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Editorial Note

The present issue of the **Silliman Journal** could very well be one of the most valuable issues ever to come out in a long time, consisting as it does of seventeen well-presented articles backed by competently accomplished research and investigation by their respective authors. No less than eight important and significant areas in biology are covered from mature and technical points of view, ranging, one might say, from the sea, to the land and the air, considering that there are discussions here on marine plants, clams, crabs, fishes, and coral reefs, as well as on frogs, snakes and bats. The extensive discussions on clams—five articles, the most number in this issue, are in fact devoted to the subject—are especially significant in view of recent indications that giant clams are well on the way to extinction.

This special issue of the **SJ** is made even more special by the involvement of two very noteworthy names in biology in the Philippine scene, namely, Angel C. Alcala and Walter C. Brown.

E. P. B.

Notice to Authors

The **Silliman Journal** welcomes contributions in all fields from both Philippine and foreign scholars, but papers should normally have some relevance to the Philippines, Asia, or the Pacific. All submissions are refereed.

Articles should be products of research, taken in its broadest sense; a scientific paper should make an original contribution to its field. Authors are advised to keep in mind that **SJ** aims at a general international audience, and to structure their papers accordingly.

SJ also welcomes submissions, such as "Notes," which generally are briefer and more tentative than full-length articles. Reports on work in progress, queries, updates, reports of impressions rather than of research, responses to the work of others, even reminiscences are appropriate here. Book reviews and review articles will also be considered for publication.

Manuscripts should conform to the conventions of format and style exemplified in this and other issues of SJ. Whenever possible, citations should appear in the body of the paper, holding footnotes to a minimum. Pictures will be accepted only when absolutely necessary. If possible, scientific papers should be accompanied by an abstract. All authors must submit their manuscripts in duplicate, typewritten double-spaced on good quality bond paper.

The Editorial Board will endeavor to acknowledge all submissions, consider them promptly, and notify authors of its decision as soon as possible. Each author of an article is entitled to twenty-five free offprints. More may be had by arrangement with the Editor before the issue goes to press.

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DISTRIBUTION AND ABUNDANCE OF GIANT CLAMS (FAMILY TRIDACNIDAE) IN THE SOUTH-CENTRAL PHILIPPINES

Angel C. Alcala

A population survey of giant clams (Family Tridacnidae) was conducted in certain coral reef areas of the Central Visayas, Western Visayas, Cagayan Islands and Palawan from February 1984 to October 1985. The largest species of Tridacna (T. gigas and T. derasa) were found to be either extinct or greatly reduced in numbers probably because of overcollection. The smaller species of Tridacna, although of variable densities, appear to be holding their own in general. Hippopus porcellanus may also be endangered. The status of H. hippopus is uncertain, but it occurred at some reefs in the Central Visayas, Cagayan and Palawan regions.

Giant clams are the largest bivalves in the world, the largest individuals of Tridacna gigas (Linn.) attaining a length of 137 cm and a weight of over 200 kg (Rosewater, 1965). These clams are obligatory inhabitants of shallow marine waters and are restricted to certain areas in the tropical Indo-Pacific region. All seven living species of the family Tridacnidae have been reported from the Philippines (Rosewater, 1965, 1982).

In the Philippines and elsewhere giant clams have formed part of the diets of coastal peoples. They have also been harvested commercially for their adductor muscles, considered a delicacy in some Asian countries, and for their shells. Dried adductor muscles are reported to fetch as much as US $82-143/kg in urban areas such as Hongkong (Munro and Gwyther, 1981). Giant clam shells have such uses in homes, restaurants and hotels as animal feeding troughs, ashtrays, washbasins and decoration (Wells, 1981). Because of the uncontrolled exploitation, the two largest species, T. gigas and T. derasa (Röding), are probably already extinct in certain parts of their range, such as western Indonesia (Salm, 1981). T. gigas has recently suffered extinction at four islands in Micronesia according to Heslinga et al. (1984). Both species are considered vulnerable by IUCN (1983). Hippopus porcellanus Rosewater, a Philippine endemic, is almost exclusively found in the Sulu Sea (Rosewater, 1982), where it is now apparently rare.

Widespread concern that some species of giant clams are threatened with extinction has resulted in noteworthy efforts to protect existing stocks in coral reef reserves (International

Union for the Conservation of Nature, 1983). In addition to protection, it is believed that restocking of coral reefs with animals spawned and reared initially in hatcheries can help prevent the extinction of these species. Captive breeding is now going on at a number of laboratories. A clam hatchery at the Micronesian Mariculture Demonstration Center at Koror, Palau has been successfully breeding T. derasa (Heslinga et al., 1984). The Orpheus Island field station of James Cook University, the University of Papua New Guinea, the Fisheries Division, Ministry of Primary Industries, Fiji, the University of the Philippines Marine Science Institute and the Silliman University Marine Laboratory have been conducting cooperative mariculture studies on giant clams since 1984 with financial support from the Australian Center for International Agricultural Research (ACIAR).

This paper on the distribution and abundance of giant clams in the south-central Philippines is part of the ACIAR-supported mariculture program. Earlier studies on giant clam abundance include those of Hardy and Hardy (1969), Hester and Jones (1974), Bryan and McConnell (1976), Hirschberger (1980) and Brown and Muskanofola (1985).

MATERIALS AND METHODS

The population survey was conducted from February 1984 to October 1985 in four regions: the Central Visayas, Western Visayas, Cagayan Islands and Palawan (Fig. 1). Twenty-five coral reef sites were surveyed in the Central Visayas, eight in the Western Visayas, ten in the Cagayan Islands, Sulu Sea, and 21 at Palawan. The sites in each region were at least 500 m apart. They were in shallow water, the average depth varying from 0.5 m to 5 m (average depth taken as the mean of maximum and minimum depths).

For most sampling sites a single observer using mask and snorkel or SCUBA was employed; two observers were used only in the few sites in the Central Visayas surveyed with the quadrat method. Sampling in shallow water (less than 2 m deep) usually required only the use of mask and snorkel. The observer swam in a straight line about one meter from the bottom. A calibrated flowmeter was used to determine the area of a sampling site. Clam species observed and individual lengths, water depth, temperature and percent live coral cover were recorded on a slateboard.

The sampling sites varied in area from 300 to 7,000 sq m, with the mode at 500 to 1,000 sq m, except for two sites in the Central Visayas of 100 sq m, which were surveyed by the quadrat method. The flowmeter method, which requires only one person, has been shown to yield comparable survey results to the widely accepted belt transect method (unpubl. data). It was assumed that the effective width of the observer's vision was about one meter, making the distance travelled equal to the area surveyed.

Because sampling sites varied in area, clam density is expressed in number per hectare for direct comparison of survey results. The formula for determining relative species density (RD) was that of Brower and Zar (1977: 65):

$$RD = \frac{\text{total number of individuals of a species}}{\text{total number of individuals of all species}} \times 100$$

RESULTS AND DISCUSSION

Species Observed.

In and outside of the sampling sites, four species [T. crocea (Lamarck), T. maxima (Röding), T. squamosa Lamarck and Hippopus hippopus (Linn.)] were observed in the Central Visayas; three species (T. crocea, T. maxima and T. squamosa) in the Western Visayas; five species (all four Tridacna species and H. hippopus) at Palawan; and seven species (all species mentioned above plus T. gigas and H. porcellanus) at Cagayan. However, only five of the seven species were observed in the sampling sites (Table 1). T. gigas and H. porcellanus were absent in the sampling sites in all regions, while T. derasa and H. hippopus were absent in the sampling sites in all regions except Palawan. Only one individual (an adult) of H. porcellanus, three individuals (all juveniles) of T. gigas and ten individuals (all juveniles except one) of T. derasa were seen outside of the sampling sites at Cagayan. Empty shells of all species, except H. porcellanus, were also observed in all regions surveyed.

It is almost certain that, although T. gigas and T. derasa still exist at Cagayan and Palawan, they are now extinct in the Central and Western Visayas. Their occurrence in areas in these two regions not covered by the present survey is very unlikely, as none were seen in an earlier intensive survey of coral reef resources (see UP Marine Science Center, 1979).

Earlier authors (e.g. Hester and Jones, 1974; Hirschberger, 1980; Brown and Muskanofola, 1983) have described the association of tridacnid species with various habitats on reefs: T. crocea, embedded in massive corals; T. maxima, firmly anchored to coral heads; T. squamosa, attached by weak byssus to living coral or coral rubble; T. derasa and T. gigas, on sand flats and coral heads in lagoons, often associated with Acropora rubble; and H. hippopus, in shallow sandy areas and reef flats. Our own observations essentially confirm most of these observations. T. squamosa, T. derasa and T. gigas were found on reefs dominated by Acropora. T. squamosa was also found on reefs with high species richness, sometimes in coral rubble. H. hippopus and H.

porcellanus occurred on sandy portions of reefs.

Most of the clams observed were at 0-3 m depth; only a few were observed at depths greater than 5 m. In isolated observations before the present survey, we recorded live individuals of *T. squamosa* (in excess of 20 cm long) and two live *T. gigas* (1+ m in length) at a depth of 18 m. These two species may occur occasionally in deeper water. Brown and Muskanofola (1985) reported 15.5 m as the maximum depth of *T. squamosa* and 13.5 m for *T. maxima* at Karimum Jawa.

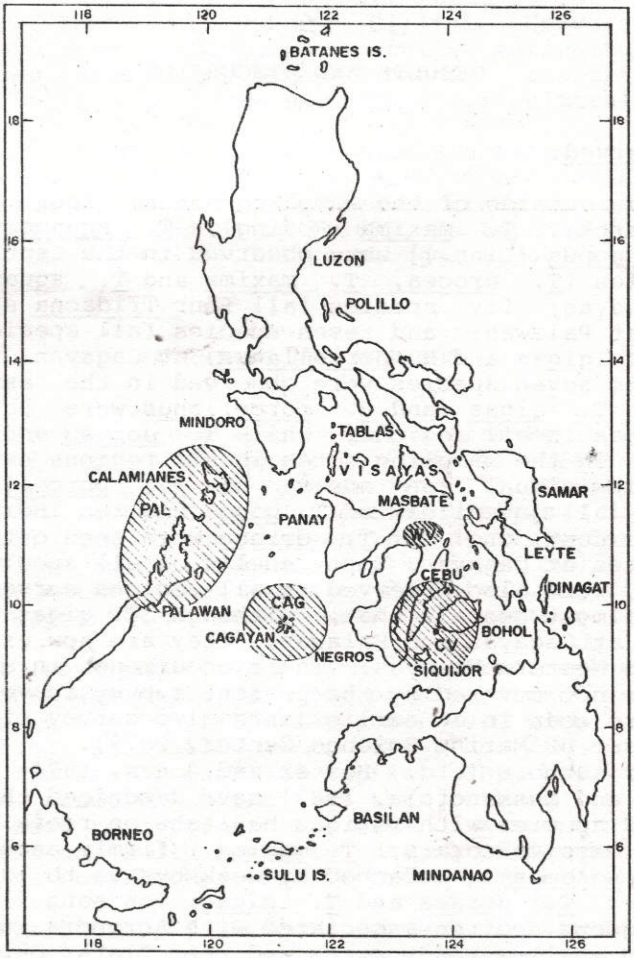

Figure 1. Areas surveyed for giant clams. Central Visayas (CV), Western Visayas (WV), Cagayan Islands (CAG), Palawan (PAL).

Length-Frequency Distribution.

Of the three species (*T. crocea*, *T. maxima* , *T. squamosa*) common to the four regions, only *T. squamosa* showed regional differences in size, the population in the Western Visayas being composed mostly of large individuals. One-way ANOVA using ten randomly picked individuals for each of the three species from each region showed statistical significance at the 5% level only for *T. squamosa* ($P<0.05$, $F=4.7133$, df=3.36).

The larger size of *T. squamosa* in the Western Visayas is probably the combined result of lower exploitation pressure on, and protection of, the stocks. The reefs explored are situated in the Visayan Sea, a prime fishing area, where people prefer fish to clams for food. Also, since 1982, one of the reefs surveyed has been closed to fishing, having been declared a marine park.

Abundance.

Abundance can be assessed in two ways: either (a) by the relative species density (RD), or (b) by the population density, here expressed as the number of clams per hectare. The RD is useful, as it indicates the predominance of a species in any one region but not in relation to all four regions, as the level of survey effort for the regions was not uniform. Population density, however, allows a comparison of the relative importance of the species common to all regions.

The RD´s of five species are summarized in Table 1. In the Central Visayas, *T. crocea* make up more than 50% of all clams seen, with *T. maxima* and *T. squamosa* equally sharing the balance. In the Western Visayas, *T. squamosa* is the most dominant species, making up about 71% of all the clams observed. At Palawan,

Table 1. Relative species density (RD) for giant clams surveyed from June 1984 to October 1985. CV, Central Visayas; WV, Western Visayas; PAL, Palawan; CAG, Cagayan Islands.

REGION	*T. crocea*	*T. maxima*	*T. squamosa*	*T. derasa*	*H. hippopus*	TOTAL
CV	52.68	25.81	21.51	0.00	0.00	100
WV	12.41	16.28	71.32	0.00	0.00	100
PAL	97.88	0.79	0.81	0.11	0.41	100
CAG	40.31	56.92	2.77	0.00	0.00	100

T. crocea make up about 98% of all individuals observed, the remaining 2% consisting of individuals of the other four species, all of which can be considered uncommon in the region. At Cagayan, *T. crocea* and *T. maxima* make up 97% of all clams observed, *T. squamosa* about 3%.

The population densities (clams per hectare) for five of the seven species in the four study regions are shown in Table 2. Not included in this table are the densities of *T. gigas* and *H. porcellanus*, both of which must be considered rare. That *T. gigas* was common at Cagayan in the past is indicated by the presence of empty shells on the sea bottom and on the walls of the Roman Catholic Church building.

Table 2. Summary of data on distribution and population density of giant clams in the Central Visayas (CV), Wes Visayas (WV), Cagayan, Sulu Sea (CAG) and Palawan (PAL) regions, Philippines. Tc, *Tridacna crocea*; *Tridacna derasa*; Tm, *Tridacna maxima*; Ts, *Tridacna squamosa*; Hh, *Hippopus hippopus*.

Region	Number of Sampling Sites	Area Explored (ha)	Total Number of Clams Observed	Number of Clams per Hectare					
				Tc	Td	Tm	Ts	Hh	All species
CV	25	3.0	93	16.33	-	8.00	6.67	-	31.00
WV	8	0.7	129	22.86	-	30.00	131.43	-	184.29
CAG	10	0.5645	253	180.69	-	255.09	12.40	-	448.18
PAL	21	2.1	7051	3286.19	3.81	26.67	27.14	13.81	3357.62

T. derasa is represented by a very low population density at Palawan of about four individuals per ha. It was so rare at Cagayan that it was not seen in any of the sampling sites there. *T. crocea*, *T. maxima* and *T. squamosa* had variable population densities in the four regions. *H. hippopus* had a low density (about 14 clams per ha) at Palawan, the only region where it was observed in the sampling sites. The Central Visayas has the lowest density among the four regions for all species combined.

The low population density of *T. derasa* at Palawan and Cagayan and of *T. gigas* at Cagayan is probably due to overcollection. The low density of 7-8 clams per ha. for *T. maxima* and *T. squamosa* in the Central Visayas can also be attributed to intense exploitation and possibly to reef destruction. The fairly high density of *T. squamosa* in the Western Visayas is mainly due to protection. However, the reasons for the extremely high population density of *T. crocea* at Palawan

Table 3. A comparison of tridacnid clam population densities (clams per hectare).

Region		Philippines [this study]	Karimum Java, Indonesia*	Helen Reef, Palau, Western Caroline Islands		
				a	b	c
No. of transects or sampling sites		8 - 25	15	12	17	8
Total area surveyed (ha)		0.56 - 3.0	1.35	4.38	2.48	1.547
Density	I. crocea	16.33 - 3,286.19	85.93	not counted; ubiquitous	not counted; ubiquitous	not counted, presence noted; density considered constant
	I. derasa	3.81	-	23.06	2.02	4.52
	I. gigas	-	-	18.72	1.61	2.59
	I. maxima	8.00 - 255.09	200.00	# 135.84	253.63	201.68
	I. squamosa	6.67 - 131.43	45.93	-	0.81	1.94
	Hippopus hippopus	13.81	-	13.24	8.87	40.72

* Brown and Muskanofola, 1985
a Hester and Jones, 1974
b Bryan and McConnell, 1976
c Hirschberger, 1980
\# Counted in 4 stations with area of 0.92 ha.

are unknown, since this species is little exploited, if at all. One environmental factor favoring a high population density may be the availability of coral heads, into which this species burrows.

The Central Visayas, where giant clams are heavily exploited for food, has the lowest population density for all species combined among the four regions. The high density figure for the Western Visayas is not representative for the whole region, as the sampling sites were situated mostly on a protected reef. The higher density estimates for species other than T. gigas for Cagayan and Palawan probably reflect the reduced collecting of these species in these regions.

The population densities of tridacnids in the Philippines may be compared with those at Karimum Jawa, Indonesia (Brown and Muskanofola, 1985) and at Helen Reef, an atoll in the South Palau District, Western Caroline Islands (Hester and Jones, 1974; Brian and McConnell, 1976; Hirschberger, 1980). For direct comparison, their densities (clams per 100 sq m) were recalculated (Table 3). *T. derasa* and *T. gigas* were not present at Karimum Jawa, and were the most uncommon species in the Philippines and on Helen Reef (Table 3). Their reduced densities on Helen Reef are due to uncontrolled exploitation (Hirschberger, 1980). This may also be the case in the Philippines. Both species should therefore now be listed in Appendix II of the Convention for International Trade in Endangered Species (CITES), as proposed by Wells (1981).

T. crocea and *T. maxima* seem to be maintaining their populations in the three Indo-Pacific areas studied. Likewise, the population of *H. hippopus* has remained stable on Helen Reef. However, this species is apparently absent at Karimum Jawa and patchy in distribution in the Philippines. *T. squamosa* is represented by fair numbers at Karimum Jawa and in the Western Visayas, Philippines, but has low densities in other Philippine regions studied and at Helen Reef.

CONCLUSION

T. gigas and *T. derasa* are either extinct or threatened with extinction in the four Philippine regions surveyed. The reason for their local extinction or threatened status is probably uncontrolled exploitation. *T. squamosa* and *T. maxima*, although variable in densities in the four Philippine regions, are generally stable. *T. crocea*, which had relatively high densities in two of the four regions, is definitely not endangered. *H. porcellanus* is very rare and may be endangered. The status of *H. hippopus* is uncertain, as its distribution is extremely variable.

ACKNOWLEDGEMENTS

The financial support of ACIAR for the survey is gratefully appreciated. We are also indebted to several staff members and colleagues at the Silliman Marine Laboratory, who assisted in the field work, analysis of the data and preparation of the illustration. They are Sally Alcazar, Daniel Catada Jr., Lawton Alcala Janet Estacion, Roberto J. Raymundo, Jojo Legaspi, Danilo Catan and Araceli Menez.

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FRY AND LARVAE OF FISHES AND CRUSTACEANS IN COASTAL MARINE WATERS OF NEGROS ORIENTAL, NEGROS ISLAND, PHILIPPINES

A. C. Alcala and A. S. Cabanban

One hundred and thirty-two species of fish belonging to 55 families and one order and ten species of crustaceans belonging to five families and three orders were found associated with Chanos chanos fry from seven sampling stations on the coast of Negros Oriental province, Negros Island, Philippines during a 12-month period from December 1984 through November 1985. About two-thirds of these species are used for food.

The fry and larvae of fishes and crustaceans collected together with those of Chanos chanos (bangus) have, in the past, been considered useless by fishermen, and are therefore discarded, often thrown on the ground to die at collection time (pers. obs.). Only in recent years have penaeid crustacean larvae been collected for culture in brackish water ponds (pers. obs.). However, the fry and larvae of fishes have remained unused.

In 1984 a research project to determine the culture potential of these fry and larvae was started jointly by a research unit of the Bureau of Fisheries and Aquatic Resources (BFAR) and the Silliman University Marine Laboratory. This paper, which is part of that project, reports on the fish and crustacean species caught from December 1984 through November 1985. Bañada (1983) gave a comparable listing of fish fry and larvae associated with Chanos chanos fry from Hamtik, Antique. Bagarinao and Taki (in press) studied the larval and juvenile fishes in Pandan Bay, Pandan Island for a different reason.

MATERIALS AND METHODS

Seven sampling stations, separated by distances ranging from 20 to 40 km, were established along the coast of Negros Oriental province (Fig. 1). The three stations at La Libertad, Manjuyod and Tanjay face the Tañon Strait, the three at Dumaguete, Zamboaguita and Siaton, the Mindanao Sea, and the station at Bayawan, the Sulu Sea. The seven stations were selected to encompass a wide range of coastal habitat types.

A sampling station measures 1,000 m parallel to the shoreline and is divided into 20 substations, each 50 m long. Twelve of these substations picked randomly at the start of the project

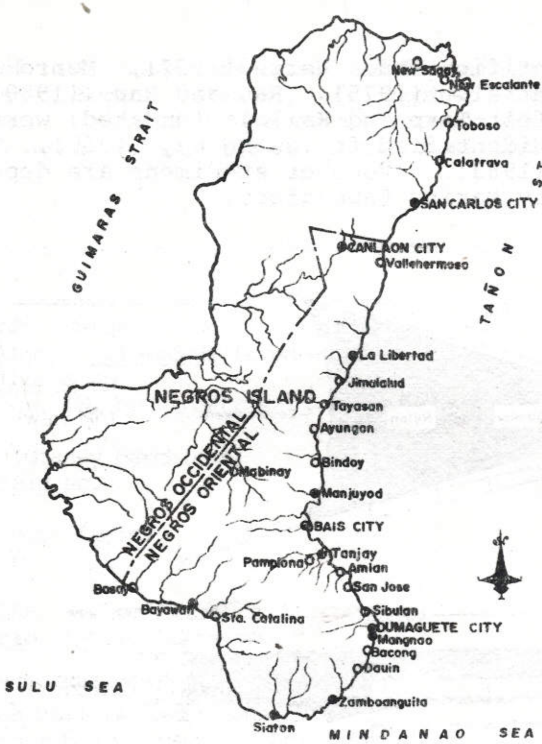

Fig. 1. Fry and larval collecting stations (●) on the coast of Negros Oriental, Philippines.

were regularly sampled by Chanos chanos fry collectors under the supervision of the BFAR group every five days (except during storms), using a quadrangular tow net similar in construction to that designed for collecting Chanos chanos fry (Fig. 2). The net is pushed by one operator at a speed of 25-50 m per min. The gape of the net is about 0.9 sq m (3 m x 0.3 m). The volume of water sampled per station per visit was therefore about 540 cu m (3 m x 0.3 m x 600 m).

The fry and larvae were transported by truck to the laboratory in oxygen-filled plastic bags for sorting, counting and identification. All identified larvae and fry were turned over to the BFAR unit for test rearing in ponds. Those not immediately identifiable were raised in laboratory aquaria to identifiable sizes. They were fed with rotifers, brine shrimps, mosquito larvae, the alga Enteromorpha and fish pellets. The rotifers and brine shrimps were cultured in the laboratory, the alga and the mosquito larvae collected from nature, and the pellets made in the laboratory.

For fish identification, Herre (1927), Munro (1967), Alle (1975), Masuda et al. (1975), Rau and Rau (1980), Schroede (1980) and Gloerfelt-Tarp and Kailola (undated) were used. Th crustaceans were identified following Day (1969), Tamei (1979 and Grey et al. (1983). Voucher specimens are deposited in th Silliman University Marine Laboratory.

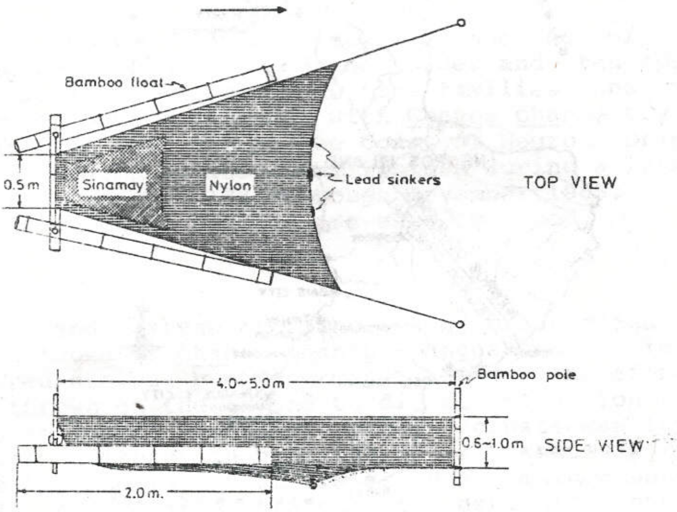

Fig. 2. Diagram of the fish fry and larva tow net (after Villalu et al., 1983). Arrow points to the direction net is pushed.

RESULTS AND DISCUSSION

A total of 132 species of fish belonging to 55 families an one order and ten species of crustaceans belonging to five fami lies and two orders were identified (Tables 1, 2). The number o fish species is almost twice the number (70) reported b Bagarinao and Taki (in press) for their onshore samples in Panda Bay and more than four times the number (30) reported by Bañad for Antique. Ninety-six out of the 142 fish and crustacea species (67.6 %) are food species in the Central Visayas; few of the fish species may also be considered aquarium specie (Table 1). Twenty-seven fish species (20.5%) may be classifie as aquarium species; many are listed as such by Munro (1967) Masuda et al. (1975), Carcasson (1977), Schroeder (1980), Rau an Rau (1980) and Gloerfelt-Tarp and Kailola (undated). Th seventeen remaining species (12.9%) are not of economi importance. The common food fishes belong to the familie Acanthuridae, Belonidae, Carangidae, Haemulidae, Kyphosidae Lethrinidae, Leiognathidae, Lutjanidae, Mugilidae, Mullidae

Table 1. List of fishes caught as larvae and fry with fry of *Chanos chanos* along the coast of Negros Oriental, Philippines from December, 1984 through November, 1985. Fish species are categorized primarily as food fish (FD), aquarium fish (AQ) or without commercial value (N).

TAXON	CATEGORY
1. ACANTHURIDAE (Surgeonfishes, unicornfishes)	
1. *Acanthurus triostegus* (Linnaeus)	FD/AQ
2. *Acanthurus* sp.	FD/AQ
3. *Naso* sp. (*N. brevirostris?*)	FD/AQ
2. AMBASSIDAE (Glassy perchlets)	
4. *Ambassis* sp.	N
3. ANGUILLIFORMES (Eels)	
5. eel sp.	FD
4. ANTENNARIIDAE (Frogfishes)	
6. *Histrio histrio* (Linnaeus)	AQ
5. APOGONIDAE (Cardinal fishes)	
7. *Apogon* sp.1 (*A. amboinensis?*)	N
8. *Apogon robustus* (Smith & Radcliffe)	N
9. *Apogonichthys* sp. (*A. brachygrammus?*)	N
10. *Apogonichthys marmoratus* (Alleyne & Maclean)	N
11. *Archamia* sp.	N
12. *Sphaeramia orbicularis* (Cuvier)	AQ
13. apogonid sp.1	N
14. apogonid sp.2	N
6. ATHERINIDAE (Silversides)	
15. *Allaneta* sp.	N
7. BELONIDAE (Needlefishes)	
16. *Strongylura strongylura* (van Hasselt)	FD
17. *Strongylura* sp.1	FD
18. *Tylosorus crocodilus* (Le Seuer)	FD
8. BLENNIIDAE (Blennies)	
19. *Alticus* sp.	N
20. *Meiacanthus* (*M. ditrema?*)	AQ
21. *Omobranchus* sp.1	N
22. *Omobranchus* sp.2?	N
23. *Petroscirtes mitratus* Ruppell	AQ
9. CALLIONYMIDAE (Dragonets)	
24. *Eleutherochir opercularis* (Valenciennes)	AQ

Table 1. (Continued.)

TAXON	CATEGORY
10. CARANGIDAE (Jacks)	
25. Alepes djedaba (Forsskal)	FD
26. Alepes sp.	FD
27. Caranx sp.	FD
28. Gnathanodon speciosus (Forsskal)	FD/AQ
29. Trachinotus blochi (Lacepede)	FD
30. carangid sp.	FD
11. CENTRISCIDAE (Shrimpfishes, Razorfishes)	
31. Aeoliscus strigatus (Günther)	AQ
12. CLUPEIDAE (Sardines and Herrings)	
32. Sardinella sp.	FD
13. CYNOGLOSSIDAE (Tongue-soles)	
33. Cynoglossus bilineatus (Lacepede)	N
34. Cynoglossus puncticeps (Richardson)	N
14. DIODONTIDAE (Porcupinefishes)	
35. diodontid sp.	AQ
15. ELEOTRIDAE (Sleepers, Gadgeons)	
36. Butis sp.	FD
37. Eleotris sp.	FD
38. Ophiocara sp.	FD
39. eleotrid sp.1	FD
40. eleotrid sp.2	FD
16. ELOPIDAE (Tarpons and Ten-pounders)	
41. Elops sp. (E. machnata?)	FD
42. Megalops cyprinoides (Broussonet)	FD/AQ
17. ENGRAULIDAE (Anchovies)	
43. Stolephorus sp.1	FD
44. Stolephorus sp.2	FD
18. EPHIPPIDAE (Batfishes)	
45. Platax orbicularis (Forsskal)	FD/AQ
46. Platax teira (Forsskal)	FD/AQ
19. EXOCOETIDAE (Flyingfishes)	
47. Parexocoeteus sp.	FD
48. Cypselurus sp.	FD
20. GERREIDAE (Mojarras)	
49. Gerres oyena (Forsskal)	FD

Table 1. (Continued.)

TAXON	CATEGORY
50. *Gerres filamentosus* Cuvier	FD
51. *Gerres macrosoma* Bleeker	FD
21. GOBIIDAE (Gobies)	
52. *Acentrogobius criniger* (Valenciennes)	AQ
53. *Acentrogobius* sp. 1	FD
54. *Amblygobius albimaculatus* (Ruppell)	FD
55. *Bathygobius* sp.	FD
56. *Glossogobius biocellatus* Cuvier & Valenciennes	FD
57. *Glossogobius* sp. (*G. circumspectus*?)	FD
58. *Oxyurichthys* sp.?	N
59. goby sp.1	N
22. HAEMULIDAE (Sweetlips, Grunts)	
60. *Plectrorinchus gibbosus* Lacepede	FD
61. *Pomadasys hasta* (Bloch)	FD
23. HEMIRAMPHIDAE (Halfbeaks, Garfishes)	
62. *Hemiramphus far* (Forsskal)	FD
63. *Zenarchopterus* sp.1	FD
64. *Zenarchopterus* sp.2	FD
24. KUHLIIDAE (Flagtails)	
65. *Kuhlia marginata* (Cuvier)	FD
25. KYPHOSIDAE (Rudderfishes)	
66. *Kyphosus cinerascens* (Forsskal)	FD
26. LABRIDAE (Wrasses, Tuskfishes)	
67. *Cheilio inermis* (Forsskal)	FD/AQ
68. *Halichoeres* sp.(?)	AQ
69. *Halichoeres* sp.1	AQ
70. *Halichoeres* sp.2	AQ
71. *Halichoeres* sp.3	AQ
72. *Stethojulis* sp.	AQ
73. Novaculichthinae (*Cymolates* sp.?)	AQ
27. LEIOGNATHIDAE (Slipmouths)	
74. *Gazza achlamys* Jordan & Starks	FD
75. *Gazza minuta* (Bloch)	FD
76. *Leiognathus* sp.	FD
77. *Secutor* sp.	FD
28. LEPTOCEPHALIDAE (= CONGRIDAE) (Conger eels)	
78. *Conger cinereus* Ruppell	FD

Table 1. (Continued.)

TAXON	CATEGORY
29. LETHRINIDAE (Emperors)	
79. Lethrinus sp.	FD
30. LOBOTIDAE (Tripletails)	
80. Lobotes surinamensis (Bloch)	FD
31. LUTJANIDAE (Snappers)	
81. Lutjanus argentimaculatus (Forsskal)	FD
82. Lutjanus fulviflamma (Forsskal)	FD
83. Lutjanus russelli (Bleeker)	FD
32. MONOCANTHIDAE (Filefishes and Triggerfishes)	
84. Aluterus scriptus (Osbeck)	FD/AQ
85. Cantherhines fronticinctatus (Gunther)	AQ
86. Stephanolepis japonicus (Tilesius)	AQ
33 MONODACTYLIDAE (Silver batfishes)	
87. Monodactylus argenteus (Linnaeus)	FD/AQ
34. MUGILIDAE (Mullets)	
88. Crenimugil labiosus (Valenciennes)	FD
89. Liza vaigiensis (Quoy & Gaimard)	FD
90. Valamugil sp. (cf. V. seheli)	FD
35. MULLIDAE (Goatfishes)	
91. Parupeneus barberinus (Lacepede)	FD/AQ
92. Upeneus sp.1	FD/AQ
93. Upeneus tragula (Richardson)	FD/AQ
36. NEMIPTERIDAE (Treadfin-breams)	
94. Scolopsis lineatus Quoy & Gaimard	FD/AQ
37. PARALICHTHYIDAE (Left-eyed flounders)	
95. paralichthyid sp.1	FD
38. PARAPERCIDAE (Grubfishes)	
96. Parapercis sp.	FD
39. PLATYCEPHALIDAE (Flathead)	
97. Cociella sp.?	FD
40. PLOTOSIDAE (Marine catfishes)	
98. Plotosus lineatus Valenciennes	FD/AQ
41. POMACENTRIDAE (Damselfishes)	
99. Abudefduf coelestinus (Cuvier)	FD/AQ

Table 1. (Continued.)

TAXON	CATEGORY
100. *Abudefduf lorenzi* Hensley & Allen	FD/AQ
101. *Abudefduf saxatilis* (Linnaeus)	FD/AQ
102. *Pomacentrus* sp.1 (*P. burroughi*?)	AQ
103. *Pomacentrus* sp.2 (*P. vaiuli*?)	AQ
42. SCARIDAE (Parrotfishes)	
104. *Scarus* sp.	FD
43. SCATOPHAGIDAE (Scats)	
105. *Scatophagus argus* (Linnaeus)	FD/AQ
44. SCORPAENIDAE (Scorpionfishes)	FD
106. *Parascorpaena* sp.?	
45. SERRANIDAE (Seabasses, Groupers)	
107. *Cephalopholis* sp.	FD/AQ
108. serranid sp.	FD
46. SIGANIDAE (Rabbitfishes)	
109. *Siganus canaliculatus* (Park)	FD
110. *Siganus guttatus* (Bloch)	FD
111. *Siganus punctatus* (Schneider)	FD
112. *Siganus spinus* (Linnaeus)	FD
113. *Siganus* sp.(*S. virgatus*?)	FD
47. SILLAGINIDAE (Common whitings)	
114. *Sillago sihama* (Forsskal)	FD
48. SOLEIDAE (Soles)	
115. *Heteromycteris hartzfeldi* (Bleeker)	FD/AQ
116. soleidae sp.1	FD
49. SOLENOSTOMIDAE (Ghost Pipefishes)	
117. *Solenostomus* sp. (*S. cyanopterus*?)	AQ
50. SPHYRAENIDAE (Barracudas)	
118. *Sphyraena barracuda* (Walbaum)	FD
51. SYNGNATHIDAE (Pipefishes, Sea horses)	
119. *Hippocampus kuda* Bleeker	AQ
120. *Syngnathoides biaculeatus* (Bloch)	AQ
121. syngnathinae sp.1	AQ
122. syngnathinae sp.2	AQ
52. SYNODONTIDAE (Lizardfishes)	
123. *Synodus* sp. (*S. variegatus*?)	FD
124. *Trachinocephalus myops* (Bloch & Schneider)	FD

Table 1. (Continued.)

TAXON	CATEGORY
53. TERAPONIDAE (Tigerfishes)	
125. <u>Pelates</u> <u>quadrilineatus</u> Bloch	FD
126. <u>Terapon</u> <u>jarbua</u> Forsskal	FD/AQ
54. TETRAODONTIDAE (Pufferfishes)	
127. <u>Arothron</u> <u>immaculatus</u> (Bloch & Schneider)	AQ
128. <u>Arothron</u> <u>hispidus</u> (Linnaeus)	AQ
129. <u>Chelonodon</u> <u>patoca</u> (Hamilton-Buchanan)	AQ
130. <u>Torquigener</u> <u>brevipinnis</u> (Regan)	AQ
55. TOXOTIDAE (Archerfishes)	
131. <u>Toxotes</u> <u>jaculator</u> (Pallas)	FD/AQ
56 TRIACANTHIDAE (Tripodfishes) *	
132. <u>Pseudotriacanthus</u> <u>strigilifer</u> (Cantor)	N

* Caught by stationary gear ("saplad") in Tanjay August, 1985.

Table 2. List of crustaceans collected as larvae with Chanos chanos fry along the coast of Negros Oriental province, Philippines.

1. GRAPSIDAE

    Varuna litterata Fabricius

2. MYSIDACEA

3. PALAEMONIDAE

    Macrobrachium sp.

4. PENAEIDAE

    Metapenaeus ensis (de Haan)

    Penaeus indicus Milne-Edwards

    Penaeus monodon Fabricius

5. PORTUNIDAE

    Portunus sp.

    Scylla serrata Forskal

6. SERGESTIDAE

7. STOMATOPODA

Table 3. A comparison of fish species in selected families reported from the Philippines.

FAMILY	NUMBER OF SPECIES		
	A	B	THIS STUDY
1. ACANTHURIDAE	26	25	3
2. BELONIDAE	7	4	4
3. CARANGIDAE	20	37	6
4. CLUPEIDAE	7	17	1
5. CYNOGLOSSIDAE	3	5	2
6. ELOPIDAE (including MEGALOPIDAE)	2	2	2
7. ENGRAULIDAE	6	10	2
8. EPHIPPIDAE (includes PLATACIDAE and DREPANIDAE)	3	3	2
9. EXOCOETIDAE	5	4	2
10. GERREIDAE	5	5	3
11. HAEMULIDAE (POMADASYIDAE)	6	8	2
12. HEMIRAMPHIDAE	4	6	3
13. KYPHOSIDAE	2	2	1
14. LABRIDAE	74	34	7
15. LEPTOCEPHALIDAE	3	-	1
16. LETHRINIDAE	13	16	1
17. LEIOGNATHIDAE	7	13	4
18. LOBOTIDAE	1	1	1
19. LUTJANIDAE	23	42	3
20. MUGILIDAE	2	8	3
21. MULLIDAE	14	16	3

Table 3. (Continued.)

FAMILY	NUMBER OF SPECIES		
	A	B	THIS STUDY
22. NEMIPTERIDAE (including SCOLOPSIDAE)	12	26	1
23. PLATYCEPHALIDAE	8	3	1
24. PLOTOSIDAE	1	1	1
25. POMACENTRIDAE	46	23	6
26. SCARIDAE	23	8	0
27. SCATOPHAGIDAE	1	-	1
28. SERRANIDAE	22	30	2
29. SIGANIDAE	13	13	5
30. SILLAGINIDAE	2	2	1
31. SOLEIDAE	2	2	2
32. SPHYRAENIDAE	5	4	1
33. SYNODONTIDAE	4	6	2
34. TERAPONIDAE	3	5	2
TOTAL	377	381	81

[A] Herre (1953); includes only reports from localities in Cebu and Negros Oriental provinces.

[B] Rau and Rau (1980); includes only fish landed at Cebu City.

Nemipteridae, Pomacentridae, Scaridae, Serranidae, Siganida Sphyraenidae and Teraponidae. The five families of crustacea used as food are the Grapsidae, Palaemonidae, Penaeida Portunidae and Sergestidae.

The number of species belonging to 34 selected familie when compared with the number listed by Herre (1953) and Rau a Rau (1980), is roughly one-fifth (21%) of the number reported each author (Table 3).

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NOTES ON THE RECOVERY OF THE CORAL REEF AT PESCADOR ISLAND, OFF MOALBOAL, CEBU, PHILIPPINES, FROM TYPHOON DAMAGE

Angel C. Alcala, Edgardo D. Gomez,
Lawton C. Alcala and Teodulo F. Luchavez

Typhoon Nitang virtually decimated the live corals on the reef flat at Pescador Island on 2 September 1984. About a year later, the bare rocky substrate had showr little recovery in terms of area covered by live corals.

Coral reefs are known to suffer destruction not only man-induced factors but also from natural catastro Degradation due to human causes has received conside attention (e.g. the International Association of Biolo Oceanographers-sponsored book, *Human Activities Causing Dama Coral Reefs: Knowledge and Recommendations*, about to com the press). Stoddart (1969a) summarized the causes catastrophic mortality of corals, including diseases, silta sewage, excessive rainfall and tropical storms. He reported the major cause of catastrophic coral mortality is mecha destruction by tropical storms during which coral colonies m uprooted, carried upward or downward, or fragmented *in sit* wave action. Although corals may survive storms, they gene succumb to resulting changes in environmental conditions Stoddart, 1969a).

Little has been documented on reef recovery following storms. Shinn (1976), using a serial photographic me reported rapid recovery of *Acropora* and massive corals in Fl within five years following hurricane-caused destruc Stoddart (1969a), however, reported that three years aft British Honduras hurricane the only corals living in any qua were those which had survived the storm; wide reef areas blanketed by algae, primarily *Padina* and *Halimeda*. Stephens al. (1958) suggested that settlement of planulae is inhibit the morbidity of debris formed by storms, and they estimated to 20-year reef recovery, which some authors (e.g. Stod 1969a) believe to be underestimated.

In the Philippines, reef damage from natural forces subsequent recovery has not been well documented. The only recovery study available to us is that by Alcala and Gomez (on dynamite-blasted reefs.

This brief note reports on the typhoon damage inflicte Pescador Island reef and the initial recovery during a peric 11 months following a severe storm. Typhoon Nitang, with mated 200 kph center winds and 3 m waves, swept through the Visayas on 2 September 1984, causing great destruction along its path.

Pescador Island is a coralline island situated in Tañon Strait about 3 km off the coast of Moalboal, western Cebu. The reef surrounding the island is an oval-shaped fringing reef composed of a gradually sloping reef flat with an area of less than one hectare to a depth of five meters and a steep slope deeper than five meters. Like most pristine reefs in the Philippines, Pescador reef was a mixture of hard and soft corals and inhabited by a wide variety of invertebrates and reef fishes (Fig. 1.). The reef was dominated mostly by branching hard coral species (Acropora, Pocillopora, Millepora, Porites and Stylophora) and species of massive corals (Porites, Favia, Coeloseris and Favites).

METHOD

The Pescador reef was surveyed three times during a period of 11 months after the typhoon damage. To serve as a basis for estimating the areal coverage of the live corals and the various substrate types in the study area, 16 1m x 1m random quadrats (total area 16 sq m) were taken during each visit. The coral recruits were measured with a caliper. Photographs of the study area were taken with a Nikonos IV-A camera. All observations were made with the aid of SCUBA.

ANALYSIS OF RESULTS

Percentage Live Coral Cover.

Pescador reef prior to the typhoon damage had a live coral cover of 51 - 60%, falling within the category of "good" reef (Fig. 1). This assessment was based on (1) a sample of five 1m x 1m quadrats taken on 11 April 1978, which gave an estimate of 60% live coral cover (actually 23.0% soft corals and 36.3% hard corals, or 59.3%) (Marine Science Center Report, 1979, Section [illegible]) and (2) a transect sample, which gave an estimate of 51.8% cover (12.5% soft coral and 39.3% hard coral) in 1983 (White, 1984). The moderately-high live coral cover had most likely been maintained because the reef was protected by the municipality of Moalboal.

On the first visit on 24 September 1984, three weeks after the typhoon occurrence, the rock substrate of the reef flat appeared bare (Fig. 2). All corals, except for a few surviving colonies of small massive species (Porites, Favia and Favites) and broken colonies of branching species (Acropora,

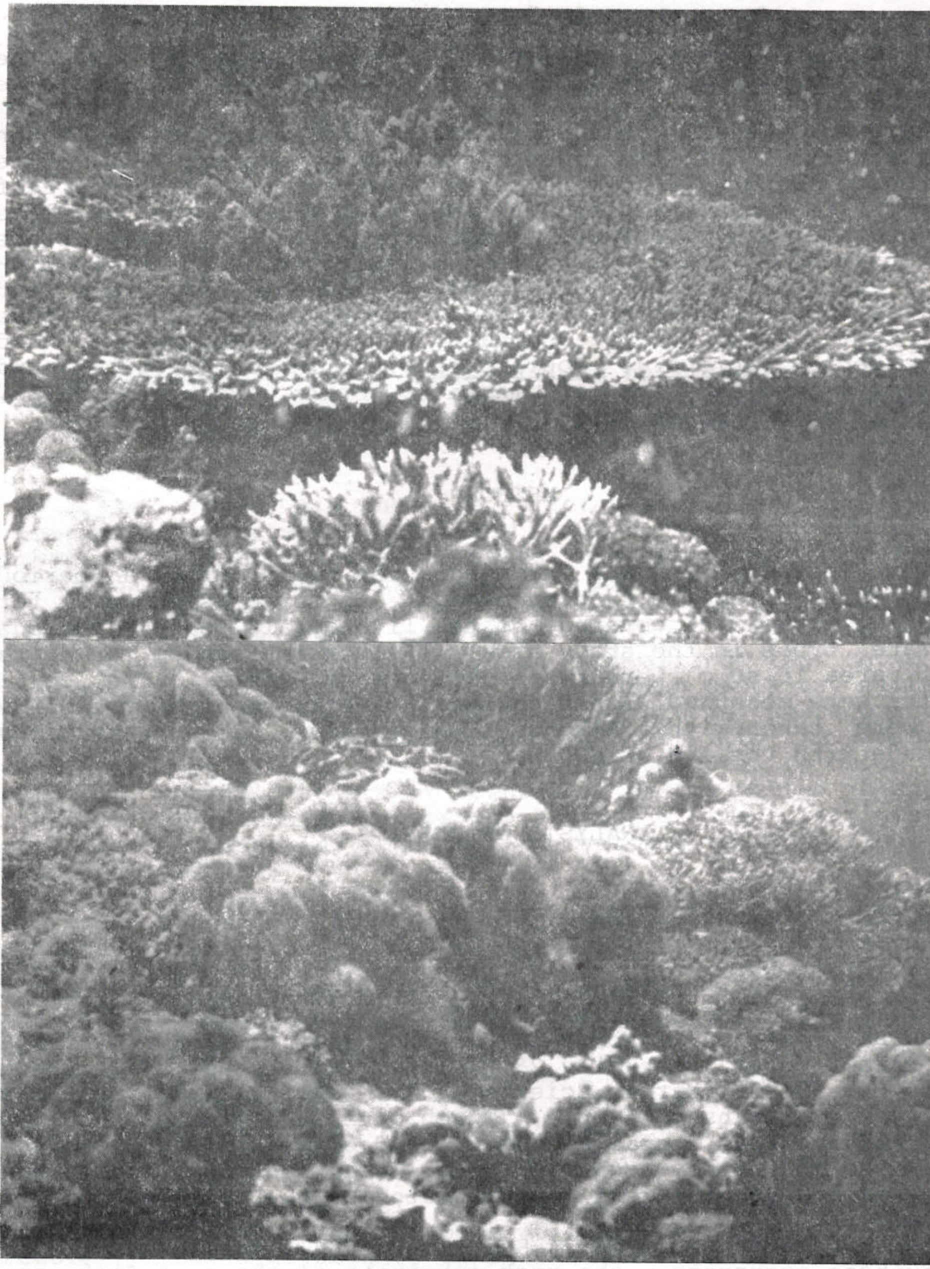

Fig. 1. Two views of the Pescador Island reef flat, sh good cover of hard and soft corals prior to typhoon da Pictures taken in 1978. Note abundance of small fish, m pomacentrids.

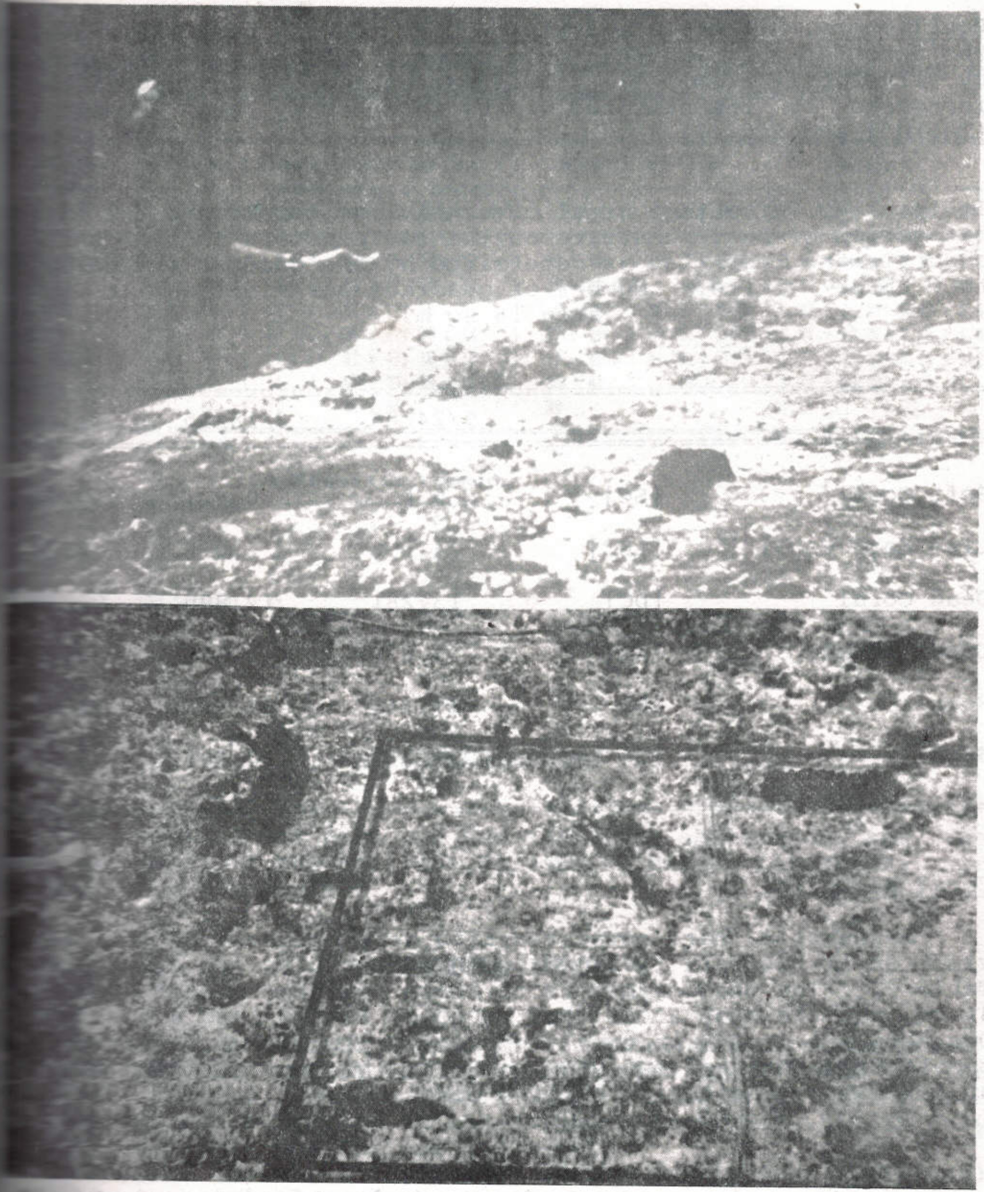

Fig. 2. Two views of the Pescador Island reef flat after damage by Typhoon Nitang, showing the rocky substrate in the same area shown in Fig. 1. A. Appearance of the reef flat on 24 September 1984. Black object is the sea cucumber Stichopus chloronotus. B. Part of the reef flat on 10 Febuary 1985. Black objects are Stichopus chloronotus. Hard coral recruits are too small to be identifiable.

Pocillopora, *Millepora* and *Stylophora*), having been swept away b the force of the typhoon. Only about 4% of the area was occupie by live coral (Table 1). This percentage had not significantl increased by the next two visits in February and August 198 (Table 1 and Fig. 2).

Table 1. Percentage areal cover of live corals and the variou categories of reef substrate on the southeastern section of Pescador Island reef flat as determined by the quadrat method durin the three visits. Number of quadrats per visit was 16 (tota area 16 sq m).

		9/24/84	2/18/85	8/3/85
Soft Coral	[SC]	0.0	0.0	0.42
Live Hard Coral	[LHC]	4.296	5.078	8.75
Dead Coral	[DC]	13.281	12.890	7.50
Coral Rubble	[CR]	5.078	3.515	7.10
Rock	[R]	77.343	77.734	76.25
Sand	[S]	0.0	0.781	0.0

Coral Recruits.

Measurable hard coral recruits were observed on the secon visit on 18 February 1985. Data on 40 recruits are summarized i Table 2. The mean diameters of these recruits ranged from 25 t 46 mm, and the mean areas they occupied ranged from 6 to 13 sq c Our data are useful in that they give a picture of the extent o recolonization after one year. Permanent quadrats have been se up for future monitoring of live coral cover.

Table 2. Summary of data on hard coral recruits on the southeastern section of the reef flat at Pescador Island, off Moalboal, western Cebu, following destruction by Typhoon Nitang on 2 September 1984.

Genus or Species	Number of Colonies	Months after Typhoon	Short and Long Diameters of Smallest & Largest Colonies (mm)	Diameter (d)* in mm		Area (cm)	
				Range	Mean ± SD	Range	Mean ± SD
Tubastrea micranthus	5	5	22 x 18; 50 x 42	20 - 46	31.3 ± 11.91	3.14 - 16.62	8.58 ± 6.21
Pocillopora	2	5	41 x 37; 51 x 36	39 - 43.5	46.25	11.94 - 14.86	13.40
Pocillopora	18	11	14 x 12; 60 x 55	13.0 - 57.5	25.63 ± 11.52	1.33 - 25.97	6.23 ± 6.63
Millepora	6	11	56 x 42; 20 x 14	17 - 49	30.75 ± 12.19	2.27 - 18.86	8.40 ± 6.41
Porites lutea	6	11	52 x 47; 18 x 16	17 - 49.5	31.50 ± 11.98	2.27 - 19.24	8.73 ± 6.29
Acropora	2	11	53 x 29; 39 x 31	35 - 41	38.0	9.62 - 13.20	11.41
[illegible]	1	11	44 x 34	39		11.95	

* Determined by the formula: $\frac{\text{Long Diameter + Short Diameter}}{2}$

** Determined by the formula: $\frac{d^2}{4}$

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MATING CALLS OF CERTAIN PHILIPPINE ANURANS (MICROHYLIDAE, RANIDAE)

Angel C. Alcala, Gerhard Joermann and Josef Brzoska

The mating calls of five Philippine anurans are analyzed. Kaloula picta and K. conjuncta, both belonging to the family Microhylidae, have stereotyped and simple-structured mating calls. The calls of these two species differ in temporal parameters. In contrast, three species of the family Ranidae--Rana erythraea, R. signata and Ooeidozyga laevis--have more complex calls. Those of R. erythraea and Ooeidozyga laevis are very variable, each with different call types, and that of R. signata contains only one type. The calls of R. erythraea include frequency-modulated tone pips and harmonic elements, while those of the other two ranids have mainly pulsed signals. Mating calls of these Philippine frogs may be used in clarifying taxonomic problems.

The taxonomy of Philippine amphibians has been based mainly on morphological characters and only to a very limited extent on other biological features such as life history and ecology (Brown and Alcala, 1983; Heyer, 1971; Schneider, 1977; Taylor 1920, 1928). In recent years herpetologists have recognized the significant role of reproductive behavior in speciation processes (Blair, 1962; Salthe and Mecham, 1974). Mating calls, which constitute an important component in the analysis of reproductive behavior, have been shown to be useful in clarifying taxonomic questions and are now considered an essential part of species characterizations in anurans (Littlejohn and Oldham, 1968; Schneider, 1974, 1977).

In the present paper we describe the vocalizations of five common anuran species in the Philippines, two species in the family Microhylidae (Kaloula picta Duméril and Bibron and K. conjuncta Peters) and three species in the family Ranidae (Rana signata Guenther, R. erythraea Schlegel and Ooeidozyga laevis Guenther). Both species of Kaloula are restricted to the Philippines, but the three ranids also occur in Borneo, the Sunda Islands and other parts of Southeast Asia. It is hoped that our data on vocalization may provide an additional basis for the taxonomy of ranid and microhylid frogs in the Philippines.

MATERIALS AND METHODS

The calls were recorded under natural conditions in t field with a condenser microphone (Sennheiser K3/ME 80) a portable tape recorders (Uher Report 4200 and Sony TCM-5000 The analysis equipment consisted of a sonagraph (Kay 7029 A an oscilloscope with camera (Tonnies Recordine) and a spectr analyser (Nicolet UA 500 A). The sonagrams shown in this pap comprise a dynamic range of 20-25 dB; they are wide-band filter if nothing else is indicated. Mean values of call parameters a given with their standard deviations following the ± sign.

Most, but not all, of the calling frogs were captured aft recording. Identification of the uncaught individuals was bas on one of the authors´ (A.C.A.) familiarity with the calls of t species. Voucher specimens are deposited in the herpetologic collections at Silliman University and the Museum Alexand Koenig, Bonn, West Germany.

Air temperatures were recorded with a quick-readi Schultheis thermometer. Water temperatures were also recorded f species calling in the water.

RESULTS

Kaloula conjuncta.

The calls of this species were recorded at Bantaya Dumaguete City, Negros Island, in the rain on 19 and 24 Ju 1984, 2000 - 2100 h. Air and water temperatures were 26 a 25.5° C, respectively. The calling sites were edges of rai filled ditches. When calling, the males had their forelimbs o land and hindlimbs in water. The population on Negros belong to the subspecies *negrosensis* Taylor (Inger, 1954).

A mating call series consists of 100 - 500 calls lasti 12 - 60 s. These calls are very short, with a mean duration o only 8.8 ± 0.5 ms (n=15), and consist of a single note (Fig. 1) The period time of the calls is 85 - 170 ms ($\bar{x}$ = 120.2 ± 18. n = 240). Successive periods generally do not change by more tha 25 ms. However, in the whole series the rhythm may accelerat and slow down several times, resulting in a large range o periods (see example in Fig. 2). The frequency spectrum has maximum at 1030 ± 15 Hz (n = 15), with the second harmoni clearly present. In one of two animals, a third harmonic, abou 20 dB weaker than the fundamental, is identifiable. Additiona frequency portions with low intensity are found between 1 and Khz.

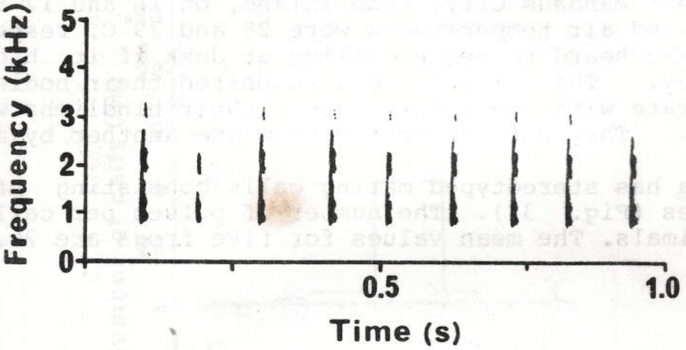

Fig. 1. *Kaloula conjuncta*. Sonagram of a section of a call series.

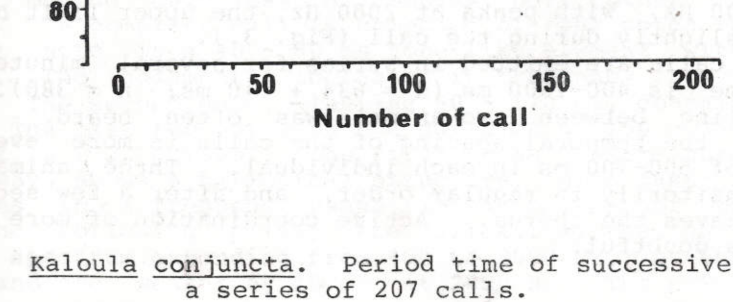

Fig. 2. *Kaloula conjuncta*. Period time of successive calls in a series of 207 calls.

Kaloula picta.

Recordings of this species were made in small ponds in rice field near Mandaue City, Cebu Island, on 16 and 17 Septembe 1983. Water and air temperatures were 28 and 29° C, respectively The frogs were heard to begin calling at dusk if it had raine during the day. The calling frogs supported their bodies on th muddy substrate with their forelimbs; their hindlimbs were fre in the water. They were separated from one another by at leas 30 cm.

K. picta has stereotyped mating calls consisting of 24 - 3 uniform pulses (Fig. 3.). The number of pulses per call differ among the animals. The mean values for five frogs are 26.4 - 33. pulses per call (Fig. 4.). The call duration is also variable the mean durations for the same five frogs are 188 - 230 ms, wit a standard deviation of 6.6 ms. The factors responsible for th variations in these two parameters are not yet known.

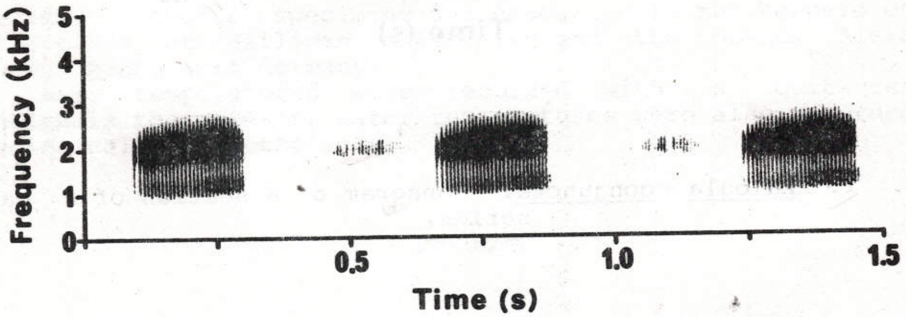

Fig. 3. Kaloula picta. Sonagram of three calls; in alternatio are two weak calls of a second male.

The period time of the pulses is 7-9 ms in the middle par of the call, often longer at the beginning, and generally shorte toward the end. The frequency range of the calls extends fro 900 to 3000 Hz, with peaks at 2080 Hz; the upper limit and peak increase slightly during the call (Fig. 3.).

The calls are emitted in series for several minutes. Th period time is 400-1500 ms ($\bar{x} = 634 \pm 140$ ms; $n = 380$). Alternate calling between two animals was often heard. In suc instances the temporal spacing of the calls is more even, wit periods of 500-700 ms in each individual. Three animals cal only transitorily in regular order, and after a few seconds on of them leaves the chorus. Active coordination of more than tw animals is doubtful.

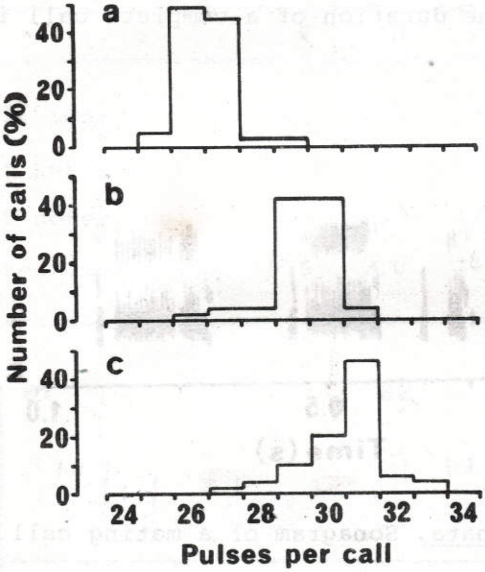

Fig. 4. Kaloula picta. Frequency distribution of the number of pulses per call in three individuals (a - c).

Rana signata.

Recordings of this species were made at Malinao, about 27 km west of Puerto Princesa, Palawan Island, on 23 June 1984, at 1900 h, with air temperature of 26.5°C. The frogs were calling from ground, at the edge of a pond fed by a mountain stream. According to Inger (1954) the population on Palawan belongs to the subspecies moellendorffi Boettger.

The mating call has a complex but rather invariable structure. A complete call is composed of four notes (Fig. 5.). The first note is a 40 - 80 ms tone-like element with 3 - 4 harmonics. The fundamental increases in frequency from 750 Hz to [illegible] Hz. The second note, lasting 50 - 170 ms, contains 2 - 14 pulses. The last two notes have a duration of 150 - 250 ms and consist of 13 - 22 pulses. The first pulse in the three latter notes always shows a harmonical structure, with fast frequency modulations in a frequency range similar to that of the first note. The following pulses are clicklike, having a broad frequency spectrum extending from 900 to 3600 Hz, peaks being at [illegible] Hz, and are weaker by 10 dB at 2800 Hz. The pulses in the last three notes are ordered, with a period of about 9 - 10 m and only the last pulse is more separated in time. In 13 cal of one animal, the first note was missing three times and t last note once. The duration of a complete call is 760 - 1140 ($\bar{x}$ = 964 ± 140).

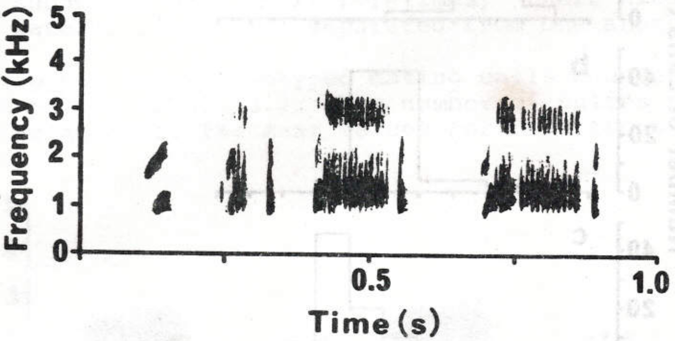

Fig. 5. Rana signata. Sonagram of a mating call.

Rana erythraea.

The calls of this species were recorded at Bantaya Dumaguete City, Negros Island, on 21 September 1983. The anima called from a medium sized pond in a coconut grove. Water and a temperatures were 30°C at 2000 h and 29°C at 2300 h.

Three types of calls can be recognized. The first type (A which has a mean duration of 580 ms, typically consists of 4 - notes (Fig. 6a). The period time of a note is 92 ms on t average; the intervals are often alternately longer and shorte resulting in a distinct rhythm. The last note may have a long interval. The temporal parameters are given in Table 1. T notes are all frequency modulated pure tones; only rarely is weak, second harmonic found above the fundamental. The type modulation is variable, mostly upward but sometimes downward both upward and downward. The single pulses cover a frequen width (difference between upper and lower limit) of 660 - 34 Hz. Within a call the frequency range or the dominant frequen decreases steadily, and only the last note may again rise pitch. The overall frequency range of a call ranges from abo 950 to 5300 Hz. The amplitude course of the notes characterized by a very steep onset; after 2 or 3 waves fu intensity has already been reached (Fig. 7a). Type A calls we mostly uttered when the animals made fast movements in flig after being startled or even without obvious disturbance.

Table 1. Characteristics of call type A in Rana erythraea.

	x̄	SD	N	MIN.	MAX.
duration of call (ms)	582	212	50	248	1046
number of notes per call	6.5	2.4	50	3	14
period times of notes (ms)	92	33	120	52	184
duration of notes (ms)	9.5	2.0	148	5.1	15.5

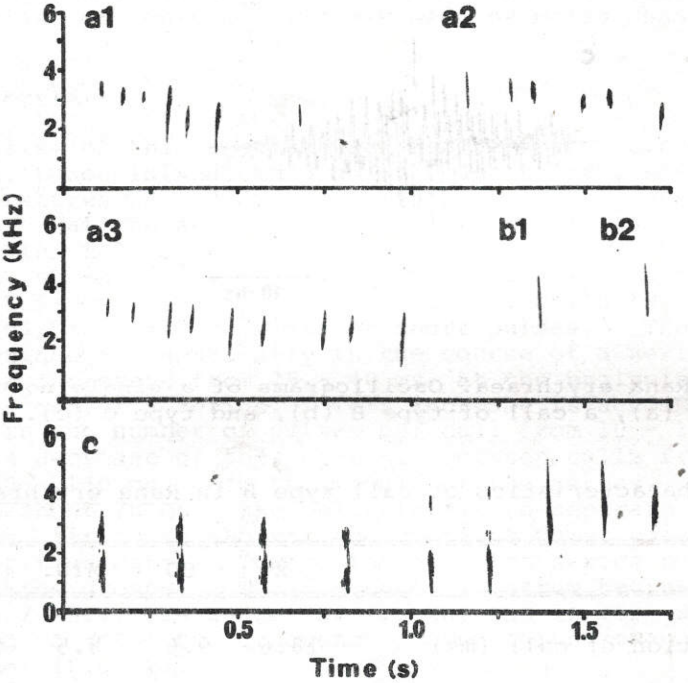

Fig. 6. Rana erythraea. Sonagram of 3 type A calls (a1 - a3), type B calls (b1 - b2), and a series of type C calls (c); this series is terminated by 2 notes similar to type A and one note similar to type B.

Type B calls consist of a single note of 18.6 ms duration o the average. The note is generally a downward sweeping ton (Fig. 6b). Only very long calls start with a faint upstroke o the frequency. At the end of the call the second harmonic ma appear with low energy. The frequency parameters are listed i Table 2. In contrast to the notes of type A, the amplitude o type B calls rises very slowly, and the maximum is not reache before two-thirds of the call duration (Fig. 7b). Calls of typ B are emitted singly and sparingly.

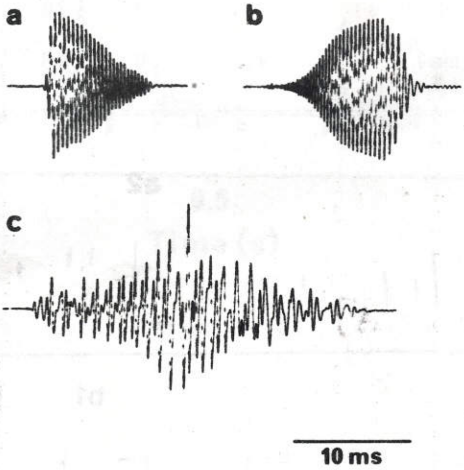

Fig. 7. *Rana erythraea*. Oscillograms of a single note of A-cal (a), a call of type B (b), and type C (c).

Table 2. Characteristics of call type B in *Rana erythraea*; n=45.

	x̄	SD	MIN.	MAX.
duration of call (ms)	18.6	9.6	8.5	45.5
upper frequency limit (Hz)	4240	590	3480	5650
lower frequency limit (Hz)	1550	450	800	2640
width of sweep (Hz)	2690	660	1460	4580

The most frequent call is type C (Fig. 6c, 7c). Containing a gle note , this call has a duration of 16 - 33 ms ($\bar{x}$ = 24.7 ± n = 120). The sonagram shows a fast up-and-down modulation 2 - 4 harmonics (Fig. 6c). Overlap of the frequency ranges of harmonics and additional non-harmonic portions results in a frequency spectrum beginning at 640 Hz and extending up to - 4500 Hz. However, the energy decreases in the upper third this range, so that type C calls clearly sound lower than type calls. Type C calls occur more often in series, although they occur singly. Typically, the frogs emit a series consisting 10 - 20 calls of type C, with intervals decreasing from 600 - ms at the beginning to 200 - 400 ms at the end. Following type C calls are one to five notes closely resembling those type A or type B; the distinction between the two is the fferent amplitude course described above (Fig. 6c). After an rval of 0.6 - 1.3 s a new series may start with C-calls. If eral series succeed in this manner, they usually are shortened one to the next through the reduction of the number of C-lls. Series of only C-calls are made by males chasing away ders.

ozyga laevis.

The calls of this species were recorded in Quezon City, Manila, Luzon Island, on 3 and 4 October 1983, with air and temperatures 28 - 29°C. The animals were in water-filled ditches. Calling activity usually started at dusk.

The calls of this frog are very variable. Typical are the series shown in Fig. 8. These calls last 2.6 - 6.0 s = 4.3 ± 1.1; n = 40) and contain 10 - 27 calls ($\bar{x}$ = 18.4 ± n = 40). A call consists of short pulses. The temporal eters change systematically in the course of a series. The duration increases from 25 - 40 ms at the beginning to 80 - ms at the end of a series. This increase is accompanied by crease in the number of pulses per call from 10 - 14 to 18 - and by a decrease of the intervals between calls from 300 - ms to 100 - 130 ms. In the middle of the series, at a call tion of about 70 ms, the pulses begin to separate into two s. The first is shorter and contains fewer pulses at a repetition rate. Toward the end of a series pulses may into three groups. The frequency spectrum begins at 2 kHz a at 3.2 kHz), is weaker at 7.5 kHz and is very weak at 10 During a call the frequency composition changes in a ex manner (Fig. 8).

Aside from these long series of calls there are often ced shorter ones consisting only of 4 - 10 calls lasting 1.3 s. The calls are divided into pulse groups from the ing, numbering 2 - 5 (Fig. 9a). Frequently, single calls sting of 1 - 6 pulse groups with a duration of 20 - 180 ms, ding upon the number of pulse groups, can be heard. These often start with a kind of "growling" formed by a long

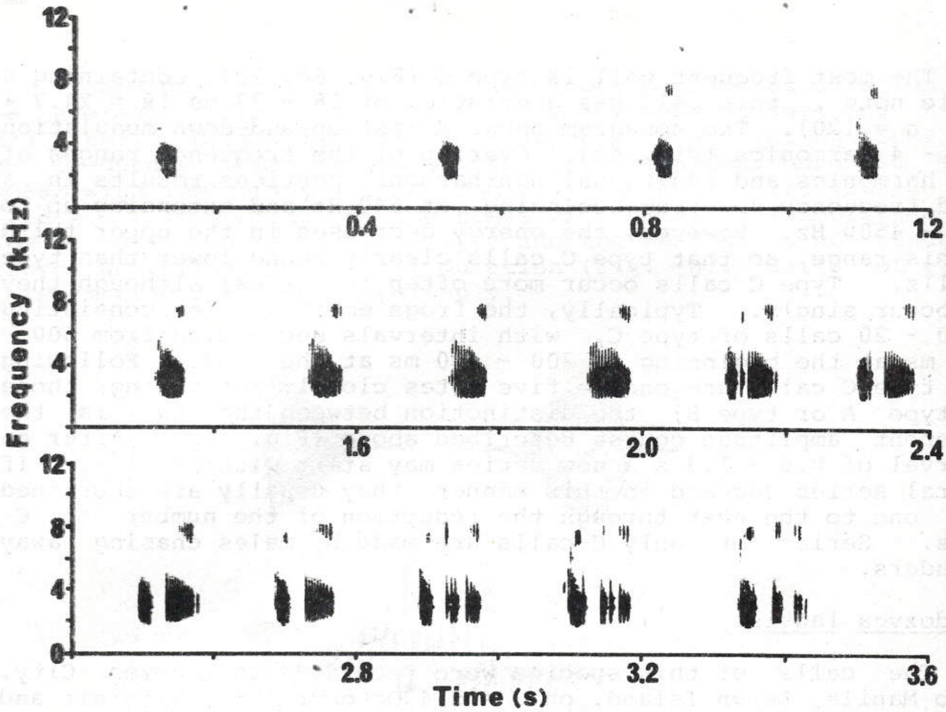

Fig. 8. Ooeidozyga laevis. Sonagram of a long call series.

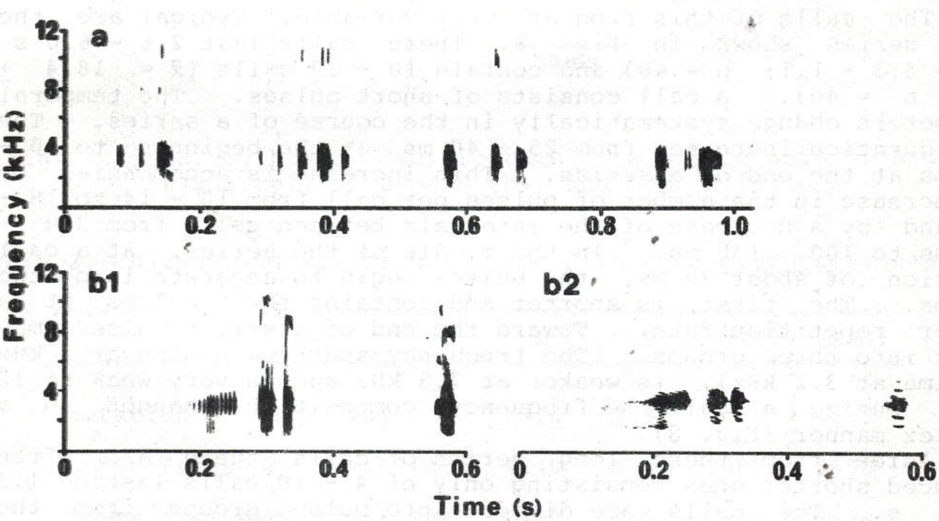

Fig. 9. Ooeidozyga laevis. Sonagram of a short call series (a) and a single call starting with a "growling" and followed by harmonic note (b); the same call was analysed with wide (b1) and narrow (b2) filters.

se train which begins very faintly and gradually increases in sity (Fig. 9b). Sometimes 200 - 250 ms after a single call re is emitted a 30 - 40 ms harmonically-structured note. This er has a fundamental of 2.9 kHz and two weaker harmonic bands e or consists of 8 - 12 harmonics in intervals of 550 Hz ting at 1650 Hz or is composed of both types (Fig. 9c). le calls are often followed by the typically long mating series in an interval of 2 s. This is not true, however, the beginning of the daily calling period or for the males ing close to other calling males.

DISCUSSION

Both species of Kaloula have very simple structured calls. ver these calls are clearly differentiated from each other, ecially in terms of temporal parameters. Unequivocal labeling supported by the high uniformity of the calls. The distinct erence in vocalization is noteworthy, as these two species alike morphologically.

In contrast, the three ranids have more complex calls, aining differently designed notes. Whereas the calls of Rana ata are rather uniform, those of the other two species show a variability, as is often the case in the genus Rana (Kuhn Schneider, 1984; Mecham, 1971; Wahl, 1969).

In Rana erythraea the calls consist mainly of modulated tone or multiharmonic components. Such a frequency pattern is rarely found in Rana; examples are R. arvalis (Schneider, 3) and three Japanese species (Matsui and Utsunomiya, 1983). more often occur are pulse-like vocalizations (Kuramoto, ; Matsui and Utsunomiya, 1983; Schneider, 1973). Matsui 2) analyzed calls of Rana erythraea from Sabah (northern eo). His animals emitted a series of 6 - 11 notes resembling type C calls in duration. But these are structured of fine ses and extend to higher frequencies. Temperature, which rally influences call parameters (Schneider, 1973, 1977), was 3 - 4 degrees lower in Matsui´s recordings; this factor ot account for the large differences in the calls of the and Negros populations of this species.

It is not known when the two populations were separated in past. The species is presently found in large numbers on ain islands in the central Philippines but is absent on anao and Palawan, the two large islands closest to Borneo. ce it is abundant wherever it occurs, local extinctions on anao and Palawan seem unlikely. It is therefore conceivable the species was accidentally carried by humans from Borneo er, 1954).

Despite their variability, the calls of R. erythraea can be rly classified into three specific types. We interpret the ctional significance of these calls with the aid of notes taken at the time of recording. The typical mating ca obviously consists of a series of type C calls followed by so notes of type A and B. Series with only C-calls are also utter in aggressive interactions, so these calls may be directed t other males. The higher pitched notes at the end of the norma mating call series probably represent the main female-attracti signal. In several anuran species such a partitioned function o optional or obligatory compound calls can be demonstrat (Arak, 1983; Narins and Capranica, 1978; Wells, 1977). Fa movements of the animals were always correlated with type calls. A distinct call in a similar situation was described i *Rana temporaria* by Van Gelder et al. (1978), who interpret t calls as an announcement of the sex of the callers to near males. It remains to be determined whether the A-calls serve t same function in *Rana erythraea*.

The classification of the calls of *Ooeidozyga laevis* is mo difficult. The long call series is unequivocally the typic vocalization at the height of the calling activity. Other call called short series or single calls, have few structur peculiarities, so that a clear function cannot yet be ascribed t them. Possibly, they are reflections of a lower motivation status of the frogs. Heyer (1971) described three call types o *O. laevis* from Thailand. One of them resembles our harmon notes. Beyond this resemblance, the calls differ very much fr those of Philippine frogs from Luzon Island. One differen noted is the lack of subdivision of the 30 - 170 ms calls o notes into pulses in Heyer's recordings. More samples from oth localities are needed to relate calls of the two population possibly through intermediate types, and to distingui conservative structural features from those that are more easi changed by evolution. A comparative study could also yield hin about the history of dispersal in this species.

ACKNOWLEDGMENTS

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SPAWNING, LARVAL REARING AND EARLY GROWTH OF HIPPOPUS HIPPOPUS (LINN.) (BIVALVIA: TRIDACNIDAE)

A. C. Alcala, E. P. Solis and S. N. Alcazar

The results of rearing laboratory-spawned eggs and larvae of the giant clam Hippopus hippopus (Linn.) in the laboratory are described. Veliger larvae reared at stocking densities of 1.2 to 5/ml and fed with the unicellular algae Isochrysis galbana and Tetraselmis sp. developed into 3-4-month-old juveniles. The survival rates of 3-4-month-old juveniles from veligers ranged from 0.03 to 2.13%. For successful mariculture, larval mortality rates must be reduced.

Tridacnid clams are presently the subject of mariculture rts in a number of laboratories in the Indo-Pacific region, arily for the purpose of preventing their extinction and menting existing stocks for food (see Munro and Gwyther, 1981; et al., 1984; Heslinga et al., 1984). Hippopus hippopus, one the seven extant species of tridacnid clams in the lippines (Rosewater, 1965, 1982), is being studied for ssible culture for its adductor muscles and mantle as food and its shell as a decorative item.

Hippopus hippopus is hermaphroditic and has been induced to in the laboratory most consistently by the introduction of shly macerated or freeze-dried gonad (Wada, 1954; Jameson, 76; Gwyther and Munro, 1981; Fitt et al., 1984) and by the agonadal injection of serotonin (Braley, 1985; Crawford et in press). Fitt et al. (1984) studied the early development fertilized eggs to the veliger stage and Jameson (1976), fertilized eggs to the 58-day juvenile stage.

The present paper deals with the spawning, larval rearing early growth of Hippopus hippopus. Our study is part of the arch program on the culture of giant clams for restocking of al reefs participated in by James Cook University, Australia, Fisheries Division, Fiji Ministry of Primary Industries, University of Papua New Guinea, Port Moresby, the University the Philippines Marine Science Institute and the Silliman ersity Marine Laboratory, Dumaguete City, Philippines.

MATERIALS AND METHODS

Broodstock.

Mature-sized *Hippopus hippopus* (18-23.3 cm long) wer collected from Sumilon Island, near Cebu Island, in October 198 and August 1985, .the Cagayan Islands, Sulu Sea in April 1985 ar Campuyo, Manjuyod, Negros Oriental in August and November 1985 The clams were held in a laboratory tank 2m long x 1m wide x 0.5 deep, and provided with unfiltered sea water for a few days t six months. Water temperatures in the holding tank fluctuate between 27 and 34° C, and salinity between 31 and 33 ppt.

Spawning.

Only broodstock clams with more than 50% mature eggs wer used in the spawning experiments. Mature eggs (spherical in shap under the microscope) were removed from the gonads with a huma biopsy needle, following the method of Crawford et al. (i press). The clams were induced to spawn by either pouring 10-20 ml of macerated gonad material into the water or injecting int the gonad 1-4 ml of 2mm serotonin (crystalline serotonin [5 hydroxytryptamine, creatine sulfate complex]) dissolved i filtered sea water. The serotonin solution was used immediatel after preparation or stored at -4°C before use. In some instance serotonin injection was followed by the addition of gona material. The experimental clams (usually two per experiment were induced to spawn in 60-l glass aquaria containing filtere sea water, mostly in the afternoon between 1400 and 1700 h.

The induced clams were allowed to release sperm until th water was dense with it. They were then repeatedly transferre to new aquaria, following the method of Jameson (1976), unti they spawned eggs. This procedure was intended to separate th sperm from the eggs. The egg-water mixture was gently aerated t disperse the eggs evenly in the aquarium.

To fertilize the eggs, 100 ml of sperm suspension from th first aquarium of the other clam was added to the egg-wate mixture. This procedure ensured cross fertilization and minimized polyspermy.

For spontaneous spawnings, the eggs or fertilized eggs wer scooped with a bucket or filter bag (70 µm mesh size) from th holding tank and transferred to 60-l aquaria filled with filtere seawater.

To estimate the density and number of eggs and the number o fertilized eggs, the volumetric technique of Castagna an Kraeuter (1984), widely used in bivalve mariculture, wa followed. The eggs and larvae were measured under th microscope using an ocular micrometer.

Larval rearing.

The fertilized eggs were allowed to develop in aerated aquaria to the veliger stage. Samples of the larvae were taken once daily for stage determination, size measurement and density determination. Size measurements were expressed in means ± standard deviation and range. Density was estimated from ten 1-ml samples, following the method of Castagna and Kraeuter (1984). Two liters of unicellular algal culture (mixture of *Isochrysis galbana* and *Tetraselmis* sp. at a density of 10^5 cells/ml) were added once to the aquaria as food for the veligers. Water temperature remained between 25 and 28.5 °C, and salinity, 31 to 34 ppt.

When most of the larvae (>50%) reached the pediveliger stage, they were transferred to 1m x 2m x 0.5m tanks with 450 liters of filtered seawater. Pediveligers from the three spawnings were stocked at different densities: 4/ml, 3/ml and 1/ml. The rearing tanks were supplied with fresh filtered seawater at a rate of 156.5 - 194.6 l/min for at least 8 hours per day. Five liters of mixed *Isochrysis galbana* and *Tetraselmis* sp. culture (10^5 cells/ml) were added to each tank every other day. Transparent plastic roofing excluded rain from the tanks. The substrate for larval settlement in the three tanks differed. One had a few pieces of coral rubble and stones; the second had coral fragments, pebbles and stones occupying about [illegible] of the bottom surface; the third had plastic matting. The bottom of the second tank was divided into five equal areas of [illegible] m², four of which contained different substrates: coral fragments, smaller coral rubble, pebbles and stones; the fifth area was bare. The intent was to assess differential use of substrate by juveniles.

RESULTS

Spawning.

A total of 18 spawnings occurred in the laboratory from December 1984 through April 1985 (numbers in parentheses): February (2), March (1), April (2), May (1), July (1), August [illegible], September (3), October (3), November (2) and December (1). Five (27.8%) spawnings occurred spontaneously and 13 (72.2%) were induced with serotonin only, macerated gonad only, or both (Table 1). All spontaneous spawnings occurred in 1985, involving an unknown number of clams. In four of these spawnings, the water temperature in the holding tanks had risen to 30-34 °C from about 1200 h to late afternoon (1730 h) and spawning must have occurred between 1545 and 1650 h. In the fifth instance there was no appreciable rise in water temperature, and spawning probably occurred between 1800 and 1900 h.

Table 1. Summary of data on Hippopus hippopus spawning induction experiments. All clams used beginning July 25, 1985 showed mature eggs by biopsy. Broodstoc were held in laboratory tanks from few days to several months.

Date of Experiment	Number of Clams Induced	Date Collected (Number)	Spawning Stimulus	Result
10 Dec 84	6	20 Oct 84	Macerated gonad	Two released sperm
05 Feb 85	8	20 Oct 84	Macerated gonad	All released sperm
12 Apr 85	6	20 Oct 84	Macerated gonad	Three released sperm
09 May 85	3	20 Oct 84	Macerated gonad	Two released sperm
25 Jul 85	3	20 Oct84(2) 24 Jul85(1)	Macerated gonad	All released sperm
14 Aug 85	2	13 Aug 85	Macerated gonad	One released sperm, the oth released sperm & then eggs; normal development to juvenil stage
16 Sep 85	3	Apr 85	Macerated gonad	All released sperm
21 Sep 85	3	20 Oct 84	Macerated gonad	All released sperm
26 Sep 85	1	Apr 85	Macerated gonad	Released sperm
20 Nov 85	3	16 Nov 85	Serotonin	All three released sperm, onl one released few eggs.
28 Nov 85	2	26 Nov 85	Macerated gonad	Only one released sperm an few ripe eggs, which develope to one-day old trochophore larvae
28 Feb 86	2	Apr 85	Serotonin followed by macerated gonad after 2 hr	Only one released sperm aft addition of macerated gonad
27 Mar 86-01 Apr 86	3	20 Mar 86	Serotonin followed by macerated gonad after 5 days	Only one released sperm after addition of macerated gonad

Table 2. Data on survival of Hippopus hippopus larvae reared in the laboratory .

	DATE SPAWNED		
	14 Aug 1985	30 Aug 1985	15 Oct 1985
Number of eggs spawned	59,940,000 (933/ml)	2,000,000 (33/ml)	-
Number of fertilized eggs	1,200,000 (20/ml)	300,000 (5/ml)	4,500,000 (75/ml)
Number of trochophore larvae	480,000 (8/ml)	250,000 (4/ml)	300,000 (5/ml)
Number of veliger larvae	300,000 (5/ml)	70,000 (1.2/ml)	240,000 (4/ml)
Density of pediveliger larvae	4/ml	1/ml	3/ml
Number of juveniles	90 (3.5 mo. old)	1,493 (3 mo. old)	4,357 (4 mo. old)
Percent survival rate of fertilized eggs to veliger	25.0	23.3	5.3
Percent survival rate of fertilized eggs to 3-4 mo. old juveniles	0.0075	0.497	0.0968
Percent survival rate of veligers to 3-4 mo. old juveniles	0.0375	2.13	1.82

Note: Numbers of eggs and larvae are estimates determined by the volumetric count method of Castagna and Kraeuter (1984); numbers of juveniles were determined by actual count.

Only sperm were released in ten induced spawnings, althou biopsy showed that at least 50% of the eggs were mature, fo experimental clams used beginning July 1985. Spawning of sper and eggs occurred during or near the full moon (4 out of 8), th new moon (3) and the first quarter (1). Sperm were released a all phases of the moon.

Larval development.

Mature eggs of *Hippopus hippopus* are spherical in shap measuring 143.16 ± 7.26 µm in diameter (n=10; range, 127.5-150. µm, excluding the membrane). One clam 183 mm long released abo 60 million eggs upon induction with macerated gonad. The numbe released by clams which spawned spontaneously was not kno because of the undetermined number of spawning individuals.

Larval development was observed for two batches of eg released on 14 and 30 August 1985. The fertilized eggs underwe cleavage after one hour, developed into trochophore larvae withi 20 hours, straight-hinge veligers in 22-26 hours and pediveliger in about five days (range 4 to 7 days). Pediveligers swam a crawled on and near the bottom. They settled on about day (ranging from day 6 to day 10) and generally metamorphosed day 9 (ranging from day 8 to day 12). Zooxanthellae were clear visible in 17-day old juveniles.

Substrate and larval settlement.

The numbers of three-month old juveniles which were fou attached to the four types of substrate in one of the larv tanks were as follows: 633 on coral fragments (length 4.2-10. cm), 211 on the coral rubble (length 1.8-5.0 cm), 215 on ston (dia. 2.5-7.4 cm), 320 on pebbles (dia. 0.5-1.5 cm) and 114 the bare area. (Most clams in the area were found attached objects which were accidentally introduced [a piece of wood, broken piece of PVC pipe and a leaf] and only 24 to the concre floor.) The clams were unevenly distributed, the largest numbe attaching to the coral fragments (chi-square from a contingen table = 539, df=4, p <.001).

Larval survival.

Larval survival rates are shown in Table 2. For the thr batches of trochophore larvae stocked at densities 8/ml, 4/ml a 5/ml, the survival rates to veligers were 62.5%, 28% and 80 respectively. Veliger survival rates to 3-4-month-old juvenil were 0.03%, 2.13% and 1.82%, respectively. The second and thi batches, with about 2% survival rates, were provided wi substantial settlement substrate, but the first batch was no This batch had the lowest survival rate. The influence of su strate on settlement is not yet known.

arval and early juvenile growth.

Growth of the larvae and juveniles up to the day-56 juvenile observed for two batches. Two-day-old straight-hinge veligers a mean length of 189.3 µm ± 24.0 (range 151-220 µm; n=10). -day-old pediveligers measured 223.5 µm ± 12.7 (range 209- n=7). Juveniles on day 17 had a mean length of 281 µm (range -301 µm; n=3) and on day 56, 382-452 µm (n=2).

Subsequent data on juvenile growth included individuals from three batches of spawn. Those from the first batch had a of 464-475 µm (n=2) on day 62 and a mean length of mm ± 2 (range 1-9 mm; n=22) on day 120. Individuals from the batch were much longer, with a mean of 12 mm ± 3.42 (range mm; n=100) on day 110. Individuals from the third batch had length of 0.5 -1 mm (n=2) on day 98 and a mean length of 7.13 ± 3.0 (range 1-15 mm; n=100) at day 134. A wide variation in in length is evident among individuals in a batch and een individuals belonging to different batches.

DISCUSSION

ing.

Of the 22 clams induced to spawn with macerated gonad or serotonin, four (18.2%) did not respond and 18 (81.8%) sed either sperm only or both sperm and eggs. Only three of 18 (16.7%) spawned eggs. In comparison, Fitt et al. (1984) ed two out of ten (20%) success for gonad induction; Braley) reported 12 out of 23 (52.2%) for serotonin induction and r (unpubl. data) gave 12 out of 14 (85.7%), also for nin induction. Despite biopsy data showing the presence of e eggs in our experimental animals, only a small proportion clams produced eggs, comparable to the results of Fitt et 1984) but much smaller than those of Braley (1985) and r (unpubl. data); these differences are significant (chi- = 18.226, df= 3, p <.001). The reason for the low tion of our clams producing eggs is not known. It should be , however, that the samples of Fitt et al.(1984) came from Caroline Islands at about the same latitude as the south-l Philippines, while those of Braley (1985) and Alcazar l. data) were from the Great Barrier Reef.

l behavior and growth.

In general, the behavior of the larvae followed that bed by Jameson (1976) and by Fitt et al. (1984). phore and veliger larvae were free-swimming, and eligers crawled and swam on and near the bottom. Settlement red 6-10 days after fertilization, mostly on day 7.

Metamorphosis to juveniles occurred between days 8 and 12, most on day 9, when the larvae were about 231-234 μm in length. Fi et al. (1984) gave 185-195 μm as the size at metamorphosis. T juveniles were first seen to harbor zooxanthellae on day 17. O veligers and pediveligers were slightly larger than those Jameson (1976) and Fitt et al. (1984), but our juveniles on da 56 and 62 were much smaller than those of Jameson (1976) on d 58.

Larval survival.

Larval (veliger) survival rates to juveniles for our thr batches of spawn varied from a low 0.03% to a relatively high 2 The low rate is tentatively ascribed to inadequate settlement substrates in the rearing tanks. Survival and growth rates m have been enhanced if the veligers were fed with a nutritio supplement (vitamins, yeast extract) in addition to t unicellular algae, following Fitt et al. (1984).

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OBSERVATIONS ON PREDATORS OF GIANT CLAMS (BIVALVIA: FAMILY TRIDACNIDAE)

Sally N. Alcazar

Giant clams are now the subject of mariculture studies throughout the Indo-Pacific region (Gwyther and Munro, 1981; Fitt et al., 1984; Heslinga and Watson, 1985). One question to be answered before large-scale culture is attempted is the extent of predation in the natural habitats. This paper presents preliminary observations on predation on five species of tridacnids (*Tridacna crocea* [Lamarck], *T. derasa* [Röding], *T. maxima* [Röding], *T. squamosa* [Lamarck] and *Hippopus hippopus* [Linn.]) in the laboratory and in nature.

METHODS AND MATERIALS

Observations on clam predation were made in the natura habitats while skin or SCUBA diving and in the laboratory. Bo laboratory-spawned juvenile clams and adult clams collected i nature were observed. Potential predators (three gastropods three fishes and three crabs) were collected from coral reefs The choice of these nine predator species was based primarily o their availability, but, for some, also on anecdotal report about their clam-feeding habits. In the laboratory, two to fo clams, each belonging to one species, were simultaneousl exposed to one unfed potential predator in 60-l glass aquaria a were observed for periods varying from two to seven days. T water in the aquaria was aerated and kept at a temperature o 26.5 to 31°C.

RESULTS AND DISCUSSION

Clam predation in nature was observed only once, despite t large number of dives (>100): a 17-cm-long tulip she *Pleuroploca* sp. attacked an 8.5-cm-long *T. maxima*.

Eight of the nine species of potential predators were fou to attack giant clams in the laboratory (Table 1). The excepti was the bat volute, *Voluta vespertilio*, which did not attack *maxima*, *T. squamosa* and *H. hippopus*. The muricid *Chicore ramosus* probably also preys on giant clams in the natur

Table 1. Summary of laboratory observations on clam predation, (+) attacked, (-) not attacked, (O) not tested.

PREDATOR SPECIES	CLAM SPECIES				
	T. crocea	T. derasa	T. maxima	T. squamosa	H. hippopus
Chicoreus ramosus	+	O	+	+	+
Pleuroploca sp.	+	O	+	+	+
Voluta vespertilio	O	O	-	-	-
Balistapus undulatus	+	O	+	+	+
Halichoeres sp. 1	+	O	+	+	-
Halichoeres sp. 2	+	O	+	+	-
Demania alcalai	+	+	+	+	+
Carpilius convexus	+	+	+	+	+
Thalamita sp.	O	O	+	O	+
Number attacked and consumed	7	9	8	8	8

habitats, as the family Muricidae is a well-known molluscan predator. Whether the other six species observed to attack clams in the laboratory do so in nature also is not known.

The predators exhibited various modes of attack. Chicoreus ramosus injects a toxic substance causing paralysis of clam muscles through a hole which it drills through the valve. It then sucks the fluids of the prey by means of its proboscis, inserted through the hole (Halstead, 1978). Chicoreus was also observed attaching directly to the clam through the gaping valves. Pleuroploca immobilized the clams by clasping the mantle with its foot, bringing its shell lip against the clams´ valves and preventing their closure. The predator then inserted its proboscis into the soft tissues, which it consumed. Balistapus undulatus fed on the mantle and the exposed byssus and foot of adult clams. Halichoeres fed only on the byssus and foot of unanchored clams. The xanthid crabs Demania alcalai and Carpilius convexus used their chelae to break the valves of juvenile clams before feeding on their soft tissues.

The portunid crab *Thalamita* probably penetrated the soft tissu of adult clams through either the byssal orifice or the inhale siphon and fed on the soft tissues and mantle from within.

Six predatory species (*C. ramosus*, *Pleuroploca* sp., *undulatus*, *Halichoeres* spp. and *Thalamita* sp.) fed on both adul and juveniles; two (*D. alcalai* and *C. convexus*), on juvenil only. *T. squamosa* was vulnerable to the attacks of *Balistap* because its valves in adult animals do not close complete exposing the mantle. Clams with a large byssal orifice (*crocea*, *T. maxima*) were readily attacked by *Halichoeres* wh detached from the substrate. Among the clams observed, *hippopus* suffered the least from predation; only *Chicore ramosus* and *Pleuroploca* attacked it. *C. ramosus* attack *Tridacna* spp. before *Hippopus* when these clam species we presented to the predator. *C. ramosus* and *Pleuroploca* attack all five species of giant clams.

Heslinga and Watson (1985) and Perron et al. (1985) report controlled experiments in Malakal harbor, Palau, Caroli Islands, in which juvenile *T. derasa* were preyed upon by t muricid gastropod *Cymatium muricinum*. Heslinga et al. (198 indicates that another muricid species, *Chicoreus ramosus*, also a natural predator at Palau.

My observations on clam predation, which lacked adequa controls, are preliminary, serving to indicate lines for futu laboratory experiments. Although a predator has been observ attacking a natural population, the extent of this predation as yet unkown.

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58 SILLIMAN JOURNAL, 1986, VOL. 33, NOS. 1-4, pp. 58-64

SPAWNING AND LARVAL REARING OF *SIGANUS GUTTATUS* (BLOCH) (PISCES: SIGANIDAE)

Sally N. Alcazar and Julieta A. Luchavez

The successful spawning and larval rearing of *Siganus guttatus* (Bloch) up to the post-metamorphosis stage is reported. *S. guttatus* generally spawns within the first quarter moon, laying an estimated half million eggs. The incubation period lasts for about 24 hours. Newly hatched larvae depend on yolk and oil globules for nourishment. They begin feeding on day two, when the yolk and oil globules have been almost consumed. Complete metamorphosis is observed to occur on day 30. Larval survival depends on (1) adequate and proper food and (2) sub-toxic nitrite concentration in the rearing container.

The earliest work on the reproductive biology rabbitfishes (Family Siganidae) in the Philippines dealt with t artificial fertilization of "danggit," *Siganus oramin* (Bloch a Schneider) [=*Siganus canaliculatus* (Park)], by Manacop (1937 Burgan and Zselecsky (1979) reported on induced spawning a larval growth of *Siganus argenteus* (Quoy and Gaimard) and Alca and Alcazar (1979) reported on the gonad morphology, oocy development and gonad index of *Siganus canaliculatus* (Park Alcala and Luchavez (1980) described the spawning and ear development of *Siganus guttatus* (Bloch). Studies on the reari and larval development of some species of rabbitfishes have be made elsewhere (May, 1970; Bryan and Madraisau, 1973; May et a 1974; Popper et al. 1976; Popper and Gunderman, 1976; Soh a Lam, 1973).

The feasibility of culturing rabbitfishes has be entertained for the last ten years (Ben-Tuvia and Kissil, 197 von Westernhagen, 1974; Tsuda et al., 1974; Popper a Gundermann, 1974; Tahil, 1978). Tahil (1978) found that reari *S. guttatus* in cages did not appear promising; however, suggested that improved techniques and further investigati might lead to successful results. Luchavez (1986) had so success in cultivating *S. guttatus* in inland ponds.

Observations on spawning and larval rearing of *Sigan guttatus* reported by Alcala and Luchavez (1980) showed that *guttatus* can spawn in captivity without hormonal treatment. Ho ever, the larvae survived only for five days due to inadequa and improper food, and nitrite accumulation in the rearing tank

This paper reports on the early development and successful ring of *Siganus guttatus* larvae up to post-metamorphosis ges.

MATERIALS AND METHODS

Preparation.

The spawners, consisting of four males and nine females ed in one concrete rearing tank measuring 1 m long x 2 m wide 1 m deep, were maintained on a mixed diet of the algae laria and *Enteromorpha* collected in nature. Food pellets red by mixing rice bran, fish meal, bread flour and vitamins added to the diet to enhance regular spawning (Jesus Juario, comm.). The spawners were fed three times daily.

Phytoplankton (*Chlorella* and *Tetraselmis*) and zooplankton ionus, copepods and the brine shrimp *Artemia*) were cultured food for the *Siganus guttatus* larvae. Trochophores of two es of oysters, *Crassostrea cucullata* (Born) and *Crassostrea* gathered in nature, were used to feed the fish larvae taneously or alternately with the cultured planktonic food. ophore cultures were prepared by stripping the male and e gonads of oysters a few hours before feeding, then mixing in a jar to effect fertilization and to allow development.

Larval feeding was done from the second day after hatching after metamorphosis, when the larvae were capable of g. The metamorphosed larvae were fed with powdered pellets arly and small amounts of *Enteromorpha* occasionally.

ing and Early Development.

The spawners (130 - 237 mm total length) were sexed by lation two or three days before the expected date of ing. A male and female pair was placed in each of the four - 1 glass aquaria. These were about one-third filled with filtered sea water and totally covered with black plastic s, to minimize stress due to disturbance. The fish were not for three to four days before spawning to prevent fecal lation and the resulting fouling of the water in the tank. and Lam [1973] observed that some species of siganids do not before spawning.) After spawning, the fish were transferred the large stocking tank and fed. The fertilized eggs were to develop and hatch in the spawning containers. By using a fitted with a 48-µm filter, water in the spawning iners was changed often to prevent excessive nitrite lation. The number of eggs laid per female spawner was ined by siphoning out all the water and replacing it with ml of sea water. The number of eggs in an aliquot of 100 ml counted. The average of three trials multiplied by 10 was taken to represent the total number of eggs laid by one femal

During the incubation period, a few fertilized eggs w observed under the microscope and the time needed for them hatch after fertilization was noted.

Larval rearing.

The newly hatched larvae were transferred to three concr tanks (2 m long, 1 m wide, 1 m deep) with water of two differ salinities (25 and 30 ppt). The first tank (oval-shap contained 30 ppt sea water and the unicellular alga Chlorel the second (rectangular-shaped), 25 ppt sea water, and the th (oval-shaped), 25 ppt sea water and zooplankton.

Water temperatures taken morning, noon and afternoon ran from 27 to 32 C. Nitrite content was determined every other from day 1 to day 10 and maintained at less than 10 mg/l, toxic level, by frequent changes of the water. Dissolved oxy was determined only on the first five days. Water in the t was changed daily until metamorphosis.

Feeding of the larvae was started on the second day, w the yolk and oil globules were almost completely absorbed. T were fed with trochophore larvae of Crassostrea spp. during first four or five days, Brachionus plicatilis from day 5 to and Artemia nauplii and copepods from day 15 to metamorphosis.

RESULTS AND DISCUSSION

Siganus guttatus spawned from one to six days after first quarter moon, based on 10 spawning events from March December 1981. The exact spawning time is not known, but se to be late afternoon (1730 - 1800 h) or evening (2200 - 2400 or early morning (0300 - 0430 h). Spawning of this species, l that of other rabbitfishes, is influenced by the lunar cy (Alcala and Alcazar, 1979; Burgan and Zselecsky, 1979; Popper Gundermann, 1976; Popper et al., 1976; Manacop, 1937).

Other siganid species with monthly spawning times similar S. guttatus are S. vermiculatus, which spawns one or two d after the first quarter moon (Popper and Gundermann, 1976), S. lineatus, which spawns three days before the full moon (Br and Madraisau, 1977). S. canaliculatus spawns from four to se days after the new moon (Manacop, 1937), while S. argent spawns from two to five days following the new moon. The ho of spawning for Siganus are as follows: S. argenteus, betw 0200 and 0400, or before dawn (Burgan and Zselecsky, 1979), canaliculatus, around midnight (Bryan et al., 1975; Manac 1937); and S. lineatus, around 0600 or 0700 (Popper et a 1976).

Based on six females, the number of eggs per female spaw was estimated at 400,000 to 500,000. The eggs were sligh ive and demersal, with several oil globules. Unfertilized were transparent, with the yolk occupying two-thirds of the re egg. The mean size of the fertilized egg was about 0.59 (SD= 0.008; range: 0.57 - 0.60 mm). About an hour after ilization, eggs became opaque and oil globules became inent.

The two-cell stage was reached after 1.5 hours; the early la stage, after 4 hours; the ring stage, after 5.5 hours. embryo, which appeared curved, began to exhibit twisting ments the twelfth hour after fertilization. Hatching occurred hours after spawning, or 12 hours after fertilization. The length of the newly-hatched larva was 2.06 - 2.10 mm (n = After hatching, the larva depended on the yolk and oil ules for nourishment. This stored food lasted for two days.

On day 1, about one day after hatching, pigmentation started appear on the antero-dorsal part of the head and ventrally, g the body from the abdominal cavity to the tail region. At stage, the lens and optic vesicle appeared bluish, slightly parent and non-functional. The mouth was not yet fully ed. The one-day-old larvae had a mean total length of 2.45 SD=0.013; range: 2.43 - 2.47 mm; n = 50).

On day 2 pigmentation thickened and became very dark. The and the optic vesicle started to become functional. The was fully opened; the yolk and oil globules were still ent, but the yolk was almost resorbed. The gut was a single lar organ. The mean total length of the larvae at this stage 2.52 mm (SD=0.012; range: 2.49 - 2.53 mm; n = 50). Migratory ior was noted when the larvae showed signs of splashing from bottom towards the midwater.

On day 3 the eyes were not yet fully developed, but the lens become conspicuous. The gut had started to form two loops the brain had begun to develop just behind the eyes. The ord was still a straight tube. The yolk at this stage was etely resorbed, but oil globules were still present. At stage, the larvae began to avoid strong illumination, ng to stay in the shaded part of the rearing tank container, food was also abundant. The mean total length of the three-ld larvae was 2.63 mm (SD=0.007; range: 2.62 - 2.65; n = 5).

On day 4 pigmentation was concentrated in the abdominal on. Oil globules had completely disappeared; the brain and nerve cord were completely formed. The vertebrae were ng to be distinct. The larvae now were capable of swimming ally and vertically from the bottom to the surface to feed, ting a snatching behavior. The mean total length of the ae was now 2.79 mm (SD=0.005; range: 2.78 - 2.79; n = 3).

On day 5 somites had formed. The heart and the gills were ional, the gut had developed into three loops, and the eyes fully developed. The mean total length of the larvae was 2.81 mm (SD=0.012; range: 2.80 - 2.81 mm; n = 3).

On days 6 and 7 the head was fully developed but the eyes still over-sized in relation to the head. The fins were also fully developed and enabled the larvae to escape from disturbance in the water. The mean total length of the six- seven-day-old larvae were 2.94 mm and 3.43 mm.

On days 8 and 9 there were no microscopic observations to limited survival (only about seven or eight larvae were see

On day 10 larvae had fully developed muscular and nerv systems and the eyes were now proportionate to the head. operculum and the ventral and dorsal fins were hig functional.

Of the 15,000 larvae stocked in the tank, only six completely metamorphosed on day 32, and only one survived to juvenile stage. That juvenile was maintained on pelletized f and Enteromorpha spp. in the laboratory.

From the second batch of eggs spawned in April 1982, larvae metamorphosed out of 30,000 stocked in a 4000-l tank, 0.03% survival rate. Six fry fed with pellets and Enteromor spp. survived to sexual maturity (ca. 100 - 160 mm total lengt

CONCLUSION

Siganus guttatus can be successfully cultured if (1) a quate and appropriate food is supplied to the larvae and (2) water quality is favorable for development. The fact affecting water quality are temperature, salinity, oxygen cont and nitrite concentration.

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SPAWNING, LARVAL DEVELOPMENT AND GROWTH OF TRIDACNA MAXIMA (RÖDING)(BIVALVIA:TRIDACNIDAE)

Sally N. Alcazar and Erwinia P. Solis

Adult T. maxima were successfully induced to spawn in the laboratory using macerated gonad in December 1984 and January 1985. Spontaneous spawnings occurred in February and October 1985. Spawning can be induced in the morning as well as in the afternoon. Larvae were reared to the juvenile stage in larval rearing tanks and larval development monitored. A stereotyped development pattern was displayed. Less than 1% of juveniles survived from eggs. Four-month-old juveniles placed in raceways provided with a continuous flow of unfiltered sea water attained a mean shell length of 38.35 mm after eight months, with an average monthly growth of 4.1mm ± 0.8.

Giant clams (F. Tridacnidae) are highly specialized bivalves inhabiting shallow waters in the Indo-Pacific region. The largest bivalves in the world, they have been known to be overharvested for their shell and meat (especially adductor muscle) (Hester and Jones, 1974; Bryan and McConnel, 1976; Hirschberger, 1980). Little is known of the biology and ecology of giant clams (Pearson, 1977); but, due to the rapid decline in their population, a number of studies have focused on their reproductive biology (e.g. Stephenson, 1934; Wada, 1954; Braley, 1984, 1985) and mariculture potential (e.g. Yamaguchi, 1977; Munro and Heslinga, 1982; Heslinga et al., 1984).

There are, however, only a few studies focusing on Tridacna maxima (Röding). Spawning induction using macerated gonad has been discussed extensively by Wada (1954). LaBarbera (1975) and Jameson (1976) reared larvae of T. maxima, and both studies reported the mechanism and rate of development from larval to postlarval stages. The effect of food supply on larval growth and substrate preference of larvae were discussed extensively by Gwyther and Munro (1981).

Studies on the spawning, larval rearing and growth of several species of giant clams are presently being conducted at the Silliman University Marine Laboratory under the Australian Center for Agricultural Research (ACIAR) Giant Clam Project. Successful spawning induction and larval rearing were conducted on T. maxima. The aim of this paper is to present data on spawning, larval development and growth of T. maxima un laboratory conditions.

MATERIALS AND METHODS

Spawning.

Wild stocks of T. maxima were collected from reefs various localities in the Visayas, central Philippines, transported to the laboratory in buckets filled with sea wat Individuals were placed in outdoor cement tanks (2m x 3m x 0. supplied with flowing sea water eight hours a day. Salinity the stocking tanks ranged from 30 to 32.5 ppt and temperature, to 33 °C.

Spawning inductions were conducted in the larval rear tanks (1m x 2m x 0.5m), filled with 400 liters of filtered water. Two larval tanks were used when inducing more than f clams at one time. Spawning was induced using macerated gon following the method of Wada (1954). Material used for induct was prepared by slicing gonads from sacrificed adult T. max into pieces, weighing each piece and packing them in plas bags for storage in the freezer. Fresh macerated gonad was u during the first spawning induction. For the succeed experiments, however, a desired amount of frozen gonad was tha out immediately prior to induction. The gonad material was min and pounded in a mortar with a small amount of filtered water. The macerated material was then filtered using an 80 mesh filter cloth to remove excess tissues and prevent bacter fouling in the larval tanks.

The clams to be used for spawning were chosen at random f the stocking tanks for any particular experiment. Adher epibiota on the shells was removed using a nylon brush. Cl were taken out of the water and left an hour to induce str and facilitate spawning induction. Clams were then transferred larval tanks and induced to spawn by pouring macerated go material near their inhalent siphons. One to three hours af spawning, adult clams were removed from the larval tanks, was and returned to the stocking tanks.

In cases of spontaneous spawning (non-induced) in stocking tanks, gametes were scooped with a fine mesh net buckets and transferred to the larval rearing tanks.

The spawning history of each clam was recorded, includ time of induction, sex of gametes and number of releases, duration of spawning.

Larval rearing.

After the removal of adult clams, filtered sea water added to the larval tanks to a total volume of 800 liters. Lar were monitored by taking water samples from the surface for the first three days and from the bottom on succeeding days. Larval development was examined under a compound microscope. Volumetric counts were also monitored for each larval stage.

Unfiltered sea water was pumped into the tanks for at least five hours a day, seven days after fertilization, until the larvae became macroscopic. After three to four months, the juveniles were scraped from the bottom of the tanks by hand or using a knife. These juveniles were then transferred to raceways containing pieces of coral, which served as a substratum. Flow of unfiltered sea water was maintained for eight hours a day.

Growth.

Growth of the juveniles reared in the laboratory from April to October 1985 was monitored. All juveniles were counted and the shell length of 50 animals was measured using a small plastic vernier caliper every one to two months. Water temperature and salinity were monitored twice a day, in the morning and afternoon. Water temperature ranged from 23 to 30 °C, salinity from 25 to 35 ppt.

RESULTS AND DISCUSSION

Spawning.

For this study, successful spawning was defined as the release of sperm and eggs by one or more clams. T. maxima, held in stocking tanks for one to three months, were successfully induced to spawn sperm and eggs by adding macerated gonad to the water. Table 1 shows the summary of spawning inductions from December 1984 to October 1985. Water temperature in the spawning tanks ranged from 26 to 29°C, and salinity was between 27 and 33 ppt. Two of five spawning inductions were successful. Spontaneous spawnings also occurred on two occasions, 28 February, 1985 and 15 October, 1985.

The two spontaneous spawnings were observed to occur at the first quarter and a day after the new moon. Of the induced spawnings during which fertilized eggs developed successfully, one occurred two days after the last quarter and the other, at the first quarter. The lunar phases in which successful spawning induction of T. maxima occurred appeared to correspond with those of T. gigas at Palau (Heslinga et al., 1985), but further investigation of spawning time is required.

Successful spawning of T. maxima in the laboratory was induced in the morning as well as in the afternoon (Table 1). Spawning probably does not occur at night; in this study, it was observed that the valves of clams were either half-way or fully closed at night. Giant clams typically close their valves and remain quiescent until dawn (Gwyther and Munro, 1981; Heslinga al., 1984).

The probable causes of spontaneous spawning in the laborato could not be determined. Other studies have shown that sponta eous spawning is stimulated by high temperature (Stephenso 1934) and by water movement (Jameson, 1976).

Table 1. Data on spawning inductions of *T. maxima*.

	DATE				
	12/18/84	01/30/85	03/14/85	04/29/85	07/31/
No. of clams used	ND	I 6 * II 6	5	I 6 * II 6	4
Size range (cm)	13-23	I 14-22 II 13-22	18-22	I 11-22 II 13-22	15-20
No. of clams spawned	ND	I 2 II 2	2	none	none
Amount of gonad used (gm)	ND	I 7 II 3	150	30	40
Time induced	1055 h	1421 h	1600 h	1050 h	1000
Time from induction to spawning	ND	I 4min. II 3min.	6-14min.	-	-
Duration of spawning	ND	I 42min. II 19min -2hrs & 19min	2 min.	-	-

ND - Not Determined
* - Two larval tanks used: 6 clams each

Preliminary results of this study have similarities with t observations of Jameson (1976) on the gonad condition of a pop lation of *T. maxima* on Guam. Our clams released their gametes the months of December, January and February, but only sperm March. Spawnings were not observed between April and July. It w only in October when the clams again released their gamete

The number of eggs released was determined only once. volumetric count, approximately 7,690,000 eggs were releas during the first successful spawning.

Fertilization and early development.

In this study, normal fertilization and early development of T. maxima eggs in the laboratory appear to be influenced by the quality of the sea water, maturity of clams and extent of polyspermy. Large numbers of ciliates in the sea water were observed to penetrate the eggs, causing the latter to break up. Immature eggs were oval-, sickle- and rod-shaped, and were not fertilized by viable sperm. Ripe eggs tended to be spherical in shape and were more opaque than unripe eggs. The abundance of sperm in the water often resulted in polyspermy, which in turn caused the nondevelopment of the eggs. Mature eggs surrounded by several sperm were observed to remain undeveloped for two days. Cases of polyspermy were also encountered by LaBarbera (1975) and Jameson (1976), indicating poorly developed barriers to polyspermy in tridacnids (LaBarbera, 1975). In addition, overabundance of sperm in the water contributed to bacterial fouling.

Larval development.

T. maxima larvae obtained from the successful spawning inductions on 18 December 1984 and 30 January 1985 were also successfully reared through the juvenile stage in the laboratory. The early life chronology and larval descriptions of T. maxima agree closely with the reports of LaBarbera (1975), Jameson (1976) and Gwyther and Munro (1981). Fertilization of eggs occurred immediately after spawning, and the blastula stage was attained after four hours. After 24 hours, trochophores hatched and swam. Straight-hinge, D-shaped veligers with ciliated velum and stomach were observed on the second day. On the fourth day, the beginnings of foot formation occurred, indicating the start of the pediveliger stage. Settlement occurred on day eight, and pediveligers were seen crawling on the bottom on day nine. Closing and opening of valves, elongation of foot and presence of [illegible] were observed in few crawling pediveligers, indicating the completion of metamorphosis. On day 15, more than 50% became juveniles. A pair of gills and brown spots (which indicate the presence of zooxanthellae) on the anterior portion of the valves were observed on day 21.

The rate of development of the laboratory-reared T. maxima in this study differed from that of those observed in Fiji (LaBarbera, 1975), Guam (Jameson, 1976) and Papua New Guinea (Gwyther and Munro, 1981). This variability is probably due to differences in culture conditions, such as temperature and rearing techniques (Heslinga, pers. comm., 1985).

Early life and juvenile survival.

Estimates of larval and juvenile survival (Table 2) showed that greatest mortality occurred in the pediveliger and juvenile stages. Only 5.5% of fertilized eggs developed into veligers;

33.3% of veligers arrived at the pediveliger stage. About 0.9
of pediveligers metamorphosed into juveniles; only 0.02%
fertilized eggs developed into juveniles. Beckvar (1981) al
encountered mortality greater than 99% from egg to juvenile sta
in laboratory-reared *T. gigas* in Palau.

Several factors have been identified to cause low surviv
in the pelagic developmental stages. These include polysperm
self-fertilization and unavailability of suitable substrate f
settlement (Gwyther and Munro, 1981). However, successful rea
ing of pediveligers of *T. derasa* and *T. squamosa* without speci
substrate has been recorded (Beckvar, 1981; Heslinga et al
1985).

Table 2. Survival rate (%) of *T. maxima* in the laboratory
from December 1984 to April 1985.

STAGE	Approximate count	% Survival based from number of fertilized eggs	% survival fr previous sta
fertilized eggs	7,680,000	-	-
trochophore	not determined	-	-
veliger	420,000	5.5	-
pediveliger	140,000	1.8	33.3 (from veli
juvenile	1,396	.02	0.99 (from pedi veliger)

Clumping of juveniles on coral rubble and in the corners
raceways was often observed, and many empty shells were found
these clumps. Juveniles 5 mm and less were observed to be sens
tive to overcrowding, and easily died. It is not known
crowding is related to the observed mortality.

Growth.

The monthly mean shell length of *T. maxima* under laborat
conditions from April (four months old) to December (one ye
old) 1985 is presented in Table 3. The results show that a me
length of 38.35 mm is attained in one year, which agrees with t
data of Munro and Heslinga (1982). Growth of four-month-old

Table 3. Data on growth of T. maxima (four-month-old) from April to December 1985 (n = 50),

MEAN SHELL LENGTH (mm) ± S. D. (range)							GROWTH RATE (mm)/month
APRIL	MAY	JUNE	JULY	SEPT.	NOV.	DEC.	
[illegible]±4.6 ([illegible]-10)	8.2±7 (1.8-15)	11±9 (12-20)	17.3±5.2 (7.4-28.9)	19.86±5.3 (8-27)	26.89±6.81 (15-45.5)	38.35±6.07 (26.3-49.7)	4.1±0.8

maxima in raceways after eight months showed that the clams grew an average of 4.1 mm per month. Intensive cultivation of T. maxima for large-scale commercial mariculture for food may not be profitable as an industry. Yamaguchi, (1977) expressed a similar view. Cultivation of this slow-growing species as an aquarium pet may be feasible, as demand is slowly growing in some parts of America (Heslinga, pers.comm., 1985).

SUMMARY AND CONCLUSIONS

Induced spawning using macerated gonad was found to be effective in inducing adult T. maxima to spawn successfully in December 1984 and January 1985. This method is not only efficient, but is also the easiest method (Jameson, 1976). Spontaneous spawnings were observed twice, in February and October 1985. Successful spawnings have been induced in the morning and in the afternoon. The quality of seawater, maturity of the eggs and polyspermy appear to be major factors influencing normal fertilization and development of eggs. Improved rearing techniques, a better quality of water and more broodstock are needed in the laboratory for increased larval and juvenile survival in the culture system.

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COMPARISON OF THE HERPETOFAUNAL SPECIES RICHNESS ON NEGROS AND CEBU ISLANDS, PHILIPPINES

Walter C. Brown and Angel C. Alcala

The terrestrial herpetofaunas of Negros and Cebu Islands, Philippines, are compared. The same non-forest species occur on both islands, except for two species recorded from Negros only. Cebu has half of the forest species recorded from Negros, virtually all of them found on both islands. This very close correspondence of species is most probably due to the origin of the Cebu fauna in the late Pleistocene, when Cebu and Negros were part of a hypothetical large island which also included Masbate and Panay. The smaller size of Cebu is probably not the primary factor in accounting for the smaller number of forest species on Cebu, since Bohol Island, nearby and about the same size as Cebu, has almost the same number as Negros. Also, no evidence is available to indicate that the forest species on Cebu have had any advantage in dispersal capabilities. Deforestation is proposed as the probable cause of the low number of forest species on Cebu Island.

The islands of Negros (land area 12,700 sq km) and C
(land area 4,400 sq km) lie in the Visayas (central) region
the Philippines, and are separated from each other by
relatively narrow and, in the north, shallow channel. Neg
consists mostly of andesitic volcanic rocks and derived volca
clastic sedimentary rocks, the oldest of which are of Cretace
age, while Cebu contains old rocks consisting of tightly fol
and slightly metamorphosed conglomerate, sandstone, shale, an
site, basalt and limestone, in which Eocene and Upper Cretace
foraminifers were embedded (see Hamilton, 1979:210-211). Neg
has higher mountain peaks than Cebu. Mt. Canlaon on Neg
reaches about 2,466 m above sea level; the tallest mountain
Cebu is only 1,013 m in elevation. It is hypothesized that C
and Negros, together with Panay and Masbate islands, formed
single land mass during periods of maximum lowering of the s
during the Pleistocene (see Heaney, 1985). Prior to that ti
Cebu most probably consisted of a series of raised islets.

In the past, most Philippine islands, including Negros and Cebu, bore a border of mangrove forests along the seacoasts and tropical rain forest elsewhere (see Merrill in: McGregor, 1920). Cebu has lost virtually all its rain forest (Table 1 and Fig. 1). Only scattered patches of typical secondary forest in ravines and approximately 90.6 sq km of mostly man-made forest remain, mostly around Buhisan Dam and Minglanilla.

Deforestation on Cebu appears to have been widespread as early as 1887-88, as inferred from comments of bird collectors. Bourns and Worcester (1894:10) noted that the bird Iole monticola (Hypsipetes siquijorensis monticola) ". . . is a highland form. It was invariably met with by us in the forest on the tops and sides of hills in Central Cebu and was never seen in open or flat country." The failure to find this bird in the lowlands implied that the lowland tropical rain forest was gone, since most species of Iole were lowland species (McGregor, 1920). Furthermore, Worcester (1898:576) mentioned the Steere Expedition's difficulty in finding suitable collection areas in Carmen town, "finding only now and then a small patch of trees at the summit of some steep incline." But in 1891, the expedition discovered a "fair-sized patch of forest" in which they collected several species in 1892. This was probably the "small amount of forest left in Cebu" in which Bourns and Worcester found the endemic bird Oriolus xanthonotus assimilis "exceedingly common" (see McGregor, 1909: 701; Rabor, 1959). Deforestation continued through the twentieth century, resulting in the total elimination of the original forest, except for very small patches near Cebu City.

In contrast to the sparse forest on Cebu, Worcester (1898:576) wrote about Negros island thus: "It offers excellent collecting ground, as its central chain of mountains . . . is abundantly clothed with forest...." The forested condition of the island persisted through the next two decades. McGregor (1920) included a map of existing commercial forests of the Philippines in his discussion of Philippine birds. The map depicted Negros as heavily forested (about 60% of the area). In the 1930s and the early 1940s no less than 50% of the land area of the island was occupied by lush rain forest (pers. obs. and pers. comm. with long-time residents). At present, less than 10%, probably a little more than 5%, is covered with primary tropical rain forest, and possibly another 20% with secondary forest, based on land satellite photographs and ground-truth verification (Table 1 and Fig. 1).

Brown and Alcala (1970:111) listed 23 species (not including Bufo marinus) which are very wide-ranging in the Philippines, either occurring primarily in or adapting readily to habitats other than dipterocarp (lowland tropical rain) forest or secondary growth forest. In characterizing species in terms of their abilities to adapt to habitats other than primary or secondary forest or such man-made habitats as abaca and coconut groves which are in contact with or close to such forest patches,

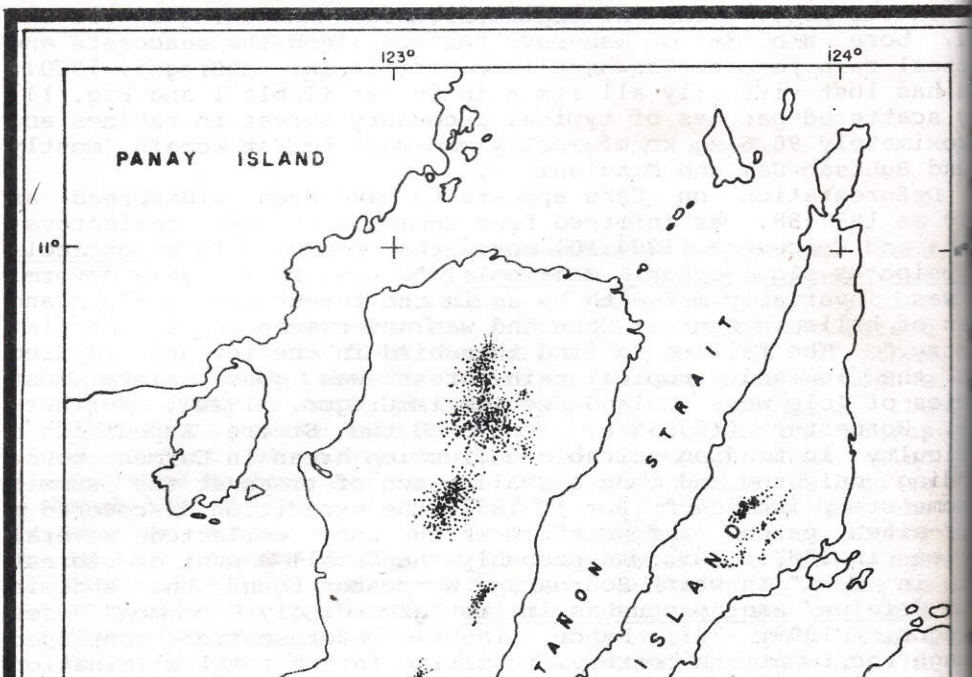

Fig. 1. Map showing the extent (stippled areas) of t
remaining primary rain forest on Negros Island and the man-ma
forest on Cebu Island.

Table 1. Summary of land areas, forest areas and herpetofaunal species of Negros, Cebu and Bohol Islands, Philippines.

	Negros	Cebu	Bohol	Philippines
Land Area (sq km)	12,700	4,400	4,000	300,000
Approximate Area of Tropical Rain Forest as of 1980 (sq km)	1,000*	91#	64+	-
Number of Amphibian Species	18	10	22	67
Number of Reptile Species	67	48	59	169
Lizards	35	27	35	109
Snakes	30	20	23	80
Turtles	1	1	1	3
Crocodiles	1	0	0	2
Total Number of Species	85	58	82	261

Primary Rain Forest, based on land satellite photograph, courtesy of the Philippine National Resources Management Center; forests are 1,000 m and above in elevation.

Personal communication, Bureau of Forest Development (BFD), Cebu City; about [illegible] sq km are man-made forest; some trees 50-65 years old.

Personal communication, BFD, Cebu City; ca 64 sq km of mostly secondary forest and man-made forest.

We now regard the following list as probably more accurate. Two species of snakes included in 1970, Ahaetulla prasina and Psammodynastes pulverulentus, have been deleted and several others added. Based on the data on habitats used by the Negros species (Brown and Alcala, 1964) and some subsequent data, 31 species are recognized as having adapted to man-made as well as non-dipterocarp, coastal vegetation types and sometimes to man's gardens and houses:

Amphibians

Bufo marinus
Ooeidozyga laevis
Rana cancrivora
Rana erythraea
Rana limnocharis
Polypedates leucomystax
Kaloula conjuncta
Kaloula picta

Lizards

Cosymbotus platyurus
Gehyra mutilata
Gekko gecko
Hemidactylus frenatus
Hemiphyllodactylus typus
Lepidodactylus herrei
Lepidodactylus lugubris
Draco volans
Varanus salvator
Emoia atrocostata
Lamprolepis smaragdina
Lipinia quadrivittata
Mabuya multifasciata

Snakes

Ramphotyphlops braminaes
Python reticulatu
Chrysopelea paradi
Dendrelaphis caudolineatus
Dendrelaphis pict
Elaphe erythrura
Hurria rhynchops
Lycodon aulicus
Calliophis calligaster
Acrochordus granulatus

Although comparable data on habitats are not available Cebu, 29 of these non-forest species have been recorded from t island.

The purpose of this paper is to compare the herpetofau species richness of Negros and Cebu Islands and to evalu probable reasons for any observed differences.

RESULTS

Negros and Cebu herpetofaunas compared.

The data on the herpetofaunas of the two islands are ba on the limited, early records (prior to 1950) and the extens field studies of the authors from 1955 to 1983. These stud have confirmed and more than doubled the number of species Negros, and quadrupled the number for Cebu as reported by earl authors (Taylor, 1920, 1922a, 1922b; Inger, 1954). For examp Brown and Alcala (1961:631) noted that prior to their survey southern Negros Island 31 species of amphibians and reptiles been reported from that area. We now have recorded 85. In (1954) and Taylor (1922a, 1922b) reported only five definite 12 probable amphibians and reptiles from Cebu. We record The lack of early records for amphibians and reptiles on Cebu have resulted from lack of interest on the part of most of collectors due to the early deforestation of Cebu.

Ten amphibians are now recorded from Cebu, all of which also known from Negros. Six of these are on the list of wi spread species or those which can adapt to a wide variety lowland habitats, often including man's agricultural habit Four are primarily forest species; seven of the additional e species recorded from Negros are also forest species.

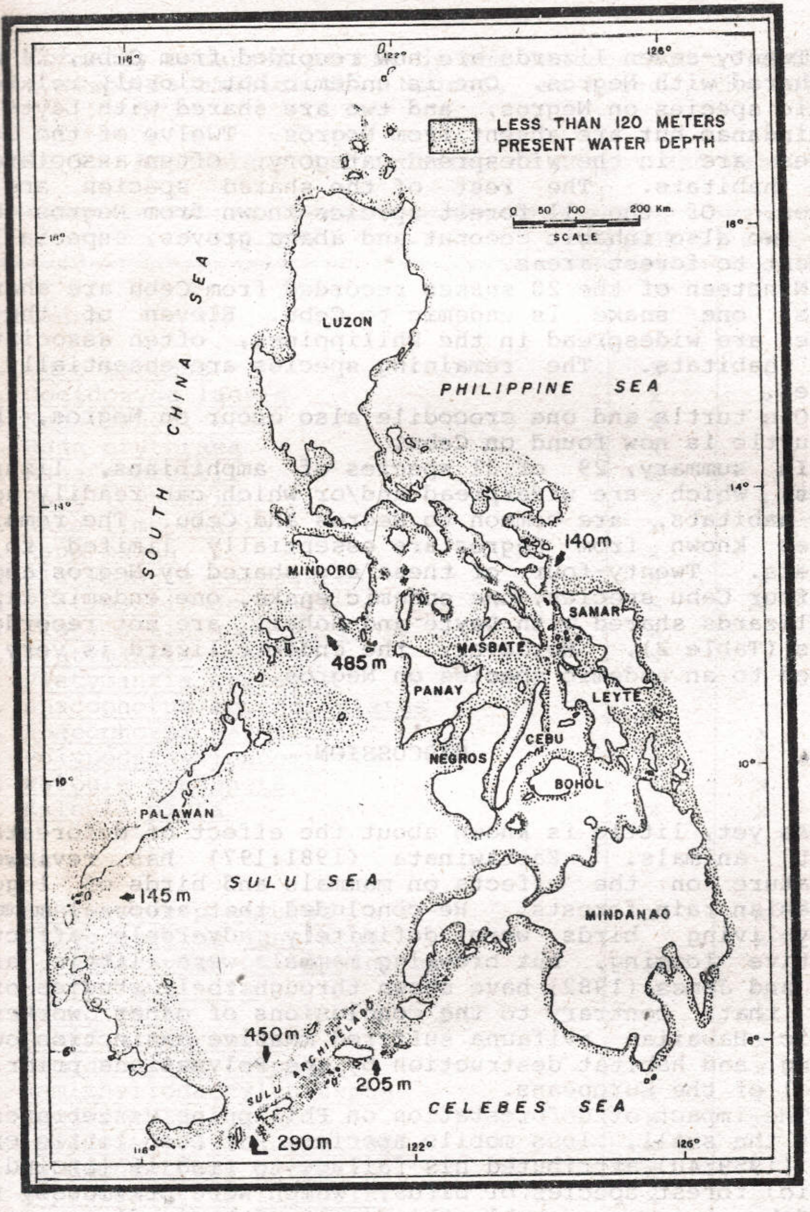

Fig. 2. Map of the Philippines showing present island boundaries (solid lines) and postulated extension of land masses during the late Pleistocene (stippled areas), at which time sea level is presumed to be at least 120 meters below the present level (after Heaney, 1985).

Twenty-seven lizards are now recorded from Cebu, 24 of wh are shared with Negros. One is endemic but closely related to endemic species on Negros, and two are shared with Leyte, Bo and Mindanao but are absent from Negros. Twelve of the 24 sha species are in the widespread category, often associated w man's habitats. The rest of the shared species are for species. Of the 11 forest species known from Negros but n Cebu, two also inhabit coconut and abaca groves, especially th adjacent to forest areas.

Nineteen of the 20 snakes recorded from Cebu are shared w Negros; one snake is endemic to Cebu. Eleven of the sha species are widespread in the Philippines, often associated w man's habitats. The remaining species are essentially for species.

One turtle and one crocodile also occur on Negros, but o the turtle is now found on Cebu.

In summary, 29 of 31 species of amphibians, lizards a snakes, which are widespread and/or which can readily adapt man's habitats, are common to Negros and Cebu. The remaining species known from Negros are essentially limited to for habitats. Twenty-four of these are shared by Negros and Ce Only four Cebu species, one endemic snake, one endemic lizard two lizards shared with Leyte and Bohol, are not recorded f Negros (Table 2). Moreover, the endemic lizard is very clos related to an endemic species on Negros.

DISCUSSION

As yet, little is known about the effect of deforestation forest animals. Kartawinata (1981:197) has reviewed literature on the effects on mammals and birds of logging Indonesian rain forests. He concluded that arboreal mammals canopy-living birds were definitely adversely affected selective logging, but browsing mammals were little affect Olson and James (1982) have shown through their studies of fos birds that, contrary to the conclusions of other workers, endemic Hawaiian avifauna suffered massive extinction owing hunting and habitat destruction by the Polynesians prior to arrival of the Europeans.

The impact of deforestation on Philippine vertebrates, es cially the small, less mobile species, has been little examin Rabor (1959:40) attributed his failure to find 16 (including n endemic) forest species of birds, which were previously recor from Cebu, as most probably the result of their disappearance to deforestation. However, he admits that there is a possibil that some of these missing species may still exist in some sma isolated areas of second growth which he and his assista failed to find. Ross and Alcala (1983) explained the absence near disappearance of the Philippine Crocodile from islands it formerly occurred partly by the destruction of forest. Since Cebu is smaller than Negros, as noted, the question

Table 2. Amphibians and reptiles of Negros and Cebu.

SPECIES	NEGROS	CEBU
Amphibians		
1. Bufo marinus	x	x
2. Ooeidozyga laevis	x	x
3. Rana cancrivora	x	x
4. Rana erythraea	x	
5. Rana everetti	x	
6. Rana leytensis	x	x
7. Rana limnocharis	x	
8. Rana magna	x	
9. Platymantis corrugatus	x	x
10. Platymantis dorsalis	x	x
11. Platymantis guentheri	x	
12. Platymantis hazelae	x	
13. Platymantis spelaeus	x	
14. Rhacophorus appendiculatus	x	
15. Rhacophorus pardalis	x	x
16. Polypedates leucomystax	x	x
17. kaloula conjuncta	x	x
18. Kaloula picta	x	x
Lizards		
1. Cosymbotus platyurus	x	x
2. Cyrtodactylus annulatus		x
3. Cyrtodactylus philippinicus	x	
4. Gehyra mutilata	x	x
5. Gekko gecko	x	x
6. Gekko mindorensis	x	x
7. Hemidactylus frenatus	x	x
8. Hemiphyllodactylus typus	x	x
9. Hemidactylus garnoti	x	x
10. Lepidodactylus christiani	x	
11. Lepidodactylus herrei	x	x
12. Lepidodactylus lugubris	x	x
13. Lepidodactylus planicaudus		x
14. Luperosaurus cumingi	x	
15. Pseudogekko brevipes	x	x
16. Calotes marmoratus	x	
17. Draco volans	x	x
18. Gonyocephalus sophiae	x	

Table 2. (Continued.)

SPECIES	NEGROS	CEBU
19. *Hydrosaurus pustulosus*	x	
20. *Varanus salvator*	x	x
21. *Dibamus novaeguineae*	x	x
22. *Brachymeles boulengeri*	x	x
23. *Brachymeles cebuensis*		x
24. *Brachymeles talinis*	x	
25. *Brachymeles tridactylus*	x	
26. *Emoia atrocostata*	x	x
27. *Lamprolepis smaragdina*	x	x
28. *Lipinia auriculata*	x	x
29. *Lipinia pulchella*	x	
30. *Lipinia quadrivittata*	x	x
31. *Lipinia rabori*	x	
32. *Mabuya indeprensa*	x	x
33. *Mabuya multicarinata*	x	x
34. *Mabuya multifasciata*	x	x
35. *Sphenomorphus arborens*	x	
36. *Sphenomorphus jagori*	x	x
37. *Sphenomorphus steerei*	x	x
38. *Tropidophorus grayi*	x	x
Snakes		
1. *Ramphotyphlops braminaes*	x	x
2. *Typhlops canlaonensis*	x	
3. *Typhlops cumingi*	x	
4. *Typhlops hypogia*		x
5. *Typhlops luzonensis*	x	x
6. *Python reticulatus*	x	x
7. *Ahaetulla prasina*	x	x
8. *Calamaria gervaisi*	x	x
9. *Chrysopelea paradisi*	x	x
10. *Cyclocorus lineatus*	x	x
11. *Dendrelaphis caudolineatus*	x	x
12. *Dendrelaphis pictus*	x	x
13. *Dryophiops philippina*	x	
14. *Elaphe erythrura*	x	x
15. *Gonyosoma oxycephala*	x	
16. *Hurria rhynchops*	x	x
17. *Lycodon aulicus*	x	x
18. *Natrix dendrophiops*	x	
19. *Oligodon modestum*	x	
20. *Oxyrhabdium leporinum*	x	x
21. *Psammodynastes pulverulentus*	x	x
22. *Pseudorabdion mcnamarae*	x	x

Table 2. (Continued.)

SPECIES	NEGROS	CEBU
23. Pseudorabdion oxycephalum	x	x
24. Pseudorabdion montanum	x	
25. Zaocys luzonensis	x	
26. Boiga angulata	x	
27. Calliophis calligaster	x	x
28. Ophiophagus hannah	x	x
29. Trimeresurus flavomaculatus	x	
30. Trimeresurus wagleri	x	
31. Acrochordus granulatus	x	x
Turtles		
1. Cuora amboinensis	x	x
Crocodiles		
2. Crocodylus mindorensis	x	

as to whether or not size might be a primary factor in ting for the smaller number of forest species found on Our data on the herpetofauna of Bohol (4,000 sq km), an to the southeast of Cebu and about the same size, might a measure of the importance of island size. Bohol, like is not heavily forested. In the 1960s and early 1970s, when conducting our survey of Bohol, the Sierra Bullones rain- had been reduced to about 43 sq km, and other scattered of man-made and secondary forest amounted to about 60 sq

On the basis of area alone, the expected number of species Negros, according to MacArthur and Wilson´s (1967:14) formula $= 1.83A^{.263}$) is 74, versus an actual number of 85; on Cebu it 56 versus 58, and on Bohol 54 versus 82. The present Bohol herpetofauna greatly exceeds the expected; that of Negros is tely excessive, that of Cebu close to the prediction. This ison supports the hypothesis that island size alone is not a good predictor of species richness; other factors, as elevation and diversity of habitats, also partly determine species richness (MacArthur, 1972; Lazell, 1983; Heaney,

The relatively high species richness of Bohol, which equals of Negros, suggests that the critical area for this number species (80+) has been reached by an island the size of Bohol or Cebu. On this basis, if size were the primary fa affecting species richness, one could argue that Negros prov space for a much greater number of species than are prese known. This may be so, and the present number may be the re of the inability of some species to disperse to Negros in past. The low species richness on Cebu compared to Negros Bohol (Cebu has even more varied terrain than Bohol), howe must be attributed to some factor other than size.

The fact that 54 of the 58 species of amphibians reptiles presently recorded from Cebu are also known from Neg while only two are endemic and two are shared with Leyte Bohol but not with Negros, strongly supports the hypothesis the herpetofauna of Cebu is (geologically speaking) a relati recent acquisition and is essentially derived from the Ne fauna. The phenomenon also can be satisfactorily explained the hypothesis that Negros, Cebu, Masbate and Panay forme single land mass in the late Pleistocene, during the period maximum lowering of sea level (Fig. 2).

Since the number of widespread, non-forest species is a the same for Negros and Cebu, what factor or factors can explain why about half (26) of the primarily forest spe occurring on Negros are presently not found on Cebu? The sma size of Cebu might be one explanation; but, as indicated earl this is unsatisfactory in view of the fact that Bohol, an is of approximately the same size as Cebu, of similar elevation located but a short distance to the east, has about the species richness as Negros.

Lack of opportunity to migrate to Cebu might be propose an explanation. However, there is no evidence that the grou forest species shared by Negros and Cebu had any advantages the non-shared group of forest species in terms of dispe over probable land connections during the Pleistocene or over a narrow water barrier.

A third possible explanation for the low number of fo species on Cebu is that it has been the result of reduction to deforestation. Unfortunately, since the only availa herpetofaunal records for Cebu until very recently (long a the almost complete removal of all original forest) were fo few widespread species, the evaluation of this explanation be on the basis of indirect evidence.

Two lines of indirect evidence may be cited. First, analogy, based on evidence on forest birds, another taxon terrestrial vertebrates, reduction of species due to defore tion is a logical expectation.

Second, on the assumption that the primarily arboreal fo species would have been much more strongly reduced in nu during deforestation early in the century and during the tim development of second growth forests, we have made this comp son for Cebu and Negros: of 52 forest species on Negros, 15 (are primarily arboreal, while of 25 forest species on Cebu, three (12%) are primarily arboreal.

The above indirect evidence supports the hypothesis that the present low number of forest species of amphibians and reptiles on Cebu as compared with Negros is most probably due to complete removal of the original rain forest from Cebu by the early part of this century.

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STRUCTURE AND VARIABILITY OF THE CALLS OF <u>POLYPEDATES LEUCOMYSTAX</u> (AMPHIBIA: RHACOPHORIDAE) FROM NEGROS, PHILIPPINES

Josef Brzoska, Gerhard Joermann and Angel C. Alcala

<u>Polypedates</u> <u>l</u>. <u>leucomystax</u> Boie on the island of Negros calls daily during the rainy season, beginning at twilight. Three calls can be distinguished. Typical mating calls have an average duration of 190 ms and are composed of 16 pulses. Short calls differ from these not only in being more brief but also in having fewer pulses and a lower frequency range. The third call is characterized by a considerably lower pulse repetition rate. These data are compared with published descriptions of the calls of <u>P</u>. <u>leucomystax</u> in two other habitats. The mating calls of the Philippine population resemble those of a population in northern Borneo despite significant differences in certain call parameters, but exhibit considerable discrepancies from those of a population in Thailand.

<u>Polypedates</u> <u>leucomystax</u> is one of the most widely distributed anuran species in Southeast Asia and parts of China. It is primarily an arboreal frog, but one with strong euryoecious tendencies, for it is also commonly found in low vegetation or on the ground. Some details of its reproductive behavior and ontogeny have been published by Alcala and Brown (1956).

In the Philippine region, <u>Polypedates</u> <u>leucomystax</u> inhabits nearly all the islands. Inger (1954), writing before the species was removed from the genus <u>Rhacoporus</u> by Liem (1970), distinguished two subspecies here: <u>Rhacophorus</u> <u>leucomystax</u> <u>linki</u> in Palawan and the Sulu Archipelago, and <u>R</u>. <u>l</u>. <u>quadrilineatus</u> on the islands further to the east, including Negros. In a later revision (1966) he raised the former to the rank of a separate species, <u>R</u>. <u>macrotis</u>, and renamed the eastern subspecies <u>R</u>. <u>leucomystax</u> <u>leucomystax</u>.

In this study, the calls of one population on the island of Negros are analyzed and the results are compared with published data from two other habitats.

MATERIALS AND METHODS

The calls were recorded in the field from 19 to 21 Septe
1983, 2000 to 2300 h. The habitat was a pond with an area
about 20 m^2 on the experimental grounds of the College
Agriculture, Silliman University, Dumaguete City. This po
densely overgrown with bushes, was occupied during the record
sessions by 10 - 15 calling *P. leucomystax* males. The anim
sat 5 - 30 cm above the water surface, maintaining an individ
distance of at least 50 cm. The habitat was also occupied by
few *Rana erythraea* during this time.

A condenser microphone (Sennheiser K3/ME80) and a U
Report 4200 tape recorder were used to record the calls.' The
temperature at the time of recording was 28 - 30 °C.
recordings were analyzed by means of a sonagraph (Kay Elect
7029A) and an oscilloscope and frequency analyzer (Nicolet UA
A). The sonagrams presented here were obtained with wide-b
filtering (effective filter width 150 Hz) to improve tempo
resolution. A total of 488 calls, produced by 17 males, w
evaluated. Nine of the animals were caught and measured af
the recordings had been made, and two of these were preserved
are kept in the Zoologisches Forschungsinstitut and Mus
Alexander Koenig, Adenauerallee 150, 5300 Bonn, Federal Repub
of Germany.

RESULTS

During the rainy season *Polypedates leucomystax* calls dai
usually beginning at the onset of twilight. Occasionally
frogs also call during the daytime. Three calls are clea
distinguishable, even to the unaided ear.

Mating call.

The frogs produce this call very persistently during
activity period. The intervals between successive calls
usually relatively long, with a distribution ranging from 1.6
70 s and peaking between 7.5 and 10 s (Fig. 1). Therefore,
was very rare for the calls of different individuals in a gr
of this size to overlap with one another. A mating call la
145 - 240 ms and consists of 10 - 22 similarly-shaped pul
(Fig. 2). The mean pulse repetition rate, defined as the num
of periods in the call divided by the time from the beginning
the first pulse to the beginning of the last, is 49 - 95 pulse
(Figs. 5 - 7). In about two-thirds of the calls the pulses oc
at very uniform intervals. The timing of the pulses in the ot
calls is irregular, with many intervals of the characteris
duration but some that are considerably longer (Fig. 2). Stat

tical tests showed these calls to be significantly longer than those with a regular pulse pattern, though they comprised fewer pulses per call (Table 1). The temporal parameters of the calls also depend on body size; the calls of small frogs (≤43 mm snout-vent length) are significantly shorter than those of larger animals (≥48 mm). Because the two groups had the same average number of pulses per call, the small animals have a significantly higher pulse repetition rate (Table 1).

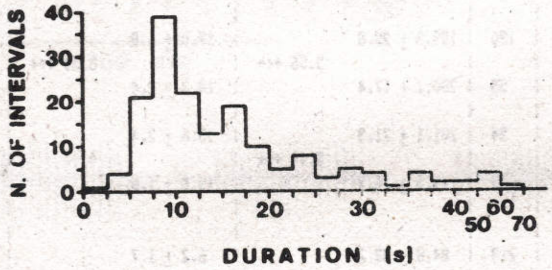

Fig. 1. Distribution of the intervals between the mating calls.

The individual pulses are usually simple in structure, with a sharp rise in amplitude and a logarithmic decay. Irregularly scattered through the pulse train are a few pulses with 2 - 4 amplitude maxima (Fig. 2a1); these are longer on average than the single-peaked pulses, 6 - 10 ms as compared with 4 - 7 ms. The frequency spectrum of the mating call is always broad, beginning at 1200 - 1800 Hz and reaching 2500 - 4000Hz. The spectrum of a given individual is quite constant but there are interindividual differences, such that larger animals call in a lower frequency range. Regression analysis showed that the peak of the frequency distribution shifts to lower frequencies as an approximately linear function of body size, by ca. 85 Hz per mm increase in snout-vent length (Fig. 8).

Short call.

Short calls last 20 - 180 ms and are composed of 2 - 12 pulses (Figs. 2, 5, 6). As in the mating call, the pulses may be either regularly or irregularly timed. Short calls with an irregular pattern on average comprise more pulses and last longer than

Table 1. The results of the statistical calculations.

CALL TYPE		N	DURATION		NUMBER OF PULSES		PULSES PER SECO	
			$\bar{X}$ ± S, (M)	t or z	$\bar{X}$ ± S, (M)	t or z	$\bar{X}$ ± S	t
Mating call	all	185	192.7 ± 20.5		16.2 ± 2.3		81.4 ± 10.6	
	reg.	130	189.3 ± 28.8	3.56 +++	17.0 ± 1.8	8.50 +++	87.0 ± 3.9	18.
	irr.	55	200.7 ± 17.4		14.3 ± 2.4		68.2 ± 9.7	
	big	54	201.1 ± 21.9	5.49 +++	15.6 ± 2.4	0.47	74.0 ± 13.5	4.
	small	45	179.3 ± 16.2		15.8 ± 1.6		85.2 ± 7.9	
Short call	all	219	84.8 ± 33.2		6.2 ± 1.7		69.5 ± 15.2	
	reg.	94	57.5 ± 19.4	15.0 +++	5.4 ± 1.6	6.63 +++	84.1 ± 8.1	22.7
	irr.	125	105.3 ± 26.0		6.8 ± 1.5		58.5 ± 8.5	
Slow rattle call	all	84	(295)		(4 - 5)		13.6 ± 2.9	
	type 1	37	(200)	2.43 +	(4)	1.32	15.0 ± 2.7	4.
	type 2	47	(340)		(6)		12.4 ± 2.7	

$\bar{X}$, arithmetic mean value; S, standard deviation; M, median; reg., calls with regular pulse pattern; irr., calls with irregular pulse pattern; big, calls of animals ≥48 mm; small, calls of animals ≤ 43 mm; comparison of means by t test: t value, comparison of medians by Wilcoxon-Mann-Whitney U test: z value; levels of significance: $P < 0.05$ +, $P < 0.01$ ++, $P < 0.001$ +++.

those with uniform intervals. The pulse repetition rates in two types of short call also differ statistically, in a relati ship very similar to that between the corresponding types mating call (Fig. 7a, b,; Table 1).

The frequency spectrum is broad-band, like that of mating calls, but shifted downward, extending from 500 Hz lower to at most 3000 Hz (Figs. 3, 4). The position of the p in the frequency spectrum is related to the number of pulses the call; regression analysis revealed a positive, li correlation between these two parameters. Again, the freque is also affected by the animal´s size. Separate evaluation the calls of large (≥48 mm) and small (≤43 mm) frogs produ two, approximately parallel regression lines (Fig. 9).

follows that a call with a given number of pulses produced by a small animal will have a frequency higher by about 300 Hz than when it is produced by a large animal.

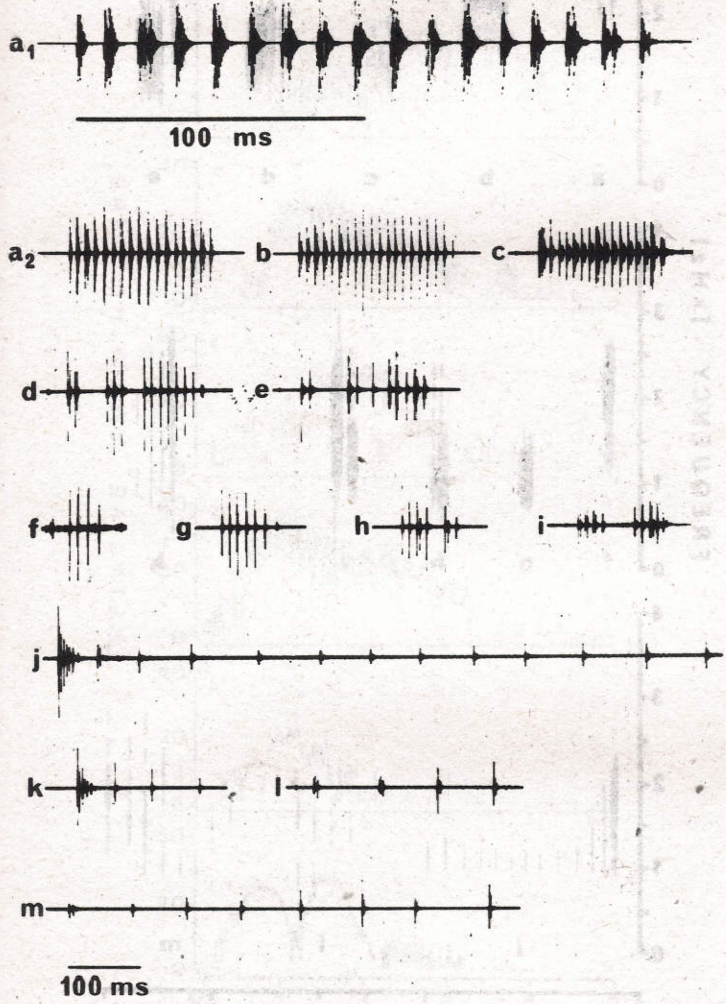

Fig. 2. Oscillograms of mating calls with regular (a - c) and irregular (d - e) pulse patterns, of short calls with regular (f, g) and irregular (h, i) pulse patterns and of slow rattle calls Type 1 (j, k) and Type 2 (l, m). In a_1 and a_2 the same call is shown on different time scales.

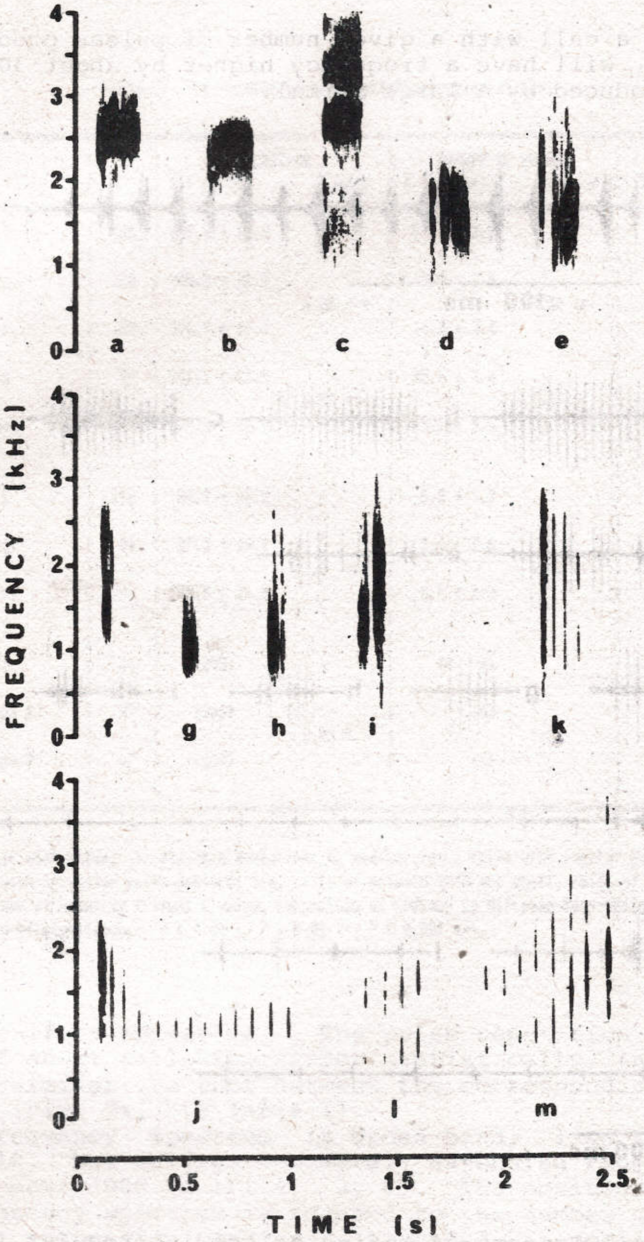

Fig. 3. Sonagrams of mating calls (a - e), short calls (f
and slow rattle calls (j - m); the calls analyzed here
identical to those in Fig. 2.

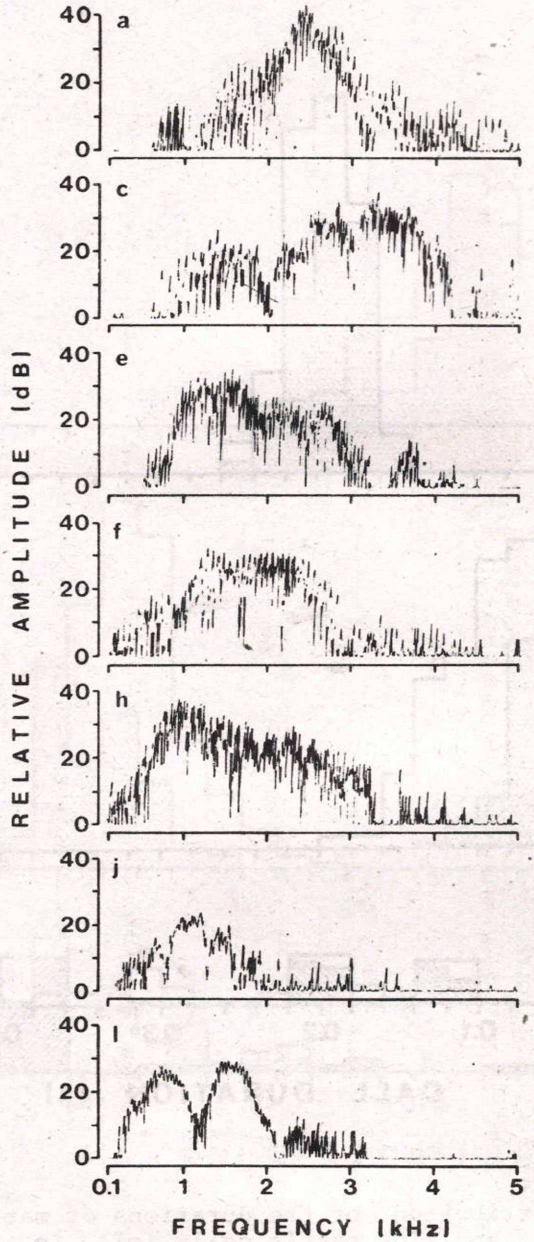

Fig. 4. Frequency spectograms of mating calls (a,c,e), short calls (f,h) and slow rattle calls (j,l); the calls analyzed here are identical to those in Figs. 2 and 3.

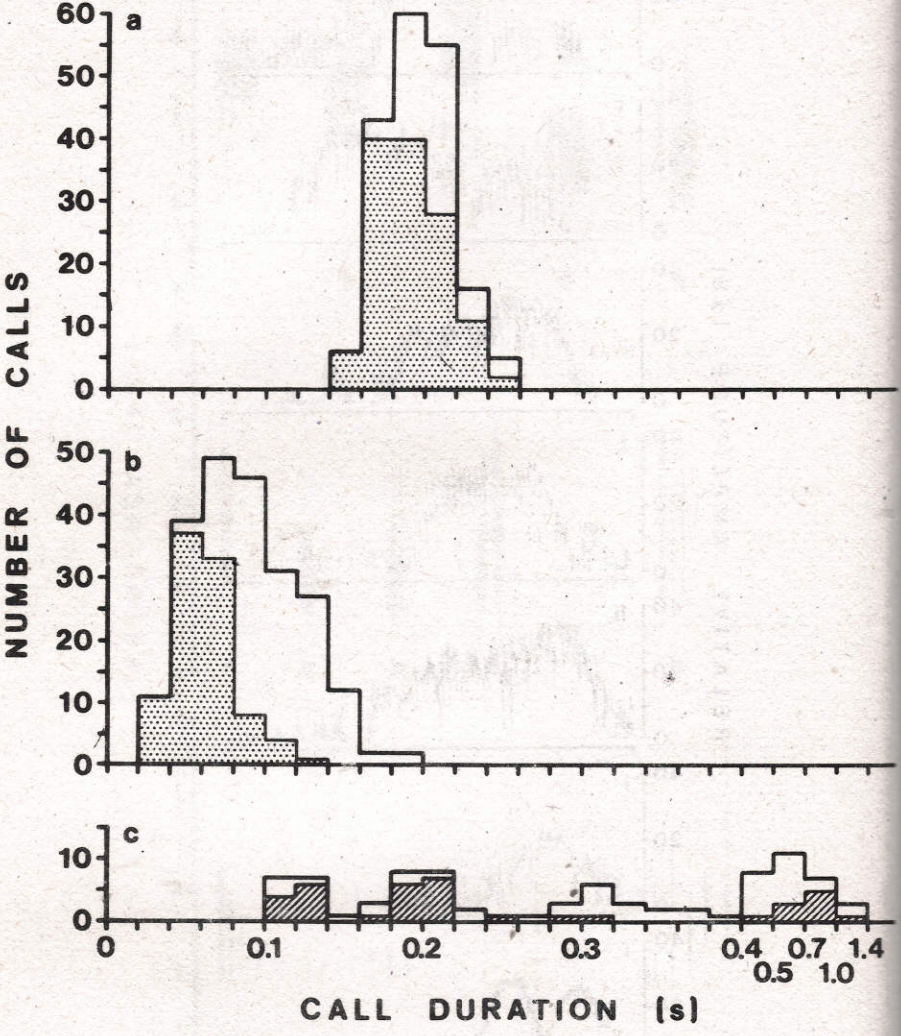

Fig. 5. Distribution of the durations of mating calls short calls (b) and slow rattle calls (c). In a and b stippled area represents calls with regular pulse patterns the remaining area, calls with irregular patterns; in c hatched area represents slow rattle calls of Type 1 and remainder, calls of Type 2.

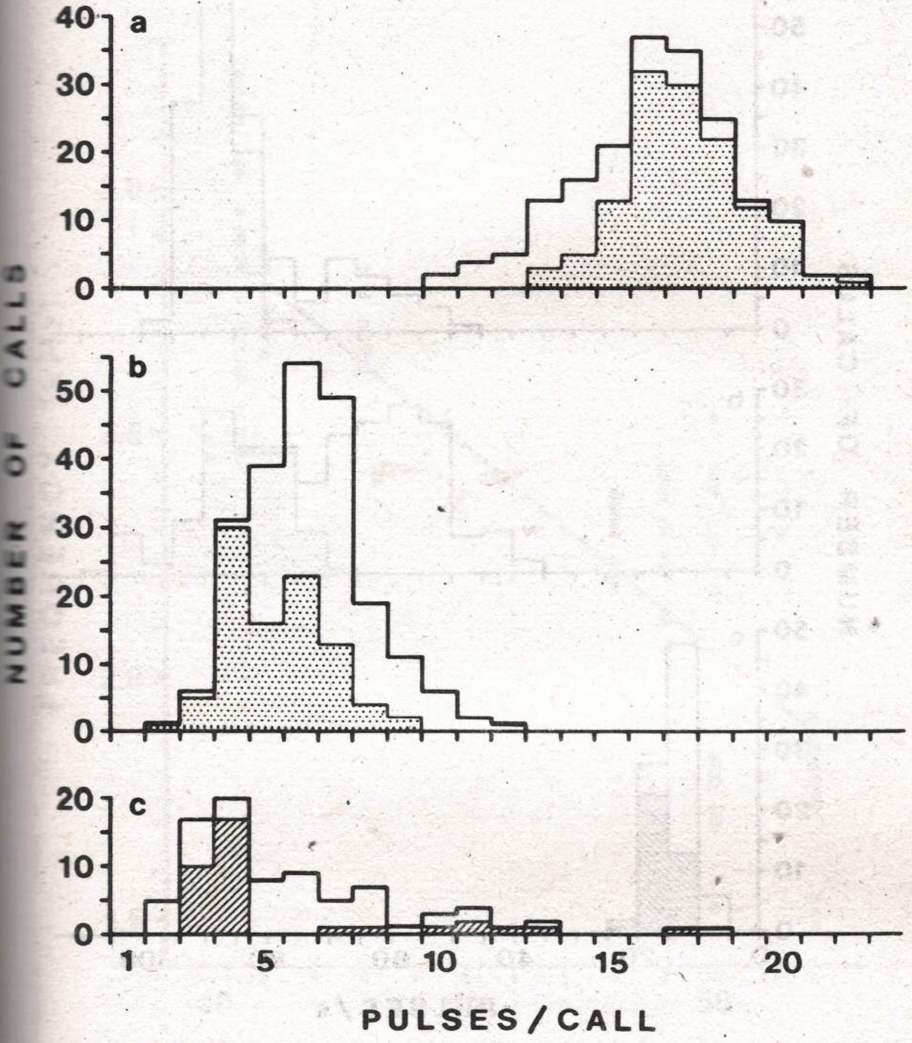

Fig. 6. Distribution of the number of pulses per call in calls (a), short calls (b) and slow rattle calls (c); shading as in Fig. 5.

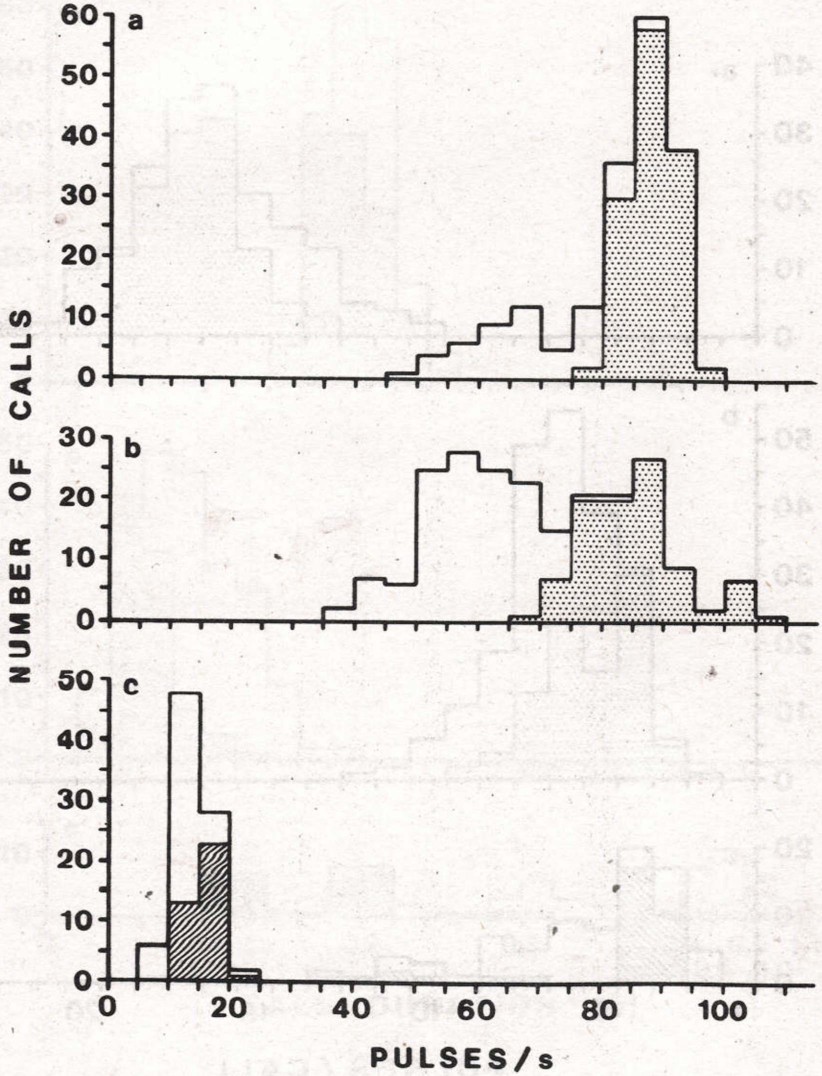

Fig. 7. Distribution of pulse repetition rates in mating calls (a), short calls (b) and slow rattle calls (c); shading as in Fig. 5.

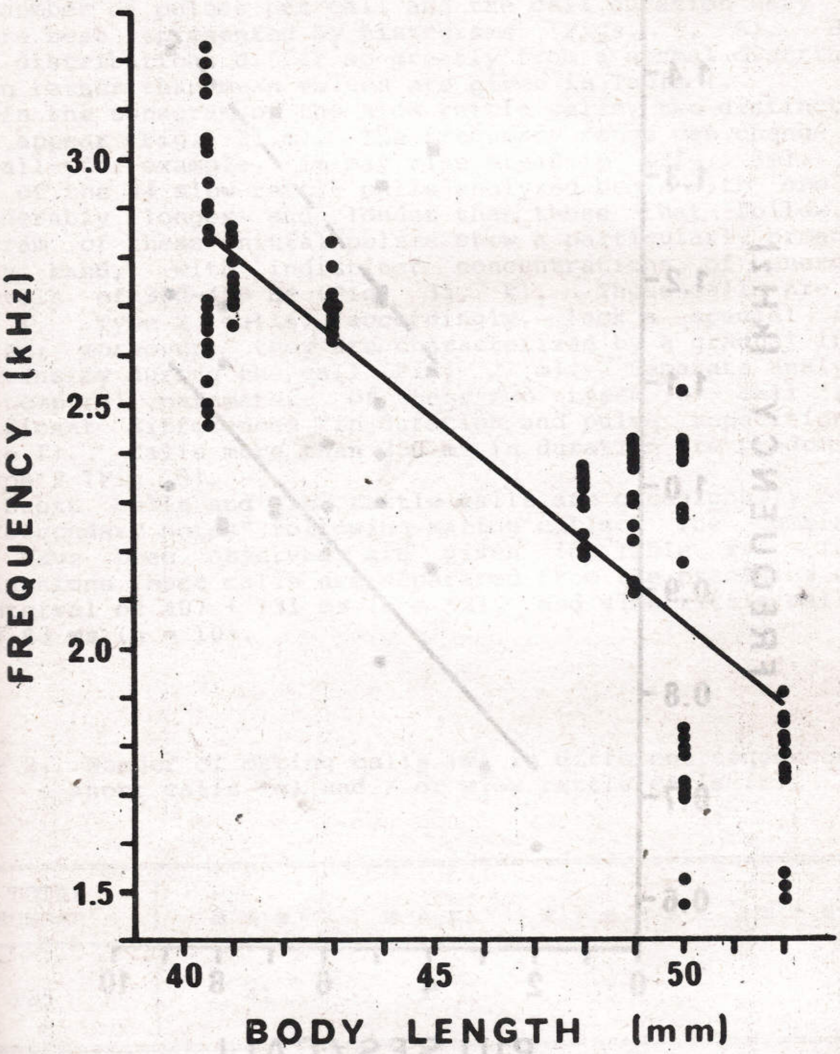

Fig. 8. Dominant frequency of the mating calls as a function body size; 10 - 12 calls of each of 9 animals are represented. equation for the regression lines is y = 6294-84.9x; r=0.86.

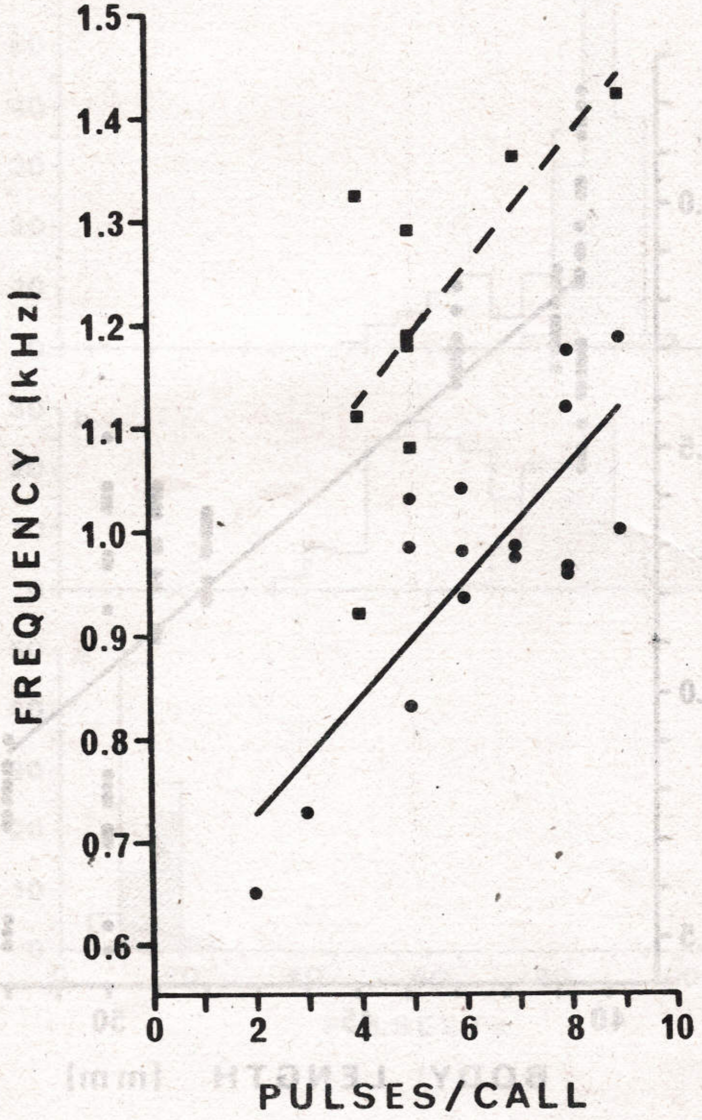

Fig. 9. Dominant frequency of short calls as a function of number of pulses per call. Circles: calls of large animals (head-trunk length 48-52 mm); y = 612 + 56.3x; r=0.81. Squares: calls of small animals (40.5-43 mm); y = 863 + 64.2x; r=0.68.

Slow rattle call.

A third call, named for its sound, is the slow rattle call (Figs. 2-4). Like the other two, it consists of pulses, but here they are repeated at a considerably lower rate (Fig. 7; Table 1). The number of pulses per call and the call duration vary widely and are best represented by histograms (Figs. 5, 6). Because both distributions differ so greatly from a normal distribution, median rather than mean values are given in Table 1.

In the sonagram of the slow rattle calls, two distinct bands often appear (Fig. 31,m). The frequency range can change during the call--for example, it may rise steadily (Fig. 3m). About half of the 84 slow rattle calls analyzed begin with one pulse considerably longer and louder than those that follow. The sonagram of these initial pulses show a particularly broad frequency band, with indistinct concentrations of energy at intervals of 300-450 Hz (Fig. 3j, k). These calls are termed Type 1. Type 2 calls, accordingly, lack a special initial impulse; moreover, they are characterized by a gradual increase in intensity during the call (Fig. 21,m). Separate analysis of the temporal parameters of these two types of call reveals significant differences in duration and pulse repetition rate (Table 1). Calls more than 250 ms in duration are predominantly of Type 2 (Fig. 5).

Short calls and slow rattle calls are occasionally produced as "secondary notes" following mating calls. The combinations that have been observed are given in Table 2. In such combinations short calls are separated from the preceding call by an interval of 407 ± 131 ms (n = 52), and slow rattle calls, by 147 ± 83 ms (n = 10).

Table 2. Number of mating calls (m) in different sequences with short calls (s) and / or slow rattle calls (r).

TOTAL NUMBER	m - s	m - r	m - s - s	m - s - r
185	41	9	5	1

DISCUSSION

The amphibians inhabiting the various islands of the Malayan archipelago often exhibit intraspecific variation. Polypedates leucomystax is particularly variable with respect to many morphological features, such as body size, the presence of vocal sacs and ossifications of the skin in the head region. For this reason, the systematic relationships within the species are difficult to establish and not yet definitively worked out (Inger, 1966; Matsui, 1979). Geographical variation can also be expected in non-morphological characters. Such characters--for example, the structure of the calls--could therefore help to clarify taxonomic questions. Two sets of data on the mating calls of P. leucomystax in other habitats are available for comparison. In Thailand, according to Heyer (1971), the species has two mating calls, comprising 4-5 and 2-4 pulses. In both, the pulse repetition rate is considerably lower than in the mating call of P. leucomystax on Negros; with regard to this parameter, they correspond approximately to the slow rattle call of our population. Their frequency ranges, 1700-3100 Hz and 300-2600 Hz, are comparable to those of the mating and short calls, respectively, of the Negros animals. Matsui (1982) analyzed the mating calls of P. leucomystax in Sabah (northern Borneo). Here both call duration and number of pulses per call are significantly lower than in the Philippine population (Fig. 10). The pulse repetition rates, on the other hand, differ by only 15%, and the frequency ranges are similar. This author also describes two types of "after notes," one or two of which may follow the mating call. In their temporal parameters, these are within the range of the short call we have described, which also appeared as a "secondary note." Hence the populations of Negros and Borneo have mating calls with a common basic structure, despite the differences mentioned above. Both of them are quite distinct from the population in Thailand.

Within the population studied here, some of the call parameters exhibit marked variation. Is there evidence of invariant features, such as might be required for an acoustic signal to be effective in communication? One problematic aspect here is the common occurrence of irregular pulse timing in the mating and short calls. Even in irregular calls, however, most of the intervals are of the characteristic duration. A receiver system tuned to a repetitive signal with a particular period--as is found, for example, in Rana temporaria (Walkowiak, 1984)--will respond only slightly less strongly to a signal with occasional irregularities than to a regular signal. Moreover, such a receiver is only slightly affected by changes in call duration or number of pulses per call. Mating calls and short calls cannot be distinguished from one another by period alone, but they are distinctly different in frequency, most conspicuously with respect to the presence or absence of sound

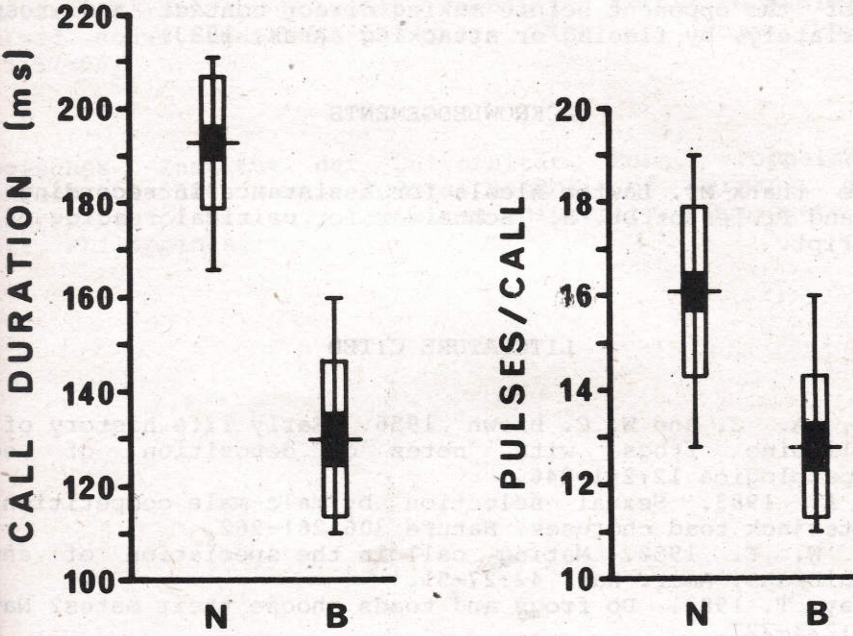

Fig. 10. Comparison of the durations (left) and numbers of pulses per call (right) of the mating calls of P. leucomystax on Negros (N, this paper) and Borneo (B, data from Matsui, 1982). Each diagram gives mean, standard error, standard deviation and extremes. The air temperatures were 28-30 °C (N) and 26-27 °C (B).

energy below 1000 Hz. Finally, the slow rattle call is most reliably characterized by its pulse repetition rate, which varies much less than the other parameters. In view of these considerations, the differences between mating calls of the populations of Negros and Borneo, mainly call duration and number of pulses per call, may be relatively inconsequential. The remarkable differences from the population in Thailand, however, remain unexplained.

Of all the call parameters, frequency in particular gives fairly reliable information about the size of the calling male. A relationship between frequency and body size is very commonly found in anurans (Blair, 1958; Loercher, 1969; Nevo and Schneider, 1976), and may result entirely from the dimensions of the vocal apparatus. Nevertheless, it remains to be considered whether this information can be utilized by the receiver. It might, for example, be a factor in the female's choice of partner (Ryan, 1980; Halliday, 1983). Another possibility is that competing males could use the frequency they hear to estimate the size of the opponent before making direct contact and respond appropriately, by fleeing or attacking (Arak, 1983).

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NOTES ON THE DIET OF *GERRES MACRACANTHUS* BLEEKER, 1854 (PISCES:GERREIDAE)

Ma. Louella L. Dolar

The food of *Gerres macracanthus* Bleeker, 1854 from inshore waters near Townsville, North Queensland, Australia, was studied from April 1984 to April 1985. Analysis of gastrointestinal contents revealed *G. macracanthus* to be a carnivore, feeding mainly on benthic invertebrates, particularly polychaetes. Molluscs, e.g. gastropods and bivalves, microcrustaceans and detrital materials make up the rest of the diet.

Fish can generally be classified on the basis of their feeding habits as carnivores, herbivores, omnivores and detritivores. Qasim (1972) further subdivided these categories, basing his subdivision on detailed analysis of the gastrointestinal contents. His classification, however, can be arbitrary in application, as most fish have mixed diets, varying considerably with locality, season and size of the fish.

Information on the food of *Gerres macracanthus* is non-existent, probably because of its confused identity. It has been synonymized with *G. filamentosus* Cuvier,1829 by Fowler (1928, 1933), who stated that *G. macracanthus* was based on immature examples of *G. filamentosus*. Various authors, e.g. Smith (1972), FAO (1974, 1983) and Cyrus and Blaber (1982b), followed this synonymy on the bases of the similarity in their meristic characters and the absence of mature specimens of G. *macracanthus* and, conversely, of juveniles of *G. filamentosus* from the samples. Contrarily, Weber and de Beaufort (1931), Munro (1967) and Venkataraman and Badrudeen (1975) have treated the two as distinct species. The author also holds them to be separate species on the bases of differences in the morphological characters and the presence in the samples of juvenile *G. filamentosus* and adult (with running ripe gonads) *G. macracanthus* (Dolar, 1986).

This paper describes the diet of *G. macracanthus* collected from the coastal waters of Townsville, North Queensland.

MATERIALS AND METHODS

The specimens were collected from Cleveland Bay (146° 55'S in the vicinity of Townsville, North Queensland, Australia. The study site is characterized by a soft, muddy bottom, and the depth ranges from 5 to 20 m. The water in this area is usually slightly turbid. Salinity variation is dependent upon summer wet season discharge from small local rivers and the Burdekin River to the south (Walker, 1981).

In order to obtain comprehensive information on the diet, a year-round collection was made, with a total of 234 specimens collected and examined. Sampling was carried out using a demersal otter trawl with a gape of 11 m and cod end mesh of 32 mm, from the James Cook University research vessel, the James Kirby. The trawl shots were of 20 minutes duration, and were conducted between 0900 and 1700 hours. The trawling formed part of the ongoing investigation by N.E. Milward of the inshore fishes in he vicinity of Townsville, North Queensland. The fish were frozen on board and later transferred to the laboratory freezer.

In the laboratory, the fish were thawed out for examination, ut kept chilled during handling. The total and standard lengths ere measured to the nearest mm using a 500 mm measuring board. he gut contents were examined under a stereomicroscope and a ompound microscope, if needed. Items not readily recognizable ere preserved in 10% formalin or 70% alcohol for a more detailed xamination. Food items were identified to the lowest taxon ossible, based on Light et al. (1961), Wickstead (1965) and arnes (1974), and with the assistance of people familiar with he local invertebrates. Recognition of polychaetes, which were nvariably in a partial, or near total, digestion was based upon he distinctive mandibles and setae.

To quantify the prey items, three methods were used: the ercent occurrence, numerical and volumetric methods as described y Hynes (1950), with some modifications of the volumetric method facilitate assessment of the smaller food items. In the odified method, food items were compared with blocks of known olume after the technique of Larimore (1957). Individually, ese methods have certain shortcomings, but taken collectively, ey may provide a good measure of species´ diet.

RESULTS

A summary of the food items found in the alimentary tracts the adults averaged from the different months using the three thods is shown in Figure 1. Food items comprising less than 3% e lumped together under the heading "misc" (miscellaneous). is evident that polychaetes are the dominant food item. Mol- scs (bivalves and gastropods), amphipods, cheliferans and juve- le brachyurans also contribute considerable amounts. Detrital terials (organic debris plus mud and sand grains) were observed be present in 60 to 100% of the individuals examined. digested plant materials, i.e. Halophila and Halodule, and

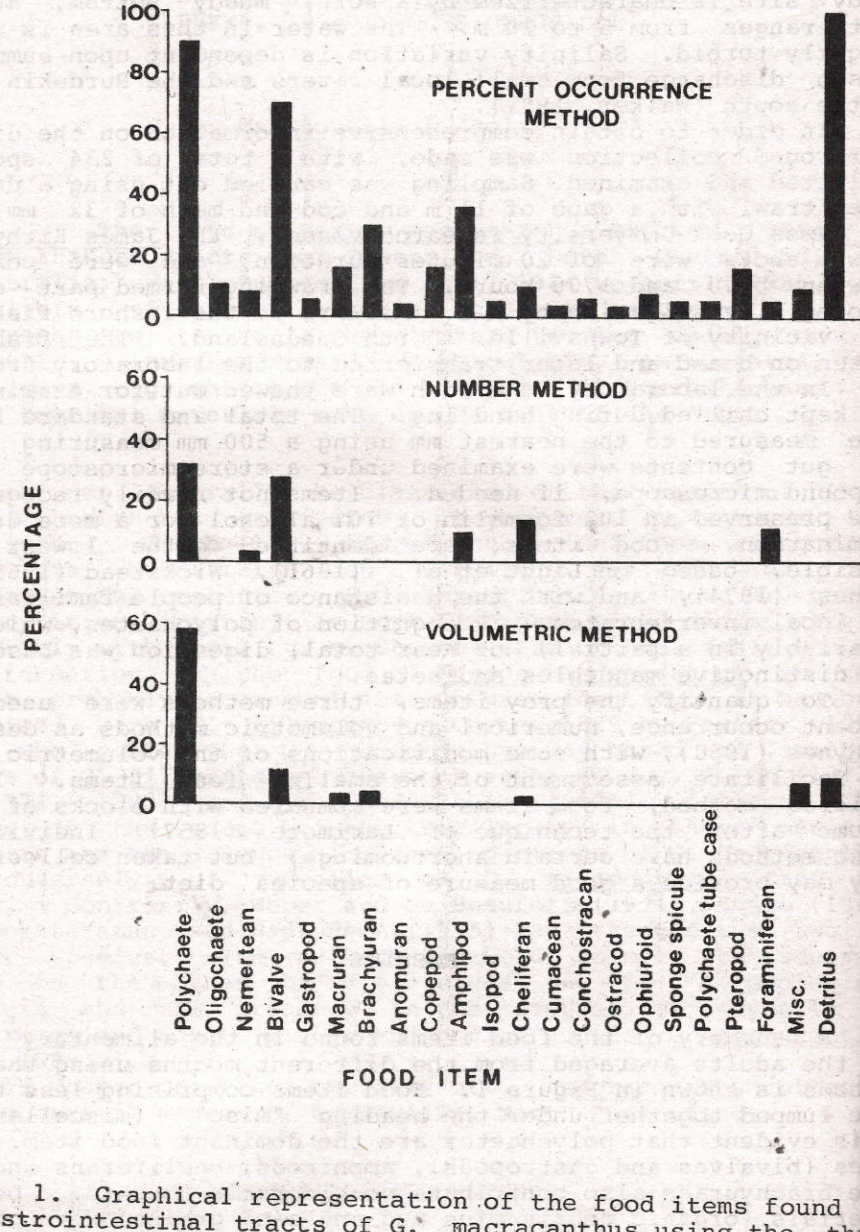

Fig. 1. Graphical representation of the food items found in the gastrointestinal tracts of G. macracanthus using the three methods of quantification.

siphon tips of bivalves were occasionally found (less than 3% in all the methods used) in the gastrointestinal tracts.

DISCUSSION

The results indicate that *G. macracanthus* is a carnivore and a benthic feeder, feeding mainly on the benthic invertebrates, particularly polychaetes, with small benthic and epiphytic crustaceans, i.e. amhipods, decapods, cumaceans, isopods and cheliferans, comprising the rest of the diet. This observation agrees closely with that made by Prabhakara Rao (1968) on *G. oyena* and *G. filamentosus*, Etchevers (1978) on *Diapterus rhombeus*, Cyrus and Blaber (1983b) on *G. acinaces*, *G. oyena*, *G. rappi* and *G. oblongus* and Dolar (1986) on *G. poieti* and *Pentaprion longimanus*.

However, some differences from the observations of other workers also appeared. Examples are the low occurrence and quantity of seagrass blades and siphon tips. The 2 to 3% occurrence of seagrass blades varies markedly from that observed by Austin (1971) in *Diapterus rhombeus* and by Chacko (1949) in three other species of gerreids. These two authors reported aquatic macrophytes to be the main component of the food items taken by the respective species they studied. Likewise, bivalve siphon tips comprised a very low percentage both in occurrence and quantity of the food items of the study species. This observation differs from that of Cyrus and Blaber (1983b, 1984) on *G. filamentosus*, which was noted to feed mainly on bivalve siphon tips.

Whole bivalves were observed to be taken more often than just siphon tips in the study species. The same observation was made by Prabhakara Rao (1968) for *G. filamentosus* and *G. oyena* from India. Whitfield (1980) reported that whole bivalves provide twice as much energy value as siphon tips. Therefore, if the bivalve resource is sufficiently large and can withstand the predation pressure, this mode of feeding would be advantageous to the fish. However, where the bivalve population is limited, feeding only on the siphon tips could be preferable since they would constitute a more rapidly renewable resource, as pointed out by Cyrus and Blaber (1983b).

The high incidence and large quantity of detrital material observed in the guts of the study species is suggestive of its importance in the diet of *G. macracanthus* and further strengthens the claim of a benthophagus way of life. Prabhakara Rao (1968) and Austin (1971) also recorded detritus as one of the major food items of *G. oyena*, *G. filamentosus* and *Diapterus rhombeus*. Settled detritus is a heterogeneous mixture of animal and plant remains, silt and sand particles coated with decaying organic matter and large colonies of bacteria and infusorians. It is perhaps the most readily and universally abundant food material in shallow areas of the sea, estuaries and lakes (Qasim, 1972). The importance of detrital material as food has been recorded for *Ethmalosa fimbriata* (Blay and Eyeson, 1975), *Sarotherodon mossambicus* (Bowen, 1979) and *Clistorina magnifica* (Anderson, 1976). Chemical analysis shows that detrital material contains carbohydrates, proteins (mainly from bacteria) and a substance believed to contain a significant amount of amino acids, which could be as valuable as assimilated protein on a weight for weight basis (Bowen, 1979). Bowen (1979) reviewed the nutritional constraints and strategy in detritivory. He stated that generally, detritivores are confronted with the problem of gaining adequate digestible protein in their diet. However, he argued that this constraint is overcome by the detritivores by using the following measures: (a) selective feeding on protein rich detrital aggregates, (b) selective ingestion of the protein-rich elements of the detrital material and (c) complementing calories gained from detritus with protein-rich animal foods. In the present study, the presence of polychaetes, molluscs and microcrustaceans in the gastrointestinal tracts of *G. macracanthus* suggests that this species probably employs strategy C.

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A PRELIMINARY STUDY OF THE EFFECT OF SUPPLEMENTARY FEEDING ON THE GROWTH OF TRIDACNA MAXIMA (RODING)(BIVALVIA: TRIDACNIDAE)

Janet Estacion, Erwinia Solis and Lourdes Fabro

The effect of supplementary feeding on the growth of the giant clam Tridacna maxima was studied using Isochrysis galbana, Tetraselmis sp. and a mixture of both. Juvenile clams fed with the mixed culture had significantly higher growth rates, after the second and third months, followed by Isochrysis and Tetraselmis alone. Unfed clams supplied with filtered seawater had the slowest growth.

Tridacnid clams are currently being studied in view of their possible extinction and mariculture potential (Beckvar, 1981; Gwyther and Munro, 1981; Heslinga et al., 1985). They are attractive mariculture subjects since their juveniles and adults contain a symbiotic dinoflagellate, Symbiodinium microadriaticum Freudenthal, which contributes significantly to the nutrition of the clam (Trench et al., 1981). These specialized dinoflagellates, zooxanthellae, live in the mantle tissues of the clam and may account for the large size attained by some species. Permanent symbiosis with the dinoflagellate is not established until after metamorphosis. Also, the larvae or juvenile must acquire complement symbionts from the environment (Fitt et al., 1984) as adult tridacnids do not pass them on to their young (LaBarbera, 1975; Jameson, 1976).

Very little is known about the nutritional requirements of larval and juvenile clams. Gwyther and Munro (1981), Fitt et al. (1984) and Crawford et al. (in press) added unicellular algae to tridacnid larvae and studied the effect of feeding on survival, while Beckvar (1981) and Heslinga et al. (1984) maintained juvenile and small adult clams without food additions until reaching a size at which they could be transplanted onto the reef. This study attempts to determine the possible effect of supplementary feeding on the growth of young T. maxima using various microalgal cultures.

MATERIALS AND METHODS

Nine-month-old laboratory-reared T. maxima were used in our study. These clams were divided into three treatment groups and a control group, with three replicates for each group. Each replicate contained 17 clams. The experimental clams were placed in 58cm x 50cm x 16.5cm basins supplied with unfiltered seawater, except for the control group, which was supplied with filtered seawater only, for eight hours a day at most. The first treatment group was fed with *Isochrysis galbana*; the second, with *Tetraselmis* sp.; and the third, with a mixture of both algae. Feeding was every other day, in the afternoon, with 30 ml of each microalgal culture, with a cell density of 10^4 to 10^7 cells/ml. Seawater flow to all basins was discontinued during feeding, resuming the following day. The clams were measured monthly using a plastic caliper. Growth was approximated by subtracting monthly measurements from initial lengths. Water temperature and salinity were monitored daily using a field thermometer and refractometer.

Growth data obtained were tested with Cochran´s Test for homogeneity of variances. Three separate analyses were done using 1-Factor Nested Analysis of Variance for the first (September - October 1983), second (October - November 1983) and third (November - December 1983) months, with the various treatments as the factor.

RESULTS

Results of the analysis for the first month failed Cochran´s Test; therefore, we did not proceed with ANOVA. However, if the means of each treatment were plotted for this month, clams fed with *Isochrysis* would appear to have had greater growth rate at this stage. Results of months two and three, on the other hand, passed Cochran´s Test, and the 1-Factor Nested ANOVA was done. Results revealed significant treatment effects during these months (Table 1). Student-Neuman-Keuls (SNK) Tests were carried out to compare individual means of each treatment for both months. Results showed that clams on the mixed *Isochrysis-Tetraselmis* diet had significantly higher growth, followed by *Isochrysis* and *Tetraselmis* (Table 1). Clams in the control group (basins supplied only with filtered seawater) had the slowest growth. Mean growth of fed and unfed clams after the second and third months is shown in Table 2. After three months, clams fed with mixed *Isochrysis-Tetraselmis* had a growth of 8.47mm (SD=1.77), followed by *Isochrysis galbana*, 7.63mm (SD=1.66), *Tetraselmis*, 5.75mm (SD=1.47) and the control, 3.25mm (SD=0.18). The same pattern was obtained for the fourth month, with the mixed culture having 10.61mm (SD=2.35), *Isochrysis*, 10.15mm (SD=1.58), *Tetraselmis*, 8.58mm (SD=1.85) and the control, 6.74mm (SD=2.08). Means were based on 51 measurements. The overall result showed significantly higher growth for clams fed with the mixed cultures than clams fed with either *Isochrysis* or *Tetraselmis* alone. Water temperature and salinity were fairly constant throughout the study, averaging 27 ± 1°C and 31 ± 1 ppt.

DISCUSSION

In a review of the literature on bivalve nutrition, de Pauw (1981) included *T. galbana* and various species of *Tetraselmis* in a list of algal species that promoted excellent growth of juvenile bivalves. He found that bivalve juveniles showed better growth in mixed cultures of suitable species (citing *T. galbana-Tetraselmis* sp. mixture) than in either culture alone.

Fitt et al. (1984) reported that appropriate nutrition of tridacnid larvae enhanced survival and growth, which may in turn influence the growth of metamorphosed juveniles. Gwyther and Munro (1981), on the other hand, reported that feeding did not so much serve to promote growth as to increase survival during metamorphosis. However, Gwyther and Munro suggested that food must be made available to the larval culture both throughout pelagic larval life and during growth from spat to adult, and unicellular algae should be introduced to encourage rapid growth of young clams.

Crawford et al. (in press) reported that densities of five-month-old juveniles of *T. gigas* which were fed with either *I. galbana* or *Chlorella* sp. from the larval to the juvenile stage differed significantly from unfed clams. Higher densities were obtained from tanks containing clams which were not fed. In the raceway where microalgae were added, they observed the development of more benthic algae, which grew over the juveniles and probably resulted in higher mortalities by the reduction of light intensity and competition for nutrients with the zooxanthellae. However, Crawford et al. could not reach any conclusion regarding the influence of supplementary feeding on the growth rates of newly-metamorphosed juveniles.

Results of the present study indicated faster growth for clams with supplementary feeding. Differences among treatments, however, were not apparent until the second month of the study. These results contrasted with those of Crawford et al. (in press), who reported that supplementary feeding was not necessary. However, the duration of their study was only two months, while, in our study, significant differences in the growth rates of the clams occurred only after two months.

The highest growth rates obtained for the *Isochrysis-Tetraselmis* culture agree with the evaluation of de Pauw (1981) for bivalve molluscs. As mentioned, the combination of *Isochrysis* and *Tetraselmis* resulted in better growth of the juveniles of some commercially important bivalves, compared to *Isochrysis* and *Tetraselmis* alone. De Pauw emphasized, however, that the use of mixed algal species does not lead to an improvement of a poor species. Differences in food value between mixed and single algal diets may be explained by two types of interactions among combinations of algae: first, synergistic nutritional interaction, explained by the deficiency in micronutrients and fatty acids; second, non-additive interaction, explained by the

Table 1. 1-factor nested ANOVA table of the growth of <u>Tridacna maxima</u> from September to November 1985 (A) and September to December 1985 (B). * - $p < 0.05$; *** - $p < 0.001$.

(A)

Source of Variation	SS	df	MS	F	P
Diets	39.01	3	13.00	16.033	*** (3,8)
Basins	6.49	8	0.811	9.541	*** (8,192)
Residual	16.39	192	0.085		
TOTAL		203			

(B)

Source of Variation	SS	df	MS	F	P
Diets	14.46	3	4.82	5.618	* (3,8)
Basins	6.86	8	0.858	9.64	*** (8,192)
Residuals	17.25	192	0.089		
TOTAL		203			

Table 2. Growth of <u>T</u>. <u>maxima</u> juveniles in the laboratory.

TREATMENT	N	MEAN GROWTH (mm) ± SD	
		after 2 months	after 3 months
Mixed <u>Isochrysis-Tetraselmis</u>	51	8.47 ± 1.77	10.61 ± 2.35
<u>Isochrysis</u> alone	51	7.63 ± 1.66	10.15 ± 1.58
<u>Tetraselmis</u> alone	51	5.75 ± 1.47	8.58 ± 1.85
Control	51	3.25 ± 0.18	6.74 ± 2.08

ration of the algae versus the rate of extra-cellular digestion.

The contrasting reports of the effect of supplementary feeding on juvenile giant clams suggest that a longer study using several species of different ages would probably be able to gauge the importance and duration of feeding in clams until such a time as they are self-sufficient enough to be transplanted to reefs.

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FLAT-HEADED BATS (MAMMALIA, TYLONYCTERIS) FROM THE PHILIPPINE ISLANDS

Lawrence R. Heaney and Angel C. Alcala

Tylonycteris robustula is reported for the first time from the Philippines: specimens are available from Calauit and Luzon. Records of Tylonycteris robustula are from Calauit, Culion, Palawan, Luzon and Mindanao; other reports are probably erroneous. These records bring the number of species of the bat family Vespertilionidae in the Philippines to 21. No species are endemic, and most are widespread in the tropical portions of the Oriental and Australian zoogeographic regions. A few are shared only with the continent and continental shelf islands of Asia.

Bats of the genus Tylonycteris are widespread in Southeast Asia. Two species are currently recognized (Honacki et al., 1982; Tate, 1942). One of these species, T. pachypus, is perhaps the smallest bat in the world. Like its competitor for the record, Craseonycteris thonglongyai of Thailand, it weighs about two grams. The tiny size and the dorso-ventrally flattened skulls of these bats allow them to utilize extremely small cavities as roosting sites, including, for example, the hollow stems of bamboo, which they enter through cracks and insect holes (Medway and Marshall, 1970), and the small, hollow area inside young, erect banana leaves (Rabor, 1977:231).

Only one species of Tylonycteris, the lesser flat-headed bat (T. pachypus), has been reported previously from the Philippines. The purpose of this paper is to provide the first records of the greater flat-headed bat (T. robustula) from the Philippines and to summarize and reevaluate the Philippine records of T. pachypus. Data such as these are essential both for biogeographic studies that rely on accurate lists of species distributions (e.g. Heaney, 1986) and for development of conservation plans for preservation of the native fauna of the Philippines.

METHODS

All measurements were taken by Heaney with calipers calibrated to 0.05 millimeters. Measurements in Table 1 are given in millimeters as mean ± one standard deviation, with the range given in brackets. Measurements of forearms were taken from both dried skins and fluid-preserved specimens. Specimens examined are housed in the following institutions: Field Museum of Natural History, Chicago (FMNH); Silliman University Museum of Natural History, Dumaguete (SU); University of Michigan Museum of Zoology, Ann Arbor (UMMZ); U.S. National Museum of Natural History, Washington, D.C. (USNM).

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ACCOUNTS OF SPECIES

Tylonycteris pachypus (Temminck, 1840).

The lesser flat-headed bat occurs from India east to southern China and south to Java (Honacki et al., 1982; Lekagul and McNeely, 1977). Peters (1872) reported the first specimen of *Tylonycteris* from the Philippines, describing it as a new species, *T. meyeri*, with only smaller size distinguishing it from *T. pachypus* (discussed below). The type locality was given only as southern Luzon. Hoffman (1887) reported an additional specimen from Mindanao, and Elera (1895) cited additional records from Cebu and Negros. Hollister (1912) cited these early records and also reported a specimen from Palawan and two specimens from Luzon (discussed below). Taylor (1934) repeated all of these records but examined none. Sanborn (1952) reported a series from Culion and Rabor (1977) again summarized these records. We have examined specimens from Calauit, Culion (first reported by Sanborn, 1952), Luzon (first reported by Hollister, 1912) and Palawan (first reported by Hollister, 1912).

We note that Elera´s (1895) paper is generally recognized to contain many errors (Hollister, 1912:54), and that Rabor et al. (1970) included *T. pachypus* in their list of mammals of Negros Island only on the basis of these earlier references. Because we have been unable to locate specimens or other positive records of this bat from Cebu or Negros in spite of extensive field work on Negros by both of us, we do not accept these records as valid.

Hollister (1912) reported two specimens of *T. pachypus* from Montalban, Luzon. We have examined both of these specimens; one of these was identified correctly (USNM 173887), whereas the other is actually *T. robustula* (USNM 173888).

Specimens from the Philippines are consistenty smaller than reference material of *T. pachypus pachypus* from Java (the type locality of the species) and of *T. pachypus fulvidus* from Indo-China, but these differences are slight (Table 1). For example, the condylo-incisive length of Philippine specimens ranges from 9.7 to 10.3, whereas specimens from Java range from 10.3 to 11.2. However, in this case, as in most others, there is some overlap.

Table 1. Selected measurements of *Tylonycteris* from the Philippines and reference areas.

LOCALITY	N	Condylo-incisive length	Zygomatic width	Interorbital width	Mastoid width	Cranial depth	C to M3	Molariform toothrow	Palatal width at M3	Forearm
Tylonycteris pachypus										
Calauit	2	9.8 (9.7-9.9)	7.5 (7.5)	3.25 (3.2-3.3)	6.5 (6.4-6.6)	3.1	3.2 (3.1-3.3)	2.5 (2.4-2.6)	2.65 (2.6-2.7)	22.35 (22.1-22.6)
Culion	5	10.12±0.19 (9.8-10.3)	7.65 (7.5-7.8)	3.24±0.15 (3.0-3.4)	6.53±0.10 (6.4-6.6)	---	3.42±0.13 (3.2-3.5)	2.66±0.09 (2.5-2.7)	2.74±0.09 (2.6-2.8)	22.76±1.02 (22.0-24.1)
Luzon	1	10.1	7.6	3.0	6.7	3.3	3.4	2.7	2.6	24.4
Palawan	1	9.9	---	3.3	6.6	3.1	3.3	2.7	2.7	23.3
Java	11	10.83±0.31 (10.3-11.2)	7.90±0.27 (7.5-8.3)	3.27±0.15 (3.1-3.6)	6.90±0.16 (6.7-7.1)	2.91±0.26 (2.6-3.5)	3.55±0.14 (3.4-3.8)	2.73±0.28 (2.7-3.1)	2.85±0.19 (2.7-3.2)	26.07±0.54 (24.9-26.7)
Vietnam and Laos	8	10.70±0.21 (10.4-11.1)	8.12±0.23 (7.8-8.5)	3.32±0.11 (3.2-3.4)	6.91±0.21 (6.6-7.2)	2.97±0.10 (2.8-3.1)	3.51±0.10 (3.4-3.7)	2.76±0.12 (2.6-3.0)	2.91±0.12 (2.7-3.1)	25.5±0.62 (24.9-26.6)
Borneo	2	11.2 (11.1-11.3)	---	3.55 (3.5-3.6)	7.25 (7.2-7.3)	3.25 (3.2-3.5)	3.75 (3.7-3.8)	2.95 (2.9-3.0)	3.0 (3.0)	---
Tylonycteris robustula										
Calauit	2	11.55 (11.5-11.6)	8.7 (8.6-8.8)	3.9 (3.8-4.0)	7.35 (7.2-7.5)	---	4.0 (4.0)	3.25 (3.2-3.3)	3.35 (3.2-3.3)	25.1 (24.8-25.4)
Luzon	1	11.9	8.9	4.1	7.6	4.0	4.1	3.3	3.3	26.5
Java	4	11.98±0.27 (11.7-12.3)	9.08±0.13 (8.9-9.2)	3.73±0.15 (3.6-3.9)	7.48±0.5 (7.4-7.5)	3.70±0.14 (3.5-3.8)	4.03±0.15 (3.8-4.1)	3.18±0.13 (3.0-3.3)	3.33±0.13 (3.2-3.5)	27.75±0.54 (27.3-28.4)
Vietnam and Laos	5	11.90±0.14 (11.8-12.1)	9.10±0.20 (8.9-9.4)	3.82±0.13 (3.7-4.0)	7.46±0.09 (7.4-7.6)	3.43±0.96 (3.3-3.5)	3.98±0.08 (3.9-4.1)	3.14±0.05 (3.1-3.2)	3.34±0.11 (3.2-3.5)	27.0 (25.7-27.9)
Borneo	3	13.1	9.9 (9.6-10.2)	4.27 (4.2-4.3)	8.33 (8.2-8.5)	3.7	4.2 (4.1-4.3)	3.4 (3.3-3.5)	3.63 (3.5-3.7)	28.2 (27.9-28.6)

The single specimen of T. pachypus from Luzon fits well with the larger series from the Palawan group of islands. Tate (1942) recognized the Philippine populations as a distinct subspecies on the basis of the size difference, using meyeri Peters (1872) as the subspecies designation. We have not examined the type of T. meyeri, but Peters described it as being very similar to T. pachypus, differing only in its smaller size; forearm length was given as 22.3 and 24 for two specimens. This description fits our Philippine species well. On this basis, we accept Tate´s assignment of the small Philippine bats as T. p. meyeri. The large amount of variation between samples (e.g. Borneo vs. adjacent populations in the Philippines) indicates that additional specimens from areas of contact between subspecies are needed in order to fully evaluate the extent of divergence between taxa.

External measurements from our two specimens from Calauit are: total length, 60, 62; tail, 24, 25; ear from notch, 8, 7; weight, 1.4, 2.7 grams. The second of these was a pregnant female which carried one embryo in each uterine horn (crown-rump length, 6.5). The other was an adult male; both were taken on 2 May 1983.

Specimens examined: PHILIPPINES. Palawan Prov.: Calauit Island, near center of island (SU 27309; UMMZ 158856). Culion Island, San Pedro (FMNH 63656, 63658, 63661, 63673, 63675). Palawan Island, Puerto Princesa (USNM 105484). Luzon: Rizal Prov.: Wawa, near Montalban (USNM 173887). INDONESIA. Borneo: Laham (USNM 198979, 198981). Java: Buitenzorg (USNM 156363, 156367-375, 156378). LAOS. Phong Saly, 4400 ft. (FMNH 32159, 32160, 32162). VIETNAM. Lai Chau (USNM 240594). Tonkin: Muong Mnun, south of Lai Chao, 1200 ft. (FMNH 32153-32155). Tonkin (USNM 260035).

Other records: PHILIPPINES. Mindanao: no specific locality (Hoffman, 1887). Luzon, southern: no specific locality (Peters, 1872).

Tylonycteris robustula Thomas, 1915.

The greater flat-headed bat is known to occur from southern China to Java and Sulawesi (Honacki et al., 1982; Lekagul and McNeely, 1977). We have examined two specimens from Calauit Island (collected from a monsoon forest) and one from Luzon. The Philippine specimens are easily distinguished from T. pachypus on the basis of their larger size (Table 1). For example, condylo-incisive length exceeds 11.5 mm in Philippine T. robustula but is less than 10.4 in Philippine T. pachypus (Table 1). Our few specimens from the Philippines are smaller than those from Java and Vietnam, although only slightly so (Table 1). Specimens from Borneo average larger than any of the other samples by a substantial margin (Table 1), indicating that the pattern of geographic variation is not simple or clinal. No subspecies of T.

robustula are currently recognized, but the distinctiveness of specimens from Borneo indicates that, as with T. pachypus, a complete review of the taxonomy of the group is needed.

External measurements from our two specimens from Calauit are: total length, 75, 71; tail, 27, 27; ear to notch, 8, 9; weight, 5.0, 4.8 grams. Both were pregnant; the first carried a single embryo (crown-rump length, 7.5) and the second carried two (crown-rump length, 8.0). Both were taken on 2 May 1983.

Specimens examined: PHILIPPINES. Palawan Prov.: Calauit Island, near center of island (SU 27310; UMMZ 158855). Luzon: Rizal Prov.: Wawa, near Montalban (USNM 173888). LAOS. Phong Saly, 4400 ft. (FMNH 32157, 32158, 32186). MALAYSIA. Sabah (Borneo): Mt. Kinabalu, Bundu Tuhan (USNM 292462-463). Sabah: Ranau (USNM 317174). INDONESIA. Java: Buitenzorg (USNM 156380). Central Java: Karangmangu, 12 km S Mt. Slamet (USNM 481396-397, 481399). VIETNAM. Mon Prov.: Quang Tri (USNM 260032-033).

DISCUSSION

With the addition of Tylonycteris robustula, the number of species of the family Vespertilionidae known from the Philippines comes to 21; these are listed in Table 2. Only the family Pteropodidae, the fruit bats, is more speciose in the Philippines, with about 25 species present. In spite of this diversity, the Philippine vespertilionids are, with few exceptions, very poorly represented in museum collections, and distributional patterns within the Philippines are very poorly known. The following is a brief summary of major patterns, based on our examination of specimens now in museum collections.

Of the nine genera of vespertilionids in the Philippines, one is primarily restricted to the Oriental faunal region (Glischropus); three are generally widespread in Asia (Murina, Scotophilus, Tylonycteris) and five are very widespread in Asia and Australasia (Kerivoula, Miniopterus, Myotis, Philetor, Pipistrellus). Thus, the majority are widespread and the others are Asian; none show certain affinity to the Australian zoogeographic region or to Wallacea, the area between the Oriental and Australian regions. This is unlike fruit bats (Pteropodidae), which show equal affinity to the Orient and to Wallacea, but in which about 25% of the genera are endemic to the Philippines (Heaney and Peterson, 1984). About 50% of the species of fruit bats are endemic to the Philippines; no vespertilionids are endemic.

The picture that emerges from these data on Philippine vespertilionids is of a fauna in which most species are very widespread in the eastern Old World tropics, but there is also a clear tendency for more species to be shared with Asia than with the Australian faunal region. Very few species are restricted to

Table 2. List of bats of the family Vespertilionidae known to occur in the Philippine Islands.

Glischropus tylopus spp.
Kerivoula hardwickii spp.
Kerivoula jagorii
Kerivoula pellucida
Kerivoula whiteheadi pusilla
Miniopterus australis paululus
Miniopterus schreibersii eschscholtzii
Miniopterus tristis tristis
Murina cyclotis peninsularis
Myotis horsfieldii jeannei
Myotis macrotarsus
Myotis muricola browni
Myotis rufopictus
Philetor brachypterus brachypterus
Pipistrellus javanicus meyeni
Pipistrellus petersi
Pipistrellus stenopterus
Pipistrellus tenuis tenuis
Scotophilus kuhli castaneus
Tylonycteris pachypus meyeri
Tylonycteris robustula

areas near the Philippines, although exceptions are present (e.g. *Myotis macrotarsus* in the Philippines and Borneo). Because many islands in the Philippines are geologically young and have not had land bridge connections to the Asian mainland at any time (Heaney, 1985, 1986), this implies that these bats have high colonization ability. On this basis, we predict that few, if any, endemic vespertilionids will be discovered in the Philippines, that vespertilionids will be among the first bats to reach new volcanic islands in Southeast Asia (e.g. the new island of Anak Krakatau) and that they should occur on isolated oceanic islands in the Philippines where non-volant mammals and even fruit bats are absent or depauperate. Field work should be undertaken to test these predictions.

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OBSERVATIONS ON THE REARING OF THE FISH SIGANUS GUTTATUS (BLOCH) (SIGANIDAE) IN BRACKISH WATER PONDS IN SOUTHERN NEGROS, PHILIPPINES

Julieta A. Luchavez

A growth rate study was conducted on Siganus guttatus fry in two brackish water ponds from 29 November 1979 to 20 September 1980. A total of 342 acclimatized fish (3 batches) were released in Pond I and 190 in Pond II. In Pond I, the monthly increase was 7.46 g for the first batch, 5.58 g for the second batch and 6.20 g for the third batch. The fish in Pond II had the highest monthly increase of 13.58 g. Tolerance of this species to salinity, temperature and dissolved oxygen is discussed.

Siganids, represented by about 25 species in the Indian and western Pacific Oceans (Woodland and Allen, 1977), are highly esteemed food fishes in the Philippines which have recently been receiving widespread attention as potential candidates for mariculture (Lam, 1974; Popper and Gundermann, 1975; von Westernhagen and Rosenthal, 1976). Studies of the growth rates of siganids include those of S. canaliculatus and S. spinus in aerated aquaria (Laviña and Alcala, 1974); S. canaliculatus and S. spinus in sea cages (Horstman, 1975); S. canaliculatus and S. concatenata (S. guttatus) in the laboratory (von Westernhagen, 1975); S. canaliculatus, S. spinus and S. guttatus in the laboratory and sea cages (Carumbana and Luchavez, 1979b); S. canaliculatus, S. spinus and S. argenteus in Guam waters (Tsuda et al., 1974); S. rivulatus in tanks and sea cages (Ben-Tuvia et al., 1973); S. vermiculatus in dirt ponds (Lichatowich and Popper, 1975); S. guttatus in sea cages and fish pens (Tahil, 1978) and S. vermiculatus in nature and ponds (Gundermann et al., 1983).

This paper reports on the growth and tolerance of S. guttatus reared in brackish water ponds in Dumaguete, southern Negros, Philippines, with a view toward assessing the potential of this species for mariculture in ponds.

MATERIALS AND METHODS

The experiment was conducted in two ponds designated as I and II, located behind the Silliman University Marine Laboratory in Bantayan, Dumaguete. The ponds were adjacent to each other, with dimensions of 28 m long, 62 m wide and 30 m long, 30 m wide, respectively. The average depth of water in both ponds was about 39 cm. Sea water was supplied by the incoming tide (of at least 1.3 meters) through a small creek and a small canal leading to the ponds. The temperature of the water was monitored three times daily (morning, noon and afternoon) for two weeks each month during the observation period, using a mercury thermometer. Salinity was determined three times a week for two weeks every month using a refractometer, while the dissolved oxygen concentration of the sea water was determined twice every month using the Winkler method.

S. guttatus fry were collected using bamboo fish traps from the mangrove swamps in Sanlagan, South Bais Bay, Negros Oriental. Collection of fry was made four times, in November 1979 and in April, July and August 1980. Before being placed in the experimental ponds, all fish were acclimatized for a week in large concrete tanks. The first day, the tank held normal seawater. Each day following, fresh water was added to reduce the salinity from 34 ppt to the salinity of pond water at the rate of 2 ppt daily. Using a steel ruler and a "Harvard Trip Balance" the standard lengths (SL) and weights of a random sample of 25 fish from each group were taken. Their mean standard length and mean weight were recorded as initial measurement and weight.

A total of 342 acclimatized fish (three groups) were released in Pond I: Batch 1, 117 on 29 November 1979, with standard lengths ranging from 31 to 80 mm; Batch 2, 79 on 23 April 1980, with standard lengths ranging from 52 to 88 mm; and Batch 3, 146 on 5 July 1980, with standard lengths ranging from 23 to 55 mm. On 9 August 1980, 190 fish were stocked in Pond II; these had standard lengths ranging from 23 to 62 mm. The fish were always released in the ponds in the evening, when the temperature of the pond water was 32°C or lower.

The experimental fish in each pond were given only about 12 kg of green filamentous algae (Enteromorpha spp. and Rhizoclonium kerneri) daily. The algae was collected from a river mouth and fishpond nearby. Oftentimes, these foods were supplemented with young fresh leaves of "ipil-ipil" (Leucaena) and "kangkong" (Ipomoea reptans).

The growth rate of the first batch of fish was determined for a sample of 25 fish harvested from Pond I on 28 May 1980. On 20 September 1980, the experiment was terminated when all experimental fish in the ponds died. The mean standard lengths and weights of the second and third batches of fish in Pond I and those in Pond II were taken from a random sample of 25 dead fish.

Their growth rates were computed.

RESULTS AND DISCUSSION

Growth rates.

Table 1 summarizes the data on growth of S. guttatus reared in the ponds. The fish in the first batch weighed 44.78 g after six months; those in the second batch 27.88 g after five months; and those in the third batch 12.31 g after two months. In Pond II, the fish weighed 13.58 g after one month. The mean monthly increase was 7.46 g for the first batch, 5.58 g for the second batch and 6.20 g for the third batch.

The first, second and third batches of fish had an almost uniform monthly growth rate. The fish in Pond II had the biggest growth rate, more than twice those in Pond I. These fish were younger than most of those in Pond I, as indicated by their initial size range of 23 to 62 mm. The lower growth rate of fish in Pond I was probably due to the smaller amount of food available per individual. As mentioned earlier, the same amount of food was placed in the two ponds, but Pond I had more fish (342) than Pond II (190).

The growth rates of S. guttatus in the ponds are much higher than those obtained by Tahil (1978), who reported an increase of only 18.09 g after six months (3.01 g/month) of rearing in sea cages and 19.0 g (3.1 g/month) in a fishpen, probably because his fish stocks were larger (initial mean standard lengths were 7.89 cm and 7.88 cm in the sea cage and fishpen, respectively). Carumbana and Luchavez (1979b) reported that S. guttatus reared in a sea cage for two months and given Enteromorpha spp. increased by 24.57 g in weight and 40.66 mm in standard length. The monthly growth increase was 12.21 g and 26.33 mm, much higher than the growth of fish in Pond I but comparable to that of the fish in Pond II.

Mortality and tolerance to physical factors.

The temperature and salinity of the water in the ponds during the experimental period from December 1979 to September 1980 fluctuated. Temperature varied from 27 to 43°C, with March and September 1980 having the highest temperatures of 40 and 43°C, respectively; salinity varied from 2 to 25 ppt, with March 1980 having the lowest salinity of 2 to 4 ppt. Dissolved oxygen concentration varied from 0.9 to 5 mg/l. It was also found that the pH of the experimental ponds varied from 7.6 to 8.0; the nitrite concentration was always below 0.1 mg/l (Carumbana and Luchavez, 1979b). Maximum temperatures of 38 to 40°C in March 1980 and 38 to 43°C in September 1980 were caused by prolonged sunny periods without rain. During this period, the water in the

Table 1. Growth rate of *Siganus guttatus* reared in brackish water ponds.

	POND NUMBER			
	I			II
	BATCH 1	BATCH 2	BATCH 3	
Number of fish stocked	117	79	146	190
Initial size range in SL (mm)	31-80	52-88	23-55	23-62
Initial mean SL (mm)*	45.92±12.76	67.16±10.04	36.0 ±10.0	39.08± 9.66
Initial mean weight (g)*	4.27± 3.93	11.02± 4.70	2.25± 1.84	2.57± 2.03
Mean SL (mm) at harvest*	110.84± 5.63	104.16± 2.63	71.64± 4.45	71.88± 6.57
Mean weight (g) at harvest*	49.05± 7.08	38.90± 5.92	14.56± 3.38	16.15± 4.07
Mean increase in weight (g) at harvest*	44.78± 3.15	27.88± 1.22	12.31± 1.54	13.58± 2.04
Mean monthly increase in weight (g)*	7.46± 0.53	5.58± 0.25	6.20± 0.77	13.58± 2.04
Number of fish sampled	25	25	25	25
Period of rearing (months)	6	5	2	1

*Figures following means are standard deviations.

ponds was shallow, only about 19 cm deep, because the low tides (neap tides) could not supply the ponds with sea water for almost two weeks. To keep the ponds from drying up, fresh water was added, resulting in the reduction of salinity to 2 ppt in March 1980.

Mortality of fish occurred twice during the experimental period. The first event was in March 1980, when 32 of 117 fish died in Pond I. The second happened in September 1980, when all experimental fish died in both ponds. At both times the maximum recorded water temperature varied from 38 to 43 °C. The high temperatures of the pond water combined with low salinity probably caused the death of the fish.

Siganus guttatus can tolerate a fairly wide range of salinities (Carumbana and Luchavez, 1979a) under moderate temperatures. Juvenile *S. guttatus* have been found in river mouths and tidal lagoons with salinities ranging from 2 to 20 ppt (Alcala, 1979) and adults are said to suffer no adverse effects when transferred from natural sea water to 5 ppt salinity (von Westernhagen and Rosenthal, 1976). Carumbana and Luchavez (1979a) also reported that S. guttatus can tolerate dissolved oxygen reduction to 0.70 mg/l at tempertaures of 28 to 29 °C. It is evident from these data that although S. guttatus is tolerant to large changes in salinity and of low dissolved oxygen concentration, this species easily succumbs to high temperatures (38 - 43°C).

CONCLUSION

The cultivation of S. guttatus in inland ponds may be feasible only if salinity and water temperatures are kept within the tolerance limits of the fish (28 - 32°C, 4 - 34 ppt) and if the rearing ponds are properly fertilized to allow abundant growth of algae serving as food for siganids. Providing shade and deep canals along the sides of rearing ponds may help ensure optimal water temperature and a steady supply of water.

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NOTES ON THE SYSTEMATICS, GEOGRAPHIC DISTRIBUTION AND BIOLOGY OF THE SANDY SHORE CRAB, MATUTA LUNARIS (FORSKAL)

Orpha S. Perez

The systematics, geographic distribution, diet and reproductive biology of M. lunaris are described. These aspects are discussed in relation to M. lunaris as a surf zone species and as a food source in a subsistence economy such as that of the Philippines.

Matuta lunaris (Forskal) (Crustacea: Decapoda), commonly known in the Philippines as "kabag-kabag" (Cebuano) and "kumong" (Ilonggo), is a common inhabitant of tropical sandy shores. It has a widespread distribution which extends from the Red Sea and South Africa to Asia and Australia. This species has been reported to be of importance in the diet of the people in Third World countries such as India, where it is eaten by the poor population (Chappgar, 1959, in Guinot, 1966). M. lunaris is also fished in West Pakistan and in the Gulf of Siam. In Madras, India and in the Philippines, M. lunaris is considered to be an important edible brachyuran species along with Portunus spp. and Scylla serrata (Guinot, 1966; Schreiber and Cases, 1984). This paper is intended as an introduction to the species in Philippine waters and a review of published studies to date.

SYSTEMATICS

Matuta lunaris is a member of the family Calappidae, a group of burrowing crabs distinguished by the location of their inhalent branchial openings. In the Calappidae, these are located in front of the basal segment of the cheliped. However, the inhalent current does not enter directly at these points, as it does in most brachyurans, but flows in at the eye sockets and is carried along a canal at the surface of the pterygostomian region (Hale, 1927). The Calappidae is subdivided into two subfamilies, the Calappinae (the ´box crabs´) and the Matutinae (the ´sand crabs´). This subdivision is based primarily on the location of the palp of the third maxilliped. In the Matutinae, it is hidden beneath the merus, which is elongate and pointed at the tip. In the Calappinae, where the merus is not elongate, it is exposed (Hale, 1927; Sakai, 1965). In the field, species in the Calappinae are distinguished by a winglike expansion on each side of the carapace which covers the walking legs, whereas species in the Matutinae are characterized by flattened swimming legs and a prominent lateral spine or tubercule on each side of the carapace.

The Matutinae contains the single genus Matuta, which is represented in both the Indo-Pacific and Atlantic Oceans (Romimohtarto, 1972). At present, it contains seven species, three of which have been recorded from the Philippines: M. lunaris, M. banksii and M. inermis (Estampador, 1959).

M. lunaris was first described by Forskal in 1775 as Cancer lunaris (Tyndale-Biscoe and George, 1962). Species that have since been synonymized with M. lunaris include M. victor (Alcock, 1896 in: Romimohtarto, 1972) and M. victrix (Lanchester, 1900). Additional descriptions of M. lunaris have been made by Miers (1877), Tyndale-Biscoe and George (1962), Sakai (1965) and Romimohtarto (1972).

M. lunaris may be identified by the possession of an accessory stridulating organ with 24-26 striae on the outer face of the dactylus in males greater than 46.5 mm full carapace width (Romimohtarto, 1972; Perez, 1985), two well-developed lateral spines on the carapace and at least two distinct spines on the outer face of the propodus (Tyndale-Biscoe and George, 1962). Based on comparative observations of Matuta species from the reference collections in the Australian Museum, M. lunaris may be differentiated from other closely related species by the following features: the absence of a postero-lateral tubercule on the carapace (present in M. banksii) and the absence of a distinct red patch at the base of the lateral spines (present in M. granulosa). The carapace of M. lunaris is relatively flat and covered with red spots. In Australia, however, the color pattern of the carapace appears to be variable (Perez, 1985). Most individuals have fine red spots, some of which occasionally form loops and lines, scattered over the carapace. A few individuals have more numerous darker red spots scattered over the carapace.

Although the individuals of both sexes of M. lunaris appear very similar in the field, several morphological differences are apparent upon detailed examination. The female abdomen is wider than that of the male, with the width becoming more pronounced with increasing size. Likewise, the first chelae spine on the propodus becomes more prominent with increasing size in females, whereas it becomes reduced in males. A ribbing on the dorsal aspect of the dactylus is present in large males but absent in smaller males and all females (Fig. 1). The functional morphology of several morphological characters of M. lunaris has been studied by Perez (1985).

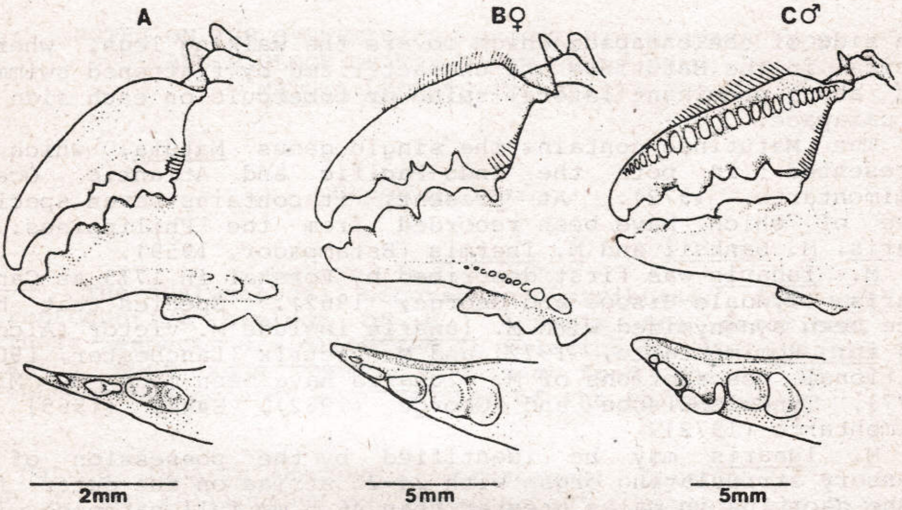

Figure 1. Details of the chela dentition of M. lunaris during ontogeny. A. Juvenile male, 15.4 mm carapace width. B. Adult female, 45.3 mm carapace width. C. Adult male, 53.9 mm carapace width.

GEOGRAPHIC DISTRIBUTION

The type locality of Matuta lunaris is the Red Sea (Forskal, 1775 in: Tyndale-Biscoe and George, 1962). It has since been recorded from the tropical beaches of numerous Indo-Pacific localities. In the Indian Ocean, M. lunaris has been recorded from the east coast of Africa (Barnard, 1950), Natal (Guinot, 1966), Somalia (Vannini, 1976), Pakistan (Hashmi, 1969) and India (Chappgar, 1957; Pillay and Nair, 1976). There are also records of collections from Madagascar (Guinot, 1966), the Andaman and Nicobar Islands (Sankarankutty, 1962), the Gulf of Siam (Guinot, 1966), and Singapore and Indonesia (Romimohtarto, 1972). Miers (1877) recorded M. lunaris from Sri Lanka, although the species identification is questionable.

In the Pacific Ocean, M. lunaris has been recorded as far north as Japan (Sakai, 1965) and as far east as Fiji (pers. obs., Australian Museum collections). It has also been recorded from the Philippines (Schreiber and Cases, 1984), the Solomon Islands (Australian Museum collections) and Australia (Tyndale-Biscoe and George, 1962; Perez, 1985).

In the Philippines, M. lunaris has been recorded from Rizal Province (Estampador, 1959), Leyte (Schreiber and Cases, 1984) and Negros (Estampador, 1959; pers. obs). In a preliminary survey of the sandy beaches of Negros Oriental, M. lunaris has been collected from the beaches of Amlan, Bantayan (Dumaguete

City) and Zamboanguita.

NOTES ON THE BIOLOGY OF MATUTA LUNARIS

M. lunaris is found in the surf zone of sandy beaches. Morphologically, it possesses two unusual characters: (1) four pairs of well developed, flattened swimming legs with paddle-like terminal joints, which enable it to maintain its position within the surf zone by either swimming in the water column or burrowing in the substratum; (2) a modified frontal opening of the respiratory channels which allows individuals to remain burrowed for extended periods of time.

In terms of total carapace width, male M. lunaris grow up to 72 mm while females grow to 62 mm. There is a considerable difference in the sizes at sexual maturity, which, in both sexes, is marked by gonad development and morphological changes. In a study of the reproductive biology of M. lunaris in Australia, it was found that the smallest sexually mature male collected was 43.5 mm carapace width, while the smallest sexually mature female was 41.0 mm carapace width (Perez, 1985).

The diet of M. lunaris is almost exclusively carnivorous. Analysis of the stomach contents of M. lunaris in Australia has indicated that it is a facultative scavenger and a predator of small crustaceans and molluscs. In Australia, the food items found in the stomach of M. lunaris included hermit crabs, sergestid shrimps, prawns, small bivalves and gastropods (Perez, 1985). Some cannibalism on small individuals was also noted.

There have been very few published accounts on the reproductive biology of M. lunaris. In India, the breeding pattern was reported to be seasonal (Pillay and Nair, 1976), while in Australia, reproductive activity in terms of gamete production, mating behavior and brood incubation was found to be continuous throughout the year (Perez, 1985). Female M. lunaris have been found to mate only once in their lifetime, that is, at the time of the puberty moult (Perez, 1985). Each female, however, was capable of producing at least two egg batches from a single copulatory event, with each batch containing approximately 65,000 eggs.

CONCLUSION

The surf zone of tropical sandy beaches is a unique environment (McLachlan, 1983). Organisms living in this hydrodynamically active region of the beach must deal constantly with a variety of problems including, food availability, exposure and wave action (Coull and Bell, 1983). The information to be gained from studies of the growth, feeding and reproduction of surf zone species is invaluable, yet the biology of these species remains one of the least studied topics in tropical marine biology. *Matuta lunaris* is one such species. On many Indo-Pacific sandy beaches, *M. lunaris* is among the dominant members of the surf zone macrofauna. It is relatively unusual in that it spends all its postlarval life in the surf zone.

In the Philippines, where brachyuran crabs are of commercial importance both as a protein source in a subsistence economy and as marketable trading goods, *M. lunaris* is one of the edible crab species collected by the local inhabitants (Schreiber and Cases, 1983). It is collected by hand or by beach seine, usually for home consumption. Biologically, there is little information about *M. lunaris* in the Philippines. The restricted distribution of *M. lunaris* in an area which is easily accessible to subsistence fishermen, i.e. the surf zone, makes it vulnerable to overexploitation. The small populations of *M. lunaris* on many Philippine beaches compared with the large populations in Australia suggests that this may already be the case (Perez, 1985; pers. obs.).

The restricted distribution, nonspecialist diet and high reproductive output of *M. lunaris* make it a promising species for further research into possible "ranching" of areas along the beach in order to increase the yield of this species. Population and reproductive studies of *M. lunaris* in Australia (Perez, 1985) indicate that *M. lunaris* has a year-round reproductive cycle and a rapid growth rate. It would be interesting to determine the nature of the reproductive and growth patterns of Philippine populations. Such information would be invaluable in assessing the aquaculture potential of *M. lunaris* and in the development of policies that would facilitate prudent management of natural stocks.

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EFFECTS OF VARYING CONCENTRATIONS OF COPPER SULFATE ON THE POPULATION DENSITY OF CHLORELLA SP., NITZSCHIA SP. AND OSCILLATORIA SP.

Merab S. Antone

The effects of varying concentrations of copper sulfate ($CuSO_4$) on the population density of the algae Chlorella sp., Nitzschia sp. and Oscillatoria sp. were studied. $CuSO_4$ was applied to the algal cultures grown in the laboratory at ordinary room conditions. The growth rates of Chlorella sp. and Nitzschia sp. were greatly reduced at concentrations 0.1 ppm. Oscillatoria sp. was more sensitive to $CuSO_4$, showing a significant reduction of growth at 0.05 ppm. Good logarithmic growth for all three species was observed in the controls.

Algae are beneficial to man and other organisms as food sources and gas exchangers (Jackson, 1964). However, some of their effects may be disturbing to man, such as the putrefaction of masses of algae in recreational lakes and in reservoirs for water supply (Prescott, 1959). An indirect effect is their ability to kill other aquatic organisms.

The freshwater plankton Chlorella sp. and Oscillatoria sp. tolerate any type of environment except intense heat and extreme chemical toxicity (Lackey, 1964; Carr and Whitton, 1973). Prescott (1959) has demonstrated that "bloom"-producing species, those which cause disturbances, are abundant in waters which are enriched with phosphates, nitrates and bicarbonates. Chlorella sp., a free-floating type of alga, grows well even in a carboy of distilled water on a laboratory shelf and may cause greenish coloration of the water (Lackey, 1964).

On the other hand, Oscillatoria sp., a clinging type, forms dense populations and produces a dark crimson coloration near the surface of the water (Carr and Whitton, 1973). Scharff (1958) has reported that other clinging types of algae appear as black spots or as a brownish or greenish mossy layer. Growth of this alga in pools or reservoirs results in an unsightly greenish or brownish appearance, accompanied by turbidity of the water.

The occurrence of certain diatom species in the water is associated with pollution, and the abundance of Nitzschia sp. is specifically related to the amount of water nitrogen (Patrick, 1964). Further research is needed regarding the toxic effects of Nitzschia on other aquatic organisms.

A polluted environment with dense algal blooms may affect other aquatic life maintained in a particular ecosystem. It is known that fish have been killed when certain algae bloomed (Lackey, 1964). Algal growths have often fostered bacterial development, imparting a very disagreeable odor to the water (Scharff, 1958; Carr and Whitton, 1973).

Controlling algal growth partly solves the above-mentioned problems. Since algae have long been known for their extreme sensitivity to excess Cu, copper salts are frequently used as algicides. Moore and Kellermañ of the United States Department of Agriculture were the first to introduce the application of $CuSO_4$ over the surface of a reservoir in 1904. In later years, $CuSO_4$ and other inorganic substances were used to remove algae from artificial pools, industrial cooling waters, an open-air swimming bath, irrigation water, salmon spawning channels, etc. (Scharff, 1958; Round, 1965; Yeo and Dechoretz, 1976).

Studies have shown Cu to be toxic to algal cells when added in excess amounts, leading to suppression of growth or death of the cells (Greenfield, 1942; Den Dooren de Jong, 1965; Soeder et al., 1967; Whitton, 1970; Levitt, 1972; Steward, 1974). According to Greenfield (1942), photosynthesis in Chlorella is inhibited by Cu concentrations higher than 0.1 um. From the data of Fitzgerald and Faust (1963), it is evident that $CuSO_4.5H_2O$ is toxic to Chlorella at a concentration of 2 mg/l or more after seven days of contact time; 0.05 mg/l (0.05 ppm) was toxic to Microcystis aeruginosa and Gloeotrichia echinulata; 0.1 mg/l was toxic to Anabaena circinalis and 0.4 mg/l, to the diatoms.

Determining the toxic level of $CuSO_4$ to destroy each type of alga is especially important, since Cu is also required as a micronutrient (Stewart, 1974). Deficiency symptoms appear when Cu is absent or when the concentration in the medium is lower than the growth requirements. It has been shown that Cu is important in photosynthesis in Chlorella ellipsoidea for plastocyanin (Katoh, 1960), a component of the photosynthetic system essential for the electron transport mechanism of pigment system I (Bishop, 1964).

This study, therefore, aims to investigate the effects of varying concentrations of $CuSO_4$ on the population density of Chlorella sp., Nitzschia sp. and Oscillatoria sp., and determine the levels of the chemical that will suppress algal growth. The results of this study may be applied in homes where aquaria are maintained for decorative purposes.

MATERIALS AND METHODS

Collection and analysis of water samples.

Algal samples were taken from a pond with an area of 21.5 m x 8 m and a depth of 0.875 m, fronting the Administration

Building of the University of the Philippines at Los Baños, College, Laguna. The depth of the water was 65 cm.

Samples were collected using a conical, fine-mesh nylon plankton net. Organisms collected with this net were 93% phytoplankton.

The pond water was stirred before dipping the net through it. The temperature of the water was taken and recorded; the pH was also measured immediately after collection using a Chem-mate pH meter model no. 72 to ensure that the same conditions would be maintained in the laboratory.

Preparation of media.

Pond water samples of about 10.5 liters were filtered using coarse filter paper, Whatman No. 1, to remove sediments. Filtered pond water and distilled water were mixed at a 1:1 ratio, and pH was adjusted to 7.9, optimum for algal growth. From the above mixture, aliquots of 7.5 ml were transferred to cotton-plugged 18 x 45 ml test tubes.

For mass culturing of algae, both organic and inorganic media were used. The organic medium was soil water extract (SWE) (25 g sieved garden soil + 100 ml tap water). The inorganic media used were modified Chu ‡‡10 (MC 10) (as described by Gerloff et al., 1950) and Tris Buffered Inorganic Medium (TIBM) (as described by Bellis, 1968). All media were sterilized in an All-American pressure cooker #941.5 for 15 minutes.

Culture experiments.

Samples were inoculated into two tubes each of SWE, MC 10 and TIBM in an effort to grow all algal species present in the pond. Test tubes with the culture were shaken daily to provide oxygen to the cells and to maintain the homogeneity of the suspension. Weekly sub-culturing was conducted for one month to obtain unialgal cultures of *Chlorella* sp., *Nitzschia* sp. and *Oscillatoria* sp.

When pure cultures were obtained, a final transfer was made to test tubes with a 1:1 ratio of filtered pond water and distilled water. The cells were allowed to grow for 48 hours, then copper (II) sulfate pentahydrate ($CuSO_4.5H_2O$) was applied at varying concentrations to the cultures. Five ml of the chemical was added to each tube.

All cultures were maintained under ordinary room condition (25-27 °C), under approximately 155 foot candles of daylight fluorescent light, so as to obtain results that would be applicable to small aquaria in Philippine homes.

Quantitative determination.

Quantitative determination of the algal population was by microscope counting with the use of a haemacytometer, as described by Martinez et al. (1975).

The first count was after a 24-hr incubation of the cells in filtered pond water and distilled water; the second, after a 48-hr incubation. First and second countings represent algal population not affected by $CuSO_4$. Successive counts were taken for four consecutive days after $CuSO_4$ application.

RESULTS

The three species differed in their degree of sensitivity to $CuSO_4$. Treatment with 0.01 ppm of $CuSO_4$ resulted in an increased number of cells per cu mm per day in the three species; however, a slight reduction in growth rate was observed, compared to the control (Figs. 1, 2 and 3). Cell division was still evident in Nitzschia sp. and Chlorella sp. at 0.05 ppm, but the rate was again lower than the control's (Figs. 1 and 2). There was 76.1% reduction of growth rate in Nitzschia and 76.7% reduction in Chlorella.

Reduction of growth rate of both Nitzschia and Chlorella was significantly different from the control at 0.1 ppm of $CuSO_4$. A slight increase in the number of cells was recorded on the sixth day of observation in Nitzschia at 0.1 ppm, but the count was only about 38% of the control, indicating a reduction in cell division.

On the other hand, there was no change in the cell count in Chlorella on the fifth and sixth days of observation, indicating absence of cell division. Since the rates of growth of both Nitzschia and Chlorella were greatly affected by $CuSO_4$ at the same minimum level (i.e. at 0.01 ppm), both organisms have the same sensitivity to the chemical. Complete suppression of growth was observed with succeeding higher concentrations (i.e. 0.01 ppm).

The blue-green alga, Oscillatoria sp., appeared to be the most sensitive among the three species studied. A sharp decrease in growth rate occurred at a concentration of 0.05 ppm $CuSO_4$, with 48.8% reduction. Such a reduction of growth rate is significantly different from the control (Fig. 3).

DISCUSSION

The selectivity of the toxic action of Cu for different algal species is probably a function of processes within the algal cells (Fitzgerald and Faust, 1963). It has been demonstrated by Steemann-Nielsen and Wium-Andersen (1971) that the growth of Nitzschia is less influenced by low concentrations of Cu. When Cu is present, the diatom excretes organic matter which may bind to the chemical, and thus make the medium suitable for growth by removing the toxic effect.

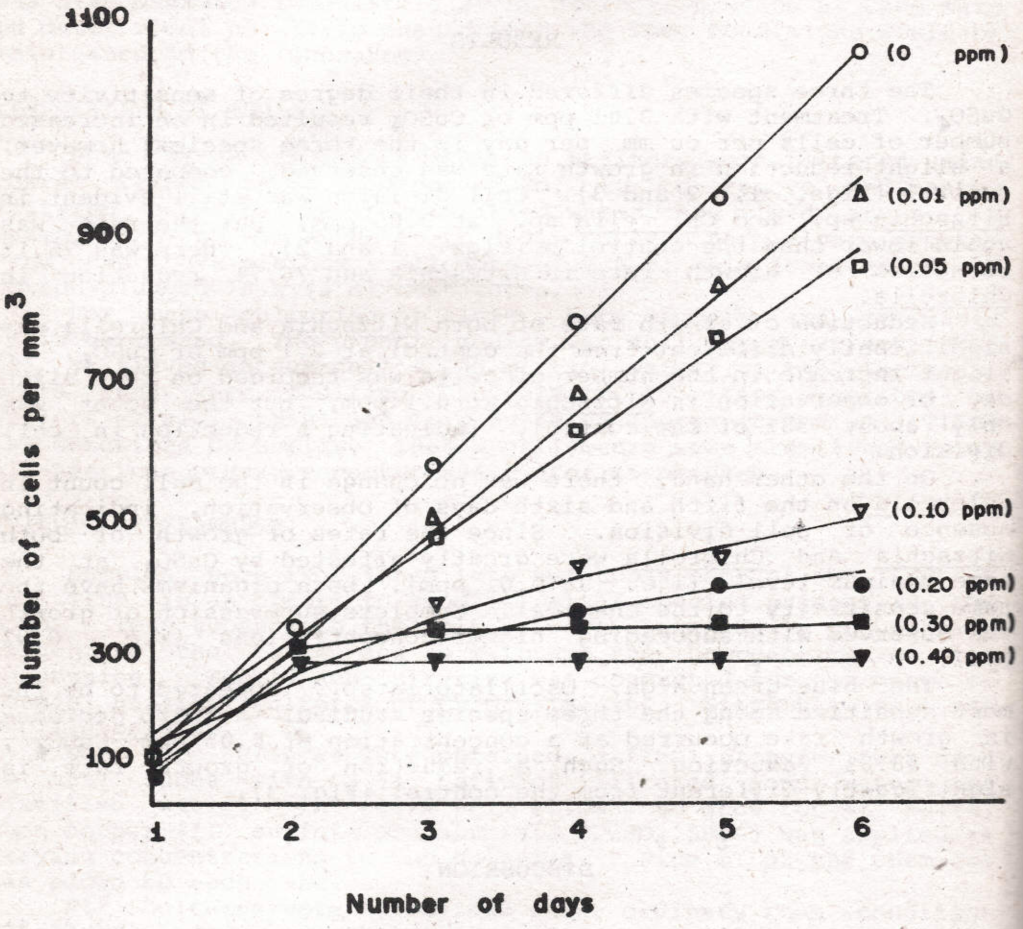

Fig. 1. Effect of varying concentrations of $CuSO_4$ on the population density of <u>Nitzschia</u> sp.

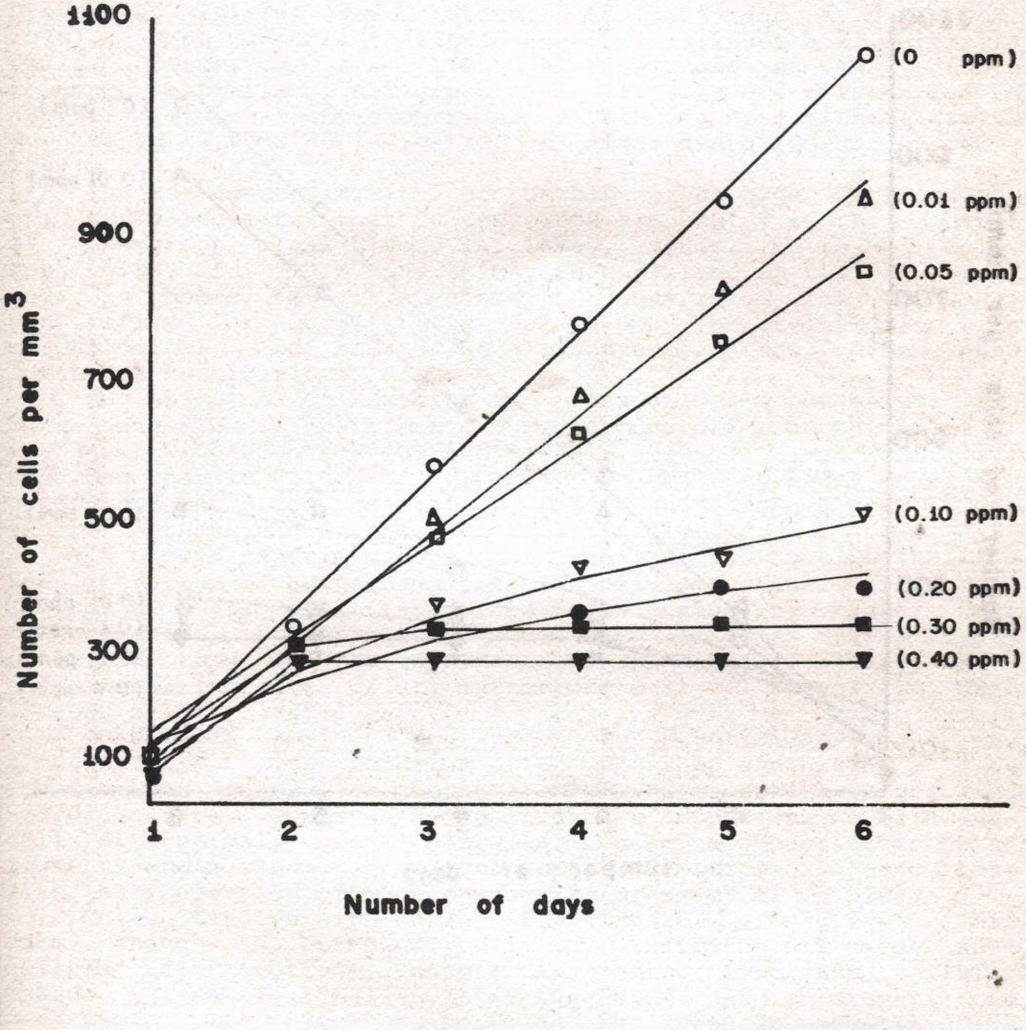

Fig. 2. Effect of varying concentration of $CuSO_4$ on the population density of Chlorella sp.

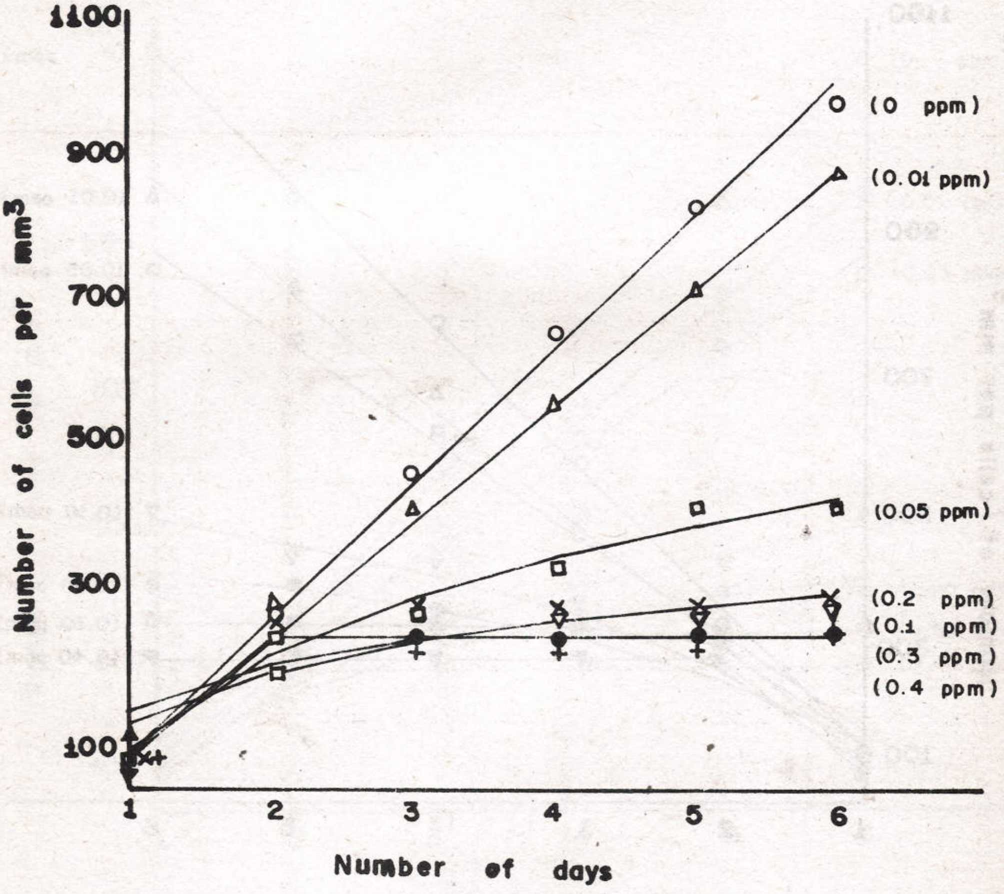

Fig. 3. Effect of varying concentrations of $CuSO_4$ on the population density of Oscillatoria sp.

Addition of low concentrations of Cu to the medium also has little effect on the growth of Chlorella. It has been shown by Steemann-Nielsen and Kamp-Nielsen (1970) that Chlorella reestablishes a normal growth rate with minute amounts of Cu added. Cu is, again, bound by the alga such that no lasting poisonous effect is observed. However, no regeneration of growth rate is seen in the cultures from a medium with Cu concentrations preventing initial growth (Steemann-Nielsen and Kamp-Nielsen, 1970). Such Cu concentrations, however, will not kill Chlorella cells. Soeder et al. (1967) have demonstrated that growth resumes, initially at a reduced rate, if cells are transferred to another medium without excess Cu. A complete cessation of growth due to Cu is thus no indication of algal death (Soeder et al., 1967).

The marked sensitivity of the blue-green alga Oscillatoria sp. to Cu indicates that Cu compounds are useful in the control of blue-green algal blooms in lakes, ponds, swimming pools, reservoirs, etc. This finding may be exploited in the laboratory and in homes for maintenance of aquaria. The unusual sensitivity of Oscillatoria to Cu may be related to its morphological and physiological characteristics, which need further investigation.

One effect of Cu toxicity is loss of cell potassium, but more potassium is lost than can be accounted for on the basis of exchange with Cu (McBrien and Hassall, 1965). McBrien (1967) reported that in Chlorella vulgaris, Cu absorbed under anaerobic conditions inhibited respiration, photosynthesis and growth more severely than did Cu absorbed aerobically.

In growth experiments, it has been observed that Cu inhibits the liberation of autospores (Steemann-Nielsen et al., 1969). If Chlorella cells are transferred to a medium of higher salt concentration, the formation of daughter cells is more strongly inhibited than is the synthesis of biomass, resulting in a transitory increase of dry matter per cell for one or two days (Soeder et al., 1967).

Herbicides acting upon the photosynthetic apparatus may either inhibit its function or prevent the synthesis of its constituents and cause a destruction of the apparatus (Boger and Schlue, 1976). Copper, added in excess amounts to non-growing cells of a normal, green Chlorella, caused a reduction in total pigments and a blue shift of chlorophyll absorption, concurrent with the inhibition of photosynthesis (Gross et al., 1970).

Cells treated with Cu appear bluish- or grey-green. This color change in poisoned cells may indicate different sub-cellular distributions, constituting another important cellular change (Hassall, 1963). It is suggested that chlorophyll is metastable with reference to Mg and the green Cu pheophytin is very stable (Hill, 1963). Perhaps, a replacement of the ionically bound Mg by a Cu atom took place, but an oxidation of chlorophyll or some other reaction cannot be excluded (Gross et al., 1970).

The action of Cu takes place primarily on the plasmalemma, which, together with the cell walls and slime envelopes, is able to bind Cu to some extent, as in the case of Chlorella (Steemann-Nielsen et al., 1969). Steemann-Nielsen et al. (1969) further reported that if both the cell walls and slime envelopes are composed of pectic acid, 12 carbon atoms at least are necessary for binding one Cu ion.

Gross et al. (1970) suggested that the mechanism of action of Cu may be influenced by the structure of the cell, with the rupture of membrane barriers as the first step in the damage sequence, or the primary toxic effect of Cu. Therefore, membrane integrity may be altered by the action of Cu. In Nitzschia, Steemann-Nielsen (1971) has shown that organic matter is lost by the cells as Cu penetrates them. This implies that Cu loosens the cell membranes.

Other evidence to show that the permeability of the cells is increased or that there is alteration in the retentive properties of the cell due to the presence of Cu is shown by McBrien (1967), in that even when only small amounts of Cu are taken up by the cells, substantial amounts of cellular K+ are released. Normally, this membrane retains K+ within the cells.

The demonstration that cells poisoned with Cu contain little soluble P suggests either that P metabolism of growing cells is severely disturbed when the ratio of sorbed Cu to nucleotide P rises above about 0.2 or, alternatively, that the Cu renders the cell permeable to solutes (Hassall, 1963).

Related to the rupture of membrane barriers (Gross et al., 1970) is the ability of the salts of heavy metals to inactivate enzymes (Myrback, 1965) and precipitate proteins (Brian, 1964, as quoted by Sutton et al., 1970; McBrien, 1967).

A major metabolic process also affected by Cu is respiration. Cell respiration is enhanced by shaking the culture. In this particular study, normal daily shaking of the tubes was stopped on the day that $CuSO_4$ was applied to the cells. Since Cu is highly toxic, it greatly reduces respiration, especially when applied to cells under anaerobic conditions or when cells are not shaken (Hassall, 1962, 1963). Respiration of mature autospore mother cells is inhibited in a more concentrated medium (Stewart, 1974). Furthermore, excess Cu in the medium delays cell division, causing a reduction of growth rate (Soeder et al., 1967). This accounts for the reduction in the number of autospores or daughter cells with higher concentrations of $CuSO_4$.

SUMMARY AND CONCLUSION

Increasing concentrations of $CuSO_4$ caused a reduction in the growth rates of Nitzschia sp., Chlorella sp. and Oscillatoria sp. Each species had a certain degree of sensitivity to toxic doses of the chemical. The toxic dose of $CuSO_4$ for Nitzschia sp. and

Chlorella sp. was 0.1 ppm with r value of 0.99 and 0.97, respectively. For Oscillatoria sp., the toxic dose was at 0.05 ppm with r = 0.97.

Given the combined toxic effects of Cu on algal cells, it is safe to say that $CuSO_4$ is a good algicide to suppress algal growth in home aquaria. $CuSO_4$ is not poisonous to fish in the concentrations ordinarily used in water treatment, Moore and Kellerman (as cited in a brochure of the Mountain Copper Company, Ltd.) have studied the toxic effect of $CuSO_4$ on various species of fish and have set the limiting safe dosage for goldfish at 0.50 ppm.

RECOMMENDATIONS

When using $CuSO_4$ as an algicide, the toxic dose for the specific algal species to be eliminated should be strictly observed. Lower concentrations than the toxic dose enhance growth and reproduction of the algae. On the other hand, higher concentrations than the toxic dose might have some toxic effect on the fish maintained in the aquaria.

It should also be noted that 24 hours after $CuSO_4$ application, the water in the aquaria must be changed. Treated water may contain considerable dead organic matter resulting from the action of $CuSO_4$, and this organic matter may clog the gills of the fish (The Mountain Copper Co., Ltd.). It is also suggested that $CuSO_4$ should be distributed evenly in the water. Uneven distribution of $CuSO_4$ may result in toxicity to fish in areas with greater concentrations of the chemical.

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SEAGRASSES IN BATANES PROVINCE, NORTHERN PHILIPPINES

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Seagrasses were collected from 11 sites at four islands in Batanes Province, northern Philippines, during 1985 and 1986. Five species in two families and five genera are recorded for the first time.

Batanes is the northernmost province in the Philippines. It lies between Taiwan and the northern tip of Luzon and consists of about a dozen islands (Fig. 1). Most of the islands are volcanic in origin, and a few are coral atolls. The larger islands, i.e. Itbayat, Batan and Sabtang, have permanent inhabitants, while the rest are uninhabited, except for fishermen stopping a few days on fishing journeys. Although fish are abundant, fishing is feasible only during April and May, when the islands are not visited by typhoons. The major source of livelihood is garlic agriculture.

Batanes is the most typhoon-wracked region in the Philippines. Heavy rains usually come in late June and may extend to early November, the month when some of the worst typhoons occur. The islands experience cold temperatures from November to March, due to the northeast winds from the frigid North Pacific and the cold and dry northeast monsoon from Siberia. By June, clouds from the South China Sea deposit rains in the Batanes region. April is the driest month, the dry season sometimes extending to early June. Numerous and treacherous tide rips, currents and swirls, caused by the meeting of the South China Sea and the Pacific Ocean currents, exist inside the channels and alongside the islands, posing a great problem to travellers.

Batanes´ only link to the rest of the Philippines is by a commercial flight three times a week to the capital city of Basco, Batan Island, if weather permits. An inter-island ship carries passengers and cargo between Batanes and Luzon twice a year. Small open dories, powered by diesel engines, are used for inter-island travel only during good weather.

The limited travel facilities, bad weather and sea conditions, and isolation are some of the reasons why very few naturalists have ventured to visit Batanes. The region is virtually biologically unexplored. The earliest attempt at biological investigation was perhaps in the first few years of this century. E. Mearns visited Batan Island on 27 May 1907 and spent the day collecting birds, which were eventually deposited at the U.S. National Museum. McGregor, about the same time, collected

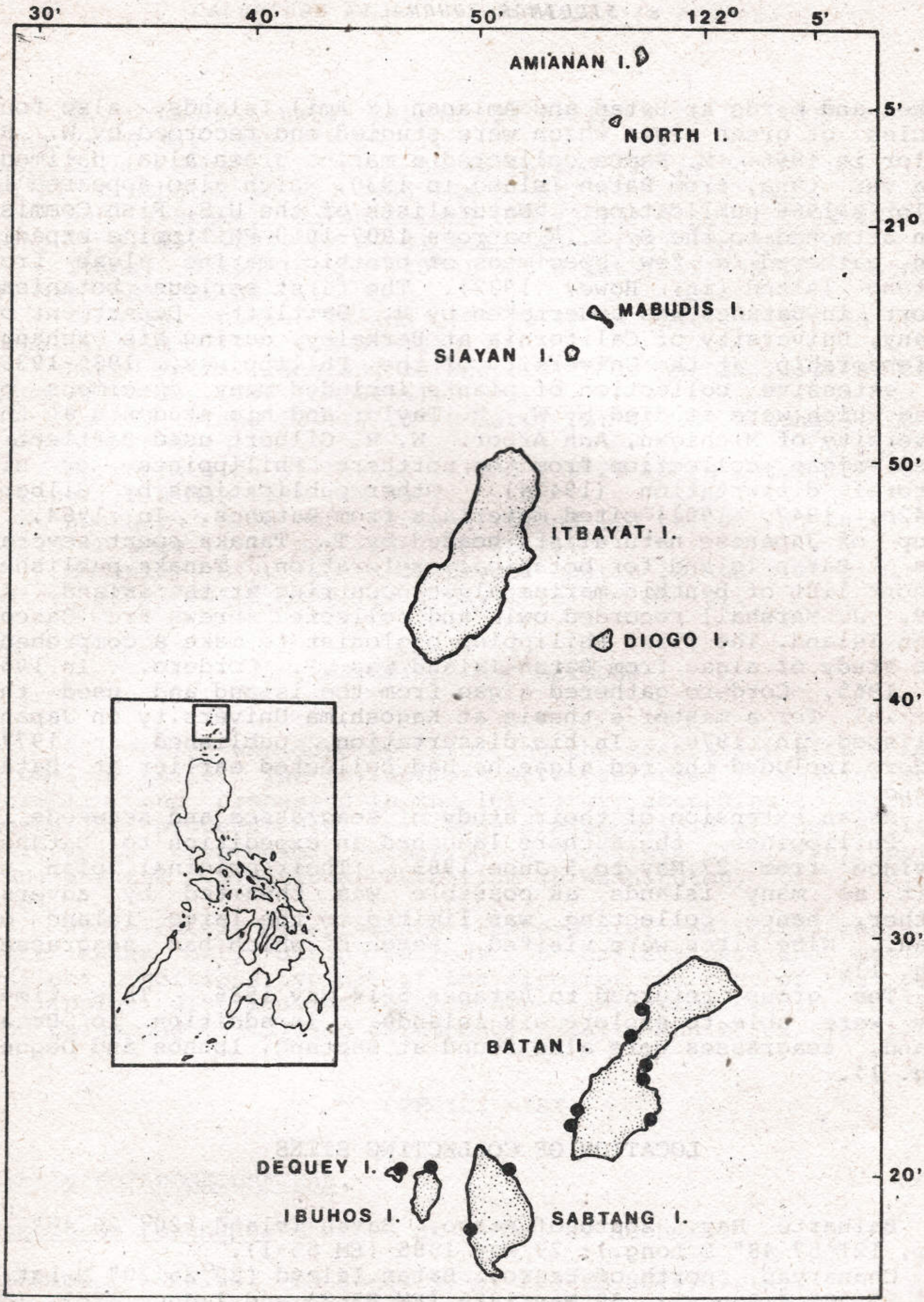

Fig. 1. Map of Batanes Province, northern Philippines. Inset is a general map of the Philippines showing location of Batanes Province. Black dots indicate collecting sites.

snakes and birds at Batan and Amianan (Y Ami) Islands, also four species of green algae which were studied and recorded by W. R. Taylor in 1966. M. Ramos collected a marine green alga, Halimeda tuna var. tuna, from Batan Island in 1930, which also appeared in Taylor's 1966 publication. Naturalists of the U.S. Fish Commission attached to the S. S. Albatross 1907-1910 Philippine expedition gathered a few specimens of benthic marine algae from Sabtang Island (in: Howe, 1932). The first serious botanical effort in Batanes was undertaken by H. Bartlett, Department of Botany, University of California at Berkeley, during his exchange professorship at the University of the Philippines, 1935-1936. His extensive collection of plants included many specimens of algae which were studied by W. R. Taylor and his students at the University of Michigan, Ann Arbor. W. R. Gilbert used Bartlett's green algae collection from the northern Philippines for his doctoral dissertation (1942a). Other publications by Gilbert (1942b, 1947, 1961) cited materials from Batanes. In 1964, a group of Japanese naturalists headed by T. Tanaka spent several days at Batan Island for botanical exploration. Tanaka published a short list of benthic marine algae occurring at the island. In 1979, J. Marshall recorded owls and collected shrews from Basco, Batan Island. The first Philippine biologist to make a comprehensive study of algae from Batan Island was P. Cordero. In 1964 and 1965, Cordero gathered algae from the island and used the material for a master's thesis at Kagoshima University in Japan, published in 1976. In his dissertation, published in 1977, Cordero included the red algae he had collected earlier at Batan Island.

As an extension of their study of seagrasses and seaweeds in the Philippines, the authors launched an expedition to Batanes Province from 27 May to 5 June 1985. Their original plan to visit as many islands as possible was thwarted by adverse weather, hence collecting was limited to the large island of Batan. Nine sites were visited, seven of which had seagrasses (Fig. 1).

The group returned to Batanes 5-14 May 1986. This time, they were able to explore six islands. In addition to Batan Island, seagrasses were also found at Sabtang, Ibuhos and Dequey (Fig. 1).

LOCATION OF COLLECTING SITES

Baluarte Bay, south of Basco, Batan Island (20° 26′45" N Lat., 121° 57′48" E Long.); 29 May 1985 (EM 85-1).

Chanaryan, north of Basco, Batan Island (20° 26′20" N Lat., 121° 57′20" E Long.); 30 May 1985 (EM 85-3) and 1 June 1985 (EM 85-12).

Mahatao, Batan Island (20° 24′50" N Lat., 121° 56′10" E Long.); 30 May 1985 (EM 85-4).

White Beach, Batan Island (20°24´32" N Lat., 121° 55´40" E Long.); 30 May 1985 (EM 85-5).

Below Mabatui Point, Batan Island (20°24´00" N Lat., 121° 55´23" E Long.); 30 May 1985 (EM 85-6).

San Vicente, Batan Island (20°23´23" N Lat., 121° 55´17" E Long.); 31 May 1985 (EM 85-8) and 2 June 1985 (EM 85-13).

Ivana, Batan Island (20°21´05" N Lat., 121° 55´14" E Long.); 31 May 1985 (EM 85-9).

Imnajbu, Batan Island (20°22´42" N Lat., 121° 58´10" E Long.); 31 May 1985 (EM 85-10).

Asked Point, Sabtang Island (20°20´30" N Lat., 121° 52´00" E Long.); 10 May 1986 (EM 86-5).

Dequey Island (20° 20´10" N Lat., 121° 47´20" E Long.); 10 May 1986 (EM 86-6).

Northern side of Ibuhos Island (20° 20´15" N Lat., 121° 48´30" E Long.); 10 May 1986 (EM 86-7).

Southern side of Sabtang Island (20°18´00" N Lat., 121° 50´25" E Long.); 11 May 1986 (EM 86-9).

Mananioy Bay, south of Basco, Batan Island (20° 24´15" N Lat., 121° 57´40" E Long.); 12 May 1986 (EM 86-10).

MATERIALS AND METHODS

Collecting was done by uprooting the seagrasses with a small trowel or knife. The collections were preserved in a solution of formalin and processed in the laboratory according to standard herbarium procedures. Specimens are deposited at the Silliman University Cryptogamic Herbarium in Dumaguete City, Philippines (SU) and the U.S.National Herbarium in Washington, D.C., U.S.A. (US).

Hydrological measurements (temperature, salinity, currents) were taken only during periods of collection, and may not reflect conditions typical of the site for the rest of the year. Philippine distribution records were taken from Meñez, Phillips and Calumpong (1983) and Calumpong, Medalla and Meñez (1985).

SPECIES LIST

Family *POTAMOGETONACEAE*.

Cymodocea *rotundata* Ehrenb. et Hempr. ex Aschers.

Specimens studied: EM 85-4, 5, 6, 12; EM 86-6, 7, 9.
Philippine distribution: Batanes (Batan I., Sabtang I., Ibuhos I., Dequey I.). Luzon (Lingayen Gulf). Catanduanes. Mindoro. Palawan (Cuyo I.). Visayas (Samar, Negros, Siquijor). Mindanao (Gulf of Davao). Tawi-tawi (Pearl Bank).

Halodule uninervis (Forssk.) Aschers.

Specimens studied: EM 85-3, 4, 12.
Philippine distribution: Batanes (Batan I.). Luzon (Ilocos Norte, La Union, Pangasinan, Manila Bay, Albay). Catanduanes. Mindoro. Palawan (Cuyo I.). Visayas (Cebu, Bohol, Leyte, Negros). Mindanao (Gulf of Davao, Zamboanga).

Syringodium isoetifolium (Aschers.) Dandy

Specimens studied: EM 85-3, 12; EM 86-7.
Philippine distribution: Batanes (Batan I., Ibuhos I.). Luzon (La Union, Pangasinan, Albay). Catanduanes. Mindoro. Visayas (Bohol, Negros, Siquijor). Mindanao (Gulf of Davao, Zamboanga).

Family HYDROCHARITACEAE.

Halophila ovalis (R. Br.) Hook. f.

Specimens studied: EM 85-3.
Philippine distribution: Batanes (Batan I.). Luzon (La Union, Pangasinan, Albay). Catanduanes. Mindoro. Masbate. Palawan (Quezon, Cuyo I.). Visayas (Samar, Leyte, Bohol, Cebu, Negros, Siquijor, Sumilon, Panay). Mindanao (Gulf of Davao, Zamboanga, Bancoran I.).

Thalassia hemprichii (Ehrenb.) Aschers.

Specimens studied: EM 85-3, 4, 5, 6, 12, 13; EM 86-6, 7, 9, 10.
Philippine distribution: Batanes (Batan I., Ibuhos I., Sabtang I., Dequey I.). Luzon (La Union, Ilocos Norte, Cagayan, Pangasinan, Manila Bay, Batangas, Albay). Catanduanes. Mindoro. Palawan (Quezon). Visayas (Samar, Leyte, Bohol, Cebu, Negros, Siquijor). Mindanao (Surigao, Gulf of Davao, Cavili I.).

DISCUSSION

There are 13 species of seagrasses recorded from the Philippines (Meñez and Calumpong, 1982, 1985; Meñez, Phillips and Calumpong, 1983), five of which occur in the northernmost province of Batanes. The five species, Cymodocea rotundata, Halodule uninervis, Syringodium isoetifolium, Halophila ovalis and Thalassia hemprichii, are widely distributed (see species list). Of the 21 sites surveyed in 1985 and 1986, 11 had seagrasses (Fig. 1). Except for Baluarte Bay, all the sites have backreefs cut by surge channels. The substrate is limestone or sand (either volcanic or coral sand); water temperatures ranged 29-31 °C at the time of collection and salinities, 30-34 ppt. The seagrasses were found growing at depths of not more than 4 m in protected bays or on very exposed tidal flats that become dry during low tides. All five species occur at the bigger island of Batan, which has protected bays and coves. Although Itbayat is the biggest island in the whole island group, the shoreline consists mostly of jagged rocks and rocky benches which make collecting impossible. No seagrasses were found at the northern islands of Diogo and Siayan. Diogo is of volcanic origin, with a rocky shore and bottom (big boulders) and virtually no suitable substrate for seagrasses to settle on. Water currents are relatively strong, and would prevent settlement even if substrate made it possible.

We were, however, puzzled at the absence of seagrasses at Siayan Island, considering that it has extensive tidal flats with tide pools and coral sand, very much like Dequey Island. It will be interesting to study water current patterns that may have limited dispersal of seagrasses to Siayan.

Thalassia hemprichii was the most commonly encountered seagrass, appearing in 10 out of 11 sites. On exposed tidal flats (EM 85-4), the plants are small and stunted, with short, narrow and highly curved leaves, generally 0.5 cm wide and 6 cm long. In protected bays (EM 85-3), plants are large, with leaves reaching 1 cm wide and 20 cm long. It was either growing in pure stands (Imnajbu) or mixed with Cymodocea rotundata (San Vicente, Ivana, White Beach, Mahatao, Asked Point, northern side of Ibuhos Island and Dequey Island), Halodule uninervis (Chanaryan, Mahatao, and southern side of Sabtang Island), Syringodium isoetifolium (Chanaryan, Mananioy Bay, and northern side of Ibuhos Island) and Halophila ovalis (Chanaryan). Halophila ovalis was rare, occurring only in one site (Chanaryan).

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ADDENDUM:

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Business Manager

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(Sgd.) JOSE C. TENG
Notary Public
Until Dec. 31, 1987
PTR No. 4657056
Dumaguete City
January 3, 1986