Fishes Inhabiting Two Small Nuclear Test Craters at Enewetak Atoll, Marshall Islands

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Abstract—Diving observations of fishes inhabiting two small nuclear test craters at Enewetak Atoll in the Marshall Islands indicate that mullids, sparids, acanthurids, scarids, kyphosids, and carangids are transient residents of the craters with their presence dependent on the tide level. Chaetodontids and lutjanids seem to be permanent residents. Censuses conducted along permanent transects demonstrate a high correlation between the spatial distribution of fish species and the distribution of shelter. Estimates of fish biomass are compared with those of other reef areas and it is concluded that the craters are an energetically open system. Utilization of crater mullids as a potential food resource is considered.

Introduction

Community studies of coral reef fishes are challenging due to the overwhelming diversity of species and the seemingly complex interactions between them. Several researchers, however, have investigated tropical fishes at the community level (Bardach, 1959; Brock *et al.*, 1965, 1966; Collette and Talbot, 1972; Hobson, 1968, 1972; Hiatt and Strasburg, 1960; Randall, 1955, 1963, 1967; Smith and Tyler, 1972; Talbot, 1965; Talbot and Goldman, 1972; and Wass, 1967). During 1971 and 1972 we had the opportunity to examine a distinctly simple association of fishes inhabiting two nuclear test craters on the reef flat of Enewetak Atoll in the Marshall Islands. Because the craters are small and relatively isolated basins, they provide convenient sites to study reef fish populations and seem well suited for fishery experimentation or mariculture manipulations.

This study is part of a larger experiment directed by Professor John Isaacs and Walter Schmitt of the Scripps Institution of Oceanography. The overall intent of these investigations is to stimulate primary productivity in the craters by introducing nutrient-rich water pumped from a drill hole deep in the reef. The discovery of small concentrations of radioactive substances, leftovers of thermonuclear testing in the 1950's near the center of Runit Island, necessitates postponing the upwelling phase of the project until the disposition of the island is decided by the Department of Defense.

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Methods

The study site consisted of two nuclear test craters located on the reef flat at the north end of Runit (Yvonne) Island (Fig. 1). Cactus, the most lagoonward crater, was created by a detonation in May 1958 and La Crosse, the more seaward,

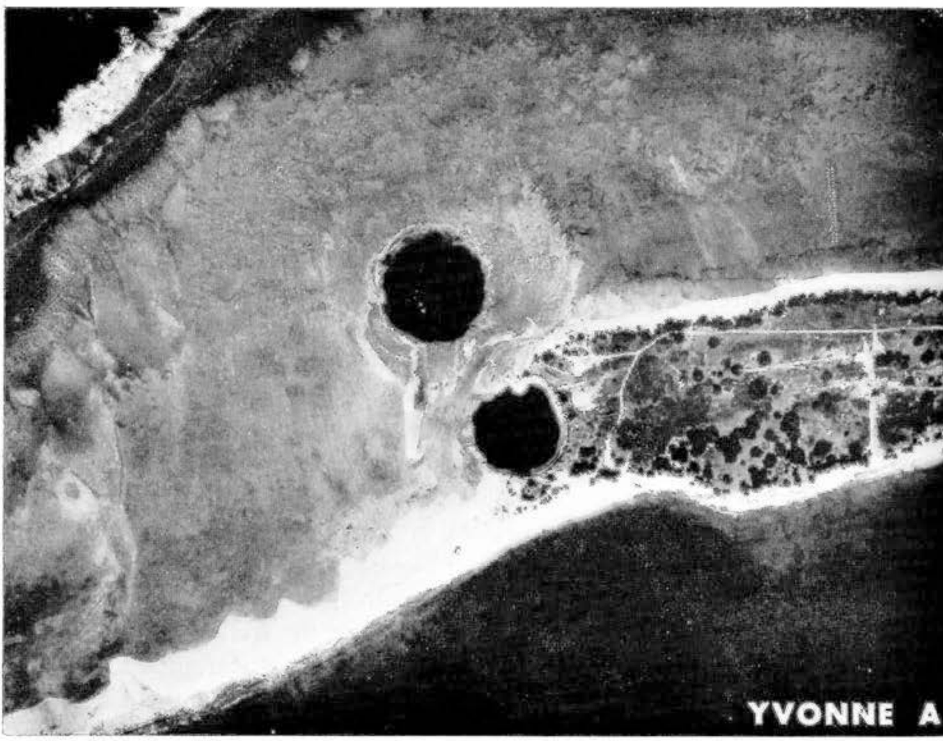

Fig. 1. Aerial photo of the north end of Runit Island showing the outer reef (top left), lagoon (lower right) and inter-connecting reef flat. Cactus Crater is smaller and lies more lagoonward than La Crosse. At low tide both craters are isolated and well defined as seen here. Photo courtesy Atomic Energy Commission.

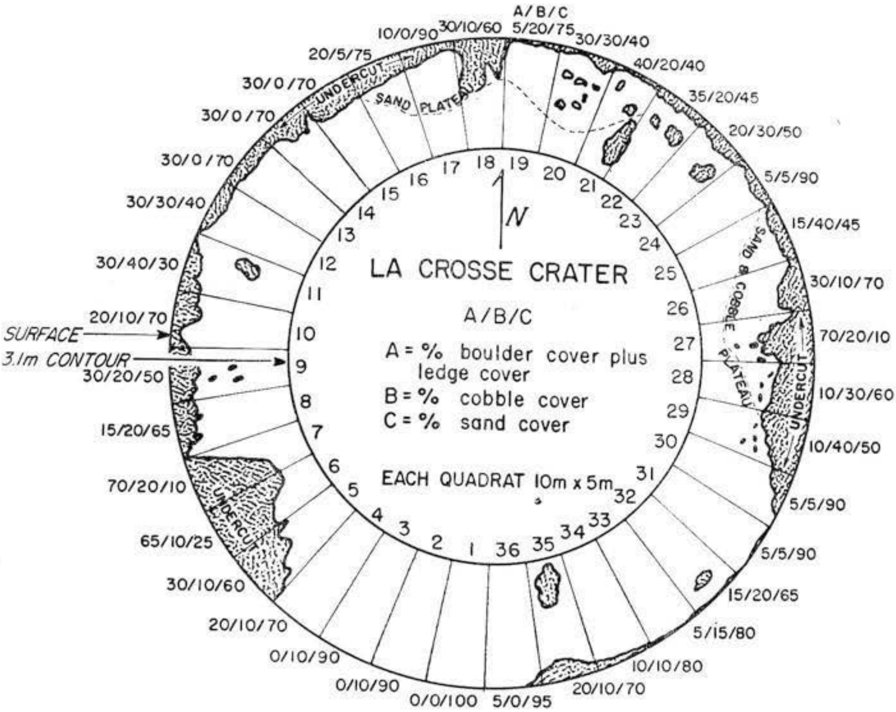

Fig. 2. Map of the peripherally located transect in Lacrosse Crater showing substrate types.

in April 1956. Both craters are circular in shape, roughly 118 m in diameter and 12 m in depth. The topography of the craters is depicted in Figs. 2 and 3. The bottom of both craters consists of a regular sand and limestone mud plain. Areas of hard substrate are restricted to the perimeter of the crater in water depths of less than 4 m. From these high relief regions, the crater floor drops rapidly to a level bottom.

During flood tides, water from the reef and from the lagoon enters the crater via channels in the surrounding reef flat (Fig. 1). At low tides, however, both craters become isolated with very little flow occurring at $-1.0'$ tides. On sunny days at low tide, surface water temperature in the craters increases 2–3°C over lagoon readings ($\bar{X}=27$°C). At these times a thermocline develops in the upper 1–1.5 m of the crater water column.

The areas of hard substrate mapped in Figs. 2 and 3 were the only regions inhabited by large or obvious fishes; however, the bottoms of both craters were heavily excavated by several species of gobies and burrowing shrimps. The calcareous alga, *Halimeda* sp., and a green siphonaceous alga, *Derbesia minima,* grew profusely on the sand and silt bottoms. These harbored many kinds of benthic gastropods, crustaceans and polychaetes. Very little living coral was present. Most of the hard substrates around the perimeter consisted of dead,

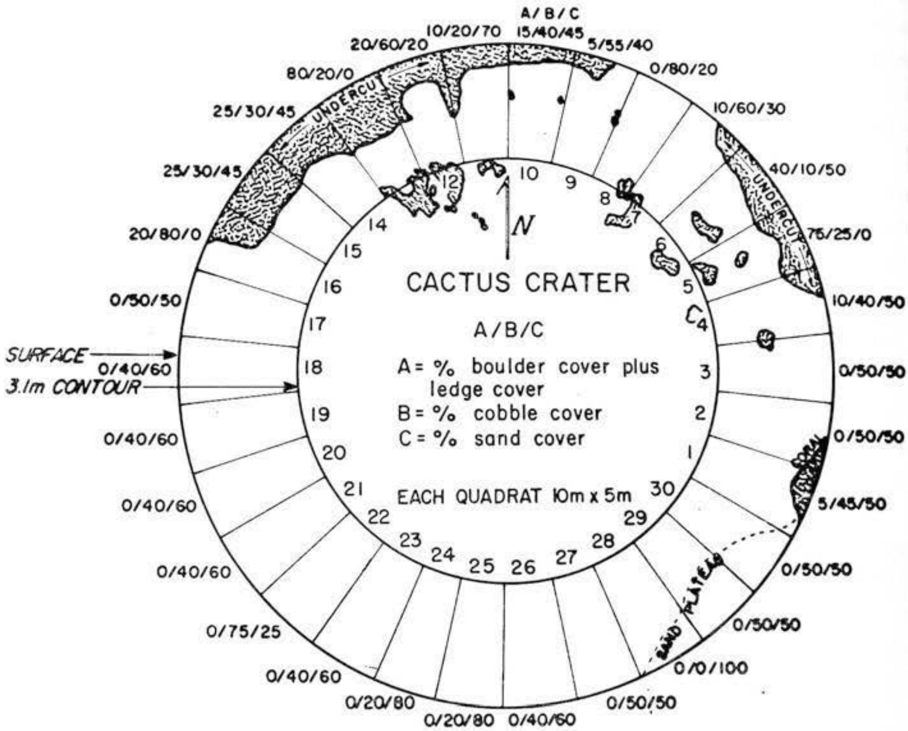

Fig. 3. Map of the peripherally located transect in Cactus Crater showing substrate types.

consolidated reef material which supported several species of filamentous green algae.

Molluscs, crustaceans, polychaetes, zooplankton, algae and phytoplankton found in the craters seemed typical of the fauna and flora occurring in the adjacent lagoon or upon the reef flat (T. Dana and A. Barnett, pers. comm.) and will not be reported here.

Our primary means of assessing fish populations was the visual technique described by Brock (1954). In each crater quadrats were delineated by underwater buoys placed around the perimeter at a depth of 3.1 m (10′ on a sensitive capillary depth gauge at a tide level of 1.0′) and with an inter-station distance of 10 m. This resulted in quadrats of approximately 5×10 m since the bottom dropped away rapidly at an average angle of 45°. Censuses were conducted during daylight hours at high and low tides within one hour of the tidal maximum or minimum. The standard procedure consisted of entering the crater with SCUBA starting at Station 1 and recording the number of individuals of thirteen selected species and estimating their total length, then proceeding on to the next station. Data were recorded on printed data sheets ("Underwater Ascot", Appleton Papers, Inc., Appleton, Wisconsin).

Some species monitored [*Lutjanus vaigiensis* (*fulvus*), *Acanthurus triostegus*, *Monotaxis grandoculis*] tended to either follow or move ahead of the diver. Population counts of these species were adjusted accordingly at subsequent stations. Schools of goatfish repeatedly circulated around the inside perimenter of the craters providing a convenient means of assessing their numbers. By remaining motionless, we could accurately count individuals as the school slowly filed by, and could further refine the counts upon later encounters with the school.

To determine the precision of the visual method, two divers simultaneously censused the fish populations in La Crosse. Replicate values taken from serial censuses for the goatfish, *Mulloidichthys vanicolensis* (Table 2), were 403 and 421 ($X^2=.770$, $p\leqq 0.1$), 1460 and 1512 ($X^2=1.788$, $p\leqq 0.1$), and 414 and 390 ($X^2=1.391$, $p\leqq 0.1$). Variability between replicate samples is low although there were considerable differences between serial censuses conducted at different tide levels on the same or on subsequent days. Similar results were obtained for the other species monitored. Preliminary observations of the crater fauna were made from 1 September to 10 September 1971. Visual censuses were performed from 19 January to 2 February 1972 and repeated on the 5th and 6th of December 1972.

The collection of specimens in the craters was limited to a few individuals speared or anesthetized with quinaldine. Most fish names are those from Schultz *et al.* (1953, 1960, 1966).

Fish tagging was done underwater with a Floy Tagging Gun and anchor tags (Floy Tag and Mfg., Inc.) on fish captured either at night with hand nets or during the day with a 50′ monofilament gill net. Inter-crater movements of diurnally active fishes were detectable by color coded tags for respective craters. Intra-crater movements of individuals between stations were noted only upon recapture.

Bardach (1958) and Randall (1961, 1963) utilized similar tagging methods to study movements in Atlantic reef fishes. We hoped to supplement our census data by tagging individuals and recording their presence or absence on subsequent censuses or by recapturing them at a later time. A species with a relatively constant population level and persistent presence of marked individuals was suspected of being a more permanent crater resident than one lacking such constancy. We have no means of assessing mortality due to capture, handling or tagging; therefore, measured residence times are necessarily minimums. The significance of the results is limited by the small numbers of animals tagged (141 individuals of 15 species) and short observation period (7 days). No tagged fish were observed when the craters were visited 11 months later.

Fish Species Composition at Day and Night

Eighty-four species of fishes were either collected or observed in Cactus or La Crosse Craters. The species list is notably incomplete for gobiids, trypterygiids, and blenniids due to our limited ichthyocide collecting. La Crosse had a higher diversity in terms of number of species (64) than Cactus (56).

Night dives in the craters showed a faunistic turnover similar to that described by Hobson (1968, 1972, 1974) in the Gulf of California and Kona Coast of Hawaii, although the nocturnal fauna of the craters was low in numbers of individuals and species when compared to that of the day. Species observed feeding at night include the goatfishes, *Mulloidichthys vanicolensis* and *M. flavolineatus*, and the snapper, *Lutjanus vaigiensis* (*fulvus*). These species school near shelter during the day and at night forage over sand substrates solitarily or in small groups. Surprisingly, the only holocentrid observed at night was *Adioryx spinifer*. Holocentrids normally constitute a large proportion of the nocturnal fauna in other tropical communities (Hobson, 1968, 1972, 1974) and in the lagoon of Enewetak (personal observations). No apogonids were seen at night, although *Paramia quinquelineata* and *Apogon novae-guineae* were observed during the day under ledges or in crevices between boulders. *Apogon novemfasciatus, A. compressus,* and *A. savayensis* were collected by releasing quinaldine in areas of shelter. At night the cardinalfishes may have been feeding in midwater and thus were not observed.

Many diurnally active species became quiescent at night and often wedged themselves into cracks or rested under ledges. The butterfly fishes, *Chaetodon lunula* and *C. auriga*, were easily captured at this time with hand nets and their tags examined. The puffers, *Arothron hispidus* and *A. alboreticulatus*, likewise were seen resting on the bottom, frequently in rubble areas or at the base of large boulders. *Fistularia petimba*, the cornet fish, was repeatedly observed at rest solitarily on sand substrates far from shelter. This species was rarely seen during daylight in the craters; however, at least one individual was seen on every night dive.

Effect of Tide Level Upon Abundance

Visual censuses of large or abundant species were performed at high and low tides in both craters. From Table 1 it is evident that population levels of most of the monitored species fluctuated with the tide. This was especially true in La Crosse which has a more open connection with the reef flat. No indications were seen that time of day (during daylight) influenced the presence of species or number of individuals.

Chaetodon lunula and *C. auriga* were among those species demonstrating significant population constancy between tidal changes. The mean number of *C. lunula* in La Crosse at high tide (19.4) was close to that at low tide (17.6); for Cactus the means were, respectively, 7.7 and 12.1 (Table 1). Nineteen *C. lunula* and 15 *C. auriga* were tagged. Recapture success was excellent in these species, with a mean recapture rate of 46% for *C. lunula* in both craters and 47% for *C. auriga*. Many tagged butterfly fishes were encountered throughout the seven-day observation period, although positive identification of individuals could be made only upon their recapture at night. We consider *C. lunula* and *C. auriga* to be permanent crater residents. A pair of *C. ephippium* (one of which was tagged) also appeared to be permanent residents.

Table 1. A comparison of mean number of individuals per census at high and low tides.

	La Crosse High (n=7)	La Crosse M-WT*	La Crosse Low (n=6)	Cactus High (n=7)	Cactus M-WT*	Cactus Low (n=6)
Chaetodon lunula	19.4	(−)	17.6	7.7	(−)	12.1
Chaetodon auriga	12.4	(−)	12.8	3.8	(−)	5.6
Mulloidichthys vanicolensis	566.4	(+)	240.1	34.4	(+)	82.3
Mulloidichthys flavolineatus	47.0	(+)	23.2	2.5	(−)	0.0
Crenimugil crenilabis	2.7	(+)	0.0	0.4	(−)	1.0
Monotaxis grandoculis	22.3	(+)	11.3	6.7	(+)	1.7
Abudefduf septemfasciatus	138.4	(+)	7.2	24.2	(+)	1.8
Acanthurus triostegus	275.4	(+)	16.8	60.0	(+)	1.7
Acanthurus guttatus	43.0	(+)	22.2	0.3	(−)	0.1
Scarus jonesi	50.1	(+)	3.3	1.5	(−)	0.6
Caranx melampygus	8.7	(+)	0.7	0.2	(−)	0.4
Kyphosus cinerascens	17.7	(+)	4.8	0.2	(−)	0.4
Lutjanus vaigiensis	30.9	(−)	30.1	28.2	(−)	17.0

n=number of censuses (all conducted during daylight)

* Mann-Whitney Test: (+) indicates that high and low tide censuses differed significantly at the 95% confidence level, (−) indicates no significant difference.

Table 2. Serial censuses of *M. vanicolensis* in La Crosse Crater.

Date	Time (hrs)	Tide	Number
24 Jan 72	1300	high	403 (421)*
25 Jan	1400	high	1512 (1460)*
26 Jan	0900	low	414 (390)*
26 Jan	1400	high	550
26 Jan	1735	low	0
28 Jan	1115	low	275
28 Jan	1530	high	250
30 Jan	1115	low	210
30 Jan	1800	high	300
4 Dec 72	1045	low	0
4 Dec	1430	high	240
6 Dec	1130	low	710
6 Dec	1545	high	709

* Replicate censuses performed simultaneously by two divers.

Mulloidichthys vanicolensis and *M. flavolineatus* frequently were observed in the craters, and underwent significant population changes with the tidal cycle (Table 1). These fluctuations are apparent when viewed in detail (Table 2). Noteworthy is the tripling in numbers between the 24th and 25th of January. There also was considerable variability between high and low tides occurring on the same day.

At night mullids foraged singly or in small groups over the crater bottom, reef flat, and sand areas in the lagoon. At the approach of daylight, they assembled in schools near small patch reefs in the lagoon; some may have retreated to deeper waters off the algal ridge, and others may have entered the craters by chance. During the day, schools of several hundred individuals circled inside the perimeter of La Crosse and persisted near regions of shelter (Stations 8–15). Dives made during rising tides found schools of goatfish and rudderfish (*Kyphosus cinerascens*) at the source of the incoming flow. As the tide broached the crater lip, fishes swam erratically at high speed parallel to the perimeter until sufficient flooding occurred to permit their escape to the reef flat. It is unclear why Cactus *M. vanicolensis* were more abundant at low rather than at high tide as the case in La Crosse. This might be due to fishes departing La Crosse on the flood tide and entering Cactus.

Tagging efforts indicate that goatfishes were probably temporary residents of the craters; however, one tagged *M. auriflamma* was noted during four consecutive tidal cycles in La Crosse. Randall (1961) attributed poor recoveries of *Mulloidichthys martinicus* in the Caribbean to tagging mortality. Our specimens were captured in a gill net and were restrained in the net for only a short time. These were observed throughout the tidal cycle following tagging and no immediate mortality occurred.

Schools of 20 to 50 mullet, *Crenimugil crenilabis*, were occasionally seen at La Crosse station 7; however, they seldom penetrated into the interior of the crater. *Crenimugil* was extremely wary of divers and possibly their contribution to the fish biomass was underestimated. Mullet were equally rare in Cactus at high and low tide.

The sparid, *Monotaxis grandoculis*, showed clear population fluctuations with the tide in both craters (Table 1). It usually was seen below the transect line at a depth of 4–5 m, and often in loose aggregations of 3–7 individuals, foraging over sand bottoms for crustaceans. At night, only solitary *Monotaxis* were observed foraging.

The damselfish, *Abudefduf septemfasciatus*, was commonly seen browsing on algae-covered rocks at high tide, although few individuals remained in the crater at low tide (Table 1). The greater amount of hard substrate with attached algae in La Crosse explains the larger populations observed there.

The surgeonfish, *Acanthurus triostegus*, was the most abundant species in Cactus at high tide; being rare at low tide (Table 2). Similarly, it was much more abundant in La Crosse at high rather than at low tides. The extreme population fluctuations of *A. triostegus* and *A. guttatus* indicate that these species are transient components of the crater fauna. Large schools of *A. triostegus, A. guttatus*, and *Abudefduf septemfasciatus* were observed browsing on the reef flat at high tide, often in very shallow water. It is interesting that the single *A. triostegus* tagged in Cactus was sighted in La Crosse seven days later. This seemingly roving herbivore may actually be localized in its activities. However, no recoveries or sightings were made of 41 *A. guttatus* tagged in La Crosse.

The jack, *Caranx melampygus*, infrequently entered the craters; however, a school of 20 individuals was recorded on a census in La Crosse. This species was commonly seen on the reef flat at high tide and may have taken refuge in the craters as the tide receded.

Although *Scarus jonesi* was the only species of parrotfish censused, several others entered La Crosse at high tide. Groups of 10–20 individuals of mixed parrotfish species congregated near the *Labroides dimidiatus* cleaning stations (9 and 20) in La Crosse. On nearly every census, some *S. jonesi* were observed posturing or being cleaned by *Labroides*.

Kyphosus cinerascens browsed extensively on benthic algae along the crater perimeter. It was moderately abundant in La Crosse at high tide ($\bar{X}=17.7$; Table 1), but was seldom seen in Cactus. Schools of up to 20 individuals entered La Crosse at Stations 25–29 at high and flooding tides.

The snapper, *Lutjanus vaigiensis* (*fulvus*), maintained a constant population regardless of tidal level in La Crosse, but did fluctuate somewhat in Cactus (Table 1). This species schooled near shelter during daylight and foraged solitarily over sand substrates at night.

The grouper, *Epinephelus merra*, and the squirrelfish, *Adioryx spinifer*, were not censused due to their reclusive habits; however, both species were common in the craters. Nearly every large boulder harbored a resident grouper and most caverns an *Adioryx*. We subjectively feel that both species should be considered permanent crater residents.

Distribution of Fishes in the Craters

Cursory observations in the craters made it clear that most fishes were concentrated at the rim of the crater near shelter. However, there were many species of gobiids, synodontids and callionymids living on sand bottoms distant from hard substrates. Occasionally, blacktip and grey reef sharks (*Carcharhinus melanopterus* and *C. menisorrah*) cruised the crater depths; and on one instance, an eagle ray, *Aetobatus narinari*, was observed resting on the sand bottom of La Crosse.

The restriction of many species of reef fishes to regions of shelter is obvious to the most casual underwater observer. Risk (1972) was able to show a significant correlation between diversity of territorial species and substrate topography on Virgin Island reefs. Cactus fishes were generally limited to stations 4–15 where the major concentrations of shelter occurred. In La Crosse, shelter is more evenly distributed around the perimeter and this is paralleled by a more uniform distribution of fishes. Quadrats in La Crosse that lacked boulder substrates also had fewer species and individuals than shelter rich areas. Boulder areas were inhabited both by species utilizing the high relief substrate for cover and by species browsing on attached algae. The role of shelter as a factor limiting to coral reef fishes is discussed elsewhere (Nolan, 1975).

Table 3. Mean biomass of crater fishes averaged over the transect and expressed in grams per square meter and (total kilograms) wet weight and length-weight conversion factors for censused fishes (values are based on a sample of ten representative individuals from the lagoon judged to be similar in size to those observed in the craters).

	La Crosse		Cactus		Conversion Factors	
	High (n=7)	Low (n=6)	High (n=7)	Low (n=6)	Mass (in grams)	Standard Length Range (in mm)
Herbivores						
C. crenilabis	1.1 (0.6)	0.0 (0.0)	0.1 (0.2)	0.3 (0.4)	394.3	194–301
A. triostegus	26.0 (4.7)	1.6 (0.3)	6.8 (1.0)	0.2 (0.0)	17.0	110–121
A. guttatus	5.8 (1.0)	3.6 (0.5)	0.1 (0.0)	0.0 (0.0)	24.2	145–156
A. septemfasciatus	14.5 (2.6)	0.8 (0.1)	3.0 (0.5)	0.2 (0.0)	18.8	135–149
K. cinerascens	4.0 (7.1)	1.1 (1.9)	0.1 (0.1)	0.1 (0.2)	401.2	257–263
S. jonesi	12.0 (21.6)	0.8 (1.4)	0.4 (0.6)	0.0 (0.3)	403.2	156–275
Total Herbivores	63.4 (38.1)	7.9 (4.2)	10.5 (2.4)	0.8 (0.9)		
Carnivores						
C. auriga	1.2 (0.2)	1.3 (0.2)	0.5 (0.1)	0.7 (0.1)	18.0	137–149
C. lunula	1.7 (0.3)	1.6 (0.3)	0.8 (0.1)	1.3 (0.2)	16.2	110–135
M. vanicolensis	60.0 (130.2)	30.7 (55.2)	5.3 (7.9)	12.6 (1.9)	229.8	211–250
M. flavolineatus	5.7 (10.2)	2.8 (5.1)	0.4 (0.5)	0.0 (0.0)	217.5	207–234
M. grandoculis	3.6 (6.6)	1.8 (3.3)	1.3 (2.0)	0.3 (0.6)	294.0	194–263
L. vaigiensis	5.7 (10.2)	5.6 (9.9)	6.2 (9.3)	3.8 (5.6)	330.0	225–255
C. melampygus	0.5 (0.5)	0.4 (0.4)	0.1 (0.1)	0.2 (0.2)	603.6	362–535
Total Carnivores	78.4 (158.2)	44.2 (74.4)	14.6 (20.0)	18.9 (8.6)		
Total Fish Biomass	141.8 (196.3)	(78.6)	25.1 (22.4)	19.7 (9.5)		

Crater Fish Biomass

We determined standing crops of our censused species by multiplying the mean population estimates of Table 1 by the conversion factors in Table 3. These factors represent the mean wet weight of ten specimens of a size similar to those observed in the craters; they were captured in the lagoon by spear or gill net. Similar methods of biomass estimation were used by Brock (1954), Odum and Odum (1955) and Talbot (1965).

Transect standing crops in g/m^2 and total kg/crater transect are also presented in Table 3. These values are high compared to those of Odum and Odum (1955) for an inter-island reef at Enewetak. They reported 10.3 g/m^2 of fish herbivores and 4.6 g/m^2 of fish carnivores in their zone of "large coral heads", which seems to us most like the habitat of the craters. We found standing crop values of La Crosse herbivores and carnivores (mean of high and low tides values to be 35.7 and 61.3 g/m^2 respectively (Table 3). In Cactus the values were closer to the Odums'; 5.7 g/m^2 for herbivores and 16.8 g/m^2 for carnivores. The very high standing crop of the craters must be a function of the energetic openness of the system.

Likewise, the proportions of herbivores and carnivores in the craters differed greatly from those of the inter-island reef. In Cactus and La Crosse, the mean proportion of carnivorous fishes (high and low tides combined) were 74.7% and 63.2%. Odum and Odum, however, reported that the biomass of their fish herbivores was four to five times greater than that of fish carnivores. Our values agree more closely with those of Talbot (1965). In assessing the fish populations of Tutia Reef, Tanganyika, he estimated that herbivorous fishes comprise only 39% of the biomass with carnivores composing the remainder. He suggested that the discrepancy might be related to the amount of algal production in the respective habitats. Up to 100% of the Tutia Reef cover was living coral, as opposed to the Enewetak inter-island reef where coral rubble and dead corals offered attachment sites for algae. Although we found the craters rich in benthic algae, the herbivore biomass contribution may have been masked by the large numbers of transient carnivores.

Crater Fishery Potential

The craters may offer a unique opportunity to harvest palatable species with a minimum of effort. Several factors indicate that species of fishery interest (especially goatfishes) are transients, obtaining most of their energy from the adjacent lagoon, reef flat, or outer reef. The absence of obstructions on the smooth crater bottom makes them well suited for a gill net fishery, or a simple weir could be erected to funnel circling goatfishes into a removable cod end.

Based on the biomass estimates of Table 2, we hypothesize that initially about 100 kg of goatfish might be harvested daily or every two days. This assumes that these fishes are transients and belong to much larger populations in the lagoon or outer reef. Observations at small study patch reefs and experimental artificial reefs in the lagoon have provided mixed evidence regarding short- and long-term movements in *M. vanicolensis* and *M. flavolineatus*. Schools of adults and solitary individuals may be present at a particular reef one day and absent the next. However, a small ($3 \times 3 \times 3$ m), caged (metal frame covered by 1–1 1/4″ stretched mesh nylon netting) study reef has sheltered a school of about 300 *M. vanicolensis* and *M. flavolineatus* for at least 150 days. All of the individuals pass easily through the cage; however, the largest (20 cm total length) may soon find it difficult to swim through the mesh. The persistence of this school of mullids might be due to the excellent protection from predators that the cage provides in a region of presumably adequate food resources (the reef is isolated by sand bottom for 20–30 m in every direction). Hobson (pers. comm.) observed schools of *M. vanicolensis* in the same location upon repeated visits to a site on the Kona Coast of Hawaii.

In December, 1972, a 50′ monofilament gill net was placed at a right angle to the crater rim of Cactus at Station 30 during low tide and fished for one hour. The catch consisted of 29 *M. vanicolensis*, 4 *M. flavolineatus*, and 18 small *Carcharhinus melanopterus*. Although we consider this experiment a poor indicator of crater fishery potential, we captured a significant percentage (72%) of the goatfish counted during an immediately preceding census.

The sustained yield potential of the craters should be examined by measuring catch per unit effort during repetitive gill nettings. If a significant, consistent yield is obtained, this fishery might contribute to the food resources of returning Enewetakese. Goatfishes are highly rated by Enewetakese currently residing on Ugelang Atoll (Ken Marsh, of Lawrence Livermore Lab, Pers. comm.).

Dr. Philip Helfrich, Director of the Enewetak Marine Biological Laboratory, has suggested that the efficiency of such a fishery might be enhanced by the installation of net doors around the perimeter of La Crosse. These would remain depressed during rising and high tides, permitting access to schooling fishes; at high tide prior to ebbing, the doors would be erected, thus trapping the fishes.

The craters offer a unique environment for research into a marine tropical ecosystem. They are small and easily manipulated, yet have large fish populations. Their shallow depth and uniform bottom makes them well suited for fishery or mariculture experiments.

References Cited

Bardach, J. E. 1958. On the movements of certain Bermuda reef fishes. Ecology 39(3):136–146.

———. 1959. The summer standing crop of fish on a shallow Bermuda reef. Limnol. Oceanogr. 4(1):77–85.

Brock, V. E. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildl. Mgmt. 18:297–308.

Brock, V. E., R. S. Jones, and P. Helfrich. 1965. An ecological reconnaissance of Johnston Island and the effects of dredging. U. Hawaii, Hawaii Mar. Lab. Tech. Rept. No. 5. 90 p.

Brock, V. E., W. Van Heukelem, and P. Helfrich. 1966. An ecological reconnaissance of Johnston Island and the effects of dredging. U. Hawaii, Hawaii Mar. Lab. Tech. Rept. No. 11. 56 p.

Collette, B., and F. Talbot. 1972. Activity patterns of coral reef fishes with emphasis on nocturnal-diurnal changeover. *In* Results of the Tektite Program: Ecology of Coral Reef Fishes. Los Angeles Co. Mus. Nat. Hist. Sci. Bull. 14:98–124.

Hiatt, R. W., and D. W. Strasburg. 1960. Ecological relationships of the fish fauna on coral reefs of the Marshall Islands. Ecol. Monogr. 30:65–127.

Hobson, E. S. 1968. Predatory behavior of some shore fishes in the Gulf of California. U. S. Fish Wildl. Serv. Res. Rept. 73. 92 p.

———. 1972. Activity of Hawaiian reef fishes during the evening and morning transitions between daylight and darkness. Fish. Bull. 70:715–740.

———. 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull. 72:915–1030.

Nolan, R. S. 1975. The ecology of patch reef fishes. Ph.D. Dissertation. Scripps Inst. Oceanog., Univ. Calif., San Diego.

Odum, H. T., and E. P. Odum. 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. Ecol. Monogr. 25(3): 291–320.

Randall, J. E. 1955. Fishes of the Gilbert Islands. Atoll Res. Bull. (47):1–243.

———. 1961. Tagging reef fishes in the Virgin Islands. Proc. Carib. Fish. Inst., 14th Annual Session. 201–241.

———. 1963. An analysis of the fish populations of artificial and natural reefs in the Virgin Islands. Caribbean J. Sci. 3(1):31–47.

———. 1967. Food habits of reef fishes of the West Indies. Studies in Tropical Ecology, No. 5, 665–847.

Risk, M. J. 1972. Fish diversity on a coral reef in the Vigin Islands. Atoll Res. Bull. (153): 1–6.

Smith, C. L., and J. C. Tyler. 1972. Space resource sharing in a coral reef fish community. *In* Results of the Tektite Program: Ecology of Coral Reef Fishes. Los Angeles Co. Mus. Nat. Hist. Sci. Bull. 14:125–170.

Talbot, F. 1965. A description of the coral structure of Tutia Reef (Tanganyika Territory, East Africa) and its fish fauna. Proc. Zool. Soc. Lond. 145(4):431–470.

Talbot, F., and B. Goldman. 1972. A preliminary report on the diversity and feeding relationships of the reef fishes of One Tree Island, Great Barrier Reef System. Proc. Symp. Corals and Coral Reefs, Mar. Biol. Assoc., India. 425–444.

Wass, R. 1967. Removal and repopulation of the fishes on an isolated patch coral reef in Kaneohe Bay, Oahu, Hawaii. U. Hawaii, MS Thesis, June 1967.