

**JOB PROGRESS REPORT  
RESEARCH PROJECT SEGMENT**

**STATE:** Territory of Guam

**PROJECT NO.:** F-1R-5

**SUB-PROJECT NO.:** F-2

**STUDY NO.:** 1

**JOB NO.:** 1

**JOB TITLE:** Freshwater Monitoring (2440)

**PERIOD COVERED:** October 1, 1996 to September 30,1997

**SUMMARY**

During FY97, the four previously selected watersheds were sampled for a second year. Faunal counts and basic observations collected in FY96 and FY97 have been summarized. The tributaries above Fena Reservoir and the drainage below were assessed to determine the influence of the dam on migrating fauna. The results of the study were completed in FY97. Comparative analyses of the data collected during FY96-97 have been completed.

Five other streams were visited during FY97 and data collected were added to the database file started in FY96.

**BACKGROUND**

Maintenance of high quality watershed ecosystems, is essential to protecting healthy coastal areas that support fisheries. In order to maintain the quality of Guam's watershed ecosystems, baseline data must first be collected which includes identifying the aquatic species residing in these ecosystems, determining their densities, the physical characteristics of the streams, and the quality of the water. Monitoring these parameters will support watershed management and thus ultimately protect Guam's coastal resources.

Although various watersheds have been monitored for different parameters, in general Guam's freshwater resources are not well studied. The methods of monitoring have seldom been replicated, making comparisons or management as a whole unrealistic. In the past ten years the island has experienced a rapid economic growth and structural development. Some existing and proposed developments, such as golf courses/resorts, occupy large tracts of land with major watersheds. Little baseline data exists by which to assess potential impacts of proposed development on streams, lakes, and coastal areas and therefore impact assessment has been difficult without extensive study and mitigation recommendations. Some development projects

initiated within the last 10 years have significantly degraded watershed quality, which has contributed to large losses of coral reef habitat. Additionally, much of the existing watershed work has been completed by off-island consultants over short intervals using techniques developed for temperate areas and not applicable in their entirety to Guam's tropical freshwater systems.

The work performed during FY97 was devoted to two projects started during FY96, which will be used to develop and implement a long-term watershed monitoring program. Four watersheds were selected at the beginning of FY96 for a short term monitoring program: 1) Fena; 2) Manenggon; 3) Ylig; and 4) Pago. These watersheds were selected because they represent a range of watershed characteristics that may help to determine the impacts of the present and proposed land uses. The short-term objective of this project was to develop a technique to survey aquatic fauna to allow statistical comparisons within and between watersheds to establish a baseline database to monitor watershed health. It has been shown that visual surveys are effective in estimating fish abundance's in small streams (Hankin and Reeves, 1988; Moyle and Baltz, 1985) like the ones found on Guam. The Modified Point Quadrat method (Baker and Foster, 1992) is a survey protocol that has been used in Hawaii (Nishimoto and Kuamoo, 1991), Guam (Parham, 1995), and elsewhere in Micronesia (Parham, 1995; Nelson et al., 1995). The Modified Quadrat technique was field tested in 1995 in the selected watersheds and determined to be feasible for the initial FY96 study. This method was also used to survey the organisms found in each of the streams during FY97.

In addition to the watershed management issue a second aspect of this job was to address the concern over the impact that man-made lakes have on watersheds.

Several islands within Micronesia have plans to develop surface water resources through the construction of reservoirs. However, aspects of the region's inland aquatic ecosystems are poorly known, and reservoirs could present migration barriers and affect the distributions and densities of freshwater fauna in the streams that drain into them. The stream fauna of oceanic islands consists of a few species whose ancestors invaded from marine sources (Maciolek and Ford, 1987). All of the indigenous, non-insect macrofauna of the streams of Guam are diadromous, spending part of their life in the sea and part in freshwater (McDowall, 1991). Thus, for species to exist in streams above reservoirs, they must have access to the marine environment, especially during the migration periods of adults, juveniles, and larvae, and they must be able to pass through the reservoir on their upstream migration to the streams. If the reservoir is a barrier to fish migration, then the macrofauna communities in the streams above the reservoir could be structured differently with regard to species composition and densities. The reservoir and the dam could pose a barrier to diadromous animals making their way up to the streams above the reservoir for several reasons. The reservoir is home to several species of fish that could prey upon migrating larvae and juveniles. Also, while some of the gobioid fishes have specialized pelvic fins that allow them to traverse the spillway, others are not adapted to climbing. Third, when the spillway is dry, or conversely, if water is flowing too rapidly over the spillway, some species may not be able to get past the dam.

In the past the Department has reviewed proposals for the placement of dams in Guam's rivers. Unfortunately, adequate data was not available to assess the potential impacts such structures would have on the indigenous aquatic macrofauna. Instead, private consultants gathered data using survey techniques that had not been field tested to work in small tropical watersheds. Based on these past experiences, the need for consistent sampling protocols, and the need for baseline data (of aquatic macrofauna) it was decided to carry out a project to address these aspects.

This project is part of the initial study started in FY95. The three streams above Fena reservoir (the experimental streams) and four control streams were surveyed to test the Modified Quadrat technique (Figures 1 and 2). All seven rivers are part of the four watersheds selected for the initial study. If the reservoir blocks macrofauna migration, then species composition and densities would be different from the control streams and experimental streams.

This project also serves as a Master of Science thesis project for the program coordinator under the University of Guam's Graduate Biology Program.

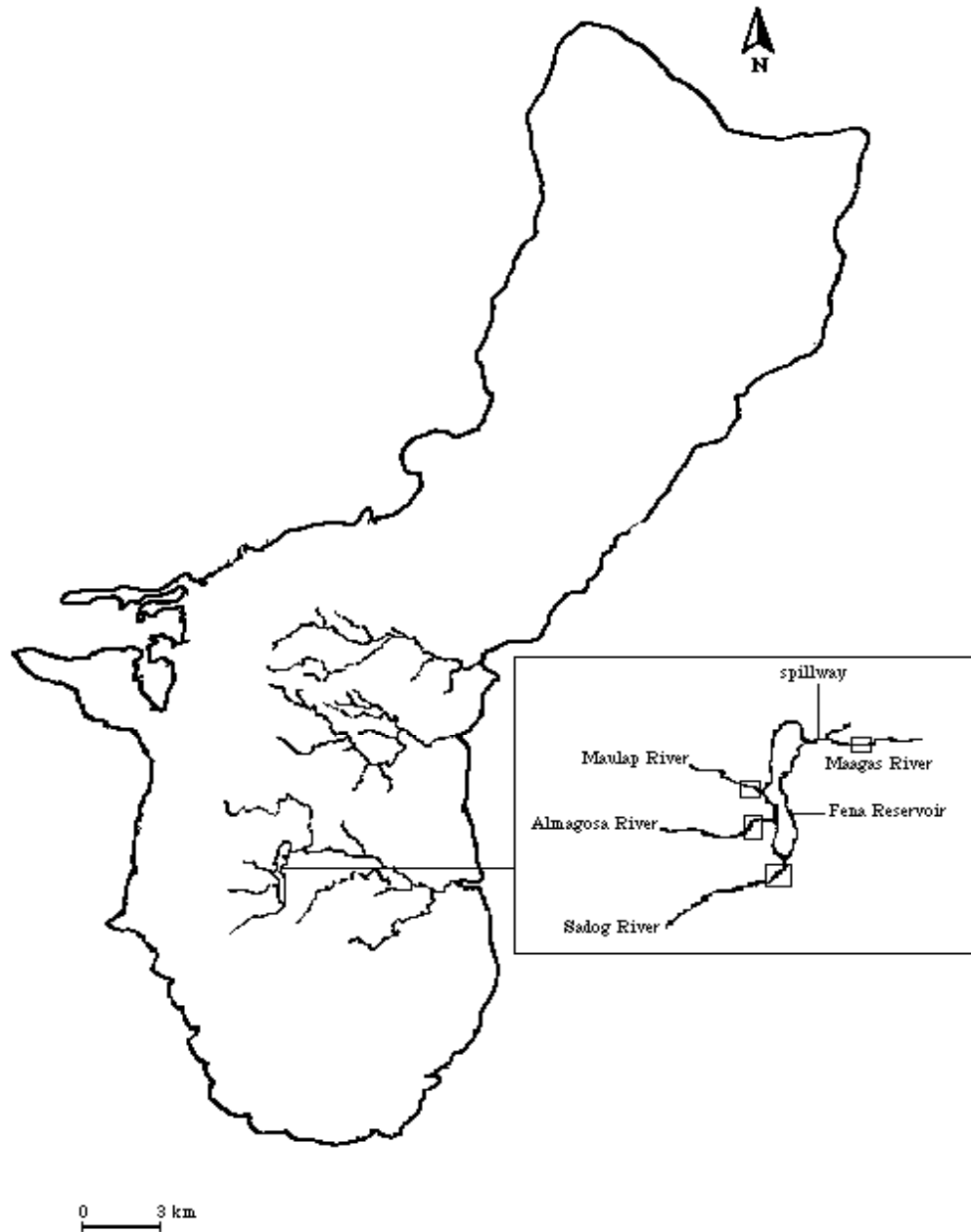


Figure 1. Guam and expanded view of streams surveyed above and below the Fena Reservoir. The Almagosa, Maulap, and Sadog = Experimental Streams and the Maagas River = 1 of 4 Control Streams.

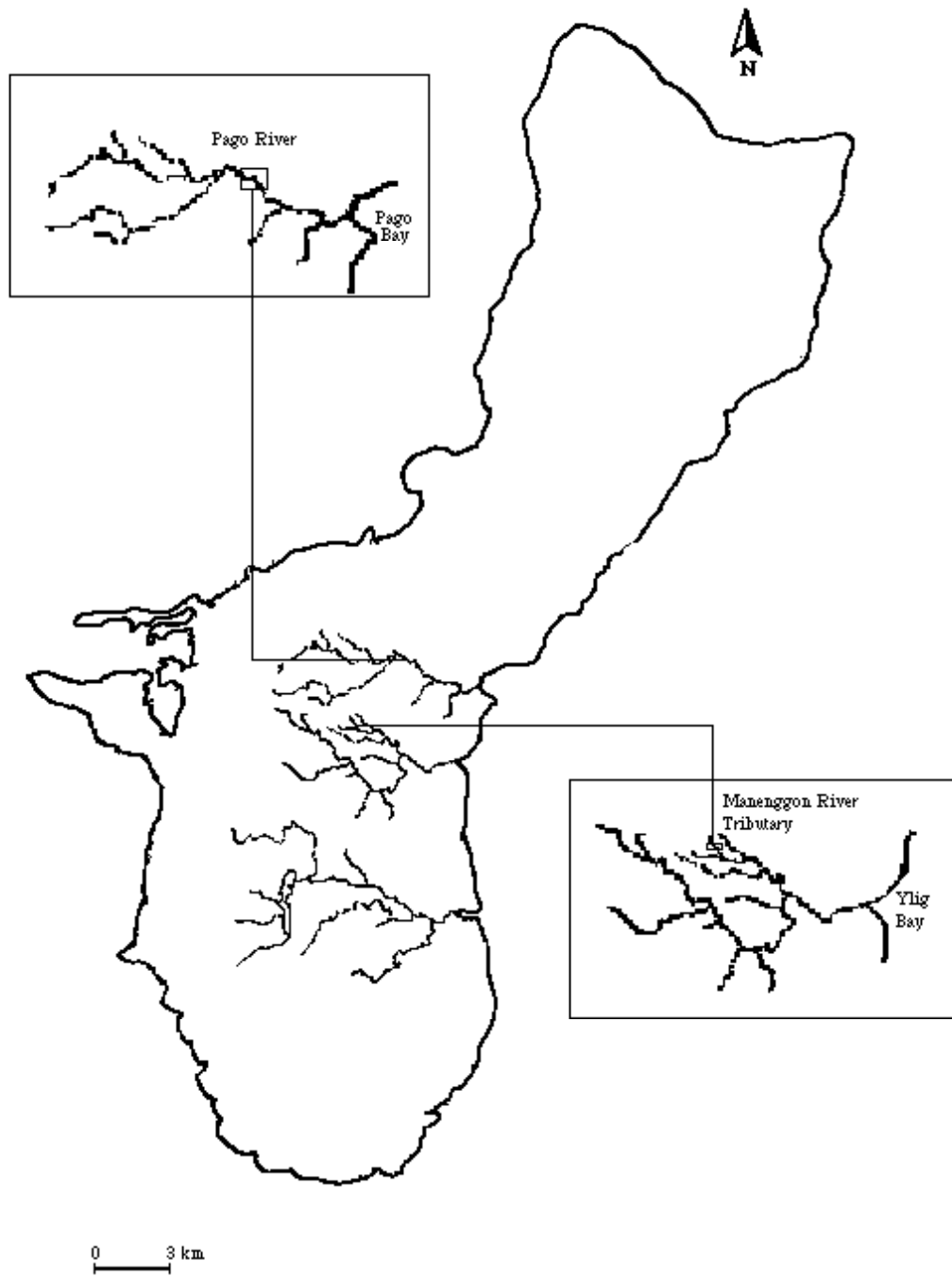


Figure 2. Guam and expanded view of control streams surveyed. The Manenggon, Pago, and Ylig = 3 of 4 streams surveyed.

## **OBJECTIVES**

1. To compile both local and watershed information and relevant related literature available for Guam watersheds and the monitoring and management of such systems; and to develop a list of watershed information needs, prioritize needs and pursue separate program development to obtain needs.
2. Develop and test sampling/survey technique.
3. Collect baseline macrofauna, and other pertinent data on representative streams.
4. Determine the role of dams/reservoirs as barriers to reproduction of freshwater macrofauna.

## **PROCEDURES**

A list of local watershed information and relevant literature available for Guam was collected both from local and off-island sources. Simultaneously, suitable monitoring techniques were also researched. This information was used to develop a scope of work for development and implementation of a long-term freshwater monitoring program. Four watersheds were selected for the initial monitoring program and the testing of a survey technique. Fena Reservoir and its tributaries are part of one of the watersheds chosen for the initial study.

Species composition and species density data was collected in the four selected watersheds using the Modified Quadrat technique. In addition species composition and species densities, several environmental parameters were measured to determine their role in the species composition of stream macrofauna and to gather information regarding the physical characteristics of the stream. The water velocity at each quadrat was measured in the center of the quadrat at 60% of the maximum depth. The readings taken during this period were averaged. A Flo-Mate portable flowmeter Model 2000 was used to measure water velocity and a wading rod was used to measure water depth. The two dominant substrate types and their percent makeup were recorded for each quadrat. The Helm, et al. (1985) classification system was used to categorize substrate types as either bedrock, boulder (>256 mm), cobble/rubble (64-256 mm), gravel (5-64 mm) or sand/sediment (<5 mm) by diameter.

A 200-m section of each stream was sampled, and the location within the stream was chosen haphazardly. The 200-m section was divided into twenty 10-m contiguous sections. Each 10-m segment was measured in a parallel line adjacent to the stream and then a number between 0 and 9 was drawn from a bag (0-9 as representing one meter segments along the transect, i.e., #4, would equal 5 meters measured along the 10-meter segment). Once the random location along the stream edge was selected, the position of the observation (whether on the left side, right side, or in the middle of the stream) relative to stream width was chosen.

Upon reaching the selected area, I chose a spot for viewing. This was done by locating objects (rocks or debris) within the stream to mark the corners of the rectangular quadrat. Because organisms may be disturbed by the observer moving into place, two minutes were allowed for them to settle back into the area prior to counts being made. Counts of fish and prawns were made from the stream bank or in the water with a snorkel and mask. The presence or absence of snail species was also noted. After all the organisms had been counted, a surveyor's tape was used to measure the length and width of each quadrat; from these measurements, the density (individuals per m<sup>2</sup>) of each species was determined.

To address the question of watershed impacts resulting from man-made dams or lakes, additional surveys were conducted within Fena Reservoir using snorkel and mask. The areas surveyed were along the banks of the reservoir that are shallow enough for the observer to see the bottom. Each species observed was recorded as being present.

When possible, analysis of variance was used for data comparison of the streams. However when the data did not conform to the assumptions for the ANOVA, the nonparametric, Kruskal-Wallis One-Way Anova for Ranks corrected for ties (SOLO 6.0, BMDP Statistical Software, Inc., Los Angeles, California U.S.A.), was used.

## RESULTS

This report marks the first significant stream monitoring dry season data set collected on this project. The FY96 and FY97 data was summarized and analyzed and an artifact in the data became apparent. Quadrat sizes ranged from 0.4 to 2.6 m<sup>2</sup> and macrofaunal densities ranged from 0 to 35 organisms per m<sup>2</sup> (Figs. 3 to 8).

It is clear that for some species, as can be seen for the 1997 data for *Macrobrachium lar* (Fig. 6), higher densities were recorded in the smaller quadrats. With smaller quadrat sizes the frequency distributions resemble a Poisson distribution more than a normal bell-shaped curve. The result is that many quadrats have zero values, and with greater densities, a pattern where density is dependent on quadrat size is apparent. In 1997, the data collected were based on a much more uniform quadrat size. For most species the pattern seen in the 1996 data, was also seen in the 1997 data, which was taken using less variable quadrat sizes; the data for *Stiphodon elegans* is a possible exception (Figs. 7 and 8).

Species composition varied between streams (Table 1). The most obvious difference between the fauna of the experimental and control streams was the absence of nerite gastropods from the streams above the reservoir. One nerite gastropod was seen in 1996 along the spillway but never in any of the experimental streams or along the edges of the reservoir. The snail *Thiara granifera* was the only species of gastropod seen in the streams above the reservoir.

Most species were present in all of the streams. Four species occurred throughout all streams surveyed: the mountain goby *Stiphodon elegans* (Steindachner), the Guam goby *Awaous*

*guamensis* (Valenciennes), the freshwater prawn *Macrobrachium lar* (Fabricius), and the eel *Anguilla marmorata* (Quoy and Gaimard). The streams above the reservoir had more species of fish than the control streams. This was primarily the result of the presence of cichlid fishes, e.g., *Tilapia zillii* (Gervais), *Tilapia mossambicus* (Peters), and *Cichla ocellaris* (Bloch and Schneider)) that had been introduced to the reservoir (Nelson and Edredge, 1991). In addition, the goby *Mugilogobius cavifrons* (Weber) was found only in the streams above the reservoir but not in the control streams. Furthermore, this goby was not seen in the Maagas River, which is located below the reservoir's spillway. The flagtail *Kuhlia rupestris* (Lacepede) was present only in the control streams. *Sicyopus leprurus* occurred only in one of the control streams, the Manenggon River, and even there it was uncommon. The introduced cichlid, *C. ocellaris*, was seen below the dam in the Maagas River on only on one occasion. The number of species per unit area was different among streams both in 1996 ( $F_{(6, 132)} = 4.15$ ,  $p=0.001$ ) and in 1997 ( $F_{(6,132)} = 9.36$ ,  $p=0.000$ ) (Figs. 9a.-b.). River definitions for figure 9 a-h (x-axis) are as follows: 1 = Almagosa; 2 = Maulap; 3 = Sadog; 4 = Ylig; 5 = Manenggon; 6 = Pago; and 7 = Maagas; experimental streams = 1 – 3; control streams = 4 – 7; 25<sup>th</sup> percentile = zero (y-axis); 50<sup>th</sup> percentile (median) = line within box; 75<sup>th</sup> percentile = line farthest from zero; 10<sup>th</sup> and 90<sup>th</sup> percentiles = standard deviations; and circles = data outliers.

Table 1. Species composition for all streams and Fena Reservoir. An “x” indicates a species is present in a stream and an empty cell indicates the absence of a species. The Maagas River is located below the Reservoir †.

SPECIES	Experimental Streams			Control Streams				†
	Almagosa	Sadog	Maulap	Maagas	Manenggon	Pago	Ylig	
<b>Fish</b>								
Gobiidae	x							
<i>Awaous guamensis</i>	x	x	x	x	x	x	x	x
<i>Stiphodon elegans</i>	x	x	x	x	x	x	x	x
<i>Mugilogobius cavifrons</i>	x	x	x					x
<i>Sicyopus leprurus</i>					x			
Cichlidae								
<i>Cichla ocellaris</i>	x	x	x	x				x
<i>Tilapia mossambicus</i>	x	x	x	x	x	x	x	x
<i>Tilapia zillii</i>	x	x	x	x	x	x	x	x
Kuhliidae								
<i>Kuhlia rupestris</i>				x	x	x	x	
Anguillidae								
<i>Anguilla marmorata</i>	x	x	x	x	x	x	x	x
Crustaceans								
Palaemonidae								
<i>Macrobrachium lar</i>	x	x	x	x	x	x	x	x
Gastropods								
Neritidae								
<i>Thiara granifera</i>	x	x	x	x	x	x	x	x
<i>Neritina pulligera</i>				x	x	x	x	x

<i>Neritina variegata</i>	x	x	x	x	x
<i>Neritina squamipicta</i>	x	x	x	x	x

Because the density data did not meet the assumptions of the ANOVA, the Kruskal-Wallis One-Way Comparison for ranks was used to test for differences in densities of individuals or particular species between streams. There was a significant difference in the densities of *Awaous guamensis* among streams in 1996 ( $H = 57.3$ ,  $p = 0$ ), but not in 1997 ( $H = 10.0$ ,  $p = 0.125$ ). Densities of *A. guamensis* (Figs. 9c.-d.) in the Manenggon River were much lower than in the control streams.

The 1996 and 1997 densities of *Stiphodon elegans* ( $H=45.6$ ,  $p=0.000$  and  $H=44.2$ ,  $p=0.000$ , respectively) (Figs 9e.-f.) and *Macrobrachium lar* ( $H = 21$ ,  $p = 0.002$  and  $H = 28.8$ ,  $p = 0.0001$ , respectively) differed significantly among streams (Figs. 9g.-h.). For both years, densities of *M. lar* were higher in the experimental streams than in any of the control streams. However, in 1997 the Manenggon River, one of the control streams, had higher densities of *M. lar* than the experimental streams.

The proportions of substrate types sampled varied from stream to stream for both 1996 and 1997 (Table 2). Some rivers had higher proportions of bedrock or sand than others. It appeared that certain species were found consistently within quadrats comprised of certain substrates. For example, *Stiphodon elegans* was sighted on harder substrates such as cobble and pebble whereas *Awaous guamensis* was more common on sand substrate.

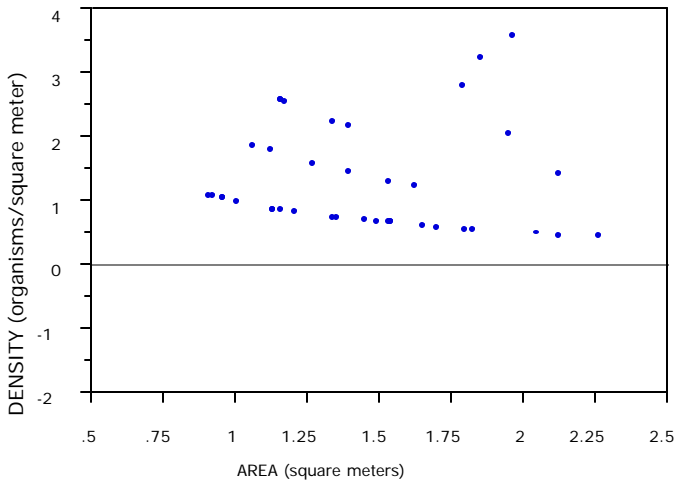
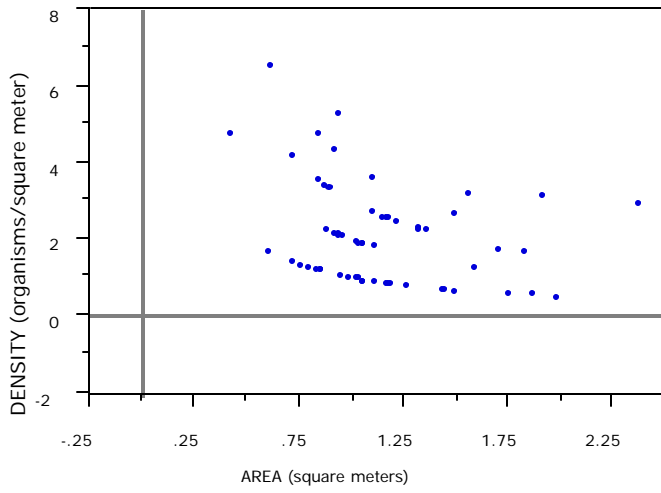


Figure 3. A plot of the Guam Goby, *Awaous guamensis*, densities on quadrat size for 1996.  
 Figure 4. A plot of the Guam Goby, *Awaous guamensis*, densities on quadrat size for 1997.

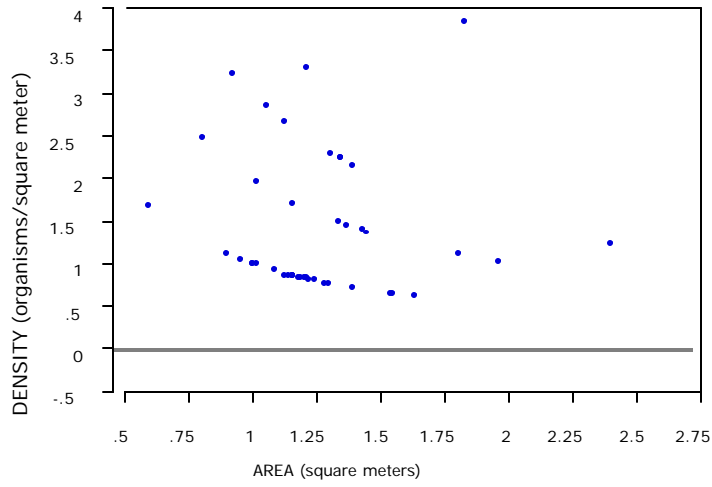
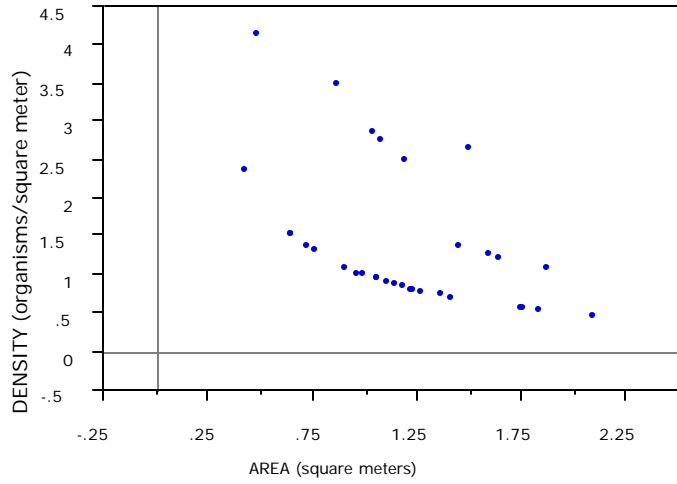


Figure 5. A plot of the Prawn, *Macrobrachium lar*, densities on quadrat size for 1996.  
 Figure 6. A plot of the Prawn, *Macrobrachium lar*, densities on quadrat size for 1997.

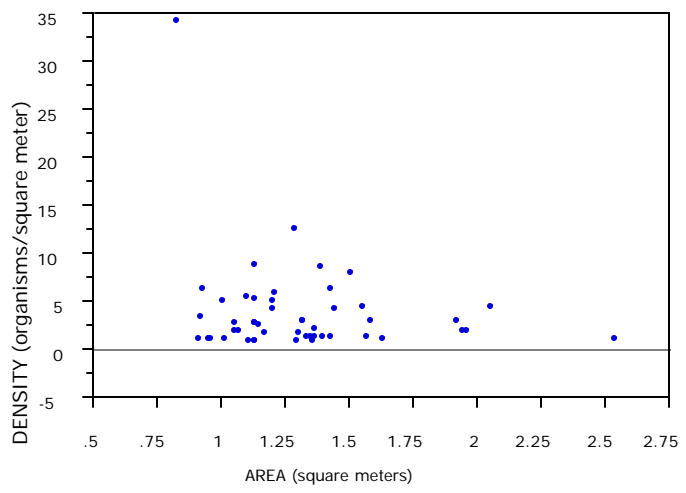
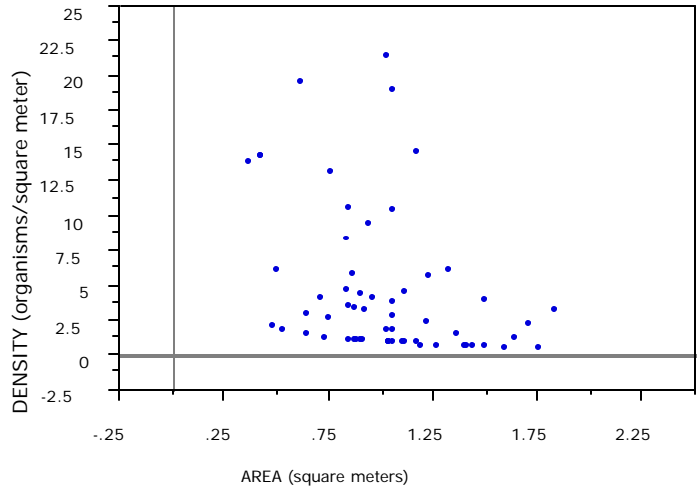


Figure 7. A plot of the Mountain Goby, *Stiphodon elegans*, densities on quadrat size for 1996.  
 Figure 8. A plot of the Mountain Goby, *Stiphodon elegans*, densities on quadrat size for 1997.

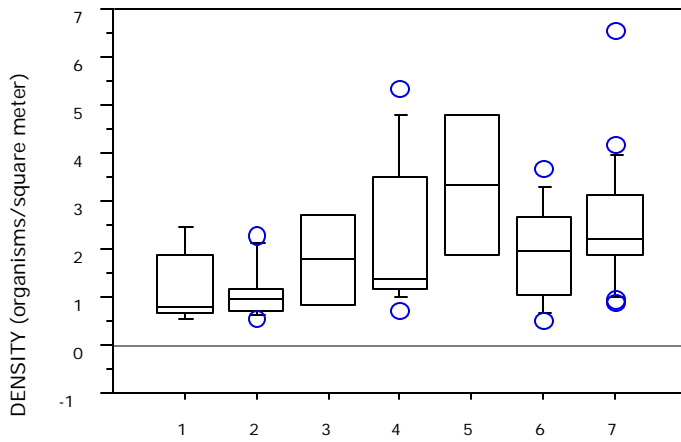
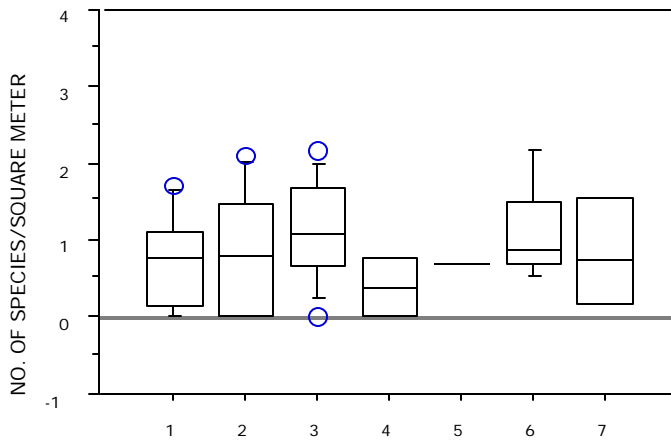
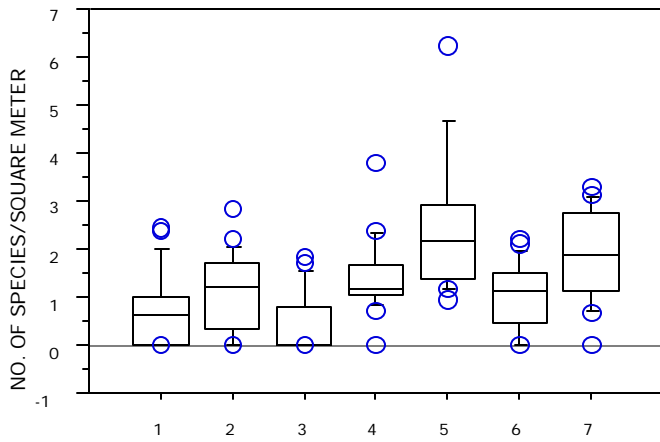


Figure 9a. Box plot of the number of species per square meter for 1996.  
 Figure 9b. Box plot of the number of species per square meter for 1997.  
 Figure 9c. Box plot of *Awaous guamensis* for 1996.

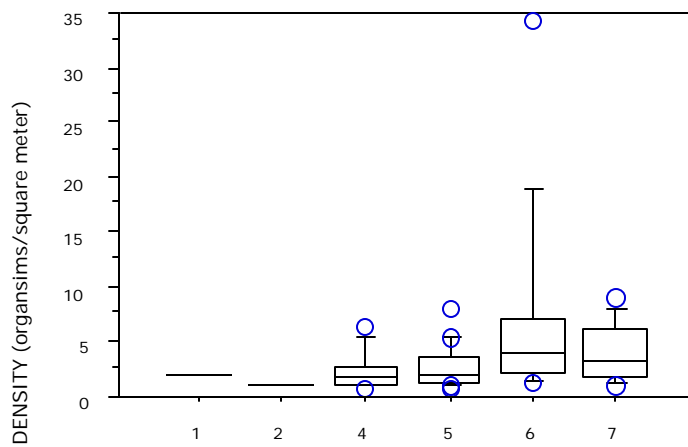
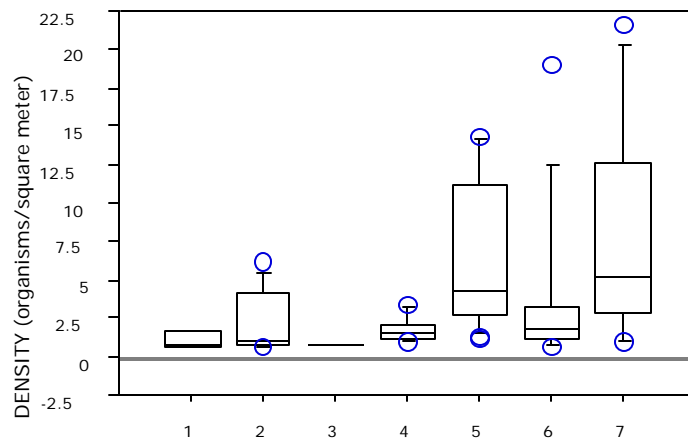
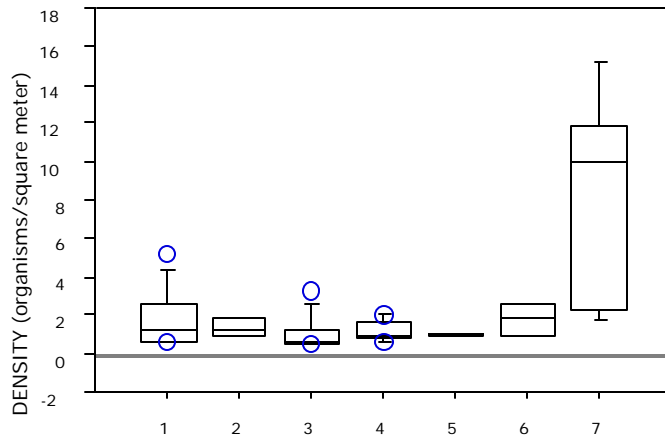


Figure 9d. Box plot of *Awaous guamensis* for 1997.

Figure 9e. Box plot of *Stiphodon elegans* for 1996.

Figure 9f. Box plot of *Stiphodon elegans* for 1997.

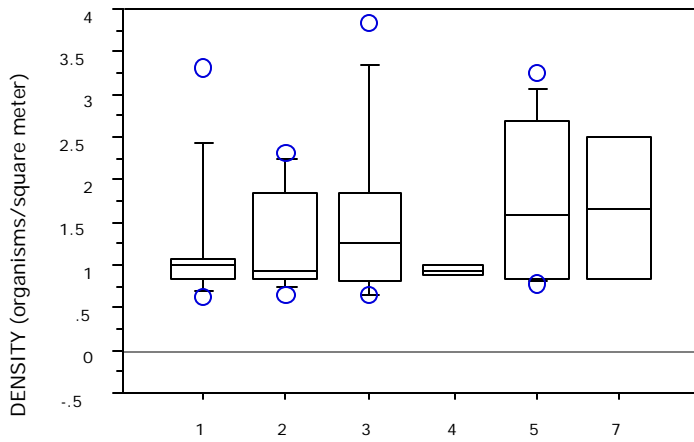
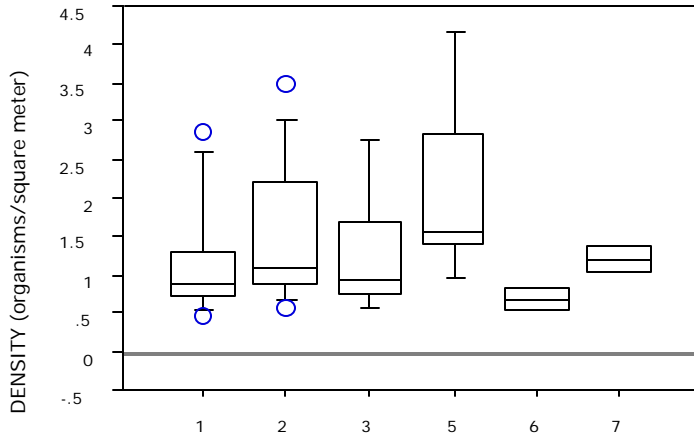
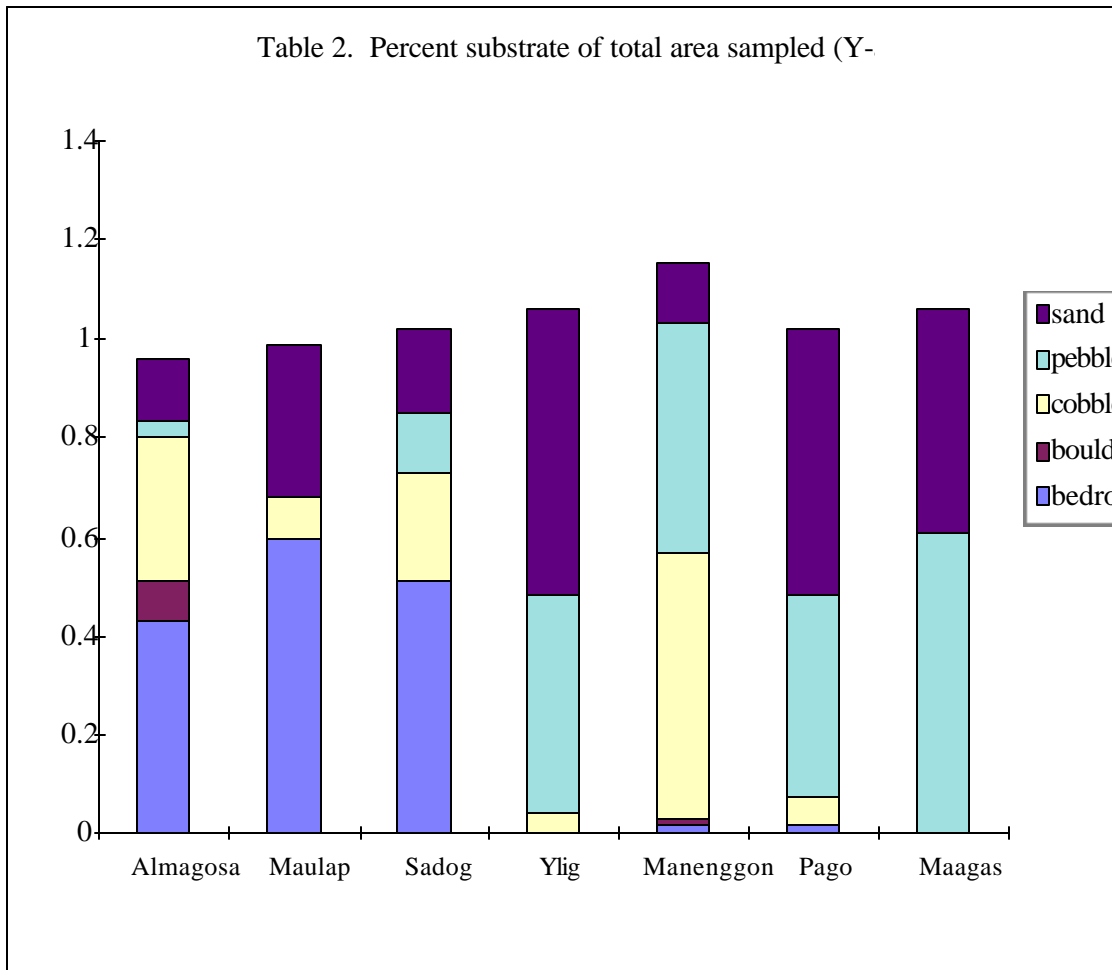


Figure 9g. Box plot of *Macrobrachium lar* for 1996.  
 Figure 9h. Box plot of *Macrobrachium lar* for 1997.



Velocity readings did not indicate any substantial patterns in terms of where fish were found. In areas where faster moving waters were predominant, *S. elegans* were seen often. However, *Awaous guamensis* were seen in slower, deeper waters. A total of 41 days were spent in the field and approximately 75% of these days were devoted to the initial study and the Fena project and the remaining 25% were devoted to identifying species residing in other rivers not associated with the initial study and Fena. A log of species identified in all rivers visited during FY97 has been started and is available upon request.

In addition to the general data needs and analysis associated with this project several individuals have visited or called the office requesting assistance in freshwater species identification. A crude version of a freshwater field guide was compiled during FY97 to address these requests and to provide some continuity for future staff, who worked on this project. This guide is available upon request.

For historical documentation purposes the US Navy (COMNAVMARIANAS) agreed to open Fena Reservoir to the public for fishing on weekends. They presently allow 50 people in a day

and this requires pre-registration and a \$5.00 fee. Data is taken at the end of each fishing day however, the data may not be qualitative enough to allow catch assessments to be made. Fish stocks and fish populations need to be tracked in order to determine the effects of fishing on this resource.

## **DISCUSSION**

Although, the Modified Point Quadrat (Baker and Foster, 1992) survey method has been used in Hawaii and elsewhere, this study raised some concern regarding small or variable quadrat size. With smaller quadrat sizes or less common organisms patterns appear in the data that are related to quadrat size. However, the use of more uniform quadrat sizes did not eliminate the problem for some species. Larger quadrat sizes would probably help, but there are practical limits to the size of quadrats that can be used in visual surveys. Also because the streams in many Pacific islands are small, variable quadrat size may be limited by the stream width. This method is useful for detecting broad patterns of distribution, but for many confirmatory statistical tests, other designs may work better. Three species of nerite gastropods and one species of fish were not found above the reservoir. The dam probably excludes the flagtail, *K. rupestris*, because it is not morphologically adapted for climbing. It is also absent above natural waterfalls in most streams of Guam.

In addition to the four species that occurred throughout all streams surveyed, there were species such as the gobies, *M. cavifrons* and *S. leprurus*, which were present only in some of the streams. *M. cavifrons*, which typically resides in the estuarine portion of streams, was recorded in the Maulap, Almagosa, and Sadog streams above the reservoir and within the reservoir. The occurrence of this species only in the streams above the reservoir was surprising and cannot be explained. *S. leprurus* is typically found in the upper portions of streams and the portion of Manenggon River sampled was typical habitat for this species (personal observation). *S. leprurus* has usually been seen in the upper reaches of streams where faster flowing water is present and where substrate is typically bedrock. The distribution of these species were not likely to have resulted from the effects of the reservoir.

It appeared that the reservoir may have affected the densities of some species, but not necessarily in ways that were predicted. The mean densities of *S. elegans* were higher in the control streams. One factor that could affect the density of macrofauna present in the streams above the reservoir is predatory fish in the reservoir. The reservoir was stocked with the peacock bass, *Cichla ocellaris*. This is a sport fish that could prey upon migrating larvae, juveniles or adult *S. elegans*. However, the control streams have flagtails, *K. rupestris*, which are also predators (Allen, 1991), but seem to feed primarily on invertebrates. The absence of flagtails above the reservoir may also explain why the densities of *M. lar* were higher in the experimental streams than in the control streams.

The differences in the proportions of substrate types sampled probably contributed to the high variability of densities between streams. Other studies have shown that *A. guamensis* and *S. elegans* are found more often on one substrate type than others (Parham, 1996 and Kinzie,

1988). Substrate type also determines food availability (Kinzie, 1988) and in turn is more than likely the driving force behind where each species is found.

This study shows that dams and reservoirs in tropical streams may not have severe effects on most species. However, these ecosystems are complex and there is high variability between streams.

A total of 41 days were spent in the field. Approximately 75% of these days were devoted to the initial study and the Fena project, and the remaining 25% were devoted to identifying species residing in other rivers not associated with the initial study and Fena. A log of species identified in all rivers visited during FY97 has been started and is available upon request.

## **RECOMMENDATIONS**

This is the second phase in developing a long-term freshwater monitoring and management program. The next phase should include assessing Fena Reservoir's fish stock as a short-term project. It is important to assess how the fish stocks within Fena could affect the indigenous macrofauna in the long run. This project should move towards assessing the quality of Guam's freshwater resource, which entails determining the rate of erosion and sediment loading in our streams thus how much actually reaches the coral reefs. This would integrate existing island-wide water monitoring and coral reef protection.

## **PROJECT COST**

The estimated cost of the program is \$361,100.

This report was prepared by: Georgette Bello Concepcion

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