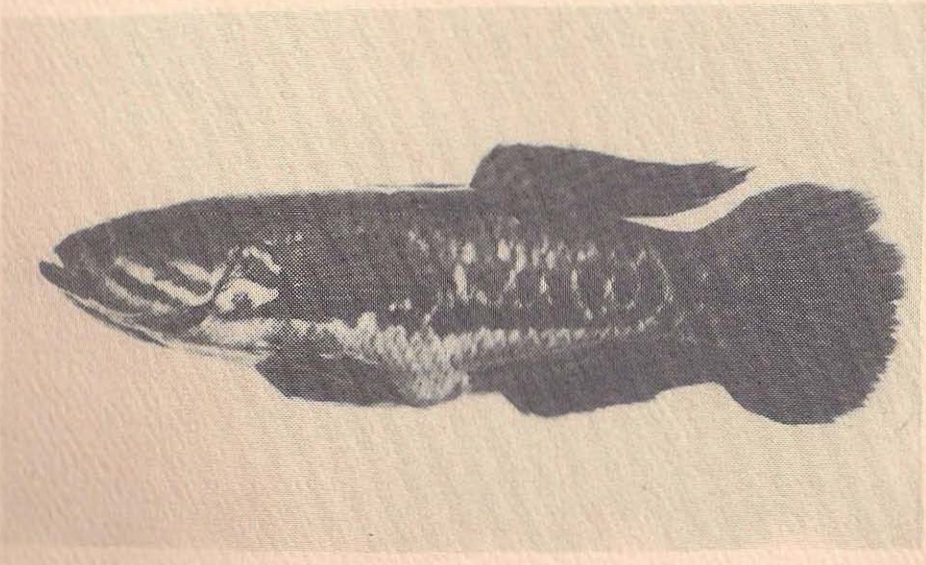
THE INLAND AQUATIC HABITATS OF YAP

Editor

Stephen G. Nelson



University of Guam Marine Laboratory
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Mangilao, Guam

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PREFACE

This report is submitted as the final report on a contract between the University of Guam (UOG) Marine Laboratory, the Marine Resource Management Division (MRMD) of the Department of Natural Resources of Yap State, and the College of Micronesia. Preserved specimens of most of the aquatic organisms collected have been deposited in collections at Yap and at the UOG Marine Laboratory. In addition, a collection of photographic slides, to be used as aids in identifying the specimens, has been prepared and stored at the MRMD office in Colonia. The project was based on interest in the development of the biological resources of the freshwaters of Yap state and was designed to provide information of use in making decisions regarding the conservation and development of these resources.

Each of us that participated in the survey sincerely appreciated the cooperation and generous hospitality that we received while we were on Yap. We are honored and grateful to have had the opportunity to conduct this study, and it is our hope that it will, in some small measure, contribute to the understanding and protection of these fascinating aquatic ecosystems.

Nutrient Characteristics of the Inland Waters of Yap

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ABSTRACT

Water samples were collected and analyzed for nutrients from various aquatic habitats on Yap. Ammonium concentrations in the streams were, on average, high 4.05 μM. Nitrates and reactive phosphates were found in low concentrations, 0.36 μM and 0.37 μM, respectively. Iron and silica were found in high concentrations, 6.30 μM and 61.18 μM, respectively. The pH of the stream water was, on average, slightly basic, mean value 7.26. Stream habitats were categorized as being runs, riffles, or pools. Oxygen content was measured at most of the stations (streams or ponds) sampled and were found to be less than saturation at all stations. The mean oxygen content of pools, 5.94 ppm, was slightly lower than those in riffles and runs, 6.31 and 6.36 ppm. Ponds were generally supersaturated with oxygen, with a mean of 7.13 ppm.

INTRODUCTION

The limnological characteristics of a tropical island are highly dependent on its geological origin and location. Yap is a group of four islands, Yap, Maap, Gagil-Tamil, and Rumung, located at 09°33'N latitude and 138°08'W longitude. The average temperature is 29°C, with a deviation which is larger diurnally than seasonally (Office of Technological Assessment, U. S. Congress, 1987). The average annual precipitation is 310 cm. (Office of Technological Assessment, U. S. Congress, 1987), with the haphazard pattern of rainfall characteristic of islands in the near vicinity of the Intertropical Convergence Zone. All of the Western Caroline Islands, along with the Mariana Islands, have this type of weather pattern. The wet season is generally between June and December, when typhoons are prevalent.

Although the geologic composition differs somewhat between the four main islands, they are predominantly of metamorphic rock. Yap and Rumung are composed chiefly of greenshcist (Yap formation); Maap and Gagil-Tamil are a mixture of breccias and conglomerates (Map formation), and andesitic and basaltic breccias (Tomil formation) (Johnson et al., 1960). The topography is mountainous, with a maximum elevation of 180m (Johnson et al., 1960).

The array of aquatic ecosystems in Yap is diverse. The relatively low elevation has led to poor formation of continuously wet ecosystems, which generally occur in higher areas (Office of Technological Assessment, U. S. Congress, 1987). Streams, ponds, and marshes can be found throughout the islands.

The predominant terrestrial vegetation is thick brush and savannah with patches of Pandanus. The latter probably succeed the denser forest growth due to excessive and uncontrolled burning (Barrau, 1961). Mangrove forests and with their associated aquatic habitats are prevalent. (Office of Technological Assessment, U. S. Congress, 1987; Johnson et al., 1960). Of all the streams, only three are greater than first order, that is having no tributaries. Also, most of the strear dry up during the dry season (Johnson et al., 1960).

The freshwater bodies in Yap fall into 4 categories (from Bright, 1979):

- o Marshes -- shallow bodies of standing waters which ma be seasonal and support vegetation,
- o Ponds -- bodies of standing water with no outflow,
- o Reservoir -- a pond formed by the artificial damming streams, and
- o Streams -- bodies of running water,

We further recognize three habitats within streams:

- o Riffles -- areas with running water, where the substra rocks protrude out of the water surface,
- o Runs -- areas with running water, where the substrate does not break the water surface, and
- o Pools -- areas of deeper water, with highly reduced fl

For the analysis of nutrients, water samples were taken f 11 sites in 6 streams on the island of Yap. Each sample was analyzed for salinity, ammonium, nitrate, reactive phosphate, iron, silica, and the pH. Oxygen content and temperature measurements were taken from the freshwater habitats of Yap, M and Gagil-Tamil.

METHODS AND MATERIALS

Site description

The characteristics of each sample station are summarize Table 1. The soil, geology, and vegetation types follow Johns et al. (1960). Site locations are illustrated in Figure 1.

TABLE 1. Station characteristics of Yap, Maap, and Gagil-Tomil streams. Soil, vegetation, and geology all follow definitions given in Johnson et al. (1960).

SITE	ISLAND	COORDINATES	SOIL[1]	VEG.[2]	GEOL.[3]
A-GITAEM	YAP	82.45 X 52.20	8	5	1
B-QOKAAW	YAP	82.60 X 55.90	9,10	5	3
C-QOKAAW	YAP	83.20 X 55.57	9	5	1
D-YYIN	YAP	84.38 X 60.03	9,10	5	1
E-MALAWAAY	YAP	84.90 X 58.37	6,9	5	1
F-LUWEECH	YAP	80.22 X 50.33	13	?	2
G-GITAEM	YAP	82.30 X 51.72	6	5	1
H-LUWEECH	YAP	80.00 X 50.00	13	8	2
I-MACHBAAB	YAP	79.43 X 50.35	13	8	2
J-MALAWAAY	YAP	81.69 X 58.15	9	5	1
K-WANEAD	MAAP	90.75 X 62.25	13,15	5	4
L-CHOQOL	MAAP	90.32 X 61.68	2,9	5	4
M-TAMALAAN	MAAP	89.50 X 62.10	5,8,9,10	5	2,4
N- CHURCH	GAGIL-TAMIL	91.95 X 56.13	2,13	3,5	5
O-THOOL	GAGIL-TAMIL	89.30 X 55.42	13	2,8	3
P-TOQAYONG	GAGIL-TAMIL	88.15 X 54.73	3	8	2
Q-DALAACH	GAGIL-TAMIL	87.93 X 55.75	2,3	5	2
R-QUAMUN	GAGIL-TAMIL	90.85 X 56.70	2	5	4

[1]SOIL CODES
2 = Giliman Clay
3 = Giliman Clay Eroded Phase
5 = Maki Clayey Graull
6 = Rull Clayey Gravel
8 = Weloy-Rull Silty Clay Loam
9 = Weloy Silty Clay Loam
10 = Kanif Soils
13 = Gachlau Clay
15 = Gal Loamy Sand

[2]VEGETATION CODES
2 = Wetland (incl. taro)
3 = Coconut grove
5 = Forest and thick brush
8 = Ferns & scattered pandanas

[3]GEOLOGY CODES
1 = Yap Formation
2 = Tomil volcanic (incl. andestic, basalt breccias, lava, and tuffs).
3 = Aluvium; clay in bottom of narrow valley.
4 = Maap Formation: Breccia and hornblende schist conglomerates
5 = serpentinite: serpentinitized periodite

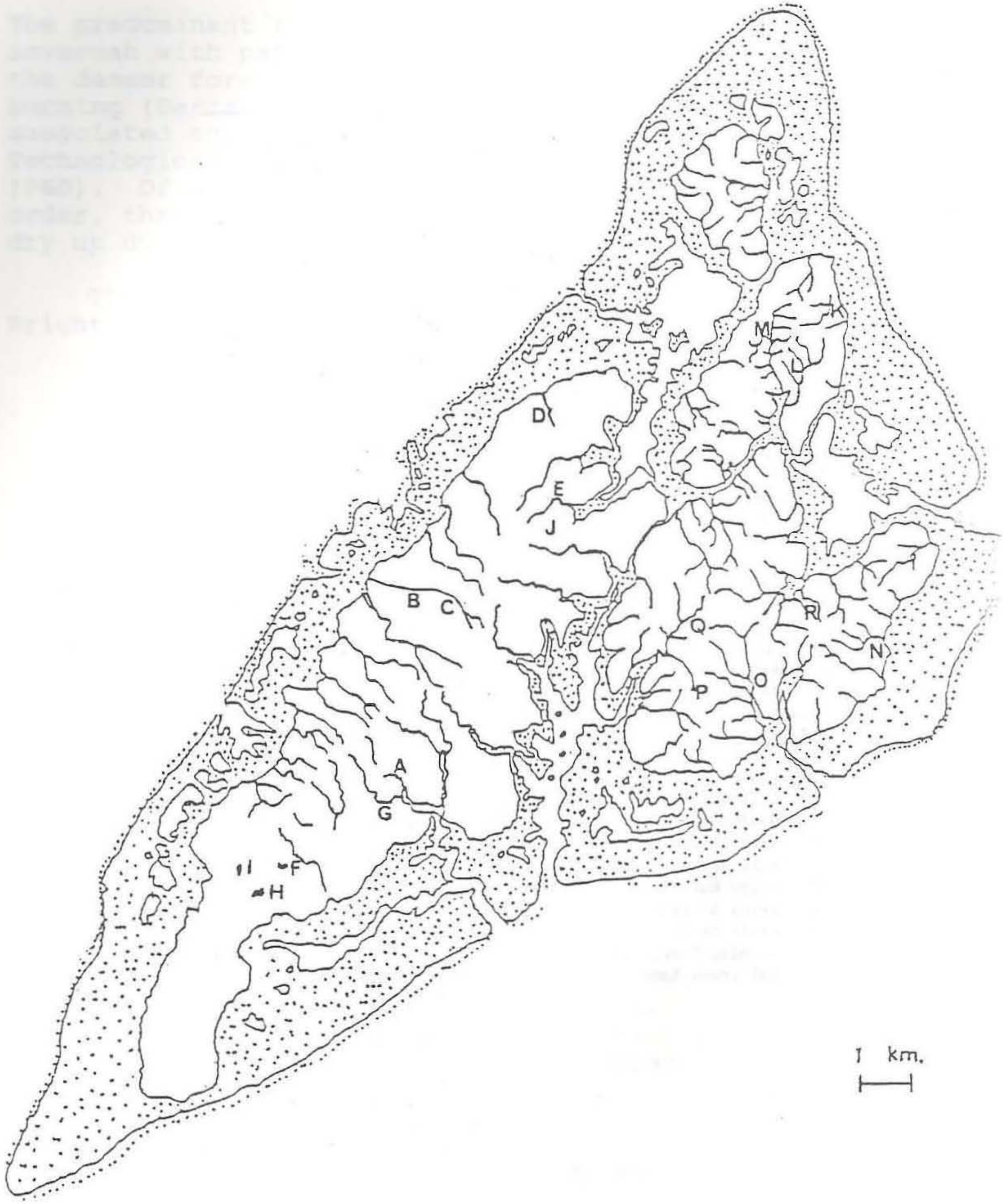

Figure 1. Locations of the study sites at Yap proper

Temperature

Determinations of water temperature were made at most sites with hand-held thermometers.

Oxygen content

Water samples were collected and analyzed for dissolved oxygen on site with a HACH water-analysis kit. DO bottles were rinsed 2-3 times with the water from the site prior to being filled. Bottles were then held at middepth and the cap was removed. Both bottle and cap were inverted and agitated to allow all bubbles to be evacuated. The cap was then screwed tight while submerged insuring that no air was trapped in the DO bottle. Winkler titrations (Parsons et al., 1984) were made immediately to determine the dissolved oxygen of the samples. Duplicate samples were taken at each station.

Nutrients, pH, and salinity

For the analysis of nutrients, chloride, ammonium, nitrate, reactive phosphorous, iron, and silica, as well as the pH, 11 sites from 6 streams in Yap were sampled. Samples were taken by submerging 200-ml Nalgene bottles and sealing them underwater. Care was taken not to contaminate the bottles with human contact. The samples were packed in ice and flown to the University of Guam Marine Laboratory where they were stored under refrigeration. The samples were analyzed within 48h of their collection. For the analysis of nitrate, phosphate, and silicate, the methods as described in Parsons et al. (1984) were used. Water samples to be used for the analysis of ammonium were treated with sodium hydroxide to convert the ammonium to ammonia which is more readily measured. Thus the values presented represent both the molecular and the ionic (ammonium) forms of ammonia. Ammonia was determined with an Orion ammonia probe model no. 9512, and an Orion microprocessor ionalyzer model 901. Determinations of iron concentration were made in accordance with the method prescribed by Murray and Gill (1978). Acidity was determined with the use of a Beckman pH probe, model SS-2. In the field, salinity measurements were taken with a refractometer at all sites sampled. Chloride ion was used in laboratory analysis as an indicator of salinity. Duplicate determinations of chloride content were made for each sample with the use of a digital chloridometer (Haake Buchler Instruments Inc.).

RESULTS AND DISCUSSION

The duration of this study was not sufficent to reveal the presence of nutrient cycles or trends that may occur on a daily or seasonal basis. The data presented here should be considered preliminary information by which only broad scale comparisons with other aquatic systems may be considered.

Temperatures

The water temperature in the streams ranged from 26.5°C to 27.5°C, with an average of 27°C. Temperatures in the ponds were higher than those of the streams and ranged from 30°C to 38°C.

Salinity

Salinity, as measured by chloride ion, was consistently low, less than .35 μM, at all sites sampled.

Dissolved Oxygen (DO)

Oxygen levels were on the average below saturation (Table 2). The saturation level for oxygen in fresh water is 8.2 ppm at 26.5°C. Oxygen content in the pools, 5.94 ppm, were on average lower than those in riffles and runs, 6.31 and 6.36 ppm, respectively. Mean oxygen content in ponds (7.13 ppm) were considerably higher than those of the riffles, runs, or pools. These ponds were supersaturated to 138%; saturation level at 28°C is 6.7 ppm.

A marked difference was observed between the pond at site F (4.50 ppm) and the ponds at sites H and I (7.70 ppm and 9.25 ppm). The pond at site F is deep (>1 m), with no benthic algae, while ponds at sites H and I were shallow (<1m) with thick algal mats on the bottom. Shallow ponds have greater surface area per unit volume of water, and this facilitates oxygenation. Also, oxygen production by algae in shallow ponds would lead to an increase in dissolved oxygen during the day.

Nitrogen and Phosphorous

Yap streams are oligotrophic, at least with regard to nitrogen and phosphorous as shown in Table 3. Determinations were made of the concentrations of two types of dissolved nitrogen, ammonium ($NH4^{+}$) and nitrate ($NO3^{-}$), and for total reactive phosphorus. Table 3 contains the values of the various ions from water samples collected from 11 sites of 6 streams of Yap proper. Most locations had concentrations of disolved ammonium below 4 μM. The two streams which had concentrations of ammonia in excess of 5 μM were at Qokaaw and the stream draining the water treatment ponds at Gitaem. These values are high when compared to measurements of streams in general. Values for nitrates ranged from 0.13 to 0.94 μM with a mean of 0.40 μM, an order of magnitude less than those of ammonium. Yearly mean concentrations of nitrate from a forested stream on Guam were found to range from 0.03 to 1.17 μM, with a mean of 0.15 μM (Neubauer, 1981). The phosphorous concentrations (total reactive phosphorous, TRP) for the sites were very similar to those for nitrate but with much less variation between sites.

Table 2. Dissolved oxygen (ppm) contents of riffles, runs, pools, and ponds of Yap.

Station		RIFFLE	RUN	POOL	POND
D	YYIN	4.30		4.15	
E	MALAWAAY		5.80	6.05	
F	MACHBAAB				4.50
G	QAYENG	7.30	7.05		
H	LUWEECH				7.70
I	MACHBAAB				9.25
J	MALAWAAY		5.90	5.85	
K	WANEAD	7.00	6.83	6.23	
L	MALAWAAY		7.10		
M	SIMINMIN	7.28	6.73	7.05	
N	ST. JOSEPH CH.	5.65		5.20	
O	THOOL		4.79		
P	TOQAYONG				7.10
Q	DALAACH		6.55	6.50	
R	QUAMUN		6.50	6.50	
MEAN		6.31	6.36	5.94	7.14
SD		1.17	0.70	0.85	1.71

TABLE 3. Nutrient characteristics of streams of Yap.

SITE	NAME	HABITAT	NH4+ (μM)	NO3- (μM)	TRP (μM)	Fe (μM)	Si (μM)	pH
A	GITAEM	POND	3.7	0.18	0.30	7.50	76	7.20
A	GITAEM	RIFFLE	8.4	0.26	0.20	9.60	74	7.40
B	QOKAAW	RUN	5.4	0.26	0.23	0.71	63	7.11
C	QOKAAW	RUN	5.0	0.16	0.34	5.10	33	7.08
C	QOKAAW	RIFFLE	5.0	0.94	0.58	20.00	31	7.20
D	YYIN	RIFFLE	3.7	0.21	0.15	1.10	66	6.88
E	MALAWAAY	RIFFLE	2.6	0.84	0.22	0.76	69	7.14
F	LUWEECH	POND	2.4	0.16	0.33	11.00	107	7.17
G	QAYENG	RUN	3.3	0.26	0.50	4.00	33	7.60
G	QAYENG	RIFFLE	3.7	0.13	0.53	4.70	3?	7.54
G	QAYENG	POOL	1.3	0.50	0.69	4.80	85	7.55
	MEAN		4.0	0.4	0.4	6.3	61.2	7.3
	SD		1.8	0.3	0.2	5.4	23.9	0.2

The two main nitrogen compounds, ammonium and nitrate, occur in the freshwaters of Yap in concentrations similar to those reported for a tropical low land river in South America (Lewis, 1986). Our mean values were 4.0 μM and 0.4 μM for ammonia and nitrate respectively, while those of Lewis were 2.1 and 1.0. In most freshwater systems nitrate typically plays a greater role as a nitrogen source in the community since ammonium is readily bound to charged substrata. Yavitt and Wieder (1988) reported that less than 1.5% of the total nitrates in tropical volcanic soils was accessible to the aquatic environment due to substrate adhesion. Ammonium is generated from biological processes. Its presence indicates either decomposition, fixation of atmospheric nitrogen by soil or root microbes, or by regeneration via excretion. Recent findings by Lewis (1986) indicate that nitrogen fixation rates may be higher in tropical systems than those of temperate or arctic regions. It is likely that the high ammonium concentrations observed in Yap are a result of high fixation rates which have resulted in the supersaturation of the sediments. Lewis also notes that ammonium, the nitrogen compound produced by nitrogen fixation, may play a vital role as an inorganic source of nitrogen in tropical forest drainage systems.

Iron

The mean iron concentration for Yap streams was 6.30 μM. Iron concentrations tended to be fairly consistent within a stream with the noted exception of the Qokaaw stream which showed a great deal of variance between sample sites. Of the other sites sampled, the ponds or pond-associated streams showed slightly higher concentrations of iron. By comparison, the streams of southern Guam which drain volcanic soils, have a yearly range of 3.4-11.8 μM for dissolved iron (Zolan and Ellis-Neill, 1986). The mean value for Yap of 6.3 μM falls well within the mean range recorded from Guam throughout the year. However, the iron concentration at one of the Qokaaw sample sites exceeded this substantially (Table 3).

Silica

Silica (SiO_2) concentrations ranged from 31-107 μM with a mean of 61.18 μM. These values are comparable to silica concentrations in streams draining volcanic soils on Guam (Matson, 1989, pers. comm.) which exhibit a broad range, between 10 and 90 μM. Neither the iron nor the silica values are surprising given the geology of the Yap group and the acidity of the streams. The predominant rock is greenschist, which is high in both silica and iron.

Acidity

The pH of Yap's streams was relatively consistent and near neutral, with a mean value of 7.26, ranging from 6.88-7.60. Given the slightly acidic nature of rain water, the increase in the streams' pH indicates the alkalinity of the soil, organic litter, and surrounding vegetation. Measured pH levels (Table 3) in the streams of Yap are comparable to values reported in the literature for tropical soils; these values range from pH 5.8 to pH 7.5 (Bright, 1979; Payne, 1986).

ACKNOWLEDGEMENTS

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LITERATURE CITED

Barrau, J. 1961. Subsistence agriculture in Polynesia and Micronesia. Bernice P. Bishop Museum Bulletin 223.

Bright, G. 1979. The inland waters of Palau, Caroline Islands. Office of the Chief Conservationist Trust Territory of the Pacific Islands. Koror, Palau.

Johnson, C. G., R. J. Alvin, and R. L. Hetzler. 1960. Military geology of Yap islands, Caroline Islands. U. S. Geological Survey.

Lewis, W.M. Jr. 1986. Nitogen and phosphorus runoff losses from a nutrient-poor tropical moist forest. Ecology 67:1275-1282.

Murray, J.W. and G. Gill. 1978. The geochemistry of iron in Puget Sound. Geochim. Cosmochim. Acta. 42:9-19.

Neubauer, C.P. 1981. The effects of land-clearing on a small watershed in southern Guam. University of Guam Water and Energy Research Institute Tech. Rept. 24. 34 p.

Office of Technology Assessment, U. S. Congress. 1987. Integrated renewable resource management for U. S. insular areas. OTA-F-325. Washington, D.C., U. S. Government Printing Office.

Parsons, T.R., Y. Maita, and C.M. Lalli. 1984. A manual of chemical and biological methods for seawater analysis. Pergamon Press. Elmsford, New York.

Payne, A.I. 1986. The ecology of tropical lakes and rivers. John Wiley & Sons. New York.

Yavitt, J.B. and R.K. Wieder. 1988. Nitrogen, phosphorous, and sulfur properties of some forest soils on Barro Colorado Island, Panama. Biotropica 20:2-10.

Zolan, W.J. and L. Ellis-Neill. 1986. Concentrations of Aluminum, Manganese, Iron and Calcium in Four Southern Guam Rivers. University of Guam Tech. Rept. 64.

The Freshwater Fishes of Yap

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ABSTRACT

A collection of fishes from the freshwater habitats of Yap was obtained by electroshocking and netting. The most abundant fishes found in the stream environments were the eleotrids *Eleotris fuscus* (Bloch and Schneider) and *Ophieleotris aporos* (Bleeker) and the freshwater eel *Anguilla marmorata* (Quoy and Gaimard). Breeding populations of the introduced cichlid *Oreochromis mossambicus* (Peters) are well established in freshwater ponds of Yap. Other fishes which were collected from the streams include the mudskipper *Periopthalmus vulgaris* Eggert, the flagtail perch *Kuhlia rupestris* (Lacepede), and the spotted scat *Scatophagus argus* (Linnaeus).

INTRODUCTION

Information concerning the distribution and abundance of freshwater fishes is important for the rational development an conservation of the inland natural resources of Yap. However, knowledge of the freshwater fishes of Micronesia, and of the Pacific islands in general, is meager. Although, there have b a few studies of the freshwater fishes of other islands in the Caroline group (Bright and June, 1979; Maciolek and Ford, 198 to our knowledge, there have been no previous published works concerning the freshwater fishes of Yap. The purpose of this work was to provide a checklist of fishes from the freshwater habitats of Yap and to provide information on the distributio and relative abundance of fishes in these habitats.

MATERIALS AND METHODS

Collections

Fish were collected, with a Coffelt Model BP-4 electroshocker and nets, from freshwater habitats of Yap prop including streams, wetlands, taro patches, and ponds. The advantages of electroshocking for sampling the fishes of small tropical streams were described by Maciolek and Timbol (1980). The habitats within streams were further divided into runs, riffles, and pools. In all, 222 fish were collected from 14 sites. Run, riffle, and pool habitats were sampled at each of nine sites. Collections were made at three of the islands comprising Yap proper. The streams of Rumung were not sample because the island was accessible only by boat, and we were constrained by time. Specimens were fixed in 10 percent form for several days and then preserved in either 90 percent ethyl alcohol or 45 percent isopropyl alcohol. For each of the specimens, with the exception of those of Anquilla marmorata, we measured the standard length to the nearest 0.1 cm and the blotted wet weight to the nearest 0.1 g. The lengths of the eels collected were determined as total length rather than standard length.

Identifications

We relied on several published works to guide us in identifying the specimens to species (Fowler, 1928; Eggert, 1935; Akihito, 1967; Munro, 1967; Masuda et al., 1975; Smith, 1975; Hoese, 1986a; 1986b; Smith and Heemstra, 1986). Representative specimens were deposited in permanent collections established at the Yap State Marine Resource Management Division and at the University of Guam Marine Laboratory.

The specimens of Eleotris fuscus, the most common freshwater fish in Yap, were difficult to identify. There are a number of similar species in this genus, and many of the characters used for identification are highly variable. The most valuable reference was the early work by Akihito (1967) on species of the genus Eleotris which are found in Japan. Our identification of E. fuscus was based largely on counts of fin rays and scales, characters which distinguished our specimens from the closely related E. melanosoma according to the descriptions of Akihito (1967). However, the infraocular pit organs of our specimens did not match those provided by Akihito for either E. fuscus or E. melanosoma. These are the only species of Eleotris known from Micronesia, but there are taxonomic problems remaining within this genus.

Since they can leave the water and since they were not numerous in the freshwater habitats of Yap, mukskippers were difficult to capture and only a few specimens of Periopthalamus were collected. These fish were most numerous in brackish waters, but these areas were not sampled. We have tentatively identified the specimens collected as being P. vulgaris Eggert. The characteristics of our specimens were consistent with those provided by Masuda et al. (1975), and the fish we collected appear similar to their color plate illustrating the species. We also based the indentification on the work of Eggert (1935) who distinguished vulgaris from kuelreuteri largely by the morphology of the first dorsal fin. According to Eggert (1935), P. vulagaris has a strongly concave first dorsal fin, while P. kuelreuteri has a convex first dorsal fin. Our specimens had strongly concave first dorsal fins.

Distributional analyses

In order to provide a more complete description of the habitat of each species, the collection sites were divided into three categories: riffles, runs, and pools. Only E. fuscus was abundant enough for the data to warrant statistical analysis. The BMDP statistical software (available from the Health Sciences Computing Facility of the University of California) was used for a comparison of the size frequency distributions of E. fuscus between habitats with a one-way Analysis of Variance (BMDP program 7D).

RESULTS AND DISCUSSION

There are relatively few fish species indigenous to the freshwaters of Yap as shown in Table 1. The most common of these in order of abundance were Eleotris fuscus (Bloch & Schneider) (Fig. 1), Ophieleotris aporos (Bleeker) (Fig. 2), the eel Anguilla marmorata (Quoy and Gaimard), Periopthalmus vulgaris Eggert, Kuhlia rupestris (Lacepede) (Fig. 3), and Scatophagus argus (Linnaeus). One reason for the relatively depauperate fauna may be that the streams and other aquatic habitats of Yap occasionally dry up. Most of the freshwater habitats, including the reservoir, had dried up during the particularly severe dry season of 1988, just a few months prior to our survey. In contrast, fifteen stream fishes were recorded from Pohnpei by Maciolek and Ford (1987), seven of which were of the family gobiidae, a taxonomic group not represented in our collections from Yap. However, the collections of Maciolek and Ford (1987) included A. marmorata, E. fuscus, and K. rupestris which we also found in the streams of Yap, but did not include O. aporos. Similarly, The freshwater fishes of Palau (Bright, 1979; Bright and June, 1981) include all of the species we found in the freshwaters of Yap, including O. aporos, except for Periopthalmus, which is an estuarine fish sometimes found in freshwater habitats in the lower portions of streams.

Although not collected, two additional species of fish, of the families Toxotidae and Ambassidae, were observed in the streams. One of these was an archerfish, presumed to be Toxotes jaculator since this species has been previously reported from Yap (Amesbury et al., 1976). However, they collected no specimens either, and the field identification has not been confirmed. This species is the most widespread of the Toxotidae and is found from India throughout the Indo-Malayan region including the Philippines (Smith, 1945). The other fish observed but not collected was a species of the genus Ambassis. Fishes of the Ambassidae, the family to which this genus belongs, are commonly known as slender glassies. Members of the genus Ambassis range from the eastern coast of Africa throughout the

Indo-Pacific (Smith and Heemstra, 1986). However, as in the case with Toxotes, since no specimens were collected, the fish could not be positively identified. However, according to Myers (1989), two species of Ambassis have been reported from the nearby islands of Palau. One of these, A. intrerruptus (Bleeker), was reported to be common in the streams of Palau by Bright and June (1979). Both the genus Toxotes and that of Ambassis are composed of species which are commonly found in estuarine areas and known to invade freshwater streams and lakes.

Table 1. List of fishes collected from freshwater habitats of Yap proper.

Anguillidae
- Anguilla marmorata (Quoy and Gaimard)
  n=13, Total Length from 10.1 to 107.0 cm

Cichlidae
- Oreochromis mossambicus (Peters)
  n= 7, SL from 2.0 to 13.0 cm

Eleotridae
- Eleotris fuscus (Bloch and Schneider)
  n=185, SL from 2.0 to 15.7 cm
- Ophieleotris aporos (Bleeker)
  n=12, SL from 3.0 to 19.5 cm

Gobiidae
- Periopthalmus vulgaris Eggert
  n=5, SL from 2.5 to 6.7 cm

Kuhlidae
- Kuhlia rupestris (Lacepede)
  n=5, SL from 8.9 to 16.3

Scatophagidae
- Scatophagus argus (Linnaeus)
  n=4, SL from 2.4 to 2.8 cm

Life Histories

As is characteristic of insular stream faunas (Meyers, 1953; Bright, 1979; Bright and June, 1981; United States Army Corps of Engineers, 1981; Maciolek and Ford, 1987; Kinzie, 1988), none of the indigenous fishes of Yap can be categorized as a primary freshwater fish. The fishes found in the freshwater habitats of Yap either are diadromous, that is they spend a portion of their life cycle in the sea, or are basically marine fish which occasionally enter freshwater. Diadromous fishes can be further categorized as either catadromous, amphidromous, or anadromous (McDowall, 1987); the freshwater fishes of Yap include representatives of the former two categories.

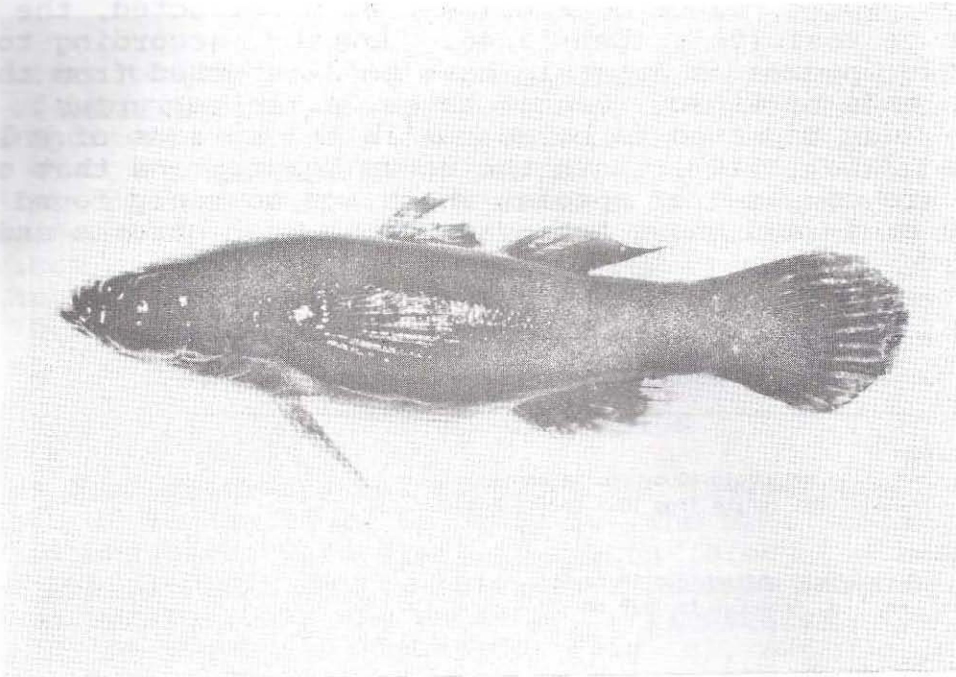

Figure 1. The most common freshwater fish of Yap, the sleeper goby Eleotris fuscus.

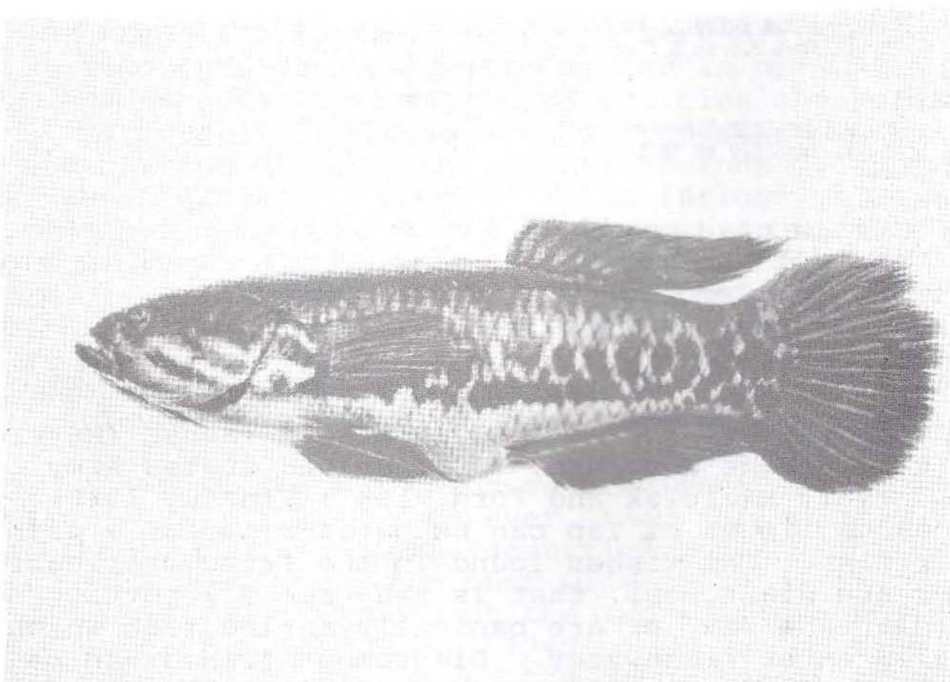

Figure 2. Another sleeper goby Ophieleotris aporos from Yap proper.

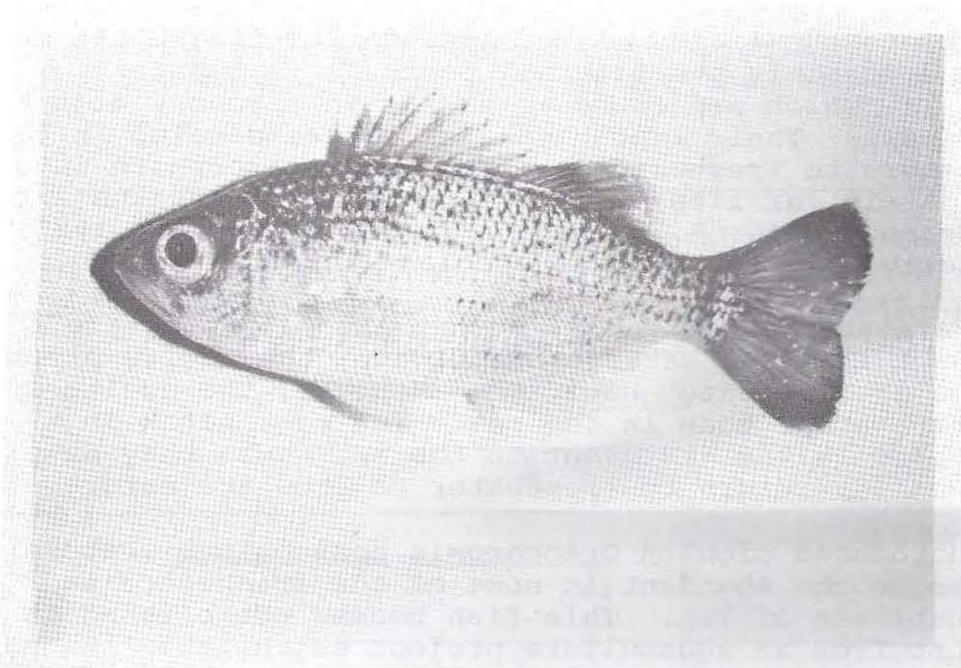

Figure 3. The flagtail perch Kuhlia rupestris.

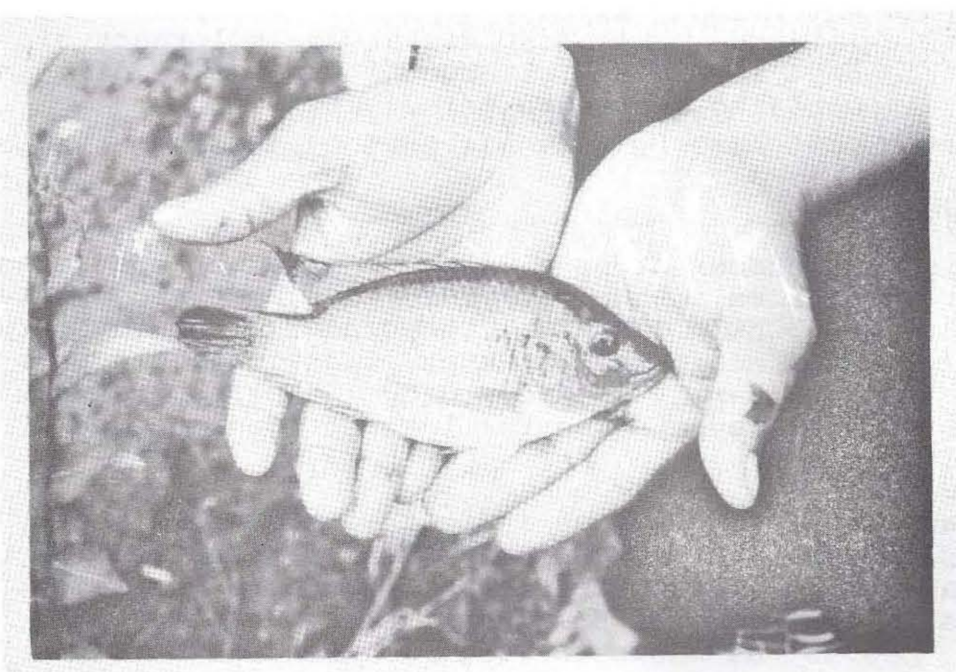

Figure 4. The introduced cichlid Oreochromis mossambicus.

The catadromous fishes of Yap include the freshwater eel A. marmorata and probably the flagtail perch K. rupestris. Anguillid eels, which are found as adults in streams, migrate to the sea to spawn. Their leptochephalus larvae develop in the ocean and return to freshwaters where they metamorphose into juveniles. A similar life-cycle, sans the leptocephalus larval stage, is suspected for K. rupestris (Lewis and Hogan, 1987), but the reproductive biology of this species is poorly known.

The two eleotrids of Yap E. fuscus and O. aporos are amphidromous. Like the catadromous fishes, the adults of these species live in freshwater habitats. However, the adults spawn in freshwater rather than in the sea. The eggs hatch in freshwater, the larvae are swept to the sea where they develop, and the juveniles return to freshwater to grow and mature.

The introduced cichlid Oreochromis mossambicus (Peters) (Fig. 4) has become abundant in some of the freshwater and estuarine habitats of Yap. This fish became established in Yap by escapement from an aquaculture project established in the 1970's. The species can now be found in Yap in the shallow estuarine waters near mangroves, in freshwater ponds, and the lower reaches of streams. The natural distribution of O. mossambicus is within southeastern Africa (Philippart and Ruwet, 1982). However, as a result of its popularity for aquaculture and mosquito control, it has been introduced throughout the world and has become established in many tropical areas, including many of the Pacific islands. This fish has a wide tolerance of salinity (Stickney, 1986), and although it spawns readily in freshwater, it can also reproduce in seawater.

Distribution

Although the number of specimens collected of most species was small, differences in habitat preferences between species were evident as shown in Table 2. The common eleotrid E. fuscus was abundant in all habitats. However, the larger eleotrid O. aporos was found primarily in pools, and A. marmorata were most numerous in riffles, eventhough the largest specimens were collected from pools.

The data for the E. fuscus indicates that there were differences in habitats between size classes. The results of a one-way analysis of variance revealed that there were significant differences in the sizes of E. fuscus between habitats ($F_{2,189}=4.01$, $p<0.05$) as shown in Table 3. The SNK Multiple Range Test showed that the differences between the mean sizes of fish in runs and pools were not significant. However, the mean sizes of fish in runs and pools both differed from the mean size of fish in riffles. The mean standard length of E. fuscus in riffles was 4.1 cm, but the mean lengths were over 4.9 in both the run and pool habitats. This is not surprizing, since many of the riffle habitats were too shallow for the larger fish.

Table 2. Distribution of the three most abundant freshwater fishes of Yap according to habitat (Sites G through R). The data are numbers of specimens collected from each habitat type.

HABITAT	FISH SPECIES *O. aporos*	 *E. fuscus*	 *A. marmorata*
Riffle	0	44	10
Run	1	56	1
Pool	7	76	2

Table 3. Mean and standard deviations of the standard lengths in centimeters of *Eleotris fuscus* collected from stream habitats in Yap proper.

Habitat	Mean Std. Length	n	Std. Dev.
Riffle	4.13	44	1.61
Run	4.96	56	1.45
Pool	4.92	76	1.86

Conclusions

The species composition of the community of freshwater fishes found in Yap was not particularly surprising, since most of the species are widespread and found in freshwater habitats throughout the Pacific. However, one interesting aspect of our observations, one which we are at a loss to explain, is the absence of gobies, other than Periopthalmus, in our collections. Gobiid fishes form a conspicuous and abundant component of the stream fauna in several nearby islands (Bright and June, 1979; Maciolek and Ford, 1987). Perhaps these fishes occur on Yap, but were more susceptible than others to the adverse conditions resulting from the recent, severe drought and were simple missed as a result of their uncommonly low abundances. The fishes are an important faunal group in the freshwater habitats fof Yap, but, as is the case for many of the freshwater fishes of the Pacific islands in general (Kinzie, 1987), their biology is poorly known. Certainly additional information on these fishes should be obtained prior to initiating developmental activities, including aquatic introductions, which could have a significant impact on the freshwater habitats of the island.

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LITERATURE CITED

Prince Akihito. 1967. On four species of the genus Eleotris found in Japan. Jap. J. Ichthyol. 14:135-167.

Bright, G.R. 1979. The inland waters of Palau, Caroline Islands. Office of the Chief Conservationist, Koror, Palau. 61 p.

Bright, G.R. and J.A. June. 1981. Freshwater fishes of Palau, Caroline Islands. Micronesica 17:107-111.

Eggert, B. 1935. Beitrag zur systematik, biologie und geographischen verbreitung der Peiopthalminae. Zool. Jahrb. Jena Syst. 67:29-116.

Fowler, H.W. 1928. The fishes of Oceania. Mem. Bernice P. Bishop Museum, Honolulu.

Hoese, D.F. 1986a. Family No. 240: Gobiidae. p. 774 to 807 In: M.M. Smith and P.C. Heemstra (eds.). 1986. Smith's sea fishes. Smith Inst. Ichthyol., Grahamstown. Macmillan South Africa, Ltd., Johannesburg.

Hoese, D.F. 1986b. Family No. 241: Eleotridae. p. 807 to 810 In: M.M. Smith and P.C. Heemstra (eds.). 1986. Smith's sea fishes. Smith Inst. Ichthyol., Grahamstown. Macmillan South Africa, Ltd., Johannesburg.

Kenzie, R.A. III. 1988. Habitat utilization by Hawaiian stream fishes with reference to community structure in oceanic island streams. Environmental Biol. Fish. 22:179-192.

Lewis, A.D. and A.E. Hogan. 1987. The enigmatic jungle perch - recent research provides some answers. SPC Fisheries Newsletter 40, 31 p.

Maciolek, J.A. and J.I. Ford. 1987. Macrofauna and environment of the Nanpil-Kiepw River, Ponape, Eastern Caroline Islands. Bull. Mar. Sci. 41:623-632.

Maciolek, J.A. and A.S. Timbol. 1980. Electroshocking in tropical insular streams. Prog. Fish Culturist 42:57-59.

Masuda, H., C. Araga, T. Yoshino. 1975. Coastal fishes of southern Japan. Tokai University Press, Tokyo.

McDowall, R.M. 1987. The occurrence and distribution of diadromy among fishes. p. 1-25 In: M.J. Dadswell, R.J. Klauda, C.M. Moffitt, R.L. Saunders, R.A. Raulifson, and J.E. Cooper (eds.) Common Strategies of Anadromous and Catadromous Fishes. American Fish. Soc. Symp. 1. American Fish. Soc. Bethesda, Maryland.

Munro, I.S.R. 1967. The fishes of New Guinea. Dept. Agric., Port Moresby, Papua New Guinea.

Myers, G.S. 1953. Paleogeographical significance of fresh-water fish distribution in the Pacific. Proc. 7th Pac. Sci. Congress 4:38-48.

Myers, R.F. 1989. Micronesian reef fishes. Coral Graphics, Guam. 298 p.; 144 plates.

Philippart, J-Cl. 1982. Ecology and distribution of tilapias. p. 15-59, In: R.S.V. Pullin and R.H. Lowe-Mconnell (eds.) The biology and culture of tilapias. ICLARM Conference Proceedings 7. Internat. Cent. Living Aquat. Resources Management, Manila, Philippines.

Smith, H.M. 1945. The freshwater fishes of Siam or Thailand Smithsonian Institute, United States Natural History Mus Bull. 188, Washington, D.C.

Smith, M.M. and P.C. Heemstra (eds.). 1986. Smith's sea fis Smith Inst. Ichthyol., Grahamstown. Macmillan South Afr Ltd., Johannesburg.

Stickney, R.R. (1986). Tilapia tolerance of saline waters: a review. Prog. Fish. Cult. 48:161-167.

U.S. Army Corps of Engineers. 1981. American Samoa stream inventory, island of Tutuila. Honolulu. 122 p.

Insects in the Freshwater Environments of Yap

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ABSTRACT

Freshwater aquatic habitats on the island of Yap were sampled to determine what species of insects were present. A total of about 50 species of insects were collected. The diversity of insects was greatest in still-water habitats with vegetation and lowest in the streams. Cyrtosperma paddies were intermediate. Only small numbers of insects were found in streams, excepting water striders and midge larvae. Occasionally we also found aquatic beetles, damselflies, and caddis flies. Waterstriders and their relatives and midge larvae were also abundant in still-water habitats, but dragonflies, beetles, backswimmers, and mosquito larvae were also often found.

INTRODUCTION

Insects are normally an important component of freshwater environments. They are important indicators of the quality of the aquatic environment, and the kinds of insects present can be used to monitor pollution levels. In ponds, streams, and other aquatic habitats insects serve several functions. They help remove detritus, often serving to shred organic matter, such as leaves, making it available to other consumers, or to remove particulate matter from the water. They may consume freshwater plants such as algae, or feed on other small aquatic organisms. In turn, they become a food source for other organisms such as fish. In Micronesia little is known about the insects found in various aquatic environments or about how important they are either in detrital breakdown or in food chains. As part of this project, an effort was made to determine which insects are present in the freshwater aquatic habitats of Yap proper.

COLLECTION METHODS

For this survey, insects were collected through the use of a variety of techniques. In streams, ponds, and taro patches, aquatic sweep nets were used to dredge the bottom and to scrape the vegetation within the pond. Trowels, siphons, and dip nets were used to sample small sources of water such as interiors of pitcher plants, crab holes, old coconut shells, tree holes, and leaf axils. Rocks in the water were overturned and searched, vegetation was examined in pans, and pools were searched for the presence of insects. Mosquitoes were collected with an aspirator as they bit people. Aerial nets were used to capture flying insects. At night, an ultraviolet light was set up near water sources to attract flying insects. Collections were qualitative, concentrating on obtaining the greatest diversity of species in each habitat.

RESULTS

On most oceanic islands, the aquatic insect faunas are not highly diverse, particularly if the island is not near continental areas. We found the diversity of aquatic insect species conformed to the typical pattern. Relatively few species of insects were found, and many families of aquatic insects found in continental areas were absent. The following orders and families were collected. Little is known about the specific biology of most of the species found in this survey, but we have included some general notes on their biology. Species which have been identified are listed by the habitat in which they occur.

Odonata - dragonflies and damselflies

Several species of dragonflies and damselflies occur on Yap (Lieftinck, 1962), but not all were found in this survey. In our aquatic collections we collected 2 species of Coenagrionidae (both known), 2 species of Aeshnidae (only 1 known previously), and 5 of the 9 species of Libellulidae present on Yap. An addtional species of Libellulidae was caught on the wing. A Corduliidae species reported as being in Yap was not found. Larval forms (naiads) of the genus Anax, not previously reported from Yap, were found in two locations.

Dragonflies and damselflies are predatory both as adults and as immatures (naiads). The naiads live in the water and breathe with gills. They have folded mouthparts that they shoot out to catch other insects, small crustaceans, mollusks, and worms. When they are ready to become adults, they climb out of the water and onto a piece of emergent vegetation. Then the skin splits, and the adult emerges. The adults are free-flying and feed on mosquitoes and other small flying insects. They generally do not re-enter the water, except for a few species which enter to lay their eggs in the stems of aquatic plants.

Hemiptera - true bugs

The streams, ponds, and taro patches all had water striders and their relatives on the surface. Other species of Hemiptera that swim in the water were found only in still water environments. The aquatic Hemiptera have not been thoroughly collected in the Pacific region. Consequently, there is a lack of information about them and there are many undescribed species. Among the groups we collected, only the Gerridae, Notonectidae and Pleidae have been identified to species. For some of the other groups, taxonomists have been located and additional identifications will be forthcoming. The following species were collected: Gerridae, 4 species; Mesoveliidae, 2 species; Veliidae, up to 5 species; Notonectidae, 1 species; and Pleidae, 1 species.

The Gerridae, Mesoveliidae, and Veliidae live on the surface of the water and prey on other insects. They eat aquatic insects that they catch just below the surface and terrestrial insects which fall into the water. Gerridae are the largest of the water skating insects. They use their back legs to glide across the surface of the water and their front legs to hold prey. Mesoveliidae are smaller than Gerridae. They are generally associated with aquatic vegetation, but can also run on open water. Veliidae are the smallest of the water skating insects. They often are found in or near ripples and rapids of streams where they wait for food brought by the current. They eat tiny insects or Metazoa. They are often gregarious.

Notonectidae live in the water. They are called backswimmers because of their habit of swimming upside down, using their long hind legs as oars. They rise to the surface to collect air and store a bubble in a trough on their abdomen. Juveniles feed on entomostracans, but adults suck the juices out of insects or even out of small tadpoles and fishes. The species on Yap is silvery-white in color.

Pleidae also live in the water. They resemble Notonectidae but are much smaller. They are found only in dense, tangled vegetation. They lay their eggs in the stems of the vegetation and feed on small entomostracans.

<u>Coleoptera - beetles</u>

The aquatic beetles were highly diverse, but rare and site-specific. In most cases, only a single specimen of each species was collected. Each location had different species. This lack of duplication implies that there are a number of aquatic beetle species as yet uncollected from Yap. We found six species of Dytiscidae, eight Hydrophilidae, and one Noteridae. Of these, we were able to identify only two species of Dytiscidae which are widespread in the Pacific.

Dytiscidae, or predaceous diving beetles, are an exclusively aquatic family. They are generally found in quiet water environments. They use their hind legs for swimming. Although they live exclusively in the water, they have wings and can fly to new locations. The small species feed on aquatic Metazoa, and the larger species feed on such organisms as dragonfly nymphs, tadpoles, and even small fish. They maintain an air bubble under the wing cover for breathing but have to surface every few minutes to replenish it. The larvae are also aquatic and are predaceous.

Noteridae are similar in their habits to the small Dytiscidae. Their larvae usually burrow in the mud around aquatic plants.

Hydrophilidae, or water scavenger beetles, are primarily aquatic, though a number of species occur in moist earth environments. They occur primarily in pools and ponds where there is aquatic vegetation. Although some species are good swimmers, many are crawlers. The adults eat carrion, decaying vegetation and living plant material, especially algae.

Trichoptera - caddis flies

Two species of immature caddis flies were found. These were not reared and no adults were captured, so they cannot be identified to the species level. Both species were case makers, one having a case made of small stones cemented together to make a tube and one living inside a piece of hollow stick.

The larvae of caddis flies are completely aquatic and have gills. The larvae of case bearing species do not swim but, instead, crawl about on the substrate. Most caddis flies are omnivorous, eating algae, other plants, and various animals. The adults emerge from the stream, mate, and lay eggs. They only live for a few days.

Diptera - flies

Three families of flies were collected in freshwater. These were Chironomidae (midges), Culicidae (mosquitoes) and Syrphidae (rat-tailed maggots). Although numerous larvae of midges were found in all of the aquatic environments, only two specimens of two different species were reared to the adult stage. Unfortunately, only adult chironomids can be identified for Micronesia, as there has been no work associating adults and larvae. Mosquito larvae were found only in still-water environments, including containers. Six of the 11 species known to occur in Yap (Bohart, 1957) were collected in various fresh-water habitats and two additional species were captured only as adults. One species, which could not be identified, was both reared and caught in the adult stage. Specimens of this species have been sent to a taxonomist (Dr. Ronald Ward) specializing in the identification of mosquitoes, but no identification has been obtained yet. Rat-tailed maggots were found in containers and in dirty water. They were not successfully reared and cannot be identified to species.

Chironomidae, or midges, is a large group of flies whose larvae occur in all types of wet and moist environments. The larvae can be pale or red in color. The red species are called bloodworms. Their red color is due to the presence of an oxygen carrying pigment similar to hemoglobin in their blood of the larvae. The pigment enables the midges to live in highly polluted water, or other water with a low oxygen level. Chironomid larvae often construct fragile tubes out of algae, fine silt or sand, and salivary secretions. Both ends of the tube are open and the larva wiggles vigorously to move water through the tube. The larvae generally feed on algae, aquatic plants and organic detritus. The adults emerge from the water but do not feed.

Culicidae, or mosquitoes, live in a variety of slow moving or still water habitats including small containers such as tires, coconut shells, or leaf axils. The larvae feed on algae, protozoa, and organic debris by filtering the water with their mouth brushes. The larvae of most species lie quietly at the surface of the water with their tail end uppermost. However when disturbed they swim down rapidly with a characteristic wriggling motion. The adult females of most species require a blood meal to produce eggs. Males feed only on nectar and other plant juices. Most species have different host preferences, and only a few species bite humans. Many species bite only birds or other animals.

Most Syrphidae are terrestrial, but one group of species is aquatic. These are known as rat-tailed maggots due to the very long breathing tube at their tail end. The aquatic species are found in highly polluted habitats.

<u>Stream habitats and species</u>

The stream habitats sampled were in small streams shaded by trees. The substrate varied from rock to hard mud, or tree root mats. There were many riffles interspersed with slow-moving deeper pools. Occasionally some streams had small waterfalls. In the pools the bottoms varied from rocky to sandy. Some pools had large deposits of dead leaves and other organic matter while others were relatively clean.

Relatively few insects were found in the streams. Most insects species were associated with vegetation trailing in the streams, either tree roots, grasses, or submerged vegetation. Certain species were living in litter in pools, in the mud along the edges of pools, or in algal mats in very shallow, riffle areas. Specific locations of stream habitats are listed within each insect group discussed.

With one exception, all the streams had dried up during the rather severe dry season earlier in the year. The one stream that did not dry up was flowing very rapidly at the time of the sample, and no insects were found in it. Thus there is no indication that this stream served as a refuge during the drought.

Odonata:

There were relatively few Odonata nymphs in the streams. No dragonflies (Anisoptera) were found, but specimens of two species of damselflies (Zygoptera) were collected. These were the Coenagrionids Agriocnemis femina femina Brauer and Ishnura aurora aurora (Brauer). A. femina was found at several sites and I. aurora at one. All specimens were collected off roots or grasses trailing in the water, and were found in pools or runs where these were present.

Hemiptera:

Gerrids were common on the pools of streams. The most common species was Limnometra pulchra Mayr. It was collected or observed on all of the streams examined. Limnogonus fossarum (F.), which is associated with still water, was collected in a stream in Dalipebinaw, but not elsewhere. A single specimen of Limnogonus sp. nr. lundbladi Usinger was also collected in Dalipebinaw. L. lundbladi, a Guam endemic, probably closely related, is only found on streams.

One species of Mesoveliidae (sp. M1), which could not be identified, was found in a stream at Simunmim. It was in a root mat at the end of a culvert in rapidly flowing water. Two species of Veliidae (sp. V1 and V2) were also collected in the same root mat. No other specimens of Mesoveliidae or Veliidae were collected in streams.

Coleoptera:

Two small species of Dytiscidae, Copelatus sp. 1 and 2, were found in upstream pools at Qokaw. Three species of Hydrophilids, Helochares sp. 1, Enochrus sp. 2, and Dactylosternum sp., were also found in stream pools and one additional species, Enochrus esuriens Walker, was found in a riffle area.

Diptera:

Bloodworms and other midges were the most common of the insects found in streams. Tubes of Chironomidae were found on rocks, dead leaves, and on the sides of muddy banks in pools. In some pools they were abundant on dead leaves. None of the species found in streams were successfully reared.

Trichoptera:

Two species of caddis flies were found in streams. One of the species was found at Malawaay in an upstream environment with a relatively clean, rocky bottom. Larvae and empty cases were located under rocks in a run with relatively fast moving water. No specimens were found in the adjacent pools or riffles. This species made a case of small rocks. The other species was collected at the head of a stream at Qokaw in a pool with relatively fast moving water. It made its case out of a hollow stick and was probably living in debris on the bottom.

Taro paddy habitats and species

Most streams had taro paddies, principally Cyrtosperma (giant swamp taro), built alongside the streams. The paddies were level, and many were filled with either slow moving or stagnant water. Water from springs or seeps or water diverted from the streams flowed into these patches. Some paddies had inlets or outlets to the stream but others did not. Of the paddies with moving water, some were flooded with water while others had the moving water confined to a small channel. The rest of the paddy either lacked standing water or there were pools and puddles with no outlets. None of the paddies were completely dry, although during prolonged dry spells many of the paddies will dry up.

Odonata:

No dragonfly or damselfly naiads were found in clean, weeded Cyrtosperma paddies. In two paddies with weeds, the damselflies I. aurora and A. femina, and the dragonfly ?Diplacodes bipunctata (Brauer) were found. The specimen of D. bipunctata was an early instar and thus can not be determined with certainty.

Hemiptera:

Cyrtosperma paddies had several species of water skaters. L. pulchra, L. fossarum and Limnogonus luctuosus (Montrouzier) were found, as well as the mesoveliid sp. M1 found in streams. Four species of Veliidae were also collected in taro paddies, two of which were the same as those found in streams. The water skaters were found in various parts of the taro paddies but were most abundant in areas where water was flowing. The notonectid Anisops tahitiensis Lundblad was collected at taro paddies at Wanaeb and Malawaay in areas isolated from the flowing water.

Coleoptera:

Among the Dytiscidae, Hydaticus sp., Copelatus sp. 1, and a species which could not be identified to genus because a male was not found, were collected from taro patches in several locations. Five species of Hydrophilidae were found in taro paddies. At Thool three species of Hydrophilidae, Helochares sp. 1, Helochares sp. 2, and Enochrus esuriens, were found among the weeds at the edge of the patch where the water was entering.

Enochrus esuriens and two other species, Enochrus sp. 2 and Cercyon sp., were collected at Yyin in a small taro paddy growing in a seep with no outlet.

Diptera:

Chironomidae larvae were found in Cyrtosperma and Colocasia paddies. Only one species was reared. It was identified as a species of Chironomus. It was found in a small puddle in the mud where a plant had been dug up. Large numbers of bloodworms were found in a muddy, polluted-looking Cyrtosperma paddy near St. Joseph's church and in organically rich water flowing out of a swamp into a Colocasia paddy at Qamun. These were not successfully reared.

Several species of Culicidae were found breeding in taro paddies. The more common species were Culex nigropunctatus Edwards, Culex gossi Bohart, Fledes vexanus (Theobald). A third species, which was collected biting people, was reared from a taro paddy near St. Joseph's church. This taro paddy had particularly muddy water and no visible outlet. This species could not be identified and has been sent to a taxonomist for identification. Mosquito larvae were only found in those parts of taro paddies which were not connected to running water. Often they were found in potholes where Cyrtosperma plants had been dug up.

A rat-tailed maggot was collected from the bottom of a crab hole in a taro paddy in Waneab. Judging from the smell, the crab had died in its hole.

Still-water habitats and species

Still-water environments ranged from large ponds to puddles. The areas sampled included several ponds, some with and some without outlets, a dammed pond at the water treatment plant, a Phragmites marsh, a large kangkong (Ipomea aquatica) patch, a small grassy swamp or slough alongside a diked stream, large puddles along the roadside or in the woods and a small cistern choked with aquatic vegetation. The greatest diversity of species was found in the kangkong patch. This patch was less than 1 meter deep and was filled with eutrophic water covered with a dense network of kangkong vines.

Odonata:

Dragonflies and damselflies reached the greatest species diversity in still water environments. The were almost always found associated with the submerged parts of the vegetation. The kangkong patch contained large numbers of the damselfly A. femina and some I. aurora. The dragonflies Tramea sp. probably transmarina Brauer, D. bipunctata, Neurothemis terminata Ris, and

Tholymis tillarga (F.) were collected. All these species are in the family Libellulidae.

Several ponds with emergent vegetation yielded Tramea species and two specimens of Aeshnidae in the genus Anax. Anaciaeschna jaspidea (Burmeister), also an aeshnid, has been reported from Yap, but no species of Anax were known to occur there. Anax guttatus (Burmeister), however, occurs widely in the Carolines, and may have been missed in previous collections in Yap. The dammed pond at the water treatment plant yielded several specimens of T. tillarga. A large puddle with pond scum and grasses trailing in it contained many Pantala flavescens (F.) as well as T. tillarga and D. bipunctata. The grassy slough yielded several individuals of A. femina and D. bipunctata.

The Phragmites marsh contained an aeshnid which appeared to be A. jaspidea, as well as the Libellulidae D. bipunctata and P. flavescens and the Coenagrionidae I. aurora and A. femina. The edges and inlet of the pond emerging from this marsh contained I. aurora, A. femina, and D. bipunctata. From the pond edge we also collected a very young nymph which could not be identified for certain, but which may have been T. tillarga.

The samples from this pond and marsh were the only ones where I. aurora was more abundant than A. femina.

Hemiptera:

The kangkong patch was not as rich in water skaters as it was in Odonata. The only gerrid species collected was L. fossarum. One mesoveliid, possibly Mesovelia orientalis Kirkaldy, was abundant, and one species of veliid was collected here. Large numbers of A. tahitiensis (Notonectidae) and Plea liturata Fieber (Pleidae) were collected at this location.

At other still-water sites, we collected L. luctuosus, which was found on several ponds, and L. fossarum, which was collected on a marsh and on a pond. Veliidae were collected in the Phragmites marsh, a puddle full of pond scum, and a pond. A. tahitiensis and P. liturata were collected from the Phragmites marsh.

Coleoptera:

Dytiscidae were found in several locations in still water. Cybister tripunctatus hammatus (Montrouzier) was collected from a pond and the headwaters of the Phragmites marsh. Hydaticus sp. was collected at the inlet of the pond emerging from the Phragmites marsh. Hydaticus sp. was collected in the kangkong patch and in the grassy slough. Hydrovatus sp. was collected from a pond at Luweech. A species which could not be identified to genus, because only a female specimen was collected, was found in the kangkong patch. A Noterid species, Hydrocoptus sp. was collected from the kangkong patch.

Among the Hydrophilidae, Enochrus esuriens and Enochrus sp. 1 were collected in a puddle with a lot of pond scum, and E. esuriens was also found at the inlet to a pond in Luweech. In addition, Enchrus esuriens was collected among grasses in the edge of a stream riffle and in taro patches, indicating a wide habitat preference. Enchrus sp. 2 was collected in a grassy puddle in the woods. Helochares sp. 2 was collected in the Phragmites marsh. Both Enochrus sp. 2 and Helochares sp. 2 were also collected in taro patches.

Diptera:

Chironomidae were abundant where there was soft mud and eutrophic water. Only one species was reared to the adult stage, a second species of Chironomus. The larvae had been scraped off a mudbank in a water storage pond.

Four species of Culicidae were recovered from still water environments. Aedomyia catasticta Knab was collected from emergent vegetation in two ponds. C. gossi was reared from the Phragmites marsh and C. nigropunctatus larvae were found in a small cistern full of kangkong and Colocasia taro. A larva of Culex fuscanus Wiedemann was also found in the cistern. In its larval stage, this species is a predator of other mosquito larvae. Aedes vexans (Theobald) was reared from a small grassy pool in the woods.

Containers habitats and species

A variety of containers with standing water were sampled. Insect larvae were found in coconut shells, old tires, flower pots, bamboo stumps, and Nepenthes mirabilis pitchers. No insects were found breeding in pandanus leaf axils or in beer cans in the dump. The latter did not appear to have collected enough organic matter to support insects. The only order of insects found in containers were Diptera.

Diptera:

Large numbers of Aedes hensilli Farner larvae and pupae were found in a variety of different containers, particularly various objects made by man. Aedes maehleri Bohart was found in Nepenthes pitchers. Bloodworms were found in a tire. Large numbers of midge larvae were found in Nepenthes pitchers. Rat-tailed maggots were found in a coconut with rotting coconut meat inside it.

CONCLUSION

Very few insects were found in the stream environment. Both the diversity of species and the numbers found were low. As in Guam (Ellis-Neill, 1987), ateyiid shrimp were much more abundant than insects in the streams and probably provide most of the food for fish and other predatory stream organisms. In Guam, mayflies (Ephemeroptera), blackflies (Simuliidae) and aquatic caterpillars (Pyralidae) are found in streams, but these groups were not found in Yap. This may due to the lack of permanent streams in Yap which could serve as a refuge during dry periods. The most abundant insects in the stream environment were bloodworms and other midges and the water skater Limnometra pulchra.

There were two basic types of Cyrtosperma paddies, those with flowing water which were connected to the streams and those with still water which were isolated from the streams. The extent of the insect fauna was strongly dependent on the type of paddy. Paddies of the first type had faunas similar to stream faunas, and insects were uncommon. Paddies of the second type had more species of insects. The more the paddy resembled a swamp, the greater the insect diversity was. Paddies with weeds and no connections to streams had the highest abundance and diversity of insects. This suggests that there is heavy predation on insects anywhere that fish can be found, and that insect abundance increases in areas which are not accessible to fish or which have lots of cover. Unfortunately, not much fish sampling was done in the Cyrtosperma paddies. The few samples taken suggested that the fish in paddies which had flowing water were the same as those found in the adjacent streams.

Still-water environments with vegetation, either algae or macrophytes within the water, had the greatest diversity of insects. This is a normal pattern for aquatic insect communities, with many different groups of insects being found predominantly in this type of environment. Many of the species found in these environments migrate more readily than do stream insects and are thus more likely to be found on oceanic islands. As in the taro paddies, the habitats with the greatest diversity of insects were those with no access for fish. In all aquatic environments, the insects tended to be among or near the vegetation, where they can find food and have shelter from predators.

The aquatic insect fauna of the region is very incompletely known. Large scale surveys of the terrestrial insect fauna of the Carolines were done in the early 1950's, but little effort was made to sample aquatic habitats. In the Bishop Museum in Honolulu the collection of aquatic groups from Micronesia is very limited, and much of what is there has not been identified. Little is published on the aquatic insects in Micronesia, except for the dragonflies, adult midges, mosquitoes, biting midges, and a few other minor groups. Even these groups are undercollected. Both species of chironomids that were reared to the adult stage in the current survey did not match any of the species descriptions in Tokunaga (1964). For other groups, published information is even less complete. For example, only two species of Dytiscidae and one Hydrophilidae are reported in the literature from all of the Caroline islands (Balfour-Browne, 1945). In this survey we collected four species of Dysticidae and ten species of Hydrophilidae from Yap alone.

ACKNOWLEDGEMENTS

We thank the staff of the Marine Management Resources Division of Yap State for their assistance during our visit to Yap. We are also grateful to Dr. Paul Spangler of the Smithsonian Institution for identifying many of our specimens.

LITERATURE CITED

Balfour-Browne, J. 1945. Aquatic Coleoptera of Oceania (Dytiscidae, Gyrinidae and Palpicornia). B. P. Bishop Occ. Pap. 18(7):103-132.

Bohart R.M. 1957. Diptera: Culicidae. Insects of Micronesia 12(1):1-85.

Ellis-Neill, L. 1987. Distribution and production dynamics of benthic invertebrates in a tropical stream on Guam. MS thesis. Univ. Guam. 51 p.

Lieftinck, M.A 1962 Odonata. Insects of Micronesia 5(1):1-95

Tokunaga, M. 1964. Diptera: Chironomidae. Insects of Micronesia 12(5):495-628.

THE FRESHWATER DECAPOD CRUSTACEANS OF YAP, CAROLINE ISLANDS

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ABSTRACT

The populations of decapod crustaceans found in the various freshwater habitats of Yap proper were sampled by means of dipnets and electroshocking. Eight species of decapod crustaceans were found. These included two species of grapsidae, four species of atyidae, and two species of palaemonidae. The most numerous of the species found in the freshwater habitats of Yap was the atyid shrimp Cardina typus. There is apparently a broad overlap in habitat use, in terms of distribution, among these species.

INTRODUCTION

Decapod crustaceans are often the dominant invertebrate in tropical island streams (Bright, 1982). They are also an important source of food for stream fish and are increasingly used in aquaculture as food for man. An understanding of crustacean biology is important in understanding how tropical streams function.

METHODS

Decapods were collected by dipnet or electroshocking at 21 sites in 11 streams on the islands of Yap Proper, Gagil-Tamil, and Maap during September 1988. The lengths of all individual shrimps and prawns were measured from the tip of the telson to the base of the antennae. The carapace width of crabs was also measured. Reproductive size was determined for each species by recording the smallest individuals which were gravid. Atyid identifications depend largely on adult size, the length of the rostrum and the number of rostral spines. These characters are difficult or impossible to observe on smaller individuals, so only adult and sub-adult atyids could be accurately identified. Representative specimens of each species were deposited in permanent collections at the Yap State Marine Resource Management Division and at the University of Guam Marine Laboratory.

RESULTS

Two hundred eighty-one individuals of freshwater decapod crustaceans were identified during the study. Within this sample, eight species were present. Maximum size, reproductive size, and the number of gravid individuals observed for each species are shown in Table 1. The list includes 2 crabs, 4 atyid shrimp, and 2 prawn species.

The atyid shrimp Caridina typus was by far the most common species, making up 67% of all individuals collected. The prawn Macrobrachium lar was second in abundance (17% of the total), while each of the remaining species made up less than 10% of the number collected. Only two species of Macrobrachium were present.

There appeared to be a broad overlap in habitat use among the decapods, as all species were found in each of the three habitats sampled (pools, riffles, and runs). The sample size was too small to distinguish habitat preference for most species, but Caridina typus clearly favored a current. Over 95% of the individuals of this common species were collected from riffles and runs.

Macrobrachium lar was the largest decapod collected, attaining a maximum length of 78 mm. Individual M. lar as small as 17 mm were collected in the same habitat as adults. The atyid shrimp were all less than 30 mm long. Caridina typus and C. gracilirostris, the two atyids most similar in size, appeared to exhibit a degree of competitive exclusion. Although sample size was small, nearly 80% of the C. gracilirostris individuals were collected where C. typus was completely absent.

Five of the eight decapod species had at least some females which were gravid in this sample. The less common species of Caridina (serratirostris, brachydactyla, and gracilirostris) all appeared to be in breeding season. For each of these species, every individual larger than the minimum reproductive size was gravid (n = 23). The two largest females of Macrobrachium lar were also gravid. In contrast, only 42% of the sexually mature Caridina typus individuals carried eggs.

DISCUSSION

Although two species were not positively identified, it is unlikely that any endemic freshwater decapod species were present in Yap's streams. The total number of species collected in this relatively small sample was similar to the number known from neighboring Pohnpei (10 species according to Maciolek and Ford, 1987) and Guam (7 species according to Best and Davidson, 1981), but fewer than in Palau (16 species according to Bright, 1979). Atyopsis and Atyoida, which were very abundant in both Palau and Pohnpei, were conspicuously absent from Yap. The smaller, mostly intermittent streams of Yap may not have adequate habitat to support these two genera, which are found only in permanently flowing, swift streams, especially in cascade areas.

Caridina typus was much more common in Yap than in Palau or Pohnpei. In Palau, this species was common only in first order streamlets which originated within 1-2 km of the sea. The predominance of this type of habitat in Yap probably accounts for the relative abundance of C. typus in Yap's streams. Johnson

Table 1. Summary of data collected concerning the freshwater decapod crustaceans collected from Yap during September, 1988. For each species is given the number of specimens examined, the maximum length, the reproductive length, the percentage of adults which were sexually mature, and the number (n) of adults examined. ND = no data available.

SPECIES (No. specimens)	LENGTH (mm) MAX.	REPROD.	% GRAVID ADULTS (n)
Grapsidae			
Varuna litterata (5) (Fabricus)	(21) (width)	ND	ND
unidentified species (4) (Parasesarma?)	25	ND	ND
Atyidae			
Caridina brachydactyla (6) (DeMan)	22	19	100 (6)
Caridina serratirostris (8) (DeMan)	15	10	100 (8)
Caridina gracilirostris (21) (DeMan)	30	23	100 (21)
Caridina typus (187) (Milne-Edwards)	30	18	43 (30)
Palaemonidae			
Macrobrachium lar (47) (Fabricus)	78	67	100 (2)
unidentified species of Macrobrachium (2)	58	ND	ND

(1963) and DeSilva (1983) both noted that this species seldom migrates far from the sea.

Without further sampling during other parts of the year, if is impossible to determine when peak breeding seasons occur for each species. However, there appeared to be an unusually high percentage of gravid individuals in the Caridina species brachydactyla, serratirostris, and gracilirostris. That all of the largest individuals of these species were gravid females suggests that these shrimp are protandrous and that a reproductive peak seems to occur in September. Protandry is also known among the atyid genera Atyoida and Paratya (Carpenter, 1978). In Palau, there was no conspicuous breeding season noted for any of the Caridina species (Bright, 1979).

The freshwater decapods of insular streams throughout the world are basically diadromous, depending on freshwater as adults but producing larvae that develop in the sea (Fryer, 1977; Smith and Williams, 1981). This principle is illustrated well in the size-frequency distribution of the prawn Macrobrachium lar collected in the present study. No prawns smaller than 17 mm were observed in these samples. Apparently, younger prawns develop in estuaries and begin migrating upstream when approximately 17 mm long. A similar pattern was observed in M. lar populations in Palau (Bright, 1979).

LITERATURE CITED

Best, B.R. and C.E. Davidson. 1981. Inventory and atlas of the inland aquatic ecosystems of the Marianas Archipelago. Univ. Guam Mar. Lab. Tech. Rept. 75. 226 pp.

Bright, G.R. 1979. The inland waters of Palau, Caroline Islands. Report: Office Chief Conserv. Trust Territory of the Pacific Islands, Koror, Palau. 61 pp.

Bright, G.R. 1982. Secondary benthic production in a tropical island stream. Limnology and Oceanography 27:472-480.

Carpenter, A. 1978. Protandry in the freshwater shrimp Paratya curvirstris (Decapoda:Atyidae) with a review of the phenomenon and its significance in the Decapoda. Journal of the Royal Society of New Zealand 8:343-358.

DeSilva, K.H.G.M. 1983. Studies on Atyidae (Decapoda, Caridea) of Sri Lanka. II. Distribution of atyid shrimps in Sri Lanka. Crustaceana 44:208-215.

Fryer, G. 1977. Studies on the functional morphology and ecology of the atyid prawns of Dominica. Philosophical Transactions of the Royal Society of London Series, B. 277:57-129.

Johnson, D.S. 1963. Distributional and other notes on some freshwater prawns (Atyidae and Palaemonidae) mainly from the Indo-West Pacific region. Bulletin of the National Museum of Singapore 32:5-30.

Maciolek, J.A. and J.I. Ford. 1987. Macrofauna and environment of the Nanpil-Kiepw River, Ponape. Eastern Caroline Islands. Bulletin of Marine Science 41:623-632.

Smith, M.J. and W.D. Williams. 1981. The occurrence of Antecaridina lauensis on the Solomon Islands: an intriguing biogeographical problem. Hydrobiologia 85:49-58.

Freshwater Plants of Yap

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ABSTRACT

This is the first report on the freshwater algae of Yap. Visible algae and other freshwater plants were collected from representative streams and ponds on three of the main islands of Yap: Yap, Maap, and Gagil-Tomil. The streams of Yap are characteristically shady and poor in freshwater algae; the ponds, in contrast, are well-lit and provide a good algal habitat. A total of 75 taxa, excluding the diatoms, were recorded: 41 green algae, 3 euglenoids, one dinoflagellate, 13 blue-green algae, 2 red algae, 2 charophytes, 3 mosses, and 10 angiosperms. The majority of the algae found are new records for Micronesia. Two desmids appear to be new species, and one red alga may also be new.

INTRODUCTION

Plants growing in freshwaters can be subdivided into those that live in moving waters (lotic) and those that live in standing waters (lentic) (Ward and Stanford, 1983). Within each of these subdivisions, we can consider the macrophytes, comprising rooted vegetation and macroscopic algae, the periphyton, comprising the submerged, attached microalgae, and the phytoplankton. Different communities appear in lotic and lentic habitats, and within lotic stretches there is a transition from periphyton to macrophytes to phytoplankton as the dominant primary producers (Wetzel, 1983).

Rooted vegetation consists of flowering plants, which may be entirely submerged, floating (with at least some leaves floating on the surface), or emergent (with leaves projecting above the water). Emergent vegetation often grades into the shore vegetation because of changing water levels. Mosses, which commonly occur in streams, may also be considered rooted vegetation, although technically they do not have roots. Algae include those that are attached to the substratum or larger vegetation (periphyton), and those that float in the water column (phytoplankton). The distinction may appear blurred, however, when one sees floating mats of algae which, buoyed by the bubbles from their own photosynthesis, have lifted off the bottom. The phytoplankton of ponds is often recruited from the benthic communities (Round, 1973).

Ponds and small streams, such as found on Yap, are unstable habitats compared to lakes and large rivers, because they tend to dry up. The abundance and diversity of the flora is reduced, especially in comparison to continental water bodies. For instance, Zolan (1981) noted a maximum of 37 diatom taxa for any particular river site on Guam, compared to 100-200 species for single collections from continental rivers.

Knowledge of the rooted vegetation of tropical Pacific islands is fairly good, and a small color guide is available (Stemmermann, 1981). Detailed distributions of the rooted vegetation have been given by Fosberg et al. (1979; 1982; 1987), which together with Stone's monograph on the flora of Guam (1970), form an excellent body of technical information pertinent to Yap. In contrast, the freshwater algae are largely unexplored, and the literature is very diverse and technical. The most useful general guide to freshwater algae is Prescott's (1964) key to genera, together with Drouet's (1981) summary of the blue-green algae. Best and Davidson (1981) inventoried the algae of the Mariana Islands, basing their compilation essentially on two reports, both from Guam: Kami et al. (1978) (all algae), and Zolan (1981) (diatoms). More recently, Bowden-Kerby (1985) completed a detailed study of freshwater red algae in Guam, Palau, and Truk. Further afield, Hustedt (1942) reported diatoms from Indonesia and Hawaii, and Fungladda (1982) studied diatoms in freshwater streams in Hawaii. Other pertinent studies of diatoms include those of Foged (1976; 1981; 1984; 1987) and Podzorski and Haakansson (1987). Some of these studies (e.g. Foged, 1971) consist of a few samples grabbed during a bus tour, so that the knowledge is not even as extensive as this list might imply. While there are few records of the flora of Micronesia, there are no records of freshwater algae from Yap.

The present collections are limited in being made in a single two-week period in September, and the checklist can be considered only preliminary. Nevertheless, they represent all the major standing waters and a large sample of the streams on the main group of Yap islands, and thus constitute one of the more thorough collections of freshwater algae, particularly diatoms, in the Pacific islands. In total, 75 taxa, not counting the diatoms, were recorded: 41 green algae, 13 blue-green algae, 2 red algae, 2 charophytes, and 10 flowering plants.

METHODS

Visible algae and rooted aquatic angiosperms were collected in the vicinities of the fish/invertebrate collection sites (see list below), and also in several estuaries, taro patches, and puddles. All together, some 200 samples were collected and anayzed. "Visible algae" included filamentous benthic or floating species, algal mats, and occasional dense aggregations of phytoplankton. Frequently, planktonic algae were present in water collected with visible mats, but no systematic effort was made to trap such species (e.g. with a plankton net). Mosses in streams, some of which may be considered aquatic rather than terrestrial, were not collected systematically. Collections were examined each day before preserving in ca. 5% formaldehyde or pressing onto herbarium paper. Taxonomic determination of diatoms required that they be cleaned of all organic material by boiling for an hour in half-strength nitric acid. This allows details of the silica shell to be seen but prevents distinction of which species were present as live cells.

Specimens were sent to several expert taxonomists for specific identification, as follows. Vascular plants: Lynn Raulerson (University of Guam); mosses: Douglas Smith (University of Guam); filamentous green algae and euglenoids: Robert W. Hoshaw (University of Arizona); desmids: Joseph Gerrath (University of Guelph); blue-green algae: William A. Daily (Butler University); dinoflagellates: F.J.R. Taylor (University of British Columbia); charophytes: Fay K. Daily (Butler University); diatoms: J. Nelson Navarro (Universidad Catolica de Puerto Rico). Without the generous assistance of these people no checklist would have been possible.

Voucher specimens of the macrophytes have been deposited in the University of Guam herbarium and will be provided to Marine Resource Development Branch, Yap. Portions of the collections sent to the taxonomists have been retained by them. A portion of each sample has been retained by the author for deposit in the reference collection of the University of Guam Marine Laboratory.

Collecting locations:
[Site letters are the approximate corresponding sites for the electroshock sites (Sanger and Hopper, this volume).]

Yap:

- Y1. Gitaem reservoir.
- Y2 [A]. Gitaem reservoir outfall stream, especially the dam face.
- Y3 [B]. Qokaaw. Stream near the village, plus adjacent taro patches and a cultivated taro/kangkong swamp.
- Y4-5. Qokaaw mangrove swamp.
- Y6 [C]. Qokaaw stream, above village (near Tabilaeg).
- Y7 [D]. Yyin estuary and lower part of freshwater stream.
- Y8 [E]. Malawaay estuary and lower part of stream.
- Y9. Maqweach: mangrove prop root sample.
- Y10 [F?]. Unmapped pond by old airport, bordered by dense floating grass mat (<u>Ischaemum</u>).
- Y11 [G]. Gitaem, south stream, near junction of road to the High School.
- Y12 [H]. Luweech pond, by weather station and old airport.
- Y13 [I]. Machbaab pond.

Y14. Malawaay estuary.
Y15 [J]. Malawaay stream above the village.

Maap:
Y16 [K]. Wanead estuary and lower part of freshwater stream.
Y17 [L] Wachaelaeb, stream at road to Choqol.
Y18. Minaeg, marine samples from mangrove prop roots.
Y19. Fangaamat, marine, mangroves.
Y20. Baqanimaqut, marine, mangroves.
Y21. Puddle in roadside ditch just south of Y17.
Y22. Colonia: water-filled post hole on concrete dock at Marine Resources Division labs.
Y23. Qamin, in headwaters of stream system.
Y24 [M]. Siminmin, part of same stream system as Y23.

Gagil-Tamil:
Y25 [N]. Wanyaan, stream emptying by St. Joseph's Church: estuary and lower freshwater stream, also taro patches in village.
Y26. Taraang (O'Keefe's Island). Marine subtidal samples from 10-12 m depth.
Y27 [O]. Thool: stream and drainage channel alongside a taro patch.
Y28. Wanyaan, very small stream to the north of Y25.
Y29 [P] Toqayong pond.
Y30 [Q]. No algal sample.
Y31. Qamun taro swamp.
Y32 [R]. Qamun stream.

Guam samples used for comparison (Fena watershed):
G1. Maulup River.
G2. Fena Lake.
G3. Imong River.
G4. Alamagosa River.

RESULTS

The freshwaters of Yap contain representatives of most, if not all major classes of algae. Blue-green algae (cyanobacteria or Cyanophyceae) predominate, with green algae (Chlorophyceae) and diatoms (Bacillariophyceae) also very common. Some red algae (Rhodophyceae), stoneworts (Charophyceae), dinoflagellates (Dinophyceae), and euglenoids (Euglenophyceae) were recognized. An annotated checklist, including the vascular plants, is given in the following section, along with notes on dominant or interesting species.

The floras of lotic and lentic habitats will be described and then a section will give brief descriptions of dominant and otherwise significant species.

Streams

Streams on Yap islands provide a patchwork of algal habitats. The primary factor governing algal growth is probably the availability of light, and most streams are heavily shaded by the forest canopy over most of their length. In addition, the sediment load in the water contributes turbidity and unstable substratum on stream beds, both of which also restrict benthic algal growth, and variations in water flow affect algal population structure. On stable substrata such as pebbles, rocks, concrete culvert ramps, firm mud banks, and rooted plants, algae may be seen growing, provided the trees are not too dense. There are some common species which were encountered in several streams, but no alga was consistently present in well-lit, stable habitats.

Filamentous blue-green algae in the family Oscillatoriaceae, especially Schizothrix calcicola, were the most common algae, not only in streams but also in ponds and other standing water such as puddles, taro swamps, and so forth. These algae also tended to be very abundant when present, forming thick, gelatinous mats which may appear blue-green, green, brown, or black. One stream habitat dominated by blue-greens was concrete culvert ramps. In other places, blue-greens were often replaced by or mixed with green algal filaments.

Several species of greens were found in streams, the most common being a species of Cladophora, which forms short, fairly stiff, dark green tufts in riffles and runs. Other green algae are often distinguishable in the field because of being lighter green in color or having longer or more delicate strands. Among and on the green algal filaments and blue-green mats may be found a variety of diatoms, including the non-motile "saddleback", Achnanthes inflata (Fig. 1) (often epiphytic on Cladophora but also found forming dense epilithic mats with other diatoms), a chain-forming species, and the motile "rostrate Navicula". Several desmids in the genus Closterium were widely distributed but never present in large numbers.

No pattern was seen in the distribution of greens, blue-greens or diatoms. Moreover, several exceptional populations of algae were found on pebbles in three different streams. At Qokaaw, a dense diatom mat was found coating some pebbles (but not all at the site). In the upper reaches of the stream at Malawaay, a population of the red alga Batrachospermum sp. was found, along with blue-greens and Cladophora, but the cryptic "Audouinella" stage of the life cycle was not seen. In the lower part of the stream at Wanead, near St. Joseph's Church and not far above the tidal reach, a large pure stand of a Thorea sp. was

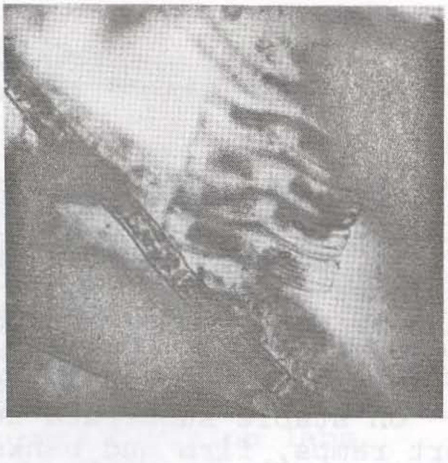

Figure 1. "Saddleback" diatom, Achnanthes inflata, attached to green algal filaments (Oedogonium?). The diatom cells are approx. 50 um long.)

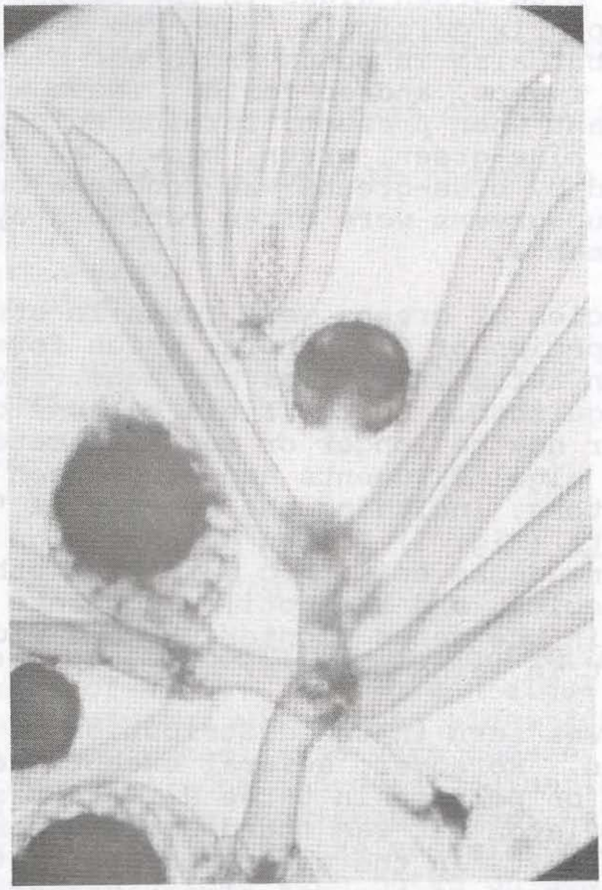

Figure 7. Microscope view of Nitella pseudoflabellata shows tip of branch with mature antheridium (center) plus immature and mature oogonia. (4x objective)

found. Salinity was checked at both low and high tides and was always nil. In Toqayong pond a diverse and interesting desmid flora was found, including Micrasterias spp. and Xanthidium armatum.

Ponds and other lentic habitats.

Ponds provide a rather different habitat from streams because the water is not flowing. Moreover, the ponds in Yap are all well-lit, surrounded by open fern/Pandanus savannah. Large algal populations were found, overwhelmingly blue-greens, which formed mats on the bottom and (in Machbaab) floating on the surface. The bottom-mat sometimes extended on to the damp shore. Also present in the two larger ponds near the old airport, was a stonewort, Nitella pseudoflabellata (Fig. 2). Rooted aquatic vegetation was also more abundant. The grasses Ischaemum polystachum var. intermedium (muraina grass), which also occurred in patches in several streams, and Eragrostis sp. (lovegrass) dominated, with some Eriocaulon sexangulare among them. Blyxa sp. formed distinctive star-shaped rosettes on the pond bottoms, and the sedges Cyperus sp. and Eleocharis ochrostachys were found in one of the ponds.

Puddles differ from ponds in being smaller and ephemeral. The largest puddle sampled was some 9 square meters, the smallest a post hole. Blue-green algae, including a form of Microcoleus vaginatus with distinctive short filaments bundled into a common sheath, again tended to be common. The easily-recognized green alga Spirogyra, with spiral chloroplasts, formed delicate wisps.

The standing water in taro patches ranged from puddles to complete coverage. In fully-flooded patches, the tiny flowering plant, Lemna perpusilla (duckweed), sometimes covered the surface, and phytoplankton aggregates (e.g. Euglena) were seen in sun spots. Several taro patches had flowing water but little algal growth. However, an unusual patch at Thool had a species of Nitella different from that in the ponds, which was also present in the adjacent stream. A taro/kangkong marsh in Qokaaw had a particularly rich and diverse algal flora, including blue-green and green filaments and various euglenoids, dinoflagellates, and other phytoplankton.

Estuaries.

The lowest parts of the streams come under tidal influence and tended also to be heavily sedimented. At low tide only fresh water was present in the streams, but at higher tide a salt wedge extended upstream under the freshwater lens. Algae on the banks are thus subjected to fluctuating salinity as the water level rises and falls. Filamentous marine algae such as Enteromorpha rises and falls. Filamentous marine algae such as Enteromorpha and Centroceras extend upstream where there are rocks lining the channel. The diatoms present on the algae and sediments included a mixture of marine and freshwater forms. Some of the freshwater species live there and tolerate increased salinity, others are washed in from upstream and may have been dead when collected.

DISCUSSION AND A BRIEF COMPARISON WITH GUAM

The dense forest through which Yap streams flow both limits algal growth and, presumably, provides the majority of the nutrient input. Abundant algae and rooted aquatics are found only in open breaks. However, algae and rooted aquatics dominate the well-lit ponds.

An assessment of the Yap vegetation requires comparison with other areas. Comparison with a continental freshwater flora, that of Rhode Island, indicates that the flora in Yap is very much reduced, as was expected. Of course, the present report is only a preliminary list, owing to limited sampling, whereas the flora of Rhode Island has been more extensively sampled (but Kaczmarczyk and Sheath, 1988 still refer to their list as preliminary). Kaczmarczyk and Sheath (1988) reported 153 subgeneric taxa from Rhode Island lake and pond periphyton, and Hambrook and Sheath (1988) reported 433 taxa of stream epilithic periphyton. In the latter, 52 taxa of Closterium were found, compared to only 6 so far from Yap.

Comparision of the freshwater red algal florae reported from Palau, Truk, and Guam by Bowden-Kerby (1985) again shows a reduction. Whereas only two taxa were encountered in the Yap collections, these other islands had 6-8 species each. However, Bowden-Kerby noted that freshwater red algae in Micronesia are limited to very restricted habitats, usually headwaters and springs. Thus a more thorough search of Yap streams might reveal a larger flora. Sheath and Burkholder (1988) reported 12 taxa from their surveys in Rhode Island.

Given the dearth of data on Micronesian freshwater algae, I made a brief survey of freshwaters on Guam. The basis of my comparison is a set of samples from Fena Lake and three rivers flowing into it. These collections were made soon after my return from Yap, using the same procedure, and they were included in the samples sent out for identification.

In general, the streams I have visited on Guam pass through grassland and are thus more open and well-lit. (There are streams on Guam that pass through dense ravine-forest, but I cannot comment on these.) The stream algae are dominated by Spirogyra sp(p). with some Cladophora and Oedogonium. The abundance of Spirogyra is not surprising, for it is a very common genus; rather, its absence in Yap, except in puddles, is remarkable. Among the diatoms in the streams feeding Fena Lake was Terpsinoe, a genus which was not found in Yap but also has not been found in other Guam watersheds. Achnanthes inflata and the "rostrate" Navicula are also common in Guam streams. The flowering plant Hydrilla verticillata (L. f.) Royle (pond weed) was common in Fena watershed but was conspicuously absent from Yap.

Fena Lake algae appeared similar to algae in Yap ponds. Abundant blue-green algal mats of Schizothrix calcicola, Microcoleus vaginatus, etc. were found floating, and in both locations contained numerous dinoflagellate shells indicative of an earlier bloom.

Many algae are cosmopolitan in their distribution, or at least pan-tropical. Thus common species such as Schizothrix calcicola and Achnanthes inflata turn up in many streams. On the other hand, the distribution of algae from island to island, or from stream to stream depends on chance, and no-one is sure how it occurs. Thus many diatoms are found in Yap which have not been recorded in Guam, and vice versa. The same probably applies to other algal groups, but there is little information. Bowden-Kerby found six new species of Batrachospermum on three islands in Micronesia (Kumano and Bowden-Kerby, 1986); and all Guam charophytes in the University of Guam herbarium are Chara and not Nitella as found in Yap.

Clearly, there is much to learn about Micronesian freshwater algae. In Yap, samples should be taken at other seasons (e.g. in March during the dry season), and plankton tows should be taken to look for more unicellular and colonial species. Preservation with Lugol's iodine (Schoen 1988) rather than formaldehyde will improve the value of plankton samples. Further examination of streams where red algae were collected should reveal more species, since Bowden-Kerby (1985) found there were usually several species present when one was found. Fertile material should be sought so that the red algae and filamentous greens can be identified. Finally, water chemistry sampling should be extended so that species distribution can be examined against such factors as pH, nutrient levels, and alkalinity.

ANNOTATED CHECKLIST

CYANOPHYCEAE

Chroococcales
Chroococcaceae
Anacystis marina (Hansg.) Dr. and Daily
Machbaab pond, in floating mat.

Chamaesiphonaceae

Entophysalis Lemaniae (Ag.) Dr. and Daily

Qokkaw, in taro/kangkong swamp.

Hormogonales

Oscillatoriaceae

Schizothrix calcicola (Ag.) Gom.

Forming loose orange flocs in Gitaem and Qokkaw streams, and abundant also in mats from taro patches, ponds, and streams: Qokkaw, Luweech ponds, Wachaelaeb, Toqayong. Also found in two samples from Guam.

Microcoleus vaginatus (Vauch.) Gom.

Common. Qokkaw, Qamun, and Malawaay streams, Machbaab pond; Guam.

M. lyngbyaceus (Kütz.) Crouan

Common. Malawaay, Gitaem, Siminmin streams; post hole at Marine Resources lab; Guam.

Oscillatoria princeps Vauch.

Qokkaw kangkong swamp; post hole at MRB.

O. lutea Ag.

Malawaay stream.

O. Retzii Ag.

Wanead stream.

O. submembranacea Ard. and Straff.

Guam; not recorded in Yap.

Nostocaceae

Calothrix parietina (Nag.) Thur.

Malawaay stream, Leuweech pond; Guam.

Nostoc commune Vauch.

Machbaab pond.

Scytonema Hofmanni Ag.

Wachaelaeb stream; post hole at MRB.

Stigonemataceae

Stigonema muscicola (Thur.) Borzi

Luweech pond.

RHODOPHYCEAE

Batrachospermales

Batrachospermaceae

Batrachospermum sp.

Slippery blue-green, branched plants, visibly banded because of the whorls of branches. Found only in the upper reaches of Malawaay stream.

Thoreaceae

Thorea sp.

Large, dark brown plants, resembling a seaweed. Monospecific stand in the lowest fully freshwater part of Wanead stream.

Bowden-Kerby (1985) found six species of Batrachospermum, apparently all undescribed, of which four occurred on only one each of the three Micronesian islands he studied (Guam, Truk, Palau). This high degree of endemism contrasts strikingly with the cosmopolitan or pan-tropical distributions of blue-greens and diatoms. Bowden-Kerby (pers. comm.) suggested that the Yap material might well also be a different species, but this cannot be determined. One species of Thorea was also undescribed; the other, T. gaudichaudii C. Ag., was originally described from Guam in 1824 (see Seto, 1979). On the basis of my verbal description, Bowden-Kerby surmised that the Yap specimens are likely to be T. gaudichaudii because of their large size.

BACILLARIOPHYCEAE

The number of diatom species collected is large, and the list is still in preparation by Dr. Navarro. The following is an interim list of taxa identified by C. Lobban from fresh or brackish waters.

Centrales
    Thalassiosiraceae
        Thalassiosira ?fluviatilis Hust.
    Melosiraceae
        Melosira Agardh
Pennales
    Diatomaceae
        Podocystis ?spathulata (Shadb.) van H.
        Synedra Ehrenb.
    Protoraphidaceae
        Eunotia
    Achnanthaceae
        Achnanthes inflata (Kütz.) Grun.
            This is the most common, and easily-recognized diatom in Yap streams, forming short chains of "saddleback"-shaped cells (as seen in girdle view). Common as an epiphyte on filamentous greens. Several much smaller species of Achnanthes are probably present also. Fig. 1.
        Cocconeis Ehrenb.
            Several species are present as epiphytes closely-appressed to filamentous greens and blue-greens.
    Naviculaceae
        Amphiprora Ehrenb.
        Amphora coffaeformis (Ag.) Kütz.
            This and several other species of Amphora are common.
        Cymbella ?turgida Grun.
            This and several other species common.
        Diploneis Ehrenb.

Several species common as stalked epiphytes on green algal filaments.

<u>Gyrosigma</u> Hassal

Several species common.

<u>Mastogloia</u> Thw. ex W. Smith

Several species common.

<u>Navicula</u> Bory

Numerous species present, including a common one with rostrate (knob-like) apices.

<u>Pleurosigma</u> W. Smith

<u>Pinnularia</u> Ehrenb.

<u>Stauroneis</u> Ehrenb.

Epithemiaceae

<u>Rhopalodia</u> O. Müll.

Nitzschiaceae

<u>Nitzschia</u> ?<u>clausii</u> Hantz.

<u>Nz</u>. <u>palea</u> (Kütz.) W. Smith

<u>Nz</u>. ?<u>linearis</u> W. Smith

Numerous other species of <u>Nitzschia</u> common.

Surirellaceae

<u>Surirella</u> Turpin

CHLOROPHYCEAE

Chlorococcales

Scenedesmaceae

<u>Scenedesmus</u> Meyen

Colonies collected among roots of kangkong in Gitaem reservoir and among filamentous greens on the dam face, and among <u>Rhizoclonium</u> filaments in Siminmin stream.

Cladophorales

Cladophoraceae

<u>Cladophora</u> Kütz.

The dominant filamentous green in Yap streams. Common in riffles, especially small waterfalls. Normally short (ca. 10 mm), highly-branched filaments, dark green, but a population in a run at Qokaaw was much longer and very sparsely branched. Possible correlation between extent of nerite grazing and algal form needs experimental evaluation. This alga is rare in Guam rivers, being replaced by <u>Spirogyra</u> and <u>Oedogonium.</u> Identification of the filamentous greens requires fresh and preferably fertile material. The samples preserved in formalin were of limited value.

Rhizoclonium Kütz.
Commonly mixed with Cladophora, but also found alone in several samples, including a puddle and on river channel rocks in the high intertidal zone at Wanead (may be different species), and in Wanyaan, Malawaay, and Yyin streams. Cladophora and Rhizoclonium are among the few genera of algae that occur in both fresh and marine waters.

Chaetophorales
Chaetophoraceae
Chaetophora Schrank
Malawaay, just above estuary.

Oedogoniales
Oedogoniaceae
Oedogonium Link
Commonly mixed with other filamentous greens in low numbers. Gitaem, Qokaaw (taro patch), Siminmin, Qamun streams.

Volvocales
Volvocaceae
Pandorina Bory ?
Rare colonies, among green filaments; Wanyaan stream; Guam.

Zygnematales
Zygnemataceae
Spirogyra Link
Rare, in puddles. Sterile. Not found in any stream, though this is the dominant filamentous green alga in Guam rivers.

Mougeotia C.A. Ag.
Mixed with other filamentous greens in the reservoir outfall at Gitaem.

Mesotaeniaceae
Cylindrocystis sp. (brebissonii group)
Toqayong pond. Zygotes are needed for specific identification. New record for Micronesia.

Netrium digitus (Bréb.) Itzigs. et Rothe var. lamellosum (Bréb. ex Kütz.) Gronblad
Common in Toqayong pond collections. New record for Micronesia.

Spirotaenia bacillaris Lutkemuller
Toqayong pond. New record.

Peniaceae
Closterium closterioides (Ralfs) Louis et Peeters
Toqayong pond. New record. Closterium spp. were commonly encountered in low numbers among green algal filments and mats, in both streams and ponds. All are new records for Yap, of course, and all but C. moniliferum and C. parvulum (recorded in Guam by Kami et al. 1978) are new

records for Micronesia.

C. ehrenbergii Menegh. ex Ralfs

Qokaaw stream.

C. moniliferum (Bory) Ehrenb. ex Ralfs

Qokaaw stream.

C. navicula (Bréb.) Lutkem. ex Cohn.

Toqayong pond.

C. parvulum Nageli

Two ponds in Luweech.

C. ralfsii Bréb. ex Ralfs var. hybridum Rabenh.

Toqayong pond.

Desmidiaceae

Actinotaenium turgidum (Bréb.) Teil. ex Ruz. et Pouz.

Unmapped pond in Luweech. New record for Micronesia

Cosmarium connatum Bréb. ex Ralfs

Luweech pond. Cosmarium spp. were encountered in low numbers in ponds and streams. All listed are new records for Micronesia except C. impressulum (recorded from Guam).

C. granatum Bréb ex Ralfs

Gitaem stream, Luweech pond.

C. impressulum Elfving

Qokaaw stream

C. multiordinatum West et West

Unmapped pond in Luweech

C. prominulum Racib. var. subundulatum West forma ornata Lutkem.

Luweech pond

C. pseudamoenum Wille

Luweech pond.

C. regnesi Reinsch

Gitaem stream

C. stigmosum (Nordst.) Krieger

Two ponds in Luweech.

Cosmarium sp.

Luweech and Toqayong ponds.

Euastrum ansatum Ehrenb. ex Ralfs

Unmapped pond in Luweech. Species of Euastrum were rare but present in all ponds. No previous record of this genus in Micronesia.

E. didelta Ralfs var. bengalicum Lagerheim

Unmapped pond in Luweech

E. elegans (Bréb.) Kütz. ex Ralfs

Toqayong pond

E. obesum Joshua var. tetmemoroides Croasd. ex Croasd. et Scott

Toqayong pond

E. sinuosum Lenorm. ex Archer var. scrobiculatum (Nordst.) Krieger

Toqayong pond

E. spinulosum Delponte var. inermius Nordst.
Luweech pond.
Hyalotheca dissiliens (Smith) Bréb. ex Ralfs
Toqayong pond. New record for Micronesia.
Micrasterias papillifera Bréb ex Ralfs var. glabra Nordst.
Abundant in Toqayong pond collections. New record of Micrasterias for Micronesia.
Staurastrum botanense Playfair
Luweech and Toqayong ponds. Staurastrum spp., not previously recorded from Micronesia, were rare in several samples.
S. gracile Ralfs var. coronulatum Boldt
Gitaem stream, two ponds in Luweech, Toqayong pond.
S. punctulatum Bréb. ex Ralfs
Toqayong pond
S. sebaldi Reinsch var. ornatum Nordst.
Luweech pond.
S. tetracerum Ralfs
Gitaem stream, two ponds in Luweech.
Staurastrum sp.
Luweech pond.
Staurodesmus pterosporus (Lundell) Bourrelly
Toqayong pond. No previous Micronesian record.
Xanthidium armatum (Bréb.) Rabenh. var. anguligerum Krieger
Abundant in Toqayong pond samples. No previous record from Micronesia.

EUGLENOPHYCEAE

Euglenales
Euglenaceae
Euglena Ehrenb.
In taro swamps at Qokaaw and Wanead.
Phacus ?minutus
In taro swamps at Qokaaw and Wanead.
Trachelomonas dubia and T. triangularis
Cysts found in sample from Wanead taro patch.

Since no plankton tows were taken, the collection of flagellates was incidental. The Euglena in the Wanead taro patch formed bright green aggregates, visible to the naked eye, in a sunspot.

DINOPHYCEAE

Peridiniales
Peridiniaceae

<u>Peridinium</u> <u>elpatiewskyi</u> (Osten.) Lemm.
Abundant shells of this dinoflagellate were found in the bottom mat in Luweech pond (by old airport) and in Fena Lake, Guam, giving evidence of a bloom, perhaps during the previous spring or summer. This species is known from Europe and eastern Asia, including the Malaysian archipelago, but apparently no freshwater dinoflagellates have been recorded from Micronesia. Other species, present in low numbers, are still under study.

CHAROPHYCEAE

Charales
Nitellaceae
<u>Nitella</u> <u>pseudoflabellata</u> var. <u>imperialis</u>, near f. <u>Wattii</u> (J. Groves) R.D. Wood
Present in both ponds by the old airport; forming very large clumps in Machbaab pond. (See Wood, 1971).
<u>Nitella</u> sp. (<u>mucronata</u> group)
Sterile and in poor condition; in flowing water, Thool.

Charophytes cannot be identified unless fertile, hence the doubt over the Thool specimens. <u>Nitella</u> has not been recorded from Micronesia (see Best and Davidson, 1981) and, interestingly, all of the specimens of charophytes from Guam lakes and streams that are in the University of Guam herbarium are <u>Chara.</u>

ANTHOPHYTA

Monocotyledonae
Cyperaceae
<u>Cyperus</u> <u>polystachyos</u> Rottb.
Luweech pond.
<u>Cyperus</u> sp.
Machbaab pond.
<u>Eleocharis</u> <u>ochrostachys</u> Steud.
Common across Luweech pond.
Poaceae
<u>Eragrostis</u> sp.
Abundant at Luweech and Machbaab ponds.
<u>Ischaemum</u> <u>polystachyum</u> var. <u>intermedium</u> (Brongn.) Fosb. and Sachet
Common in Gitaem reservoir and stream and in Malawaay and Qokaaw streams.
Eriocaulaceae

Eriocaulon sexangulare var. micronesicum Mold.
Present at Luweech pond, and abundant at Machbaab pond.

Hydrocharitaceae

Blyxa sp.
Present at Luweech pond, and carpeting the bottom of Machbaab pond. Not flowering, but probably B. aubertii L.C. Rich., as this has been recorded from Yap and is the only Micronesian species listed by Fosberg et al. (1987).

Lemnaceae

Lemna perpusilla Torrey
Forming widespread mats over flooded taro patches in Qokaaw and Wanead.

Araceae

Cyrtosperma chamissonis (Schott) Merr.
Cultivated swamp taro. This is the species cultivated in all the taro patches in which collections were made.

Dicotyledonae

Convolvulaceae

Ipomoea aquatica Forsk.
Kangkong. "Wild" plants in Gitaem reservoir, and cultivated plants in a swamp in Qokaaw.

All of the flowering plant species listed here have previously been recorded from Yap, as given by Fosberg et al. (1979; 1987).

LITERATURE CITED

Best, B.R. and C.E. Davidson. 1981. Inventory and Atlas of the Inland Aquatic Ecosystems of the Marianas Archipelago. Univ. Guam Mar. Lab. Tech. Rep. 75. 226 pp.

Bowden-Kerby, W.A. 1985. The freshwater red algae (Rhodophyta) of Guam, Palau, and Truk: a biogeographical, ecological, and distributional account. M.S. Thesis, Univ. Guam. 45 pp.

Foged, N. 1971. Freshwater diatoms in Thailand. Nova Hedwigia 22:267-369.

Foged, N. 1976. Freshwater diatoms in Sri Lanka (Ceylon). Bibliotheca Phycologica 23, 113 pp. J. Cramer, Vaduz.

Foged, N. 1984. Freshwater and Littoral Diatoms from Cuba. Bibliotheca Diatomologica, 5, 243 pp. J. Cramer, Vaduz.

Foged, N. 1987. Diatoms from Viti Levu, Fiji Islands. Bibl. Diatom., 14, 195 pp. J. Cramer, Vaduz.

Fosberg, F.R., M-H. Sachet and R. Oliver. 1979. A geographical checklist of the Micronesian Dicotyledonae. Micronesica 15: 41-295.

Fosberg, F.R., M-H. Sachet and R. Oliver. 1982. Geographical checklist of the Micronesian Pteridophyta and Gymnospermae. Micronesica 18:23-82.

Fosberg, F.R., M-H. Sachet and R. Oliver. 1987 (1988). A geographical checklist of the Micronesian Monocotyledonae. Micronesica 20:19-129.

Fungladda, N. 1982. A contribution to the freshwater diatom flora of the Hawaiian Islands. Ph.D. Dissertation, Brigham Young Univ.

Hambrook, J.A. and R.G. Sheath. 1988. Stream epilithic periphyton. p. 60-74 In: R.G. Sheath and M.M. Harlin (eds.) Freshwater and marine plants of Rhode Island. Kendall-Hunt, Dubuque, Iowa.

Kaczmarczyk, D. and R.G. Sheath. 1988. Lake and pond periphyton. p. 35-42 In: R.G. Sheath and M.M. Harlin (eds.) Freshwater and marine plants of Rhode Island. Kendall-Hunt, Dubuque, Iowa.

Kami, H.T. et al. 1978. Job progress report, Federal aid to fish and wildlife restoration. Guam Aquatic and Wildlife Resources Div., Dept. Agric. 146 pp. (unpubl.)

Kumano, S. and W.A. Bowden-Kerby. 1986. Studies on the freshwater Rhodophyta of Micronesia. I. Six new species of Batrachospermum Roth. Jpn. J. Phycol. 34:107-128.

Podzorski, A.C. and H. Haakansson. 1987. Freshwater and marine diatoms from Palawan (a Philippine island). Bibliotheca Diatomalogica, 13, 245 p.

Prescott, G.W. 1964. How To Know the Freshwater Algae. W.C. Brown, Dubuque. 272 p.

Round, F.E. 1973. The biology of the algae. 2nd ed. Arnold, London. 278 pp.

Schoen, S. 1988. Cell counting. In, C.S. Lobban, D.J. Chapman and p. 16-22 In: B.P. Kremer (ed.) Experimental phycology: a laboratory manual. Cambridge Univ. Press, New York.

Seto, R. 1979. Comparative study of Thorea gaudichaudii (Rhodophyta) from Guam and Okinawa. Micronesica 15:35-39.

Sheath, R.G. and J.M. Burkholder. 1988. Stream macrophytes. p. 53-59 In: R.G. Sheath and M.M. Harlin (eds.) Freshwater and Marine Plants of Rhode Island. Kendall-Hunt, Dubuque, Iowa.

Stemmermann, L. 1981. A guide to Pacific wetland plants. U.S. Corps of Engin., Honolulu, Hawaii.

Stone, B.C. 1970. The flora of Guam. A manual for the identification of the vascular plants of the island. Micronesica 6:1-660.

Ward, J.V. and J.A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. p. 29-42 In: T.D. Fontaine and S.M. Bartell (eds.) Dynamics of lotic ecosystems. Ann Arbor Science, Ann Arbor.

Wetzel, R.G. 1983. Limnology. 2nd ed. Saunders, Philadelphia.

Wood, R.D. 1971. Characeae of Australia. Nova Hedwigia 22:1-120.

Zolan, W.J. 1981. Diatom Assemblages as Indicators of Water Quality in Freshwater Habitats of Guam. Univ. Guam Water and Energy Res. Inst. Tech. Rep. 29. 47 pp.

Survey of the Mosquitoes of Yap

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ABSTRACT

The mosquito fauna of Yap was surveyed in the period Sept. 15-27, 1988. Streams, taro paddies, and other habitats near streams were searched for larvae. Adults of 8 of the 11 species known from Yap were collected biting man or reared from larvae. No species new to Yap were collected. The species most commonly found biting man were Aedes hensilli and A. pipkini. A. hensilli was found breeding in large numbers in coconut shells, tires, and other small containers in or near villages. In taro paddies mosquitoes were only collected in areas where there was no access for fish. The most common species found in taro patches were the non-biting species Culex nigropunctatus and Culex gossi and the non-biting species Aedes vexans.

INTRODUCTION

Mosquitoes are extremely annoying to man, but more importantly, are vectors of a wide variety of serious diseases. In Micronesia Aedes albopictus (Skuse) and A. aegypti (Linnaeus) are vectors of dengue fever, a disease which recently broke out on Belau. Culex quinquefasciatus Say and C. annulirostris Skuse can transmit filariasis, a parasitic worm that infects man and can cause elephantiasis if the lymph nodes become blocked. The worm is widely distributed in Micronesia. C. quinquefasciatus, which occurs on Yap, is the primary vector in Micronesia. C. tritaeniorhynchus Giles, which occurs only in the northern Marianas, transmits Japanese Encephalitis Virus.

Because of the medical importance of mosquitoes, periodic surveys should be done to determine which species are present. Several islands in the Pacific have acquired new species of mosquitoes in the period after World War II due to increased plane transport to the islands. In Guam, at least 14 species of mosquitoes have been accidentally introduced since 1945 (Ward 1984). These include several species of Anopheles, the mosquitoes which carry malaria. This genus of mosquitoes was absent from the Micronesian region prior to 1945. No recent collections of mosquitoes have been made on any of the islands of the Federated States of Micronesia.

Mosquitoes have a life cycle which consists of four different stages: egg, larvae, pupae, and adult. The eggs are laid either singly or in rafts on or near water, depending on the species. The eggs may hatch in a few days, or may remain in a dormant storage for months or years. When conditions are suitable, the eggs hatch, and the larvae develop. All mosquitoes have aquatic larvae. The larvae do not possess gills, however, and must have access to air to breathe. In most species, the larvae either feed by scraping microorganisms from solid objects or by filtering microorganisms out of the water. A few species are predators of aquatic organisms including other mosquitoes. The larvae take about a week to mature, and they then form a nonfeeding stage called the pupae. In this stage the organism undergoes physiological and morphological changes that transform it from an aquatic, feeding stage to a terrestrial adult. The pupal stage lasts from 2-3 days and then moults into the adult. Adults are the reproductive stage of the mosquito. Males feed on plant juices or nectar. The female of most species require a blood meal to develop their eggs. Most species feed on birds or mammals, but some species feed on reptiles, amphibians, insect larvae, or even fish which spend time exposed to air. The hosts for different species can be quite specific, and many species will not bite man. Adults live for about two weeks.

METHODS AND MATERIALS

As part of this inventory of the fresh water resources of Yap, we conducted a mosquito survey to locate breeding habitats at all locations where other aquatic collections were made. All sources of water which might contain mosquitoes were searched for mosquitoe larvae. Any larvae found were collected and reared to the adult stage. Rearing was done in plastic cups with water and organic material from the site where the mosquitoes were collected. Adult mosquitoes were collected whenever individuals were found biting humans. Collections were done during the day and in the evening up to 11:00 p.m. No samples were collected in the hours between 11:00 p.m. and 8:00 a.m.

RESULTS AND DISCUSSION

All of the adult mosquitoes except one species have been identified, and forwarded to a taxonomist for verification or further identification. The larvae have not yet been mounted for identification. Four species were caught biting man. These were Aedes hensilli Farner, Aedes pipkini Bohart, Culex sitiens Wiedeman, and an unidentified species (Mos1) which may be Culex quinquefasciatus. Most of the mosquitoes caught biting people were either A. hensilli or A. pipkini. The other two species were relatively rare. In addition to the species we caught biting man, Aedes vexans (Theobald), Culex fuscanus Wiedemann and Mansonia crassipes (van der Wulp) are on Yap and will bite man at least occasionally.

C. sitiens breeds in brackish pools, and larvae are often found in boats left at the edge of the water if these have rainwater in them (Bohart 1957). A. pipkini has never been reared. It is a species endemic to Western Micronesia and its larval habits, and males are unknown (Bohart 1957). We did not find any larvae of A. pipkini or C. sitiens in the areas we surveyed. A. hensilli was reared from a variety of containers. It was abundant in coconut shells lying on the ground around the villages (Wanaeb and area near St. Josephs church). It was also found in old tires (Qokaw) and a flower pot containing standing water (Colonia). Larvae which appeared to be this species were found in a temporary pool in a dump at Qokaw, a bamboo stump in Qamun, and in a pond at Luweech. Mos1 was reared from a muddy Cyrtosperma swamp near St. Joseph's church. This taro patch was filled with standing water and was not connected to the stream. Mosquito larvae of at least two species (Mos 1 and Culex nigropunctatus) were collected in this patch.

Aedes vexans (Theobald) was reared from a grassy pool in the woods at Wachaebach. This pool was not connected to other water sources. It was also found in taro patches at Yyin and Malawaay. A. vexans is a fierce biter. A larva of Culex fuscanus was found in a weedy cistern at Wanead. The larvae of this species are predators and feed on other mosquito larvae. The adults occasionally bite humans.

Several species which are not known to bite humans were also reared. Aedeomyia catasticta Knab was reared from larvae collected among pond vegetation at Luweech and Taqayong. The larvae of this species attach to the plants to obtain oxygen. They do not come to the surface as do most species of mosquitoes. Culex nigropunctatus Edwards was reared from Cyrtosperma paddies at Qamun and Gagil near St. Joseph's church, and from a small cistern full of kangkong and Colocasia in Wanaeb. C. nigropunctatus is normally found in grassy pools, but has also been collected in tin cans (Bohart 1957) and apparently has a wide habitat range. Culex gossi Bohart was reared from a Cyrtosperma paddy (at Tamalaang) and from a Phragmites marsh (Luweech). Aedes maehleri Bohart was reared from Nepenthes mirabilis pitchers at various locations. The pitchers in the savanna area had no mosquito larvae in them. Larvae were only found in Nepenthes growing at the edge of wooded areas, presumably somewhat wetter areas, though liquid was found in all the pitchers. Both C. gossi and A. maehleri are endemic to Yap.

In the villages where mosquitoes were a problem, almost all of the mosquitoes biting man that we collected were A. hensilli, which bit during the daytime hours, and A. pipkini, which bit both day and night. However, nocturnal samples were limited, and other species may also be important. We cannot make any suggestions about controlling A. pipkini without knowing its breeding places, but the problems with A. hensilli could be considerably alleviated by simple measures. Larvae of this species were found breeding principally in man-made containers. In our survey these were flower pots, cans, tires, and split coconut shells. Other known breeding spots are discarded drums, barrels, bottles, and tree holes. Containers that collect standing water should not be left around. Tires and cans should not be left near villages or areas frequented by man. Coconuts shells should either be cracked or at least turned so that they cannot hold water. Control of A. hensilli is of primary importance from a disease standpoint. Neither of the known vectors of dengue fever in Micronesia, Aedes albopictus or A. aegypti, are present on Yap. However, A. hensilli belongs to the same group of mosquitoes and possibly could vector the virus.

We were informed that the Department of Agriculture has considered releasing Gambusia for control of mosquitoes in the Cyrtosperma paddies. We do not feel that this is advisable without further study. Although several biting species was reared from Cyrtosperma paddies, the common species of mosquitoes present were was C. nigropunctatus. This species does not bite man as far as we can determine from our collections and from published literature. Before altering the freshwater ecosystem with imported fish, the incidence of biting mosquitoes in paddies should be determined to see if control is really warranted. Also, the specific areas within the paddies where larvae of biting mosquitoes occur should be investigated further. Our survey results indicate that mosquito larvae were found in locations within the paddy where fish do not have access. Most of the larvae were found either in puddles and potholes or in paddies which were not connected to streams. Though few samples of the fish fauna of Cyrtosperma paddies were taken, those that were taken suggest they are the same as those in the streams. In the water bodies which contained fish, the insect fauna was depauperate and rare. The fish already present in Yap freshwater appear to be highly efficient predators of insects including mosquitoes. If further study determines that human biting mosquitoes are important in the Cyrtosperma paddies, then Gambusia would only be useful if they could be seeded into paddies not connected to the streams, and if they could survive the fluctuating water levels.

Of the mosquito species that were identified, all were previously recorded as being present on Yap. Once Dr. Ward has identified the one species that we could not identify and the larvae are identified, we will be able make a more general statement. However, it is apparent that the flood of exotic mosquitoes which have invaded Guam in recent years has not been a problem in Yap. We found the same fauna as was found in the years immediately following World War 2. At this time there do not appear to be any new, important disease vectors. However, since aircraft are no longer routinely sprayed between Micronesian destinations, this situation could change.

ACKNOWLEDGEMENTS

We thank the staff of the Marine Management Resources Division of Yap State for their assistance during our visit to Yap.

LITERATURE CITED

Bohart R.M. 1957. Diptera: Culicidae. Insects of Micronesia 12(1):1-85.

Ward, R.A. 1984. Mosquito fauna of Guam: Case history of an introduced fauna. p. 143-161 In: M Laird (ed.) Commerce and the spread of pests and disease vectors. Praeger, New York.

An Assessment of the Potential for Freshwater Aquaculture on Yap Proper

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The development of subsistence, freshwater aquaculture in Yap is constrained by the availability of freshwater and by the attitudes of the Yapese people toward freshwater fish and shrimp. The African cichlid Oreochromis mossambicus was introduced to Yap for aquaculture in the 1970's but was not highly regarded and is not cultured today. The introduced aquatic plant Ipomoea aquatica is currently being cultivated in shallow ponds associated with taro cultivation of Yap proper. Of the organisms found naturally in the freshwaters of Yap, only the shrimp Macrobrachium lar is sporadically fished by the Yapese; the eel Anguilla marmorata is occasionally captured by the ethnic Filipinos on Yap but is considered undesirable to local islanders. Other, euryhaline, fishes, such as milkfish and mullet, which are primarily found in brackish or marine habitats, can be acclimated to freshwater, and small-scale production of these species could be developed.

INTRODUCTION

In recent years there has been a growing interest in the development of aquaculture in Yap state. Several small ponds were constructed in the early 1970s at Meer for the purpose of aquaculture demonstration, and these have been occasionally used for the small-scale production of milkfish and tilapia. In 1980 a team of aquaculture consultants was brought in to provide information on the possibility of culturing milkfish in Yap (Handog et al., 1980). A consultant from Japan was brought in to assist in identifying formalin-preserved fish larvae that had been collected as part of a larger study conducted by the Marine Resources Management Division of Yap state with the purpose, in part, of determining seasons when fry might be available for stocking ponds. Recently, a brief study of existing fishponds was conducted and recommendations were made for the development of subsistence aquaculture within Yap proper (Nelson, 1987). In addition, the culture of giant clams has been initiated with the introduction of juveniles at numerous sites at villages throughout Yap including the outer islands.

The interest of the Marine Resource Management Division of Yap state in their freshwater aquatic resources and their potential for development through small-scale freshwater aquaculture prompted the present study. Small-scale subsistence aquaculture is emphasized since commercial freshwater aquaculture is constrained by the limited freshwater resources, particularly in the dry season when many streams dry up. The information and recommendations contained in this review are based on the data presented in the companion studies in this volume, on interviews conducted on Yap, and on a review of the pertinent literature.

The scope of work was narrowly focused, and this review is limited to the potential development of freshwater aquaculture within Yap proper; brackish water and marine culture systems are not discussed.

AGRICULTURE AND AQUACULTURE

The processes involved in agriculture and freshwater aquaculture are similar, and the two methods of food production are often closely integrated. For example, some forms of traditional aquaculture practiced in the Hawaiian islands developed in relation to the irrigated cultivation of taro (Summers, 1964; Kikuchi, 1976). Therefore, some of Yap's agricultural practices were reviewed with the aim of discovering information useful in devising strategies for the development of small-scale freshwater aquaculture.

Taro and Water Spinach

Two types of agricultural crops are cultivated in submerged plots near the streams in Yap. These are taro and the more recently introduced *Ipomoea aquatica*, commonly referred to as either water spinach or kangkong. I was interested in the production of these plants in order to determine whether the culture systems for these crops could be modified to include the culture of either fish or shrimp.

According to Falanruw (1986) there are two main types of taro produced in Micronesia. These are the *Colocasia esculenta*, also known as true taro, and *Cyrtosperma chamissonis*, which is the more commonly cultivated taro within Yap proper. Taro patches are managed usually either by an individual or by a family. This management involves the regulation of water flow through the patch. Although most of the taro patches of Yap are too shallow to be used for growing fish, ponds could be constructed in adjacent areas. The ancient Hawaiians grew fish in taro patches by planting the taro on mounds surrounded by channels for the fish (Summers, 1964), and a similar small-scale system might be implemented in Yap. The fish most commonly raised in traditional Hawaiian fishponds were mullet and milkfish, but *Kuhlia*, eleotrids, and gobies were also raised in the freshwater ponds (Kikuchi, 1976). One of the ponds on Yap from which milkfish are sometimes harvested was formerly used to cultivate taro but was abandoned for this purpose as a result of saltwater intrusion (Nelson, 1987).

Actually, the cultivation of water spinach *Ipomoea aquatica* could be considered a form of freshwater aquaculture which has already been implemented in Yap. This floating aquatic plant roots in the soil and is cultivated as a leafy vegetable in Hong

Kong, Indonesia, and Thailand, sometimes in conjunction with the culture of fish (Edwards, 1980). In Yap it is not produced commercially, but it is commonly grown near houses for family use. It is often fried with mackerel or briefly boiled and prepared with soy sauce and lime juice.

Pigs and chickens

Tethered pigs and freely roaming chickens are common in the villages of Yap. Recent estimates are that there are 1,888 pigs and over 26,000 chickens in Yap proper (Marine Resources Management Division and Department of Agriculture and Forestry, 1986). I mention these since they represent a source of organic fertilizer which could be used in aquaculture. Various forms of integrated agriculture and aquaculture such as rice cum fish culture or duck cum fish culture are practiced in other areas, particualry in China and Southeast Asia. However, the use of animal wastes for producing fish is in many places not culturally acceptable. In Yap, the production of fish in ponds receiving animal wastes would probably not be accepted.

FISH AND SHELLFISH CONSUMPTION

Fish consumption

A recent survey (Marine Resources Management Division and Department of Agriculture and Forestry, 1986) showed that fish and shellfish constitute a major portion of the Yapese diet. It was estimated that an average of 1.07 pounds of fish is consumed per individual per day. Also, 76% of the 6,559 pounds of combined meat, poultry, and fish consumed daily within Yap proper is comprised of fresh fish with an additional 9% being attributed to canned fish. Shellfish are a significant component of the diet in many Yapese households; there is an average daily consumption of 0.24 pounds of crab per person. Only a small portion of the fish and shellfish consumed is purchased. The fishery on Yap is, in most part, of a subsistence nature, and only 9% of the locally caught fresh fish enters the cash economy.

Although the average availability of fish and shellfish is high in Yap proper, not all villages have equal access to fish or to fishing areas. Reports from volunteers of the United States Peace Corps who live with families in Yap indicate that some households eat fresh fish every day while others rarely do.

Local markets for seafood

It has been estimated that 160,000 pounds of locally caught fish are sold each year in local outlets including restaurants, institutions, and retail markets (MRMD, 1986). Retail prices for fresh fish in Colonia range from US$ 0.80 to 0.95 per pound while the prices to fishermen range from US$ 0.60 to 0.80. The fish entering the market are all from marine habitats.

Freshwater fishes and shrimp are not marketed in Yap and are rarely fished except by those who do not have access to lagoonal fishing areas. In general, freshwater fishes are not highly regarded. Freshwater prawns are occasionally caught with scoop nets at night or during dry periods when they are concentrated and exposed by the drying of the streams, but they are more often eaten by children than by adults.

POTENTIALLY CULTURABLE FISH AND SHELLFISH

Fish

None of the indigenous freshwater fishes of Yap have much potential for local cultivation. The eel Anguilla marmorata is eaten in some parts of Micronesia, particularly in Guam and in Kosrae. However, attempts to culture A. marmorata in Taiwan have not been successful (Chen, 1976). Also, eels are considered undesirable by the Yapese, and even though we offered large specimens which were collected in the course of our survey to numerous people, they were not accepted. This dislike of eels, together with the fact that in Southeast Asia where other species of freshwater eels are cultured, each pound of eel raised requires from 8 to 10 pounds of trash fish as food (Ling, 1977), rules out the subsistence culture of eels on Yap. The eleotrids found in the Yap streams are generally too small to be of value locally although similar fish known as "biya" are sometimes sold in Filipino fish markets on Guam for US $3.60 per pound. There has been some preliminary work on the culture of Scatophagus argus, a brackish-water fish which is found in the streams of Yap and which is considered a delicacy in the Philippines, but results to date have not proven promising (Fast, 1988). Work with Kuhlia rupestris in Fiji (Lewis and Hogan, 1987) indicates that it spawns only in seawater and thus would not be a good candidate for freshwater aquaculture in Yap.

Another possibility for the development of freshwater aquaculture in Yap is the production of either milkfish or mullet, marine fishes which can be acclimated to and cultured in freshwater. These fish often enter natural freshwater and low-salinity ponds on Yap. Some strategies for developing the small-scale culture of milkfish and mullet were presented in a recent study of the existing fish ponds of Yap proper (Nelson, 1987).

For culturing milkfish, fry would have to be obtained from the wild, and studies would be needed to determine both areas and seasons of fry abundance. The occurrence of milkfish fry varies with locality, but fry are generally more abundant at times near either full or new moons (Kumagai, 1984). Milkfish fry are usually available all year round near the equator (Villaluz, 1986). Fry can be collected by means of fine-meshed nets as described by Villaluz (1986). If juvenile mullet are as common on Yap as they are on Guam, they can be collected with a fine (0.25-inch mesh) cast net and stocked in small ponds.

Milkfish produced on Yap could conceivably be marketed either to Guam or Nauru, since both of these islands currently import milkfish. Milkfish are cultured commercially on Guam and locally produced milkfish are sold at wholesale prices of approximately US$ 2.00 per pound and for retail prices of US$ 2.50 to $ 3.00 per pound. On Guam, the price of locally produced milkfish is usually somewhat lower than the price of milkfish imported from the Philippines which is often near $3.60 per pound for whole chilled fish. The charge for air freight between Yap and Guam is $0.75 per kg.

<u>Invertebrates</u>

Of the freshwater crustaceans of Yap, only the prawn <u>Macrobrachium</u> <u>lar</u> (Fig. 1) deserves mention as a possible candidate for aquaculture. This is a common, relatively large prawn which is fished occasionally on Yap. A larger, species <u>Macrobrachium</u> <u>rosenbergii</u>, for which the techniques for mass production of post-larvae are well developed, is commercially cultured in many tropical areas, including Guam, but this species is not present on Yap. Although the adults of <u>M</u>. <u>lar</u> can be found even in the upper reaches of the streams of Yap, their larvae are restricted to brackish or marine waters; their life cycle can not be completed in freshwater. As attempts at the mass rearing of <u>M</u>. <u>lar</u> larvae have not proven successful to date (Atkinson, 1975), the juveniles for stocking would have to be collected from the wild. This would be feasible if the prawn were to be cultured on a small-scale, and this has been undertaken in Mauritius and Tahiti (Maciolek, 1972). However, our studies showed that even though <u>M</u>. <u>lar</u> are common in the streams of Yap they are rarely fished; this being the case, it may be that most villagers would not devote much time to culturing prawns.

There are several species of nerites in the freshwater habitats of Yap. I learned from discussions with various people that similarly appearing nerites collected from the ocean are often collected and eaten. The freshwater nerites, however, are not harvested.

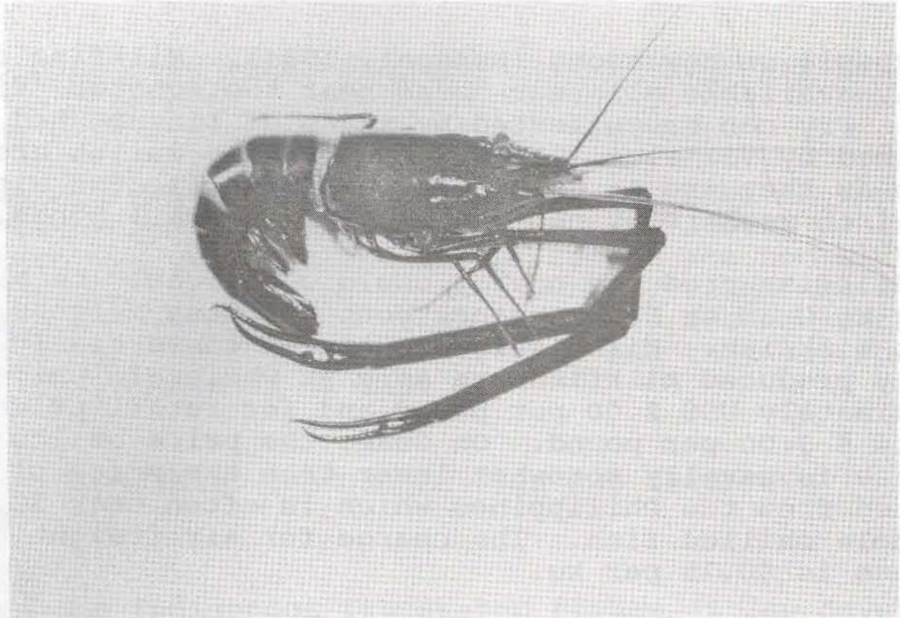

Figure 1. The freshwater prawn Macrobrachium lar.

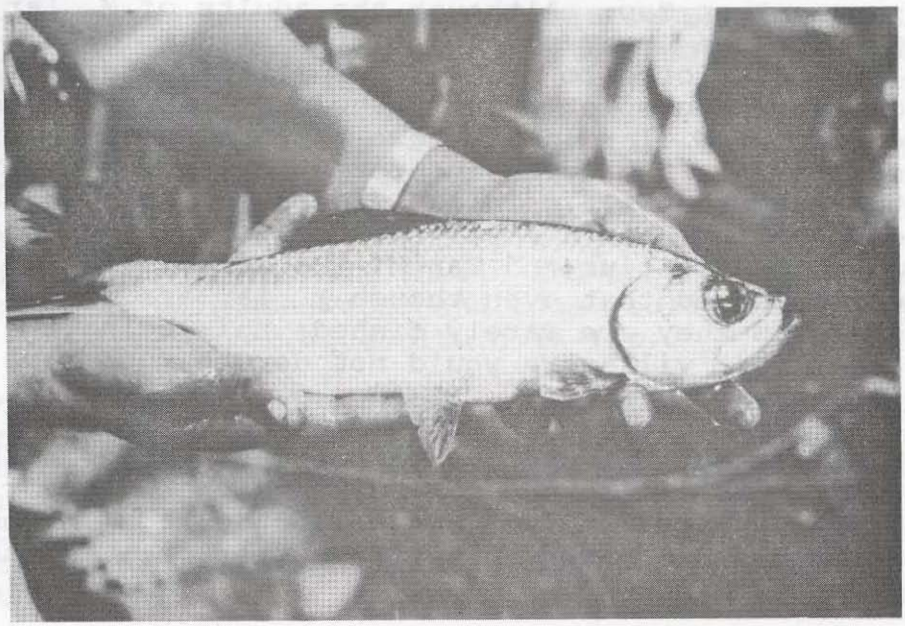

Figure 2. Tarpon enter ponds as larvae or juveniles and feed on milkfish if the pond intake is not screened.

CONCLUSIONS AND RECOMMENDATIONS

The development of freshwater aquaculture on Yap is constrained by several factors including the limited water resources, the general attitude of the Yapese toward freshwater fish, and the limited selection of indigenous species for aquaculture development. However, given that some groups in Yap have limited access to lagoonal fishing grounds, there may be some interest in exploring means of culturing fish or prawns in freshwater on a subsistence basis. The recommendations below are made with this type of development in mind.

1. If the subsistence culture of either milkfish or mullet is to be explored, studies are needed to determine areas and seasons of fry or juvenile availability. This information is necessary in order for culturists to be able to obtain seed for stocking ponds. To prevent the larvae of predatory fishes from entering the ponds, the milkfish fry should be collected with nets and then transferred to the culture site. If milkfish fry were to be allowed simply to enter from the environment, predators such as tarpon (Fig. 2) would undoubtedly enter the ponds as well.

2. Similarly, if the culture of M. lar is to be explored, studies of the seasonal availability of juveniles are needed. The juveniles could be collected from the river mouths and transported to ponds for culture. Care must be taken to prevent predatory fishes, particularly eleotrids and gobies, from entering the culture ponds.

3. The recent establishment of tilapia in the freshwater habitats of Yap illustrates the danger of bringing in exotic species no matter how well intentioned the introduction. Given that freshwater fish are not highly desired on Yap, further introductions should be strongly discouraged.

4. The small-scale culture of water spinach has been widely adopted in Yap. Studies of methods to increase the yield of this vegetable, perhaps in conjuction with fish culture, would be valuable. Also, the potential for developing markets for the fresh vegetable in Guam should be explored.

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LITERATURE CITED

Atkinson, J.M. 1977. Larval development of a freshwater prawn Macrobrachium lar (Decapoda, Palaemonidae), reared in the laboratory. Crustaceana 33:119-132.

Chen, T.P. 1976. Aquaculture practices in Taiwan. Fishing News Books, Ltd., Surrey, England.

Edwards, P. 1980. Food potential of aquatic macrophytes. ICLARM Studies and Reviews 5. International Center for Living Aquatic Resources Management, Manila, Philippines. 51 p.

Falanruw, M.V.C. 1986. Traditional agriculture/resource management systems in the high islands of Micronesia. Office of Technology Assessment. 99 p.

Fast, A.W. (ed.). 1988. Spawning induction and pond culture of the spotted scat (Scatophagus argus Linnaeus) in the Philippines. Hawaii Institute of Marine Biology No. 39. Mariculture Research and Training Center, Hawaii Institute of Marine Biology, Univ. Hawaii, Honolulu. 145 p.

Handog, L.G., E. Caelang, and W.A. Espejo. 1980. Fishpond technical feasibility studies in Yap State. Bureau of Fisheries and Aquatic Resources, Ministry of Natural Resources, Philippines. 56 p.

Kikuchi, W.K. 1976. Prehistoric Hawaiian fishponds. Indigenous aquaculture influenced the development of social stratification in Hawaii. Science 193:295-298.

Kumagai, S. 1984. The ecological aspects of milkfish fry occurrence, particularly in the Philippines. p. 53-68 In: J.V. Juario, R.P. Ferrais, and L.V. Benitz (eds.), Advances in milkfish biology and culture. Inland Publishing House, Manila.

Lewis, A.D. and A.E. Hogan. 1987. The enigmatic jungle perch - recent research provides some answers. SPC Fisheries Newsletter 40, 31 p.

Ling, S.W. 1977. Aquaculture in Southeast Asia. A historical review. Univ. Washington Press, Seattle.

Maciolek, J.A. 1972. Macrobrachium lar as a culture prawn in the tropical insular Pacific. Proceedings of the Fifty-Second Annual Conference of the Western Association of State Game and Fish Commissioners, Portland, Oregon:550-558.

Marine Resources Management Division. 1986. Local fish flow through the cash economy of Yap proper: A preliminary examination. Marine Resources Management Division, Yap State Department of Resources and Development. 17 p.

Marine Resources Management Division and Division of Agriculture and Forestry. 1986. Agriculture and marine resource survey of village households in Yap proper: 1986. Yap State Department of Resources and Development. 144 p.

Nelson, S. G. 1987. A survey of existing fish ponds on Yap proper with recommendations for the development of subsistence fish culture. Marine Resources Management Division, Yap State Department of Resources and Development. 14 p.

Villaluz, A.C. 1986. Fry and fingerling collection and handling. p. 153-180 In: C.S. Lee, M.S. Gordon, and W.O. Watanabe (eds.) Aquaculture of milkfish (Chanos chanos): state of the art. Oceanic Institute, Waimanalo, Hawaii.

A Preliminary Report on the Freshwater Gastropods of Yap, Caroline Islands

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ABSTRACT

Freshwater habitats of Yap Proper were surveyed to characterize the aquatic gastropod communities. Fourteen species of freshwater and brackish water gastropods were distributed among lentic and lotic waters of streams, ponds, taro gardens, mangrove swamps, and drainage ditches. The families Neritidae and Thiaridae were the predominant taxa of the freshwater gastropod assemblage. Neritina variegata, Melanoides plicaria, and Melanoides tuberculata, the most abundant and widespread species, occupied substrates ranging from rock to mud and leaf litter.

INTRODUCTION

Gastropods inhabiting freshwater streams of the insular Pacific have received little attention until recently. Faunistic surveys of freshwater gastropods have been performed primarily in islands of the South Pacific including New Caledonia (Franc, 1956; Solem, 1961; Starmuhlner, 1976; 1979), Fiji (Haynes, 1984; 1985; 1988), Solomon Islands (Starmuhlner, 1976), Vanuatu (Solem, 1959a; 1959b; Starmuhlner, 1976), and Tahiti (Starmuhlner, 1976). In Micronesia, surveys of freshwater gastropods have been made in Palau (Bright, 1979) and Pohnpei (Maciolek and Ford, 1987), and a preliminary list of freshwater snails of Guam was presented by Raulerson (1979). The nonmarine aquatic snail fauna of Yap, however, apparently has not been documented.

The purposes of this study were to conduct a survey of the major freshwater habitats of Yap, Caroline Islands, to identify the aquatic snails inhabiting those areas, and to provide a synoptic collection of the material to the Yap government.

METHODS

Freshwater ecosystems surveyed during this study included flowing streams, ponds, and static water impounded in taro (Cyrtosperma spp.) gardens of the Yap Central Islands. Samples collected from streams were segregated by stream habitats. The stream habitats were defined as cascades, riffles, runs, and pools, based on relative flow rate of the water (see Sanger and Hopper, this volume).

Snails were collected either by hand or by hand dredge. The upper and lower surfaces of stones and boulders were examined for conspicuous species. Stream beds and banks were searched, as was aquatic vegetation, where present. Leaf litter and gravel were dredged from deposits in pools, ponds, and taro gardens for examination in enamel trays. Samples were preserved in 70% ethanol for further investigation.

RESULTS

Fourteen species of aquatic gastropods (Table 1) were distributed among 25 freshwater and brackish water stations sampled on three of the four islands of Yap Proper (Fig. 1). All the habitats investigated were inhabited by at least one species of aquatic snail. Members of the prosobranch families Neritidae and Thiaridae were the predominant species of snails both in abundance and in species diversity.

Stream Habitats

Freshwater neritids were the most diverse component of the gastropod communities inhabiting stream habitats, comprising 69% of all species present. Although several neritids inhabited all four stream habitats designated in this study, *Neritina variegata* (Lesson) was the most widespread species, occurring in all streams sampled except Thool, where no snails were found. *Neritina variegata* was also the most generalized species in terms of the variety of substrates inhabited in streams. This species was found on boulder and shingle substrates associated with stream pools and runs. In riffles and in cascades, *Neritina variegata* occupied substrates ranging from rock through shingle and vegetation. The snails were most frequently observed at the waterline, but specimens were also recorded from the bottom of pools and the main currents of cascades. Some individuals were noted on muddy stream embankments and on vegetation at elevations as high as 1 meter above the waterline. This species was also observed near Qamun in an isolated spring with no obvious stream flow exiting it.

Like *Neritina variegata*, *Neritina squamipicta* Recluz and *Neritina pulligera* Linnaeus inhabited a variety of substrates in the four stream habitats. However, these two species were most frequently found in the main stream flow on rock and shingle substrates. They were never observed more than 1-2 cm above the waterline. *Neritina pulligera* occurred in 14 of the 18 stream sampling stations, and *Neritina squamipicta* was found in only four.

Although they were observed in all four stream habitats, *Neritina petiti* Recluz and *Neritodryas subsulcata* (Sowerby) occupied fewer substrate types than the preceding species.

Neritina petiti was found at the waterline on rock and boulder substrates. Neritodryas subsulcata inhabited similar substrates, but this species was commonly found above the waterline, occurring at elevations as high as 0.5 meters. Neritodryas subsulcata was found at 10 of the 18 stream sampling stations, and Neritina petiti occurred at three.

Table 1. Distribution of nonmarine aquatic snails of Yap by habitat and substrate type.

Habitat:	Pool	Run	Riffle	Cascade	Pond	Taro Patch	Mangal	Drainage Ditch
Species:								
Prosobranchia								
Neritidae								
Clithon corona			3					
Neritina auriculata		2,7						
Neritina petiti	1	2	1	1				
Neritina pulligera	3	1,3	1,2,3	1,7	5,7			
Neritina squamipicta	3,4	3,4	1,2,3,7	1,7				
Neritina turrita		2,3	3				4	
Neritina variegata	2,3	2,3	1,2,3,4,6,7	1		4,5		
Neritodryas subsulcata	1,2	2	1,2	1				
Septaria porcellana	3	3	1,3,7					
Thiaridae								
Melanoides plicaria	3,5	1,3,4	3,5,6,7	1	4,5	4,5		
Melanoides tuberculata	5	1,3,4	3,5,6,7	1	4,5	4,5		
Melanoides sp.	3		3	1	4,5	4		
Potamididae								
Terebralia sulcata		3,4					4	
Pulmonata								
Lymnaeidae								
Lymnaea sp.								6

Substrate types:
- 1 = rock
- 2 = boulders
- 3 = stones and gravel
- 4 = mud
- 5 = leaf litter
- 6 = vegetation
- 7 = concrete culvert

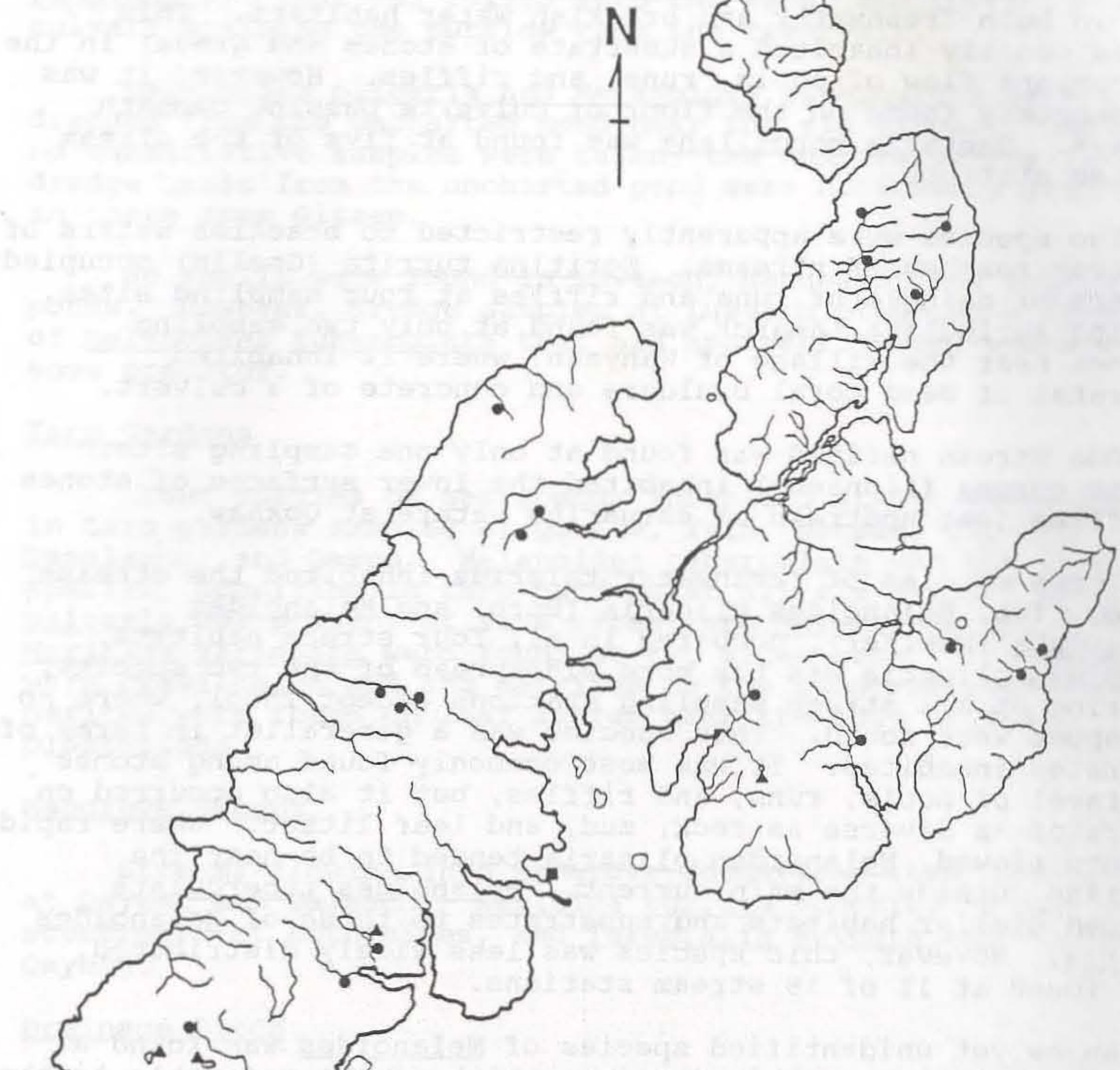

Figure 1. Sites sampled on Yap proper.

The limpet-like nerite Septaria porcellana (Linnaeus) was found in both freshwater and brackish water habitats. This species usually inhabited a substrate of stones and gravel in the main current flow of pools, runs, and riffles. However, it was also commonly found on the floor of culverts passing beneath roadways. Septaria porcellana was found at five of the stream sampling stations.

Two species were apparently restricted to brackish waters of the lower reaches of streams. Neritina turrita (Gmelin) occupied boulders or shingle of runs and riffles at four sampling sites. Neritina auriculata Lamarck was found at only two sampling stations near the village of Wanyaan, where it inhabited substrates of dead coral boulders and concrete of a culvert.

One stream neritid was found at only one sampling site. Clithon corona (Linnaeus) inhabited the lower surfaces of stones in riffles just upstream of estuarine waters at Qokaaw.

Three species of freshwater thiarids inhabited the streams of Yap. Two, Melanoides plicaria (Born) and Melanoides tuberculata (Mueller), occurred in all four stream habitats. Melanoides plicaria was the more widespread of the two species, occurring at all stream sampling stations except Thool, where no gastropods were found. This species was a generalist in terms of substrates inhabited. It was most commonly found among stones and gravel of pools, runs, and riffles, but it also occurred on substrates as diverse as rock, mud, and leaf litter. Where rapid currents flowed, Melanoides plicaria tended to be near the waterline outside the main current. Melanoides tuberculata occupied similar habitats and substrates to those of Melanoides plicaria. However, this species was less widely distributed, being found at 11 of 18 stream stations.

An as yet unidentified species of Melanoides was found at two stream stations. This species, which may be referable to the Stenomelania sp. found in Palau by Bright (1979), inhabited pools, riffles, and cascades, but it was apparently restricted to substrates of rock and shingle.

The potamidid snail Terebralia sulcata (Born) was found in estuarine waters of the lower reaches of two streams. These euryhaline gastropods inhabited muddy substrates covering stones and gravel.

Ponds

Freshwater snails were found in only two of the five ponds sampled. Gitaem reservoir supported the greatest number of species. Melanoides plicaria, Melanoides tuberculata, and Melanoides sp. were dredged with quantities of detritus and mud from the floor of the pond. Neritina pulligera was found around the perimeter of the reservoir, inhabiting stems and leaves of Pandanus sp. that had fallen into the water and the walls of the culvert draining the outflow from the reservoir.

Melanoides plicaria and Melanoides tuberculata were also dredged from the uncharted pond near the old airport. Although no quantitative samples were taken, the numbers of snails in the dredge hauls from the uncharted pond were noticeably greater than in those from Gitaem.

No snails were found in Luweech, Machbaab, and Toqayong ponds. However, dredge samples at Luweech produced a dead shell of Melanoides tuberculata that had apparently been crushed by some predator.

Taro Gardens

Four species of gastropods inhabited static water impounded in taro gardens sampled at Qokaaw, Yyin, Wanead, Qayeng, Tamalaang, and Qamun. Melanoides tuberculata was the predominant species, occurring in taro gardens at all six sites. Melanoides plicaria was present at five sites, and Melanoides sp. and Neritina variegata were found at two sites each. The thiarids were crawling on mud and detritus on the substrate, and the nerites were found on leaf litter near the edge of the plantations.

Mangrove Swamps

Streams flowing into mangrove formations were investigated at Qayeng and Dalaach. Neritina turrita occurred on mud substrates at both sites, and Terebralia sulcata was found at Qayeng.

Drainage Ditch

Static water in a drainage ditch outside a government building in Colonia was inhabited by an unidentified species of Lymnaea. These snails were found associated with mats of blue-green algae and detritus.

DISCUSSION

The gastropod fauna is a diverse and conspicuous component of the freshwater biota of Yap. Snails were found in all habitat types investigated. The two most important families in terms of abundance and diversity were the Neritidae and the Thiaridae.

The species composition of the freshwater gastropod community is representative of that reported for other islands of Micronesia. Of the 15 species of stream neritids reported from islands north of the equator (Haynes, In Press), 9 species were found in the present study of Yap streams, as compared to 5 in Palau (Bright, 1979), 11 in Pohnpei (Maciolek and Ford, 1987), and 10 in Guam (Smith, unpubl. data). Similarly, 3 species of thiarids were identified from Yap, while 2 were reported from Pohnpei (Maciolek and Ford, 1987), 3 from Palau (Bright, 1979), and 4 from Guam (Smith, unpubl. data).

Perhaps the most surprising aspect of the gastropod assemblage was the absence of Thiara scabra Mueller. Maciolek and Ford (1987) characterized this species as ubiquitous and abundant at Pohnpei, and it is common at Guam (Abbott, 1952) and Rota (Smith, unpubl. data) in the Mariana Islands.

The most abundant and widespread species of freshwater gastropods at Yap were thiarids which were found on a variety of habitat and substrate types. The thiarids Melanoides plicaria and Melanoides tuberculata occurred on almost every substrate encountered in streams, ponds, and taro gardens. Two neritids, Neritina variegata and Neritina pulligera, that are characteristic of flowing water in streams also inhabited static water impounded in taro gardens and a pond.

Field observations indicate that the gastropods play an important part in food webs of freshwater ecosystems of Yap. Besides their roles as browsing herbivores and detritivores, the snails are food resources for other aquatic organisms. In laboratory experiments, the freshwater prawn Macrobrachium lar (Fabricus) consumes thiarids after peeling the apertural lip of their shells (S. G. Nelson, 1980, pers. comm.). Entire shells of thiarids were also found in the feces of eleotrids during this survey of freshwater biota of Yap (S. G. Nelson, 1988, pers. comm.). Hermit crabs were observed using shells of the freshwater snails as habitat as far inland as 200 meters inland from the stream mouth. Finally, I noted evidence of snails used as bait by fishermen at the Gitaem reservoir.

Knowledge of the freshwater gastropod fauna is also of considerable interest because of their potential medical importance in the transmission of human parasitic diseases. Some species of freshwater snails serve as the intermediate host for trematodes infecting humans. Fortunately, no species implicated in parasitic infections of humans were found during the present study. However, precautions should be taken by government agencies of Yap to avert introductions of freshwater gastropods such as those that have occurred recently in Palau (D. Idip, 1987, pers. comm.) and Guam (Burch, 1984; Smith, unpubl. data).

LITERATURE CITED

Abbott, R. T. 1952. A study of an intermediate snail host (Thiara granifera) of the Oriental lung fluke (Paragonimus). Proc. U. S. Nat. Mus. 102:71-116.

Bright, G. 1979. The inland waters of Palau, Caroline Islands. Office of the Chief Conservationist, Trust Territory of the Pacific Islands, Palau. 61 p.

Burch, J. B. 1984. Freshwater snails of the Philippines. Walkerana 2(7):81-112.

Franc, A. 1956. Mollusques terrestres et fluviatiles de l'Archipel Neo-Caledonien. Mem. Mus. Nat. Hist. Nat., Ser. A, Zool. 13:1-200.

Haynes, A. 1984. Guide to the brackish and fresh water gastropods of Fiji. Inst. Nat. Resources, Univ. S. Pacific. 37 p.

Haynes, A. 1985. The ecology and local distribution of non-marine aquatic gastropods in Viti Levu, Fiji. Veliger 28:204-210.

Haynes, A. 1988. The gastropods in the streams and rivers of five Fiji islands (Vanua Levu, Ovalau, Gau, Kadavu, and Taveuni). Veliger 30:377-383.

Haynes, A. In Press. Notes on the stream neritids (Gastropoda; Prosobranchia) of Oceania. Micronesica 21.

Maciolek, J. A., and J. I. Ford. 1987. Macrofauna and environment of the Nanpil-Kiepw River, Ponape, Eastern Caroline Islands. Bull. Mar. Sci. 41:623-632.

Raulerson, L. 1979. Terrestrial and freshwater organisms within, and limnology and hydrology of, the Guam Seashore Study Area and the War in the Pacific National Park. Univ. Guam., Dept. Biol. 93 p.

Solem, A. 1959a. Systematics of the land and fresh-water Mollusca of the New Hebrides. Fieldiana: Zool. 43:1-238, 34 pls.

Solem, A. 1959b. Zoogeography of the land and fresh-water Mollusca of the New Hebrides. Fieldiana: Zool. 43:239-343.

Solem, A. 1961. New Caledonian land and fresh-water snails, an annotated check list. Fieldiana: Zool. 41:413-501.

Starmuhlner, F. 1976. Bietrage zur kenntis der susswasser-gastropoden pazifischer inseln. Ann. Naturhist. Mus. Wien 80:473-656.

Starmuhlner, F. 1979. Distribution of freshwater molluscs in mountain streams of tropical Indo-Pacific islands (Madagascar, Ceylon (Sri Lanka), and New Caledonia). Malacologia 18:245-255.