PeerJ Preprints NOT PEER-REVIEWED

A 20-year comparison of shrimp populations in the Opunohu Valley of Moorea, French Polynesia

Ari H Goldstein Corresp. [1]

[1] Department of Integrative Biology, University of California, Berkeley, Berkeley, California, United States

Corresponding Author: Ari H Goldstein
Email address: arihgold@berkeley.edu

Global change is a central issue in many fields of science, particularly related to climate. One impact of climate change is changing weather patterns. This study focuses on the effects of changes in rainfall on freshwater stream ecosystems. Streams on small tropical islands are extremely fragile ecosystems. On the South Pacific volcanic island of Moorea, French Polynesia, lies the Opunohu Valley watershed. The Opunohu valley watershed is inhabited by three species of shrimp: *Macrobrachium* sp., *Atyoida pilipes,* and *Caridina weberi*. These shrimps are key components of their ecosystem because they break down organic material that falls into the stream thereby creating habitat for many other living organisms. Thus, they are a good measure of stream ecosystem health. This study focused on nine different sites throughout Opunohu valley. These sites had been surveyed in 1996 by C. Feldman. Comparisons to survey data collected in 1996 revealed no significant changes over time, demonstrating that shrimp populations have not declined or increased significantly in the last two decades.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2674v1 | CC BY 4.0 Open Access | rec: 24 Dec 2016, publ: 24 Dec 2016

PeerJ Preprints NOT PEER-REVIEWED

A 20-year comparison of Shrimp Populations in the Opunohu Valley of Moorea, French Polynesia

Ari Goldstein

[1] Integrative Biology, University of California Berkeley, Berkeley, CA, U.S.A
Marine Biology, University of California Santa Cruz, Santa Cruz, CA, U.S.A

Corresponding author:

Ari Goldstein

Email Address: arihgold@berkeley.edu

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2674v1 | CC BY 4.0 Open Access | rec: 24 Dec 2016, publ: 24 Dec 2016

Abstract

Global change is a central issue in many fields of science, particularly related to climate. One impact of climate change is changing weather patterns. This study focuses on the effects of changes in rainfall on freshwater stream ecosystems. Streams on small tropical islands are extremely fragile ecosystems. On the South Pacific volcanic island of Moorea, French Polynesia, lies the Opunohu Valley watershed. The Opunohu valley watershed is inhabited by three species of shrimp: *Macrobrachium* sp.*, Atyoida pilipes,* and *Caridina weberi*. These shrimps are key components of their ecosystem because they break down organic material that falls into the stream thereby creating habitat for many other living organisms. Thus, they are a good measure of stream ecosystem health. This study focused on nine different sites throughout Opunohu valley. These sites had been surveyed in 1996 by C. Feldman. Comparisons to survey data collected in 1996 revealed no significant changes over time, demonstrating that shrimp populations have not declined or increased significantly in the last two decades.

Introduction

The climate on our planet is changing rapidly (Meehl *et al.* 2007). This change and its consequences can be seen in a wide variety of biological and environmental indicators and is thus a driving factor in many scientific studies. There is a multitude of ways to quantify the drivers of climate change, including anthropogenic augmentation of atmospheric CO2 levels, and indicators of change such as global temperature increase, rising ocean levels, and poleward migration of climate zones (EPA 2016). Another way of quantifying climate change is by examining variability in an environmental factor such as rainfall (Trenberth 1998). Changing weather patterns may devastate whole ecosystems, especially ones in terrestrial and freshwater environments (Weltzin *et al.* 2003, Lake 2003). Drought especially affects freshwater ecosystems because all the organisms within the ecosystem depend on there being enough water in the system for them to survive (Lake 2003). While the amount of water necessary for survival varies greatly from species to species, and over space and time, stream ecosystems are notoriously sensitive to drought (Lake 2003).

In general, small tropical island ecosystems are quite fragile (Cronk 1997), and stream ecosystems on such islands seem particularly sensitive to environmental perturbations (Smith *et al.* 2003). Accordingly, the Opunohu Valley watershed on Moorea, a small tropical island stream, faces many stressors that affect the health of all organisms living within it. Climate change may cause a multitude of stresses on stream environments, and benthic invertebrates can be particularly sensitive indicators of these stresses (Prather *et al.* 2013). Rainfall is a key factor in regulating the amount of water found in stream environment (Lake 2003). In the South Pacific climate change is predicted to cause weather patterns to be more extreme, meaning that heavy rains will be heavier and droughts will be dryer and longer (Houghton et al., 2001). Large rains can cause drastic changes throughout the whole ecosystem, especially after long periods of little rain (Lake 2003). On small islands the effect of large storms is magnified because the small size and length of streams leaves them unable to buffer against high flow events caused by large storms (Smith *et al.* 2003). When large storms occur after periods of drought, dry streambeds fill with water creating previously nonexistent habitats waiting to be colonized (Craig 2003). Oftentimes these habitats are temporary;

shifting of boulders and loose soil can make the previously dry streambed the new main flow of the stream (Craig 2003). This variability affects many organisms living within streams. With the predicted changes in climate the variability will also become more extreme with larger shifts from more flooded streams to dryer ones.

Shrimp can be considered a keystone species in tropical island stream environments, specifically at mid to high altitudes (Fossati *et al.* 2002). Shrimp are responsible for the breakdown of detritus which is essential to creating a biologically diverse benthos (March *et al.* 2002). On Moorea, there are multiple common shrimp species: *Macrobrachium sp., Atyoida pilipes,* and *Caridina weberi* (Resh *et al.* 1990). In 1996, Feldman focused on the distribution of these three species of shrimp. This study built on Feldman's study and re-surveyed the same localities, using the same procedures. By comparing these data sets this study aims to assess impact of changing weather patterns on stream health. Using shrimp population numbers as a measurement of stream health, this study will analyze whether significant changes in populations of these three species are observable over the past 20 years. This study aims to answer the question of whether the stream ecosystem has changed, and if it has been affected by changing weather patterns.

Materials and Methods

Study site and species

This study focused on three species of shrimp, *Macrobrachium sp., Atyoida pilipes,* and *Caridina weberi,* in the Opunohu River on the island of Moorea, French Polynesia (Fig. 1). Moorea is a small (133 km^2) tropical island formed by hotspot volcanism with a tropical (average temperature of 25-30 ºC) and humid (relative humidity 80-90%) climate, variation in elevation from 0-1207 m and seasonal rainfall of approximately 200-400 cm per year (Resh, Barnes, & Craig 1990). Water flow in rivers on Moorea is highly seasonal, peaking in December and January and slowing to low flow in June and July (Resh, Barnes, & Craig 1990). The three freshwater shrimp species included in this study occur widely across the island. Their life cycles are all diadromous and they are thought to have different feeding techniques (Resh, Barnes, & Craig 1990). Shrimp in the genera of *Atyoida* and *Caridina* have setae on the distal ends of the first and second pereiopods; the setae can be used for passive filter-feeding or they may have teeth-like modifications for feeding on algae on rocks and other food and detritus; *Macrobrachium sp*. are thought to be more opportunistic and aggressive feeders (Resh, Barnes, & Craig 1990).

Field sampling

Shrimp populations were compared at nine study sites along an elevational gradient in the Opunohu Valley. Three sites were selected at each of low, middle, and high elevations. The exact locations of the sites are shown in Figure 2 and described in Table 1. Shrimp were sampled at each of the 9 sites in 6 different microhabitats: riffle, run, pool, leaf pack, bank with vegetation, and bank without vegetation. Riffles, runs, and pools were differentiated by water velocity. Riffles had a water velocity between 20m/ min and 60m/min, runs had water velocities below 20m/ min, and pools had a water velocity of 0m/min. Water velocity was measured using a small piece of

Styrofoam and a measuring tape. Leaf pack was defined as small bundles of leaves caught against boulders or large debris. A bank with vegetation had a minimum 50% cover of vegetation. A bank without vegetation was devoid of all vegetation. A total of 12 microhabitats were absent from a given site. Some sites did not contain all six microhabitats. Four out of nine sites did not contain banks with over 50 percent vegetation. Low elevation sites 1A and 1B were devoid of pools and riffles. Site 1A also didn't have any leaf pack and site 1B lacked banks without vegetation. Additionally, at sites 1C and 2A riffles were not present making a total of four out of nine sites without riffles.

Shrimp were collected using an aquatic D frame net. Samples were taken by dipping the net into the water 15 times at each microhabitat in each location. Net dips were done with the intention of maximizing the amount of area sampled. This method was repeated a total of six times at each microhabitat in every location. A total of 90 net dips were done in each microhabitat. Once captured, shrimp were identified to species using characteristic body color and pattern (Fig. 1). Additionally, data on important habitat factors was collected including percent rooted vegetation, percent leafy material, substrate type, depth, and width. Sampling was designed so that results would allow direct comparison with a baseline assessment conducted in 1996 (Feldman 1996) and thereby allow examination of shrimp distributions and abundance over time.

Statistical analyses

To test if certain species prefer certain habitat factors such as leafy material in the stream bed or rooted vegetation along the stream or elevation, a Pearson correlation test was run (Table. 2) between each habitat factor and each species using Microsoft excel (Microsoft excel spreadsheets 2016). A matched-pair t-test was used to test the difference between data collected in 2016 and those from 1996 using Graphpad.com (Graphpad software 2016). Additionally, percent change between 1996 and 2016 was calculated for each species at each elevational gradient and each microhabitat.

Results

Elevational comparison

A total of 1765 shrimp were sampled in the Opunohu Valley watershed. *Caridina weberi* was numerically dominant accounting for 53% of all shrimp sampled (927 individuals). *Macrobrachium sp*. was the second most common, accounting for 26% (463 individuals) of shrimp caught. *Atyoida pilipes* was the least abundant species, accounting for only 21% (375 of all individuals).

The low elevation sites (1A, 1B, 1C) were largely populated by *Macrobrachium sp.*. They represented 91% of shrimp found at the three low elevation sites (235 out of 257 individuals). Of all *Macrobrachium* counted, 51% were sampled in these three low elevation sites. C. *weberi* and A. *pilipes* were 5%(12) and 4%(10) of shrimp sampled at low elevation sites respectively. The middle elevation sites (2A, 2B, 2C) were numerically dominated by C. *weberi. Caradina weberi* represented 60% (296 out of 496 individuals of all species) of all shrimp sampled in middle elevation sites. *Macrobrachium* were second most abundant at 29% (144) of shrimp at middle elevation

sites. Atyoida *pilipes* were most scarce in middle elevation sites, representing only 11% (56) of all shrimp caught at sites 2A, 2B, and 2C. High elevation sites (3A, 3B, 3C) were also dominated numerically by C. *weberi*; which represented 61% (619 out of 1015 individuals of all species) captured at high elevation. Atyoida *pilipes* obtained were 30% (309) of all shrimp found at high elevation sites. *Macrobrachium* were least abundant at high elevation accounting for only 9% (87) of shrimp sampled. All of these observations are depicted in Figure 3.

A matched-pair t-test was used to compare data from 1996 with data from the present study. The results of the matched-pair t-test showed no statistically significant change in the population. When examining the percent change of species at each elevational gradient where all species of shrimp were present in both years high percent changes occurred only in *C. weberi* at middle elevation sites where the species had a 370 percent increase in population. All other percent changes in the elevational analysis were between negative and positive 100.

Microhabitat comparison

The three species of shrimp partitioned themselves differently among all the microhabitats. *Macrobrachium* was the most generalist, showing the least preference for specific microhabitats; A. *pilipes* and C. *weberi* were more specialized showing large preferences for leaf pack. *Macrobrachium* was captured most often in banks without vegetation, leaf pack, runs, and pools. *Macrobrachium* were less commonly captured in banks with vegetation and riffles. Of the 463 *Macrobrachium* sp. sampled, 109 came from banks without vegetation, 106 from runs, 91 from pools, 80 from leaf packs, 37 from banks with vegetation, and 31 from riffles. Atyoida *pilipes* was most abundant in leaf packs. Of the 375 A. *pilipes* caught, 143 were caught in leaf packs, 79 in riffles, 47 in banks without vegetation, 35 in pools, 26 in runs, and 6 in banks with vegetation. Caradina *weberi* was by far most abundant in leaf pack. Of the 927 C. *weberi* collected, 452 were collected from leaf packs, 129 from banks without vegetation, 67 from runs, 62 from pools, 48 from riffles and 3 from banks with vegetation. These observations are depicted in Figure 4.

Once again when this data was compared to the paired data from 1996 using a matched-pair t-test no significant difference between 2016 and 1996 was detected. Examining percent change calculations revealed large changes in the shrimp populations within the leaf pack. Both *C. weberi* and *Macrobrachium* showed large increases of 335 and 167 percent respectively. All other percent changes were between negative and positive 100.

Habitat Factors

Relationships between each individual species, percent leafy material, percent rooted vegetation, distance from stream mouth, and elevation were determined by using a pearson correlation. This study found many statistically significant correlations. *Atyoida pilipes* and *C. weberi* were positively correlated with leafy material and showed a slight negative correlation with rooted vegetation. While *Macrobrachium sp.* showed no

correlation with leafy material or rooted vegetation, this study found them to have a slight negative correlation with elevation and distance from stream mouth. Both smaller species, *A. pilipes* and *C. weberi* were found to be positively correlated with elevation and distance from stream mouth especially *A. pilipes*. All of these correlation values can be seen in Table 2.

Discussion

Elevational comparison

Although the shrimp family Atyidae was not found at low elevation sites in Feldman's 1996 study, this study found both C. *weberi* and A. *pilipes* to be present at low elevation sites. This contradiction between data sets suggests that there may have been a shift in the range of these two species. A shift such as this could have been caused by loss of habitat at higher elevation sites where they are more abundant or by range expansion due to favorable conditions being found at new locations (Opdam and Wascher 2004). Such changes in habitat can be caused by drought or extreme weather patterns (Opdam and Wascher 2004). *Caradina weberi* have shown some changed in their elevational preferences. Not only were they found at low elevation where they hadn't been previously. They were also found in higher numbers at middle elevation sites (370 percent increase) and were less dominant at the higher elevation sites than they were in 1996 (37 percent decrease). Additionally, this study found that A. *pilipes* and *Macrobrachium* sp. were more abundant in high elevation sites than in 1996 (70 and 50 percent increases respectively). It appears that where there was a gap in habitat space due to fewer C. *weberi* that the other two species of shrimp filled this available space. While there are slightly fewer shrimp in the streams of Opunohu Valley overall, it appears that there has been some shifting in which elevational macro habitats each species in choosing to reside in. However, this study did not find any larger scale changes in shrimp populations; rather it found that shrimp populations have been resistant against large scale change over the last two decades.

Microhabitat comparison

Atyoida pilipes was found to be absent from banks with and without vegetation by Feldman. However, this study found A. *pilipes* in banks with and without vegetation. This could be due to decreased area with fast moving water which a previous study found that they prefer (Feldman 1996). Less fast moving water also causes less sediment resuspension which leads to more leaf litter at the bottom of pools and less leaf litter pushed up against boulders creating leaf packs (Madsen *et al.* 2001). Leaf pack is usually preferred over pools by *A. pilipes*. Perhaps there is a lack of high flowing water which has caused a change in availability of habitat and thus a shift in where A. *pilipes* is most commonly found.

In 1996, Feldman found large numbers of *Macrobrachium* in banks with vegetation. This 2016 study did not have similar findings however; this may not be because of a change in microhabitat preference but instead may be due to a change in microhabitat availability. This study often did not find banks with vegetation at the sample sites. This is reflected in Figure 4 where 2016 has much smaller bars for bank

with vegetation. Overall this study found a larger negative percent change in *Macrobrachium* than the other species of shrimp in Opunohu streams.

Caradina weberi was found by Feldman in 1996 to dominate runs and pools whereas this 2016 study found *C. weberi* in the highest abundance in leaf packs. This difference is intriguing because these habitats are areas with lower flow rates. Thus, it is unsurprising to find *C. weberi* in the leaf pack associated with pools and runs because they would prefer the slower moving water surrounding these leaf packs. The question is why weren't *C. weberi* sampled in higher numbers by this study in pools and runs where they had previously been shown to dominate. Perhaps there is less water in the streams creating less habitat area in pools and runs, leaving relatively large leaf packs within and around runs and pools.

Habitat factors

Pearson correlation tests revealed many statistically significant correlations between habitat factors and species. Some of these correlations are supported by previous studies and others are contradictory. Due to large sample size, most values are significant (Fig. 5). The finding that *Macrobrachium sp.* were slightly negatively correlated with elevation and distance from stream mouth was consistent with Feldman's 1996 survey. However, this study found that *Macrobrachium* showed negligible correlations with leafy material and rooted vegetation whereas the previous study found *Macrobrachium* to have a slight negative correlation to leafy material and a moderately strong correlation to rooted vegetation. As discussed previously, the lack of correlation between *Macrobrachium* and rooted vegetation is probably due to a general lack of rooted vegetation along stream banks. When comparing correlations in the species *A. pilipes,* 1996 and 2016 show no large difference in correlations with leafy material or rooted vegetation. On the contrary, there was a large difference observed in the correlation of *A. pilipes* with elevation and distance from stream mouth in 2016 when compared to 1996. This study found a large positive correlation between both elevation and distance from stream mouth with *A. pilipes*, whereas Feldman's study found negligible correlation between these variables and *A. pilipes.* This result is particularly interesting considering that in 2016 *A. pilipes* were found at low elevation sites where they were not found in 1996. This suggests that *A. pilipes* populations at high elevations are extremely dense when compared to 1996. *Caradina weberi* were not found to have quite as large change in what habitat factors they were correlated to. They showed slight change in preference for leafy material (less preference), elevation (more preference), and distance from stream mouth (more preference) while showing no significant preferences for or against rooted vegetation.

By comparing shrimp populations in the Opunohu Valley watershed over two decades this study found that populations of shrimp have remained stable with some shifting in microhabitat and elevational distributions. Shrimp populations appear to have been resilient, suggesting that any changes which have occurred, including possible changes in weather patterns due to global climate change, have not yet significantly impacted the shrimp populations. By continuing to study these shrimps and small island streams on Moorea over a longer time period, more insight could be gained on how

exactly this ecosystem continues to be resilient, or changes in the future, as our planet's conditions change. This information could be invaluable in understanding species changes and potentially preserving species in similar habitats as global climate change continues altering our planet.

Works cited

"Climate Change: Basic Information." *EPA*. Environmental Protection Agency, 29 Sept. 2016. Web. 28 Oct. 2016.

Craig, D A. "Geomorphology, development of running water habitats, and evolution of black flies on Polynesian islands." *BioScience* 53.11 (2003): 1079-1093.

Cronk, Q. C. B. "Islands: stability, diversity, conservation." *Biodiversity & Conservation* 6.3 (1997): 477-493.

Feldman, C. "Distribution and Ecology of Freshwater Shrimp (Decapoda) in the Opunohu River, Moorea, French Polynesia." The Biology and Geomorphology of Tropical Islands (1996): 151-62. Web.

Fossati, O., Merri, M., and Philipe, K. "Distribution and habitat utilization in two atyid shrimps (Crustacea: Decapoda) in rivers of Nuku-Hiva Island (French Polynesia)." *Hydrobiologia* 472.1-3 (2002): 197-206.

Houghton, J..T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J, Dai, X., Maskell, K., Johnson, C. A. (eds). 2001. "Climate Change 2001:The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge University Press: Cambridge, UK.

Lake, P. S. "Ecological effects of perturbation by drought in flowing waters." *Freshwater biology* 48.7 (2003): 1161-1172.

Madsen, J. D., Chambers, P. A., James, W. F., Koch, E. W., and Westlake, D. F. "The interaction between water movement, sediment dynamics and submersed macrophytes." Hydrobiologia, 444. 1-3 (2001): 71-84.

March, J. G. , Pringle, C. M. , Townsend, M. J., and Wilson, A. I. "Effects of freshwater shrimp assemblages on benthic communities along an altitudinal gradient of a tropical island stream." Freshwater Biology, 47 (2002): 377–390.

Meehl, G. A., *et al.* "Global climate projections." *Climate change* 3495 (2007): 747-845.

Opdam, P., and Dirk, W. "Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation." *Biological conservation* 117.3 (2004): 285-297.

Prather, C. M., Pelini, S. L., Laws, A., Rivest, E., Woltz, M., Bloch, C. P., Del Toro, I., Ho, C.-K., Kominoski, J., Newbold, T. A. S., Parsons, S., and Joern, A. “Invertebrates, ecosystem services and climate change.” Biol Rev, 88 (2013): 327–348.

Resh V. H. Barnes, J. R., Craig, D. A. “Distribution and ecology of benthic macroinvertebrate in the Opunohu river catchment, Moorea, French Polynesia.” Annls Limnol. 25, 2-3 (1990):195-214.

Smith, G. C., Alan, P. C, and Anne, M. D. B. "An ecological perspective on the biodiversity of tropical island streams." *BioScience* 53.11 (2003): 1048-1051.

Trenberth, K. E. "Atmospheric moisture residence times and cycling: Implications for rainfall rates and climate change." *Climatic change* 39.4 (1998): 667-694.

Weltzin, J. F., Loik, M. E., Schwinning, S., Williams, D. G., Fay, P. A., Haddad, B. M., ... and Pockman, W. T. “Assessing the response of terrestrial ecosystems to potential changes in precipitation.” Bioscience, 53, 10 (2003): 941-952.

PeerJ Preprints NOT PEER-REVIEWED

Figure 1(on next page)

Shrimp identification images

Figure 1: Images of each of the three shrimp species observed in the Opunohu Valley watershed on Moorea (Images used for identification are from the Moorea Biocode project website)

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2674v1 | CC BY 4.0 Open Access | rec: 24 Dec 2016, publ: 24 Dec 2016

PeerJ Preprints NOT PEER-REVIEWED

Caradina weberi

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2674v1 | CC BY 4.0 Open Access | rec: 24 Dec 2016, publ: 24 Dec 2016

PeerJ Preprints NOT PEER-REVIEWED

Atyoida Pilipes

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2674v1 | CC BY 4.0 Open Access | rec: 24 Dec 2016, publ: 24 Dec 2016

PeerJ Preprints NOT PEER-REVIEWED

Macrobrachium sp.

PeerJ Preprints NOT PEER-REVIEWED

Table 1 (on next page)

Site locations

Table 1. Name and approximate location of nine sites sampled in Opunohu Valley, three each at low, middle, and high elevations.

1. Low elevation sites
1A: (mouth of Opunohu) 0m elevation, 0km from the Opunohu river mouth
1B: 2m elevation, 0.25km from the Opunohu river mouth
1C: 2m elevation, 0.4km from from the Opunohu river mouth
2. Middle elevation sites
2A: (W. fork of Opunohu) 5m elevation, 0.7 km from the Opunohu river mouth
2B: (W. fork of Opunohu) 10m elevation, 1.0 km from the Opunohu river mouth
2C: (E. fork of Opunohu) 16m elevation, 1.7 km from the Opunohu river mouth
3. High elevation sites
3A: (Below Marae Tetiiroa) 120m elevation, 2.8 km from the Opunohu river mouth
3B: (Marae Tetiiroa) 140m elevation, 3.0 km from the Opunohu river mouth
3C: (Behind/below belvedere lookout) 245m elevation, 3.6 km from the Opunohu river mouth

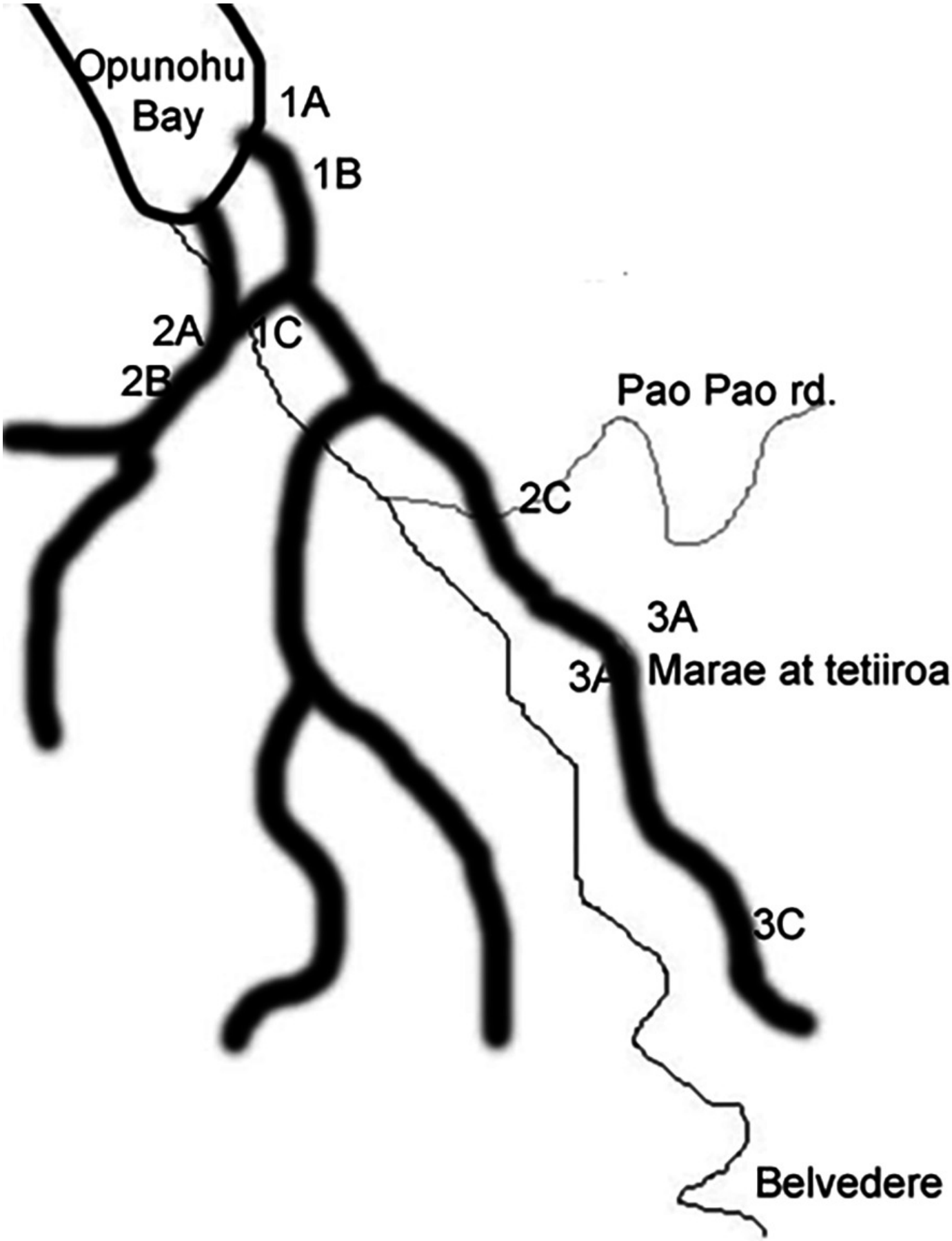
PeerJ Preprints NOT PEER-REVIEWED

Figure 2

Map of study sites

Figure 2: Map of approximate location of study sites

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.2674v1 | CC BY 4.0 Open Access | rec: 24 Dec 2016, publ: 24 Dec 2016


Opunohu
Bay
1A
1B
2A
1C
2B
Pao Pao rd.
2C
3A
3A
Marae at tetiiroa
3C
Belvedere

PeerJ Preprints NOT PEER-REVIEWED

Table 2 (on next page)

Pearson correlation values

Table 2: Pearson Correlation values between shrimp species populations and observed stream variables.

sample size	shrimp species	% leafy material	% rooted vegetation	elevation (m)	distance from stream mouth (km)
n=927	Caridina weberi	0.40844399	-0.123942263	0.351015	0.29445644
n=375	Atyoida pilipes	0.34000526	-0.137626033	0.74339731	0.62108443
n=463	Macrobrachium	-0.0593305	0.029974957	-0.2025226	-0.2842023

Figure 3

Shrimp Abundance by Species Elevation and Time

Figure 3: This graph depicts the shrimp sampled in 2016 alongside the shrimp sampled in 1996 by Feldman. It categorizes Shrimp on the x axis by species elevation and year. On the y axis by the number of shrimp caught .

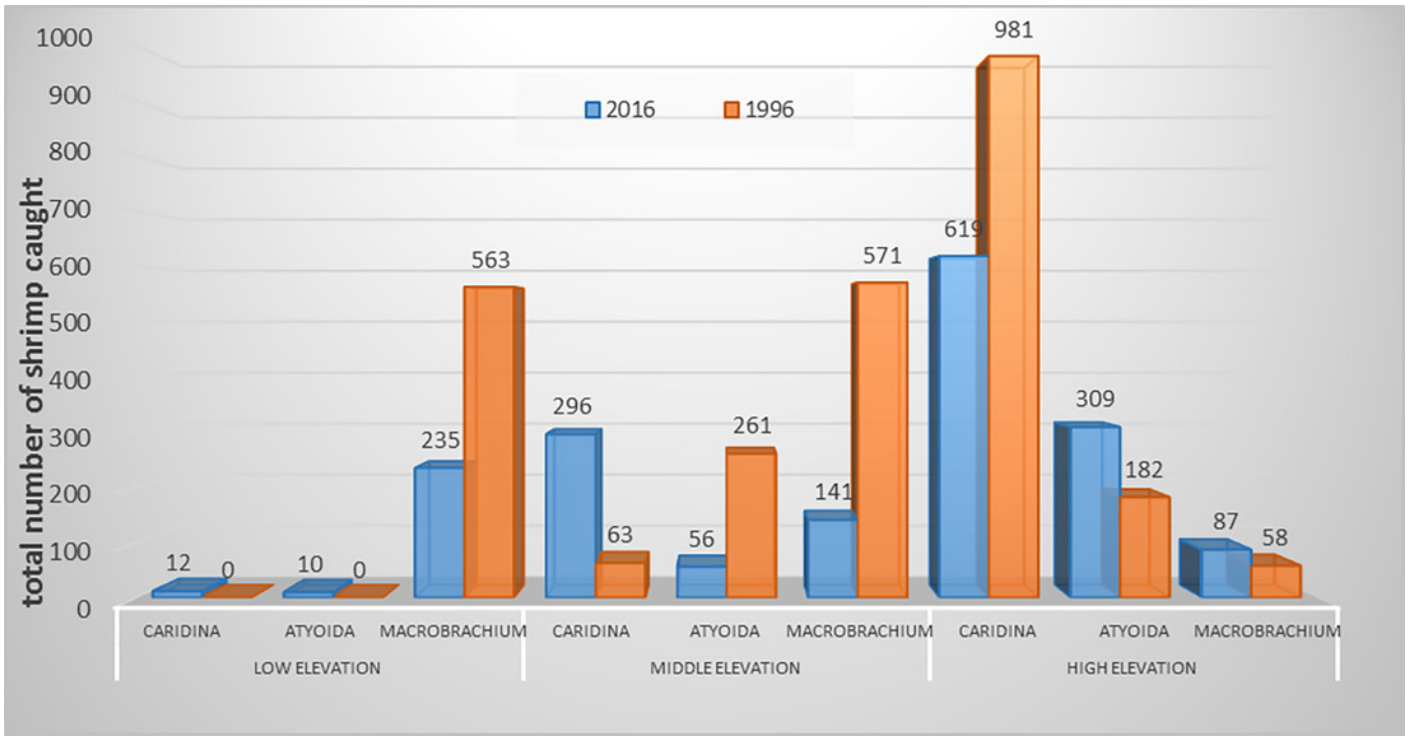


Figure 4

Microhabitat preferences then and now

Figure 4: This graph shows microhabitat preference by species and year on the x axis. The solid bars represent data from 2016 and the checkered bars represent data from 1996. Each color represents a different species. On the y axis, the total number of shrimp caught is shown.

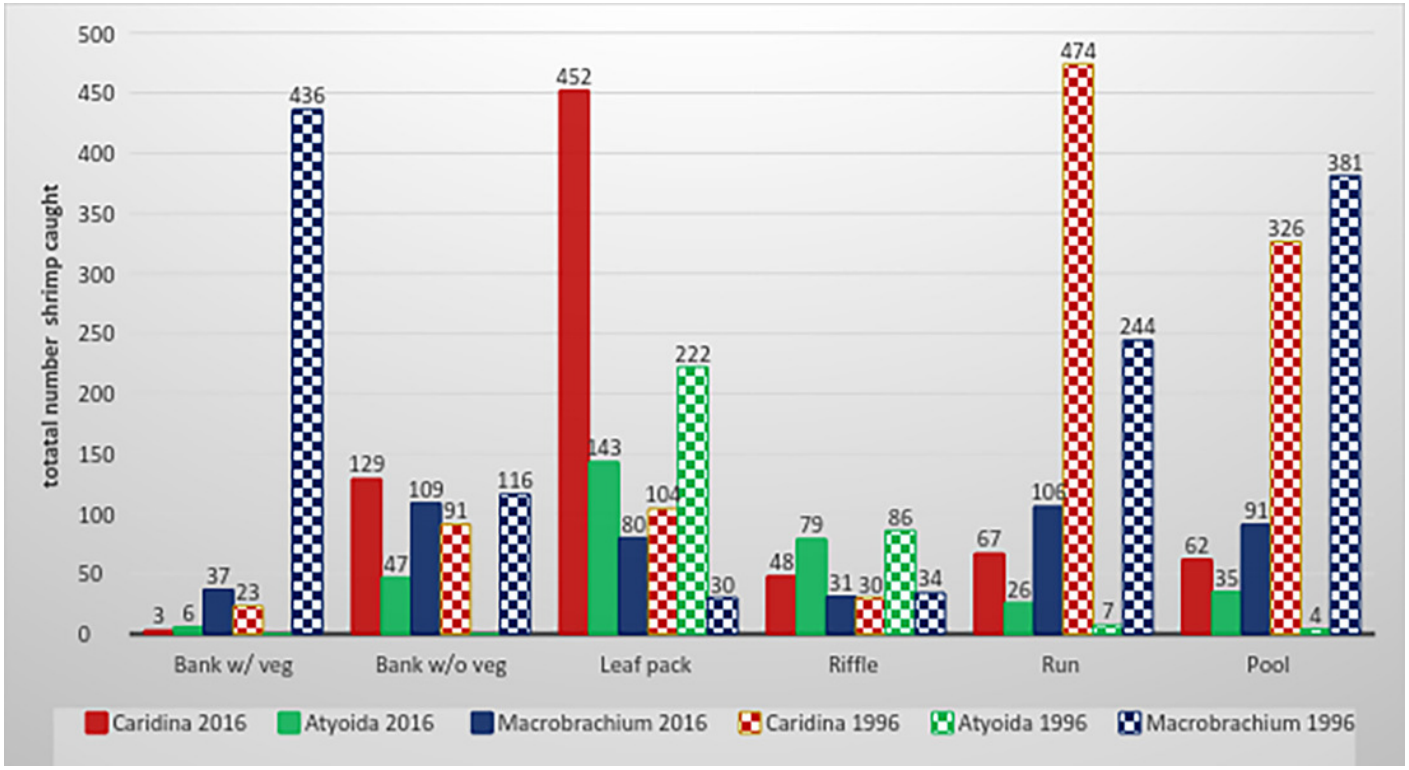


Figure 5

Correlation significance

Figure 5: This plot shows the minimum value of Pearson's correlation coefficient that is significantly different from zero at the 0.05 level, for a given sample size. (Skbkekas - Own work, CC BY 3.0,)