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AN ABSTRACT OF THE THESIS presented by Georgette Bello Concepcion for the Degree of Master of Science in Biology, July 23, 1997.

Title: Effects of a dam and reservoir on distributions and densities of tropical stream macrofauna.

Approved: Stephen G. Nelson, Chairperson, Thesis Committee

In order to determine whether the presence of a reservoir affected the biota in streams above it, I surveyed three streams above Fena Reservoir on Guam, three control streams not connected to a reservoir, and the stream that drains the reservoir. The organisms surveyed were fishes, crustaceans, and gastropods. Most species were present in all the streams. The reservoir appeared to act as a barrier to some species but not all. The most obvious difference in species composition between the experimental and control streams was the absence of nerite gastropods in the experimental streams (those above the reservoir). However, a goby *Mugilogobius cavifrons* was only seen in the three experimental streams and another goby species, *Sicyopus leprurus* was seen only in one of the control streams. The experimental streams and Fena Reservoir lacked the flagtail fish *Kuhlia rupestris* which was present in all the control streams.

For the most part the species densities were lower in the experimental streams. One exception was the prawn *Macrobrachium lar* which occured in higher densities in the experimental streams in comparison to the densities found in the control stream.

# EFFECTS OF A DAM AND RESERVOIR ON DISTRIBUTIONS AND DENSITIES OF TROPICAL STREAM MACROFAUNA

by

GEORGETTE BELLO CONCEPCION

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I thank my parents, Robert and Josephine Duenas, for their unconditional support. They were very help and understanding, especially during the last three years.

This work is dedicated to my significant other, Zachary, who has always encouraged me to fulfill my goals no matter how unpleasant life would be for him. He has provided me with the strength and encouragement I needed especially during the roughest times when I was ready to give up and quit.

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# INTRODUCTION

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.

The objective of this study was to determine the effects of Fena Reservoir on the distribution and density of fishes, crustaceans, and gastropods comprising the macrofauna in the streams above it. 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 this study I test the following null hypotheses: 1) there are no differences in the number of species between the experimental streams (those above the reservoir) and control streams (those unconnected to a reservoir); 2) there are no differences in the number of species per unit area between experimental and control streams ; and 3) there are no differences in densities of stream organisms between the experimental and control streams.

## METHODS AND MATERIALS

Guam is located at 13.5° N latitude 145° E longitude and has a tropical climate. The mean annual rainfall on Guam ranges from 250 cm on the east side of the higher mountains to about 200 cm along the coast of the west side of the southern half of the island (Young, 1988). There are two seasons, a dry season, which usually extends from December through May, and a wet season, which occurs from June through November. There is notable year to year variability in rainfall within seasons.

Southern Guam is characterized by mountainous uplands that are deeply dissected by numerous rivers and streams (Young, 1988). The streams surveyed in this study are classified as perennial (Polhemus et al., 1992). Generally, they are surrounded by a combination of ravine forest and hilly grasslands on steep terrain. The upper reaches of these streams typically have relatively high water velocities, high percentages of canopy cover, predominantly bedrock substratum, steep gradients, and many waterfalls. The midregion of a tropical stream has less canopy cover, abundant algal growth, less gradient, and many runs and pools.

### Study Areas

Fena Reservoir is located in the south central region of the island. The maximum width of the reservoir is 0.64 km, and the length is 3.1 km. The dam is 26 m high, and its spillway is 320 m in length (Kennedy Engineers, 1974). Three streams drain into the reservoir formed by the dam. These are the Sadog, the

Almagosa, and the Maulap. Of the three, the Sadog is the stream whose mouth is furthest away from the spillway, and the approximate length of its main channel is 1555 m. The Almagosa River is fed by the Almagosa Springs, and the length of its main channel is 2195 m. The Maulap River, which is the stream closest to the spillway, has a main channel length of 2438 m (Best and Davidson, 1981). These streams were examined to determine whether their fauna was affected by the presence of Fena Dam and Reservoir.

The four control sites were as follows: 1) The Maagas River, where the Fena Reservoir drains, via the spillway, 2) an unnamed tributary of the Manenggon River, 3) a portion of the Ylig River, and 4) a portion of the Pago/Lonfit River. The criteria for the selection of control streams were that the streams were not above a reservoir or dam, that there was no saltwater intrusion, i.e., they were inland, and that they are similar in habitat makeup and in slope to the three streams that drain into the Fena Reservoir.

The length of the Maagas River is 2,926 m. The tributary of the Manenggon River chosen for this study has a main channel length of about 2,240 m. The portion of the Ylig River has a channel length of 11,994 m. The fourth control stream, a portion of the Pago/Lonfit River, has a main channel length of 6,706 m (Best and Davidson, 1981).

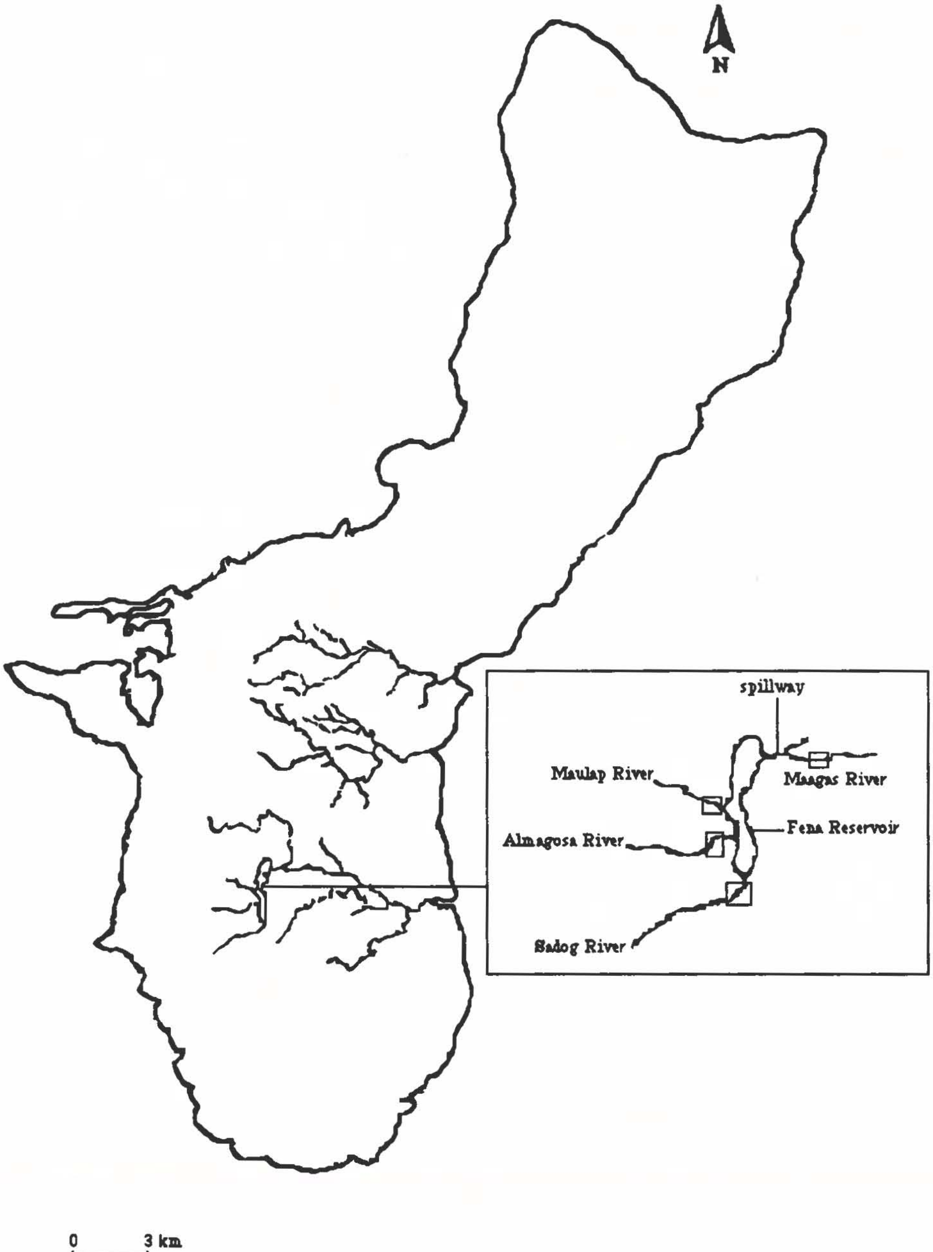


Figure 1. Guam and an expanded view of rivers surveyed above and below Fena Reservoir. The Sadog, Almagosa, and Maulap are the experimental rivers. The Maagas River, located below the spillway, is one of the four control streams.


Figure 2. Guam and an expanded view of the control rivers surveyed. Three of the four control streams surveyed were Pago, Manenggon, and Ylig.

Visual Survey

It has been shown that visual surveys are effective in estimating fish abundances 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). This method was used to survey the organisms found in each of the streams.

A 200-m section of each stream was sampled, and the location within the stream was chosen haphazardly. A quadrat was chosen within each of the twenty 10-m segments in each stream. The location of the quadrats (one per each 10-m segment) was chosen randomly. A 10-m segment was measured parallel to the stream then a number between 0 and 9 was drawn from a bag (0-9 as representing one meter segments along the transect). This number marked the first point along the length of the stream. Next, the position of the quadrat (whether left, right , 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 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 fishes 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 $m^2$) of each species was determined

Fena Reservoir was also surveyed by a diver 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.

## Analytical Methods

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

## Sampling Method

During the course of analysis, an artifact in the data became apparent. Quadrat sizes ranged from 0.4 to 2.6 $m^2$ and macrofaunal densities ranged from 0 to 35 organisms per $m^2$ (Fig. 3 to 8). It is clear that for some species, as can be seen for the 1997 data for *Macrobrachium lar* (Fabricius) (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* (Steindachner) is a possible exception (Fig. 7 and 8).

## Species Distribution and Densities

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* (Lamarck) was the only species of gastropod seen in the streams above the reservoir.

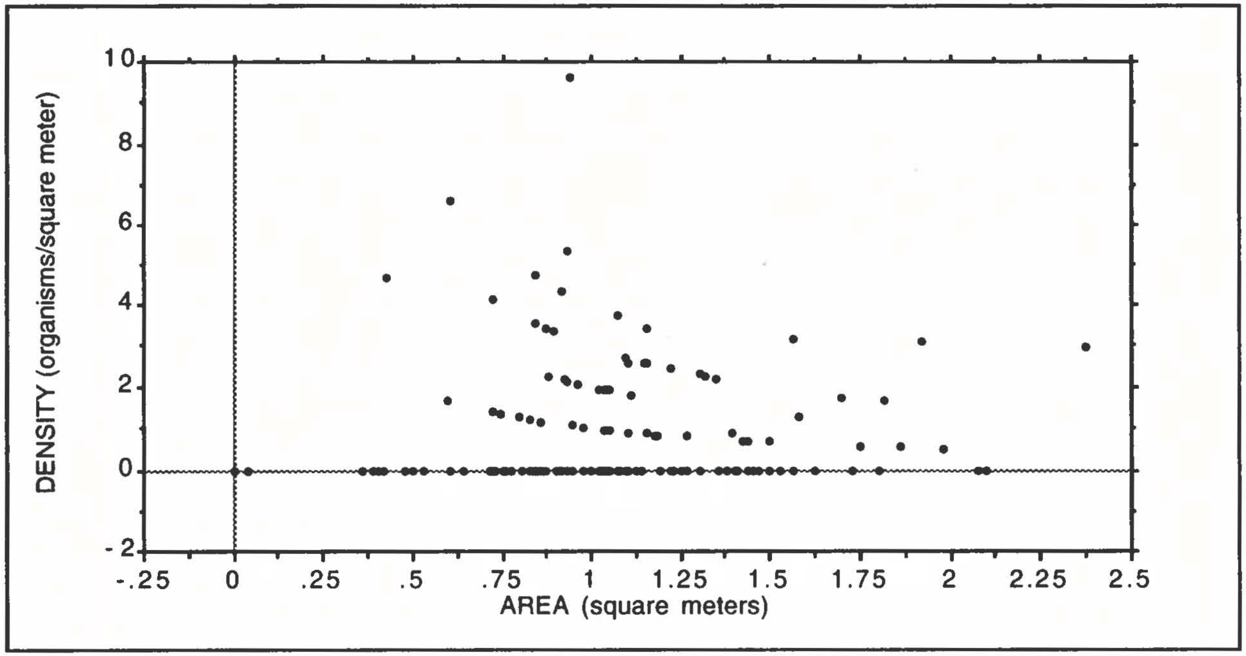


Figure 3. A plot of the Guam goby *Awaous guamensis* densities on quadrat size for 1996.

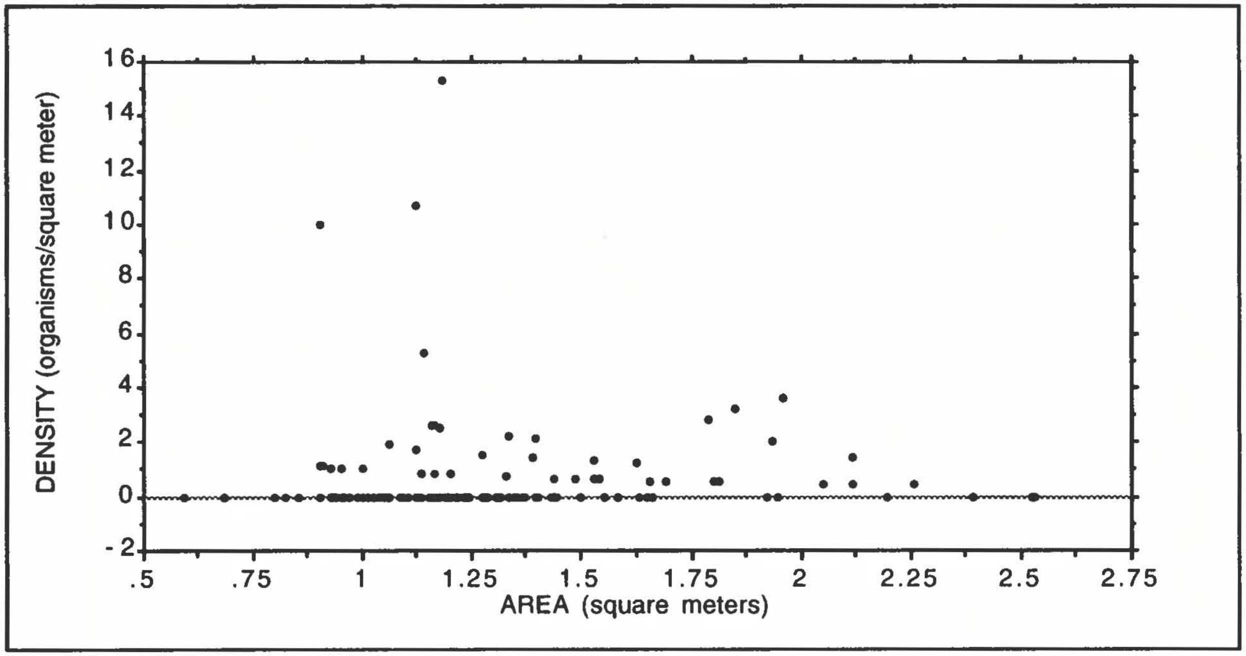


Figure 4. A plot of the Guam goby *Awaous guamensis* densities on quadrat size for 1997.

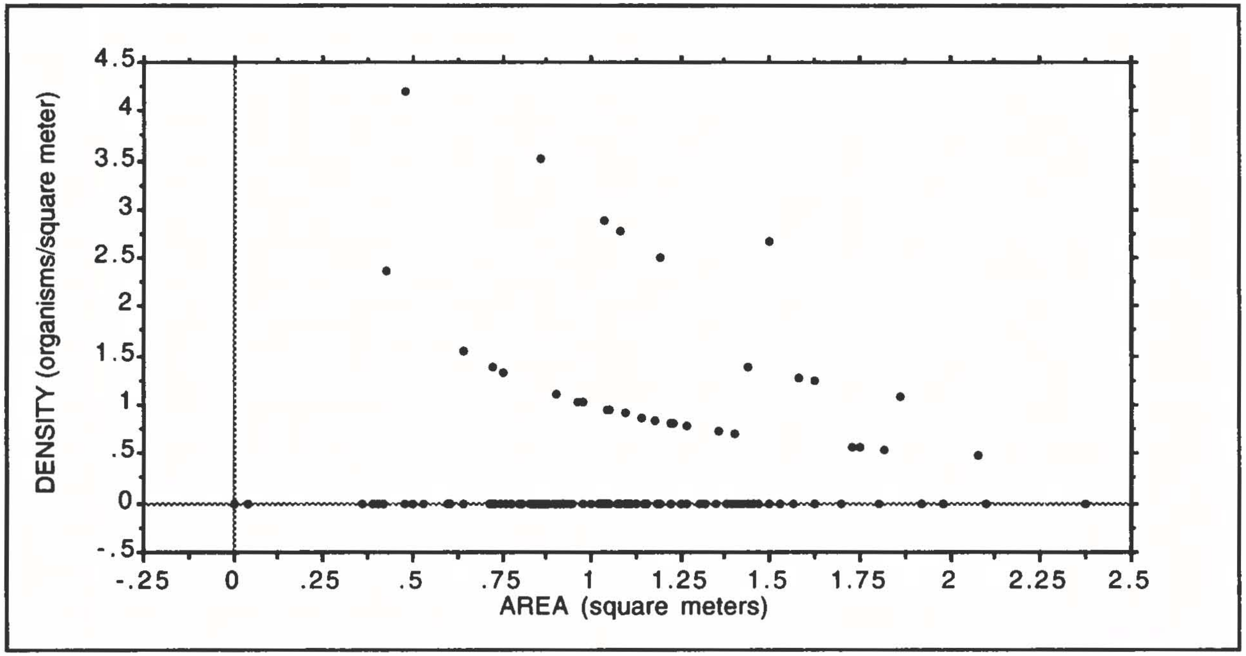


Figure 5. A plot of the prawn *Macrobrachium lar* densities on quadrat size for 1996.

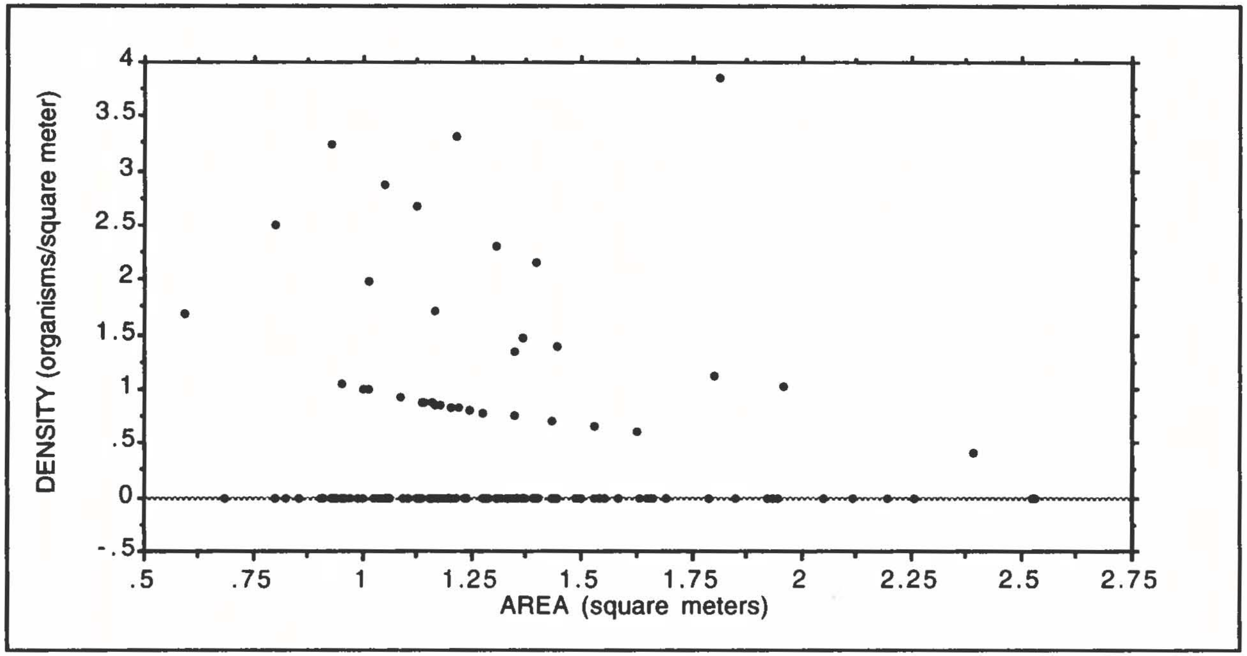


Figure 6. A plot of the prawn *Macrobrachium lar* densities on quadrat size for 1997.

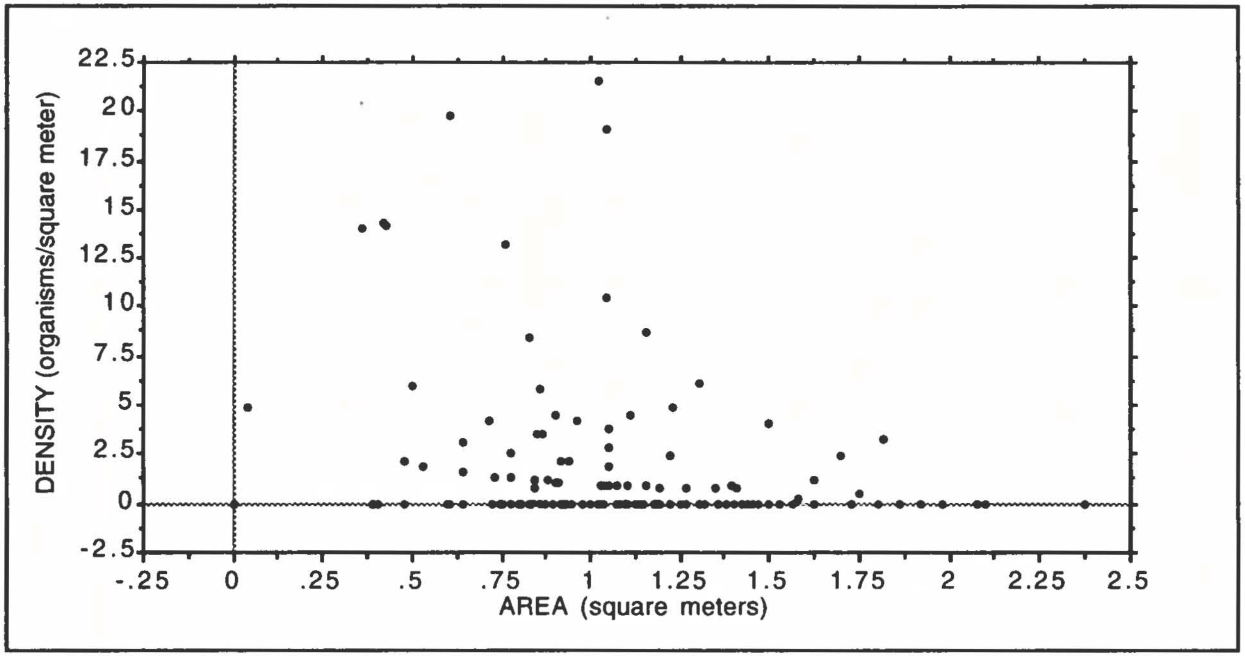


Figure 7. A plot of the mountain goby *Stiphodon elegans* densities on quadrat size for 1996.

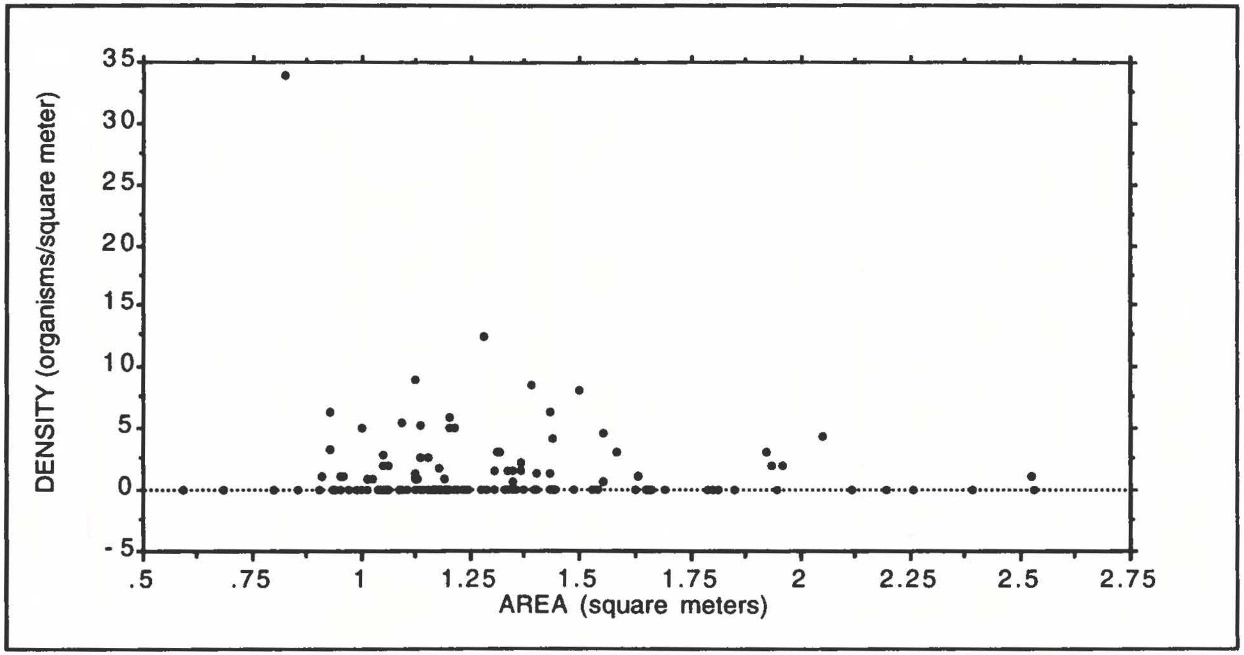


Figure 8. A plot of the mountain goby *Stiphodon elegans* densities on quadrat size for 1997.

| | Experimental Streams | | | Control Streams | | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Almagosa | Sadog | Maulap | Maagas | Manenggon | Pago | Ylig | Reservoir |
| Fish | | | | | | | | |
| Gobiidae | x | | | | | | | |
| *Awaous guamensis* | x | x | x | x | x | x | x | x |
| *Stiphodon elegans* | x | x | x | x | x | x | x | x |
| *Mugilogobius cavifrons* | x | x | x | | | | | x |
| *Sicyopus leprurus* | | | | | x | | | |
| Cichlidae | | | | | | | | |
| *Cichla ocellaris* | x | x | x | x | | | | x |
| *Tilapia mossambicus* | x | x | x | x | x | x | x | x |
| *Tilapia zillii* | x | x | x | x | x | x | x | x |
| Kuhliidae | | | | | | | | |
| *Kuhlia rupestris* | | | | x | x | x | x | |
| Anguillidae | | | | | | | | |
| *Anguilla marmorata* | x | x | x | x | x | x | x | x |
| Crustaceans | | | | | | | | |
| Palaemonidae | | | | | | | | |
| *Macrobrahium lar* | x | x | x | x | x | x | x | x |
| Gastropods | | | | | | | | |
| Neritidae | | | | | | | | |
| *Thiara granifera* | x | x | x | x | x | x | x | x |
| *Neritina pulligera* | | | | x | x | x | x | x |
| *Neritina variegata* | | | | x | x | x | x | x |
| *Neritina squamipicta* | | | | x | x | x | x | x |

Table I. 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.

Most species were present in all of the streams. Four species occurred throughout all streams surveyed: the mountain goby *Stiphodon elegans*, the Guam goby *Awaous guamensis* (Valenciennes), the freshwater prawn *Macrobrachium lar* , 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, i.e., *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 occassion. 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) (Fig. 9 and 10).

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* (Fig. 11 and 12) in the Manenggon River were much lower than in the control streams.

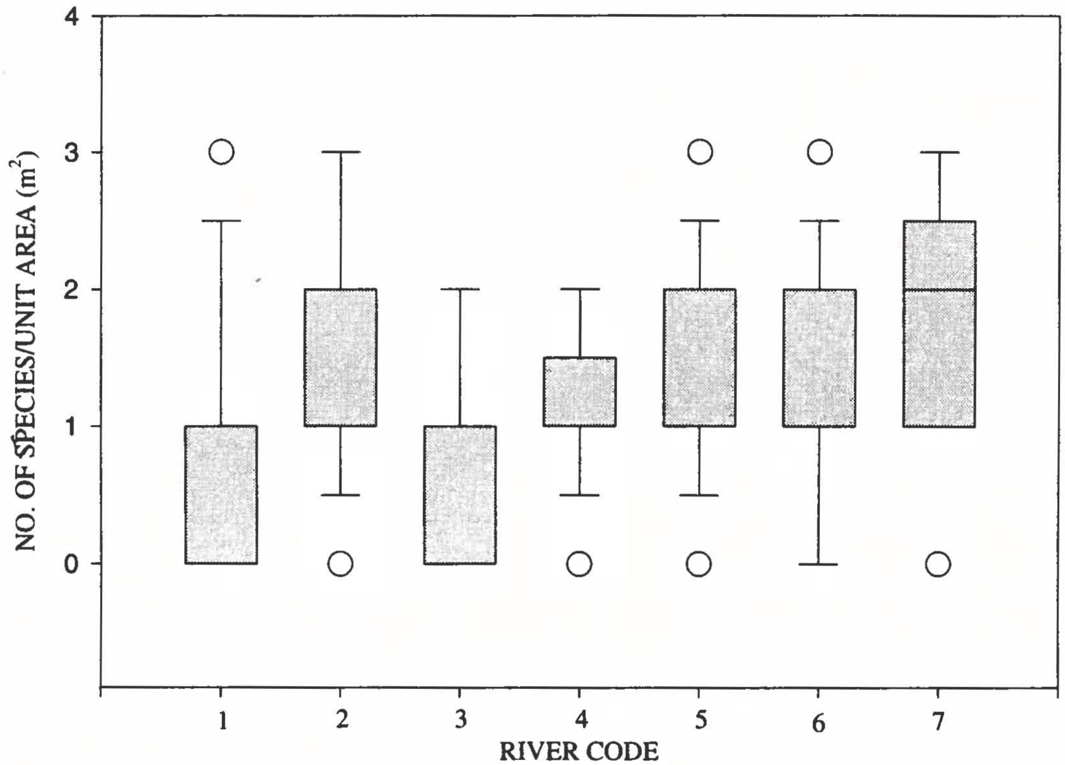


Figure 9. Box plot of the number of species per unit area ($m^2$) for 1996. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

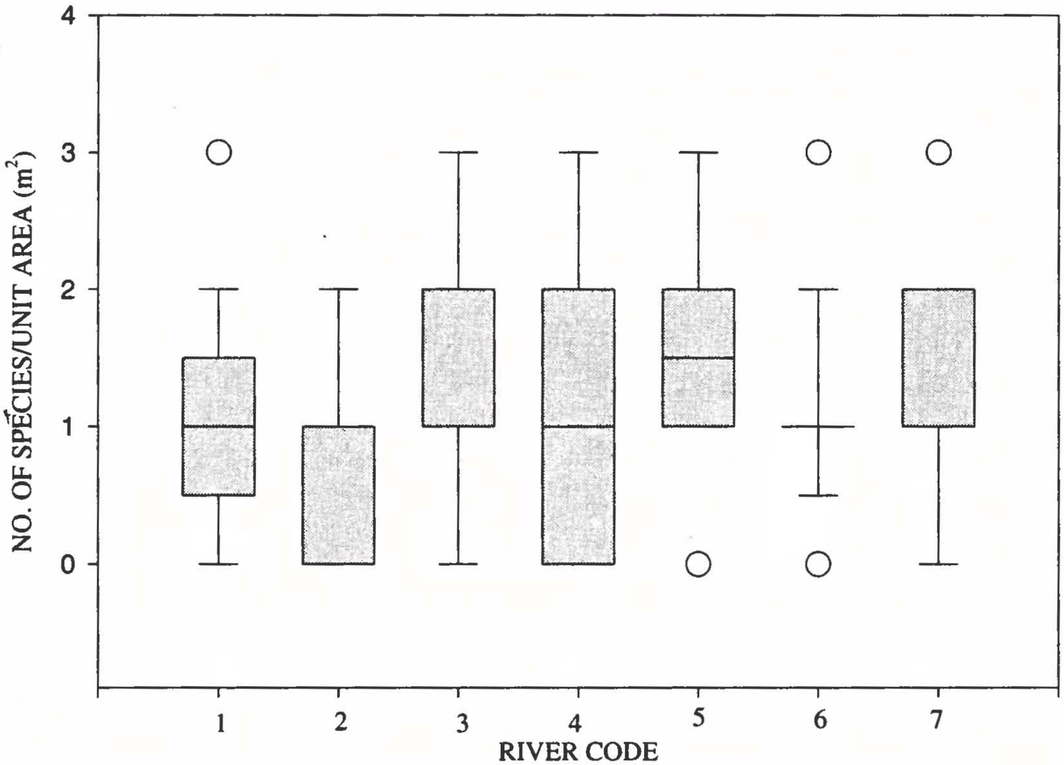


Figure 10. Box plot of the number of species per unit area ($m^2$) for 1997. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

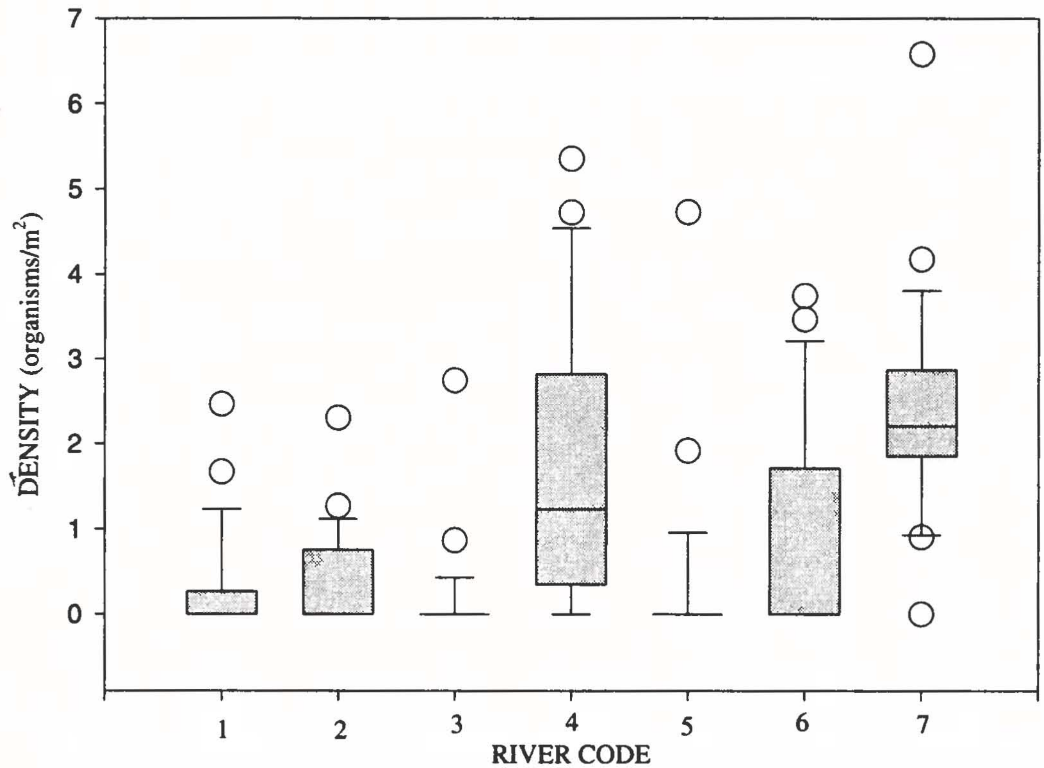


Figure 11. Box plot of *Awaous guamensis* densities for 1996. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

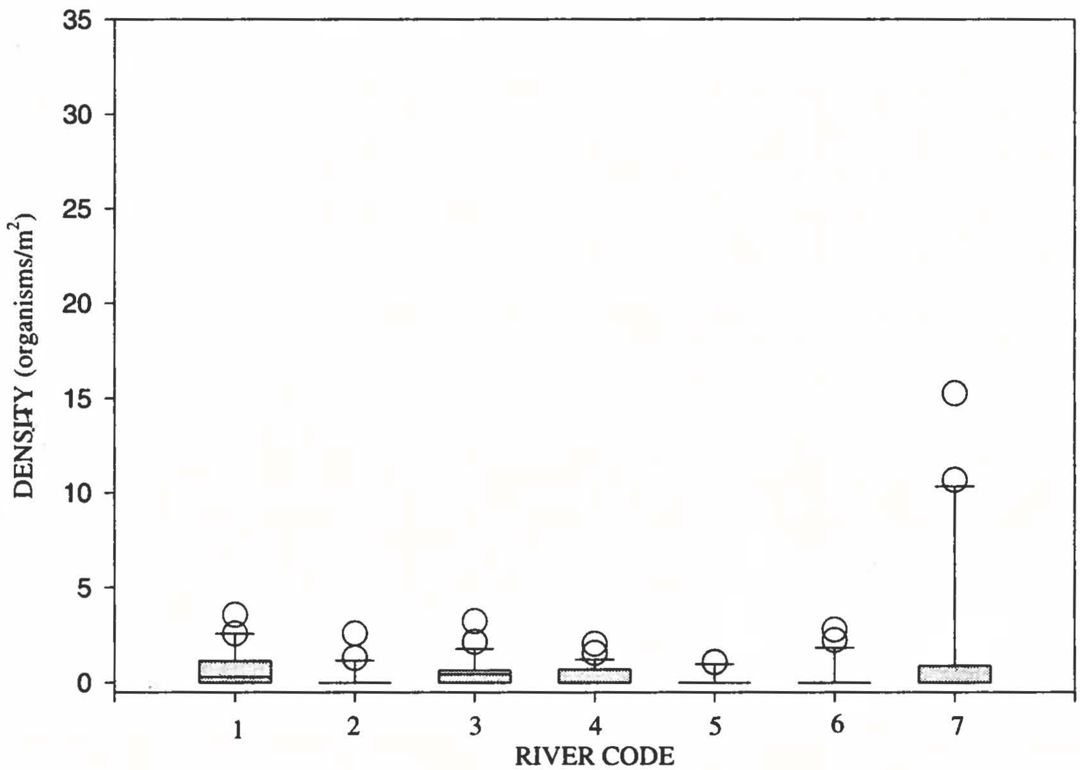


Figure 12. Box plot of *Awaous guamensis* densities for 1997. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

The 1996 and 1997 densities of *S. elegans* ($H=45.6$, $p=0.000$ and $H=44.2$, $p=0.000$, respectively) (Fig. 13 and 14) and *M. lar* ($H = 21$, $p = 0.002$ and $H = 28.8$, $p = 0.0001$, respectively ) differed significantly among streams (Fig. 15 and 16). 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.

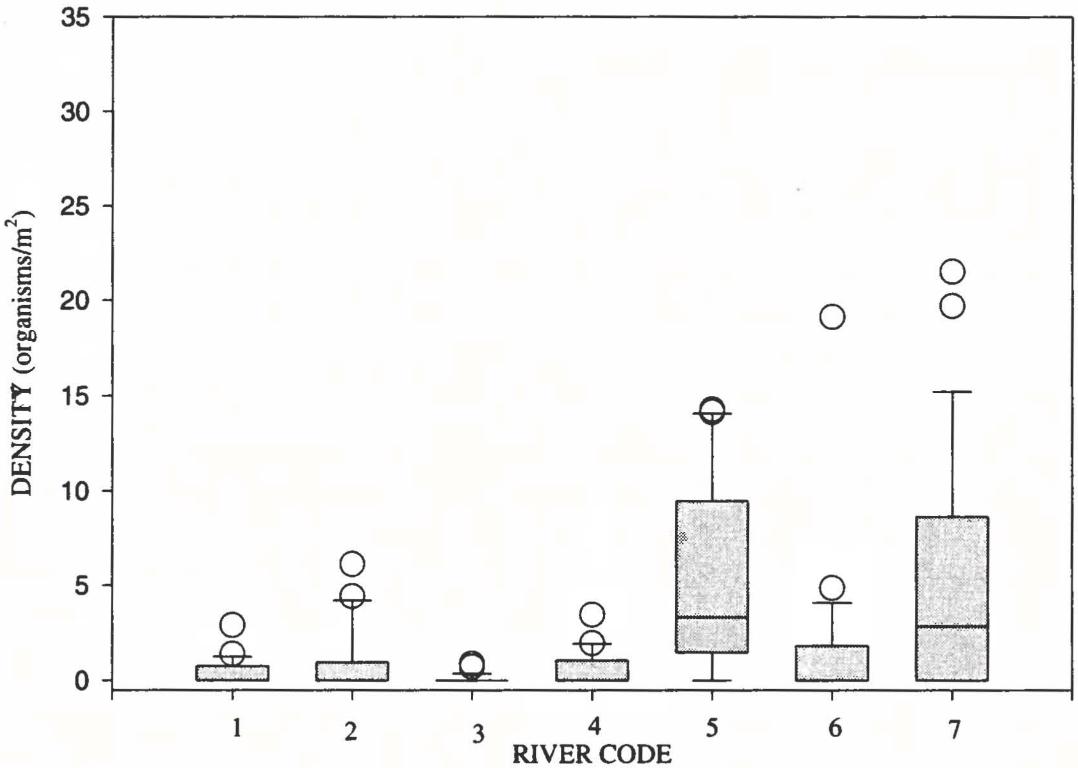


Figure 13. Box plot of *Stiphodon elegans* densities for 1996. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

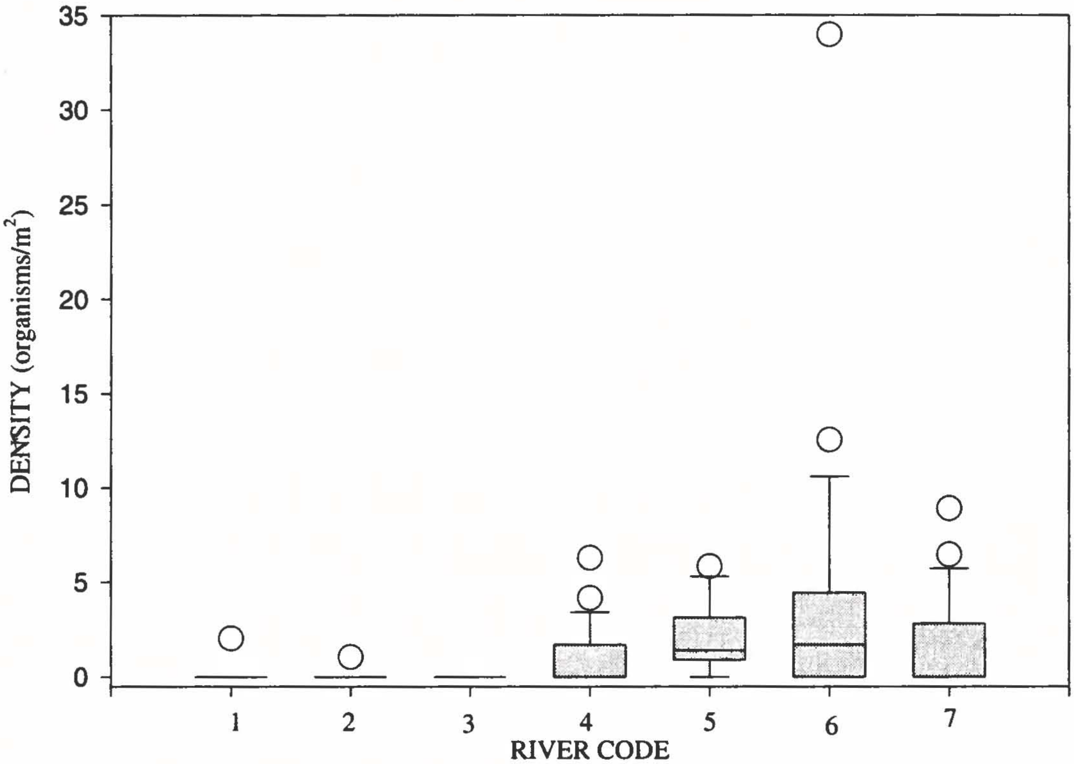


Figure 14. Box plot of *Stiphodon elegans* densities for 1997. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

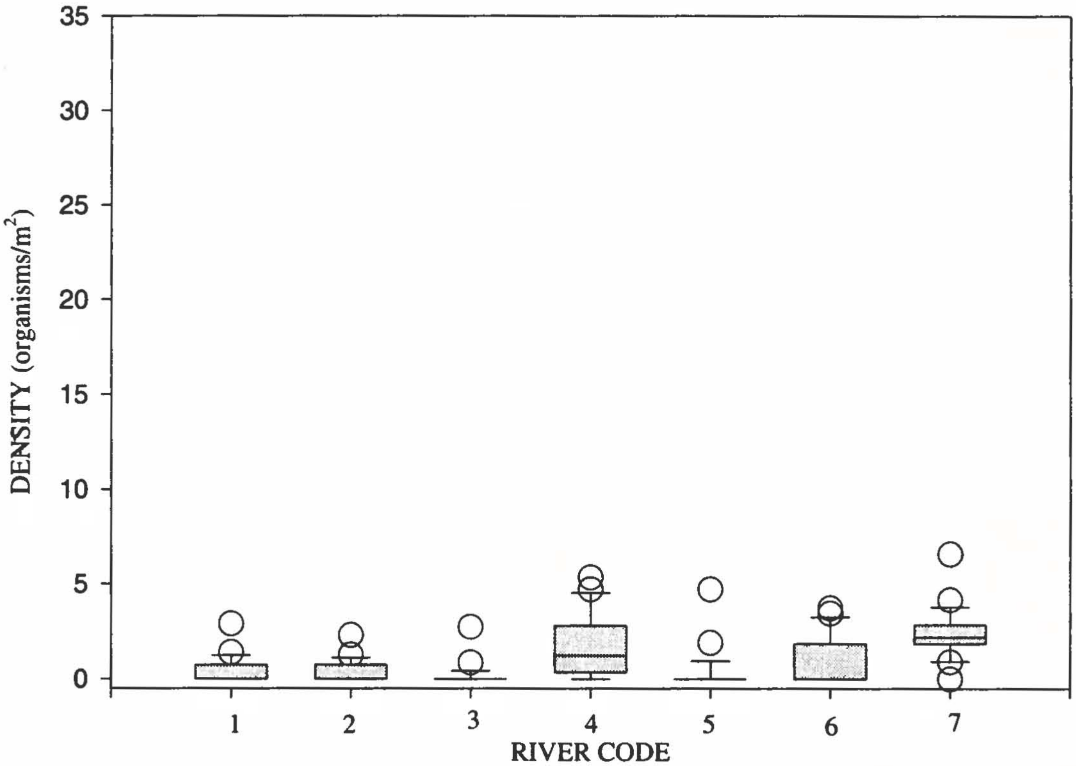


Figure 15. Box plot of *Macrobrachium lar* densities for 1996. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

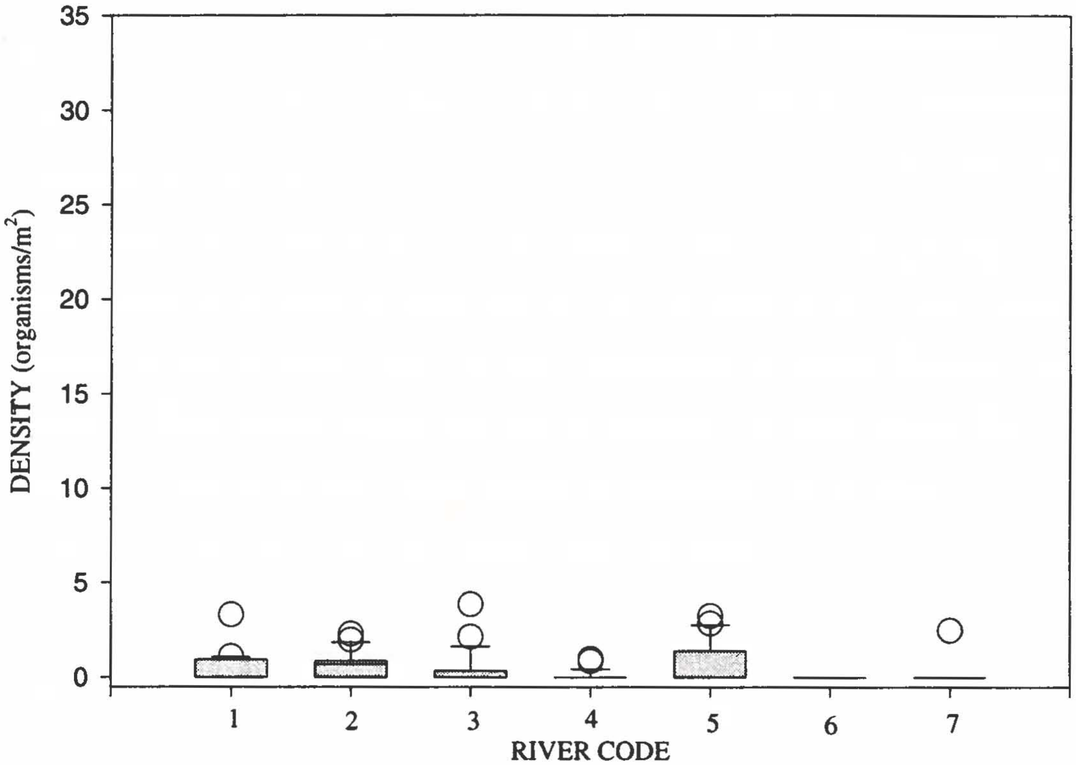


Figure 16. Box plot of *Macrobrachium lar* densities for 1997. River code: 1=Almagosa; 2=Maulap; 3=Sadog; 4=Ylig; 5=Manenggon; 6=Pago; 7=Maagas. The first three are experimental rivers and the last four are control rivers. The edge of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the edge of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. The circles represent data outliers.

# DISCUSSION

## Sampling Method

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.

## Species Distribution and Density

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 occured 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 *C. ocellaris*. This fish 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 experimenal streams than in the control streams.

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. I hope that the information included here will be of value in designing future monitoring programs for stream ecosystems throughout the tropical, insular Pacific.

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