Surveys of the Macrofauna of the Nanpil Kiepw and Lehn Mesi Rivers of Pohnpei

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INTRODUCTION

The recent population growth and rapid pace of development in Pohnpei have placed increasing demands on local water resources, resulting in a need for information concerning the freshwater aquatic fauna. Data on habitat requirements, abundances, and distributions of these stream organisms in Pohnpei's rivers are necessary to develop effective water management strategies.

This ecological survey of the freshwater systems of Pohnpei was undertaken at the request of the Pohnpei government through the local office of The Nature Conservancy. The overall goal was to provide information useful in developing bioassessment protocols for monitoring these ecosystems and for designing studies to detect the effects of environmental interventions.

In this study, we conducted visual surveys of the stream fishes and non-insect macroinvertebrates in two of the major rivers on Pohnpei. The first river system that we investigated is the Lehn Mesi (Figure 1), which drains a large watershed on the southwest side of Mt. Nanalaut in Kitti municipality. The Lehn Mesi River channel originates at nearly 650 m elevation and is approximately 11 km long. This river system was previously sampled up to 200 m elevation in 1982 (Parenti and Maciolek, 1993), but no distributional patterns, population density estimates, or data on the microhabitats of the fishes have been published.

The second river system that we studied is the Nanpil Kiepw (Figure 2), which drains a smaller watershed on the opposite side of Mt. Nanalaut. The Nanpil Kiepw River originates at nearly 800 m elevation in Sokehs municipality and extends into Nett municipality, approximately 2 km from the headwaters. The Nanpil Kiepw River has a channel length of approximately 10 km.

The specific objectives of this survey were: 1) to conduct a survey of stream fishes and aquatic, non-insect macroinvertebrates that would determine their within-stream patterns of distribution in the Lehn Mesi and Nanpil Kiepw Rivers, especially in relation to major waterfalls or other physical barriers to upstream migration; 2) to provide quantitative estimates of the densities of the stream fishes and freshwater prawns; 3) to determine the habitats used by each fish and prawn species; and 4) to provide recommendations for establishing programs for the conservation and protection of the stream organisms.

METHODS AND MATERIALS

The stream surveys were carried out by three-person teams during two periods in early 1996. We chose to use visual survey methods that have been employed in the study of other Pacific island streams, because these surveys are rapid and are not destructive. The biologists conducting the surveys (JEP, RBT, FAC, and TL) were all experienced with the techniques and had worked together on numerous occasions on previous projects of this nature in other areas.

Description of Sites

The locations of the Lehn Mesi and Nanpil Kiepw Rivers on the island of Pohnpei are shown in Figures 1 and 2. The reaches of river that were studied are also indicated. Sites below the hydroelectric dam and weir on the Nanpil Kiepw and below the first waterfall of the Lehn Mesi were accessible by road. All other study sites were reached by hiking on foot along mountain trails or upstream through the rivers.

The upper Nanpil Kiepw was surveyed from January 4 to 13, 1996. The lower reach of the Nanpil Kiepw, as well as the upper and lower reaches of the Lehn Mesi, were sampled from March 31 to April 7, 1996. Visibility underwater was good; the water was clear on the days on which the surveys were conducted.

The lower reach of the Nanpil Kiepw was characterized by numerous boulders and a poor overstory canopy, the latter largely because of the width of the river at this site. The riparian vegetation was dominated by *Hibiscus tiliaceus,* a tree known locally as *kalau* (Glassman, 1952), and various grasses occupying a narrow margin (approx. 5–10 m) between the river and the access road to the hydroelectric dam. While there were no houses within 20 m of either side of the riverbanks along the study reach, the area was frequented by people from Kolonia village as a site to wash clothes. We started sampling 5 m upstream of a deep pool with a rope bridge overhead. We completed our survey in this reach 100 m downstream from the hydroelectric plant. Just below the hydroelectric plant but above our last site, a second river intersected with the Nanpil Kiepw. There was a considerable amount of suspended material in the water column because of intermittent rain showers during the survey. However, 15 sites were surveyed while the visibility underwater was adequate.

We also sampled areas above the first and second waterfalls of the upper Nanpil Kiepw. Sites above Lihduduhniap Falls, but below the weir, had several houses on the riverbanks, so we sampled areas just upstream of the last house. These sites were located downstream of a 3-m high cascade and supported considerable primary productivity, as evidenced by the presence of thick algal mats on the substrate. Patchy stands of *kalau* trees (*Hibiscus tiliaceus*) along the riverbank provided a weak canopy cover. Sites above the weir and second waterfall of the

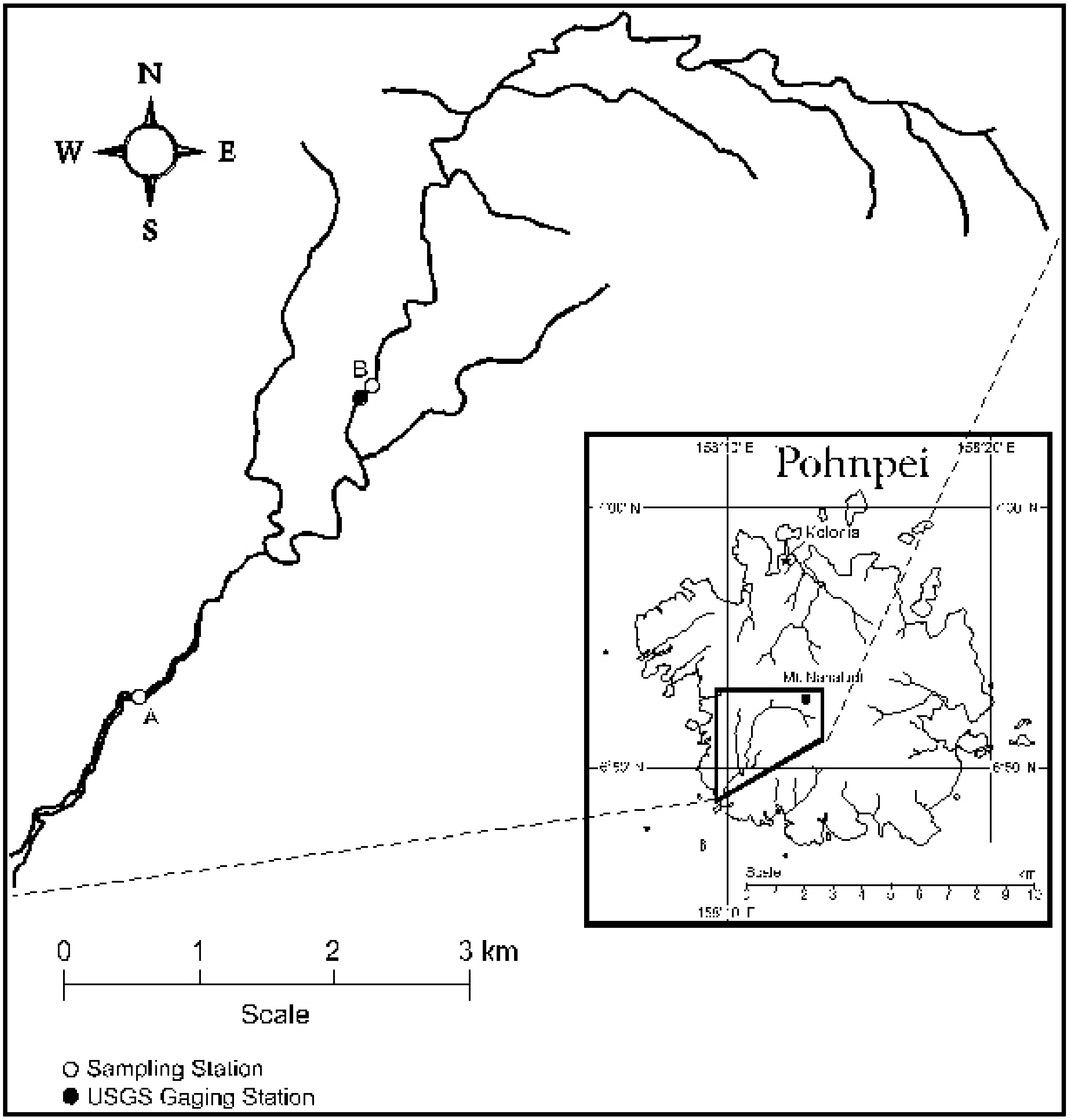

Figure 1. Map of the Lehn Mesi drainage basin showing sites sampled during this survey.

Nanpil Kiepw generally had dense riparian overstory characterized by ivorynut (*Metroxylon amicarum*) and tree-ferns (*Cyathea* sp.). *Kalau* trees (*H. tiliaceus)* were present, but relegated to areas with open canopy. Several strong washout events preceded the survey of the upper reach, but water clarity was adequate throughout the sampling.

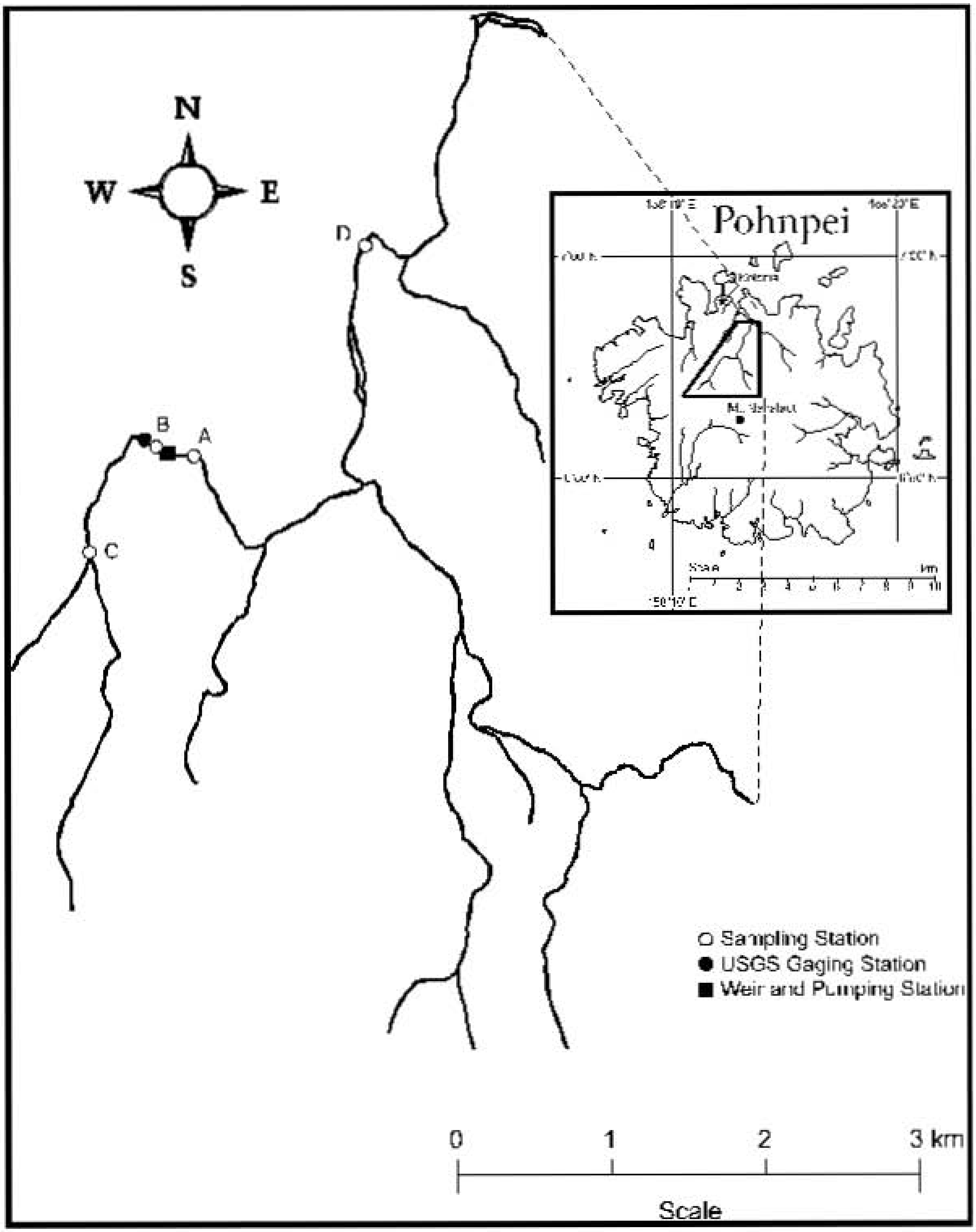

Figure 2. Map of the Nanpil Kiepw drainage basin showing sites sampled during this survey.

The lower reach of the Lehn Mesi had numerous deep pools (>2 m) and long, slow runs. The riparian vegetation was similar to that of the lower Nanpil Kiepw and was composed primarily of *H. tiliaceus* and the reed *Phragmites karka*, as well as several stands of banana *Musa textilis* and mango *Mangifera indica*. The latter two plant species were probably cultivars planted there by people from the nearby village. We sampled just upstream of the Pilen Pwadapwad River, a small tributary draining 20 m upstream of the Lehn Mesi bridge. This tributary has had chronically high fecal coliform and streptococci counts, as it is the main river running through Sapwtakai village at the base of Mt. Nanalaut (Gary Denton, Water and Energy Research Institute, University of Guam, unpublished data).

The coordinates of study sites on the upper reaches of the Lehn Mesi surveyed are shown in Table 1. We started sampling just upstream of U.S.G.S. Gauging Station No. 898690 and proceeded upstream until just beyond the last access trail to Salapwuk village. The study area was situated in a deep valley with steep banks and dense stands of *Cyathea* sp. and *Hibiscus tiliaceus*. Pools and sand substrate were rare in this reach.

Table 1. Coordinates and elevations of the study sites on the Nanpil and Lehn Mesi Rivers.

River	Reach Code	Sampling Date	Location to first major waterfall	Coordinates	
				Latitude	Longitude
Nanpil	A	January 11, 1996	Above	6˚ 55' 06" N	158˚ 12' 03" E
Nanpil	B	January 11, 1996	Above	6˚ 55' 44" N	158˚ 12' 11" E
Nanpil	C	January 12, 1996	Above	6˚ 54' 47" N	158˚ 11' 47" E
Nanpil	D	April 5, 1996	Below	6˚ 55' 50" N	158˚ 12' 48" E
Lehn Mesi	A	April 2, 1996	Below	6˚ 49' 25" N	158˚ 10' 08" E
Lehn Mesi	B	April 3, 1995	Above	6˚ 50' 41" N	158˚ 11' 02" E

Visual Survey

The locations of individual organisms were determined by direct visual observation. Where practical, observations were made in the water with the aid of a mask and snorkel. Observations were suspended during heavy rain showers and resumed when water clarity permitted.

The visual survey method that we used was modified from that described by Baker and Foster (1992). The method involved counting organisms located within quadrats of variable size. The size of the quadrat used was determined by the observer's ability to count organisms accurately from a single observation position (Baker and Foster, 1992). We used a stratified random design to determine the quadrats to be sampled. The quadrats were categorized according to reach (below the first waterfall and above the first waterfall), by habitat type (riffle, run, or pool) and by location in the stream channel (i.e., side or middle).

Each quadrat was approached from downstream. Conspicuous landmarks along the banks or in the stream were used to mark the boundaries. For each species at each quadrat, data were collected on the number of individuals, the focal point substrate code (i.e., substrate directly underneath the organism, see Table 2 for quantification of substrates), their position in the water column, and their use of cover. After recording information on individuals, the quadrat area was determined with a measuring tape.

Table 2. Substrate categories, codes, sizes and field references (adapted from Baker and Foster, 1992).

Category	Substrate Code	Particle Size Range: mm	Particle Size Range: inches	Field Reference
Bedrock	1	N/A	N/A	N/A
Boulder	2	>256.0	>10.0	basketball-sized and larger
Cobble	3	64.0–256.0	2.5–10.0	softball-sized
Gravel	4	5.0–63.9	0.5–2.49	marble-sized
Sand	5	<5.0	<0.5	sand-sized
Organic Matter	6	N/A	N/A	leaf litter, algal mats, etc.

Individuals were considered to be using cover if they remained underneath or against a sheltering object. Position in the water column, or relative depth, was estimated in tenths from 0 = bottom to 1 = surface. The densities of each species (number of individuals per square meter) were calculated for each quadrat. For each quadrat the percentage of each substrate category was estimated. The categories of bedrock, boulder, cobble, gravel, sand, and organic matter were used.

Species Identifications

We used several reference works to identify the organisms that we collected. For the fishes, these included the works of Fehlmann (1960), Bright and June (1981), Allen (1991), and Parenti and Maciolek (1993). For the decapod crustaceans, we used Bouvier (1925), Edmondson (1935), Chace (1983), Chace and Bruce (1993), and Hung et al. (1993). We used the works of Starmühlner (1976, 1993), Haynes (1984), and Haynes and Wawra (1989) to identify the gastropods that we collected.

Statistical Analysis

For species for which we had sufficient sample sizes, we compared densities among reaches and habitats with analysis of variance (ANOVA). One of the major assumptions of ANOVA is that there are equal variances among groups. We tested this assumption with Levene's test (BMDP 7D), and the data were transformed as needed. Although there may be some bias in back-transforming the means, our interest was in detecting differences between groups rather than providing precise estimates of fish density. The use of transformed data allows statistical comparisons of appropriate power with much smaller sample sizes than would be required for raw data (Norris et al., 1992). This point is especially important for small streams where sufficient replication of habitat types can be a problem.

RESULTS

We observed and obtained quantitative estimates of densities for nine species of stream fishes and two species of freshwater prawns in the two rivers. In addition, we obtained data on the distributions and qualitative estimates of abundance of two species of atyid shrimps and several species of gastropods.

Fishes

On tropical Pacific islands, including Pohnpei, gobies are the most abundant fishes in the upper reaches of rivers (Ryan, 1991). The most abundant fish in the streams of Pohnpei is the herbivorous goby *Stiphodon caeruleus*. This species was found in all reaches and habitats of both streams. It is active during the day and is often observed actively feeding by scraping algae from the hard surfaces of bedrock, boulders, and cobble within the stream. Courting males are bright blue in coloration and were often seen in the water column displaying towards females or chasing rival males. A list of the fishes for which we obtained data is shown in Table 3.

For sites above the first major waterfall, we found that there were significant differences shown in the densities of gobies between rivers and habitats, but there was also no significant river-habitat interaction (Table 4). This means that the fish were not just randomly distributed among the habitats, and their habitat use was similar between streams. However, the sites in the Lehn Mesi River generally had higher densities of fish than those in the Nanpil Kiepw River. The estimated densities for each habitat in each river are shown in Table 5.

A knowledge of the distribution of the data is important for planning and for the design of ecological assessment or monitoring programs. For the goby data, the sites with low densities or zeros were more frequently encountered than sites with high densities. The resulting distributions, therefore, are closer to a Poisson distribution than a normal distribution. The log-transformation helped make the data more normally distributed and helped to equalize the variances between groups, both of which are major assumptions of an analysis of variance.

Table 3. The species of stream fishes of the Nanpil Kiepw and Lehn Mesi Rivers of Pohnpei that were included in the density estimates obtained from our visual surveys.

Group	Species	Description	Remarks
Gobies:			
	Glossogobius celebius	large goby	found over sand in lower reaches
	Redigobius bikolanus	small goby	found in lower reaches
	Sicyopterus eudentata	large, herbivorous goby	rare in all reaches
	Sicyopterus lividus	large, herbivorous goby	males brightly colored, common in all reaches
	Sicyopus nigriradiatus	small, herbivorous goby	uncommon
	Stiphodon caeruleus	small, herbivorous goby	abundant throughout the streams
	Stiphodon sp.	small, herbivorous goby	sporadically common in lower reaches, rare in upper reaches
Flagtails:			
	Kuhlia rupestris	a bass-like predator	only found below the first major waterfall
	Kuhlia marginata	a bass-like predator	only found below the first major waterfall

We found some interesting relationships between goby densities and physical characteristics of the sites. Goby density was weakly, but significantly, positively correlated (Pearson $r = 0.1809$, $n = 131$, $p = 0.039$) with the percentage of hard substrate (bedrock, boulders, and cobble)(Figure 3). Most sites in both rivers had over 50% hard substrate, and there was a greater variation in the densities at sites with high percentages of hard substrate, which weakened the correlation. Still, it can be seen that the sites with goby densities above 10 m^{-2} were all at sites where hard substrate comprised 60% or more of the stream bed.

There was a significant negative, though weak, correlation ($n = 109$, Pearson $r = -0.2058$, $p = 0.032$) between the density of *Stiphodon caeruleus* and the percent canopy cover. For sites above the first waterfall, there was a significant negative correlation (Pearson $r = -0.2356$, $n = 99$, $p = 0.0189$) between total goby density and percent canopy cover (Figure 4).

Macroinvertebrates

The non-insect invertebrate macrofauna included two species of palaemonid shrimp, two species of atyid shrimp, and three species of gastropods. A list of the invertebrates observed or collected is shown in Table 6. With the visual survey method we were able to obtain quantitative estimates of the densities only of the large freshwater prawns *Macrobrachium latimanus* and *M. lar*.

Table 4. Analysis of variance comparing the means of the total goby densities between rivers and habitats. We used log-transformed data for the analysis. Levene's tests showed that the variances were not significantly different between rivers, habitats or for the river-habitat interaction.

Source	Sum-of-squares	Degrees of Freedom	Mean sq.	F value	P Value
River	5.7782	1	5.7782	53.9751	7.44E–11
Habitat	1.0033	2	0.5017	4.6862	0.0115
Interaction	0.2487	2	0.1243	1.1613	0.3175
Error	10.0630	94	0.1071		

Table 5. Means of total goby densities at sites above the first major waterfalls of the Lehn Mesi and Nanpil Kiepw Rivers of Pohnpei.

River	Habitat	N	Mean (log density)	Standard Error	Back-Transformed Mean
Lehn Mesi	pool	3	0.8286	0.1229	6.7391
Lehn Mesi	riffle	16	1.2131	0.1065	16.334
Lehn Mesi	run	21	0.9321	0.0855	8.5526
Nanpil Kiepw	pool	11	0.3888	0.0996	2.4479
Nanpil Kiepw	riffle	19	0.4208	0.0742	2.6351
Nanpil Kiepw	run	30	0.2710	0.0372	1.8664

The large prawns were common throughout the upper reaches of both streams, but *Machrobrachium latimanus* was far more abundant than *M. lar*. No prawns were observed in the areas below the first waterfall, presumably because these lower sites contain the flagtails *Kuhlia rupestris* and *K. marginata*, which are very active predators of *Macrobrachium*. As shown in Table 7, and unlike the case for the gobies, there were no differences in the densities of prawns either between rivers or among the habitats (Table 7). Table 8 shows the mean prawn density and the standard error of the mean for each combination of river and habitat. The data included in the analysis of variance are only for the sites above the first waterfall, without flagtails. The overall mean density of *Macrobrachium* in these sites was 1.83 prawns with a standard error of 0.228.

During our survey, we collected only two species of atyid shrimps: *Atyoida pilipes* and *Caridina weberi*. These two, along with *Atyopsis spinipes*, were found to be the most common atyids on Pohnpei (Maciolek and Ford, 1987). Although densities of atyids were not determined in our survey, qualitative estimates (i.e., rare, common, or abundant) were made. Atyids were not seen where *Kuhlia* were present, a pattern also found on Guam. However, in sites without *Kuhlia*, atyids were nearly always abundant and found in all three habitat types (riffles, runs, and pools).

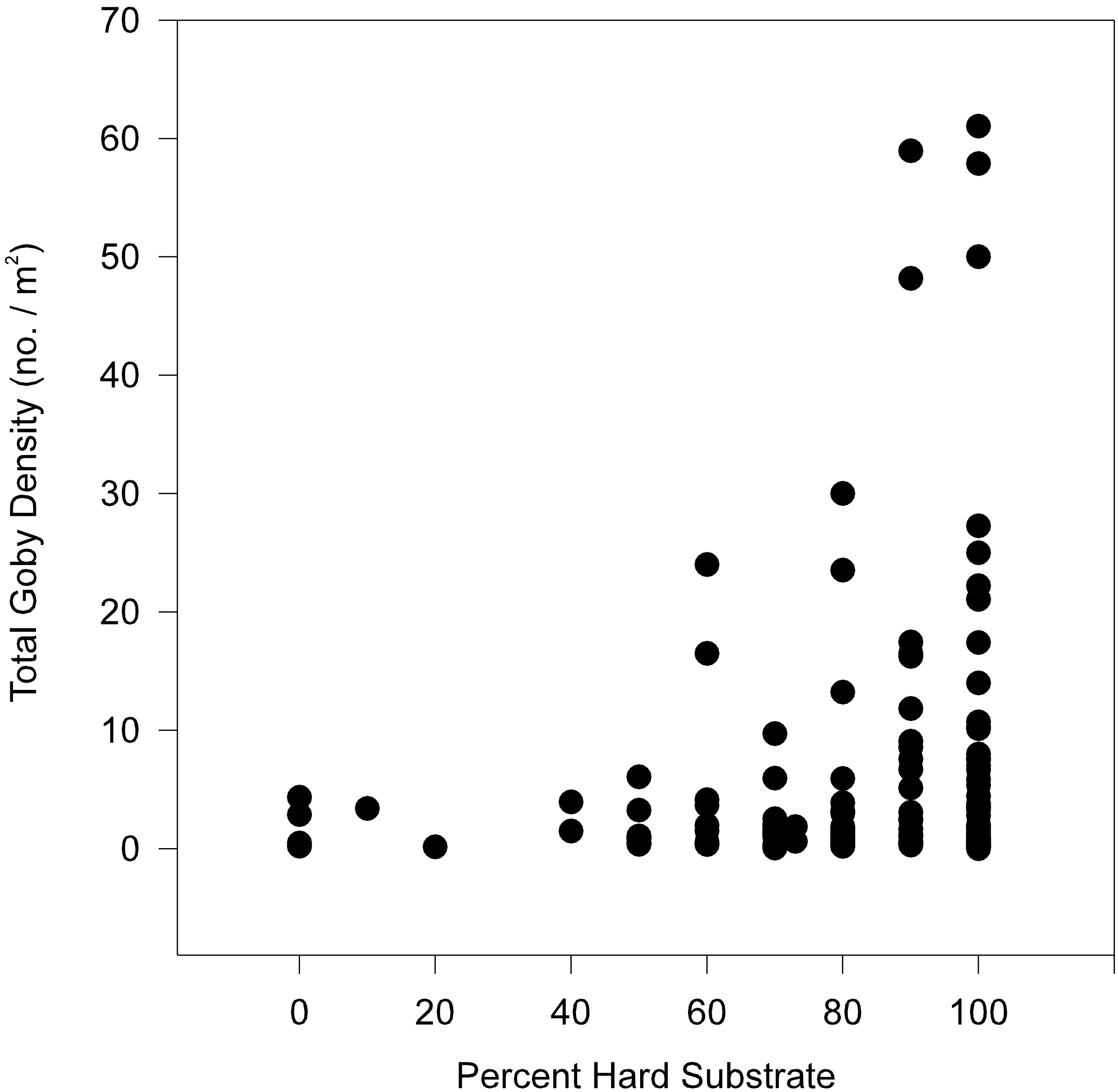

Figure 3. The relationship between total goby density and the percent hard substrate in the stream bed.

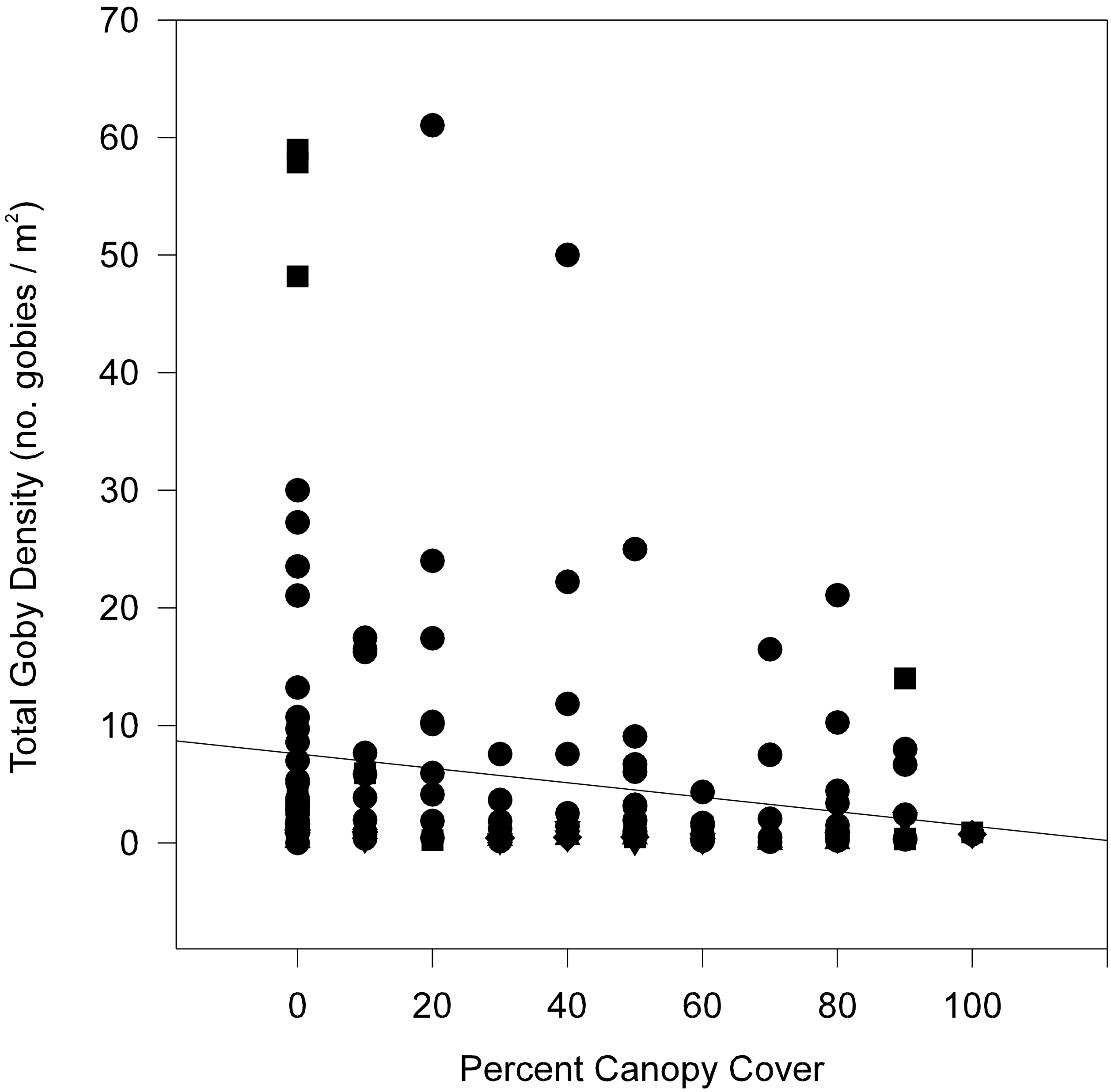

Figure 4. The relationship between total goby density and percent canopy cover.

Three snail species were recorded in the Lehn Mesi and the Nanpil Rivers: the thiarid snail *Melanoides tuberculata*, the nerite *Neritina variegata* and one septariid *Septaria sanguisuga*. Of these, only *Melanoides tuberculata* and *Neritina variegata* were found in the upper and lower reaches of both rivers. The septariid was found in the upper and lower reach of the Lehn Mesi, as well as the lower reach of the Nanpil.

Table 6. Macroinvertebrates of the Lehn Mesi and Nanpil Kiepw Rivers in Pohnpei.

Group	Species	Distribution
Palaemonid shrimp		
	Macrobrachium latimanus	abundant above the first major waterfall
	Macrobrachium lar	common throughout the streams above the first major waterfall
Atyid shrimp		
	Atyoida pilipes	abundant above the first major waterfall in all habitats
	Caridina weberi	abundant above the first major waterfall in all habitats
Gastropods		
	Neritina variegata	abundant throughout both rivers in all habitats
	Septaria sanguisuga	found on hard substrate in upper reach of Lehn Mesi and below the first waterfall in the Nanpil Kiepw
	Melanoides tuberculata	abundant throughout both rivers in all habitats

Table 7. Comparison between rivers and among habitats of the densities of *Macrobrachium* (*M. latimanus* and *M. lar*) at sites in the Nanpil Kiepw and Lehn Mesi Rivers in Pohnpei. In both rivers, the sites compared were all above the first major waterfall.

Source	Sum-of-squares	Degrees of Freedom	Mean sq.	F value	P Value
River	2.8370	1	2.8370	0.5596	0.4563
Habitat	8.1367	2	4.0683	0.8025	0.4513
Interaction	9.95386	2	4.7693	0.9408	0.3940
Error	476.5373	94	5.0695		

Melanoides tuberculata was the most common snail in the two rivers and was found in all habitat types above and below the first major waterfall. *Neritina variegata* typically occurred on exposed hard substrate and often co-occurred in the same habitats as *Melanoides tuberculata*. *Septaria sanguisuga* was the largest gastropod that we found in the rivers, but this species was not very abundant.

Table 8. Mean densities of freshwater prawns (*Macrobrachium latimanus* and *M. lar*) in pool, riffle, and run habitats within the Lehn Mesi River and the Nanpil Kiepw River in Pohnpei.

River	Habitat	N	Mean	Standard Error
Lehn Mesi	pool	3	2.9467	1.2340
Lehn Mesi	riffle	16	1.1413	0.4782
Lehn Mesi	run	21	1.0762	0.4337
Nanpil Kiepw	pool	11	2.1682	0.4313
Nanpil Kiepw	riffle	19	1.8805	0.5096
Nanpil Kiepw	run	30	2.4420	0.5077

DISCUSSION

The ecological groups of stream organisms found on Pohnpei were similar to those that we have found in other Micronesian streams. However, the predominant species differ strikingly between islands. In Pohnpei the most abundant stream goby was *Stiphodon caeruleus*. In the streams of Guam and Palau, *Stiphodon* sp. is, by far, the most abundant stream goby. This species was referred to previously as *Stiphodon elegans*, but it is now thought to be undescribed and may possibly be two species (Ronald Watson, Forschungs-Institut Senckenberg, Frankfurt, personal communication). Although this species of *Stiphodon* is common in some sections of the streams of Pohnpei, it is not nearly as abundant as *S. caeruleus*. Also, after examining specimens from Pohnpei, we suspect now that the specimens thought to be *S. caeruleus* that we collected on Guam and Palau are another undescribed species. There is still considerable taxonomic confusion in this and related genera, and the genus *Stiphodon* is currently being revised by Ronald Watson.

Similarly, the most abundant species of freshwater prawn in the streams of Pohnpei is *Macrobrachium latimanus*, a species that has not been recorded from either Guam or Palau. On the latter islands, the most abundant of the freshwater prawns is the Tahitian prawn *Macrobrachium lar*. The latter is common in the streams of Pohnpei, but not nearly as abundant as *M. latimanus*. Such differences in the fauna between islands, especially with regard to species with long, pelagic, larval stages such as the gobies and the shrimp, raise some interesting ecological questions, particularly in regard to dispersal, recruitment, speciation, and competition.

Within-Stream Zonation

As is typical of the streams of Micronesia, there is a marked zonation of the assemblages of the aquatic organisms within the streams of Pohnpei, with the first major waterfall constituting a major factor determining the zonation. Within-stream patterns of zonation have been described for the Ngermeskang River (Nelson et al., 1995) and the Arakitaoch Stream in Palau (Fehlmann, 1960), the Asmafines River in Guam (Parham, 1995), and for the streams of Pohnpei (Maciolek and Ford 1987). The flagtails, species of the genus *Kuhlia,* are abundant in the lower reaches of Micronesian streams below the first major waterfall, but they are not able to ascend large waterfalls and so are absent upstream. In the Nanpil and Lehn Mesi Rivers of Pohnpei, two species of flagtail are found: *Kuhlia rupestris* and *K. marginata*. These and other species that can not climb the falls are restricted to the lower reaches.

The restricted upstream movement of these predators appears to affect the distribution of some of the other stream organisms. Small gobies and particularly the palaemonid shrimps (*Macrobrachium* spp.) and atyid shrimps are in much greater abundances in the upper areas, where there are no *Kuhlia* present. When *Macrobrachium* are found in areas with *Kuhlia*, they are usually large and sequestered. Young atyid shrimps are found in the lower reaches, but these are usually buried within the substrate. Thus, predation by flagtails is likely to have a major influence on the communities of fishes and invertebrates in the freshwater streams of Micronesia. Because this pattern of zonation in the distributions and abundances of stream fishes and aquatic invertebrates is evident, stratified sampling methods will be required in designing monitoring programs or statistical procedures for detecting ecological changes resulting from environmental interventions.

Habitat and Microhabitat

In this work we have provided the first quantitative data on the densities and microhabitats of fishes and aquatic invertebrates in the streams of Pohnpei. This information is important for developing programs to monitor these, and similar, aquatic ecosystems throughout the region. In our previous work in the streams of Palau and Guam, we found that habitat type (riffle, run, pool) and type of substrate are important determinants of the distribution and abundances of some of the stream fishes (Nelson et al., 1995; Parham, 1995) We found this to be true also for the fishes of the Nanpil Kiepw and Lehn Mesi Rivers in Pohnpei. However, we found that the densities of freshwater prawns in the streams of Pohnpei are independent of habitat.

The significant positive correlation found between goby density and percentage of hard substrate at a site most likely results because most of these fishes are herbivorous and feed by scraping diatoms or algae growing on the hard surfaces in the stream. Many of these species have teeth specialized for this purpose; their teeth wear out and are continually replaced (Mochizuki and Fukui, 1983). The total goby density at a site was determined primarily by the density of the very abundant *Stiphodon caeruleus*, a species that is observed feeding almost constantly. The correlation is weak because the gobies are found in all types of habitats. However, in other studies (Nelson et al., 1995; Parham, 1995) when we examined the substrate at the specific location of an individual fish, rather than that of the site that it is found in, the use of hard substrate by these herbivorous gobies becomes more apparent. For example, in the Ngermeskang River in Palau, Nelson et al. (1995) found that *Stiphodon* sp. (referred to as *S. elegans*) were found primarily on bedrock and boulders. Also, Fehlmann (1960) reported that, in Palau, many of the mountain gobies are found only in areas with cobble, boulder, or bedrock substrates. We found that in the streams of Pohnpei most of the sites have high percentages of hard substrates, and the sites with the highest goby densities have high percentages of hard substrates. However, we found considerable variation in goby density, even at sites with high percentages of hard substrates, and this indicates that other factors are also operating to determine goby densities at a particular site.

Another factor that we examined was the percentage of canopy cover. Because most of the common gobies are herbivorous, we hypothesized that their densities would be higher in sites that were most open, and therefore exposed to more sunlight. Our data support our hypothesis because densities declined as percent canopy cover increased. Although the correlation between percent cover and goby density is significant and negative, it is not a strong correlation. The percentage cover alone is not sufficient to predict goby densities, but it appears to be a contributing determinant.

There is a complex interplay of factors determining the distribution and abundance of the tropical stream fishes. Moyle and Senanayke (1984) were able to construct an “ecological key” to the species of stream fishes in Sri Lanka based on velocity, substrate, relative depth, and diet. Parham (1995) was able to construct an ecological key to the stream fishes of the Asmafines River in Guam. Additional ecological data would be needed to construct detailed keys or predictive models determining the distribution and abundance of the stream organisms of Pohnpei, but such information would be useful in designing monitoring and conservation programs.

Riparian Reserves

The amounts and kinds of riparian vegetation (plants growing along stream banks) can effect stream organisms in a variety of ways. The removal of riparian vegetation, for road construction, agriculture, or other development, may result in an increase in downstream temperatures (Barton et al., 1985; Li et al., 1994) and may also lead to increased exposure of aquatic organisms to ultraviolet radiation. The effects of riparian disturbances on streams have been documented in some temperate areas. For example, in streams of the Oregon desert, cattle grazing resulted in a reduction of riparian vegetation and trout biomass was found to be negatively correlated with solar radiation, although algal biomass increased with increases in solar input (Li et al., 1994). In addition, the riparian vegetation also effects stream hydrology, and severe reduction of this vegetation may result in lowering of the water table. As a result of a lowered water table, a permanently flowing stream could become intermittent. For example, Li et al. (1994) found that a temperate stream in an area of heavy cattle grazing that reduced the riparian vegetation had intermittent flow, while its sister (control) stream, in a nearby area unaffected by grazing and with a well developed riparian flora, had permanent flow.

It is clear that riparian reserves along the banks of streams are needed to prevent these and other effects associated with development (i.e., increased sedimentation, reduction of cover, reduction of organic inputs). The width of riparian reserves needed varies greatly between sites and is dependent on factors such as the size of the stream, the stream biota, and the nature of the sediments (Forest Ecosystem Management Assessment Team, 1993). In Pohnpei, it is the less steep areas of the lower stream reaches where the riparian vegetation is most likely to be disturbed as a result of construction or agriculture. An undisturbed, buffer zone adjacent to the stream banks should be maintained to avoid undesirable, indirect effects resulting from reduced vegetation.

Conservation Areas

The conservation of fishes and other aquatic organisms in Pohnpei would be aided by establishing and protecting some pristine streams or watersheds as conservation areas. The designation of conservation areas will allow the fishes in the protected area to reproduce naturally, thus providing a supply of larvae and juveniles that can re-establish populations in areas that have suffered short-term ecological disturbances. This is possible because all of the stream fishes, and most of the invertebrates, spend portions of their life cycle in marine waters. The stream gobies, for example, spawn in fresh water and when the eggs hatch, the larvae drift out to sea. The juveniles migrate back upstream to freshwater habitats. Because of the amphidromous life histories of the Micronesian stream fauna, recruitment from conservation areas can serve to repopulate streams that may have suffered from ecological disturbances. In order for the conservation areas to be effective, the migratory pathways of the fishes in disturbed streams must remain unimpeded. The temporal staggering of land clearing during construction would be prudent. This would allow disturbed streams to recover prior to allowing disturbances on nearby watersheds.

Monitoring

Visual surveys are practical for determining the microhabitats (Moyle and Blatz, 1985) and densities of stream fishes (Baker and Foster, 1992, Nelson et al., 1995; Parham, 1995) in areas such as Pohnpei where water clarity in the streams is usually good. We have found the protocol for estimating stream fish abundances based on visual surveys that was recently developed and tested in the streams of Hawaii (Baker and Foster, 1992), to be effective in the streams of Palau (Nelson et al., 1995) and Guam (Parham, 1995), as well as in Pohnpei.

Visual surveys have an advantage over other methods that are commonly used for sampling stream fishes, such as electroshocking or poisoning, in that they are non-destructive. Because of this, the same sites can be repeatedly sampled over time, without the effects of previous sampling influencing the results of subsequent efforts. We found that electroshocking was highly effective for some species. For example, *Eleotris fusca,* a sleeper goby common on Guam, is very sensitive to electroshocking. In electrical collecting on Guam, *Eleotris* was killed by relatively low voltages. However, electroshocking is almost totally ineffective for collecting other, particularly smaller, species. Small gobies such as those of the genus *Stiphodon* appeared unaffected by the electroshocker and would swim through the electric field with no apparent harm. Ichthyocides are also used to collect stream fishes, but this technique would not be suitable for frequent monitoring. In his studies of the streams of Palau, Fehlmann (1960) intensively collected fishes by using an ichthyocide; he found that some sites had not recovered almost one year later, when he collected in the same areas again. Another advantage of the visual method is that the survey team does not have to carry the equipment and protective gear needed for electroshocking.

In spite of many advantages, there remain problems in the use of visual survey techniques in monitoring. One of these is that some species are more cryptic than others. A particularly striking case from the streams of Guam is the sleeper goby *Eleotris fusca* mentioned above. These fishes are not commonly observed in the visual surveys, but they are very common in samples collected by electroshocking. Other fish that are nocturnal, remain hidden, blend well with the background, or stay in the shadows may be under-represented in visual surveys. Determining the densities of highly mobile, schooling fishes is also a problem when visual surveys are used. In Micronesian streams, the densities of the flagtails *Kuhlia rupestris* and *K. marginata* were difficult to assess at some sites because the fish were numerous and constantly in motion.

RECOMMENDATIONS

1) Sites being compared to detect the effect of some environmental intervention should be matched with regard to elevation and position relative to major waterfalls or other barriers to upstream migration. There is a marked zonation of fishes in the Nanpil Kiepw and the Lehn Mesi, especially with regard to the position of the sites relative to location of the first major waterfall.

2) The mountain goby *Stiphodon caeruleus* and the freshwater prawn *Macrobrachium latimanus* are abundant in a wide range of habitats throughout the rivers of Pohnpei. These species can be censused easily with visual techniques and would be good indicator species in studies designed to detect various forms of intervention.

3) The ecological data base for the aquatic ecosystems of Pohnpei is meager. Additional work is needed in the areas of reproduction, recruitment, trophic relations, and species interactions.

4) Reserves should be established in relatively pristine watersheds allowing stream populations that had been affected by short-term ecological disturbances to be re-established from off-shore larval recruitment. In addition, the path for upstream migration of recruiting juveniles in affected streams must remain unobstructed.

5) The effects of land clearing near streams should be minimized by establishing riparian reserves as buffers. Studies are needed to determine the minimum effective widths of such reserves for the streams of Pohnpei. In the absence of such studies, we recommend that minimum widths of ten meters be established for riparian reserves on each stream bank, although greater widths would be desirable in many (perhaps most) cases.

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