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MONITORING OF THE FRESHWATER AMPHIDROMOUS POPULATIONS OF THE 'OHE'O GULCH STREAM SYSTEM AND PUA'ALU'U STREAM, HALEAKALA NATIONAL PARK

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ABSTRACT

Conservation and management of Hawai'i's native freshwater-amphidromous fishes, crustaceans, and gastropods is hindered by a lack of biological information. A one year project was begun at 'Ohe'o Gulch, Haleakalā National Park in November, 1992 to develop population survey methodologies for application at 'Ohe'o and other streams, to establish a baseline of population information at 'Ohe'o, and to gather population data which could be compared to populations elsewhere. Direct observation quadrat methods were used to survey the populations of 'o'opu (*Lentipes concolor, Sicyopterous stimpsoni*, and *Awaous guamensis*), 'ōpae kuahiwi (*Atya bisulcata*), and hīhīwai (*Neritina granosa*). Trapping was used to survey the alien prawn *Macrobrachium lar*. During the project the 'o'opu and 'ōpae populations were surveyed twice each. Hīhīwai and *M. lar* were surveyed three and four times each respectively. Habitat quality appeared poor overall, but good in some upper segments of the stream system. The method developed for 'o'opu provided consistent results between observers and through time. Methods for the other species also provided good results. In the cases of 'o'opu and 'ōpae, numerical resampling of survey data demonstrated that statistical power to detect temporal changes in overall density is likely to be enhanced by using fewer quadrats per station and a greater number of stations in subsequent surveys. The overall size frequencies and the within-stream distribution of average sizes of 'o'opu, 'ōpae, and *M. lar* were fairly stable. The within-stream species distribution of 'o'opu conformed to expectations and was also stable. In comparison with other streams in pristine areas of Hawai'i, 'o'opu and 'ōpae abundance was generally low. However, 'o'opu 'alamo'o were locally abundant and individual 'alamo'o were very large in some areas. Hīhīwai were almost non-existent and appear to have declined in abundance since a prior survey two decades ago. *M. lar* were abundant and exhibited symptoms of 'black-spotted' disease. Other demographic characteristics of these species were analyzed. The causes of the observed low native faunal abundance in 'Ohe'o are unknown. Limited surveys were also carried out in next-door Pua'alu'u Stream. Within-stream species distribution differed between lower 'Ohe'o and the lower reach of Pua'alu'u. Such difference may be attributed to differing hydrology and geomorphology. Population monitoring in 'Ohe'o should continue and include monitoring of reproduction and recruitment via larval trapping at the terminus. Such monitoring might be conducted in conjunction with an *M. lar* control program.

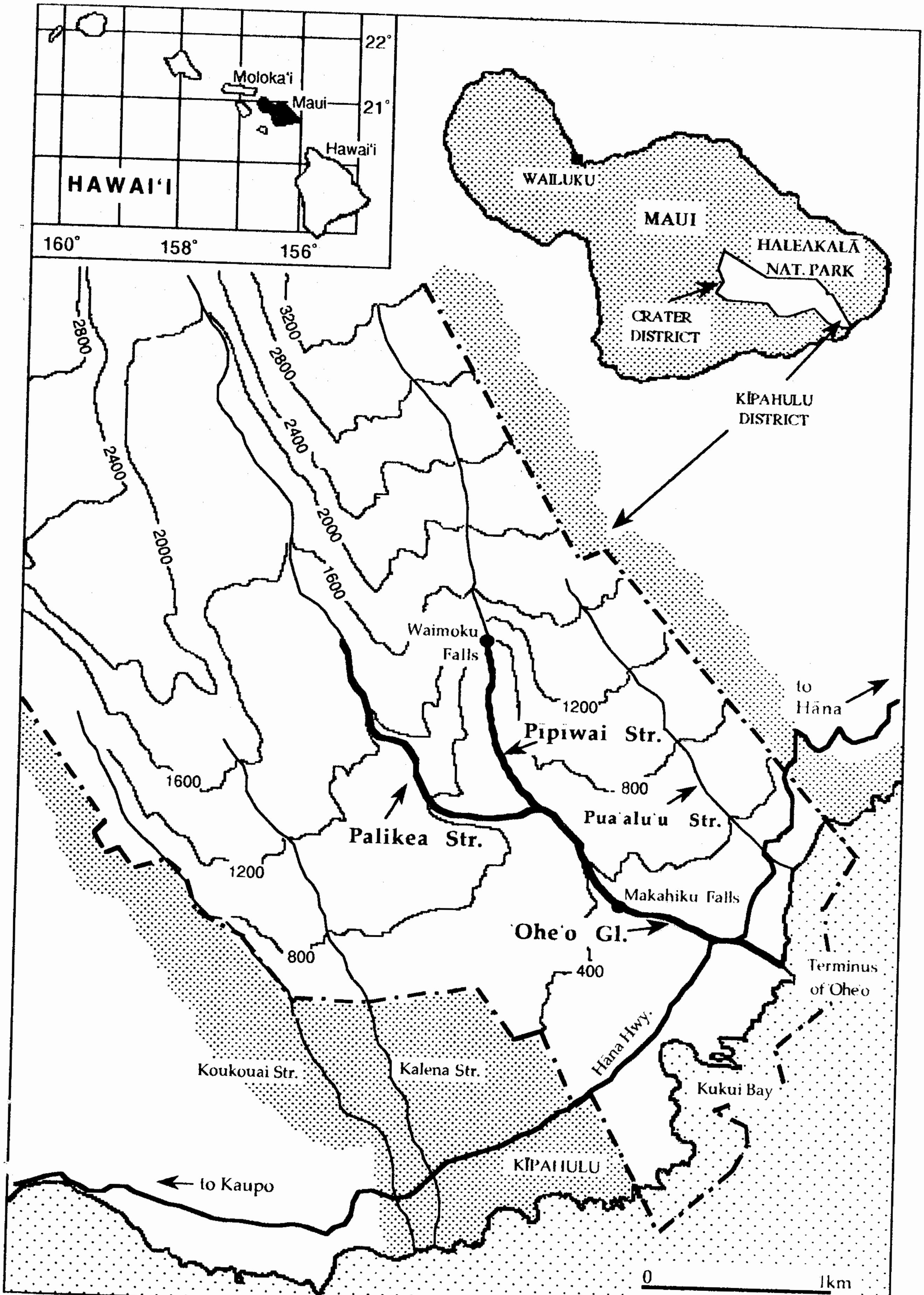


Fig. 1. Study area. Lower Kīpahulu Valley and the 'Ohe'o Stream System, Maui. (Redrawn from Kinzie and Ford 1977).

INTRODUCTION

The Research Division of Haleakalā National Park recognized the need for the establishment of baseline population information, and initiation of long term population monitoring of the native aquatic macrofauna species at 'Ohe'o, in the Kīpahulu District of the Park. The overall goal was to gather information necessary for management of Hawaiian stream populations. The specific objectives of this project were:

- develop survey methodologies and protocol for application in 'Ohe'o and other streams;
- establish baseline information on the aquatic populations in 'Ohe'o for monitoring of population trends in 'Ohe'o, and comparison of population data from 'Ohe'o to that of other streams.

Development and application of population survey methods for the macrofauna were begun in November of 1992. The methods developedhere were based on work by Baker 1991, Baker and Foster 1992, Hodges 1992, A. Brasher, R. Nishimoto, R. Kinzie, W. Kubota, and others.

Hawaiian Streams and Stream Life

Hawaiian streams host a unique, disharmonic fauna (Kinzie 1988). This fauna includes insects, five species of goby (four are endemic), two endemic decapod crustaceans, and endemic gastropods (Anon 1990).

In the islands and archipelagos of Oceania, as geographic isolation increases, species richness in many community types declines. Hawai'i is the most isolated archipelago in the world. As a result, although the faunal community in Hawaiian streams is very similar to faunal communities in streams throughout the Indo-Pacific, Hawaiian streams have comparatively few species (e.g. Timbol et al. 1980, Maciolek 1984). Kinzie (1990) provides an excellent profile of Hawaiian freshwater species.

The streams which these species inhabit are most often exorheic and relatively pristine. Such streams occur primarily in remote areas on the windward sides of the main Hawaiian Islands. They are cool and well-oxygenated, with boulder, cobble and gravel substrates (e.g. Anon. 1990).

The Hawaiian freshwater macrofauna (gobies, decapod crustaceans, and neritid gastropods) share an important life history trait. They are all freshwater-amphidromous (Ford and Kinzie 1982, Kinzie and Ford 1982, McDowall 1992). The adult forms occur in freshwater. Larvae are released through various methods into the water column of the stream where they are swept to the sea to continue development as marine plankton. Any dispersal among streams occurs during this stage. After a period of development in the sea, the larvae enter a stream and migrate to the adult habitat. Adults habitat can range from the mouth to many kilometers upstream.

The range and populations of the Hawaiian macrofauna have been drastically reduced since historical times (Ford and Yuen 1988). The primary threat to Hawaiian stream life is anthropogenic habitat degradation (Maciolek 1975, Maciolek 1978, Parrish et al. 1978, Ford and Yuen 1988). Extensive invasion of native communities by alien species also occurs (Maciolek 1975, Kinzie and Ford 1977, Timbol et al. 1980, Kinzie and Ford 1982, Maciolek 1984, Kinzie 1988). Justified concern for the management and conservation of this unique fauna has grown recently (e.g. Lum et al. 1989, Anon. 1990). A few high-quality streams now enjoy private and public conservation efforts (e.g. Ford and Yuen 1988). However, there has been little direct management effort. Lack of biological information is one of the obstacles to effective management (Anon. 1990). Comparatively little is known of the Hawaiian aquatic macrofauna species, and quantitative population time series data sets are still rare.

'Ohe'o Gulch

Kīpahulu District of Haleakalā National Park encompasses the entire channel length of the 'Ohe'o Gulch stream system. 'Ohe'o is one of only two Hawaiian stream systems fully within National Park Service management jurisdiction. However, in both instances the State of Hawai'i retains water development rights.

Three of the four endemic gobioid fishes, *Lentipes concolor* ('o'opu 'alamo'o), *Sicyopterous stimpsoni* ('o'opu nōpili) and *Awaous guamensis* ('o'opu nākea); the endemic decapod crustaceans *Atya bisulcata* ('ōpae kuahiwi, referred to herein as "ōpae') and *Macrobrachium grandimanus* ('ōpae 'oeha'a); one of the two endemic neritid molluscs, *Neritina granosa* (hīhīwai); and a range of native and endemic insects are known to inhabit 'Ohe'o. The alien prawn *Macrobrachium lar* also occurs in this stream system. Kinzie and Ford (1977) conducted initial faunal surveys in 'Ohe'o.

Study Area

Physical setting

The 'Ohe'o Gulch stream system is comprised of Palikea and Pīpīwai Streams, and 'Ohe'o Gulch (Fig. 1). Palikea is the main drainage of Kipahulu Valley. The headwaters of Palikea are at approximately 1800 m elevation. Palikea flows over ten km from its headwaters to its confluence with Pīpīwai at 500 m elevation. Pīpīwai, with headwaters at 987 m, drains a portion of the northern shoulder of Kīpahulu Valley. Pīpīwai flows approximately 3 km from headwaters to the confluence. Palikea and Pīpīwai together drain 2,250 ha. Palikea joins with Pīpīwai at the confluence to become 'Ohe'o Gulch. 'Ohe'o Gulch flows 1.8 km to its terminus at the sea near 156°30" W, 20°N. I defined Upper 'Ohe'o Gulch as that segment extending from the confluence to Station 1270 just below Makahiku Falls, and Lower 'Ohe'o Gulch as extending seaward from this point to the terminus. I refer to Palikea, Pīpīwai and 'Ohe'o Gulch collectively as the 'Ohe'o stream system, or simply 'Ohe'o. Kinzie and Ford (1977) diagram the vertical profile of the 'Ohe'o stream system.

The area drained by 'Ohe'o Gulch, the length of Pīpīwai between the confluence and Waimoku Falls ('lower Pīpīwai'), and the length of Palikea between the confluence and a point approximately 1.5 km upstream ('lower Palikea') is dominated by alien vegetation and pasture land. Much of this area was cleared for sugar planting and cattle during the 1920's (Kinzie and Ford 1977). Although sugar is gone, cattle are still pastured on the valley slopes above Palikea and Pīpīwai. In sharp contrast to these poor watershed conditions, upper Palikea and Pīpīwai drain high quality native forestlands.

Morphology and Hydrology

The channel morphology of 'Ohe'o Gulch is extremely heterogeneous, characterized by large waterfalls and pools, bedrock runs and cascades, and stretches of boulder riffles. Bank to bank width varies from a few meters at constricted bedrock runs to more than 50 meters in the larger pools. During the period of this study, flow was extremely variable but for the most part continuous in time and space. Large flood events were common. Water clarity was usually low near the terminus but high in the upper reaches.

The channel morphology of lower Palikea is very similar to that of 'Ohe'o Gulch. Kinzie and Ford (1977) described lower Palikea as intermittent. This was also the case during this study. Although water remained in large pools and bedrock pockets during periods of low flow, several long stretches (e.g. 10^2 m) of boulder riffle, which occur between pools, dried completely. During non-spate conditions water clarity was generally very high. Insolation caused considerable temperature stratification in the large pools during low flow conditions. Large spates were common in this region during the study.

Lower Pīpīwai is essentially a single, three meter-wide, boulder riffle. Kinzie and Ford (1977) described Pīpīwai as perennial, and noted that although no water records are available, discharge appears to be much less than that of Palikea. They also noted that aspects of streambed appearance, such as a high proportion of fine bed material and vegetation growing to the very edge of the stream, suggested that the 'scouring torrential floods common to Palikea' were uncommon in Pīpīwai. No great fluctuations in water quality were observed during their work. The conditions apparent at Pīpīwai during the present study were very similar to what they described. Flow was continuous during all observations. Fine bed materials were common. Riparian vegetation grew close to the water's edge. Water clarity was most often high. However, on a handful of occasions increased flows and turbidity were observed.

Water Quality Information

Certain water quality parameters were recorded by the U.S. Geological Survey at the former gage station site (Palikea) on a number of occasions between 1972 and 1981 (U.S. Geological Survey 1972, 1974 to 1981). Of the USGS observations, specific conductance averaged 33.6 μS cm^{-1} (± 9.4, n = 52); pH, 6.8 (± 0.4, n = 52); temperature, 19.22 (± 1.9, n = 50); and sum of constituent dissolved solids, 23 mg/l (± 7.5, n = 9).

I recorded selected water quality parameters at Lua Falls, Palikea on 5/28/93; Pīpīwai station 2710 on 5/29/93; 'Ohe'o station 1560 on 5/27/93; and 'Ohe'o station 40 on 5/26/93. Five measurements were taken across the channel at each location.

The Lua Falls station is very close to the USGS gage station site on Palikea. At Lua Falls specific conductance averaged 32.3 μS cm^{-1} (± 0.4); pH, 6.59 (± 0.32); temperature, 19.5 (± 0.3); and total dissolved solids, 16.1 mg/l (± 0.3).

Values recorded at the other three locations in 'Ohe'o during this study have no comparable historical records, but allow a glance at water quality differences among regions of 'Ohe'o. At Pīpīwai station 2710 specific conductance averaged 85.5 μS cm^{-1} (± 0.7); pH, 7.0 (± 0.32); temperature, 18.7 (± 0.9); and total dissolved solids, 42.9 mg/l (± 0.4). At 'Ohe'o 1560 the average values were 61.2 μS cm^{-1} (±2.4); 6.7 (± 0.4); 20.3 (± 0.3); and 29.1 mg/l (± 0.4). At 'Ohe'o 40 they were 52.3 μS cm^{-1} (± 1.3); 7.3 (± 0.32); 20.3 (± 0.3); and 23.6 mg/l (± 0.3).

Discharge Information

A USGS gaging station was located at Palikea near 490 m elevation for 48 years prior to the 1984 water year. That gage ceased operation in 1983. Gaging activities were begun again in 1988 on 'Ohe'o Gulch at 128 m elevation (U.S. Geological Survey 1991, Fig. 2).

The average of mean monthly discharges at the new 'Ohe'o gage for the 1988-1989, 1989-1990 and 1990-1991 water years were 79.3 (9.65 to 218), 61.5 (5.28 to 145), and 101.7 (12.5 to 334) cfs respectively (discharge data for the 1992-1993 water year at the new gage site are not yet available). Discharge in 'Ohe'o is extremely variable: the ranges of instantaneous discharge in each of the 88-89 and 90-91 water years were .63 to 6,470 and 2.5 to 3200 cfs respectively (data from U.S. Geological Survey 1989, 1990, 1991).

The mean daily discharge of 'Ohe'o can be strongly correlated with that of other East Maui streams. Mean daily discharge measurements are temporally auto-correlated and thus not independent. This prevents the use of regression to determine the extent of correlation. However, a correlation coefficient calculated from WY 1991 data between 'Ohe'o and the other East Maui streams at which USGS records daily discharge measurements illustrates this correlation: Hanawi-r^2 = .623; West Wailuaiki - r^2 = .535; Honopou - r^2 = .518. Scattergrams demonstrate that these correlations are solid. Correlation coefficients are also fairly strong with the West

Maui stream 'Iao - r^2= .542. Gaged streams further west than Iao exhibit a positive correlation but scattergrams indicate curvilinearity and increasing variability in the residuals with increasing discharge.

METHODOLOGY

Station Layout

Permanent sampling stations were established along 'Ohe'o Gulch, lower Pīpīwai and lower Palikea (Figs. 2,3). Difficulty of access discouraged survey work above these points. Kinzie and Ford (1977) conducted their work in these same three areas. However, in that study the emphasis was on 'Ohe'o Gulch. During the present surveys, effort was allocated randomly throughout these three areas. The locations of sampling stations were randomly chosen. Station numbers represent the approximate distance in meters between the station and the terminus at the ocean. Not all stations were used for all of the taxa surveyed.

In the case of 'o'opu, the upper limit of sampling in Palikea corresponds with the upper limit of 'o'opu occurrence. The 'o'opu may occur above Waimoku Falls in Pīpīwai. Again, extreme difficulty of access discouraged sampling in this area. However, observations at comparable elevations in Palikea indicate that 'o'opu are very unlikely to occur much above Waimoku Falls.

Kinzie and Ford (1977) performed aquatic population survey work at nine stations located in 'Ohe'o, and two in each of Palikea and Pīpīwai. Their Stations 1 through 4 correspond generally to Stations 40 to 170 of this survey, 5 through 8 to Stations 490 to 1120, 12 and 13 very roughly to Pīpīwai 2110 and 2710, and 10 and 11 very roughly to 1904 and Lua Falls (2770) respectively.

Survey Methods

Direct observation techniques with a facemask and snorkel were used to survey the populations of 'o'opu, 'ōpae and hīhīwai. Non-destructive trapping was used to survey *M. lar*.

Direct Observation

I used direct observation to survey the populations of hīhīwai, 'o'opu, and 'ōpae. Observations were made in randomly placed quadrats. Observations at each quadrat were restricted to a specific period of time for each of 'ōpae and 'o'opu. Ten quadrats were used at each station to survey hīhīwai, 'o'opu, and 'ōpae. Quadrats locations were different for each taxa, but fixed for a given taxa throughout the study.

Sample area: The sampling area (the area from which samples were drawn) at each station was fixed. This prevented variation in sampling fraction among stations, and

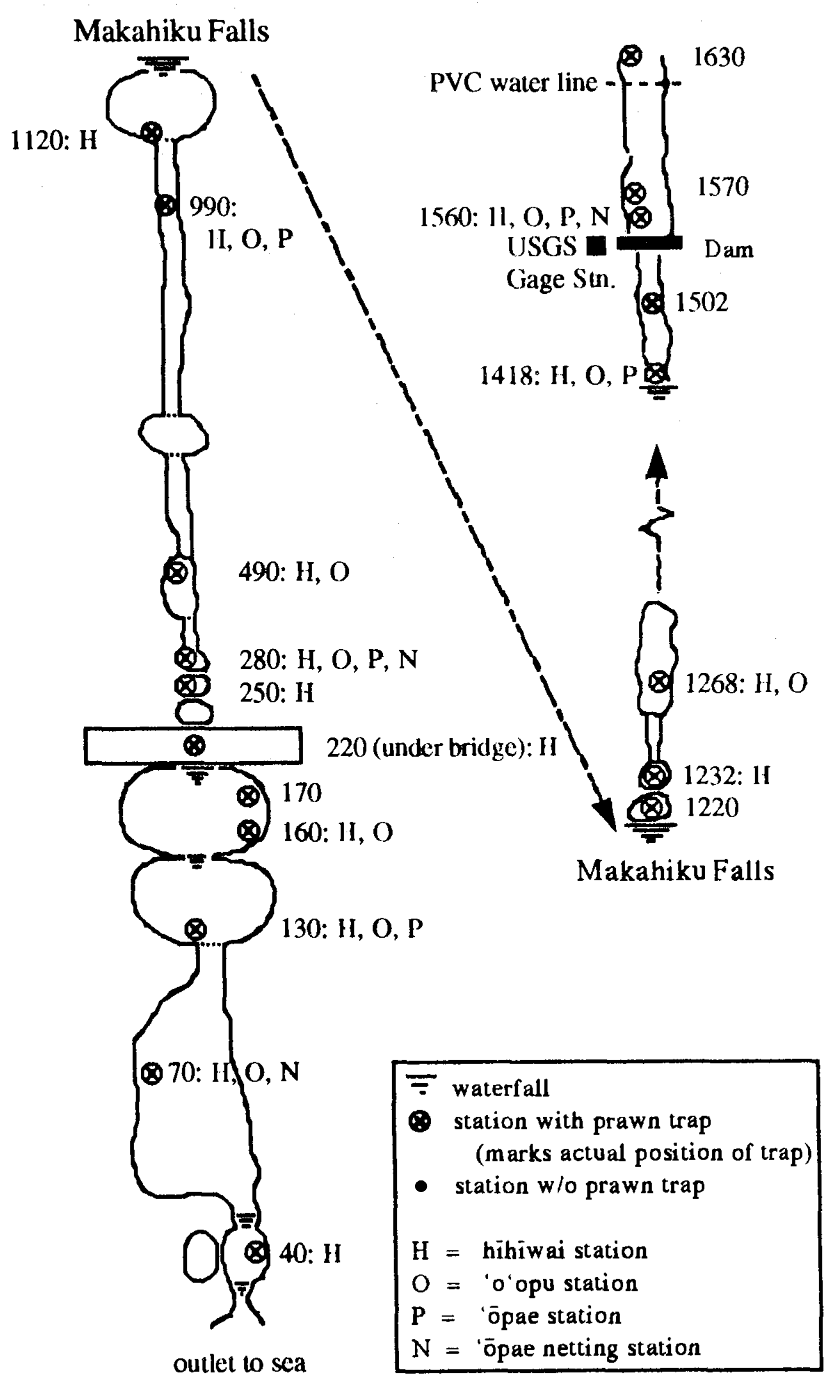


Fig. 2. Locations of stations for *M. lar* trapping; hīhīwai, 'o'opu and 'ōpae surveying; and 'ōpae netting in 'Ohe'o. Schematic sectioned for ease of presentation. Station numbers are indicated. Schematic not to scale.

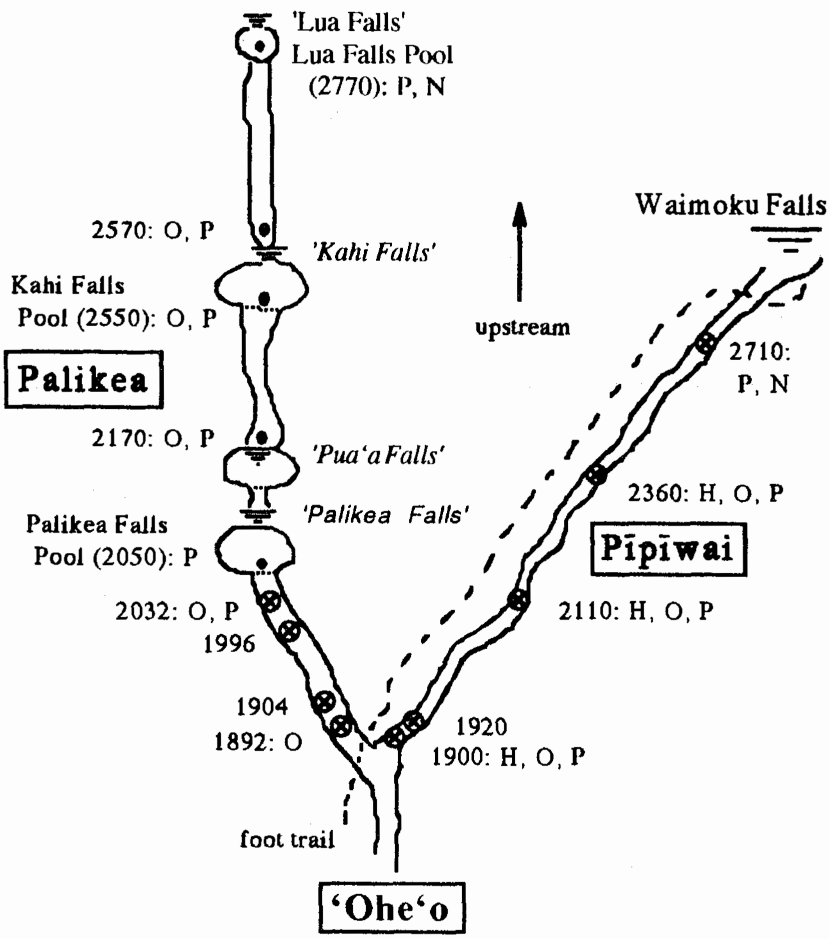


Fig. 3. Locations of stations for *M. lar* trapping; hīhīwai, 'o'opu and 'ōpae surveying; and 'ōpae netting in Palikea and Pīpīwai. Schematic sectioned for ease of presentation. Station numbers are indicated. Schematic not to scale. See Fig. 2 for legend.

hence prevented area-based variation in sampling intensity. The sampling area at each station was defined as one hundred square meters for hīhīwai, and three hundred square meters for 'o'opu and 'ōpae.

Bank to bank width was measured to the nearest meter at the time of initial establishment of each station. The lengths (upstream-downstream dimension) of stream to be sampled at each station for hīhīwai and 'o'opu/'ōpae were determined by dividing one hundred and three hundred square meters respectively by the bank to bank width. For example, the approximate bank to bank width at the station shown in Figure 4 is four meters. Hence, the length of the area from which samples will be drawn at this station for hīhīwai is 100/4 = 25 meters, for 'o'opu/'ōpae 300/4 = 75 meters. Thus the dimensions of the sampling areas at this station are 25x4 (hīhīwai) and 75x4 ('o'opu/'ōpae).

Coordinate system: A frequently shifting substrate discourages the use of permanent quadrat markers in most Hawaiian streams. Hence, the quadrat locations were defined as Cartesian coordinates (Fig. 4 - see Appendix I for coordinates used). Once the dimensions of the sampling areas at a given station were determined, the coordinates to be used for quadrat placement at that station were found by randomly choosing pairs of numbers falling within the respective dimensions of the sample areas.

During survey work, the observer began at the station benchmark, defined as (0,0). Although the benchmark can be any permanent object, the station flag was used throughout this survey. The observer paced off the necessary number of meters up the stream from the benchmark, then paced off the necessary number of meters from the right bank to relocate the correct area for placement of the first quadrat. Once observation in that quadrat was completed the process was repeated, using the current quadrat location as the point of departure, to find the location of the next quadrat.

If, during placement of the quadrat, an observer encountered an object such as a log or large rock which protruded above water level and which obstructed > ca. 40% of the quadrat, the quadrat was moved directly upstream. Quadrats containing less dry surface area than this were not moved.

It was not possible to survey the bottom of deep pools. Instead, the coordinate system was modified to place the quadrats around the pool periphery (Fig. 5). SCUBA should be employed in the future to determine faunal occurence in deep pools, and the correlation between faunal densities in mid-pool and those on the periphery.

'o'opu: The density and size class distribution of all species of 'o'opu (alamo'o, nōpili, and nākea have been observed to date) were recorded using ten $1m^2$ quadrats at each of 18 stations. After carefully approaching the proper quadrat location via the coordinate system, the observer used a one meter long, narrow wire rod to quickly determine and visualize the four corners of the $1m^2$ quadrat. The observer watched the defined area for three minutes, recording the highest number of each size class of each species occurring within the quadrat. Inches were used as the unit of measurement because I felt less comfortable with the metric equivalent during visual estimation. Individual 'o'opu less than 0.5 in. standard length were classified as hinana, regardless of species. (Naked eye determination of species at this size is not feasible). Other size classes were defined using half inch increments between 0.5 and 9 inches. Any individual over nine

inches in standard length was placed in a single 9+ class.

After the observation period at each quadrat the observer classified the habitat, the substrate composition within the quadrat, and the depth in centimeters at the center of the quadrat. Habitat types used were riffle (> 30 cm depth, primarily cobble/gravel substrate), boulder riffle (variable depth, primarily rock and boulder substrate), pool, run (variable depth, significant current, primarily bedrock substrate), and edgewater (edge of channel, shallow, little to no current, often high silt and vegetation, noticeably higher water temperature than mid-channel).

Substrate composition was designated as percent cover of sand (< 5 mm longest diameter), gravel (5 ≤ x < 20), cobbles (20mm ≤ x < 15 cm), rocks (15 cm ≤ x 40 cm), boulders (≥ 40 cm), and bedrock. Detritus, though fairly rare, occurred in a layer above the substrate. Percent detrital cover was recorded separately.

All observations were made by myself and Anne Brasher. Working together, we each counted five quadrats at each station. One observer counted the five seaward-most quadrats, while the other counted the five quadrats above these. It was both safer and a lesser disturbance to the ʻoʻopu if the observer approached the quadrat from downstream. Consequently, observers always began with the downstream-most quadrat in a set of five, and worked upstream. After each observer had counted the assigned set of five quadrats both observers moved on to the next station.Though each observer always counted half of the quadrats at each station the given half counted was not necessarily the same during all surveys.

Stations were not counted in any particular order. However, we commonly worked through a given reach by starting with the seaward-most station in the reach and working upwards. It took three days to count all of the ʻoʻopu stations.

ʻōpae: Trapping vs. Direct Observation: On a number of occasions

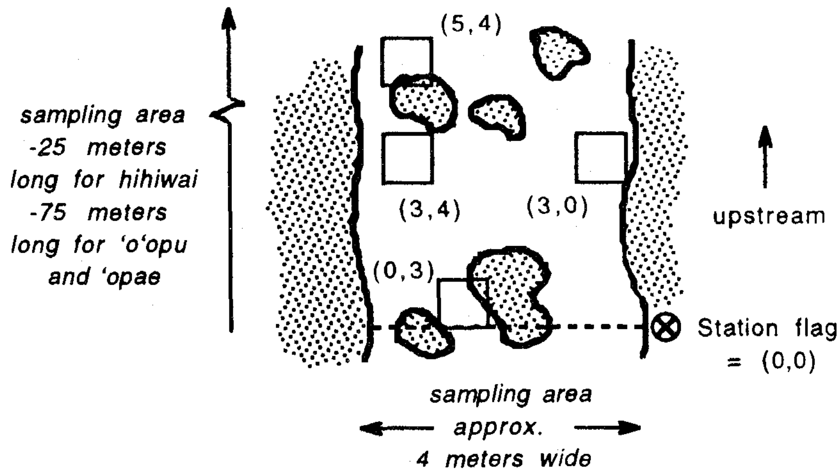
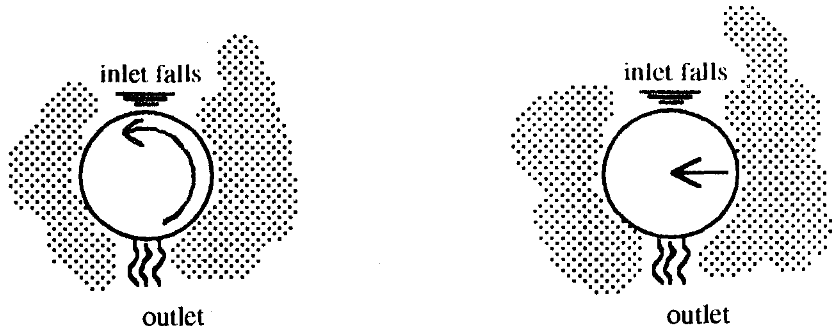


Fig. 4. Use of Cartesian coordinate system to define quadrat locations in stream channel. Dimensions of sampling area indicated. Quadrats shown are 1 m2.



A: Count sample area 'length' in clockwise direction along perimeter of pool.

B: Count sample area 'width' towards center of pool.

Fig. 5. Adaption of cartesian coordinate system to deep pools.

ʻōpae were found in the prawn traps during preliminary prawn trapping efforts. Trapping has clear advantages over direct observation in terms of sampling effort, accuracy of count and size frequency distribution, opportunity to determine sex ratio and percent fecundity, presence of disease/parasites, etc. The ʻōpae feed primarily on filamentous algae and detritus (Couret 1976). However, the occurrence of individuals in the *M. lar* traps suggested that ʻōpae might be trapped with the same bait used for *M. lar*. Or ʻōpae might enter a trap while moving about.

To determine if ʻōpae might be easily trapped, I constructed three small traps following the design and baiting scheme of those for *M. lar* (mesh size = 1/8 in^2, diameter = 8 in., length = 12 in.). Traps were left overnight on 1/20/93 in an area with abundant ʻōpae near Station 2170. No ʻōpae were caught. Consequently, I chose to survey ʻōpae abundance by using a modification of the direct observation method developed for ʻoʻopu.

Night vs. Day Counts: Nishimoto (1992), using a visual survey method, observed a higher abundance of ʻōpae during the late evening hours than during the day at three locations in Hakalau Stream on Hawaiʻi. In addition, during the day Nishimoto saw ʻōpae primarily along the edge of the channel. But, during the late evening hours Nishimoto saw ʻōpae occur throughout the channel.

Population surveys conducted for monitoring and among-stream comparisons need only to provide a consistent index of abundance, regardless of actual densities. However, given the high frequency of daylight zero counts in ʻōpae surveys in ʻOheʻo (see below), if the difference in abundance and spatial distribution observed by Nishimoto between daylight and late evening hours also occurs in ʻOheʻo, it seemed quite possible that late evening surveys in ʻOheʻo would yield a lower coefficient of variation (c.v.) and/or fewer zero counts than daylight counts. A lower c.v. would lower the necessary sample size for the desired degree of accuracy, and fewer zero counts might allow application of parametric statistical methods (see below).

Although Nishimoto (1992) did not specify the actual time of the 'late evening' survey, if surveys are to be carried out during the evening/night rather than the day, the difference must be observable at all times during the night to allow sufficient time for survey work. To assess whether the c.v. and the frequency of zero counts in ʻOheʻo were different between day and night hours, I counted ʻōpae at ten $1m^2$ quadrats during the day and night at each of Stations 1418 and 1900 on 3/3/93. I made observations at 1pm and again at 9 pm at Station 1900, and at 2 pm and again at 10 pm at Station 1418. I observed each quadrat for three minutes, and recorded the maximum number of ʻōpae occurring within. I used a dive light during night counts.

No consistent change in c.v. was observed between day and night counts (c.v. day: 2330 = 80.6, 3040 = 85.5; c.v. night: 2330 = 117.6, 3040 = 47.1). The result is similar for the frequency of zero counts. Ten percent of the day counts at 1418 were zero, while 50% of night counts were zero. This difference was not quite significant (X^2 = 3.81, p = .051). Twenty percent of day counts at 1900 were zero, while no night counts were zero. Again the difference is not significant (X^2 = 2.22, p = .136). The small sample sizes suggests a significant difference is possible. However, concern over pseudoreplication discourages pooling of counts across stations for a combined X^2. In any case these counts offer no evidence to conclude that the frequency of zero counts will be lower for surveys conducted at night. Interestingly, the overall mean daytime count was 4.7 individuals per quadrat. That of the night was 2.4.

In addition to the lack of evidence for an increase in sampling efficiency to be gained from night counts, movement is more difficult for the observer during the night than during the day, and fatigue is more likely to be a significant factor. Perhaps most importantly, the dive light restricted observation to a small area within the quadrat at any given moment, and the ʻōpae were moving quickly and difficult to see. Further, on numerous occasions individuals were clearly attracted to the light. Given the lack of a clear sampling efficiency advantage, the additional difficulty in movement and observations, and the attractive effect of the light, I chose to perform ʻōpae survey work during the day.

Direct Observation: The density of ʻōpae were recorded using ten $1m^2$ quadrats at each of 16 stations. Quadrat locations, habitat type, substrate composition and depth were determined in the same manner as that for the ʻoʻopu. As with the ʻoʻopu, quadrat locations were carefully approached and the boundaries determined with the aid of a one meter wire rod. Each quadrat was observed for two minutes and the maximum number of ʻōpae occurring within was recorded.

An estimate of the size class distribution was determined by sampling with an ʻōpae net at stations 560 and 2560 in ʻOheʻo, 2710 in Pīpīwai, and Lua Falls in Palikea. The ʻōpae net is available in many fishing stores in Hawaiʻi. It is an open-fronted, two handled scoop net constructed of soft nylon mesh attached to two short bamboo poles. The leading edge of the net is weighted with lead sinkers. Diagonal mesh length on the net which I used was three millimeters. I used the net to capture ʻōpae by scooping along smooth rock surfaces, or by placing the leading edge of the net on the bottom of the stream and disturbing the substrate just upstream of the net, much as 'kick-sampling' is done for insects. The amount of ʻōpae finally taken from each sampling station varied considerably, but netting was always continued until at least thirty individuals were captured. The captured ʻōpae were taken from the field and preserved in an alcohol solution. Post orbital carapace length, measured to the nearest millimeter with dial calipers, and presence of eggs were recorded soon after preservation.

I made all of the ʻōpae observations alone. As with the ʻoʻopu, stations were not counted in any particular order, however quadrats within stations, and stations within reaches were counted in the upstream direction. Two and a half days were required to count all stations.

hīhīwai: The density of individuals, size class distribution, and density of egg cases of hīhīwai were determined using ten 625 cm^2 quadrats at each of seventeen stations. Quadrats were delineated by square plot frames constructed of heavy wire.

After finding the proper quadrat location via the coordinate system, the plot frame was placed on the substrate. While observing carefully with the facemask, all loose rocks, cobbles and gravel were removed from the quadrat, and the shell lengths of any hīhīwai encountered were measured to the nearest millimeter with dial calipers. Shell lengths were measured as the greatest distance between the apex (origin of whorl) and the anterior margin (Ford 1979, Hodges 1992). Hīhīwai were immediately released after measurement. After each quadrat was counted, hīhīwai egg cases were counted in a 156 cm^2 quadrat placed 50 cm directly upstream. This egg case quadrat was formed by using a quarter of the plot frame.

Trapping

Kubota (1972) used wire mesh, baited traps to capture *M. lar* in Kahana Stream and Estuary, Oʻahu. I constructed funnel-mouthed cylindrical traps from 1/4" square mesh wire hardware cloth (Fig. 6). I designed the traps to be particularly large to reduce 'trap saturation' by high densities of *M. lar*. Each trap was baited by placing 35 pieces of dry commercial dog food in the bait box (Purina Dog Chow® was used throughout). Wire was used to suspend and fasten the bait box inside and near the back of the trap.

Twenty eight trapping stations were established throughout 'Ohe'o, Pipiwai and Palikea (Figs. 2,3). A single trap was placed at each of these stations. The actual location of a trap at a given station (e.g. riffle vs. pool) may significantly affect the catch at that station. Hence, Figs. 2,3 indicate the relative trap location at each station.

A full trapping survey was a three day process requiring the efforts of at least two people. One trap was placed at each of fourteen stations during the afternoon of the first day. Traps were fully submerged during placement, with the mouth facing downstream to avoid collection of floating debris. Traps were secured to the stream bank with rope. Traps were retrieved the next morning in the order that they were placed. Retrieval of this first set of fourteen traps was completed by noon. The next set of fourteen traps were placed at those stations which were not trapped the previous night. These traps were retrieved during the morning of the third day, again in the order that they were placed.

Data was obtained from the catch immediately after each trap was retrieved, and prawns were subsequently released. Post orbital carapace length was measured to the nearest millimeter. Presence of eggs was also recorded. Sex was determined according to the methods of Kubota (1972). Only those individuals ≥ 12 mm carapace length were sexed. Individuals smaller than this were difficult to sex under field conditions. Recording of sex data was begun in March.

Kubota (1972) reported the occurrence of large carapace lesions in *M. lar* in Kahana Estuary on O'ahu. He attributed the lesions to fungal infection and termed the symptoms "black-spotted disease." The occurrence of large lesions and deformations of the carapace in *M. lar* in 'Ohe'o was noticed during the March trapping. The lesions, which were often severe enough to fully expose many of the internal organs, closely matched Kubota's photograph and description of "black-spotted disease." I began systematic recording of the incidence of symptoms during the third trapping. Symptoms (lesions and/or deformations) were scored on a presence/absence basis.

Pua'alu'u Stream

Limited survey work was carried out in Pua'alu'u Stream. Pua'alu'u is a small, second-order stream occurring just to the north of 'Ohe'o. The watershed is 63 ha. in area, headwaters occur at ca. 600 m elevation, channel length is 2.4 km, and discharge has been reported as .27 cfs (Kinzie & Ford 1979). The segment of Pua'alu'u between the Hāna Highway and the terminus is steep. Flow moves through a number of small plunge pools and over bedrock cascades and steep runs. Flow is deposited directly onto the beach through a steep, narrow chute. The macrofauna populations of Pua'alu'u were surveyed by Kinzie and Ford (1979). They provide photographs and a description of the stream and watershed.

During the year in which this study was conducted, the water in Pua'alu'u was characteristically clear. Pua'alu'u is considered by local residents to be largely spring-fed, and is apparently a primary source of drinking water because of its high quality. On 12/4/93, the five streams from 'Ohe'o to Wailua, except Pua'alu'u, were spating or showing obvious signs of increased flow and turbidity. Pua'alu'u was at normal flow level and the water was clear. This suggests that the flow regime of Pua'alu'u is independent of the other streams in the vicinity. Independence might be caused by some combination of small watershed size, elevation of headwaters, or a preponderance of spring water rather than runoff.

I surveyed Pua'alu'u at three stations which roughly correspond to Stations 70, 130, and 280 in 'Ohe'o (see Appendix II for quadrat coordinates used in Pua'alu'u). The initial survey was carried out on 7/3-4/93. The purpose of the initial survey was to compare the fauna of lower Pua'alu'u with lower 'Ohe'o. However, on numerous occasions high flow prevented 'o'opu survey work in 'Ohe'o. I used some of these opportunities to carry out additional surveys of Pua'alu'u: Two back-to-back surveys were carried out on 10/5-6/93 and 10/6-7/93. These surveys were intended to provide a rough assessment of the error rate of the counting method under a limited sampling scenario. A follow-up survey was performed on 12/4/93. The 12/4 sur-

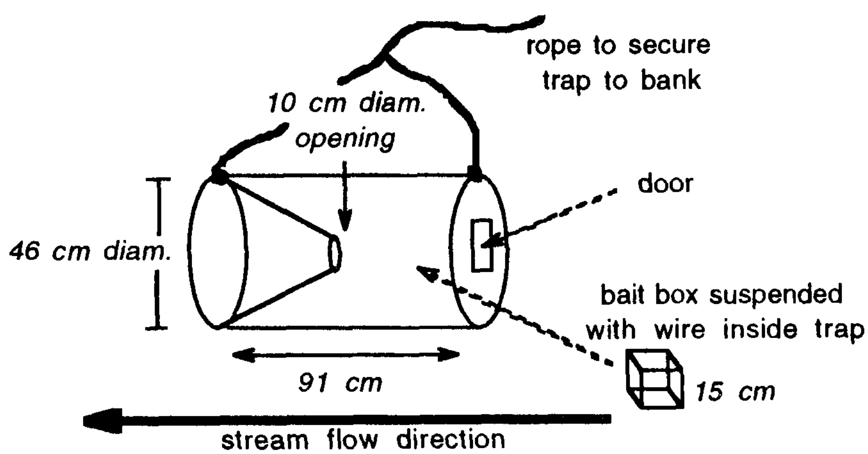


Fig. 6. Diagram of wire mesh trap used for *M. lar*.

vey was the first to incorporate new personnel beyond myself and A. Brasher, and I considered this survey partly a training exercise.

Survey Design and Statistical Analysis

The total number of quadrats to be counted was determined by the maximum sampling time and effort which was reasonable given the circumstances, and is considered fixed for the following brief discussion. The spatial allocation of the quadrats, i.e. ten quadrats per station, was designed to allow comparison of the results among stations, through time, and among streams with a ≥ 2-way ANOVA. Such an ANOVA would be constructed by blocking according to station, survey, and, if desired, stream.

In addition, a significant objective of the study was to evaluate the survey method. The quadrat observation method is still in its infancy for 'o'opu, and had not been previously applied to 'ōpae population surveys. Grouping of quadrats by station facilitates this evaluation. The means of groups of quadrat counts will exhibit less inherent variation, i.e. less 'noise', than individual quadrat counts. The consistency of the quadrat observation method can be better assessed by examining consistency through time in the means of groups of quadrat counts, i.e. the means at each station, rather than individual quadrat counts.

Further, in evaluating the survey method where more than one observer is employed, it is essential to determine if there is consistency among observers in their observations. Grouping quadrats at stations, where each observer counts half of the quadrats at each, allows for an assessment of inter-observer consistency by testing for correlation between observers in the mean number of individuals counted at each station during a given survey. More quadrats per station give a more accurate mean, and hence a more accurate assessment of correlation.

During the first surveys of 'o'opu and 'ōpae I noticed that zeroes were the most frequent quadrat count (see Results). The presence of too many zeroes (or any other single number) in a distribution prevents parametric statistical analyses by confounding attempts to transform the data to meet normal assumptions. This fact left me with three general options to prepare for tests for changes in population abundance through time. I could abandon the quadrat method in favor of some other observation method, enlarge the size of the quadrat, or change the method of analysis (e.g. use station means instead of quadrat counts as the parameter to be analyzed and/or switch to nonparametric methods).

The only real observation-based option to the quadrat method is a transect or whole-reach survey method wherein observations are made while swimming along a transect or reach. Baker and Foster (1992) describe this method further and conclude that it compares poorly to a quadrat or 'point' count method for 'o'opu. I agree with this conclusion. Shallow reaches, complex habitat, and the detailed nature of the data to be recorded make transect counts involving any more than a handful of 'o'opu difficult to replicate. Additionally, quadrat count methods are now being applied by researchers carrying out 'o'opu survey work in other streams throughout Hawai'i. A significant objective of this study was to generate data which would be comparable to survey data being collected by researchers in other streams. A transect method would not meet this objective.

Excessive zero counts may be avoided by enlarging the quadrat size (e.g. Goldsmith 1991). However, the low densities of 'o'opu and 'ōpae in 'Ohe'o would require a dramatic increase in quadrat size to overcome the preponderance of zero counts. Because of cryptic behavior and movement of these species, accurate visual counts in quadrats much larger than 1 m^2 would be very difficult.

I chose to keep the existing survey design for the remainder of the first survey and for a second full survey, and to change the intended method of analysis. By using the mean of the ten counts at each station as the parameter to be analyzed for stream-wide changes in density, the proportion of zero counts might be reduced to an acceptable level. If not, nonparametric methods could be applied.

Because the survey was designed for analysis by ≥ 2-way ANOVA, the quadrat counts at a station are essentially pseudo-replicates when considered in a stream-wide context. Therefore, quadrats from different stations should not be directly pooled together. Neither Sokal and Rohlf (1981) nor Sprent (1993) provide a suitable nonparametric analogue to the multi-way ANOVA. Thus, without a nonparametric procedure for ≥ 3 samples which allows blocking by station, it is necessary to apply nonparametric tests to the station means rather than the quadrat counts.

Use of the station means rather than the quadrat counts in a test for change in population abundance causes a considerable loss in sample size. With this in mind, it makes sense to increase the sample size for a test for a change in population abundance by reducing the number of quadrats per station and increasing the number of stations. However, the assessments of consistency in the quadrat observation method itself, and of consistency between observers in this method, require grouping of quadrats by station (see above). As noted, more quadrats per station allow a better assessment of method consistency. An assessment of method consistency based on correlation of station means through time requires that the survey design be carried out at least twice without changes. I chose to continue with ten quadrats per station for the remainder of the first survey and the second survey to allow this essential assessment.

In summary, given the various constraints of method and normal assumptions, I chose to use the means of counts at each station as the parameter to be analyzed for changes in population abundance between the first and second surveys. Because the assessment of inter-observer variation and overall method consistency require a fairly large number of quadrats per station, and an unchanged design through at least two surveys, I chose to remain with ten quadrats per station for the completion of the first, and the second survey.

Once the method is found to be consistent, it is appropriate to change the survey design to increase the statistical power and sampling efficiency of future surveys. Using the data from the first and second 'ōpae and 'o'opu surveys I evaluate changes in the survey design in terms of statistical power (see Discussion).

Both the Kruskal-Wallis and Friedman tests detect differences in locations or means among ≥3 samples. of these, only the Kruskal-Wallis tolerates differences in sample size and is used here. The multiple comparison procedure used with the Kruskal-Wallis test is from Sprent (1993). All results reported from rank-based nonparametric tests are corrected for ties.

RESULTS

Surveys in 'Ohe'o were begun in early January, 1993. The 'o'opu were counted on 2/5-7/93 and 5/4-6/93. The 'ōpae were counted and netted on 3/3-5/93 and 5/26-29/93. Heavy rainfall and turbidity repeatedly prevented the additional 'o'opu and 'ōpae surveys which were scheduled. Hīhīwai were surveyed on 1/19-21/93, 3/20-21/93, and 5/26-29/93. Prawns were trapped on 1/3-5/93, 3/31-4/2/93, 7/17-19/93, and 11/20-23/93.

The 'o'opu in 'Ohe'o

Figure 7 illustrates the frequency distributions of quadrat counts from the first and second surveys.

Temporal Differences

Comparisons Between Surveys 1 and 2 of Densities of Entire Populations

All species - all sizes: The mean number of 'o'opu of all species at each station during the 2/5-7/93 survey ranged from 0 to 3.1 'o'opu per quadrat, and the mean of these means was .619 (n = 16, variance = .783). The mean number of all species of 'o'opu at each station during the 5/4-6/93 survey ranged from 0 to 2.3 'o'opu per quadrat, and the mean of these means was .567 (n = 18, variance = .471). The station means of the raw counts from each of the first and second surveys are randomly distributed (Elliott's (1971) Index of Dispersion: *first*: $X^2 = 22.6$, $d.f. = 17$; *second*: $X^2 = 14.1$, $d.f. = 17$). A $\sqrt{(x+.05)}$ transformation normalized the station means of the first and second surveys (Lilliefors test for departure from normality- *First survey*: $n = 16$, all comparisons < .213, $p > .05$. *Second survey*: $n = 18$, all comparisons < .200, $p > .05$ (Sprent 1993, p. 79). The difference in the means of station means was not significant (mean $x_i - y_i = -.0006$, $d.f. = 15$, paired $t = -.102$, $p > .50$). However, the test has very low power to detect the observed 9.2% change in the mean of station means (see Discussion).

alamo'o - all sizes: The mean number of 'alamo'o at each station during the 2/5-7/93 survey ranged from 0 to 2.1 individuals per quadrat, and the mean of these means was .437 (n = 16, variance = .472). The mean number of 'alamo'o at each station during the 5/4-6/93 survey ranged from 0 to 1.5 individuals per quadrat, and the mean of these means was .361 (n = 18, variance = .213). A paired-t test has very low power to detect the observed 21% change in the mean of station means (see Discussion).

nākea - all sizes: The mean number of nākea at each station during the 2/5-7/93 survey ranged from 0 to .3 individuals per quadrat, and the mean of these means was .05 (n = 16, variance = .012). The mean number of nākea at each station during the 5/4-6/93 survey ranged from 0 to 1.9 individuals per quadrat, and the mean of these means was .167 (n = 18, variance = .2). Although the observed 334% change in the mean of station means would be detected by the paired t test, the data cannot be normalized. Using the nonparametric two-sample analogue, this difference in the mean of means was not significant (Mann-Whitney $U = 123$, $Z = -.936$, $p > .30$).

nōpili - all sizes: No nōpili were recorded at any of the 16 stations observed during the 2/5-7/93 survey. The mean number of nōpili at each station during the 5/4-6/93 survey ranged from 0 to .2 individuals per quadrat, and the mean of these means was .011 (n = 18, variance = .002). The data cannot be normalized. Using the nonparametric two-sample analogue, this difference in the mean of means was not significant (Mann-Whitney $U = 136$, $Z = -.943$, $p > .30$).

hinana - all sizes: The mean num-

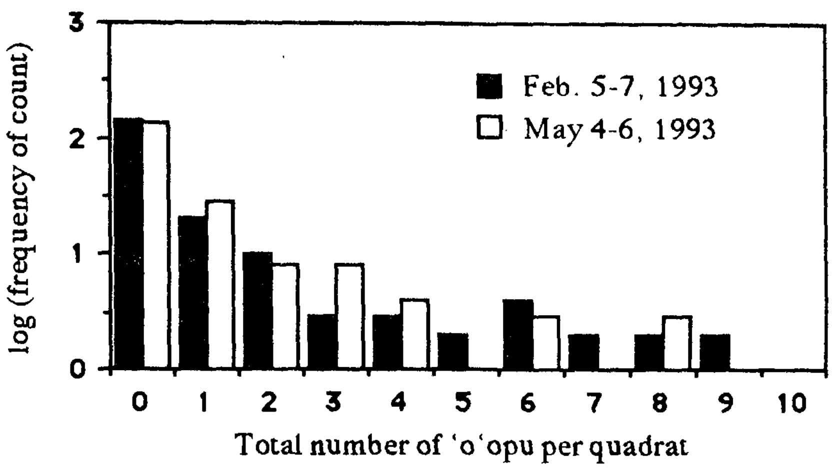


Fig. 7. Frequency distribution of the number of 'o'opu per quadrat ('alamo'o, nōpili, nākea and hinana combined, all quadrats at all stations combined) recorded in the 'Ohe'o Stream System during the first and second surveys.

ber of hinana at each station during the 2/5-7/93 survey ranged from 0 to 1.2 individuals per quadrat, and the mean of these means was .131 (n = 16, variance = .113). The mean number of hinana at each station during the 5/4-6/93 survey ranged from 0 to .3 individuals per quadrat, and the mean of these means was .028 (n = 18, variance = .007). The observed 467% change in the mean of station means would be detected by the paired t test. However, the data cannot be normalized. Using the nonparametric two-sample analogue, this difference in the mean of means was not significant (Mann-Whitney $U = 131.5$, $Z = -.7$, $p > .40$).

Comparisons Between Surveys 1 and 2 of Spatial Distribution of Densities of Entire Populations

All species - all sizes: The mean number of 'o'opu of all species, including hinana recorded at each station during the first survey was highly correlated with that at each station during the second survey (Kendall's *tau* = .711, $n = 16$, $Z = 3.839$, $p < .0005$).

'alamo'o - all sizes: The same was true for the mean number of 'alamo'o at each station (Fig.8; (Kendall's *tau* = .587, $n = 16$, $Z = 3.173$, $p < .005$). Figure 8 also illustrates the high densities observed in the lowest and upper reaches.

nākea - all sizes: A similar pattern is visible for the mean number of nākea (Fig. 8; Kendall's *tau* = .964, $n = 16$, $Z = 5.209$, $p << .0001$), however a look at the undue influence of zero counts and considerable non-linearity visible in a scattergram cautions against strong conclusions for this species. In any case, the restriction of this species to the lower and mid reaches of the 'Ohe'o Stream System is clear from Figure 8.

nōpili - all sizes & hinana: Neither the number of nōpili nor the number of hinana observed were sufficient to make this a meaningful comparison.

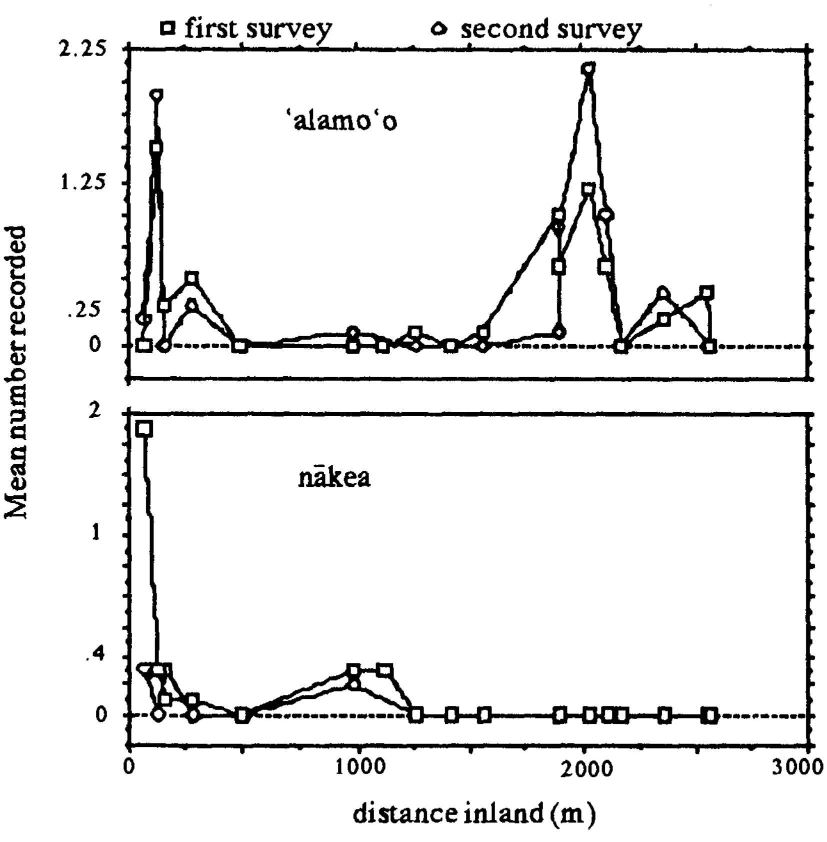


Fig. 8. Mean number of 'o'opu recorded at each station during the first and second surveys, 'Ohe'o Stream System.

Comparisons Between Surveys 1 and 2 of Size-Frequencies of Entire Populations

All species (w/o hinana): The observed difference in frequency distribution between the first and second surveys was not significant ($X^2 = 8.098$, $d.f. = 5$, $p = .1509$; size classes ≥ "3 to 3.5" pooled for each survey to satisfy minimum sample requirements of counts ≥ one for each category - e.g. Koopmans 1987, p. 420).

alamo'o: Figure 9 illustrates the size frequency distribution of 'alamo'o observed throughout the 'Ohe'o Stream System during the first and second surveys. The observed difference in frequency distribution between the first and second surveys was not significant ($X^2 = 5.138$, $d.f. = 4$, $p = .2735$; size classes ≥ "2.5 to 3" pooled for reasons above).

nākea: Figure 9 illustrates the size frequency distribution of nākea observed throughout the 'Ohe'o Stream System during the first and second surveys. The observed difference in frequency distribution between the first and second surveys was not significant ($X^2 = 2.305$, $d.f. = 4$, $p = .6798$; size classes ≥ "2.5 to 3" pooled for reasons above, differences apparent in figure muted by pooling).

nōpili: The nōpili was not observed during the first survey. Only two individuals were observed during the second. This is insufficient abundance to allow for a meaningful test for change in size frequency distribution.

Comparisons Between Surveys 1 and 2 of Size-Frequencies From Each Area

'alamo'o: Only the 'alamo'o was present in sufficient numbers to make this comparison meaningful. And, such numbers were observed in Pīpīwai and Palikea alone (Figs. 10, 11). Thus, no comparison of this type is made involving nākea, nōpili, Lower 'Ohe'o or Upper 'Ohe'o. Pīpīwai: No significant difference was observed in the size-frequency distribution of 'alamo'o at Pīpīwai between the first and second surveys ($X^2 = 2.532$, $d.f. = 2$, $p = .2819$, size class ".5 to 1" pooled with class "1 to 1.5" and size classes ≥ "2.5 to 3" pooled with class "2 to 2.5"). Palikea: No significant difference was observed in the size-frequency distribution of 'alamo'o at Palikea between the first and second surveys ($X^2 = 2.261$, $d.f. = 3$, $p = .5201$, size class ".5 to 1" pooled with class "1 to 1.5" and size classes ≥ "3 to 3.5" pooled with class "2.5 to 3").

Spatial Differences

Comparisons During Both Surveys 1 and 2 of Densities Among Areas

The 'alamo'o were observed most often in Lower 'Ohe'o, Pīpīwai, and Palikea. The nākea were observed most often in Lower 'Ohe'o with some individuals in Upper 'Ohe'o. None were observed in either Pīpīwai or Palikea. The nōpili were observed only in Lower 'Ohe'o. These differences between areas were apparent during both the first and second surveys for 'alamo'o and nōpili (Fig. 8).

Comparisons During Both Surveys 1 and 2 of Size-Frequencies Among Areas

Figures 10 and 11 illustrate the distribution of sizes of 'alamo'o, nākea and nōpili in Lower 'Ohe'o, Upper 'Ohe'o, Pīpīwai and Palikea during the first and second surveys. Both surveys revealed the same pattern. The 'alamo'o found in Lower 'Ohe'o were small and probably recruits. Few were observed in Upper 'Ohe'o. Larger 'alamo'o were found in Pīpīwai and the largest were located in Palikea. The nākea observed in Lower 'Ohe'o were small with some large individuals, again probably reflecting a preponderance of recruits. Larger individuals were seen primarily in Upper 'Ohe'o. Nōpili were only observed in Lower 'Ohe'o. The temporal consistency in the size frequency distribution observed stream system-wide is also apparent at each of these four major areas. As with the stream system-wide observations, the consistency in size frequency distribution is most apparent in the 'alamo'o. In both cases the increased apparent consistency is likely a result of a higher density and hence a larger sample size.

Only the 'alamo'o was present in sufficient numbers to make a formal comparison meaningful. Such numbers were only observed at Pīpīwai and Palikea (Figs. 10, 11). Thus, no formal comparison is made involving nākea or nōpili, or Lower and Upper

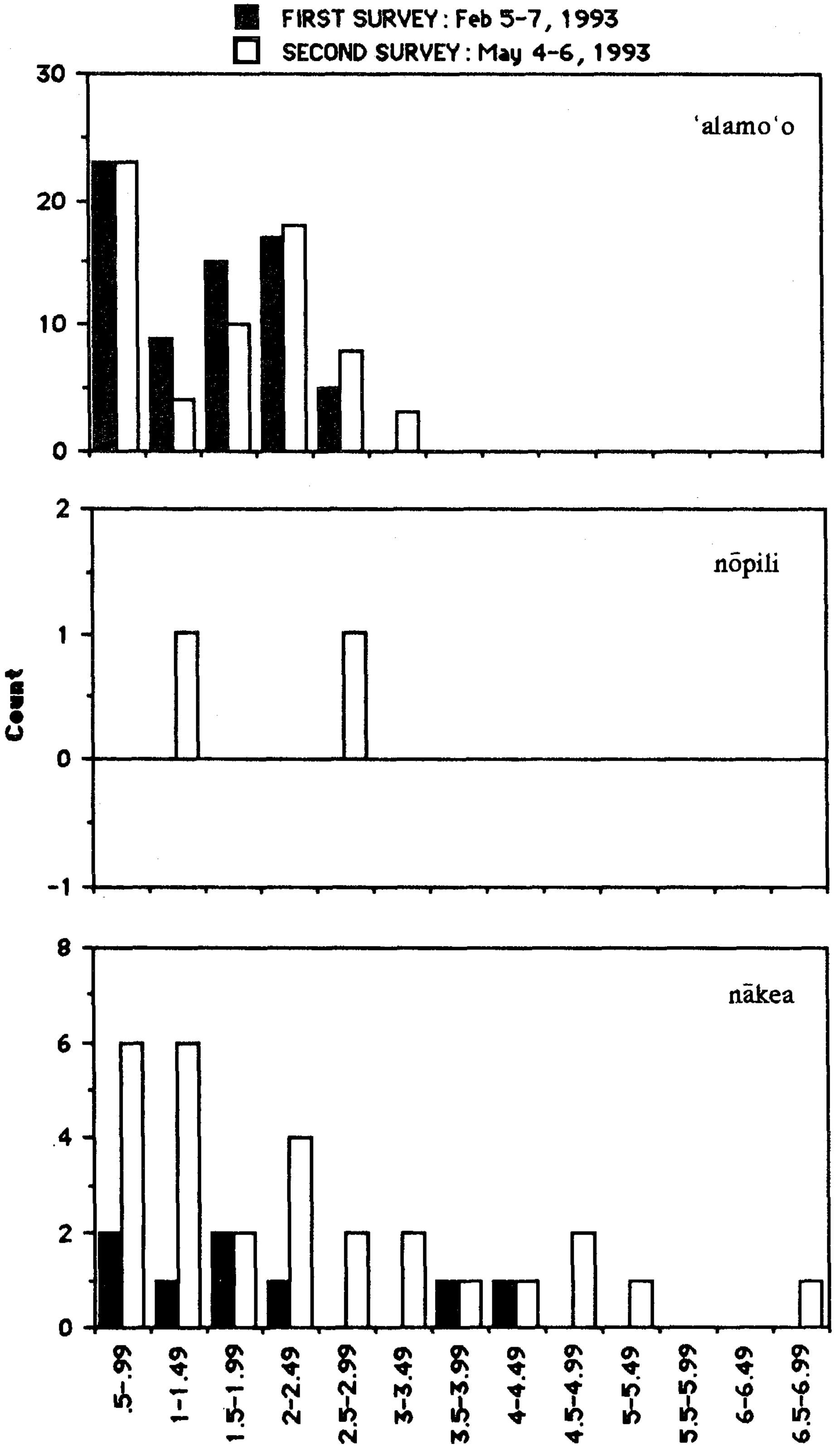


Fig. 9. Size classes of 'o'opu recorded in the 'Ohe'o Stream System during the first and second surveys (all quadrats at all stations combined).

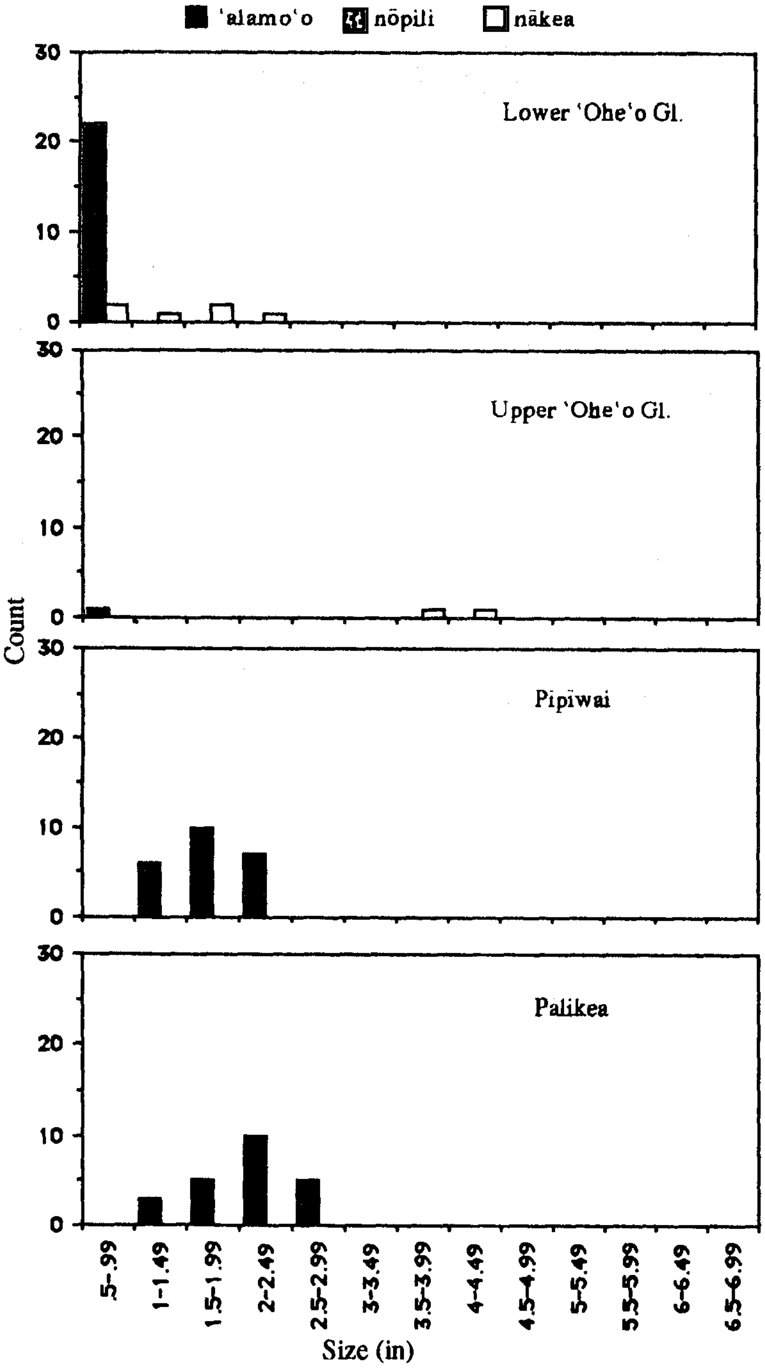


Fig. 10. Size classes of 'o'opu recorded in the four areas of the 'Ohe'o Stream System during the first survey (Feb 5-7, 1993).

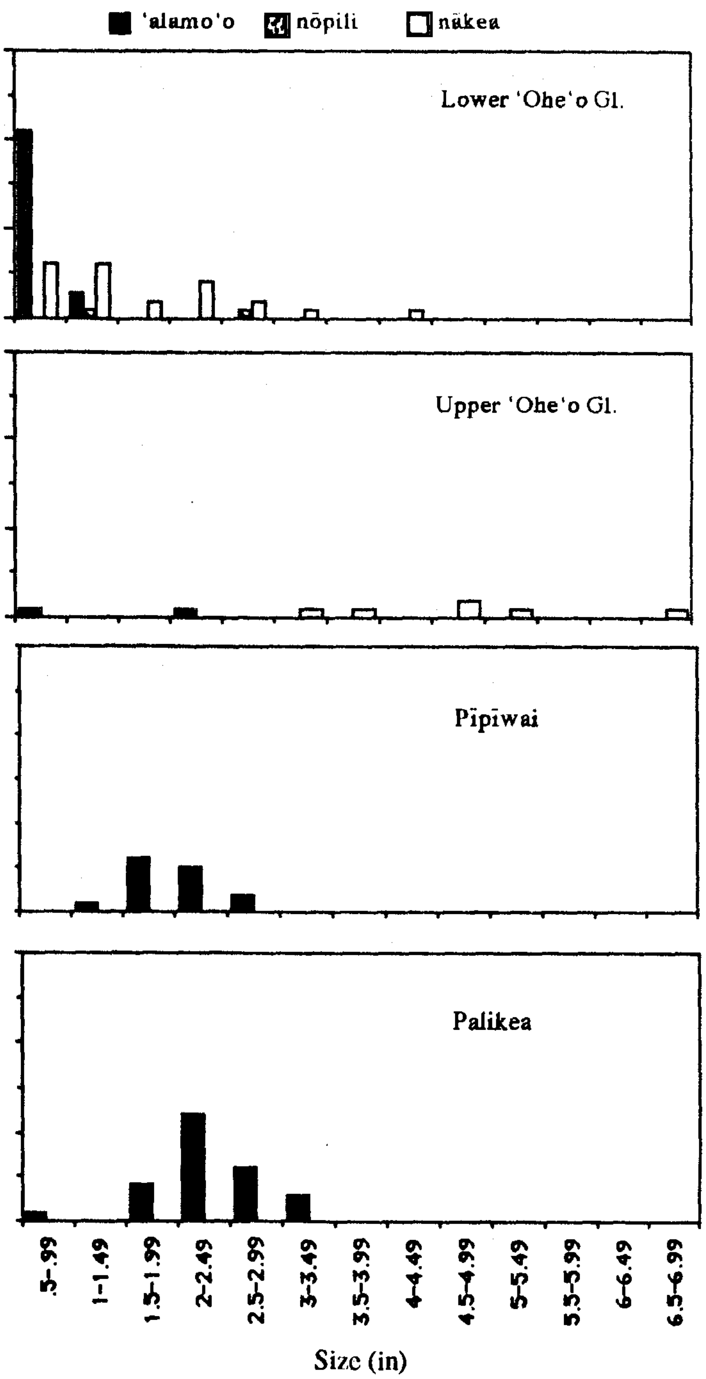


Fig. 11. Size classes of 'o'opu recorded in the four areas of the 'Ohe'o Stream System during the second survey (May 4-6, 1993).

'Ohe'o. *Pipiwai vs. Palikea, Survey 1:* No significant difference was observed in the size-frequency distribution of 'alamo'o between Pīpīwai and Palikea during the first survey (X^2 = 5.576, *d.f.* = 2, *p* = .0616, size class ".5 to 1" pooled with class "1 to 1.5" and size classes ≥ "2.5 to 3" pooled with class "2 to 2.5"). *Pipiwai vs. Palikea, Survey 2:* No significant difference was observed in the size-frequency distribution of 'alamo'o between Pīpīwai and Palikea during the second survey (X^2 = 4.176, *d.f.* = 2, *p* = .1239, size class ".5 to 1" pooled with class "1 to 1.5" and size classes ≥ "2.5 to 3" pooled with class "2 to 2.5"). However, the low value of *p* of the comparison from the first survey, and the consistent difference in location of mode between Pīpīwai and Palikea during both surveys (Figs. 10, 11), indicate that further sampling is likely to reveal a difference.

Additional Observations

Lack of consistent correlation between 'o'opu counts and time of day

A negative correlation was observed between the mean number of 'o'opu of all species observed at a station, and the time of day at which the counts at that station were made (Kendall's *tau* = -.403, Z = -2.092, $p < .05$). However, no such correlation was observed during the second survey (Kendall's *tau* = .184, Z = -1.065, $p < .35$). If a strong relationship between the time of day and mean ʻoʻopu count existed it would have been apparent during both surveys. There is no strong evidence to indicate that, during the daylight hours over which surveys 1 and 2 were conducted, the ʻoʻopu population survey protocol in ʻOheʻo need take special account of the time of day.

Inter-observer variation in ʻoʻopu counts

Each observer counted half of the ʻoʻopu quadrats at each station. The question of whether different trained observers report substantially different data can be addressed to begin with by testing for a difference in the statistical distribution of each observer's data. There is no significant difference between myself and Brasher in the distribution of means of quadrat counts of ʻoʻopu recorded at each station (Counts are of all species/sizes. *First survey*: Kolmogorov-Smirnov: *d.f* = 2, 16 cases each survey, max difference = .188, K-S chi-square = 1.125, Z = .53, $p > .60$; *second survey*: *d.f* = 2, 18 cases each survey, max difference = .278, K-S chi-square = 2.778, Z = .883, $p > .30$).

The question may be further addressed by testing whether one trained observer consistently recorded more ʻoʻopu than the other. Although a paired t-test for a difference in the mean of these station averages would be ideal, non-normality discourages parametric tests (see discussion of zero counts above). A Mann-Whitney *U* test was employed. During the first survey the mean of mean ʻoʻopu counts recorded by A. Brasher was .662, that of myself was .562. During the second survey that of Brasher was .411 and that of myself was .722. No significant difference in the mean of mean ʻoʻopu counts was detected between observers during either the first or second survey (*First survey*: $n = 16$, $U = 127.5$, Z = -.02, $p > .90$; *second survey*: $n = 18$, $U = 122$, $p > .20$).

Finally, mean observations at each station were highly correlated between observers during both the first and second survey (*First survey*: n= 16, Kendall's *tau* = .624, $p < .001$; *second survey*: n= 18, Kendall's *tau* =

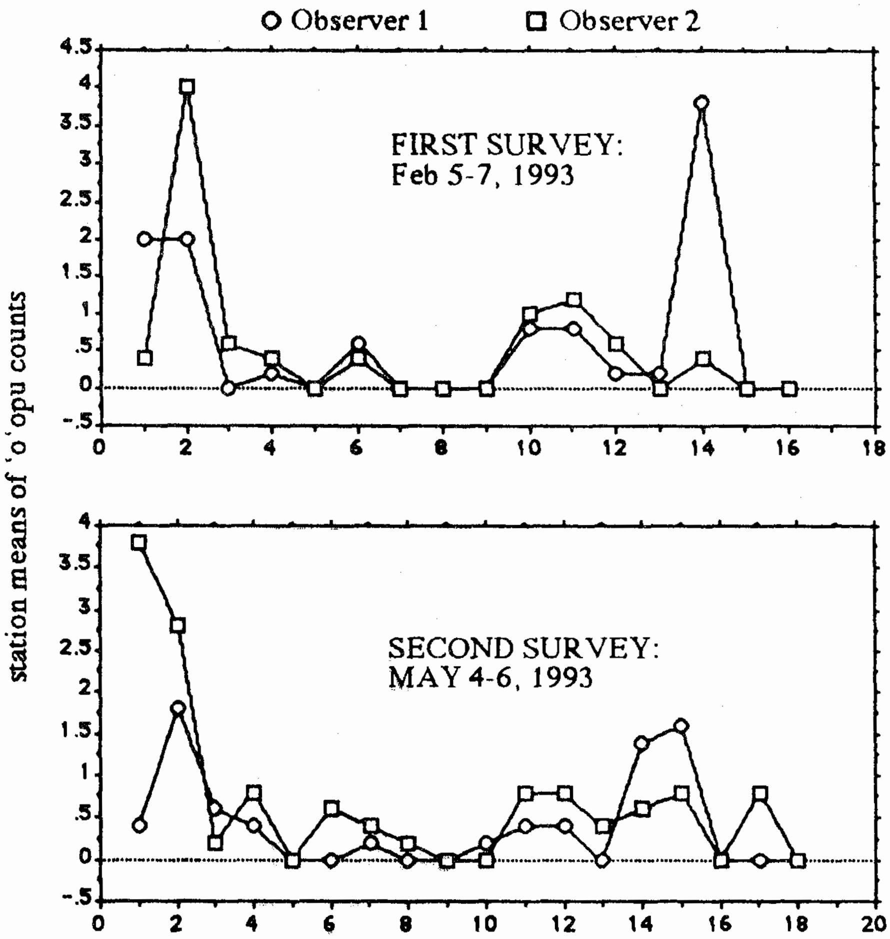


Fig. 12. Means of counts of all species and sizes of ʻoʻopu made by each observer at each station during the first and second surveys, ʻOheʻo Stream System. Stations ordered by distance inland but x-axis not to scale. Observer 1 = AB, 2 = MH.

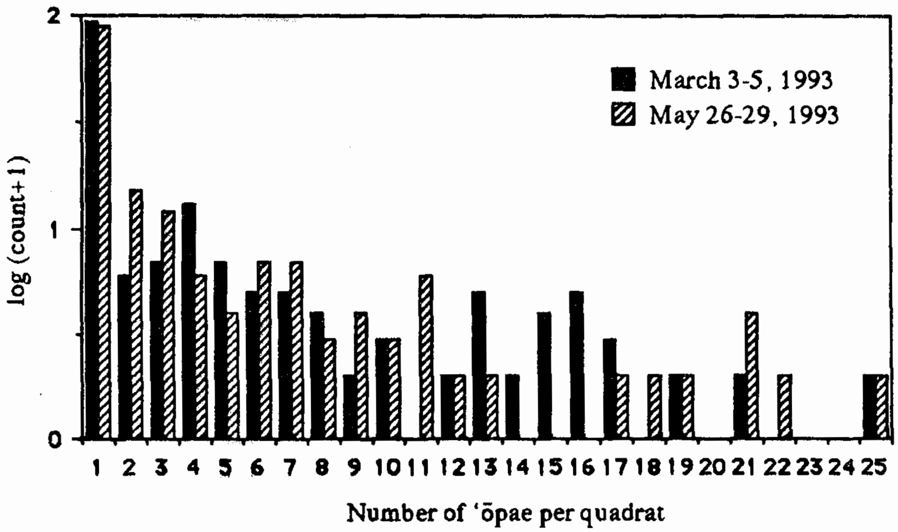


Fig. 13. Frequency distribution of number of ʻōpae per quadrat in the ʻOheʻo Stream System during the first and second surveys (all stations and quadrats combined).

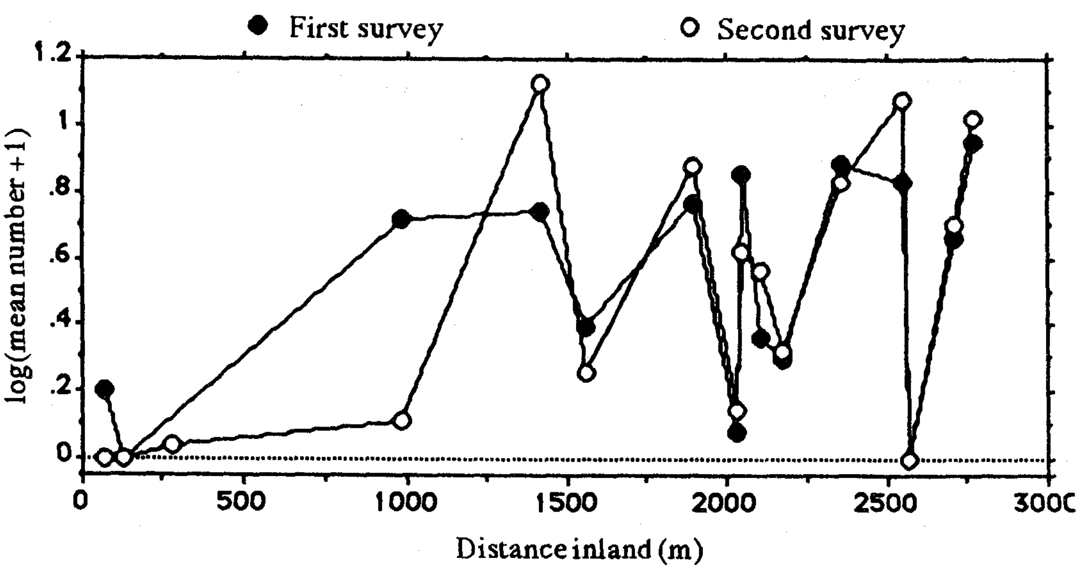


Fig. 14. Distribution of 'ōpae along the 'Ohe'o Stream System during the first and second surveys.

.501, $p < .005$; Fig. 12). Thus, there is no evidence for a consistent difference between trained observers in the nature of count data and the number of 'o'opu reported. This analysis does not evaluate interobserver variation where untrained observers are used. It is likely that such variation would be significant.

The 'ōpae in 'Ohe'o

Figure 13 illustrates the frequency distributions of quadrat counts from the first and second surveys.

Temporal Differences

Comparison Between Surveys 1 and 2 of Density of Entire Population

The mean number of 'ōpae of all sizes at each station during the 3/3-5/93 survey ranged from 0 to 8 individuals per quadrat, and the mean of these means was 3.213 (n = 15, variance = 7.353, data from station 280 was the result of large recruitment event. An outlier, it was converted to zero). The mean number of 'ōpae of all sizes at each station during the 5/26-26/93 survey ranged from 0 to 12.4 individuals per quadrat, and the mean of these means was 3.612 (n = 16, variance = 17.86).

Both of these sets of data met the definition of a 'contagious' or clumped distribution (Index of Dispersion: $X^2 = 32.039$, $d.f. = 14$, $p < .05$; and $X^2 = 74.169$, $d.f. = 15$, $p < .05$ respectively), and were $log(x+1)$-transformed accordingly (Elliott 1971). Following transformation, I tested for compliance with normality. The data from the first survey conformed, but that from the second did not {Lilliefors- *First survey*: $n = 16$, all [standard normal cdf(z_i) - sample cdf(z_i)] and all [standard normal cdf(z_i) - sample cdf(z_{i-1})] < .213, p > .05. *Second survey*: $n = 16$, [standard normal cdf(z_8) - sample cdf(z_8)] = .219, p < .05)}.

The paired-*t* test is powerful and somewhat robust to departures from normal assumptions. However, the power of this test to detect the observed 12.4% change is very low (see Discussion). The non-parametric analogue failed to detect a difference between surveys 1 & 2 in the mean of raw station means (Mann-Whitney $U = 111.5$, $Z = -.337$, $p > .70$).

Comparison Between Surveys 1 and 2 of Spatial Distribution of Density of Entire Population

Figure 14 illustrates the distribution of 'ōpae in the 'Ohe'o Stream System (stations ordered by distance inland, data for station 280 treated as above). The mean count of 'ōpae at each station was well correlated between the first and second surveys (Kendall's $tau = .621$, $n = 15$, $Z = 3.229$, $p < .005$).

Comparison Between Surveys 1 and 2 of Size-Frequency of Entire Population

All netting stations combined: Figure 15 illustrates the size frequency distribution of 'ōpae netted at all four netting stations in the 'Ohe'o Stream System during the first and second surveys. The observed difference in frequency distribution between the first and second surveys is highly significant ($X^2 = 37.212$, $d.f. = 8$, $p = .0001$; size classes 2 and 3 pooled and size classes 11,12,13

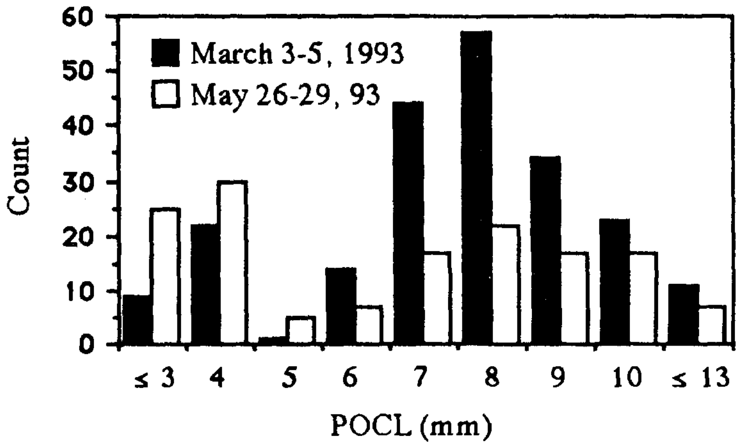


Fig. 15. Post-orbital carapace lengths (POCL) of 'ōpae samples taken from 'Ohe'o during the first and second surveys. Samples from all netting stations pooled. Data from Station 280 removed-see text.

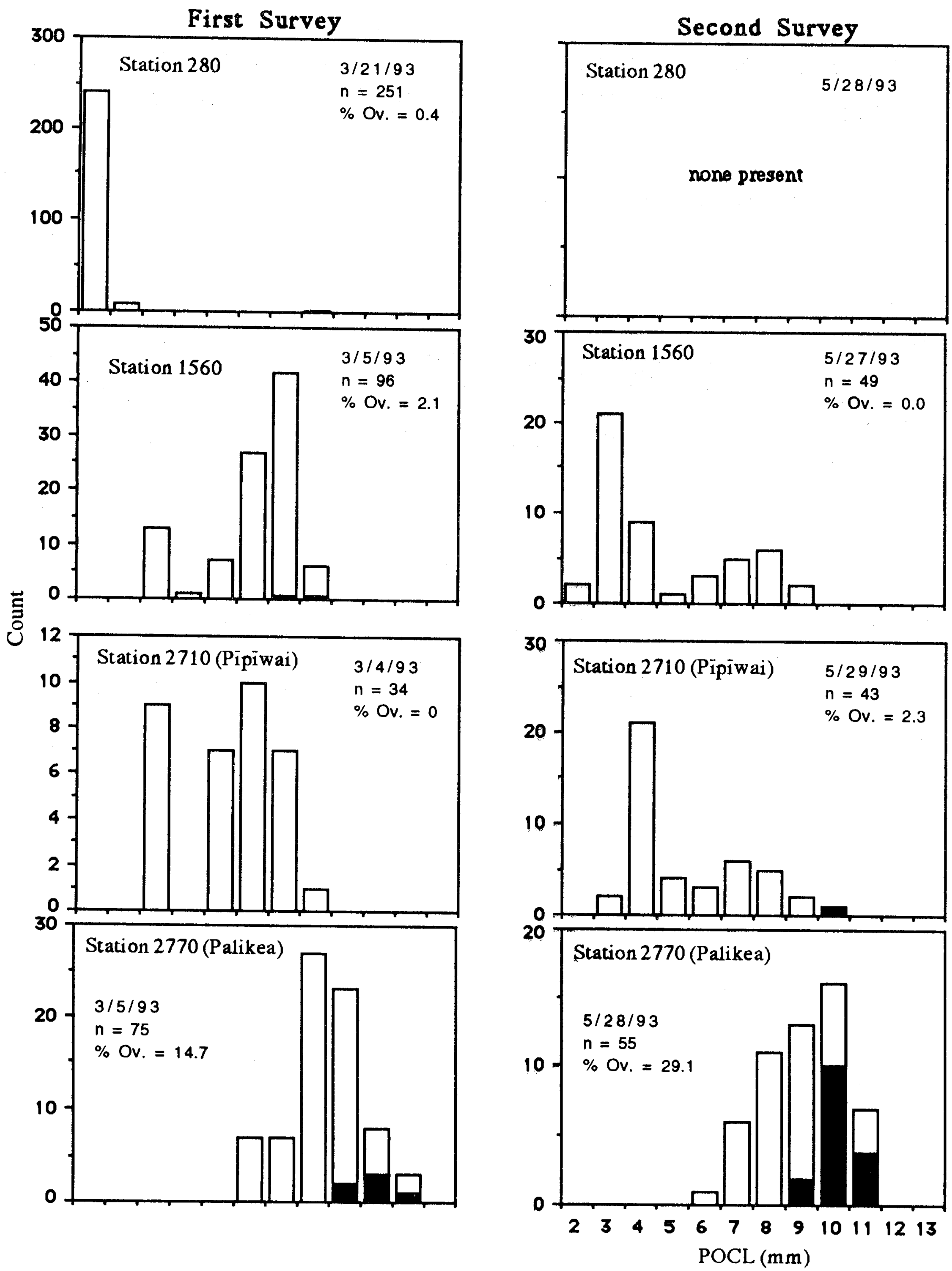


Fig. 16. Post-orbital carapace lengths (POCL) of 'opae in the 'Ohe'o Stream System during the first and second surveys. Percent ovigerous denoted by '% Ov'. Darkened bars represent ovigerous individuals.

pooled within each survey to satisfy minimum sample requirements of ≥ one count for each category - e.g. Koopmans 1987, p 420; data for size class 2-3 from station 280 treated as result of large recruitment event and removed from this analysis). The analysis shows that this significant result is due primarily to the difference at size class '2-3 mm POCL pooled' (z_{11} = -2.490; z_{21} = 3.011; all other z_{ij}< 1.960). However, some disproportionate decrease in abundance in the larger modal size class is apparent in Figure 15. Other differences in size class abundance appear to be a result of a general decline in density in individuals larger than POCL 5.

Comparisons Between Surveys 1 and 2 of Size-Frequencies From Each Netting Station

Figure 16 illustrates the size frequency distribution of 'ōpae netted at each of the four netting stations.

Station 280: The unusually high abundance of 2mm POCL individuals during the first survey is apparent. Absence of individuals during the second survey precludes formal comparison.

Station 1560: The observed difference in frequency distribution between the first and second surveys is highly significant (X^2 = 43.034, *d.f.* = 5, *p* = .0001; size classes 2,3,4 pooled and size classes 9 through 13 pooled-see above). This significant difference is due primarily to differences at size classes '2,3,4 mm POCL pooled' and 8 mm POCL (z_{11} = -3.076; z_{21} = 4.305, z_{25} = -2.538; all other z_{ij} < 1.960).

Station 2710: The observed difference in frequency distribution between the first and second surveys is significant (X^2 = 11.846, *d.f.* = 4, *p* = .0185; size classes 2,3,4,5 pooled and size classes 9 through 13 pooled-see above). This significant difference is due primarily to differences at size classes '2,3,4,5 mm POCL pooled', 6 mm POCL, and to a lesser extent 7 mm POCL (z_{11} = -1.689; z_{12} = 1.264, z_{13} = 1.148).

Station 2770 (Lua Falls): The observed difference in frequency distribution between the first and second surveys is not significant (X^2 = 4.639, *d.f.* = 4, *p* = .3264; size classes 2 through 7 pooled and size classes 11 through 13 pooled-see above).

Spatial Differences

Comparisons During Both Surveys 1 and 2 of Densities Among Areas

As with 'o'opu, the relatively low number of stations in each of the four areas discourages a formal comparison of 'ōpae density among these areas. However, Figure 14 illustrates the instream distribution of 'ōpae density. The density is fairly low in Lower 'Ohe'o, but sporadically higher throughout Upper 'Ohe'o, Pīpīwai and Palikea.

Comparisons During Both Surveys 1 and 2 of Size-Frequencies Among Netting Stations

Figure 16 illustrates the size-frequency distribution of 'ōpae at each of the four netting stations. Both surveys 1 and 2 exhibit essentially the same pattern. Station 280 harbored no adults. Individuals recorded there appear to be recruits (POCL = 2,3). Small individuals are also found at Station 1560. The size distribution of the larger 'ōpae at Station 1560 is similar to that at Station 2710 (Pīpīwai). The largest individuals are found at Station 2770 (Lua Falls-Palikea). None of the smaller individuals recorded at the other stations were observed at Station 2770.

Additional Observations

Occurrence of Ovigerous Individuals

The proportion of individuals ovigerous increased between surveys 1 and 2. Of the 456 individuals netted during the first survey, 14 (3.1%) were ovigerous. During the second survey 18 of 147 (12.2%) were ovigerous. Although this difference in proportion was significant (X^2 18.621, *d.f.* = 1, *p* = .0001), a ratio constructed using the number of females rather than the total number of individuals would be more instructive. The sex of sampled 'ōpae was not determined. Fig. 16 demonstrates that ovigerous individuals were most common at Station 2770. In addition, those ovigerous tended to be larger.

Lack of correlation between 'ōpae counts and time of day

No significant linear correlations were observed between the mean number of 'ōpae at a station, and the time of day at which the counts at that station were made during either survey 1 or 2 (1st: Kendall's *tau* = -.306, Z = -1.591, *p* < .20; 2nd: Kendall's *tau* = -.178, Z = -.962, *p* < .40). Yet, scattergrams of both surveys suggested a slight but recognizable decline in mean count with time of day. Although there is no strong evidence at this point to indicate that, during the daylight hours over which surveys 1 and 2 were conducted, 'ōpae survey methods in 'Ohe'o need to take special account of the time of day, data from future surveys should be monitored for this possibility.

The hīhīwai in 'Ohe'o

Hīhīwai were extremely rare in the 'Ohe'o Stream System. No individuals were recorded during the first and third surveys. Two individuals were recorded at Station 1120 during the second survey. These measured 40 and 34 mm in shell length.

Hīhīwai egg cases were recorded only from Station 1120. The mean counts at 1120 were 5.4 (0 to 19), 6.9 (0 to 59), and 0.5 (0 to 4) egg cases per quadrat during the first, second, and third surveys respectively.

The M. lar in 'Ohe'o

Temporal Differences

Comparison Among Surveys 1,2,3 and 4 of Abundance of Entire Population

The mean number of *M. lar* in each trap during the first survey was 3.04 (variance = 8.63, range: 0 to 11, n = 28, $\sum$ = 85); during the second: 5.96 (var = 19.40, range: 0 to 16, n = 26, $\sum$ = 155); the third: 11.3 (var = 86.642, range: 0 to 39, n = 20 $\sum$ = 226); the fourth: 7.07 (var = 43.624, range: 0 to 29, n = 28, $\sum$ = 198). Means were significantly different among surveys (ANOVA applied to log(x+1)-transformed number per trap, *p* < .0001). The detrans-

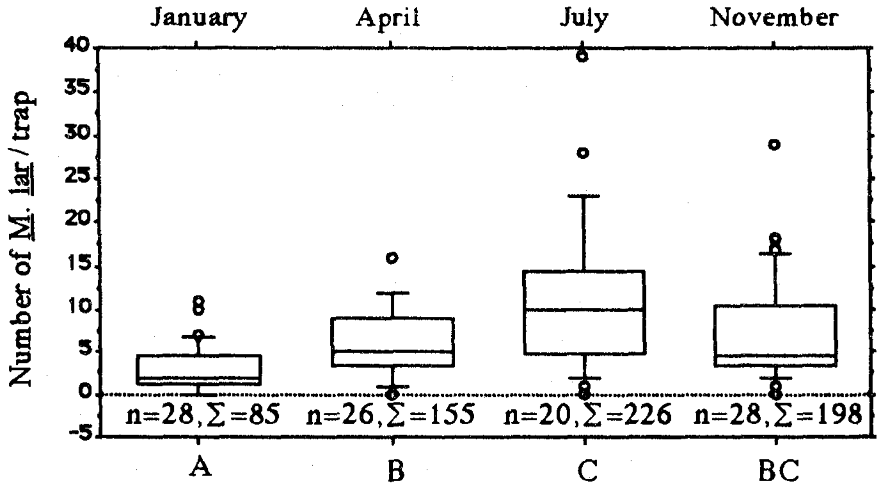


Fig. 17. Numbers of *M. lar* trapped in the 'Ohe'o stream system (n = number traps set, Σ = total number *M. lar* trapped). The means of surveys 1, 2 and 3 are significantly different from each other. The mean of survey 4 is different from 1 but indistinguishable from 2 and 3 (see capital letters - comparison of survey means using Fisher's Least Significant Difference, $p < .05$).

formed means using the variance correction of Elliott (1970) are 3.1, 6.3, 12.3, and 7.2.

The mean number of *M. lar* per trap increased significantly between the first and second, and second and third surveys. The mean of the fourth survey was significantly different from that of the first survey only (Fisher's LSD, $p < .05$, Fig. 17).

The total number of males trapped increased from 117 to 163 and again to 166 during the second, third and fourth trappings. The number of females trapped increased from 28 to 59, then declined to 30. Thus the overall increase between the second and third trappings appears due to both males and females.

Comparison Among Surveys 1, 2, 3 and 4 of Spatial Distribution of Abundance of Entire Population

The number of prawns trapped at each station during the first survey was not significantly correlated to that of Surveys 2,3, and 4. However, Surveys 2,3, and 4 were significantly intercorrelated (Survey 1 vs. Survey 2: Kendall's *tau* = .23, $n = 26$, Z = 1.646, $p < .10$; Survey 1 vs. Survey 3: Kendall's *tau* = .28, $n = 20$, Z = 1.727, $p < .10$; Survey 1 vs. Survey 4: Kendall's *tau* = .244, $n = 28$, Z = 1.821, $p < .10$; Survey 2 vs. Survey 3: Kendall's *tau* = .441, $n = 20$, Z = 2.721, $p < .01$; Survey 2 vs. Survey 4: Kendall's *tau* = .534, $n = 26$, Z = 3.822, $p < .0005$; Survey 3 vs. Survey 4: Kendall's *tau* = .474, $n = 20$, Z = 2.921, $p < .005$).

Comparisons Among Surveys 1, 2, 3, and 4 of Mean Size of Entire Population

The mean of the mean POCL(mm) of those trapped at each station during the first survey was 32.2 (var = 101.7, range: 11 to 46, n = 24 stations); second: 34.0 (var = 58.2, range: 18 to 45.6, n = 24); third: 34.9 (var = 53.5, range: 14 to 45.5, n = 19); and fourth: 33.6 (var = 54.3, range: 16.5 to 45.5, n = 27). These differences among surveys in the mean of mean size at each station were not significant (ANOVA, $p = .7459$).

Comparisons Among Surveys 1, 2, 3, and 4 of Size-Frequency of Entire Population

All stations combined: Figure 18 illustrates the size frequency distribution of *M. lar* trapped throughout the 'Ohe'o Stream System during the four surveys. The differences in size frequency distribution among the surveys are significant (two smallest size classes pooled to satisfy minimum sample requirements-see above, 4 x 9 matrix, $X^2 = 42.229$, $d.f. = 24$, $p = .0122$).

Spatial Differences

Comparisons Among Surveys 1, 2, 3 and 4 of Abundances Among Areas

Differences in abundance among areas were not consistent:

first: The mean number of *M. lar* trapped in Upper 'Ohe'o, Lower 'Ohe'o, Pīpīwai and Palikea were 5.4, 1.67, 1.6, and 2, respectively. This difference was significant (log(x+1) transformed, ANOVA, *d.f.* between = 3, *d.f.* within = 24, $p = .0145$; significance due to differences between Lower and Upper 'Ohe'o, and between Lower 'Ohe'o and Pīpīwai, Fisher's LSD, $p < .05$).

second: The mean number of *M. lar* trapped in Upper 'Ohe'o, Lower 'Ohe'o, Pīpīwai and Palikea were 7.7, 2.1, 10.8, and 2.5, respectively. This difference was significant (log(x+1) transformed, ANOVA, *d.f.* between = 3, *d.f.* within = 22, $p = .0001$; the only non-significant pairwise comparisons were between Lower 'Ohe'o and Pīpīwai and between Upper 'Ohe'o and Palikea, Fisher's LSD, $p < .05$).

third: The mean number of *M. lar* trapped in Upper 'Ohe'o, Lower 'Ohe'o, and Pīpīwai were 13, 6.29, and 16, respectively. No data was collected in Palikea. This difference was not significant (log(x+1) transformed, ANOVA, *d.f.* between = 2, *d.f.* within = 17, $p = .0874$).

fourth: The mean number of *M. lar* trapped in Upper 'Ohe'o, Lower 'Ohe'o, Pīpīwai and Palikea were 8.8, 4.7, 9, and 5.7, respectively. This difference was significant (log(x+1) transformed, ANOVA, *d.f.* between = 3, *d.f.* within = 24, $p = .304$).

Comparisons Among Surveys 1, 2, 3 and 4 of Size-Frequencies Among Areas

The size frequency distribution of *M. lar* differed among Lower 'Ohe'o, Upper 'Ohe'o, Pīpīwai and Palikea (Fig. 19). Such differences were consistent for the most part. However, the mode at Upper 'Ohe'o shifted noticeably upwards between the second and third surveys.

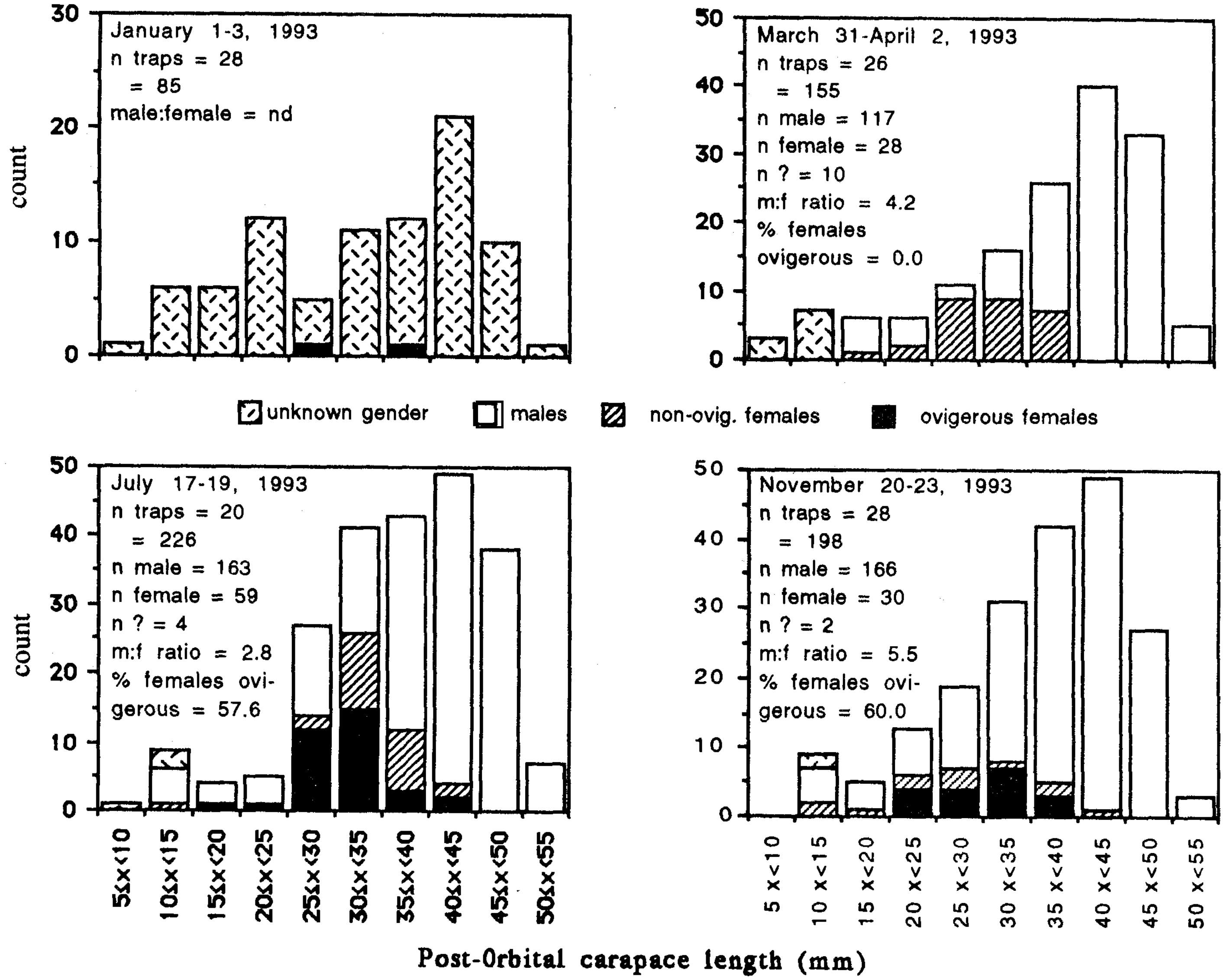


Fig. 18. Lengths and related statistics of Macrobrachium lar during survey trapping in the 'Ohe'o stream system, Kipahulu, Maui. Sizes of male, non-ovigerous and ovigerous female, and individuals of undetermined gender are indicated.

Additional Observations

Comparisons Among Surveys 1, 2, 3 and 4 of Sex Ratio and Percent Ovigerous

Sex was not recorded during the first survey. The sex ratio (m:f) was 4.2, 2.8, and 5.5 during Surveys 2,3,and 4 respectively. The difference among these was significant ($X^2 = 8.289$, $d.f. = 2$, $p < .0159$; Fig. 18) and was caused primarily by an excess of females over that expected by chance during Survey 3 and a deficit of females over expected during Survey 4 ($z_{11} = .215$, $z_{12} = -.388$; $z_{21} = -.970$, $z_{22} = 1.895$; $z_{31} = .861$, $z_{32} = -1.681$).

Likewise, the proportion of females which were ovigerous was significantly different among Surveys 2,3 and 4 ($X^2 = 29.493$, $d.f. = 2$, $p = .0001$; Fig. 18). This difference in the proportion ovigerous was caused primarily by a deficit over expected of ovigerous females during Survey 2, but also by an excess of ovigerous females over expected during both Surveys 3 and 4 ($z_{11} = -3.527$, $z_{12} = 3.154$; $z_{21} = 1.519$, $z_{22} = -1.359$; $z_{31} = 1.279$, $z_{32} = -1.144$)

Incidence of "black-spotted disease"

The proportion of individuals in each trap which exhibited symptoms of "black-spotted disease" showed no correlation with the distance inland (m) of the trapping location (third: $n = 18$, Kendall's $tau = -0.128$, $Z = -0.787$, $p > .40$; fourth: $n = 27$, $tau = -.067$, $Z = -.488$, $p > .60$).

During both the third and fourth surveys, the proportion of individuals in each trap which exhibited symptoms of "black-spotted disease" showed no linear correlation with either the number (third: Kendall's $tau = 0.1$, $Z = 0.666$, $p > .50$; fourth: $n = 27$, $tau = .104$, $Z = .762$, $p > .40$), or the mean carapace length (*third:* Kendall's $tau = 0.165$, $Z = 0.986$, $p > .40$; *fourth:* $tau = 0.067$, $Z = 0.491$, $p > .50$) of individuals in the trap. An examination of the corresponding scattergrams indicated that no simple non-linear correlations were likely.

Data from the third survey show a clear tendency for *increased* incidence

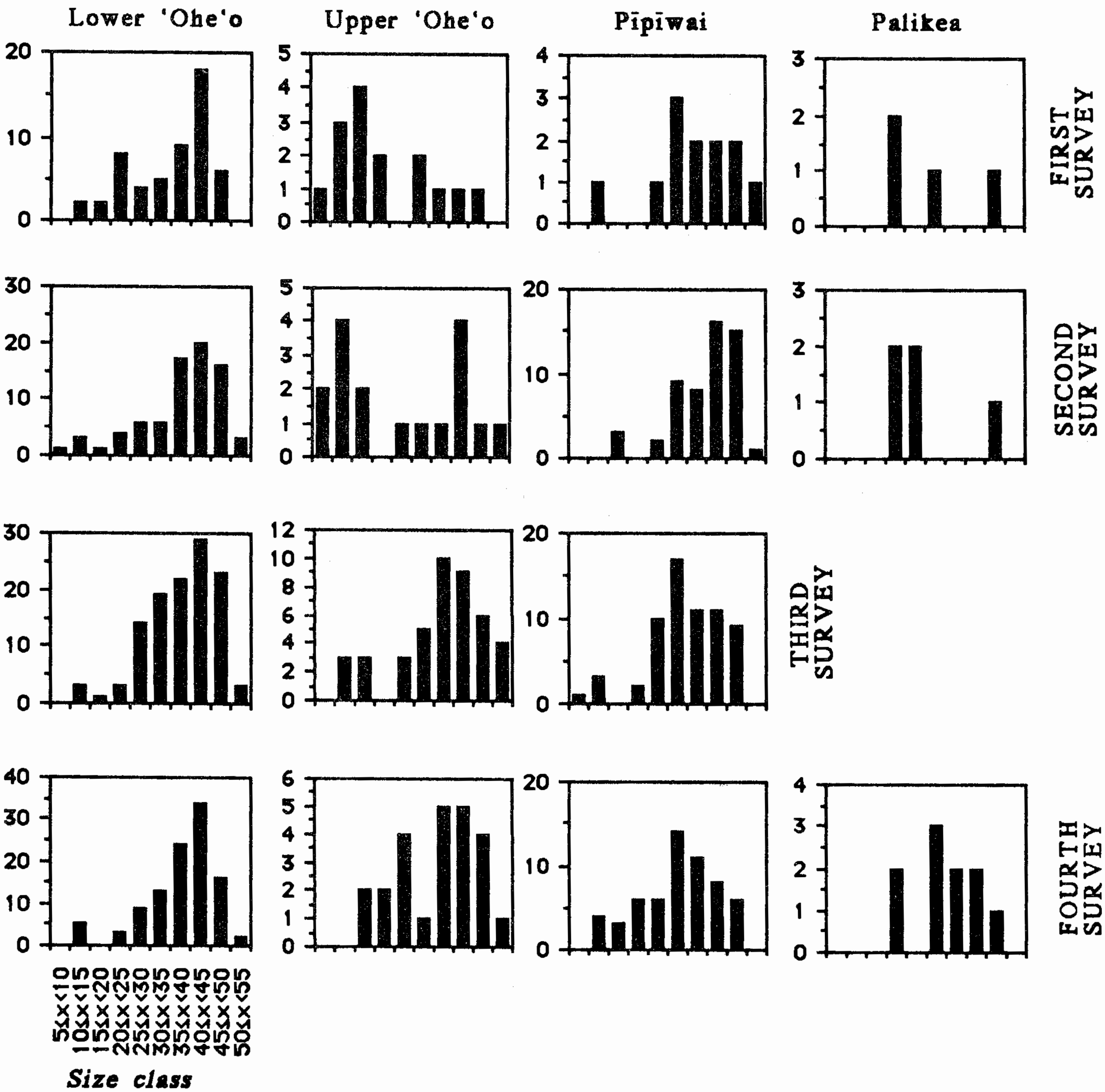


Fig. 19. Size frequency distributions of *M. lar* trapped in Lower 'Ohe'o, Upper 'Ohe'o, Pīpīwai, and Palikea during the first, second, third and fourth surveys. Note differing axes.

of symptoms with size. This pattern was not as clear during the fourth (Fig. 20). In both cases, however, individuals of both sexes exhibiting symptoms of "black-spotted disease" during the third and fourth surveys were among the larger of all individuals trapped during those surveys (all traps combined; $n = 225$, range in carapace length = 9 to 55 mm, mean carapace length = 36.3 mm; symptoms: n = 45, range in carapace length = 28 to 51 mm, mean carapace length = 41.9 mm, Fig. 20). The mean carapace length of individuals exhibiting symptoms was significantly greater than that of those without symptoms (no symptoms: n = 180, range in carapace length = 9 to 55 mm, mean carapace length = 34.9 mm; Mann-Whitney $U = 2174.5$, $Z = -4.806$, $p < .00001$).

Thus incidence of symptoms of "black-spotted disease" per trap during the third and fourth surveys was independent of distance inland, and the number and mean size of individuals in each trap. However, although large individuals were trapped which showed no symptoms, those individuals which exhibited symptoms were significantly larger than those which did not.

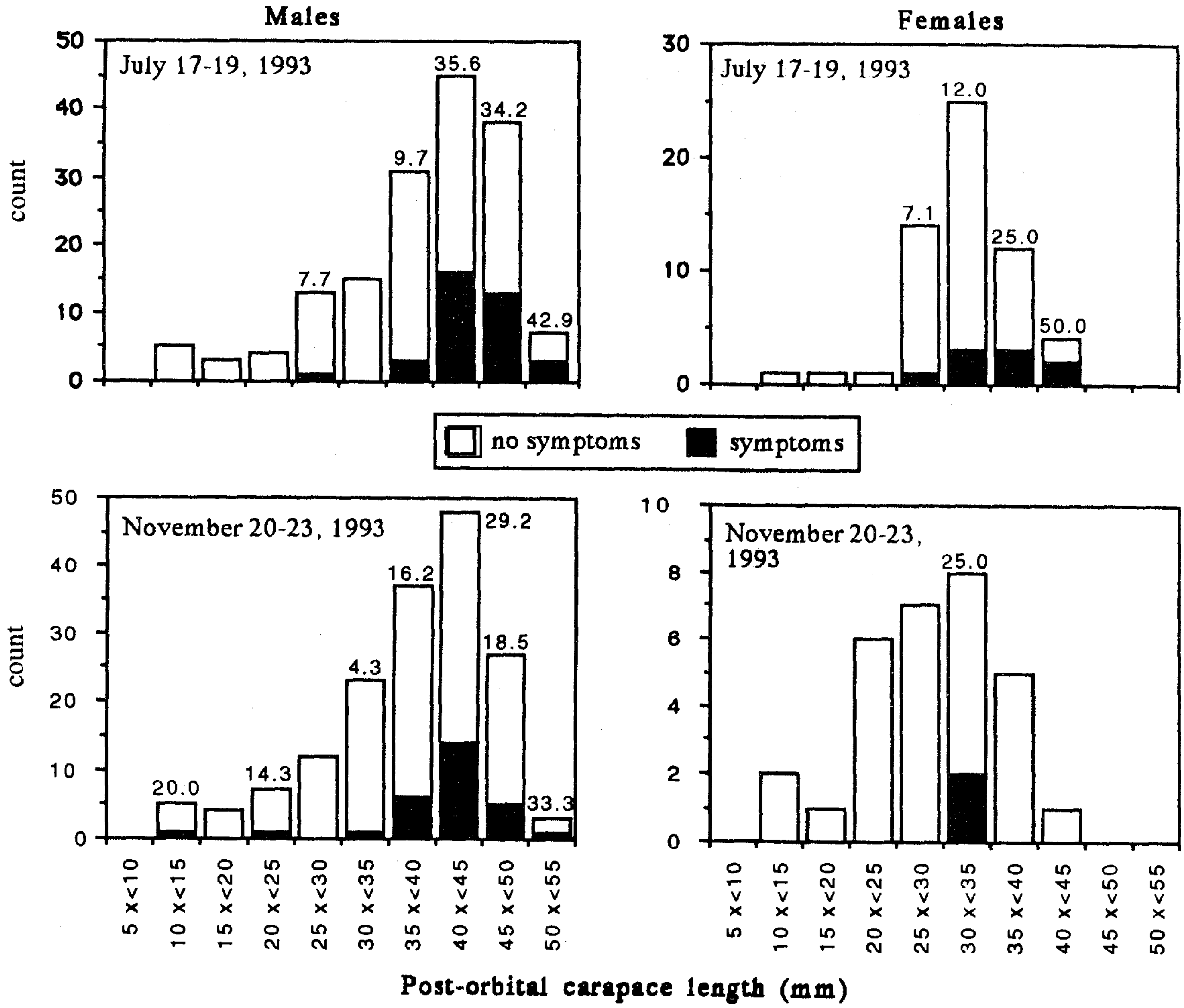


Fig. 20. Lengths of *M. lar* exhibiting symptoms of 'black-spotted disease' during survey trapping, 'Ohe'o Gulch, Kipahulu, Maui. Percentages of individuals exhibiting symptoms in each size class are indicated. Note differing axes.

Number trapped not correlated with mean size trapped

The number of individuals per trap showed no linear correlation with the mean carapace length in each trap (first: n = 24, Kendall's *tau* = -.039, Z = -.27, *p* > .70; second: n = 24, tau = .105, Z = .721, *p* > .40; third: outlier at station location 1630 removed, n = 18, tau = .047, Z = 0.273, *p* > .70; fourth: n = 27, tau = .254, *p* >.05, though slight curvilinearity apparent, result no different for *log*(# trapped)).

Mean POCL not correlated with distance inland

The mean carapace length of individuals in each trap showed no linear correlation with distance inland (first: n = 24, *tau* = 0, Z = 0, *p* -> unity; second: n = 24, tau = -.08, Z = -.546, *p* > .50; third: outlier at station location 1630 removed, n = 20, tau = -0.216, Z = -1.294, *p* > .10; fourth: n = 27, tau = -.169, Z = -1.237, *p* > .10).

Number trapped not strongly correlated with distance inland

The number trapped was negatively correlated with distance inland during the first (n = 28, Kendall's *tau* = -.323, Z = -2.41, *p* < .02); but not so during the remaining surveys (second: n = 26, *tau* = -.032, Z = -.228, *p* > .80; third: n = 20, *tau* = -.027, Z = -.166, *p* > .80; fourth: n = 28, *tau* = -.019, Z = -.144, *p* > .80).

Number of hours trap in water not consistently related to number of M. lar trapped During the first, second, third, and fourth surveys the traps remained in the water for 14.5 to 19, 17.5 to 20, 15 to 18.5, and 17 to 18.5 hours respectively. The mean number of hours the traps were in the water differed significantly among the four surveys (mean of 1st = 17.3, 2nd = 18.4, 3rd = 17.0, 4th = 17.6; Kruskal Wallis: *d.f.* = 3, *H* = 16.869, *p* < .001).

The number of *M. lar* trapped declined significantly with the number

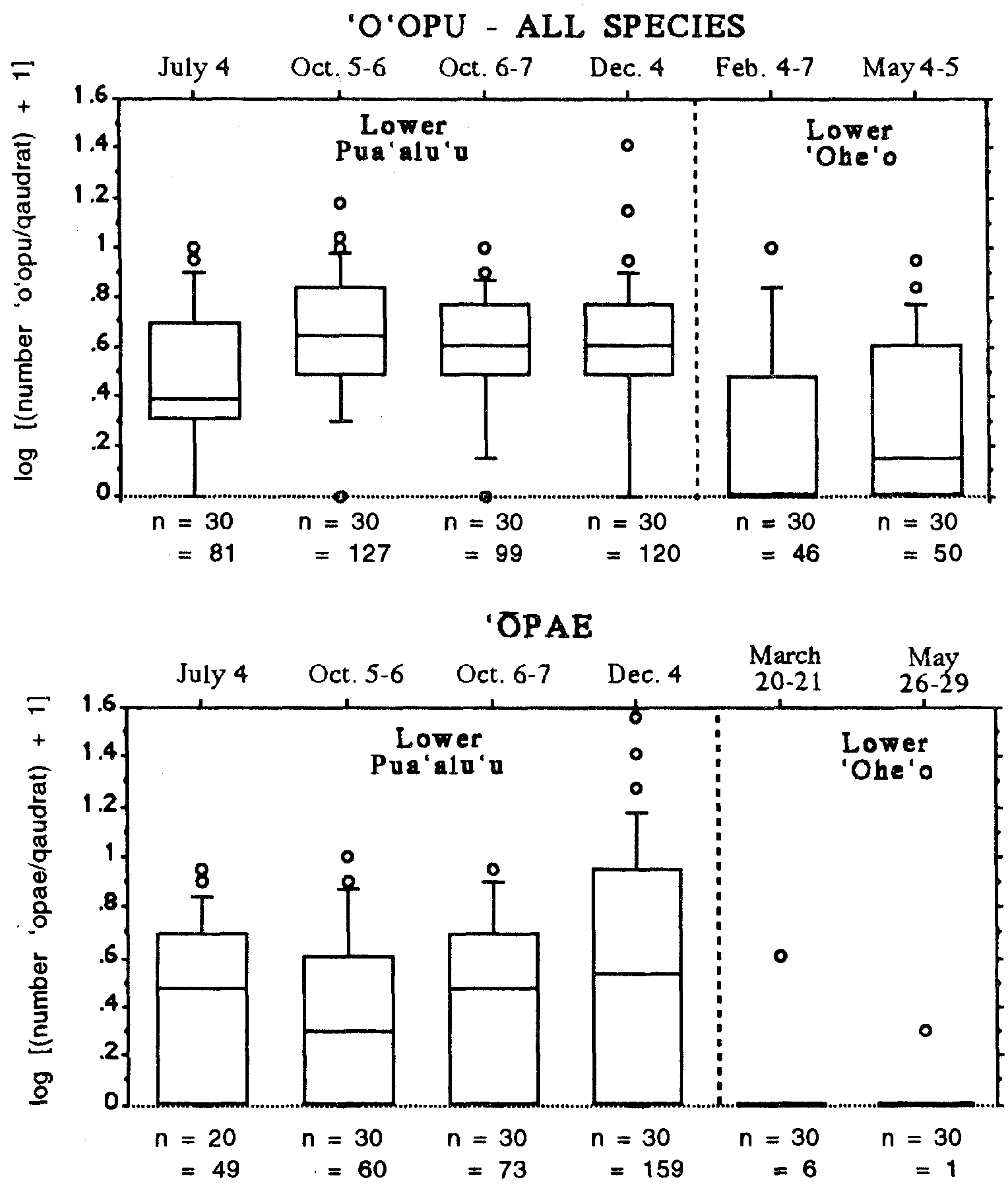


Fig. 21. Densities of 'o'opu and 'ōpae in lower Pua'alu'u and lower 'Ohe'o (see text). Note recruit pulse at 'Ohe'o Station 280 removed from above graph).

of hours the trap was in the water during the first survey (n = 28, Kendall's *tau* = -.544, Z = -4.061, $p <$ .0001), but was not significantly correlated with the number of hours during either the second (n = 26, Kendall's *tau* = .068, Z = .486, $p <$ .70), or third (n = 28, Kendall's *tau* = -.102, Z = -.63, $p < .60$) surveys. The small range of the number of hours discourages a correlation computation for the fourth survey, however the number of hours the trap remained in the water during the fourth survey showed no apparent linear relationship with the number of *M. lar* trapped. Also, though the sample size is small there is a lack of both any visible or significant relationship between the mean number trapped (see above) and the mean number of hours (n = 4, Kendall's *tau* = -.333, Z = -.609, $p < .60$). Thus, although the mean trapping times differed, over the range of trapping times used any observed differences in the number or mean number of *M. lar* trapped is unlikely to have been a function of trapping time.

The 'o'opu in Pua'alu'u

The mean numbers of 'o'opu of all species and sizes were 2.7, 4.2, 3.3, and 4.0 individuals per quadrat during the first, second, second-repeat, and third surveys respectively (n=30 in each instance). Elliott's (1971) Index of Dispersion categorized the distributions of the first, second and third surveys as 'clumped' and that of the second-repeat as 'random' (comparatively little distance among stations indicated concern over hierarchy of spatial autocorrelation here unnecessary, thus quadrat counts pooled among stations; X^2 = 75.7, 72.7, 164.0 and 43.1 respectively; *d.f.* = 29 in all cases). The full data set could not be normalized. Using the nonparametric analogue, the mean number did not differ significantly among the four surveys (see above rationale for pooling of quadrat counts. Kruskal-Wallis: d.f. = 3, H = 4.617, $p > .10$).

The 'ōpae in Pua'alu'u

(See above discussion of effect of new personnel employed during third survey). The quadrat counts from the 2nd-repeat and third surveys appear to have arisen from a common distribution (Kolmogorov-Smirnov: d.f = 2, 30 cases each survey, max difference = .233, K-S chi-square = 3.267, Z =

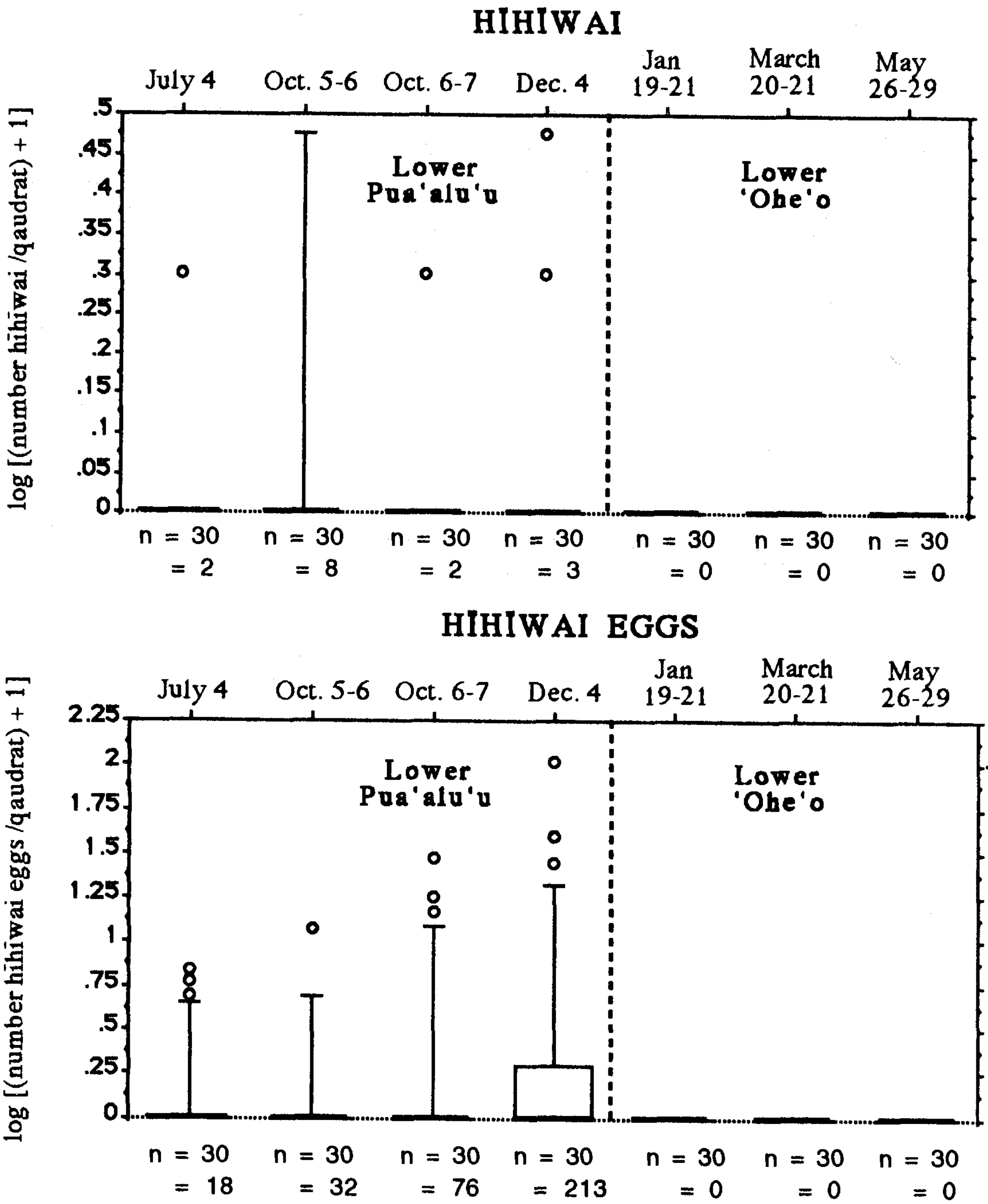


Fig. 22. Densities of hihīwai and hihīwai eggs in lower Pua'alu'u and lower 'Ohe'o (see text).

.904, $p > .30$).

The mean numbers of 'ōpae were 2.5, 2.0, 2.4, and 5.3 individuals per quadrat during the first, second, second-repeat, and third surveys respectively (n=20 during first, n = 30 during following). No significant difference was detected among these surveys (Kruskal-Wallis: d.f. = 3, H = 3.041, $p > .25$).

A look at Appendix II shows that the mean value for the third survey is inflated by two observations: 25 and 35. It is unknown whether these counts are accurate. However, both were reported by the newer personnel.

The hīhīwai in Pua'alu'u

Hīhīwai were present in low abundance. The mean numbers recorded were .067, 2.0, 2.4, and 5.3 individuals per quadrat respectively (n=20 during first, 30 in latter).

'Ohe'o vs. Pua'alu'u

Densities of 'o'opu, 'ōpae, hīhīwai and hīhīwai egg cases were higher in Pua'alu'u than in 'Ohe'o (Figs. 21, 22; no formal comparison). Although, Pua'alu'u surveys were not concurrent with 'Ohe'o, the relative temporal consistency of the data sets indicates that the differences are real.

DISCUSSION

The 'o'opu in 'Ohe'o

Method

The results indicate that the direct observation method provides realistic data: The strong correlation between both surveys 1 and 2 in the mean number of 'o'opu counted at each station indicates that the survey method employed detects actual spatial differences in 'o'opu abundance. These spatial differences were also detected by different observers. Further, the results do not seem to be consistently affected by the time of day in which the counts are made.

Within-stream distribution of 'o'opu species

Fitzsimons and Nishimoto (1991) describe what can be viewed as the typical instream distribution of 'o'opu: akupa are found in the lower reaches; nōpili are found from the lower reaches to the mid reaches; nākea occur in the lower, mid, and occasionally upper reaches; and 'alamo'o are most often found in the upper reaches. Because 'o'opu species may differ in their climbing ability (e.g. Nishimoto 1992), this ideal in-stream distribution may be strongly influenced by geomorphological features such as waterfalls (e.g. Ford 1979).

The distribution of 'o'opu in 'Ohe'o follows this model. Akupa were not recorded, and could have been restricted from entry into 'Ohe'o by the small terminal waterfall. The tiny handful of nōpili recorded were in Lower 'Ohe'o. The nākea were recorded in Lower and Upper 'Ohe'o. All adult 'alamo'o were located in Pīpīwai and Palikea.

Generally low abundance but significant 'alamo'o

In comparison with what I have observed in high-quality streams such as Hanawi, Wailau, Waikolu, and Hanakapi'ai, the densities of hīhīwai, 'ōpae, and 'o'opu in the 'Ohe'o Stream System were generally low. However, the densities of 'alamo'o in certain areas were the highest I have seen anywhere in Hawai'i. Individual 'alamo'o at these locations are also the largest I have seen.

The 'ōpae in 'Ohe'o

The apparent general decline in density in individual 'ōpae larger than POCL 5 observed from netting data suggests that the destructive sampling may be the cause of decline. Caution is advisable. Future surveys should rely on live measurements, especially if the sampling interval will be short and/or the population abundance is similar to that observed in the first and second surveys.

The hīhīwai in 'Ohe'o

During preliminary reconnaissance at the initiation of this study, almost the entire channel length of the study area was visually examined. During both reconnaissance and subsequent survey work, hīhīwai were observed at only two locations. A single spat was seen near Station 40 during reconnaissance. A very small number of adults (estimated at 20-100) was observed at a small section of boulder riffle at Station 1120 during reconnaissance. The only hīhīwai recorded during a survey were at Station 1120. The density recorded was very low. Egg cases were also observed only at Station 1120 during reconnaissance, and were recorded only at Station 1120 during the three surveys.

The mean number of adults (.20) recorded at Station 1120 compares well with the mean number of adults per station recorded in Waiohue (.65), Honomanu (.09), and Hanawi (.49) Streams during 1991 (Hodges 1992). Likewise, the mean number of egg cases recorded during each of the three surveys (5.4, 6.9, .50) at Station 1120 compare well with the mean number of egg cases per station recorded in these other streams (4.1, .9, 6.9 respectively). Unlike these other streams, however, the hīhīwai and egg cases in 'Ohe'o occur only at one small location rather than throughout the stream.

Kinzie and Ford (1977) stated that hīhīwai were present at locations in 'Ohe'o which correspond roughly to Stations 130,160,990, and 1120. Kinzie and Ford gave no quantities with which to compare present observations. However, both reconnaissance in the areas examined by Kinzie and Ford, and subsequent surveys in identical or very nearby locations, indicate that hīhīwai are no longer as widely distributed as they were during the time of Kinzie and Ford's observations.

The M. lar in 'Ohe'o

Abundance

The abundance of *M. lar* in 'Ohe'o cannot be quantitatively compared to that of other streams until a standardized method using the same or similar gear is applied in other streams. However, based qualitative observations I have made in a large number of streams throughout Hawai'i, *M. lar* appears quite abundant in 'Ohe'o. A. Brasher (pers. comm. - 1994) suggests that abundance of this species increases with increasing temperature and increasing availability of pool habitat. This appears likely.

Incidence of "black spotted disease"

Kubota (1972) noted that Kahana Stream and estuary, O'ahu was the only stream thus far investigated in Hawai'i in which symptoms of 'black-spotted disease' had been found on *M. lar*. of the *M. lar* that he worked with from Kahana 17.4% exhibited symptoms. The incidence frequency of symptoms in 'Ohe'o is very similar to that observed in Kahana. During the third and fourth surveys respectively, 20.0% and 15.7% of those trapped in the 'Ohe'o Stream System exhibited symptoms.

Effect of M. lar on native amphidromous fauna

During the course of the surveys it was very common to observe *M. lar* displacing 'ōpae and 'o'opu by apparently aggressive movement into the spaces occupied by the 'ōpae and 'o'opu. High densities of *M. lar* must pose a bioenergetic cost to natives from frequent displacement and interruption of feeding and mating activities.

The *M. lar* may also be a significant predator of natives. Kubota (1972) suggests that *M. lar* take 'o'opu egg masses, and reports incidences of *M. lar* taking adult 'o'opu both in the aquarium and *in situ*. In one case, Anne Brasher and myself observed an *M. lar* feeding on the head of an 'o'opu nōpili during the night in Waikolu Stream on Moloka'i. The head was retrieved and was not at all decomposed. In addition, *M. lar* were observed by Anne Brasher and myself on a number of occasions feeding on adult hīhīwai in Waikolu Stream. The effects of *M. lar* on the native amphidromous fauna is a critical area for future study.

Control

If *M. lar* is shown to have a strong adverse effect on native species it may be desirable to initiate a control program in 'Ohe'o. The data gathered in this study will provide an ample baseline with which to evaluate control efforts. Because *M. lar* is amphidromous, if a high proportion of *M. lar* originate in other streams control efforts will have to be carried out indefinitely. If, however, proportionally few *M. lar* originate from other streams, i.e. most of those in 'Ohe'o are aboriginal, control efforts could generate lasting success. Common wisdom holds that the great majority of individuals of all the macrofauna species in a Hawaiian stream are from some other stream. However, Hodges (1992) used population genetic and demographic data to show that it is quite possible that the vast majority of hīhīwai in streams with large hīhīwai populations are aboriginal. An experimental control program in 'Ohe'o would provide valuable insight into whether this is the case for *M. lar*. Because of the abundant *M. lar* population, comparatively easy access to the stream, a data baseline, and the regulatory authority and manpower available to prevent uncontrolled harvest, 'Ohe'o is an ideal location at which to study the effects of an *M. lar* control program.

Additional observations in 'Ohe'o

Does the present visual survey sampling strategy produce adequate statistical power?

'ōpae

The power of a parametric statistical test to detect a given difference depends on the variability of the data (expressed as standard deviation) and sample size. I used 10 quadrats at each of 16 stations for the 'ōpae surveys. I took the mean of the quadrat counts at each station as the parameter to be used in the testing for difference in abundance among the two surveys. This caused the the sample size (number of stations) to sampling effort (number of quadrats counted) ratio to be very low: 16/160 = 10%. However, an increased number of quadrats per station can significantly reduce the standard deviation of station means.

Given a fixed sampling effort (i.e. a fixed total number of quadrats to be counted, in this case 160), the question in terms of efficient spatial allocation of such sampling effort is whether the gain in power caused by reduced standard deviation of the station means is offset by the loss in power caused by reduced sample size. Or, in other words, does the design of 10 quadrats at each of 16 stations produce more or less statistical power than some other spatial allocation of the quadrats, such as 8 quadrats at each of 20 stations, or 6 quadrats at each of 27 stations? The relative dominance of either standard deviation or sample size in a power equation depends on the nature of the statistical distribution being sampled. Thus, to approach this question I needed actual data from 'Ohe'o.

The Model: I addressed this question by writing a computer program in True BASIC® to repeatedly re-sample the real data from the first 'ōpae survey in 'Ohe'o, then, under different quadrat allocation scenarios, calculate the statistical power likely to be generated under each such scenario (Fig. 23, see Appendix III for program code). The data was log(x+1) transformed and tested successfully for normality (see Results) before being inputted in to the model. I compared the statistical power likely to be generated by these scenarios to the power of the sampling scheme used in the first and second surveys (which was 10 quadrats at each of 16 stations).

For the model, I chose a set of four quadrat allocation scenarios where the number of quadrats to be counted were 2,4,6, and 8 quadrats at each of 16 stations. I also chose a set of four quadrat allocation scenarios where the total number of quadrats to be counted (sampling effort) was fixed at ca. 160, and, simply, the number of stations x = ca. 160/the number of quadrats per station y. These scenarios were: 8 quadrats at each of 20 stations, 6 at each of 27, 4 at each of 40, and 2 at each of 80 stations.

For each scenario, the program randomly selected y quadrat counts without replacement from the 10 actual quadrat counts recorded at each of the 16 stations used during the first survey. A mean (my) of these y counts was calculated for each station, and an overall mean (mmy) and standard deviation (smy) of these 16 means was calculated.

Using mmy and smy the program calculated the non-centrality parameter ∂ of a one-sample, two-tailed t-test for a 50% change in mmy using the equation:

∂ = (.50 * mmy)/(smy/(x^0.5)) ;

where x is the number of stations for the sampling scenario, and power π = f(∂). In the case of the first set of four scenarios x = 16. In the case of the second set of sampling scenarios x = the number of stations corresponding to the number of quadrats y; i.e. 20, 27, 40, and 80 stations respectively. Koopmans (1987, p. 287) provides a graphical representation of the relationship between ∂ and π, and this graph was used to determine the corresponding π for representative values of ∂. The program ran 30 trials for each sampling scenario.

Given the possibility of substantial changes in population abundance or distribution, future data may not conform to normal assumptions, regardless of data transformation. In these cases nonparametric tests will need to be employed. Further, it will probably be desirable to carry out tests comparing three or more surveys. In light of these considerations the power equation for the t-test is inappropriate. However, transformation will normalize the results of some surveys. The 'Ohe'o results are naturally paired between any two surveys, and the paired t-test is the most powerful two-sample test available. Because the paired t-test treats the differences among paired observations as the sample distribution, then essentially carries out a one-sample t-test for H_1: mean difference ≠ 0, in the case where the data from any two surveys can be brought into conformance with normal assumptions, the power equation for a one-sample t-test is directly applicable to the paired t-test. In addition, power relationships for non-

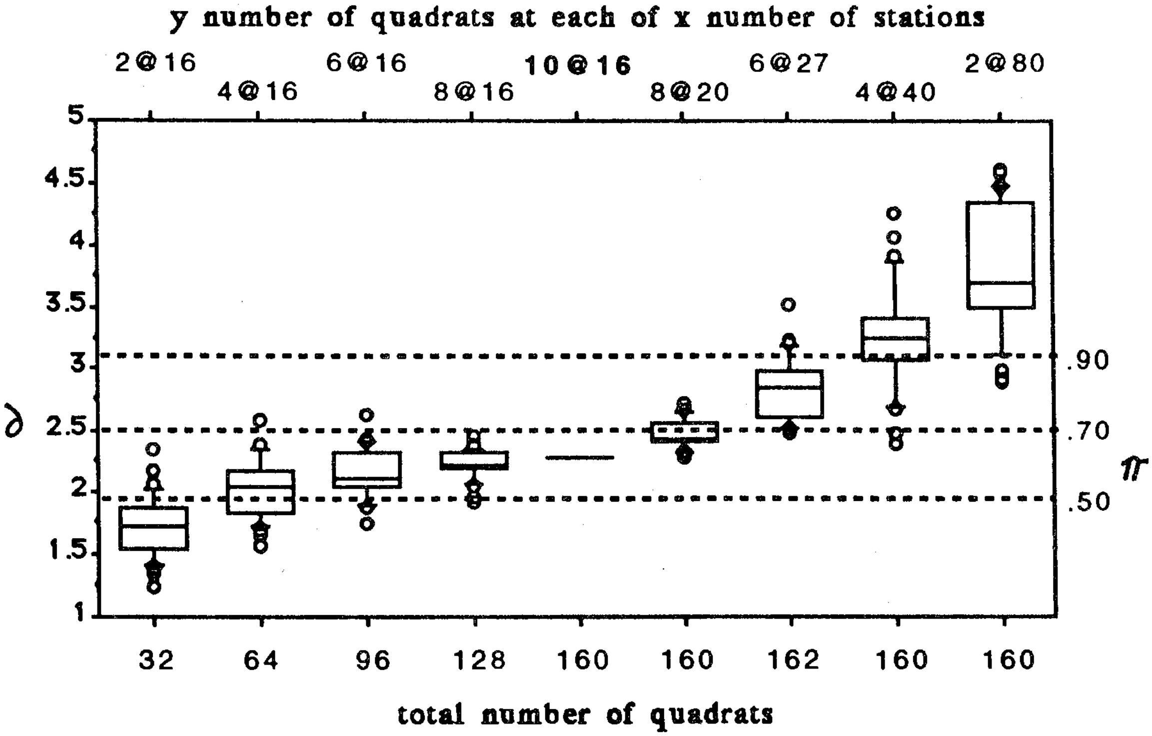


Fig. 23. Non-centrality parameter (∂) as a function of the number of quadrats per station (y) and the number of stations (x) from hypothetical ʻōpae surveys in ʻOheʻo, Kipahulu. The value of ∂ calculated from the actual observations made during the first ʻōpae survey in ʻOheʻo is at the center of the diagram (sampling design: 10 quadrats at each of 16 stations). The other values of ∂ were calculated from simulations of various sampling scenarios using the count data of the first ʻōpae survey (see text). The four data sets on the left of center are the likely values of ∂ given the hypothetical sampling scenarios of 2, 4, 6, and 8 quadrats at each of 16 stations respectively. The four data sets on the right of center are the likely values of ∂ given the hypothetical sampling scenarios of 8 quadrats at each of 20 stations, 6 quadrats at each of 27 stations, etc. The total number of quadrats which each hypothetical sampling scenario entails are indicated on the lower horizontal axis. The set of ∂ generated for each hypothetical sampling scenario is the result of 30 trial runs. Representative values of the power (π) of a one-sample, two-tailed t - test, where the difference to be detected is ± 50% of the population mean, corresponding to ∂ are indicated on the right vertical axis.

parametric tests are very difficult to establish (Sprent 1993, p. 297). And, power calculations for tests involving three or more samples (e.g. ANOVA) require data from an additional survey beyond the two carried out to date. Consequently, I used the power relationship for the one-sample t-test in this model to a) provide a guideline for the planning of future sampling strategies where the t-test proves appropriate, and b) to gain insight into the relative differences in power likely to be generated by the different sampling scenarios regardless of the test to be employed.

Model results: Figure 23 displays the results of the simulations for each sampling scenario. For the first set of four sampling scenarios (y varies but x is fixed at 16) ∂ decreases as y decreases. This is caused by an increase in smy with decreasing y. However, once x is allowed to increase in proportion to the decrease in y, ∂ increases with the decrease in y. Thus, the change in sample size x has a greater effect on ∂ than the corresponding change in y. In other words, for the nature of the statistical distribution of quadrat counts of ʻōpae at ʻOheʻo, the power of a t-test improves as the number of stations increases, even if the number of quadrats at each station decreases proportionally.

Figure 23 also illustrates representative values of π for the corresponding ∂. The actual data from the first ʻōpae survey yield a very low π. Only the scenarios 4 @ 40 and 2 @ 80 yield $\pi \geq$ the standard .90.

A large number of quadrats at each station has a number of advantages. More quadrats per station allow a more meaningful comparison of observations among stations. In instances of low population abundance, as has been observed in ʻOheʻo, more quadrats per station mean fewer station means which equal zero and thus a greater chance that transformations will bring station means in conformance with normal assumptions. The meeting of such assumptions allow application of the more powerful parametric methods. Of course, the sampling scenario model 1 used depended on a comparatively large number of quadrats per station from which to re-sample. These benefits aside, the very low power observed for the first ʻōpae survey indicates that future surveys focussing on changes in population abundance should utilize far more stations than the 16 used in the first and second surveys. The model demonstrates that for the case of ʻōpae in ʻOheʻo, sufficient power for a t-test will be achieved, for the same sampling effort as applied at present, by using 40 to 80 stations with a corresponding decrease in the number of quadrats per station.

ʻoʻopu

The same model as that used for ʻōpae was used for ʻoʻopu. Quadrat counts from the second survey in ʻOheʻo were transformed as the square root of (x + 0.05) and tested successfully for normality (Lilliefors: $p > .05$) before being used in the model.

The relative results are much the same as for ʻōpae (Fig. 24). Where

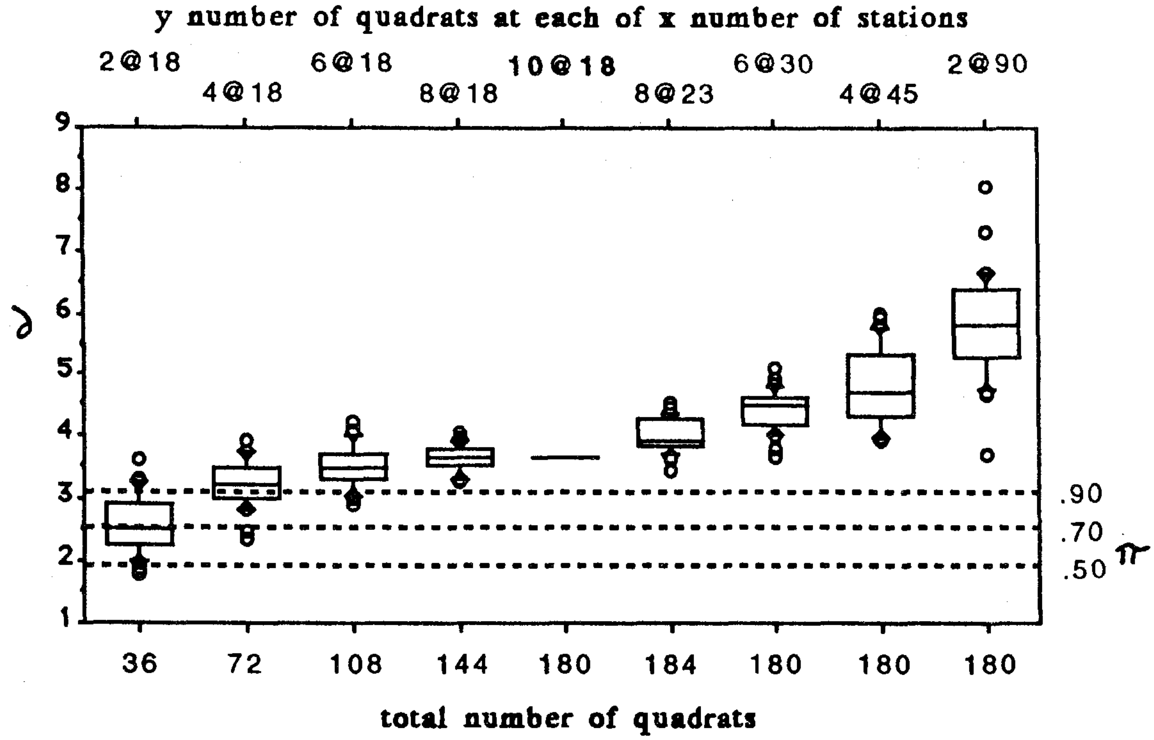


Fig. 24. Non-centrality parameter (∂), and power (π) for 'o'opu calculated and plotted as for 'ōpae in Fig. 23. Data used is from second 'o'opu survey. Max number of stations = 18.

the number of stations is held constant, power increases with increasing number of quadrats per station, and increases further with an increasing number of stations and a proportionate decrease in the number of quadrats per station. However, power is greater overall in the case of 'o'opu than of 'ōpae. According to the model, most of the sampling strategies, including that used in the first and second surveys, deliver sufficient power to detect a change in population abundance of ± 50%. However, the strategy used during the first and second survey does not deliver sufficient power (i.e. $\pi \geq .90$) to detect finer population changes. The data of the second survey provide powers of .84, .59, and .28 for 40%, 30%, and 20% abundance changes respectively. In fact, for a 20% abundance change the 2 quadrats at each of 90 stations sampling plan delivers a power of only .62.

Thus, the power of a *t*-test on 'ōpae counts drawn using the existing sampling strategy, even for as large a population change as ± 50%, is inadequate. That for 'o'opu is adequate. For both 'ōpae and 'o'opu, power will be improved by reducing the number of quadrats per station and increasing the number of stations during future surveys. (This is not a foregone conclusion. In the case where variability within stations is high compared to variability among stations, power changes in the opposite manner).

In the tests carried out in this study a number of data sets could not be normalized. This led to the application of nonparametric methods. Where normal assumptions are met, the power of a nonparametric test is generally lower than that of its parametric analogue. When the data is not normal, the power of the nonparametric is difficult to assess.

Generally low a\bundance

Despite the areas of high 'alamo'o density, based on my experience and research on other Hawaiian streams, I found the overall abundance of 'o'opu and 'ōpae in the 'Ohe'o Stream System to be low. Hīhīwai are almost nonexistent.

Abundance of the amphidromous fauna in Hawaiian streams is some function of instream effects and recruitment history (e.g. Hodges 1992). Instream effects include habitat quality parameters such as water quality, food availability, predation/harvest, competition and flow regime. Recruitment may be significantly affected by instream processes and the effects of these processes on reproduction (Hodges 1992). In this case, habitat quality, by affecting reproduction, may affect recruitment in a given stream.

Based on my qualitative observations of other streams, the habitat in Lower and much of Upper 'Ohe'o is poor. Turbidity is often high, and the ample current and boulder riffles so common in streams hosting large populations of the amphidromous fauna are lacking. Extremely large spates were common during this study, and may impact the populations.

Likewise, and again compared to my observations in other streams, recruitment to 'Ohe'o is low to nonexistent. In the case of 'o'opu the observations in other streams are qualitative. For hīhīwai, the total lack of recorded recruits in 'Ohe'o is in sharp contrast to the high abundances measured in Hanawi, Honomanu and Waiohue Streams (Hodges 1992). As with many streams in Hawai'i, the true extent of harvest in 'Ohe'o is unknown and could be great.

I don't know the relative importance, nor interrelationship of these effects on the abundance of the amphidromous fauna. Consequently, I cannot identify the causes of low abundance of 'o'opu, 'ōpae, and hīhīwai in 'Ohe'o. Such effects are a key area of research for Hawaiian stream ecology.

Populations Are Fairly Stable Over Survey Period

I have found (Hodges 1992) that the within-stream distribution of mean sizes and the overall size frequencies of hīhīwai were stable over three months in Waiohue, Honomanu, and Hanawi Streams. In Waiohue, an earlier study allowed me to determine that the within-stream distribution of mean sizes of hīhīwai remains stable over decades, but the overall size frequency can change dramatically in the same period. The present study indicates that the within-stream distribution of mean sizes and the overall size frequencies of 'o'opu, 'ōpae and *M. lar* of 'Ohe'o were fairly stable over the time interval surveyed (6-12 months). Likewise, the within-stream distribution of 'o'opu species remained stable over the same period.

Pua'alu'u and 'Ohe'o are good study sites

Adult 'alamo'o and 'ōpae occur in the lower reach of Pua'alu'u but do not occur with any significance in the comparable lower reach of 'Ohe'o. The nākea and nōpili are largely absent from the lower reach of Pua'alu'u. The nākea occurs in that of 'Ohe'o. Both 'alamo'o and 'ōpae are species normally found in the upper reaches of Hawai'i's streams. Nākea is most often found in the lower reaches but occurs at higher elevations where the gradient is not severe. The lower reach of Pua'alu'u is a steep grade with a small, fast rush of water, and closely resembles the upper reaches of Hawai'i's streams. The lower reach of 'Ohe'o is made up of very large, warm pools. These two neighboring streams seem to demonstrate the effects of habitat, including vertical profile, on species distribution in Hawaiian streams.

Pua'alu'u is a very small stream. The amphidromous populations are also very small. This makes Pua'alu'u an excellent location to study population processes. In addition, Pua'alu'u and 'Ohe'o together provide an interesting location for an in-depth comparative study of 'o'opu distribution and abundance and its relation to habitat characteristics. The termini of both Pua'ulu'u and 'Ohe'o are very shallow and narrow. This makes monitoring of recruitment and reproduction much easier.

SUMMARY

The surveys have been a successful step for stream research in 'Ohe'o and elsewhere:

- The surveys demonstrate that the visual observation method can produce consistent data sets. While it is advisable to use the same observers whenever possible, the data strongly suggest that, as long as all observers are well trained, the use of different observers will not jeopardize survey results. Future surveys should employ the sampling design modifications suggested.
- The within-stream distribution of the macrofauna has been described.
- A demographic and abundance data baseline has been established for both 'Ohe'o and Pua'alu'u.
- As with observations of hīhīwai in other streams, the overall size frequency distribution and the within-stream distribution of mean size of the 'o'opu, 'ōpae and *M. lar* in 'Ohe'o was fairly stable over the survey period (6-12 months). The within stream distribution of 'o'opu species was also stable over the same time period.
- In comparison with what I have observed in high-quality streams such as Hanawi, Wailau, Waikolu, and Hanakapi'ai, the overall densities of hīhīwai, 'ōpae, and 'o'opu in the 'Ohe'o Stream System were generally low. However, in certain areas of 'Ohe'o, 'alamo'o densities were high and individual 'alamo'o were large in comparison with these other streams.

Future Research

Population monitoring should continue, with results to be compared to the baseline established during this project. Such monitoring should include quantification of reproduction and recruitment of the macrofauna using larval trapping schemes. Population monitoring might be carried out in conjunction with an *M. lar* control program.

The causes of macrofauna abundance in Hawaiian streams remain unknown. These causes are key subjects of future research.

Habitat information was collected during the survey, but has not yet been analyzed. These data are not included in the Appendices. An analysis (e.g. multivariate, detrended correspondence) of the relationship between habitat and faunal occurrence will probably be fruitful.

Also, I made no attempt to develop quantitative definitions for observations such as "normal flow", "spate", "flood", etc. Such stream-specific definitions would be valuable and should be developed using a long (≥ 20 years) period of discharge record. Once a greater number of surveys are carried out in 'Ohe'o, it will be worthwhile to compare densities/abundance and other demographic characteristics of the fauna to discharge information.

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APPENDIX I

RAW DATA FROM 'OHE'O

NUMBER OF 'O'OPU RECORDED

RAW DATA - 'O'OPU SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; ‘a = ‘alamo‘o; nō = nōpili; nā = nākea; hi = hinana

Station	Quad ID		FIRST SURVEY: Feb 5-7, 1993							SECOND SURVEY: May 4-6, 1993						
			Date	Time	Obs	Number / quadrat				Date	Time	Obs	Number / quadrat			
	U	A				‘a	nō	nā	hi				‘a	nō	nā	hi
‘Ohe‘o	0	3	2/7	826	MH	1	0	0	0	5/4	952	AB	0	0	0	0
70	0	4			MH	0	0	0	0		955	AB	0	0	1	0
	1	1			MH	1	0	0	0		959	AB	0	0	1	0
	5	1			MH	0	0	0	0		1002	AB	0	0	0	0
	7	1			MH	0	0	0	0		1005	AB	0	0	0	0
	9	2		835	AB	0	0	0	0		957	MH	0	0	6	0
	10	7		840	AB	0	0	0	0		1001	MH	0	0	2	0
	19	5		845	AB	0	0	0	0		1007	MH	0	0	3	0
	25	0		850	AB	0	0	1	0		1011	MH	0	0	0	0
	32	4		855	AB	0	0	2	7		1017	MH	0	0	6	2
‘Ohe‘o	0	2		920	AB	0	0	0	4		1028	AB	0	0	0	0
130	0	7		927	AB	0	0	0	0		1031	AB	3	0	0	3
	1	4		934	AB	0	0	0	0		1035	AB	0	0	0	0
	7	5		940	AB	0	0	0	6		1038	AB	0	0	3	0
	16	0		945	AB	0	0	0	1		1041	AB	0	0	0	0
	19	0			MH	6	0	0	0		1033	MH	4	0	0	0
	25	0			MH	4	0	0	0		1037	MH	0	0	0	0
	29	0			MH	2	0	0	0		1042	MH	3	0	0	0
	31	0			MH	6	0	0	0		1047	MH	3	1	0	0
	39	0			MH	1	0	0	1		1053	MH	2	1	0	0
‘Ohe‘o	1	0		1020	AB	0	0	0	0		1111	AB	0	0	0	0
160	7	0		1024	AB	0	0	0	0		1115	AB	1	0	0	0
	10	0		1028	AB	0	0	0	0		1118	AB	1	0	0	0
	16	0		1031	AB	0	0	0	0		1121	AB	0	0	1	0
	25	0		1035	AB	0	0	0	0		1125	AB	0	0	0	0
	3	0		1005	MH	0	0	1	0		1114	MH	1	0	0	0
	8	0			MH	0	0	0	0		1119	MH	0	0	0	0
	14	0			MH	0	0	2	0		1123	MH	0	0	0	0
	16	0			MH	0	0	0	0		1127	MH	0	0	0	0
	22	0	2/7		MH	0	0	0	0		1132	MH	0	0	0	0
‘Ohe‘o	5	2	2/5	823	MH	0	0	0	0		1215	MH	0	0	0	0
280	14	1		924	MH	0	0	0	0		1219	MH	0	0	0	0
	16	1			MH	2	0	0	0		1224	MH	4	0	0	0
	22	0		938	MH	0	0	0	0		1229	MH	0	0	0	0
	25	1			MH	0	0	0	0		1236	MH	0	0	0	0
	25	3		905	AB	0	0	0	0		1208	AB	0	0	1	0
	31	5		910	AB	1	0	0	0		1213	AB	0	0	0	0
	38	3		932	AB	0	0	0	0		1217	AB	0	0	0	0
	47	2		938	AB	0	0	0	0		1221	AB	0	0	0	0
	59	5		945	AB	0	0	0	0		1225	AB	1	0	0	0
‘Ohe‘o	1	0			MH	0	0	0	0		1300	AB	0	0	0	0
490	1	5			MH	0	0	0	0		1303	AB	0	0	0	0
	2	1			MH	0	0	0	0		1307	AB	0	0	0	0
	12	5			MH	0	0	0	0		1310	AB	0	0	0	0
	13	0			MH	0	0	0	0		1313	AB	0	0	0	0

RAW DATA - 'O'OPU SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; 'a = 'alamo'o; nō = nōpili; nā = nākea; hi = hinana

			FIRST SURVEY: Feb 5-7, 1993							SECOND SURVEY: May 4-6, 1993						
Station	Quad ID		Date	Time	Obs	Number / quadrat				Date	Time	Obs	Number / quadrat			
	U	A				'a	nō	nā	hi				'a	nō	nā	hi
	14	6		1022	AB	0	0	0	0		1305	MH	0	0	0	0
	17	6		1025	AB	0	0	0	0		1309	MH	0	0	0	0
	24	1		1031	AB	0	0	0	0		1314	MH	0	0	0	0
	25	5		1035	AB	0	0	0	0		1318	MH	0	0	0	0
	43	4		1041	AB	0	0	0	0		1324	MH	0	0	0	0
'Ohe'o	0	2			MH	0	0	0	0		1405	MH	0	0	0	0
990	7	2			MH	0	0	0	0		1420	MH	0	0	1	0
	16	3			MH	0	0	1	0		1417	MH	0	0	0	0
	25	0			MH	0	0	1	0		1424	MH	0	0	0	0
	31	2			MH	0	0	0	0		1430	MH	0	0	2	0
	48	2		1140	AB	0	0	0	0		1401	AB	0	0	0	0
	62	3			AB	1	0	0	2		1404	AB	0	0	0	0
	77	2		1150	AB	0	0	0	0		1408	AB	0	0	0	0
	87	2		1205	AB	0	0	0	0		1411	AB	0	0	0	0
	96	0	2/5	1210	AB	0	0	0	0		1415	AB	0	0	0	0
'Ohe'o	8	1	n.s.			* * * * * * * * * * * * *					1449	AB	0	0	0	0
1120	12	1	n.s.			* * * * * * * * * * * * *					1453	AB	0	0	0	0
	27	2	n.s.			* * * * * * * * * * * * *					1456	AB	0	0	0	0
	37	0	n.s.			* * * * * * * * * * * * *					1500	AB	0	0	0	0
	46	1	n.s.			* * * * * * * * * * * * *					1503	AB	0	0	1	0
	2	2	n.s.			* * * * * * * * * * * * *					1454	MH	0	0	1	0
	7	0	n.s.			* * * * * * * * * * * * *					1458	MH	0	0	0	0
	16	3	n.s.			* * * * * * * * * * * * *						MH	0	0	1	0
	25	2	n.s.			* * * * * * * * * * * * *					1508	MH	0	0	0	0
	31	3	n.s.			* * * * * * * * * * * * *				5/4	1513	MH	0	0	0	0
'Ohe'o	2	0	2/5	1306	MH	0	0	0	0	5/5	819	MH	0	0	0	0
1268	13	1			MH	0	0	0	0		825	MH	1	0	0	0
	14	1			MH	0	0	0	0		830	MH	0	0	0	0
	25	1			MH	0	0	0	0		836	MH	0	0	0	0
	37	0			MH	0	0	0	0		842	MH	0	0	0	0
	38	4		1320	AB	0	0	0	0		813	AB	0	0	0	0
	44	1		1324	AB	0	0	0	0		816	AB	0	0	0	0
	59	0		1330	AB	0	0	0	0		820	AB	0	0	0	0
	66	4		1335	AB	0	0	0	0		824	AB	0	0	0	0
	70	4		1340	AB	0	0	0	0		827	AB	0	0	0	0
'Ohe'o	33	0			MH	0	0	0	0		925	MH	0	0	0	0
1418	45	0			MH	0	0	0	0		931	MH	0	0	0	0
	73	2			MH	0	0	0	0		937	MH	0	0	0	0
	77	2			MH	0	0	0	0		942	MH	0	0	0	0
	79	1			MH	0	0	0	0		946	MH	0	0	0	0
	88	1			AB	0	0	0	0		918	AB	0	0	0	0
	94	2			AB	0	0	0	0		921	AB	0	0	0	0
	131	2			AB	0	0	0	0		926	AB	0	0	0	0
	145	0		1500	AB	0	0	0	0		931	AB	0	0	0	0
	150	1		1510	AB	0	0	0	0		936	AB	0	0	0	0

RAW DATA - 'O'OPU SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; 'a = 'alamo'o; nō = nōpili; nā = nākea; hi = hinana

Station	Quad ID		FIRST SURVEY: Feb 5-7, 1993							SECOND SURVEY: May 4-6, 1993						
			Date	Time	Obs	Number / quadrat				Date	Time	Obs	Number / quadrat			
	U	A				'a	nō	nā	hi				'a	nō	nā	hi
'Ohe'o	0	3			MH	0	0	0	0		1003	MH	0	0	0	0
1560	0	6			MH	0	0	0	0		1009	MH	0	0	0	0
	1	0			MH	0	0	0	0		1014	MH	0	0	0	0
	1	7			MH	0	0	0	0		1019	MH	0	0	0	0
	3	5			MH	0	0	0	0		1024	MH	0	0	0	0
	5	15			AB	0	0	0	0		1002	AB	1	0	0	0
	7	18			AB	0	0	0	0		1006	AB	0	0	0	0
	7	20			AB	0	0	0	0		1009	AB	0	0	0	0
	9	1			AB	0	0	0	0		1014	AB	0	0	0	0
	10	15	2/5		AB	0	0	0	0		1017	AB	0	0	0	0
Pipiwai	0	1	2/6	900	MH	0	0	0	0		1139	MH	3	0	0	0
1900	0	3			MH	1	0	0	0		1144	MH	1	0	0	0
	7	3			MH	2	0	0	0			MH	0	0	0	0
	43	1			MH	2	0	0	0		1155	MH	0	0	0	0
	53	3		945	MH	0	0	0	0		1200	MH	0	0	0	0
	77	2		920	AB	2	0	0	0		1131	AB	0	0	0	0
	81	1		927	AB	0	0	0	0		1140	AB	0	0	0	0
	85	3		933	AB	0	0	0	0		1143	AB	1	0	0	0
	87	2		937	AB	1	0	0	0		1147	AB	1	0	0	0
	96	1		944	AB	1	0	0	0		1152	AB	0	0	0	0
Pipiwai	1	1		1017	MH	1	0	0	0		1237	MH	0	0	0	0
2110	11	0			MH	0	0	0	0		1240	MH	0	0	0	0
	11	1			MH	0	0	0	0		1245	MH	1	0	0	0
	18	0			MH	0	0	0	0		1252	MH	2	0	0	0
	18	1			MH	5	0	0	0		1257	MH	1	0	0	0
	29	3		1028	AB	1	0	0	0		1233	AB	1	0	0	0
	30	0		1035	AB	1	0	0	0		1236	AB	0	0	0	0
	52	1		1040	AB	2	0	0	0		1240	AB	1	0	0	0
	63	0		1047	AB	0	0	0	0		1244	AB	0	0	0	0
	95	0		1050	AB	0	0	0	0		1249	AB	0	0	0	0
Pipiwai	15	1		1130	MH	0	0	0	0		1331	MH	0	0	0	0
2360	15	2			MH	1	0	0	0		1335	MH	0	0	0	0
	25	3			MH	1	0	0	0		1340	MH	0	0	0	0
	29	1		1152	MH	0	0	0	0		1345	MH	0	0	0	0
	33	1			MH	1	0	0	0		1350	MH	2	0	0	0
	46	0		1125	AB	0	0	0	0		1325	AB	0	0	0	0
	68	2		1139	AB	0	0	0	0		1329	AB	0	0	0	0
	71	2		1143	AB	0	0	0	0		1332	AB	0	0	0	0
	85	0		1148	AB	0	0	0	0		1335	AB	0	0	0	0
	88	1		1150	AB	1	0	0	0	5/5	1338	AB	0	0	0	0
Palikea	1	4			MH	0	0	0	0	5/6	1609	MH	0	0	0	0
1892	13	3			MH	0	0	0	0		1613	MH	0	0	0	0
	18	1			MH	0	0	0	0		1617	MH	1	0	0	0
	39	2			MH	0	0	0	0		1622	MH	0	0	0	0
	54	1			MH	0	0	0	0		1628	MH	2	0	0	0

RAW DATA - 'O'OPU SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; 'a = 'alamo'o; nō = nōpili; nā = nākea; hi = hinana

Station	Quad ID		FIRST SURVEY: Feb 5-7, 1993							SECOND SURVEY: May 4-6, 1993						
			Date	Time	Obs	Number / quadrat				Date	Time	Obs	Number / quadrat			
	U	A				'a	nō	nā	hi				'a	nō	nā	hi
	55	2		1310	AB	0	0	0	0		1602	AB	1	0	0	0
	59	3		1315	AB	0	0	0	0		1606	AB	1	0	0	0
	61	2		1320	AB	0	0	0	0		1611	AB	3	0	0	0
	66	4		1325	AB	0	0	0	0		1614	AB	2	0	0	0
	77	1		1330	AB	1	0	0	0		1619	AB	0	0	0	0
Palikea	5	4		1405	MH	0	0	0	0		1510	MH	0	0	0	0
2032	26	1			MH	0	0	0	0		1516	MH	2	0	0	0
	29	0			MH	0	0	0	0		1521	MH	0	0	0	0
	37	4			MH	0	0	0	0		1526	MH	1	0	0	0
	39	0			MH	2	0	0	0		1531	MH	1	0	0	0
	42	0		1315	AB	1	0	0	0		1511	AB	0	0	0	0
	43	4		1320	AB	3	0	0	0		1514	AB	0	0	0	0
	45	0		1325	AB	0	0	0	0		1518	AB	0	0	0	0
	58	3		1330	AB	7	0	0	0		1522	AB	0	0	0	0
	65	4	2/6	1335	AB	8	0	0	0		1527	AB	8	0	0	0
Palikea	14	1	2/7		MH	0	0	0	0		1241	MH	0	0	0	0
2170	42	2			MH	0	0	0	0		1245	MH	0	0	0	0
	55	0		1320	MH	0	0	0	0		1250	MH	0	0	0	0
	59	0			MH	0	0	0	0		1254	MH	0	0	0	0
	88	1			MH	0	0	0	0		1259	MH	0	0	0	0
	112	1		1325	AB	0	0	0	0		1240	AB	0	0	0	0
	115	0		1337	AB	0	0	0	0		1245	AB	0	0	0	0
	116	1		1340	AB	0	0	0	0		1248	AB	0	0	0	0
	118	0		1345	AB	0	0	0	0		1251	AB	0	0	0	0
	119	2	2/7	1350	AB	0	0	0	0		1255	AB	0	0	0	0
Palikea	1	2	n.s.			*************					1131	AB	0	0	0	0
2550	7	1	n.s.			*************					1135	AB	0	0	0	0
	10	3	n.s.			*************					1138	AB	0	0	0	0
	16	0	n.s.			*************					1141	AB	0	0	0	0
	75	0	n.s.			*************					1148	AB	0	0	0	0
	3	1	n.s.			*************					1135	MH	0	0	0	0
	8	0	n.s.			*************					1139	MH	0	0	0	0
	14	0	n.s.			*************					1144	MH	0	0	0	0
	16	2	n.s.			*************					1148	MH	1	0	0	0
	32	3	n.s.			*************					1154	MH	3	0	0	0
Palikea	4	1	2/7	1541	MH	0	0	0	0		928	MH	0	0	0	0
2570	9	2			MH	0	0	0	0		933	MH	0	0	0	0
	34	0			MH	0	0	0	0		939	MH	0	0	0	0
	39	0			MH	0	0	0	0		943	MH	0	0	0	0
	44	3			MH	0	0	0	0		947	MH	0	0	0	0
	47	3		1550	AB	0	0	0	0		922	AB	0	0	0	0
	88	1		1601	AB	0	0	0	0		928	AB	0	0	0	0
	96	1		1606	AB	0	0	0	0		931	AB	0	0	0	0
	98	0		1600	AB	0	0	0	0		934	AB	0	0	0	0
	99	1	2/7	1610	AB	0	0	0	0	5/6	937	AB	0	0	0	0

SIZE CLASSES OF 'O'OPU RECORDED

FIRST SURVEY: Feb 5-7, 1993. 'a = 'alamo'o, nō = nōpili, nā = nākea

size class	Station 70			Station 130			Station 160			Station 280			Station 490			Station 9		
(inches)	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā
.5 to 1	2	0	2	19	0	0	0	0	0	1	0	0	0	0	0	1	0	0
1.1 to 1.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.6 to 2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
2.1 to 2.5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2.6 to 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1 to 3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.6 to 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4.1 to 4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4.6 to 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

size class	Station 1120			Station 1268			Station 1418			Station 1560			Station 1900			Station 2		
(inches)	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā
.5 to 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1 to 1.5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0
1.6 to 2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	4	0	0
2.1 to 2.5	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	0
2.6 to 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1 to 3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.6 to 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.1 to 4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RAW DATA - 'O'OPU SURVEYS - 'OHE'O STREAM SYSTEM

FIRST SURVEY: Feb 5-7, 1993. 'a = 'alamo'o, nō = nōpili, nā = nākea

size class	Station 2360			Station 1892			Station 2032			Station 2170			Station 2550			Station 2:		
(inches)	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā
.5 to 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1 to 1.5	1	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
1.6 to 2	1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
2.1 to 2.5	2	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
2.6 to 3	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
3.1 to 3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.6 to 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.1 to 4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SECOND SURVEY: May 4-6, 1993.   'a = 'alamo'o, nō = nōpili, nā = nākea

size class	Station 70			Station 130			Station 160			Station 280			Station 490			Station 990		
(inches)	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā
.5 to 1	0	0	3	13	0	2	3	0	0	5	0	1	0	0	0	0	0	0
1.1 to 1.5	0	0	5	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1.6 to 2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.1 to 2.5	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.6 to 3	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
3.1 to 3.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.6 to 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4.1 to 4.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5.6 to 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
7.1 to 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

size class	Station 1120			Station 1268			Station 1418			Station 1560			Station 1900			Station 2110		
(inches)	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā
.5 to 1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1 to 1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1.6 to 2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0	0
2.1 to 2.5	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0
2.6 to 3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
3.1 to 3.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.6 to 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.1 to 4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RAW DATA - 'O'OPU SURVEYS - 'OHE'O STREAM SYSTEM

SECOND SURVEY: May 4-6, 1993. 'a = 'alamo'o, nō = nōpili, nā = nākea

size class	Station 2360			Station 1892			Station 2032			Station 2170			Station 2550			Station 2570		
(inches)	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā	'a	nō	nā
.5 to 1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1 to 1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.6 to 2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.1 to 2.5	2	0	0	5	0	0	7	0	0	0	0	0	0	0	0	0	0	0
2.6 to 3	0	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	0
3.1 to 3.5	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0
3.6 to 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.1 to 4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NUMBER OF ʻŌPAE RECORDED

RAW DATA - 'OPAE SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; # = number 'opae/quadrat

Note: unless otherwise indicated, all observations made by MH

Station	Quad ID U	Quad ID A	FIRST SURVEY MARCH 3-21, '93 Time/Date	Obs	#	SECOND SURVEY MAY 26-29, '93 Time/Date	Obs	#
70	0	3	3/21	MD	0	5/29		0
70	0	4	1415	MD	0	1330		0
70	1	1		MD	0			0
70	5	1		MD	3			0
70	7	1		MD	0			0
70	9	2		MD	3			0
70	10	7		MD	0			0
70	19	5		MD	0			0
70	25	0		MD	0			0
70	32	4		MD	0			0
130	0	2	3/21	MD	0	5/29		0
130	0	7	1500	MD	0	1340		0
130	1	4		MD	0			0
130	7	5		MD	0			0
130	16	0		MD	0			0
130	19	0		MD	0			0
130	25	0		MD	0			0
130	29	0		MD	0			0
130	31	0		MD	0			0
130	39	0		MD	0			0
280	5	2	3/20		0	5/26		0
280	14	1	1300		18	1515		0
280	16	1			12			0
280	22	0			15			0
280	25	1			67			0
280	25	3			63			0
280	31	5			83			1
280	38	3			35			0
280	47	2			37			0
280	59	2			16			0
990	0	2	3/20		0	5/26		0
990	7	2	1150		0	1700		0
990	16	3			9			1
990	25	0			0			1
990	31	2			0			0
990	48	2			0			0
990	62	3			0			0
990	77	2			0			1
990	87	2			24			0
990	96	0			9			0
1418	12	0	3/3		1	5/27		26
1418	19	1	1400		3	1005		28

RAW DATA - 'OPAE SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; # = number 'opae/quadrat

Note: unless otherwise indicated, all observations made by MH

			FIRST SURVEY MARCH 3-21, '93			SECOND SURVEY MAY 26-29, '93		
Station	Quad ID		Time/			Time/		
	U	A	Date	Obs	#	Date	Obs	#
1418	19	2			4			21
1418	38	2			13			2
1418	58	2			2			4
1418	60	2			5			18
1418	64	1			0			4
1418	85	2			6			7
1418	85	3			5			8
1418	86	2			6			6
1560	0	0	3/5		0	5/29		0
1560	0	2	1520		0	1145		0
1560	1	5			0			0
1560	1	10			0			0
1560	1	20			15			4
1560	2	5			0			0
1560	2	10			0			1
1560	2	19			0			3
1560	3	6			0			0
1560	4	9			0			0
1900	12	0	3/3		6	5/27		12
1900	19	1	1310		11	1245		2
1900	19	2			6			2
1900	38	2			4			0
1900	58	2			4			2
1900	60	2			0			0
1900	64	1			2			0
1900	85	2			0			11
1900	85	3			12			17
1900	86	2			3			20
2110	12	0	3/4		0	5/27		2
2110	19	1	1312		4	1420		5
2110	19	3			3			5
2110	38	2			1			6
2110	58	2			0			1
2110	60	3			0			3
2110	64	1			0			1
2110	85	3			2			1
2110	85	5			0			3
2110	86	2			3			0
2360	12	0	3/4		1	5/27		0
2360	19	1	1410		5	1445		1
2360	19	2			7			10
2360	38	2			14			10

RAW DATA - 'OPAE SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; # = number 'opae/quadrat

Station	Quad ID U	Quad ID A	FIRST SURVEY MARCH 3-21, '93 Time/Date	Obs	#	SECOND SURVEY MAY 26-29, '93 Time/Date	Obs	#
2360	58	2			12			9
2360	60	2			3			16
2360	64	1			7			3
2360	85	2			8			5
2360	85	3			3			3
2360	86	2			•			0
2710	0	4	3/4		3	5/29		2
2710	5	1	935		2	930		7
2710	7	0			4			0
2710	29	1			0			6
2710	29	2			12			6
2710	37	2			3			6
2710	38	1			2			2
2710	41	3			4			1
2710	45	2			1			0
2710	69	1			5			10
2032	0	4	3/4		0	5/28		0
2032	3	1	1515		0	1540		2
2032	5	0			0			0
2032	5	1			0			2
2032	9	0			0			0
2032	10	2			0			0
2032	10	4			0			0
2032	16	4			0			0
2032	19	2			0			0
2032	21	1			2			0
2052	12	0	3/4		0	5/28		2
2050	19	1	1430		0	1555		0
2050	19	4			0			0
2050	38	0			0			0
2050	58	0			15			6
2050	60	1			15			9
2050	64	1			14			0
2050	85	1			3			10
2050	85	0			14			5
2050	86	1			0			0
2170	12	0	3/5		0	5/28		0
2170	19	1	1345		0	1330		0
2170	19	2			0			0
2170	38	2			0			0
2170	58	2			0			0
2170	60	2			0			0

Note: unless otherwise indicated, all observations made by MH

RAW DATA - 'OPAE SURVEYS - 'OHE'O STREAM SYSTEM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; # = number 'opae/quadrat

Note: unless otherwise indicated, all observations made by MH

Station	Quad ID U	Quad ID A	FIRST SURVEY MARCH 3-21, '93 Time/Date	Obs	#	SECOND SURVEY MAY 26-29, '93 Time/Date	Obs	#
2170	64	1			0			0
2170	85	2			3			0
2170	85	3			7			1
2170	86	2			0			10
2550	12	0	3/5		16	5/28		47
2550	19	1	1300		0	1244		2
2550	19	2			0			0
2550	38	2			0			0
2550	58	2			41			36
2550	60	2			0			1
2550	64	1			0			24
2550	85	2			0			0
2550	85	3			0			0
2550	86	2			0			0
2570	12	0	3/5		0	5/28		0
2570	19	1	1130		0	1200		0
2570	19	2			0			0
2570	38	2			0			0
2570	58	2			0			0
2570	60	2			0			0
2570	64	1			0			0
2570	85	2			0			0
2570	85	3			0			0
2570	86	2			0			0
2770	2	0	3/5		0	5/28		8
2770	9	0	930		0	1015		20
2770	9	1			0			27
2770	28	2			59			1
2770	38	2			0			0
2770	40	2			20			8
2770	44	1			0			5
2770	55	0			1			5
2770	55	2			0			1
2770	60	2			0			20

SIZE CLASSES OF ŌPAE RECORDED

RAW DATA - 'OPAE SURVEYS - 'OHE'O STREAM SYSTEM

'OPAE CAPTURED - POCL = Post-orbital carapace length, Ov = ovigerous

FIRST SURVEY, MARCH 3-21, 1993

Date: 3/21 Station 280 POCL	Count	#Ov	Date: 3/5 Station 1560 POCL	Count	#Ov	Date: 3/4 Station 2710 POCL	Count	#Ov	Date: 3/5 Station 2770 POCL	Count	#Ov
2	241	0	2	0	0	2	0	0	2	0	0
3	9	0	3	0	0	3	0	0	3	0	0
4	0	0	4	13	0	4	9	0	4	0	0
5	0	0	5	1	0	5	0	0	5	0	0
6	0	0	6	7	0	6	7	0	6	0	0
7	0	0	7	27	0	7	10	0	7	7	0
8	0	0	8	42	1	8	7	0	8	7	0
9	1	0	9	6	1	9	1	0	9	27	0
10	0	0	10	0	0	10	0	0	10	23	3
11	0	0	11	0	0	11	0	0	11	8	5
12	0	0	12	0	0	12	0	0	12	3	3

SECOND SURVEY, MAY 26-29, 1993

Date: 5/28 Station 280 POCL	Count	#Ov	Date: 5/27 Station 1560 POCL	Count	#Ov	Date: 5/29 Station 2710 POCL	Count	#Ov	Date: 5/28 Station 2770 POCL	Count	#Ov
2	0	0	2	2	0	2	0	0	2	0	0
3	0	0	3	21	0	3	2	0	3	0	0
4	0	0	4	9	0	4	21	0	4	0	0
5	0	0	5	1	0	5	4	0	5	0	0
6	0	0	6	3	0	6	3	0	6	1	0
7	0	0	7	5	0	7	6	0	7	6	0
8	0	0	8	6	0	8	5	0	8	11	0
9	0	0	9	2	0	9	2	1	9	13	2
10	0	0	10	0	0	10	1	1	10	16	10
11	0	0	11	0	0	11	0	0	11	7	4
12	0	0	12	0	0	12	0	0	12	0	0

NUMBER, SIZE CLASSES, AND NUMBER OF EGG CASES OF HĪHĪWAI RECORDED

U, A = 'Up', 'Across' quad coordinates; Obs = observer;
h =hihiwai; sl = shell length (mm); e = hihiwai egg case

FIRST SURVEY: JANUARY 20, 1993

Station	Quad ID U	Quad ID A	Date	Time	Obs	# / quad h	# / quad sl	# / quad e
'Ohe'o	2	0	1/20	943	MH	0		0
1120	5	3			MH	0		0
	7	4			MH	0		7
	9	4			MH	0		0
	11	3			MH	0		0
	12	5			MH	0		15
	14	4			MH	0		19
	15	0			MH	0		4
	15	2			MH	0		0
	18	1			MH	0		0

SECOND SURVEY: MARCH 20, 1993

Station	Quad ID U	Quad ID A	Date	Time	Obs	# / quad h	# / quad sl	# / quad e
'Ohe'o	2	0	7/4	1145	MH	0		0
1120	5	3			MH	0		10
	7	4			MH	1	40	0
	9	4			MH	0		0
	11	3			MH	0		0
	12	5			MH	0		0
	14	4			MH	0		59
	15	0			MH	0		0
	15	2			MH	1	34	0
	18	1			MH	0		0

THIRD SURVEY: MAY 26, 1993

Station	Quad ID U	Quad ID A	Date	Time	Obs	# / quad h	# / quad sl	# / quad e
'Ohe'o	2	0	7/4	1800	MH	0		0
1120	5	3			MH	0		0
	7	4			MH	0		4
	9	4			MH	0		0
	11	3			MH	0		0
	12	5			MH	0		0
	14	4			MH	0		0
	15	0			MH	0		0
	15	2			MH	0		0
	18	1			MH	0		1

Note: No hihiwai or hihiwai egg cases were recorded at any other station during any other survey.

HIHIWAI QUADRAT COORDINATES-'OHE'O STREAM SYSTEM

U, A = 'Up, 'Across' quadrat cordinates

Station	U	A
40	0	1
	0	5
	0	7
	0	10
	1	25
	2	0
	2	9
	3	13
	3	18
	3	19
70	0	4
	0	5
	1	8
	1	9
	2	2
	3	1
	3	8
	7	7
	9	9
	10	10
130	0	20
	1	2
	1	4
	1	10
	1	11
	1	15
	2	5
	2	6
	3	1
	5	1
160	5	2
	13	2
	14	3
	19	3
	27	1
	29	1
	38	3
	41	3
	48	2
	57	3
220	0	1
	0	3
	0	7
	2	8
	4	6
	5	8
	6	7
	7	6
	8	0
	9	8
250	0	1
	0	2
	0	2
	0	2
	0	0
	10	0
	15	0
	15	1
	16	2
	29	1
280	0	5
	0	2
	0	0
	0	1
	0	5
	0	3
	10	3
	13	0
	18	3
	19	2
490	1	0
	2	3
	3	2
	5	4
	7	0
	9	5
	10	1
	13	0
	18	0
	19	3
990	1	4
	2	0
	3	1
	3	9
	5	7
	6	4
	6	8
	8	6
	8	9
	9	8
1120	2	0
	5	3
	7	4
	9	4
	11	3
	12	5
	14	4
	15	0
	15	2
	18	1
1232	1	0
	3	4
	6	3
	7	0
	11	3
	11	4
	17	4
	18	2
	18	3
	19	3
1268	0	8
	1	3
	1	7
	2	4
	4	0
	9	2
	10	4
	11	3
	12	3
	12	5
1418	4	1
	5	2
	6	2
	11	3
	15	2
	16	0
	21	2
	24	1
	28	1
	33	1
1560	0	0
	0	21
	2	20
	3	1
	3	5
	3	6
	3	15
	4	7
	4	15
	4	24
1900	1	0
	1	1
	9	2
	10	0
	12	1
	13	0
	18	0
	25	1
	25	3
	30	3
2110	1	0
	1	1
	9	2
	10	0
	12	1
	13	0
	18	0
	25	1
	25	3
	30	3
2360	1	0
	1	1
	9	2
	10	0
	12	1
	13	0
	18	0
	25	1
	25	3
	30	3

NUMBER, SIZE CLASSES, AND ADDITIONAL CHARACTERISTICS OF Macrobrachium lar RECORDED

RAW DATA - M. lar SURVEYS - 'OHE'O STREAM SYSTEM

POCL - Post orbital carapace length (mm); Ov - ovigerous; BSD - presence of black-spotted disease symptoms.
'* = *time (2400 clock), date trap set and retrieved;*

FIRST SURVEY
Jan 3-5, '93

Station	POCL
**1720, 3 - 0850, 4*	
40	45
40	46
40	39
40	29
40	22
**1735, 3 - 0900, 4*	
70	47
70	36
70	40
70	23
70	36
70	41
70	43
**1830, 3 - 0920, 4*	
130	41
130	40
130	34
130	36
130	24
130	34
130	36
130	42
130	41
130	37
130	26
**1800, 3 - 0906, 4*	
160	31
160	48
160	35
160	44
160	41
160	43
**1815, 3 - 0930, 4*	
170	37
170	26
170	40
170	42

SECOND SURVEY
MARCH 31-April 2, '93

Station	POCL	Sex	Ov
**1300, 31 - 0628, 1*			
40	48	m	
40	38	m	
40	39	m	
40	44	m	
40	34	m	
**1311, 31 - 0630, 1*			
70	46	m	
70	47	m	
70	39	m	
70	46	m	
70	39	m	
70	39	m	
70	39	m	
70	38	m	
70	45	m	
**1320, 31 - 0704, 1*			
130	14		
130	25	f	n
130	17	m	
130	27	f	n
130	38	m	
130	34	m	
**1323, 31 - 0718, 1*			
160	48	m	
160	39	m	
160	47	m	
160	50	m	
160	45	m	
160	42	m	
160	48	m	
**1320, 31 - 0726, 1*			
170	47	m	
170	45	m	
170	40	m	
170	44	m	
170	47	m	
170	43	m	
170	41	m	

THIRD SURVEY
JULY 17-19, '93

Station	POCL	Sex	Ov	BSD
**1547, 17 - 0655, 18*				
40	31	m		n
40	45	m		n
40	37	m		n
**1554, 17 - 0704, 18*				
70	47	m		y
70	45	m		n
70	30	m		n
70	45	m		y
70	44	m		n
70	33	f	n	n
70	34	f	n	n
70	27	f	y	n
70	26	f	y	n
70	37	m		n
70	27	f	y	n
70	49	m		n
70	37	f	n	n
70	22	m		n
70	44	m		n
70	25	m		n
70	46	m		n
70	40	m		y
70	32	f	n	n
70	41	m		n
70	38	m		n
70	46	m		n
70	28	m		y
70	33	f	n	n
70	26	f	y	n
70	30	f	y	n
70	43	m		y
70	26	f	n	n
70	36	m		n
70	42	m		n
70	30	f	n	n
70	35	m		n
70	48	m		n
70	12	?		n
70	41	m		n
70	45	m		n
70	37	f	n	n

FOURTH SURVEY
November 20-23, '93.

Station	POCL	Sex	Ov	BSD
**1420, 20 - 0711, 21*				
40	38	m		y
40	35	m		n
40	41	m		n
**1424, 20 - 0726, 21*				
70	48	m		n
70	46	m		n
70	42	m		n
70	36	m		n
70	48	m		y
70	35	m		n
70	38	m		n
70	37	f	y	n
70	31	m		n
70	25	m		n
70	31	m		n
70	31	f	y	n
70	42	m		n
70	25	m		n
70	34	m		n
70	42	m		n
70	34	m		n
70	40	f	n	n
70	24	f	y	n
70	48	m		n
70	38	m		n
70	37	f	y	n
70	43	m		y
70	29	f	n	n
70	40	m		n
70	34	m		n
70	44	m		n
70	41	m		y
70	37	m		n
**1428, 20 - 0756, 21*				
130	46	m		n
130	36	m		n
130	41	m		n
130	30	f	y	n
130	35	m		n
130	31	m		n

RAW DATA - M. lar SURVEYS - 'OHE'O STREAM SYSTEM

POCL = Post orbital carapace length (mm); Ov = ovigerous; BSD = presence of black-spotted disease symptoms.
' = time (2400 clock), date trap set and retrieved;*

FIRST SURVEY
Jan 3-5, '93

Station	POCL
**1451, 3 - 0650, 4*	
220	28 OVIGEROUS
**1500, 3 - 0700, 4*	
250	11
250	17
250	21
**1510, 3 - 0707, 4*	
280	41
**1535, 3 - 0722, 4*	
490	45
490	23
490	14
490	34
490	44
490	40
**1605, 3 - 0745, 4*	
990	40
990	43
990	40
990	24
990	49
990	33
990	16
990	36
990	23
990	20
**1610, 3 - 0758, 4*	
1120	18
1120	10
1120	16
1120	32
1120	39
1120	15
**1205, 4 - 0702, 5*	
1220	none caught
**1210, 4 - 0706, 5*	
1232	9

SECOND SURVEY
MARCH 31-April 2, '93

Station	POCL	Sex	Ov
170	46	m	
**1345, 31 - 0749, 1*			
220	29	f	n
220	31	f	n
220	46	m	
**1340, 31 - 0754, 1*			
250	23	m	
250	11		
250	35	f	n
**1341, 31 - 0759, 1*			
280	32	m	
280	24	m	
280	38	m	
280	24	m	
280	40	m	
280	25	m	
280	35	m	
280	44	m	
280	29	f	n
280	24	f	n
280	32	m	
280	36	m	
**1359, 31 - 0808, 1*			
490	40	m	
490	50	m	
490	11		
490	41	m	
490	42	m	
490	44	m	
490	41	m	
490	52	m	
**1413, 31 - 0824, 1*			
990	30	f	n
990	39	m	
990	9		
990	39	m	
990	43	m	
990	39	m	
990	43	m	

THIRD SURVEY
JULY 17-19, '93

Station	POCL	Sex	Ov	BSD
70	22	m		n
70	28	f	y	y
**1600, 17 - 0735, 18*				
130	46	m		n
130	45	m		y
130	36	m		n
130	42	m		y
130	45	m		y
130	35	m		n
**1610, 17 - 0751, 18*				
160	51	m		n
160	42	m		n
160	46	m		n
160	39	m		n
160	42	m		n
160	42	m		n
160	48	m		y
160	36	m		n
160	42	m		y
160	46	m		n
160	44	m		y
160	34	m		n
160	45	m		n
160	43	m		y
160	47	m		n
160	46	m		y
160	44	m		y
160	45	m		y
**1611, 17 - 0806, 18*				
170	30	m		n
170	42	m		y
170	42	m		n
170	32	m		n
170	46	m		n
170	42	m		y
170	41	m		y
170	40	m		n
170	32	m		n
170	30	m		n
170	34	m		n
170	37	m		n

FOURTH SURVEY
November 20-23, '93.

Station	POCL	Sex	Ov	BSD
130	46	m		n
130	47	m		n
130	45	m		y
130	42	m		y
130	37	m		n
130	34	m		n
**1440, 20 - 0811, 21*				
160	38	m		n
160	44	m		n
160	44	m		n
160	23	m		n
160	44	m		y
160	43	m		y
**1447, 20 - 0824, 21*				
170	35	m		y
170	41	m		n
170	35	m		n
170	32	f	y	n
170	26	f	n	n
170	41	m		n
170	37	m		n
170	38	m		y
170	37	m		y
170	44	m		n
170	35	m		n
170	40	m		n
170	40	m		y
170	40	m		y
**1545, 20 - 0941, 21*				
220	25	f	y	n
220	13	m		n
**1538, 20 - 0931, 21*				
250	25	f	n	n
250	31	m		n
250	28	f	y	n
**1530, 20 - 0918, 21*				
280	28	m		n
280	20	m		n

RAW DATA - M. lar SURVEYS - 'OHE'O STREAM SYSTEM

POCL = Post orbital carapace length (mm); Ov = ovigerous; BSD = presence of black-spotted disease symptoms.
'* = *time (2400 clock), date trap set and retrieved;*

FIRST SURVEY
Jan 3-5, '93

Station	POCL
1232	13
**1216, 4 - 0712, 5*	
1268	43
1268	46
**1245, 4 - 0738, 5*	
1418	none caught
**1300, 4 - 0742, 5*	
1502	none caught
**1323, 4 - 0753, 5*	
1560	33
**1325, 4 - 0801, 5*	
1570	21
1570	18
*1338, 4 - 0810, 5	
1630	11
1630	20
*1619, 4 - 1009, 5	
1892	33
**1410, 4 - 0833, 5*	
1900	34
1900	50
**1636, 4 - 1037, 5*	
1904	none caught
**1422, 4 - 0842, 5*	
1920	43
1920	47
1920	43
1920	36 OVIGEROUS
**1650, 4 - 1046, 5*	
1996	21
1996	24
**1510, 4 - 0918, 5*	

SECOND SURVEY
MARCH 31-April 2, '93

Station	POCL	Sex	Ov
990	45	m	
990	41	m	
990	29	f	n
990	41	m	
990	41	m	
990	37	m	
990	48	m	
990	44	m	
990	41	m	
**1420, 31 - 0835, 1*			
1120	9		
1120	41	m	
1120	12		
1120	40	m	
1120	41	m	
**1445, 31 - 0957, 1*			
1220	8		
1220	37	f	n
*1545, 31 - 1002, 1			
1232	41	m	
1232	14		
**1545, 31 - 1006, 1*			
1268	18	m	
1268	30	m	
1268	51	m	
**1630, 31 - 1033, 1*			
1418	18	m	
**1620, 31 - 1038, 1*			
1502	none caught		
**1611, 31 - 1045, 1*			
1560	12		
1560	48	m	
1560	55	m	
**1612, 31 - 1051, 1*			
1570	14		
1570	28	f	n

THIRD SURVEY
JULY 17-19, '93

Station	POCL	Sex	Ov	BSD
170	34	f	y	n
170	45	m		y
170	26	f	y	n
170	31	m		n
**1650, 17 - 0900, 18*				
220	35	m		n
220	34	m		n
220	18	f	y	n
220	38	m		n
220	28	f	y	n
220	25	m		n
220	29	f	y	n
220	32	m		n
220	39	m		n
220	29	m		n
**1707, 17 - 0912, 18*				
530	trap exposed			
*1700, 17 - 0920, 18				
280	43	m		y
280	30	f	n	n
280	14	m		n
**1720, 17 - 0930, 18*				
490	20	m		n
490	51	m		y
490	46	m		n
490	51	m		y
490	40	m		n
490	43	m		n
490	27	m		n
490	45	m		n
490	42	m		n
**1740, 17 - 1003, 18*				
990	36	m		n
990	37	m		y
990	37	m		n
990	12	m		n
990	41	m		n
990	35	m		n
990	35	m		n

FOURTH SURVEY
November 20-23, '93.

Station	POCL	Sex	Ov	BSD
280	13	m		n
280	35	m		n
280	42	m		n
280	14	f	n	n
**1555, 20 - 0955, 21*				
490	34	m		y
490	40	m		n
490	47	m		n
490	25	m		n
**1410, 20 - 1020, 21*				
990	44	m		n
990	45	m		n
990	40	m		n
990	36	m		n
990	40	m		n
990	44	m		n
990	40	m		n
990	47	m		n
990	41	m		n
**1430, 20 - 1036, 21*				
1120	11			n
1120	11			n
1120	51	m		n
1120	36	m		n
1120	48	m		n
1120	34	m		n
1120	38	m		y
1120	40	m		y
1120	38	m		n
1120	46	m		y
1120	45	m		n
1120	43	m		n
1120	43	m		y
1120	44	m		n
1120	42	m		y
1120	50	m		y
1120	48	m		y
1120	45	m		n
**1415, 21 - 0724, 22*				
1220	none caught			

RAW DATA - M. lar SURVEYS - 'OHE'O STREAM SYSTEM

POCL = Post orbital carapace length (mm); Ov = ovigerous; BSD = presence of black-spotted disease symptoms.
'* = *time (2400 clock), date trap set and retrieved;*

FIRST SURVEY
Jan 3-5, '93

Station	POCL
2032	46
**1450, 4 - 0905, 5*	
2110	31
**1700, 4 - 1100, 5*	
2360	46
**1532, 4 - 0932, 5*	
2710	31
2710	27
2710	39
2710	14

SECOND SURVEY
MARCH 31-April 2, '93

Station	POCL	Sex	Ov
1570	55	m	
**1630, 31 - 1058, 1*			
1630	none caught		
**1320, 1*			
1892	low flow trap not set		
**1218, 1 - 0710, 2*			
1900	47	m	
1900	31	m	
1900	30	f	n
1900	47	m	
1900	36	m	
1900	45	m	
1900	37	F	n
1900	38	m	
**1320, 1*			
1904	low flow trap not set		
**1223, 1 - 0732, 2*			
1920	46	m	
1920	44	m	
1920	46	m	
1920	36	m	
1920	49	m	
1920	41	m	
1920	33	f	n
1920	46	m	
1920	48	m	
1920	44	m	
1920	34	f	n
1920	31	f	n
**1350, 1 - 1000, 2*			
1996	24	m	
**1358, 1 - 1017, 2*			
2032	26	f	n
2032	24	f	n
2032	25	m	

THIRD SURVEY
JULY 17-19, '93

Station	POCL	Sex	Ov	BSD
990	39	m		n
990	38	m		n
990	40	m		n
990	43	m		y
990	42	m		n
990	43	m		n
**1748, 17 - 1020, 18*				
1120	39	m		y
1120	42	m		y
1120	33	m		n
1120	17	m		n
1120	30	f	y	n
1120	14	f	n	n
1120	32	f	n	n
1120	35	m		n
1120	44	m		n
1120	44	m		n
1120	41	m		y
1120	36	m		n
1120	46	m		n
**1307, 18 - 0700, 19*				
1220	none caught			
**1310, 18 - 0703, 19*				
1232	27	f	y	n
1232	38	f	n	n
1232	47	m		y
1232	42	f	n	y
**1311, 18 - 0717, 19*				
1268	42	f	y	y
1268	33	f	y	n
1268	38	m		n
1268	49	m		n
1268	33	f	y	n
1268	39	f	n	n
1268	50	m		y
1268	35	m		n
1268	45	m		y
1268	40	f	y	n
1268	38	f	y	n
1268	40	f	n	n

FOURTH SURVEY
November 20-23, '93.

Station	POCL	Sex	Ov	BSD
**1416, 21 - 0728, 22*				
1232	39	f	n	n
1232	25	m		n
1232	38	m		n
1232	41	m		n
**1420, 21 - 0739, 22*				
1268	46	m		n
1268	45	m		n
**1441, 21 - 0813, 22*				
1418	15	m		n
1418	18	m		n
**1436, 21 - 0804, 22*				
1502	40	m		n
1502	28	m		n
1502	31	m		n
**1448, 21 - 0828, 22*				
1560	45	m		n
1560	42	m		n
1560	29	m		n
1560	50	m		n
1560	47	m		n
**1453, 21 - 0842, 22*				
1570	35	m		n
1570	35	f	y	n
1570	28	m		n
1570	37	m		n
1570	24	f	y	n
1570	40	m		n
**1500, 21 - 0853, 22*				
1630	23	m		y
1630	42	m		n
**1524, 22 - 0906, 23*				
1892	43	m		n
1892	39	m		n
1892	35	m		n

RAW DATA - M. lar SURVEYS - 'OHE'O STREAM SYSTEM

POCL = Post orbital carapace length (mm); Ov = ovigerous; BSD = presence of black-spotted disease symptoms.
'* = *time (2400 clock), date trap set and retrieved;*

FIRST SURVEY
Jan 3-5, '93

Station	POCL

SECOND SURVEY
MARCH 31-April 2, '93

Station	POCL	Sex	Ov
2032	47	m	
**1242, 1 - 0800, 2*			
2110	42	m	
2110	49	m	
2110	18	f	n
2110	49	m	
2110	46	m	
2110	40	m	
2110	48	m	
2110	41	m	
2110	33	f	n
2110	43	m	
2110	35	f	n
**1251, 1 - 0830, 2*			
2360	44	m	
2360	30	m	
2360	18	m	
2360	33	f	n
2360	18	m	
2360	43	m	
2360	32	f	n
2360	48	m	
2360	35	f	n
2360	50	m	
2360	43	m	
**1303, 1 - 0900, 2*			
2710	45	m	
2710	43	m	
2710	35	f	n
2710	37	f	n
2710	44	m	
2710	46	m	
2710	40	m	
2710	42	m	
2710	26	f	n
2710	43	m	
2710	42	m	
2710	28	f	n

THIRD SURVEY
JULY 17-19, '93

Station	POCL	Sex	Ov	BSD
**1330, 18*				
1418	trap not set			
high water threat				
**1340, 18*				
1502	trap not set			
high water threat				
**1400, 18 - 0750, 19*				
1560	51	m		n
1560	55	m		n
1560	55	m		n
1560	29	m		n
1560	35	f	n	n
1560	45	m		n
1560	51	m		n
1560	53	m		n
1560	39	m		n
1560	42	m		n
**1403, 18 - 0803, 19*				
1570	16	m		n
1570	12	m		n
1570	15	m		n
1570	49	m		n
1570	27	m		n
**1407, 18 - 0815, 19*				
1630	14	m		n
**1500, 18*				
1892	trap not set			
threat of high water				
**1440, 18 - 0843, 19*				
1900	trap exposed			
**1500, 18*				
1904	trap not set			
threat of high water				
**1445, 18 - 0850, 19*				
1920	30	f	y	n

FOURTH SURVEY
November 20-23, '93.

Station	POCL	Sex	Ov	BSD
**1515, 21 - 0922, 22*				
1900	17	m		n
1900	13	f	n	n
1900	13	m		y
1900	37	m		n
1900	46	m		n
1900	14	m		n
1900	12	m		n
**1544, 22 - 0913, 23*				
1904	31	m		n
1904	33	m		n
1904	30	m		n
**1522, 21 - 0939, 22*				
1920	30	f	y	n
1920	31	m		n
1920	40	m		y
1920	42	m		n
1920	23	f	y	n
1920	42	m		y
1920	34	f	y	y
1920	35	m		y
1920	39	m		n
1920	43	m		y
1920	42	m		n
1920	35	m		n
**1552, 22 - 0925, 23*				
1996	22	f	n	n
**1557, 22 - 0933, 23*				
2032	42	m		n
2032	45	m		n
2032	20	f	n	n
**1447, 22 - 0802, 23*				
2050	22	m		n
2050	38	m		n
2050	48	m		n
2050	48	m		n
2050	47	m		n
2050	32	m		n
2050	34	m		n

RAW DATA - M. lar SURVEYS - 'OHE'O STREAM SYSTEM

POCL = Post orbital carapace length (mm); Ov = ovigerous; BSD = presence of black-spotted disease symptoms.
' = time (2400 clock), date trap set and retrieved;*

FIRST SURVEY
Jan 3-5, '93

Station	POCL

SECOND SURVEY
MARCH 31-April 2, '93

Station	POCL	Sex	Ov

THIRD SURVEY
JULY 17-19, '93

Station	POCL	Sex	Ov	BSD
1920	46	m		y
1920	25	f	y	n
1920	32	f	y	n
1920	31	m		n
1920	26	f	n	n
1920	35	m		n
1920	44	m		y
1920	26	m		n
1920	28	m		n
1920	29	m		n
1920	42	m		n
1920	37	m		n
1920	31	f	y	n
1920	47	m		n
1920	29	f	y	n
1920	35	f	n	y
1920	33	f	n	
1920	41	m		n
1920	33	f	y	n
1920	39	m		n
1920	31	m		n
1920	36	f	n	y
1920	47	m		n
1920	36	f	n	y
1920	28	m		n
1920	29	m		n
1920	41	m		n
'1500, 18				
1996 trap not set threat of high water				
'1500, 18				
2032 trap not set threat of high water				
'1517, 18 - 0930, 19				
2110	34	f	n	y
2110	48	m		y
2110	11			n
2110	10			n
2110	13	m		n
2110	43	m		y

FOURTH SURVEY
November 20-23, '93.

Station	POCL	Sex	Ov	BSD
2050	27	m		n
2050	32	m		n
2050	29	m		n
2050	37	m		n
2050	29	m		n
2050	37	m		n
2050	37	m		n
2050	47	m		y
'1436, 22 - 0733, 23				
2110	44	m		y
2110	24	m		n
2110	34	f	n	y
2110	22	m		n
2110	22	m		n
2110	32	f	y	n
2110	18	m		n
2110	19	f	n	n
2110	36	m		n
2110	25	m		n
2110	33	m		n
2110	20	f	y	n
2110	25	f	y	n
2110	33	m		n
2110	44	m		n
2110	33	m		n
2110	34	m		n
'1457, 22 - 0857, 23				
2710	46	m		n
2710	29	f	y	n
2710	35	m		n
2710	36	f	n	n
2710	34	f	y	n
2710	44	m		n
2710	30	m		n

RAW DATA - M. lar SURVEYS - 'OHE'O STREAM SYSTEM

POCL = Post orbital carapace length (mm); Ov = ovigerous; BSD = presence of black-spotted disease symptoms.
* = *time (2400 clock), date trap set and retrieved;*

FIRST SURVEY	SECOND SURVEY	THIRD SURVEY	FOURTH SURVEY
Jan 3-5, '93	MARCH 31-April 2, '93	JULY 17-19, '93	November 20-23, '93.
Station POCL	Station POCL Sex Ov	Station POCL Sex Ov BSD	Station POCL Sex Ov BSD

Station	POCL	Sex	Ov	BSD
2110	44	m		n
2110	22	f	y	n
2110	44	m		n
2110	26	m		n
**1530, 18 - 0950, 19*				
2360	34	m		n
2360	45	m		y
2360	20	m		n
2360	45	m		n
2360	9			n
2360	30	f	n	y
2360	42	m		n
2360	34	f	y	n
2360	31	f	n	n
2360	47	m		n
**1550, 18 - 1011, 19*				
2710	36	f	y	n
2710	27	f	y	n
2710	43	m		n
2710	32	f	y	n
2710	34	f	y	y
2710	35	f	n	n
2710	32	f	y	n
2710	40	m		n
2710	38	m		y
2710	35	f	y	n
2710	47	m		n
2710	45	m		n
2710	34	f	y	n
2710	43	m		n
2710	37	m		n
2710	34	f	y	n

APPENDIX II

RAW DATA FROM PUA'ALU'U

NUMBER OF 'O'OPU RECORDED

RAW DATA - ʻOʻOPU SURVEYS - PUAʻALUʻU STREAM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; ʻa = ʻalamoʻo; nō = nōpili; nā = nākea; hi = hinana

Station	Quad ID U	Quad ID A	FIRST SURVEY: JULY 4, 1993 Date	Time	Obs	Number / quadrat ʻa	nō	nā	hi	SECOND SURVEY: Oct. 5-6, 1993 Date	Time	Obs	Number / quadrat ʻa	nō	nā	hi
Puaʻaluʻu	0	3	7 / 4	1145	MH	2	0	0	1	10 / 6	1300	MH	2	0	0	0
70	0	4			MH	6	0	0	1			MH	5	0	0	1
	1	1			MH	3	0	0	0			MH	12	1	0	1
	5	1			MH	1	0	0	0			MH	3	0	0	0
	7	1			MH	4	1	0	0			MH	3	0	0	0
	9	2			MH	1	0	0	0			MH	1	0	0	0
	10	1			MH	1	0	0	0			MH	1	0	0	0
	19	2			MH	1	0	0	0			MH	10	0	0	0
	25	0			MH	5	0	0	4			MH	1	0	0	0
	32	1			MH	5	1	0	0			MH	6	1	0	0
Puaʻaluʻu	0	2	7 / 4	1300	MH	1	0	0	2	10 / 6	1400	MH	7	1	0	0
130	0	3			MH	3	0	0	0			MH	2	0	0	0
	1	1			MH	0	0	0	0			MH	6	0	0	1
	7	2			MH	1	0	0	0			MH	2	0	0	0
	16	0			MH	1	0	0	0			MH	5	0	0	0
	19	1			MH	0	0	0	0			MH	2	0	0	0
	25	2			MH	7	0	0	0			MH	0	0	0	0
	29	0			MH	3	0	0	0			MH	1	0	0	0
	31	0			MH	1	0	0	0			MH	7	0	0	0
	39	2			MH	5	1	0	0			MH	5	0	0	0
Puaʻaluʻu	5	2	7 / 4	930	MH	0	0	0	0	10 / 5	1100	MH	9	0	0	0
160	14	1			MH	1	0	0	0			MH	3	0	0	0
	16	1			MH	4	0	0	0			MH	4	0	0	0
	22	0			MH	8	0	0	0			MH	2	0	0	0
	25	1			MH	0	0	0	0			MH	5	0	0	0
	25	3			MH	1	0	0	0			MH	5	0	0	0
	31	5			MH	3	0	0	0			MH	2	0	0	0
	38	3			MH	2	0	0	0			MH	5	0	0	0
	47	2			MH	0	0	0	0			MH	0	0	0	0
	59	2			MH	0	0	0	0			MH	5	0	0	0

RAW DATA - 'O'OPU SURVEYS - PUA'ALU'U STREAM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; 'a = 'alamo'o; nō = nōpili; nā = nākea; hi = hinana

Station	Quad ID		SECOND-REPEAT SVY: Oct. 6-7, 1993							THIRD SURVEY: Dec 4, 1993						
			Date	Time	Obs	Number / quadrat				Date	Time	Obs	Number / quadrat			
	U	A				'a	nō	nā	hi				'a	nō	nā	hi
Pua'alu'u	0	3	10/7	1330	MH	6	0	1	0	12/4	1040	PK	5	0	0	0
70	0	4			MH	5	0	0	0			PK	12	0	1	0
	1	1			MH	7	2	0	0			PK	1	0	0	0
	5	1			MH	3	0	0	0			PK	1	0	0	0
	7	1			MH	2	0	0	0			PK	3	0	0	0
	9	2			MH	3	0	0	0		1048	MD	2	0	0	0
	10	1			MH	3	0	0	0		1056	MD	4	0	0	0
	19	2			MH	3	0	0	0		1102	MD	5	0	0	0
	25	0			MH	3	1	0	0		1106	MD	6	2	0	0
	32	1			MH	4	0	0	0		1114	MD	4	1	0	0
Pua'alu'u	0	2	10/7	1430	MH	6	0	0	0	12/4	1240	MD	3	0	0	0
130	0	3			MH	1	0	0	0		1246	MD	3	0	0	0
	1	1			MH	2	0	0	0		1253	MD	5	0	0	0
	7	2			MH	2	0	0	0		1245	PK	0	0	0	0
	16	0			MH	4	0	0	0			PK	0	0	0	0
	19	1			MH	2	0	0	0			PK	6	0	0	0
	25	2			MH	1	0	0	0		1250	MH	4	0	0	0
	29	0			MH	0	0	0	0			MH	2	0	0	0
	31	0			MH	5	0	0	0			MH	2	0	0	0
	39	2			MH	5	0	0	0			MH	3	0	0	0
Pua'alu'u	5	2	10/6	1150	MH	7	0	0	0	12/4	1400	PK	3	0	0	0
160	14	1			MH	3	0	0	0		1412	PK	2	0	0	0
	16	1			MH	4	0	0	0		1424	PK	4	0	0	0
	22	0			MH	5	0	0	0		1404	MD	0	0	0	0
	25	1			MH	4	0	0	0		1410	MD	25	0	0	0
	25	3			MH	1	0	0	0		1414	MD	3	0	0	0
	31	5			MH	1	0	0	0		1415	MH	2	0	0	0
	38	3			MH	3	0	0	0			MH	3	0	0	0
	47	2			MH	0	0	0	0			MH	3	0	0	0
	59	2			MH	0	0	0	0			MH	0	0	0	0

SIZE CLASSES OF 'O'OPU RECORDED

RAW DATA - ʻOʻOPU SURVEYS - PUAʻALUʻU STREAM

ʻa = ʻalamoʻo, nō = nōpili, nā = nākea

FIRST SURVEY: July 4, 1993

size class	Station 70			Station 130			Station 160		
(inches)	ʻa	nō	nā	ʻa	nō	nā	ʻa	nō	nā
.5 to 1	2	0	0	4	0	0	1	0	0
1.1 to 1.5	5	0	0	1	0	0	0	0	0
1.6 to 2	6	0	0	3	0	0	0	0	0
2.1 to 2.5	11	1	0	6	0	0	5	0	0
2.6 to 3	3	0	0	4	0	0	6	0	0
3.1 to 3.5	2	0	0	4	0	0	7	0	0
3.6 to 4	0	0	0		0	0	0	0	0
4.1 to 4.5	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	1	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	1	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0

SECOND SURVEY: Oct. 5-6, 1993

size class	Station 70			Station 130			Station 160		
(inches)	ʻa	nō	nā	ʻa	nō	nā	ʻa	nō	nā
.5 to 1	0	0	0	5	0	0	1	0	0
1.1 to 1.5	13	0	0	3	0	0	3	0	0
1.6 to 2	5	0	0	3	0	0	4	0	0
2.1 to 2.5	12	0	0	9	0	0	9	0	0
2.6 to 3	9	0	0	17	1	0	18	0	0
3.1 to 3.5	3	0	0	0	0	0	2	0	0
3.6 to 4	1	0	0	0	0	0	2	0	0
4.1 to 4.5	0	2	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0

SECOND-REPEAT SURVEY: Oct. 6-7, 1993

size class	Station 70			Station 130			Station 160		
(inches)	ʻa	nō	nā	ʻa	nō	nā	ʻa	nō	nā
.5 to 1	3	0	0	2	0	0	0	0	0
1.1 to 1.5	11	0	0	4	0	0	4	0	0
1.6 to 2	4	0	0	9	0	0	7	0	0
2.1 to 2.5	16	0	0	6	0	0	12	0	0
2.6 to 3	4	0	0	7	0	0	5	0	0
3.1 to 3.5	1	1	0	0	0	0	0	0	0
3.6 to 4	0	1	0	0	0	0	0	0	0
4.1 to 4.5	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	1	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0

THIRD SURVEY: Dec. 12, 1993

size class	Station 70			Station 130			Station 160		
(inches)	ʻa	nō	nā	ʻa	nō	nā	ʻa	nō	nā
.5 to 1	10	0	0	2	0	0	11	0	0
1.1 to 1.5	14	1	0	13	0	0	14	0	0
1.6 to 2	4	2	0	12	0	0	11	0	0
2.1 to 2.5	8	0	0	1	0	0	6	0	0
2.6 to 3	7	0	0	0	0	0	3	0	0
3.1 to 3.5	0	0	0	0	0	0	0	0	0
3.6 to 4	0	1	0	0	0	0	0	0	0
4.1 to 4.5	0	0	0	0	0	0	0	0	0
4.6 to 5	0	0	0	0	0	0	0	0	0
5.1 to 5.5	0	0	0	0	0	0	0	0	0
5.6 to 6	0	0	0	0	0	0	0	0	0
6.1 to 6.5	0	0	0	0	0	0	0	0	0
6.6 to 7	0	0	0	0	0	0	0	0	0
7.1 to 7.5	0	0	0	0	0	0	0	0	0
7.6 to 8	0	0	0	0	0	0	0	0	0
8.1 to 8.5	0	0	0	0	0	0	0	0	0
8.6 to 9	0	0	0	0	0	0	0	0	0
9.1 +	0	0	0	0	0	0	0	0	0

NUMBER OF ʻŌPAE RECORDED

RAW DATA - 'OPAE SURVEYS - PUA'ALU'U STREAM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; # = number 'opae/quadrat

Station	Quad ID U	Quad ID A	FIRST SURVEY JULY 4, 1993. Time/ Date	Obs	'#	SECOND SURVEY Oct. 5-6, 1993. Time/ Date	Obs	'#	SECOND-REPEAT SURVEY Oct. 6-7, 1993. Time/ Date	Obs	'#	THIRD SURVEY DEC.4, 1993. Time/ Date	Obs	'#
70	0	3	1430	MH	4	1300	MH	0	1330	MH	0	1140	PK	0
	0	4	7/4	MH	4	10/6	MH	0	10/7	MH	0	12/4	PK	0
	1	1		MH	0		MH	0		MH	0		PK	0
	5	1		MH	2		MH	4		MH	3		PK	1
	7	1		MH	4		MH	0		MH	0		PK	0
	9	2		MH	2		MH	6		MH	7		MD	4
	10	1		MH	0		MH	3		MH	4		MD	3
	19	2		MH	0		MH	7		MH	7		MD	11
	25	0		MH	0		MH	0		MH	0		MD	9
	32	1		MH	0		MH	0		MH	0		MD	0
130	0	2	ND		ND	1400	MH	2	1430	MH	2	1240	MD	3
	0	3	ND		ND	10/6	MH	0	10/7	MH	2	12/4	MD	25
	1	1			ND		MH	0		MH	0		MD	1
	7	2			ND		MH	0		MH	0		PK	3
	16	0			ND		MH	1		MH	0		PK	1
	19	1			ND		MH	1		MH	4		PK	0
	25	2			ND		MH	1		MH	8		MH	3
	29	0			ND		MH	2		MH	0		MH	6
	31	0			ND		MH	2		MH	3		MH	8
	39	2			ND		MH	2		MH	7		MH	1
$60	5	2	1515	MH	0	1100	MH	1	1150	MH	4	1400	PK	4
	14	1	7/4	MH	4	10/5	MH	2	10/6	MH	0	12/4	PK	1
	16	1		MH	8		MH	3		MH	2		PK	2
	22	0		MH	1		MH	0		MH	1		MD	1
	25	1		MH	4		MH	0		MH	0		MD	18
	25	3		MH	7		MH	0		MH	0		MD	35
	31	5		MH	2		MH	9		MH	8		MH	0
	38	3		MH	5		MH	5		MH	2		MH	9
	47	2		MH	0		MH	2		MH	6		MH	0
	59	2		MH	2		MH	7		MH	3		MH	10

NUMBER, SIZE CLASSES, AND NUMBER OF EGG CASES OF HīHīWAI RECORDED

RAW DATA - HIHIWAI SURVEYS - PUA'ALU'U STREAM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; h =hihiwai; sl = shell length (mm);
e = hihiwai egg case

	FIRST SURVEY: JULY 4, 1993								SECOND SURVEY: Oct. 5-6, 1993							
Station	Quad ID		Date	Time	Obs	# / quad			Quad ID		Date	Time	Obs	# / quad		
	U	A				h	sl	e	U	A				h	sl	e
Pua'alu'u	4	1	7 / 3	1546	MH	0		0	0	3	10/5	1300	MH	0		0
70	5	2			MH	0		5	0	4			MH	0		11
	6	2			MH	1	9	0	1	1			MH	2	20,22	4
	11	3			MH	0		0	5	1			MH	0		0
	15	2			MH	0		0	7	1			MH	0		0
	16	0			MH	0		6	9	2			MH	2	21,20	0
	21	2			MH	1	22	0	10	1			MH	2	24,20	0
	24	1			MH	0		4	19	2			MH	0		0
	28	1			MH	0		0	25	0			MH	0		0
	33	1			MH	0		0	32	1			MH	2	31,20	0
Pua'alu'u	4	1	7 / 4	1400	MH	0		0	0	2	10/5	1400	MH	0		0
130	5	2			MH	0		0	0	3			MH	0		0
	6	2			MH	0		0	1	1			MH	0		0
	11	3			MH	0		0	7	2			MH	0		0
	15	2			MH	0		0	16	0			MH	0		0
	16	0			MH	0		0	19	1			MH	0		0
	21	2			MH	0		0	25	2			MH	0		0
	24	1			MH	0		0	29	0			MH	0		0
	28	1			MH	0		0	31	0			MH	0		4
	33	1			MH	0		0	39	2			MH	0		11
Pua'alu'u	4	1	7 / 4	1500	MH	0		0	5	2	10/6	1100	MH	0		0
160	5	2			MH	0		0	14	1			MH	0		0
	6	2			MH	0		0	16	1			MH	0		0
	11	3			MH	0		0	22	0			MH	0		0
	15	2			MH	0		0	25	1			MH	0		2
	16	0			MH	0		0	25	3			MH	0		0
	21	2			MH	0		3	31	5			MH	0		0
	24	1			MH	0		0	38	3			MH	0		0
	28	1			MH	0		0	47	2			MH	0		0
	33	1			MH	0		0	59	2			MH	0		0

RAW DATA - HIHIWAI SURVEYS - PUA'ALU'U STREAM

U, A = 'Up', 'Across' quad coordinates; Obs = observer; h =hihiwai; sl = shell length (mm);
e = hihiwai egg case

			SECOND-REPEAT SURVEY: Oct. 6-7, 1993.						THIRD SURVEY: Dec. 4, 1993					
Station	Quad ID		Date	Time	Obs	Number / quadrat			Date	Time	Obs	Number / quadrat		
	U	A				h	sl	e				h	sl	e
Pua'alu'u	0	3	10/6	1330	MH	0		0	10/6	1300	PK	1	19	1
70	0	4			MH	1	23	0			PK	0		0
	1	1			MH	0		0			PK	0		0
	5	1			MH	0		0			PK	0		1
	7	1			MH	0		6			PK	0		0
	9	2			MH	1	19	14			MD	0		13
	10	1			MH	0		17			MD	0		38
	19	2			MH	0		29			MD	2	28,23	27
	25	0			MH	0		0			MD	0		104
	32	1			MH	0		0			MD	0		0
Pua'alu'u	0	2	10/6	1430	MH	0		0	10/6	1400	MD	0		0
130	0	3			MH	0		0			MD	0		1
	1	1			MH	0		0			MD	0		3
	7	2			MH	0		0			PK	0		0
	16	0			MH	0		0			PK	0		0
	19	1			MH	0		0			PK	0		0
	25	2			MH	0		0			MH	0		0
	29	0			MH	0		0			MH	0		0
	31	0			MH	0		0			MH	0		0
	39	2			MH	0		1			MH	0		0
Pua'alu'u	5	2	10/7	1150	MH	0		0	10/5	1100	PK	0		0
$60	14	1			MH	0		0			PK	0		15
	16	1			MH	0		0			PK	0		10
	22	0			MH	0		0			MD	0		0
	25	1			MH	0		0			MD	0		0
	25	3			MH	0		0			MD	0		0
	31	5			MH	0		0			MH	0		0
	38	3			MH	0		9			MH	0		0
	47	2			MH	0		0			MH	0		0
	59	2			MH	0		0			MH	0		0

APPENDIX III

CODE FOR RESAMPLING PROGRAM

PROGRAM TO ESTIMATE THE NON-CENTRALITY PARAMETER
FOR THE POWER OF A ONE-SAMPLE, TWO-TAILED t-TEST

```
REM "numberofstations" is the number of stations used during the actual survey.
REM "quadnum" is the number of quadrat counts to be randomly selected from each
REM    station by the program from the real data recorded during the actual survey
REM    (i.e. the desired number of quadrats to be used in some future survey)
REM "nt" is the number of trials for the simulation.
REM "nsp" is the number of stations used in the calculation of the non-centrality
REM    parameter (i.e. the desired number of stations to be used in some
REM    future survey)
REM "differencetodetect" is the change in population abundance desired to be detected
REM Note: The first subscript of the arrays "stnBack", "q", and "sqrd" must be
REM    changed manually to equal "numberofstations."
REM Note: The second subscript of the arrays "q" and "sqrd" must be changed manually
REM    to match "quadnum."
REM The data entered in statement "DATA" are the quadrat counts from
REM    the actual survey.
REM The output of this program is five files entitled "amongstationcvub",
REM "themeans", "thevariances", "thedelta", and "theamongsmeanstandardev."
REM These files contain the unbiased coeffcient of variation for the mean counts from
REM    each station, the mean of the means from each station, the variance for the mean
REM    counts from each station, the non-centrality parameters for the mean counts
REM    from each station, and the standard deviation for the mean counts from each
REM    station, respectively.

LET numberofstations = 16        ! this is 16 for 'opae, 18 for 'o'opu
LET quadnum = 2
LET nt= 30
LET nsp = 80
LET differencetodetect = .50
RANDOMIZE
DIM stnBack(16,10), stn(16, 10)
DIM q(16,8), sqrd(16,8)
MAT READ stnBack
DATA 0,0,0,0,0,0,0,0,0,0         ! each data line contains the series
DATA 0,0,0,0,0,0,0,0,0,0         ! of quadrat counts recorded at a given station
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0
DATA 0,0,0,0,0,0,0,0,0,0

DIM wssum(16),wsss(16),smean(16),wsstandardev(16),wsvar(16),wscv(16),wscvub(16)
DIM thevariances(30)
DIM themeanofmeans(30)
DIM amongstationcvub(30)
DIM thedelta(30)
DIM theamongsmeanstandardev(30)

FOR t = 1 to nt
FOR i = 1 to numberofstations
FOR j = 1 to 10
LET stn(i, j) = stnBack(i, j)
NEXT j
NEXT i
LET unbiasedcorrector = (1/(4*quadnum))+1
FOR j = 1 to numberofstations
LET y = 10
```

```
FOR i = 1 to quadnum
LET thechoice = int(y*rnd) + 1
LET q(j,i) = stn(j,thechoice)
LET stn(j,thechoice) = stn(j,y)
LET y = y - 1
LET sqrd(j,i) = (q(j,i))^2
NEXT i
NEXT j
FOR k = 1 to numberofstations
LET wssum(k) = 0
LET wsss(k) = 0
NEXT k
FOR k = 1 to numberofstations
FOR m = 1 to quadnum
LET wssum(k) = wssum(k) + q(k,m)
LET wsss(k) = wsss(k) + sqrd(k,m)
NEXT m
LET smean(k) = wssum(k) / quadnum
LET blah = abs((wsss(k)-(wssum(k)/quadnum))/(quadnum-1))
LET wsstandardev(k) = sqr(blah)
LET wsvar(k) = (wsstandardev(k))^2
IF smean(k) > 0 then
LET wscv(k) = (wsstandardev(k)*100)/smean(k)
ELSE
LET wscv(k) = 0
END IF
LET wscvub(k) = (wscv(k))* unbiasedcorrector  ! this is Sokal and Rohlf's
    ! (1981, p. 59) unbiased estimator of the coefficient of variation
NEXT k
LET unbiasedcorrectorII = (1/(4*numberofstations))+1
LET sumofsqrdsmean = 0
LET sumofsmean = 0
FOR p = 1 to numberofstations
LET sumofsmean = sumofsmean + smean(p)
LET meanofstationmeans = sumofsmean / numberofstations
LET sqrdsmean = smean(p)^2
LET sumofsqrdsmean = sumofsqrdsmean + sqrdsmean
LET amongsmeanstandardev = sqr((sumofsqrdsmean- (sumofsmean^2/numberofstations))/(numberofstations-1))
     ! calc of standard deviation
LET amongsmeanvar = amongsmeanstandardev^2    ! variance calculation
IF meanofstationmeans = 0 then
LET amongsmeancv = 0
ELSE
LET amongsmeancv = (amongsmeanstandardev*100)/meanofstationmeans    ! calc for c.v.
END IF
LET amongsmeancvub = amongsmeancv * unbiasedcorrectorII
    ! this is Sokal and Rohlf's unbiased estimator of the
    ! coefficient of variation.
LET meanminusmeannought = differencetodetect*meanofstationmeans
IF meanminusmeannought = 0 then
LET delta = 99999
ELSE
LET delta = meanminusmeannought/(amongsmeanstandardev/sqr(nsp))
END IF
LET dfi = numberofstations - 1  ! this is degrees of freedom for I
IF meanofstationmeans = 0 then
LET I = 99999
ELSE
LET I = (amongsmeanvar*dfi)/meanofstationmeans  ! this is Elliott's (1971-page 40)
    ! index of dispersion
END IF
NEXT p
PRINT t, delta
LET amongstationcvub(t) = amongsmeancvub
LET themeanofmeans(t) = meanofstationmeans
LET thevariances(t) = amongsmeanvar
LET thedelta(t) = delta
LET theamongsmeanstandardev(t) = amongsmeanstandardev
NEXT t
```

```
OPEN #1: name "amongstationcvub", create newold
ERASE #1
FOR t = 1 to nt
PRINT #1: amongstationcvub(t)
PRINT #1
NEXT t
OPEN #2: name "themeans", create newold
ERASE #2
FOR t = 1 to nt
PRINT #2: themeanofmeans(t)
PRINT #2
NEXT t
OPEN #3: name "thevariances", create newold
ERASE #3
FOR t = 1 to nt
PRINT #3: thevariances(t)
PRINT #3
NEXT t
OPEN #4: name "thedelta", create newold
ERASE #4
FOR t = 1 to nt
PRINT #4: thedelta(t)
PRINT #4
NEXT t
OPEN #5: name "theamongsmeanstandardev", create newold
ERASE #5
FOR t = 1 to nt
PRINT #5: theamongsmeanstandardev(t)
PRINT #5
NEXT t
END
```