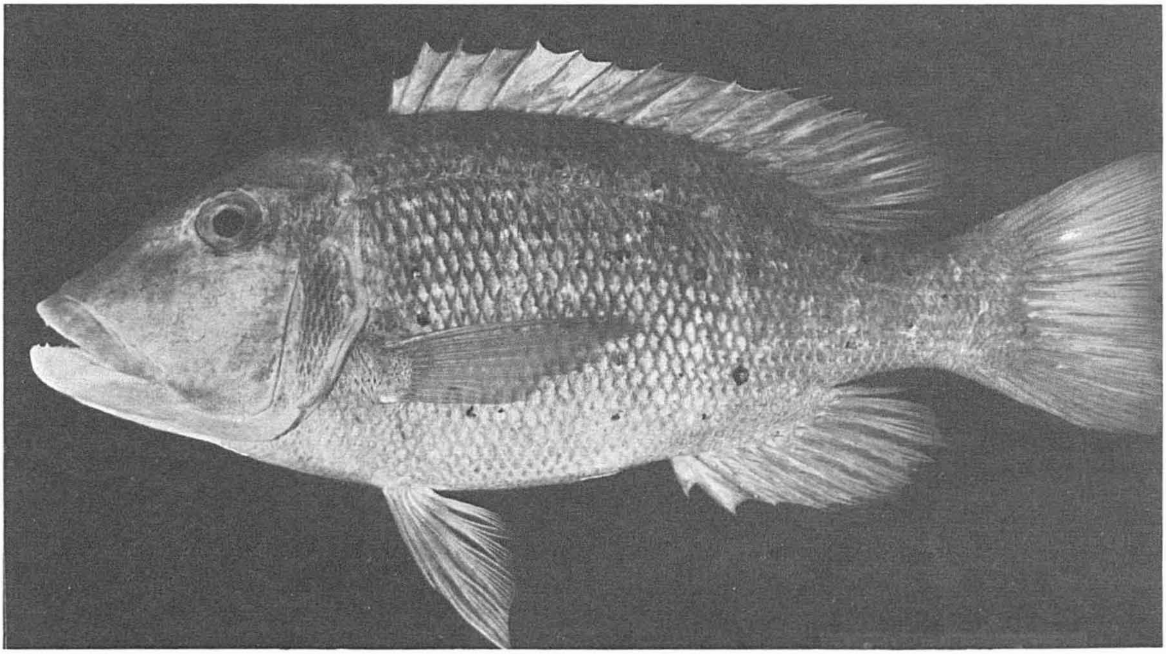

FIGURE 32.—*Lethrinus kallopterus,* 345 mm SL, Enewetak, Marshall Islands.

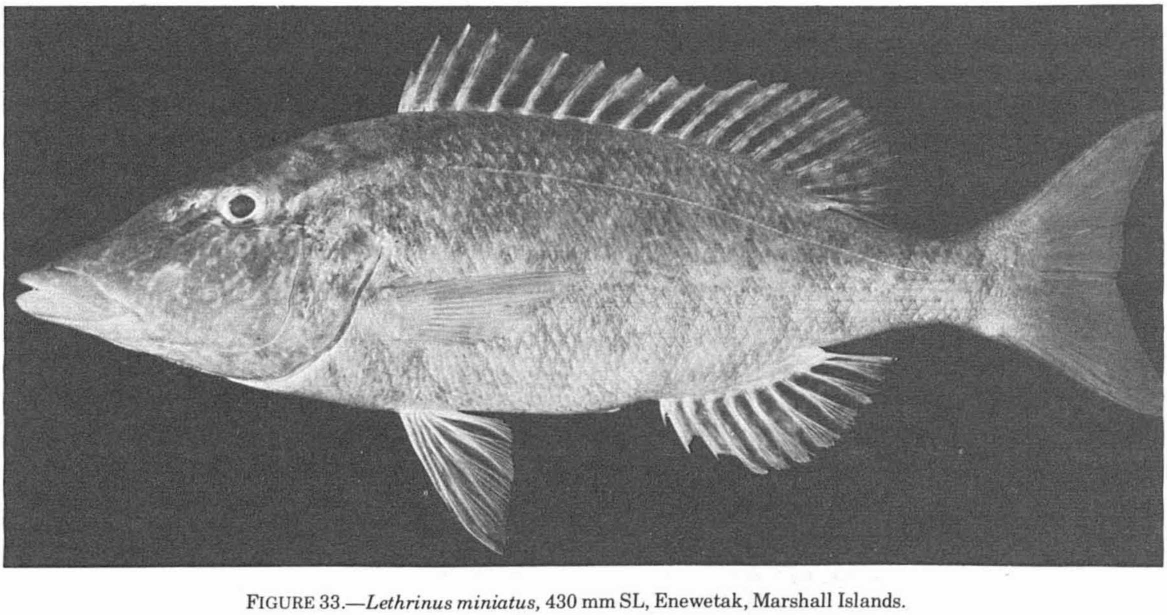

FIGURE 33.—*Lethrinus miniatus,* 430 mm SL, Enewetak, Marshall Islands.

Lethrinus 115 mm SL; the remaining three had eaten crustaceans (stomatopod, crab, and alpheid shrimp).

Lethrinus xanthochilus Klunzinger (Figure 34): This emperor is one of the more slender species of *Lethrinus* (depth 3.1-3.3 in SL). The interorbital space is nearly flat. The teeth on the sides of the jaws are conical. The upper lip is orange-yellow, and there is a red spot at the upper pectoral base. It is found more in lagoons than exposed reef habitats; it will venture into shallow water.

Two specimens, 445 and 550 mm SL (smallest 1.7 kg, largest not weighed), were collected at

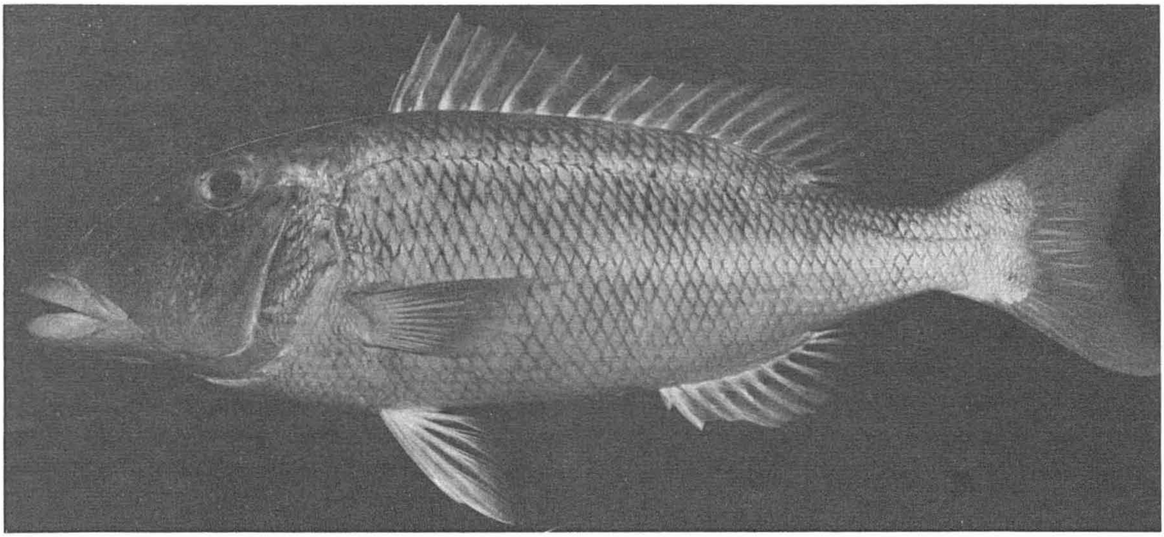

FIGURE 34.—*Lethrinus xanthochilus*, 395 mm SL, Fanning Island, Line Islands.

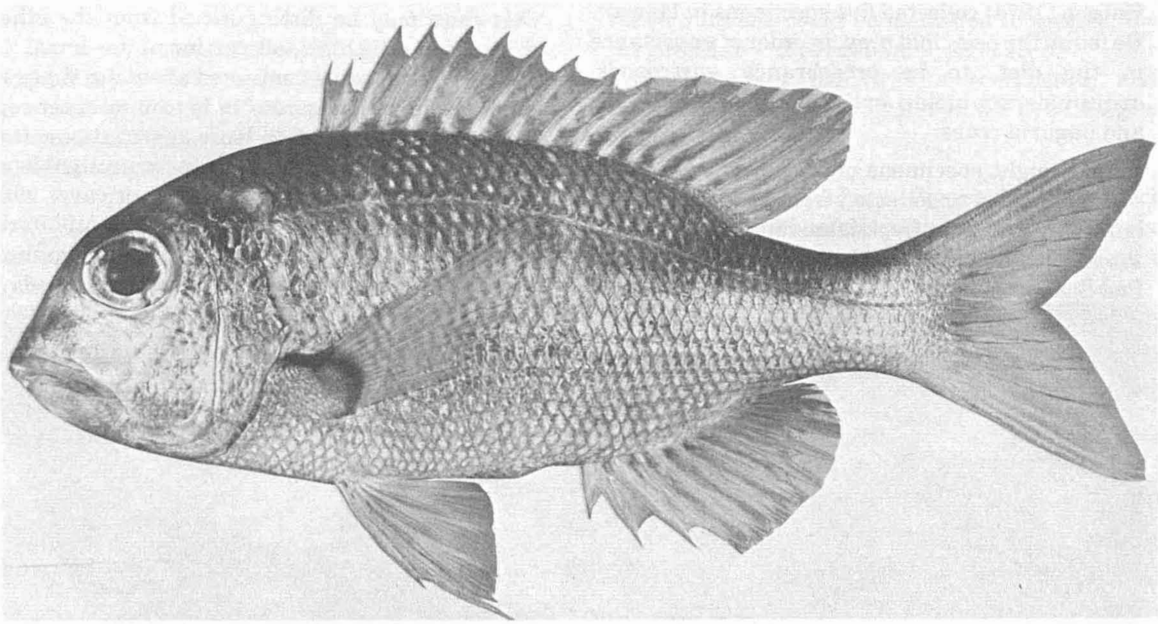

FIGURE 35.—*Monotaxis grandoculis*, 220 mm SL, Enewetak, Marshall Islands.

Enewetak; two, 305 and 432 mm SL, were taken at Bikini. All were nontoxic.

The stomach and gut contents of these four specimens and one of 466 mm from the Society Islands were examined. One fish contained crushed echinoids, one the remains of a calappid crab, one a digested fish, another both crab and fish remains, and one (the largest) a freshly ingested fish (probably from a rotenone station).

Monotaxis grandoculis (Forsskål) (Figure 35): *M. grandoculis* has been classified in the past principally in the Sparidae or Lutjanidae, but is now recognized as a lethrinid. It is readily distinguished by its large eyes, short blunt snout, and single row of well-developed molariform teeth along the side of the jaws. It occurs in a wide variety of reef habitats. Adults are difficult to approach underwater. This fish feeds mainly on invertebrates with calcareous or chitinous hard parts. Although rarely implicated in serious cases of poisoning, it is capable of being ciguatoxic. Halstead (1967) listed 11 references attesting to its toxicity.

Five specimens, 277-362 mm SL (0.73-1.6 kg), from Enewetak were tested for toxicity. Four were nontoxic and one gave a reaction of 1 from the mongoose feeding.

Randall (1955a) reported on the gut contents of two specimens, 158 and 160 mm SL, from the Gilbert Islands; these consisted mainly of crushed shells of small mollusks and sea urchins. Hiatt and Strasburg (1960) examined the contents of the digestive tracts of eight specimens, 195-220 mm SL, from the Marshall Islands. One fish was empty. Crushed gastropods (including *Atys* sp. and *Cerithium* sp.) were found in all stomachs, pelecypods in 71%, crabs in 42%, hermit crabs in 28%, and spatangids and polychaetes each in 14%. Hobson (1974) collected five specimens in Hawaii. He found the principal prey, in order of importance in the diet, to be prosobranch gastropods, ophiuroids, echinoids, opisthobranch gastropods, and pagurid crabs.

Forty-eight specimens of *M. grandoculis,* 155-440 mm SL, were collected from the Marshall Islands, Line Islands, Cook Islands, Society Islands, Pitcairn, Hawaiian Islands, New Guinea, and the Red Sea for the study of food habits. Unless fish of this species are captured during the night or very early morning hours, their stomachs are nearly always empty. Occasional feeding by *M. grandoculis* does occur during the day, as indicated by Hiatt and Strasburg's (1960) observation of its "blowing" away sand to expose fossorial forms. Also one specimen taken at 2 p.m. during the author's survey had the remains of a freshly ingested crab in its stomach. Five of the fish collected in late afternoon hours had completely empty digestive tracts. The remaining fishes contained, on a volume basis, 39.4% gastropods, 18.9% crabs, 16.8% pelecypods, 13.9% echinoids (principally *Echinometra* and spatangoids such as *Clypeaster*), 6.1% pagurid crabs, 1.7% ophiuroids, 1.2% polychaetes, 1.0% unidentified worms, 0.7% fishes, and 0.3% foraminifera.

Kyphosidae (Sea Chubs)

Kyphosus cinerascens (Forsskål) (Figure 36): This chub may be distinguished from the other *Kyphosus* by the high soft portion of the dorsal fin (longest dorsal spine contained about 1.8 times in longest soft ray). It occurs in lagoon or outer reef areas and is often seen in loose aggregations. It is associated with hard substratum for its algal food, generally in the vicinity of crevices or caves with more than one entrance. Bartsch et al. (1959) reported this species as toxic from Majuro, Marshall Islands, but their data and the few other records of

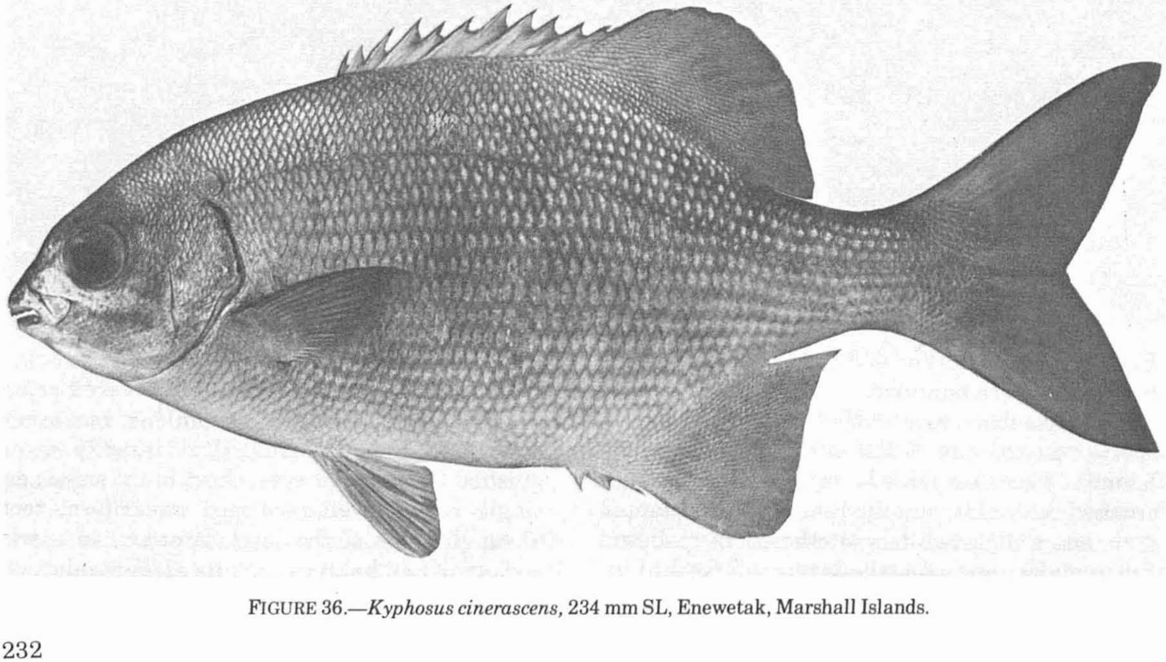

FIGURE 36.—*Kyphosus cinerascens,* 234 mm SL, Enewetak, Marshall Islands.

toxicity would seem to indicate that it is only marginally a cause of ciguatera.

Of two specimens from Enewetak, 356 and 364 mm SL, 1.8 kg, one was nonpoisonous and the other toxic at level 1.

Hiatt and Strasburg (1960) found benthic algae in the stomachs of three of four specimens examined in the Marshall Islands. Hobson (1974) reported algae in three stomachs from Hawaii; however, *K. cinerascens* apparently does not occur in the Hawaiian Islands (though two other species are present).

Three specimens, 330-364 mm SL, from Enewetak were opened. The stomach of one was empty, and the other two contained benthic algae. The algae of one were identified by Tsuda[8] as the reds *Gelidium pusillum*, *Champia parvula*, and *Leveillea jungermannoids* (90%) and the brown *Sphacelaria tribuloides*.

Carangidae (Jacks)

Caranx ignobilis (Forsskål) (Figure 37): This steep-headed jack is the largest species of the genus. Bagnis et al. (1972) stated that it can attain a length of 2 m and a weight of 80 kg. It can be differentiated from other Marshall Islands species by the absence of scales on the thorax except for a small median patch. Like other large carangids, it is a roving carnivore; it may be encountered anywhere in the atoll environment including water surprisingly shallow for such a large fish.

The author interviewed a man and wife in Moorea who were poisoned from eating the liver of a large individual of this species (estimated 1.5 m) which overturned their canoe in the long struggle to catch it. Both were very ill with ciguatera, the man comatose for several hours.

Five specimens, 573-920 mm FL, 3.6-16.3 kg, were obtained at Enewetak for the testing of toxicity. Three gave a 0 reaction and two a reaction of 1. Two specimens from Bikini, 635 and 1,105 mm FL, 4.5 and 27.3 kg, were nontoxic.

A total of 14 specimens were collected for food-habit study from the Marshall Islands, Line Islands, Hawaiian Islands, Pitcairn Group, and the Marquesas. Seven stomachs were empty, and the rest contained the digested remains of fishes, of which only one could be identified to species, the surgeonfish *Zebrasoma flavescens*. One stomach-content fish was a scorpaenid, and another (from a jack of 1,217 mm FL, 37.5 kg) a scarid.

Caranx lugubris Poey (Figure 38): The black jack is a circumtropical species with a well-earned reputation for causing ciguatera. Although the

[8]Roy T. Tsuda, Marine Laboratory, University of Guam, Box EK, Agaña, Guam 96910, pers. commun. 1972.

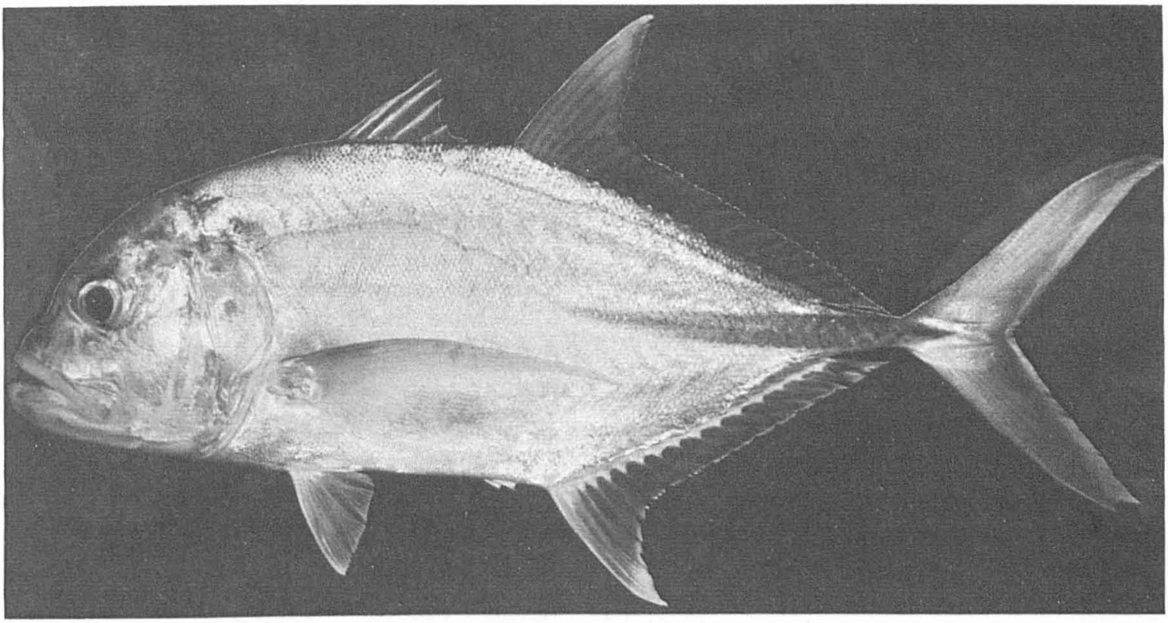

FIGURE 37.—*Caranx ignobilis*, 378 mm FL, Fanning Island, Line Islands.

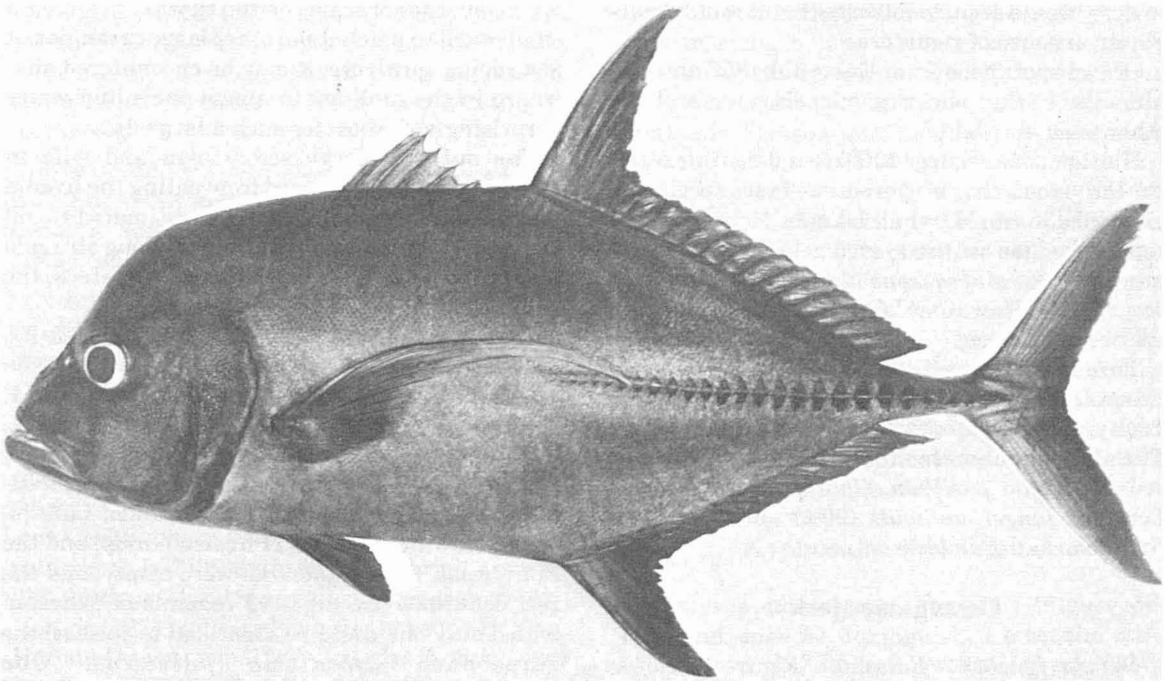

FIGURE 38.—*Caranx lugubris,* 557 mm FL, 3.1 kg, St. John, U.S. Virgin Islands.

dark color (especially on the scutes) and distinctive configuration generally permit identification, the fully scaled breast will provide separation from *C. ignobilis,* the low number of scutes on straight portion of lateral line (26-33) from *C. melampygus,* and the high gill raker count (18-20 on lower limb) from *C. sexfasciatus.* This species is found mainly around oceanic islands and is nearly always encountered in the clear water of outer reef environments.

Fifteen specimens were obtained at Enewetak for testing. These ranged from 488 to 910 mm FL and weighed from 2.5 to 15.5 kg. Eleven were nonpoisonous, two gave reactions of 1, one was a 2, and one a 3. No specimens were collected at Bikini.

Randall (1955a) reported a fish in one of two specimens collected in the Gilbert Islands and Randall (1967) found fishes in two of six specimens from the Caribbean Sea.

For the present food-habit study, 10 specimens were obtained from Enewetak and Henderson Island in the Pitcairn Group. Four had empty stomachs, and the remaining six contained the remains of fishes, one of which was a labrid.

Caranx melampygus Cuvier and Valenciennes (Figure 39): This is the most abundant jack of the genus in Oceania; it is widespread in the tropical and subtropical Indo-West Pacific and ranges to the eastern Pacific as well. It is irridescent blue along the back and median fins in life with a scattering of small blackish spots on the head and body except ventrally. The chest is completely scaled, and there are 38-44 scutes in the straight portion of the lateral line.

Thirty specimens were collected at Enewetak, 417-722 mm FL, 1.4-6.8 kg, for the assay of ciguatera. Twenty-four were nontoxic, four gave a reaction of 1, one was a 2, and one a 3.

Six specimens from Bikini, 394-686 mm FL, 1.8-6.6 kg, were nontoxic.

Randall (1955a) examined the stomach contents of four specimens from the Gilbert Islands. Two contained many small freshly ingested fishes which were probably the result of a rotenone station kill. Of the other two which were speared, one contained the anthiine fish *Mirolabrichthys tuka* (= *Anthias pascalus*). Hiatt and Strasburg (1960) found fish in the stomachs of two from the Marshall Islands, one of which was identified as *Trachurops* (= *Selar*) *crumenophthalmus*. Hobson (1974) examined the stomach contents of six specimens from Hawaii. One contained larval fishes and mysids, a second had fish and shrimp remains, and three contained well-digested fragments at least one of which was fish.

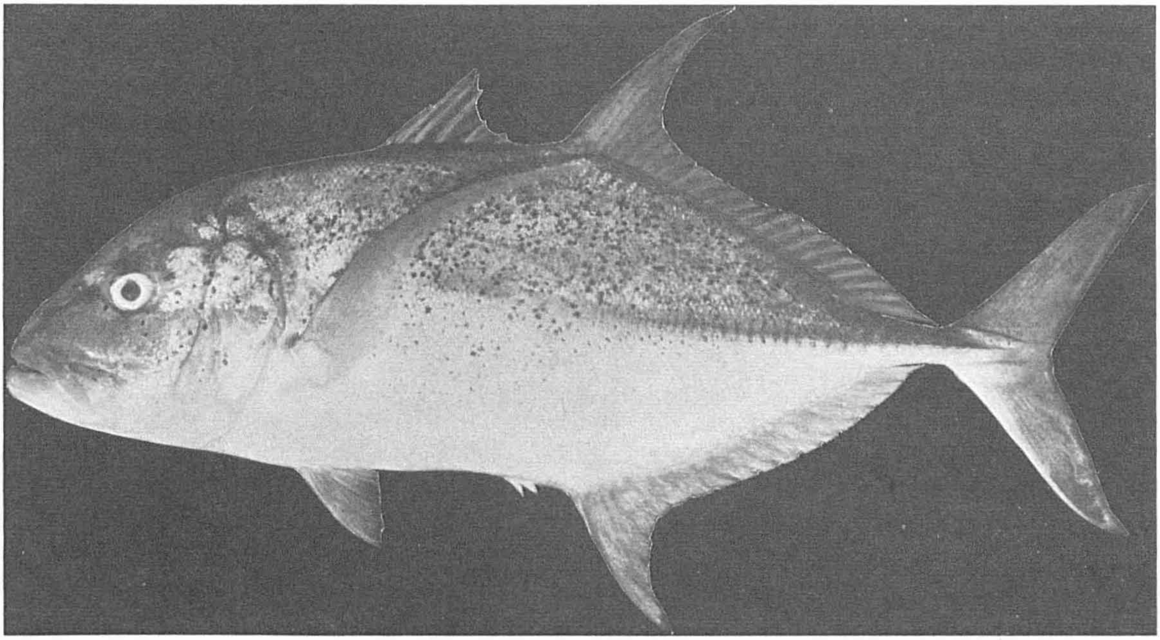

FIGURE 39.—*Caranx melampygus*, 498 mm FL, 1.9 kg, Sanganeb Atoll, Red Sea.

Sixty-one specimens, 298-722 mm FL, from the Marshall Islands, Hawaiian Islands, Line Islands, Marcus Island, Solomon Islands, and the Red Sea were collected for stomach-content study. Seventeen stomachs were empty. All the others contained the digested remains of fishes, though one had, in addition, a squid pen. The following fishes were identified from the stomach material: eel, *Anthias thompsoni*, *Caranx* sp. (90 mm FL in a 520 mm *C. melampygus*), *Priacanthus cruentatus*, *Cirrhitops fasciatus*, *Caesio* sp., *Parupeneus* sp., *P. trifasciatus*, *Pomacentrus pavo*, *Chromis caerulea*, labrid, *Thalassoma purpureum*, *Ptereleotris microlepis*, *Caracanthus unipinnus*, *Acanthurus triostegus*, acronurus stage of acanthurids (in two stomachs), and a subadult acanthurid.

Caranx sexfasciatus Quoy and Gaimard (Figure 40): This jack, which ranges from the Red Sea to eastern Oceania, is closely related to *C. hippos* of the Atlantic. It is usually seen in small schools, but is not common in the Marshall Islands. It is more elongate than the *Caranx* spp. discussed above, and it has a larger eye. The lower-limb gill raker count is 15-17. The scutes are blackish, there is a small black spot at the upper end of the gill opening, and the soft dorsal and anal fins are tipped with white. The dark bars of the young are the basis for the specific name.

Only two specimens were caught at Enewetak, 496 and 700 mm FL, 2.3 and 4.6 kg. Both were nontoxic. No specimens were obtained from Bikini.

Ommanney in Wheeler and Ommanney (1953) reported on the stomach contents of specimens caught during a survey of the Mauritius-Seychelles region. Eight specimens contained fish remains, one had squid remains, one had megalops larvae, and nine were empty. A parrotfish and two eels were noted among the stomach contents.

The stomachs of six specimens of *C. sexfasciatus*, 385-700 mm FL, from Enewetak and Tahiti were opened. Five were empty, and one contained well-digested fish remains. (This jack was speared at 11:30 a.m.)

Bagnis et al. (1972) stated that *C. sexfasciatus* is nocturnal. Wheeler and Ommanney (1953) on the other hand, wrote, "It often takes a lure..."; presumably he meant one trolled by day.

Scombridae (Tunas)

Gymnosarda unicolor (Rüppell) (Figure 41): The dogtooth tuna is named for its large conical teeth; it is also unique in having two patches of villiform teeth on the tongue. It lacks dark stripes or spots on the body; the second dorsal and anal fins are

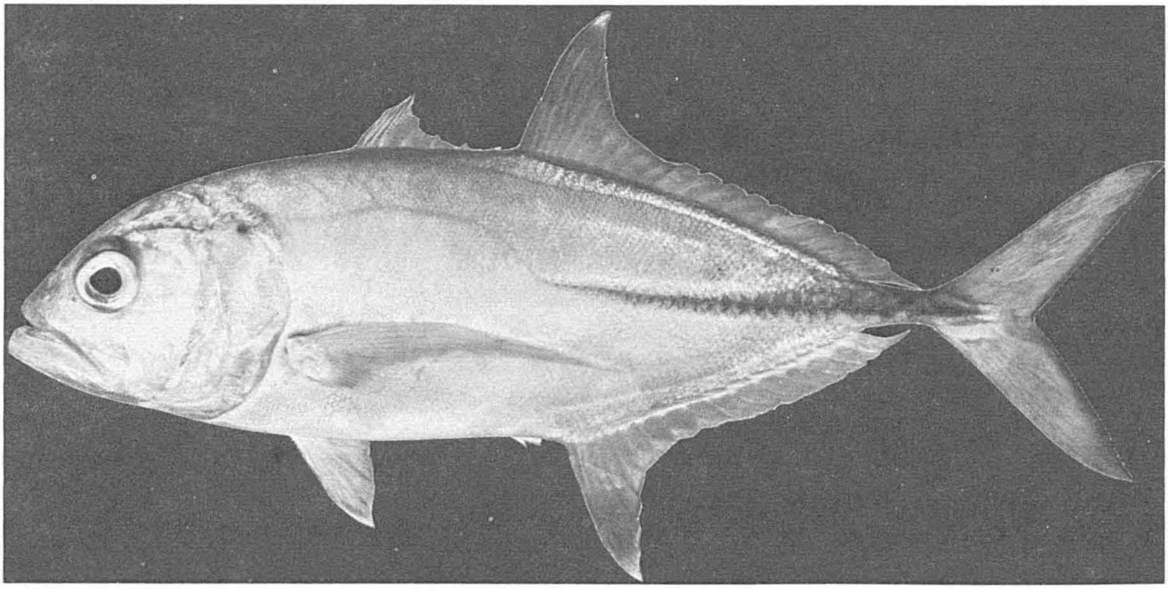

FIGURE 40.—*Caranx sexfasciatus*, 472 mm FL, 1.8 kg, Enewetak, Marshall Islands.

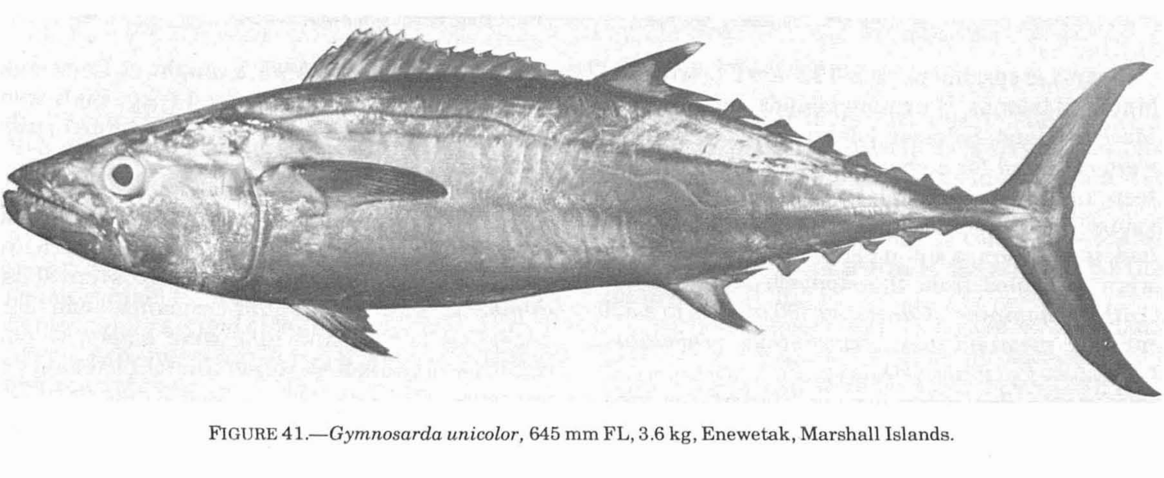

FIGURE 41.—*Gymnosarda unicolor*, 645 mm FL, 3.6 kg, Enewetak, Marshall Islands.

white tipped. A large species, Masuda et al. (1975) recorded it to a length of 2.4 m. Unlike other large tunas, in general, it occurs in relatively shallow coastal water, often around coral reefs, and it readily penetrates the deeper lagoons of atolls.

Thirteen individuals were collected from Enewetak which ranged from 550 to 1,350 mm FL (3.2-35.4 kg). Seven caused no symptoms when liver tissue was fed to mongooses; four produced a reaction of 1, one was a 2, and one a 3.

Three from Bikini, 737-940 mm FL, 6.4-11.8 kg, were nontoxic.

Hiatt and Brock (1948, after unpublished data of J. Marr and O. Smith) stated that the scad, *Decapterus sanctaehelenae*, was most frequently encountered in the stomachs of dogtooth tunas in the Marshall Islands. Schultz in Schultz and collaborators (1953) reported that *D. muroadsi* and *Caesio xanthonotus* were regurgitated by *Gymnosarda nuda* (= *G. unicolor*) which were caught at Bikini.

Five of 17 specimens from the Marshall Islands taken during the survey had empty stomachs. The others contained fishes, five of which were identified as: *Naso brevirostris*, *N. vlamingii*, *Cirrhilabrus* sp., *Caesio* sp., *Pterocaesio* sp. The two prey specimens of *Naso* were large adults. The *N. vlamingii*, taken from the largest *G. unicolor*, measured 370 mm SL.

Labridae (Wrasses)

Cheilinus undulatus Rüppell (Figure 42): The giant humphead wrasse is one of the largest of bony fishes. It has been recorded to a length of 2.29 m and a weight of 190.5 kg (Marshall 1964). The hump on the forehead develops only on larger individuals. Two dark lines which extend posteriorly from the eye are useful in identifying juveniles and subadults of this species. It is usually found on outer reef slopes or in deep channels, but also occurs in lagoons. It is difficult to approach underwater. According to Bagnis et al. (1972) individual fish have a home cave to which they retreat when threatened and to which they retire at night. Randall (1958) reported this species as capable of being moderately to strongly toxic in Tahiti, where it is called "mara" (Randall 1972). It is one of nine species of fishes which are banned from sale in the Papeete market (Bagnis 1968).

Seven specimens, 515-995 mm SL, the largest weighing 34.5 kg, were procured at Enewetak for testing. The largest gave a reaction of 2 on feeding to mongooses; the others were 0.

Randall et al. (1978) reported on the food habits of the giant humphead wrasse based on the examination of 72 specimens from the Red Sea and islands of Oceania. The diet is highly varied, the dominant groups of food organisms being mollusks (gastropods a little more numerous than pelecypods), crustaceans (especially crabs), echinoids, and fishes. The hard parts of the invertebrates are crushed to fragments by the powerful pharyngeal dentition.

Coris aygula Lacepède (Figure 43): This is one of the two largest species of *Coris* (the other an undescribed endemic from Lord Howe Island). The largest collected, from the Red Sea, measured 465 mm SL and 583 mm TL. Adult males develop a gibbosity on the forehead similar to that of *Cheilinus undulatus,* but these two wrasses could hardly be confused; the *Coris* is more elongate (depth about 3.2 in SL) and has small scales (60-65 lateral line scales for *C. aygula,* compared with about 25 for *Cheilinus undulatus*); also, the lateral line of *Cheilinus* is interrupted.

Coris aygula has apparently not been reported as causing ciguatera but because of its large size and similar food habits it would seem to be at least as suspect as *C. gaimard* which is known to be poisonous at times. The latter is more colorful, displaying bright blue spots and a yellow caudal fin.

Five adults of *C. aygula,* 329-377 mm SL (0.9-1.9 kg), were obtained from Enewetak for testing. One of 368 mm SL (1.4 kg) produced a toxic reaction of 1 when its liver and viscera were fed to a mongoose; the others were nontoxic.

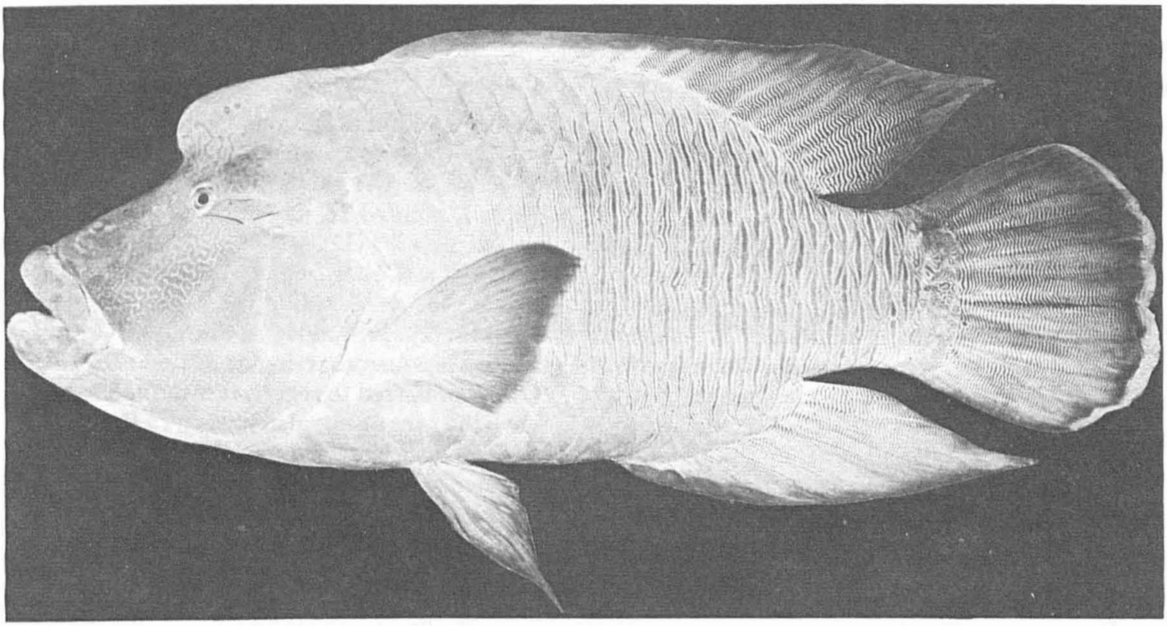

FIGURE 42.—*Cheilinus undulatus,* 915 mm SL, 25.8 kg, Enewetak, Marshall Islands.

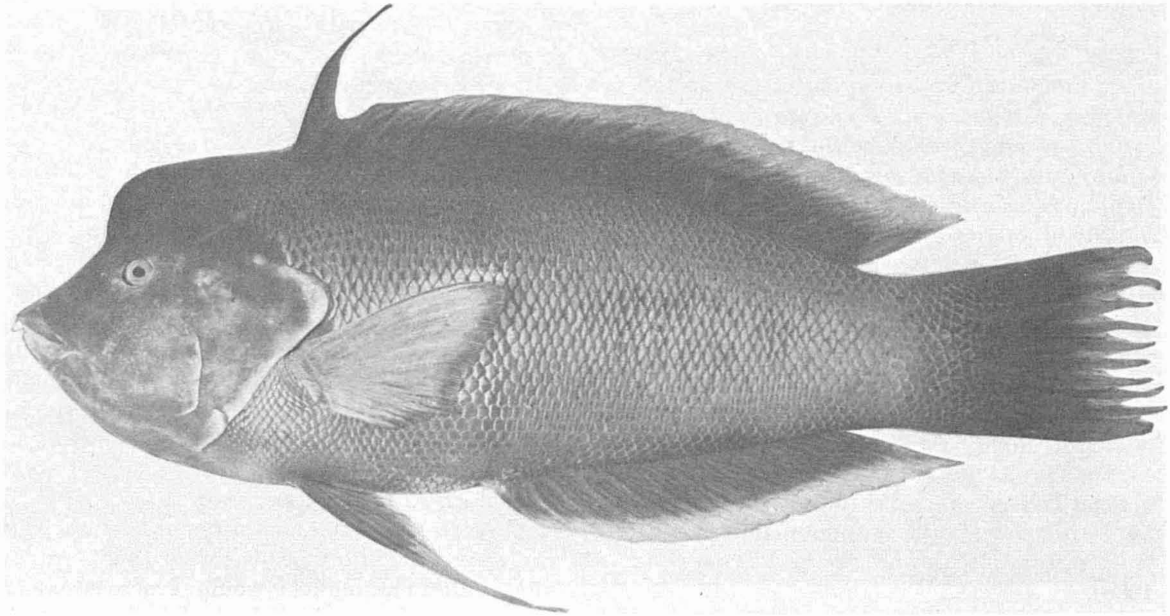

FIGURE 43.—*Coris aygula*, 380 mm SL, Marcus Island.

Al-Hussaini (1947) listed the food of the species as gastropods (*Turbo, Trochus*), *Dentalium,* and hermit crabs. Hiatt and Strasburg (1960) found the crushed remains of sand-dwelling pelecypods and gastropods in a single specimen (identified as *C. angulata*) from Enewetak.

Randall, G. J. Vermeij, and H. A. Rehder (manuscript in progress) will report in detail on the food habits of this wrasse. The principal food animals are gastropods, pelecypods, pagurid crabs, echinoids, and brachyuran crabs.

Epibulus insidiator (Pallas) (Figure 44): This unmistakable labrid, popularly known as the slingjaw wrasse because of its ability to enormously protrude its mouth, occurs from the Red Sea and east Africa to French Polynesia. Halstead (1967) listed nine references citing it as ciguatoxic.

Five specimens from Enewetak, 175-228 mm SL, 0.34-0.55 kg, were tested for toxicity. None caused any symptoms in the mongooses.

Hiatt and Strasburg (1960) collected one specimen from Enewetak and one from Bikini for food-habit study; both fish had eaten alpheid shrimps. They wrote, "This wrasse habitually feeds in ramose corals by extending its exceedingly protractile snout into the interstices to capture small alpheid shrimps and xanthid crabs living there."

For the present food-habit study 16 specimens, 183-240 mm SL, were collected from the Marshall Islands, Johnston Island, American Samoa, and the Society Islands. Two had empty stomachs; six had eaten only fishes and four only crabs. Other food items were shrimps, unidentified crustaceans, polychaetes, bryozoans, and unidentified eggs.

Scaridae (Parrotfishes)

Hipposcarus harid (Forsskål) (Figure 45): Smith (1956) created a new genus, *Hipposcarus,* for this species on the basis of the triangular patch of scales on the cheek with three or four rows behind, pointed snout, and minute nostrils. Although Schultz (1958, 1969) did not recognize this genus, it will be considered valid by Nelson and Randall.[9]

Smith (1959) described a Philippine form of this species as new, naming it *H. schultzi.* Schultz (1969) preferred to regard this form, for which he gave the range central and western Pacific Ocean, as a subspecies, *Hipposcarus harid longiceps* (Cuvier and Valenciennes).

Halstead (1967) has listed four references reporting the occasional toxicity of this parrotfish.

[9]G. J. Nelson, Department of Ichthyology, American Museum of Natural History, New York, and the author conferred in October 1977 on the generic limits of the Scaridae. Eventual publication is planned.

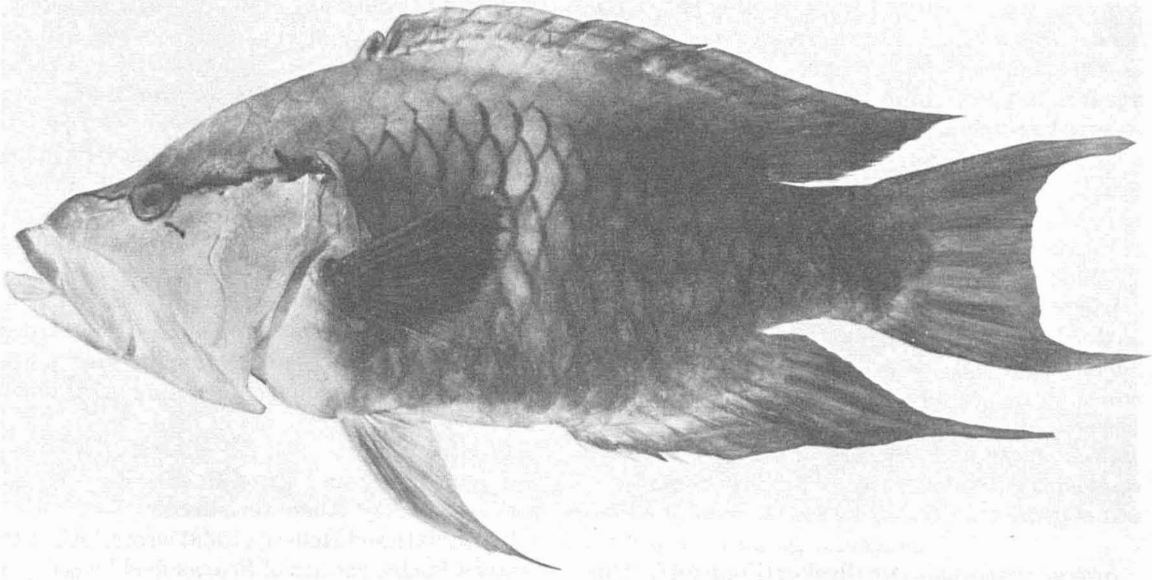

FIGURE 44.—*Epibulus insidiator,* 185 mm SL, Enewetak, Marshall Islands.

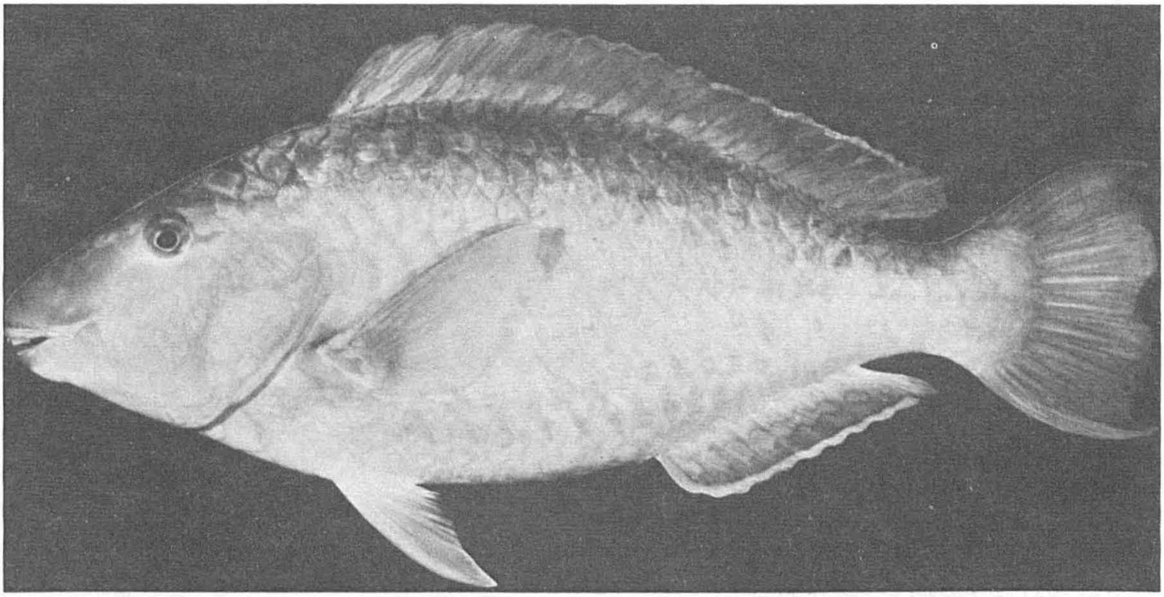

FIGURE 45.—*Hipposcarus harid,* 282 mm SL, Rangiroa, Tuamotu Archipelago.

Of four specimens, 340-412 mm SL, 1.3-1.8 kg, obtained at Enewetak, three were nontoxic, and one produced a reaction of 1.

Reporting on the stomach contents of *Cetoscarus bicolor, Scarus sordidus,* and seven unidentified species of *Scarus* in the Marshall Islands, Hiatt and Strasburg (1960) concluded that they fed mainly on live coral. This is contradictory to the investigation of scarid food habits by Wood-Jones (1910), Choat (1966), Randall (1967, 1974), Rosenblatt and Hobson (1969), and Hobson (1974). Randall (1974), however, presented evidence that the largest of the parrotfishes, *Bolbometopon muricatus,* feed heavily on living coral. Also Glynn et al. (1972) listed three scarids as coral predators off the Pacific coast of Panama.

Scarus gibbus Rüppell (Figure 46): The name *Scarus microrhinos* Bleeker has generally been used in the Pacific for this species (Schultz 1958), and it is under this name that its toxicity has been reported (Halstead 1967). Smith (1959) resurrected the name *Scarus gibbus* Rüppell for the Red Sea form of this species, though he still recognized *S. microrhinos*. Schultz (1969) placed four nominal species, including *S. microrhinos*, under the one name *S. gibbus*. The large males are readily distinguished by the near-vertical anterior profile of the head. Other useful characters for distinguishing the species are four median predorsal scales, three rows of scales on the cheek, and 16 or 17 pectoral rays.

Of 19 specimens, 326-414 mm SL, 1.05-2.8 kg, speared from Enewetak, only 1 of 410 mm (2.3 kg) was slightly toxic (mongoose reaction of 1).

Scarus rubroviolaceus Bleeker (Figure 47): This parrotfish was selected as the type-species of a new genus, *Scarops,* by Schultz (1958) principally on the basis of its having a single enlarged row of teeth on each upper pharyngeal bone. This genus, however, was not recognized by Rosenblatt and Hobson (1969). The primary phase of *S. rubroviolaceus* is reddish with small blackish spots and short streaks on the scales; the terminal male phase (the nominal *Pseudoscarus jordani* Jenkins and *Callyodon africanus* Smith were based on this form) is complexly colored, but mainly purplish on the anterior part of the body and abruptly green posterior to about the base of the seventh dorsal spine (this bicolored effect more evident in live than on freshly dead specimens); the head is mainly blue-green, shading to orange-yellow on the opercle, with transverse bands of turquoise and salmon on the lips and chin. There are generally 6 median predorsal scales, 3 rows of scales on the cheek, and 15 pectoral rays.

Like the other species of *Scarus*, *S. rubroviolaceus* is closely tied to coral reefs. It ranges from east Africa to the tropical eastern Pacific. Although this species has not been reported as poisonous, it would seem to have the same potentiality of causing ciguatera as other parrotfishes which may be toxic.

Three specimens, 355-370 mm SL, 1.4-1.6 kg, were obtained from Enewetak in order to test for possible toxicity. None were toxic.

Rosenblatt and Hobson (1969) wrote, "All of the eastern Pacific species of *Scarus* feed by scraping algae from the surface of rocks. We did not see evidence that they bit off pieces of coral. . . ." *Scarus rubroviolaceus* is one of the four species they studied. Glynn et al. (1972), on the other hand, included *S. rubroviolaceus* among the three scarids they regarded as coral predators from observations off Panama.

Acanthuridae (Surgeonfishes)

Acanthurus xanthopterus Cuvier and Valenciennes (Figure 48): This is the largest member of

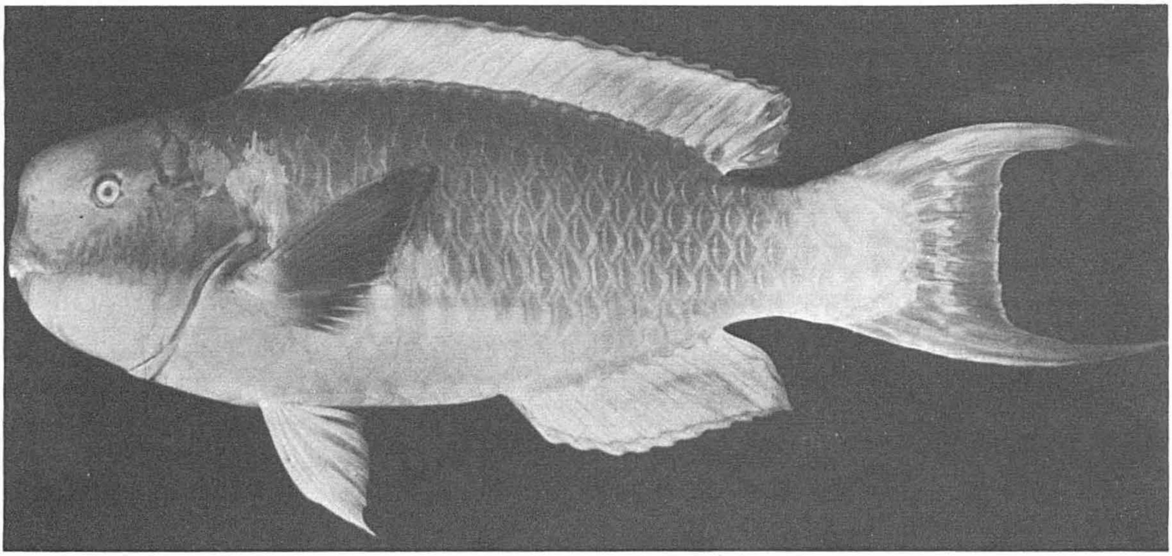

FIGURE 46.—*Scarus gibbus,* 417 mm SL, 2.8 kg, Tahiti, Society Islands.

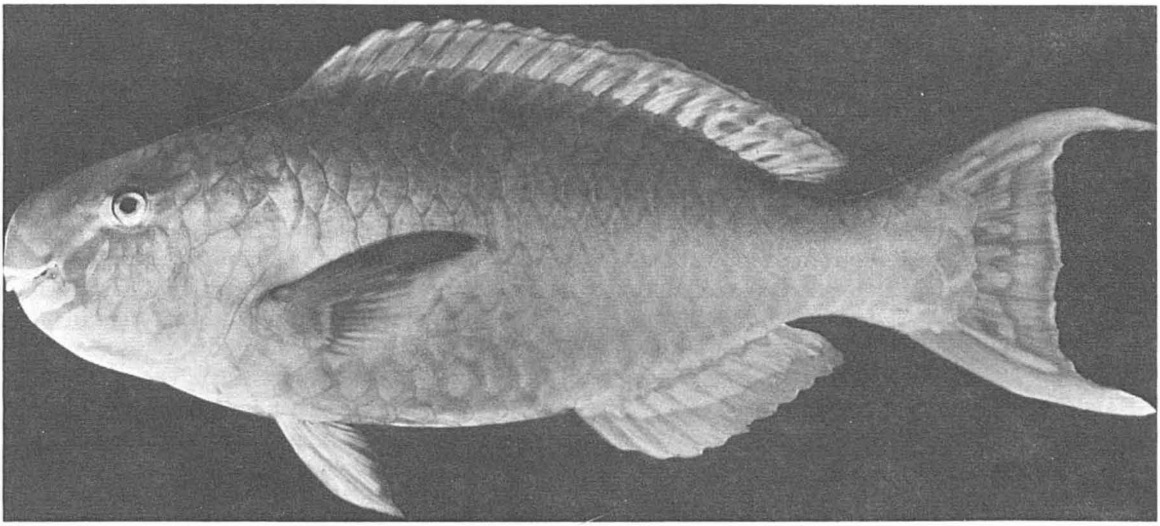

FIGURE 47.—*Scarus rubroviolaceus*, 355 mm SL, 1.35 kg, Enewetak, Marshall Islands.

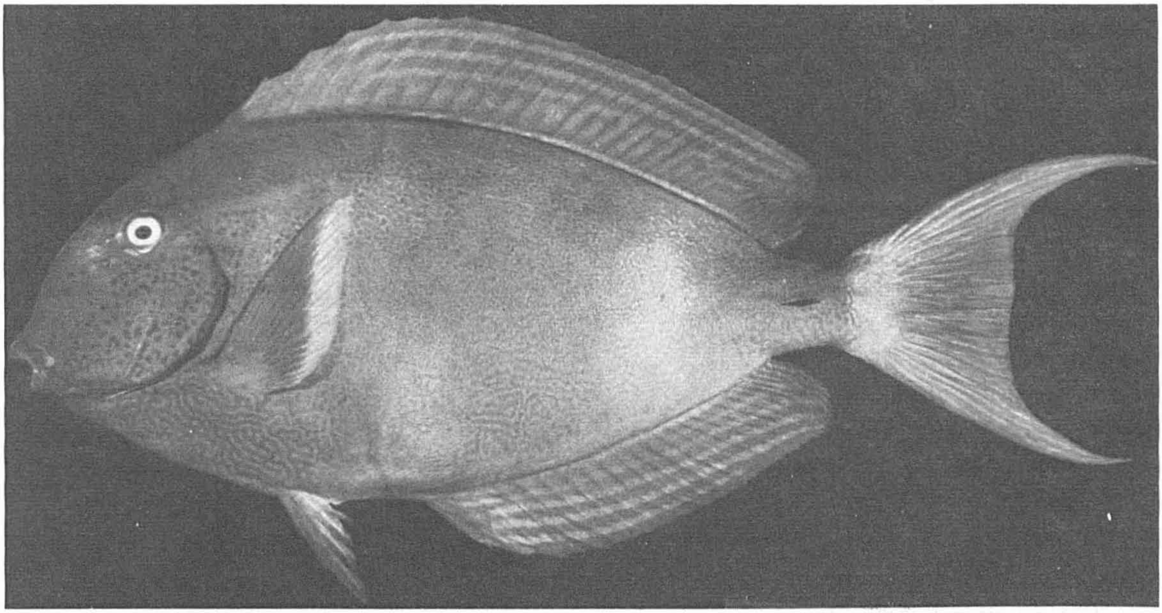

FIGURE 48.—*Acanthurus xanthopterus*, 400 mm SL, 2.3 kg, Enewetak, Marshall Islands.

the genus *Acanthurus*. It is one of a complex of species with a gizzardlike stomach. In the Marshall Islands it could only be confused with *A. mata*, also a large species. The outer third of the pectoral fins of *A. xanthopterus* are yellowish (fins uniform brown on *A. mata*), and there are about 4 lengthwise bands in the dorsal fin (about 8 in the fin of *A. mata*); there are fewer gill rakers (16-22 for *A. xanthopterus*, compared with 21-25 for *A. mata*). This species is distributed from east Africa to the eastern Pacific. It occurs more in lagoons and bays than exposed outer reef areas, and it ranges into deeper water than other *Acanthurus* in general. Also it ventures farther from the cover of coral reefs than other species. Schultz in Schultz and collaborators (1953) used the name *Acanthurus fuliginosus* Lesson for this fish, but there is no basis for equating it to Lesson's illustration and description, as explained by Randall (1956). The junior synonym *Teuthis crestonis* Jordan and

Starks was created for the species from Mexico.

Two specimens, 423 and 425 mm SL, 2.7 kg, were obtained from Enewetak for the assay of toxicity. Neither were toxic.

Hiatt and Strasburg (1960) examined the stomachs of four specimens from Enewetak, two of which were empty. The other two contained short filaments of algae with much sand, hydroid hydrocaulus, and wood splinters (probably from grazing on pilings). Jones (1968) classified *A. xanthopterus* as a grazer on diatoms and detritus in sand patches. That it will take animal food when the opportunity arises was aptly shown by Helfrich and Banner (1963) who used this species to induce ciguatera toxicity by feeding the poisonous flesh of *Lutjanus bohar*.

Ctenochaetus striatus (Quoy and Gaimard) (Figure 49): This surgeonfish is much the most common of the four species of the genus that occur in the Marshall Islands. It is, in fact, one of the most abundant reef fishes throughout the Indo-West Pacific region (though not Hawaii). The genus is named for its comblike teeth which are numerous, slender with expanded incurved tips, and flexible in the jaws. Randall (1955b) has differentiated *C. striatus* from the other species by having 5-7 denticulations on the expanded distal tips of the upper teeth, the highest average number of dorsal and anal soft rays (modally 29 dorsal rays and 26 or 27 anal rays), and a lunate caudal fin.

Bagnis et al. (1968) reported that surgeonfishes (particularly *C. striatus*) are responsible for 65% of the cases of ciguatera in Tahiti. There are three reasons for this: 1) the abundance of *C. striatus*, 2) its good-eating quality, and 3) the knowledge that the symptoms will be mild if ciguatera is incurred.

Bagnis (1968) documented the great variation in the symptoms of ciguatera in French Polynesia. He noted that digestive and neurologic symptoms predominated among those patients who had ingested surgeonfishes.

Yasumoto et al. (1971) determined that there are two principal toxins in *C. striatus*, one of which is fat soluble and chromatographically identical with ciguatoxin, and the other is water soluble. The latter was found only in the liver and gut contents. In a few specimens from Tahiti a different fat-soluble toxin and a different water-soluble toxin were detected.

In order to determine if more than one toxin is present in *C. striatus* in the Marshall Islands, 22 adult specimens were speared on lagoon reefs of

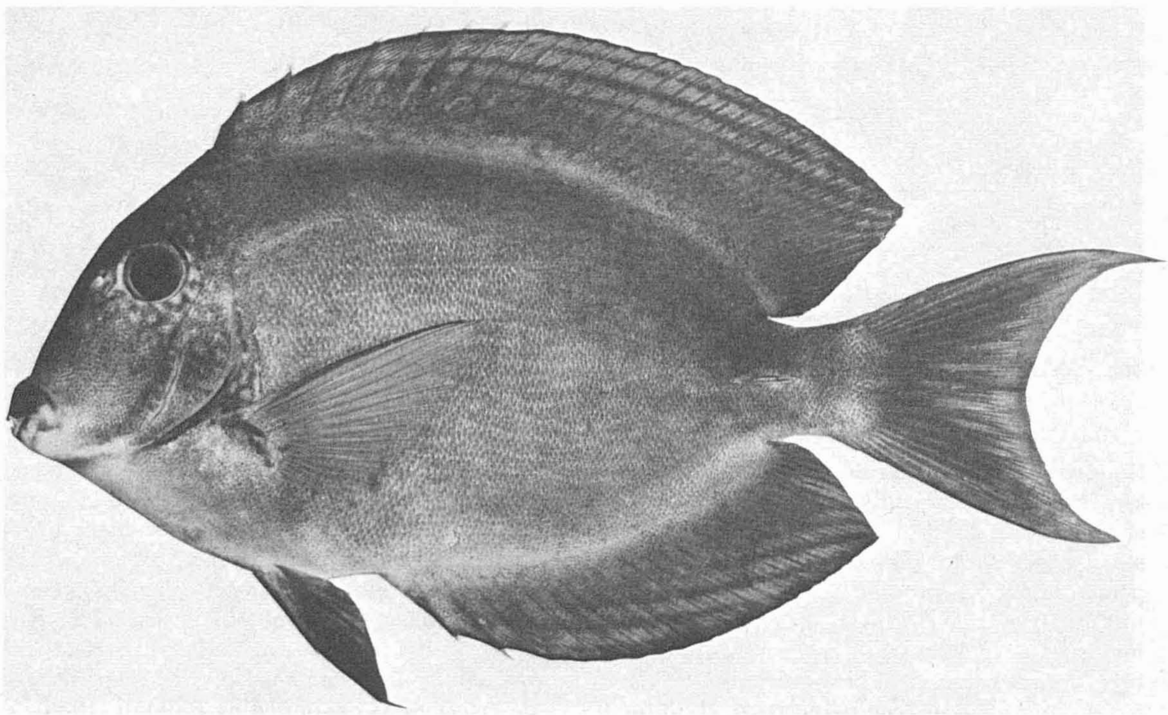

FIGURE 49.—*Ctenochaetus striatus*, 94 mm SL, Enewetak, Marshall Islands.

Enewetak and sent frozen to the Laboratory of Marine Biochemistry of the University of Tokyo. The specimens, which weighed from 130 to 230 g each, were pooled in groups of three (four for one group). The flesh and the viscera were separated for each group, and the gut contents of all groups were pooled. Fat-soluble and water-soluble fractions were prepared and injected intraperitoneally into mice at doses of 4,000, 2,000, and 1,000 μg/g. Two mice were used for each dose. If the mice were not killed by a dose of 4,000 μg/g within the observation period of 48 h, the preparation was regarded as nontoxic. If they were killed by a dose of 1,000 μg/g, it was classified as strongly toxic, at 2,000 μg/g moderately toxic, and at 4,000 μg/g weakly toxic. The results were reported in a letter by the late Yoshiro Hashimoto, then the Director of the Laboratory. None of the preparations were strongly toxic. All the preparations from the flesh were nontoxic. Four of the seven fat-soluble preparations of the viscera were moderately toxic, one was weakly toxic, and one nontoxic. Five of the seven water-soluble fractions from the viscera were weakly toxic and the remaining two nontoxic. Both the fat-soluble and the water-soluble preparations of the pooled gut contents were moderately toxic.

The food habits and mode of feeding of *C. strigosus* from the Hawaiian Islands were investigated by Randall (1955b); underwater observations of *C. striatus* indicate that its feeding is essentially the same. These fishes are detritus feeders. From a near-vertical position (if the bottom is horizontal) about 15 mm above the substratum, the fish move abruptly downward with mouth open. The lips and teeth scrape over the surface at the same time that suction is initiated. The soft detrital material and fine inorganic sediment are ingested. If coarse particles of sand are picked up, they are forcefully ejected. The stomach contents of seven adults of *C. strigosus* from Hawaii consisted of inorganic sediment (up to 90% by volume); fragments of red, green, and blue-green algae; diatoms; and unidentified soft organic material. In an aquarium experiment *C. strigosus* was unable to feed on an intact thallus of the filamentous alga *Polysiphonia* sp. When the same algae was finely fragmented and placed on the bottom, it was readily consumed.

Balistidae (Triggerfishes)

Pseudobalistes flavimarginatus (Rüppell) (Figure 50): This is one of three large species of triggerfishes that occur in the Marshall Islands. It may be distinguished from other balistids by the following characters collectively: the second dorsal and anal fins elevated anteriorly, five or six rows of spines on the caudal peduncle, no scales on the cheek (of adults), caudal fin of adults emarginate, and yellowish margins on the median fins. Woods in Schultz and collaborators (1966) failed to list this species from the Marshall Islands, but the color plate in Hiyama (1943, pl. 22, fig. 61) and the study of Hiatt and Strasburg (1960) clearly indicate its presence there. Hiatt and Strasburg stated that it is solitary, uncommon, and occurs on lagoon and interisland reefs in quiet water of 10-30 ft (3.1-9.1 m) deep. Although Hiyama wrote that this fish was not regarded as poisonous in the Marshalls, other records (Halstead 1967) demonstrate its capacity for causing ciguatera. It is one of the nine species of fishes forbidden to be sold in the fish market in Papeete, Tahiti (Bagnis 1968).

Two specimens, 465 and 535 mm SL, weight not taken, were collected in Bikini. Neither was poisonous.

Clark and Gohar (1953) reported pieces of branched coral (*Stylophora*) 2-3 cm long in the stomach of a specimen 440 mm SL from the Red Sea. Hiatt and Strasburg (1960) examined two stomachs from the Marshall Islands. They found the crustacean *Lydia annulipes* and isopods, crushed gastropods including *Oliva* sp., foraminifera, and colonial tunicate fragments.

The stomach and gut contents of only two specimens were obtained for the present study. One of 254 mm SL from the Red Sea was empty. The second of 390 mm SL from Tahiti had eaten *Diadema*.

Balistoides viridescens (Bloch and Schneider) (Figure 51): This is another large triggerfish for which there have been a few records of toxicity. It shares the elevated anterior part of the second dorsal and anal fins and the rows of spines on the caudal peduncle with *P. flavimarginatus*, but is differentiated by having its cheek totally scaled and its caudal fin rounded to slightly double emarginate as an adult; also the margins of its median fins are broadly blackish. It ranges from the Red Sea to eastern Oceania. It occurs in both lagoons and outer reef slopes. Like other triggerfishes, it has a favorite hiding place in the reef into which it wedges itself when threatened.

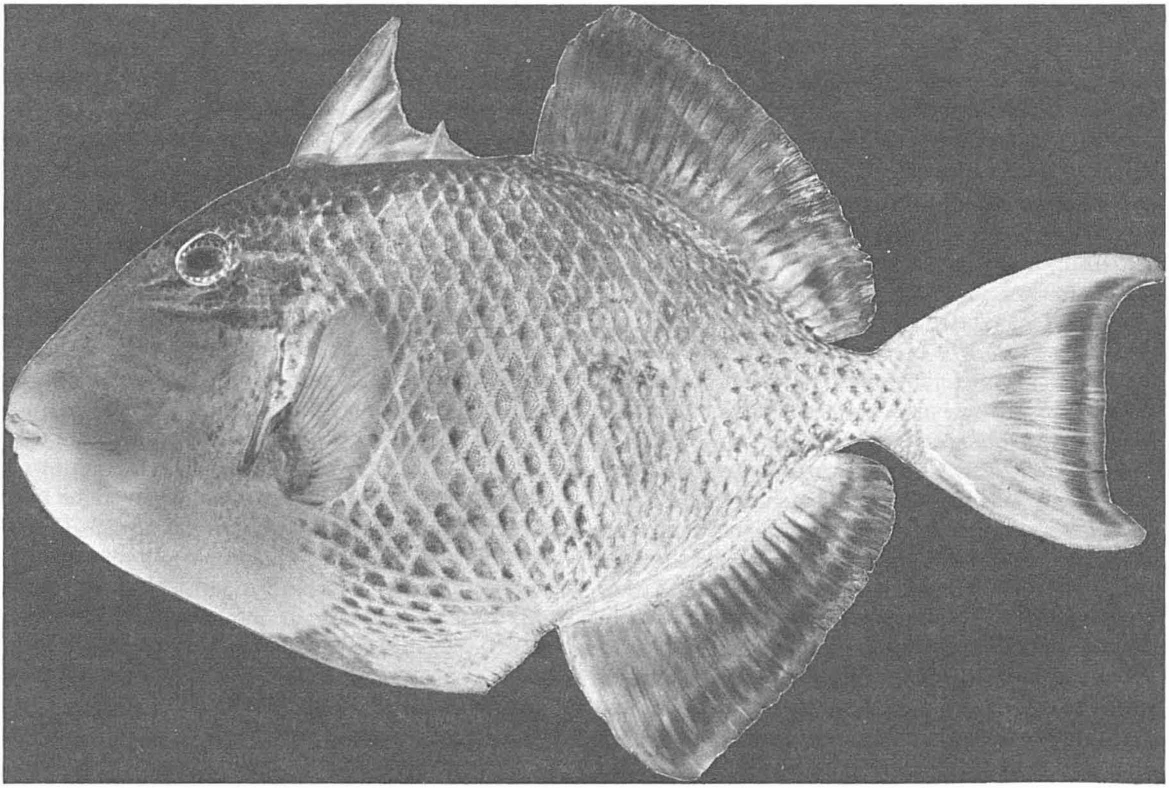

FIGURE 50.—*Pseudobalistes flavimarginatus*, 265 mm SL, Palmyra, Line Islands.

A single specimen, 456 mm SL, 4.5 kg, from Enewetak was nontoxic.

The stomach and gut contents of four specimens, 278-525 mm SL, from the Society Islands and the Red Sea were examined. Echinoids, including *Diadema*, *Echinometra*, and spatangoids, were the main items of diet, but pelecypods, crabs, polychaete tube worms, gastropods, chitons, foraminifera, and algae and detritus were also present.

DISCUSSION AND SUMMARY

As mentioned in introductory remarks, the initial testing for level of ciguatera at both Enewetak and Bikini revealed only an occasional toxic fish among the species responsible for most cases of this type of poisoning in the Pacific. As expected, the toxic individuals were invariably adults of moderate to large size for the species. A decision was then made to concentrate the fishing effort on the larger individuals of the species most often implicated in ciguatera. These dangerous species are, in general, not common. They are at or near the peak of the well-known "pyramid of numbers," i.e., the reduction in number of individuals one encounters analyzing the populations in successive steps up the food chain. Consequently, much more effort was expended in catching not only these fishes but just the larger individuals of these species. Also, it is for this reason that some relatively common species such as *Lutjanus fulvus* and *Adioryx spinifer* are represented by few individuals in this report and others such as the smaller species of groupers of the genera *Epinephelus* and *Cephalopholis* were not collected. In highly toxic sectors these species can be poisonous, though even there the incidence is low.

A total of 551 specimens of 48 species were tested from Enewetak and 256 specimens of 23 species from Bikini. In addition, 12 adult specimens of *Lutjanus bohar* from Rongelap were tested, one of which was toxic at the 5 level. The results of the testing of fishes from Enewetak are summarized in Table 1, and for Bikini in Table 2; 37.3% of the fishes from Enewetak gave a positive reaction for ciguatoxin, and 19.7% of those from Bikini.

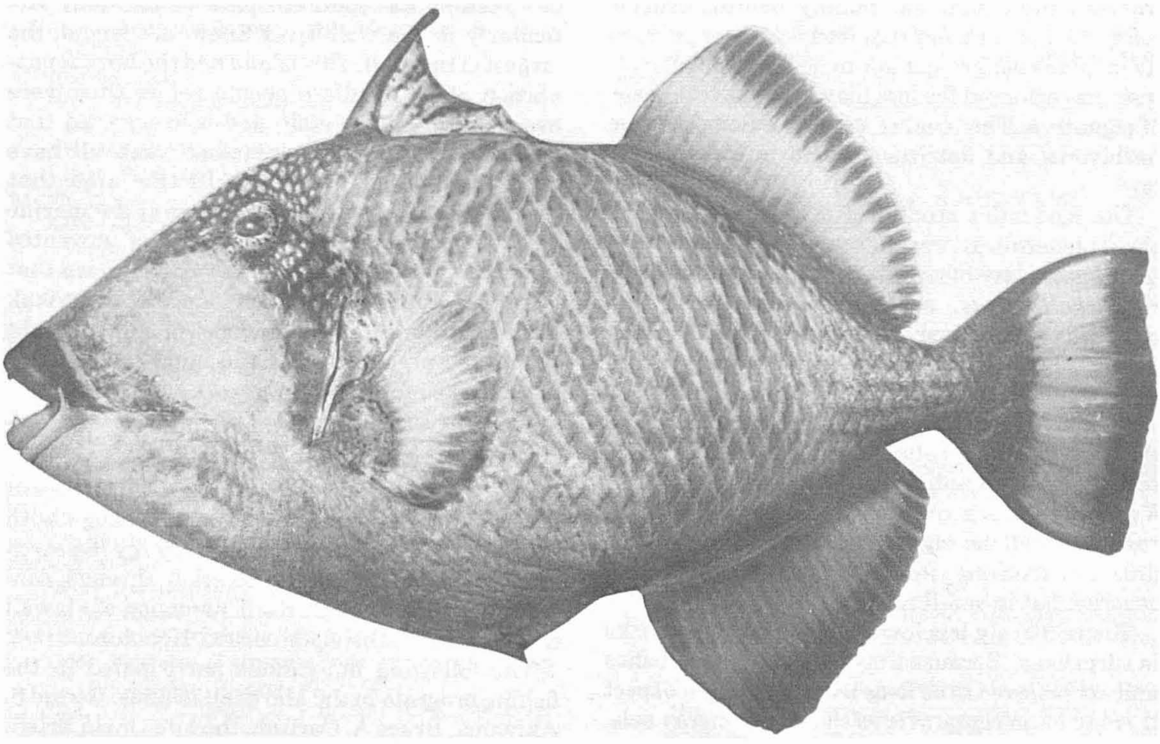

FIGURE 51.—*Balistoides viridescens*, 456 mm SL, 4.5 kg, Tetiaroa, Society Islands.

It must be emphasized that liver and viscera of the suspect fishes were used in the mongoose feeding tests (except for sharks) and not flesh. Because of the much higher level of ciguatoxin in the internal organs than in muscle tissue, low-level toxicity (indicated by mongoose reactions of 1 or 2) from liver and viscera would probably not result in a detectable level of toxin if flesh from these fishes had been used in the tests. When the percentage of toxicity is computed for the reactions 3-5 (it is this level at which a human eating the flesh of these species might be expected to fall ill with ciguatera), the percentage of toxic fishes drops to 16.2 for Enewetak and 1.4 for Bikini.

When one considers the effort directed almost entirely to the worst offenders in ciguatera, the level of toxicity at Enewetak must be regarded as relatively low and that of Bikini decidedly so. Most of these fishes are avoided as adults by islanders in Oceania regardless of the area of capture. Therefore it is concluded that the returning residents to Enewetak and Bikini need not fear at this time any unexpected threat of ciguatera at their atolls.

Only eight species of fishes produced reactions of 4 or 5 in the test animals; that is, severe illness or death: *Lycodontis javanicus*, *Cephalopholis argus*, *Epinephelus hoedtii*, *E. microdon*, *Plectropomus leopardus*, *Aprion virescens*, *Lutjanus bohar*, and *Lethrinus kallopterus*. Had more specimens of *Sphyraena barracuda*, *Caranx ignobilis*, and *Cheilinus undulatus*, particularly of large size (none of the specimens taken during this survey approached the maximum size), been collected, then they may be expected to be included in the above list (in view of their reputations for causing ciguatera in other areas).

The moray *Lycodontis javanicus* was clearly the most toxic of all the species tested, with all individuals producing a reaction of 2 or more in mongooses and one-third of them the lethal 5.

Randall (1958) analyzed the kinds of fishes which have caused ciguatera in terms of habitat, mode of life, and food habits. These species are shore fishes associated with reefs. Usually they are bottom-dwelling generally in < 60 m, but they may be semipelagic open-water forms that range into the reef habitat to feed. They may be carnivorous or they may feed on benthic algae or detritus. Of the carnivores, those that prey heavily on reef fishes are the most prone to be poisonous, whereas those that eat mainly benthic crustaceans the least. Fishes that feed wholly or primarily on plankton are not apt to be toxic. Some mollusk and echinoid feeders may cause severe cases of ciguatera. The level of toxicity among benthic herbivores and detritus feeders is consistently low.

The food-habit studies of this survey support these generalizations. Seven of the eight most toxic species are piscivorous. The one other, *Lethrinus kallopterus*, appears to feed mainly on echinoids and mollusks. No specimens of *Lutjanus fulvus*, *Epinephelus socialis*, and *Adioryx spinifer* were found to be toxic (although relatively few specimens were collected); these feed more on crustaceans than fishes. Among the herbivores tested, only two individuals of *Scarus* and one of *Kyphosus* gave a reaction of 1. A water-soluble toxin as well as ciguatoxin were found in the detritus-feeding surgeonfish *Ctenochaetus striatus*, but in small amounts.

The relatively low level of ciguatoxin in sharks is surprising. Because they feed heavily on fishes and are believed to be long-lived, one might expect them to be as ciguatoxic as the larger moray eels. The tropical species of sharks are not as widely eaten as bony fishes. If they were, no doubt more cases of ciguatera would be attributed to them. The species of *Carcharhinus* appear to prey to a significant degree on pelagic fishes, and when they do feed on reef-dwelling species, they seem to take many plankton-feeding forms. This may in part explain their apparent relatively low level of ciguatoxin. Still another possibility is that sharks may not accumulate as much ciguatoxin in their tissues as bony fishes.

Because ciguatera can be highly localized to certain reefs or even sectors of reefs, the fish collecting was carried out at many different locations at the atolls. No one area was detected as having a notably higher level of toxicity.

Many of the most dangerous ciguatoxic species are roving predators. Examples are the barracudas, jacks, dogtooth tuna, emperors, and, to a lesser extent, the snappers. They can be caught at a different area from which they acquired most of their toxicity. The strong localization of ciguatera occurs more where the level of toxicity is high and the smaller more resident species are poisonous. Our fishing has not been sufficiently extensive to demonstrate minor differences in the incidence of ciguatera with locality.

At Enewetak most of the fishing was undertaken on the southern part of the atoll, particularly in the vicinity of Enewetak Island, the largest of the atoll. This island had the largest population of Marshallese people before they were evacuated from the atoll, and it is expected that it will have the largest number when all have been repatriated. Also it is in this area that most of the long-term disturbances of the marine environment, such as the dumping of unwanted material, have taken place. It is fortunate that ciguatera, though more in evidence at Enewetak than at Bikini, is not a major problem as might have been predicted from the impact of western man on the atoll.

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The testing of the toxicity was carried out by James Murphy and Lambert Yamashita at the Hawaii Institute of Marine Biology of the University of Hawaii, under the direction of A. H. Banner, except for the last sampling in May 1978 for which an initial screening was made by Yoshitsugi Hokama of the Department of Pathology, University of Hawaii, by radioimmunoassay (Hokama et al. 1977). The higher reactions were then confirmed by mongoose feeding at the Bernice P. Bishop Museum by Arnold Y. Suzumoto.

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