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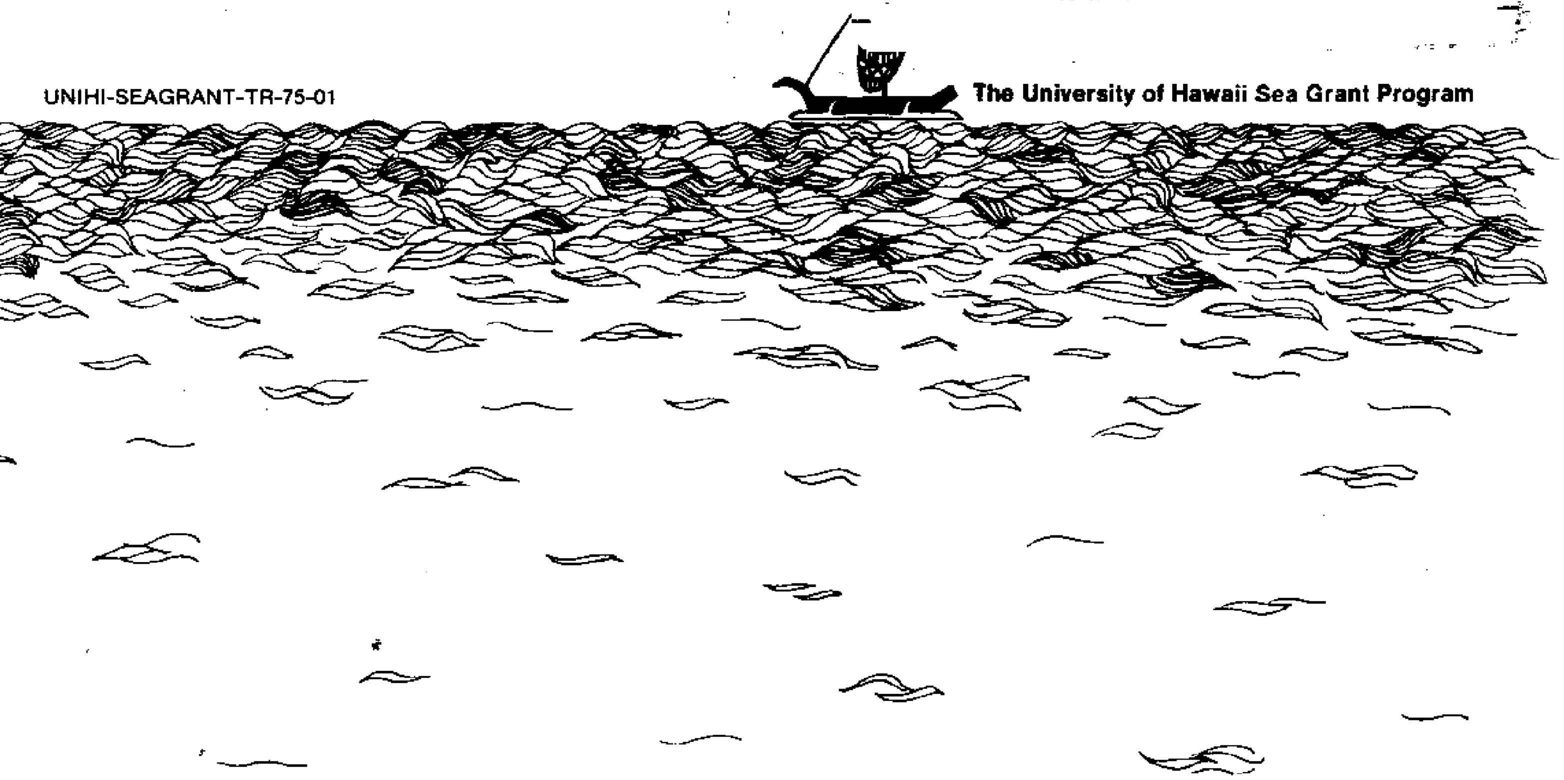

Ichthyoplankton of Kaneohe Bay, Hawaii

A One-year Study of Fish Eggs and Larvae

William Watson and Jeffrey M. Leis

November 1974

ICHTHYOPLANKTON OF KANEOHE BAY, HAWAII

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by

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ABSTRACT

A one-year (March 1971 through April 1972) survey of the ichthyoplankton of Kaneohe Bay, Oahu, Hawaii yielded 43 types of pelagic fish eggs and 38,505 larvae of 175 types. Inside the bay four egg types comprised 80% of the egg catch and 13 larval types comprised 94% of the larvae, while in the entrance channel 11 and 18 types comprised 80% and 94% of the eggs and larvae, respectively. The catches of ichthyoplankton did not reflect the abundance of adult fishes in Kaneohe Bay: larvae encountered in large numbers were from pelagic bay species which spawn pelagic eggs and reef species which spawn demersal eggs. Larvae of oceanic fishes and reef fishes with pelagic eggs were taken in small numbers. Statistically significant relationships were most often found between egg abundance, surface water temperature, and day length. Some offshore eggs were correlated with rising tides. Most of the fish species spawned year-round; however, definite periods of increased spawning were demonstrated by most. Reef species demonstrated spawning peaks during the months from March to May and from September to October. The carangids (Caranx mate *and* Gnathanodon speciosus) *had spring, summer, and fall peaks.*

The engraulid, Stolephorus purpureus, *spawned primarily during the winter and spring, unlike 20 years earlier when it spawned primarily during the summer. No decline in the abundance of* S. purpureus *eggs or larvae between the two periods was detected.*

The spawning peaks of nearshore fishes which do not live strictly in bays were apparently synchronized with a semiannual shift in current direction around Oahu.

A key to the pelagic fish eggs of Kaneohe Bay is presented in Appendix A and 28 of the eggs are illustrated.

These data suggest adaptations by Hawaiian fishes: (a) the pelagic eggs of reef species allow their larval stages to more easily reach the open ocean where they apparently develop into juvenile stages before returning to settle on the reef; and (b) the synchronization at spawning peaks with current shifts to increase retention of the larval stages near the islands. A season-independent periodicity, a shift away from summer spawning due to pollution-induced stress during the summer, or a shift in the season of maximum fishing pressure on the adult population is indicated by the data on S. purpureus.

TABLE OF CONTENTS

LIST OF FIGURES

Figure

Appendix A

LIST OF FIGURES (continued)

LIST OF TABLES

Table

Appendix A

Appendix B

(Regression)

(Correlation)

Appendix C

Appendix D

LIST OF TABLES (continued)

INTRODUCTION

Despite the great interest in the fishery and aquacultural potential of tropical and subtropical waters, very little is known of the ichthyoplankton of these areas. For example, although the aquaculture program at the Hawaii Institute of Marine Biology (HIMB) had been conducting rearing and nutritional experiments with pelagic fish eggs and larvae for several years, by 1971 it was not yet possible to consistently predict either the occurrence or abundance of any ichthyoplankter. Of the approximately 350 species of Hawaiian inshore fishes (Gosline and Brock, 1960), only a handful were identifiable: the eggs and larvae of the nehu (*Stolephorus purpureus*), maomao (*Abudefduf abdominalis*), and iao (*Pranesus insularum*). Several additional types had been tentatively identified in south Kaneohe Bay including the makiawa (*Etrumeus micropus*), omaka (*Caranx mate*), and pa'opa'o (*Gnathanodon speciosus*). These were often confused with other species, however. Finally, some data on diel and seasonal changes were available for the nehu (Yamashita, 1951; Tester, 1951, 1955; Nakamura, 1970), iao (Chase, 1969), and maomao (Helfrich, 1958; May, 1967).

This study was initiated in order to assess the pelagic fish egg resources of Kaneohe Bay available to the aquaculture program. Its immediate goals, therefore, were to: (1) determine the species composition of the ichthyoplankton of Kaneohe Bay; (2) define diel changes in the abundance of these plankters; (3) determine seasonal changes in the availability of the ichthyoplankton; and (4) relate the seasonal changes in egg abundance to certain environmental factors.

Additionally, it was intended that the definitions of diel and seasonal spawning patterns would provide baseline information for attempting induced spawning of fishes in the laboratory. Also, conditions in south Kaneohe Bay include nutrient inputs and increased turbidity, not unlike typical culture conditions. Those eggs spawned and larvae residing in south Kaneohe Bay would be expected to respond more favorably to a culture regime than would the species imported from the open ocean through the Sampan Channel.

In order to meet these goals, surface plankton tows were conducted at two-week intervals for 13 months. Tows were taken during the morning, afternoon, and night. Because of time and manpower limitations, only two sampling stations were selected; one in Sampan Channel, the other in the middle part of south Kaneohe Bay (Figure 1).

The Sampan Channel station was selected as a representative of the relatively clean-water environments of Kaneohe Bay and because it was thought to be a significant import route for offshore eggs and larvae. The southern station was selected to represent the pollution-stressed, less actively circulating environments of Kaneohe Bay. It was thought that the fish eggs and larvae taken at these stations would include the more common types available in the bay (Miller et al., 1973).

Vertical differences in numbers and kinds of fish eggs and larvae were not considered during this study primarily because of time and equipment limitations. This was at least partially justified, since water at the Sampan Channel station is only about 4 m deep and vertically well mixed

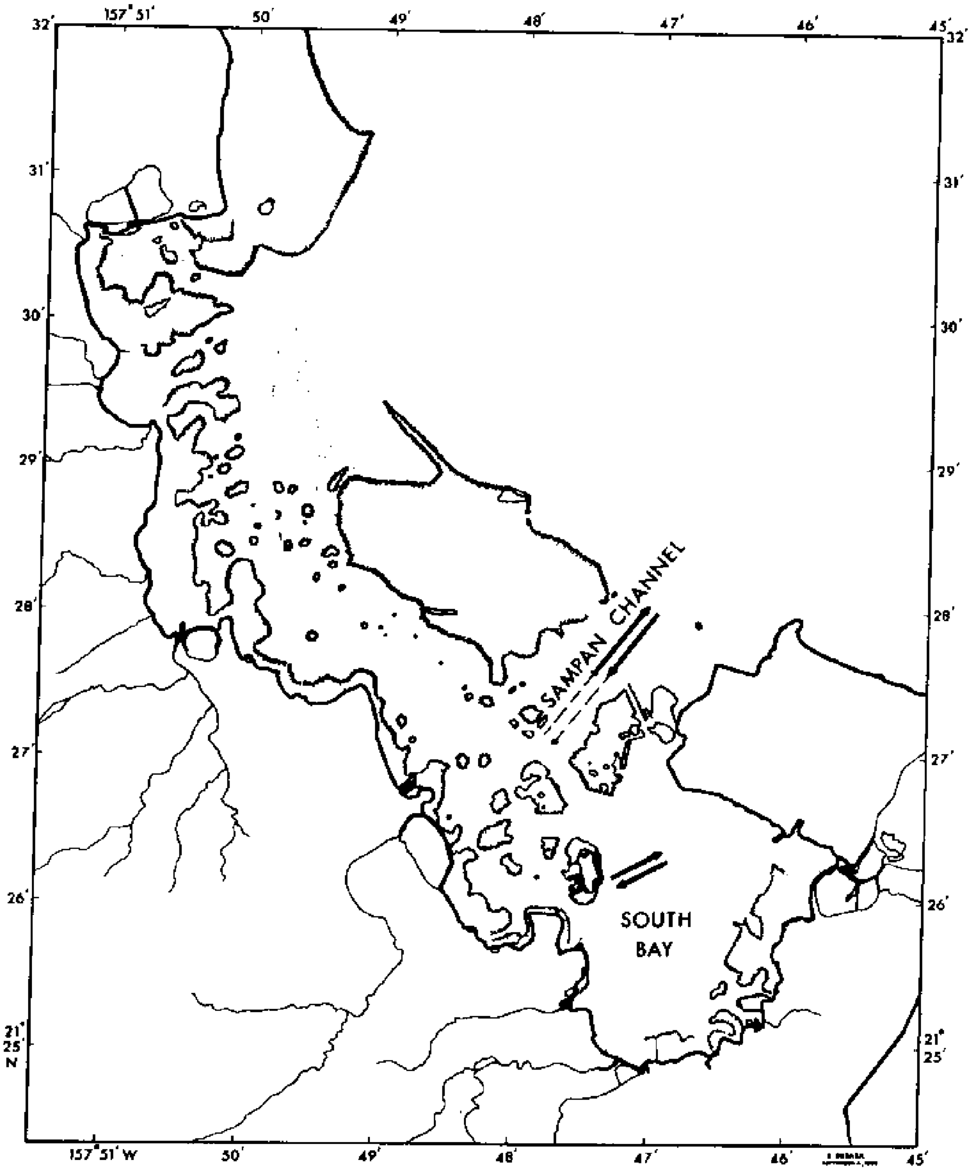

Figure 1. Map of Kaneohe Bay showing sampling stations. Dashed lines at the Sampan Channel station show the alternate sampling location (see text).

while water at the southern station is, at most, only weakly stratified during the summer months (Bathen, 1968). A few preliminary deep tows (*ca* 10 m) showed no additional species in south Kaneohe Bay (J.M. Miller, 1972: personal communication). And in a series of vertically stratified tows in south Kaneohe Bay, Tester (1951) found slightly more nehu eggs at the surface, but no significant differences in the abundance of nehu larvae. Another series of vertically stratified tows at the southern station made after the main sampling program had been completed also showed no additional species of eggs or larvae at a depth of about 4 m. Wilcoxon rank-sums test (Bradley, 1968) showed no significant differences in the abundances of omaka or makiawa eggs between the surface and this depth. The vertical distributions of pelagic fish larvae in south Kaneohe Bay are presently being studied in detail by the senior author. Results of this work will resolve the validity of the assumption of no vertical changes and aid in interpreting the data obtained in the survey.

The attempt to extract relationships between the abundance of fish eggs and physical factors for the purpose of being able to make more exact predictions of the seasonal abundance of the eggs was decided upon at the end of the study. Thus, the relationships must be considered tentative.

This study provides, for the first time, detailed information on the spawning patterns of many Indo-Pacific fishes and will provide vital baseline data not only for the Hawaiian Islands but the rest of the Indo-Pacific region as well.

MATERIALS AND METHODS

Twenty-nine series of tows were made at approximately two-week intervals between March 25, 1971 and April 20, 1972 with an additional series on July 18, 1972. Each series consisted of morning, afternoon, and night tows taken as near as possible to mid-tides in the Sampan Channel and in south Kaneohe Bay. At each sampling station, two replicate tows were made in opposite directions.

Sampan Channel tows were made at an average speed of 2.5 knots over a constant distance (approximately 925 m; average tow time of 16.5 min) seaward and shoreward between navigation buoys 6 and 4. Owing to high waves, a few tows were taken closer inshore between buoys 8 and 6. These are listed in Table D1 of Appendix D. A few tows were not included in the data analyses for various reasons; these are also listed in Table D1 of Appendix D. Because buoys were not present in south Kaneohe Bay, tows were taken for 10 minutes at the same speed over a fixed course about 620 m long starting approximately 200 m east-northeast of the entrance to the HIMB lagoon and returning to the same location by the end of the replicate tow (Figure 1).

All tows were taken with a standard 1-m, .505-mm mesh, Nitex plankton net equipped with a TSK flowmeter and glass cod end. This was towed with the top of the net *ca* 5 cm above the surface of the water at an average speed of 1.3 m/sec (varying between 2 and 3 knots). At the Sampan Channel station an average of 712 m^3 of water was filtered per tow (standard deviation 127 m^3); in south Kaneohe Bay the average volume was 390 m^3 (standard deviation 96 m^3).

At the conclusion of each tow, the sample was transferred to a 12-liter bucket of seawater and aerated whenever it was necessary. Keeping the zooplankton alive in this manner was essential since fish eggs become virtually unidentifiable when dead (see Appendix A).

Physical data including daytime light intensity, surface water temperature, salinity, and oxygen content were taken once during each pair of replicate tows. Water properties were measured on a 10-liter sample which was usually dipped at the midpoint of the first tow of each pair. Measuring gear included a standard non-reversing mercury thermometer (precise to ± 0.05°C), an American Optical refractometer (± a maximum of 0.8°/oo), a Yellow Springs Instrument Co. oxygen probe (± a maximum of 0.32 ppm), and a Gossen Tri-Lux light meter (± 8%). Weather conditions and wave activity were also noted.

In the laboratory, each sample was filtered through a 1.5-mm mesh sieve to remove large zooplankters which were preserved immediately in 10% buffered formalin, then filtered twice through a .420-mm mesh sieve and suspended in one liter of seawater. The fine fraction was thoroughly stirred and two 25-ml aliquots were immediately dipped from each for fish egg counts. Occasionally, larger or more aliquots were necessary when numbers were very low; i.e., 25 or fewer eggs per standard aliquot. During the early part of the survey, each aliquot was resuspended in one liter of seawater and the eggs identified and counted by visual inspection and then removed with a pipette. As the study progressed, it became apparent that this method did not allow the distinctions necessary in egg identification to be made. Beginning in September 1971, aliquots were placed in plexiglass counting chambers and fish eggs were identified and counted with binocular microscopes. (See Appendix A for details of identification methods.) The two aliquots of each sample were counted by different people in order to avoid individual bias in identification.

After counting, aliquots were returned to their respective samples, filtered through a .420-mm mesh sieve, combined with their coarse fractions, and preserved in 10% buffered formalin. Various types of eggs were often removed prior to the final filtration for rearing purposes.

Each preserved sample was later divested of its fish larvae, then suspended in one liter of dilute formalin. A 40-ml aliquot of each, dipped immediately after vigorous stirring, was preserved for future invertebrate-zooplankton analysis; the rest were discarded. All fish larvae were counted and identified as completely as possible using binocular dissecting microscopes.

Mathematical Methods

Two types of statistical methods were employed in most of the data analyses: Wilcoxon signed-ranks tests (Bradley, 1968) for differences in groups of means of replicate numbers of fish eggs and larvae (except where noted) and multiple regression analyses (Snedecor and Cochran, 1967) for the elucidation of relationships between fish egg abundance and environmental variables. In certain instances, the Student's t test (or the t-test; Snedecor and Cochran, 1967) was used to detect differences in means.

The Wilcoxon test was chosen because: (1) it required only continuity in the distribution of the data points; (2) the necessary assumptions were met by data obtained during this study; and (3) it has fairly high efficiency relative to the Student's t test (0.955 when the distribution of differences is normal; Bradley, 1968). Throughout the analysis the null hypothesis that the populations of differences (e.g., day-night differences in fish egg abundance) were symmetrically distributed about zero was tested against the one-tailed alternative that they departed positively from zero (i.e., that greater numbers of eggs or larvae occurred in the first member of each paired data set). Zero differences and tied differences of opposite algebraic signs, neither of which were particularly common, were not used. The results of all Wilcoxon tests are given in the text; significance levels were taken from Bradley (1968), Table II.

Multiple regression was used primarily because a computer program was available, greatly reducing the amount of time required for data analysis. There were no *a priori* reasons for assuming either normality or non-normality in the populations from which data were taken (normality is required for multiple-regression analysis), but since it was intended only to suggest possible relationships rather than test hypotheses, any loss of exactness associated with departures from normality should not be critical. The independent variables are listed and results of the analyses given in Appendix B; significance levels were taken from Snedecor and Cochran (1967), Table A4.

For much of the seasonal abundance data, the curve-smoothing technique of moving averages was employed in addition to the statistical analyses of the original data. The purpose for doing this was to eliminate small-scale abundance fluctuations so as to clarify general trends. Since the uncertainty in abundance estimates about any given sampling date was nearly ± one sampling date (i.e., almost four weeks total), three sampling date moving averages were computed.

Tides in Kaneohe Bay are mixed, varying from diurnal to predominately semidiurnal in character (Bathen, 1968). Therefore, they cannot be dealt with solely in terms of amplitude or duration. Tidal effects were quantified by applying the following factor:

$$\frac{H_{\text{Nearest High Tide}} - H_{\text{Nearest Low Tide}}}{\left| T_{\text{Nearest High Tide}} - T_{\text{Nearest Low Tide}} \right|} \times T_{\text{Nearest Low Tide}} - T_{\text{Tow Time}}$$

where H = height of the tide in feet
and T = time.

Although this oversimplifies the situation, the numbers should be approximately proportional to the amount of water which had flowed through the Sampan Channel station in the tidal current by the time the tows were made. Negative values indicate rising tides with water moving into the bay; positive values correspond to falling tides with water moving out of the bay. This tide factor was used an an independent variable in certain of the regression analyses.

Net Clogging

Because only one flowmeter was used, no quantitative estimate of net clogging was possible, although it was observed at the southern station. In order to assess the importance of this effect, a comparison was made between the mean volumes filtered per minute of tow time in south Kaneohe Bay and in Sampan Channel where clogging was not observed. If significant clogging did occur in the bay, this number would be expected to be smaller for the southern station than for the channel. Values obtained were 38.95 m^3/min for the southern station and 44.84 m^3/min for the channel. Applying a modified t-test (Snedecor and Cochran, 1967) to the means gave a probability of less than 0.002 (167 degrees of freedom) that the means were not different (versus the one-tailed alternative that Sampan Channel means were greater). From this, it was concluded that clogging did occur at the southern station.

Volumes filtered per minute of towing time were calculated for the replicate tows at each station in order to determine whether differential clogging occurred at either station. The results were as follows:

Location	No. of Samples	Mean No. (m^3/min)	Standard Deviation (m^3/min)	t'	Probability Level (one-tailed)
Sampan Channel					
Buoy 6 - 4	83	43.18	10.04	0.961	0.80
Buoy 4 - 6	83	45.60	9.11		
South Kaneohe Bay					
HIMB - KMCAS	79	38.15	9.84	0.842	0.80
KMCAS - HIMB	79	40.12	8.46		

This suggests that clogging occurred to a similar degree in each of the replicate tows at the southern station, as would be expected since the net was washed between tows. Because plankton volumes did not appear to vary seasonally to any appreciable degree in south Kaneohe Bay, it was considered unnecessary to test for seasonal differences in clogging.

Although quantitative comparisons between south Kaneohe Bay and Sampan Channel catches were not made, these are possible since the clogging at the southern station was not sufficient to qualitatively change egg or larval catches to a significant degree.

Environmental Variables

Surface water temperatures and salinities are given in Tables C1 and C2 of Appendix C. These differed little on any day between the Sampan Channel and south Kaneohe Bay stations, with water temperatures usually being slightly higher at the southern station and salinities varying depending on rainfall, tides, etc.

Between December and March, water temperatures and salinities were generally reduced somewhat at both stations (Figures 2 and 3). Temperatures averaged 23.1°C and 23.0°C for the Sampan Channel and south Kaneohe Bay, respectively, while salinities averaged 34.7°/oo and 35.5°/oo. From April through November, corresponding values were 25.2°C and 25.6°C for temperature and 34.7°/oo and 34.6°/oo for salinity.

Afternoon water temperatures and salinities were slightly higher than morning or night values, but the differences were small. In the Sampan Channel the mean day-night temperature change was 0.7°C and the mean day-night salinity variation was 0.9°/oo. Values for the southern station were 0.5°C and 0.8°/oo, respectively.

Owing to equipment failures and procedural errors, it was felt that oxygen content measurements (Tables C1 and C2 of Appendix C) were not sufficiently accurate to warrant inclusion in the data analyses.

Surface light intensity measurements (Tables C1 and C2 of Appendix C) were extremely variable, depending on the rapidly changing cloud cover during sampling periods. Differences of as much as 7,000 foot-candles during a single tow were not uncommon. For this reason, light intensities were not included in the data analyses. Day lengths and moon phases are shown in Figure 4.

Variables utilized in the regression analyses include surface water temperature and change in water temperature, surface salinity, day length and change in day length, moon phase, and tide height and phase.

FISH EGGS

South Kaneohe Bay

Twenty kinds of pelagic fish eggs were distinguished in south Kaneohe Bay. Of these, eleven kinds were identified to at least the familial level; nine others could not be identified. The most abundant eggs were of four species including, in order of decreasing abundance, the carangids, *Caranx mate* and *Gnathanodon speciosus*, the engraulid *Stolephorus purpureus*, and the dussumieriid *Etrumeus micropus*. These four species accounted for 78.2% of the total south Kaneohe Bay eggs, varying from 20.7% to 100% of the eggs collected on any given day. Only two other kinds of eggs--a synodont, possibly *Saurida gracilis*, and an unidentified species tentatively called Labrid II--were numerically important at any time. The synodonts were generally rare, but accounted for 14.0% and 38.5% of the eggs on two occasions (in November and December of 1971). Labrid II's were nearly always present in small numbers; however, on two occasions (in January of 1972) they accounted for 60.5% and 75.2% of all the eggs collected.

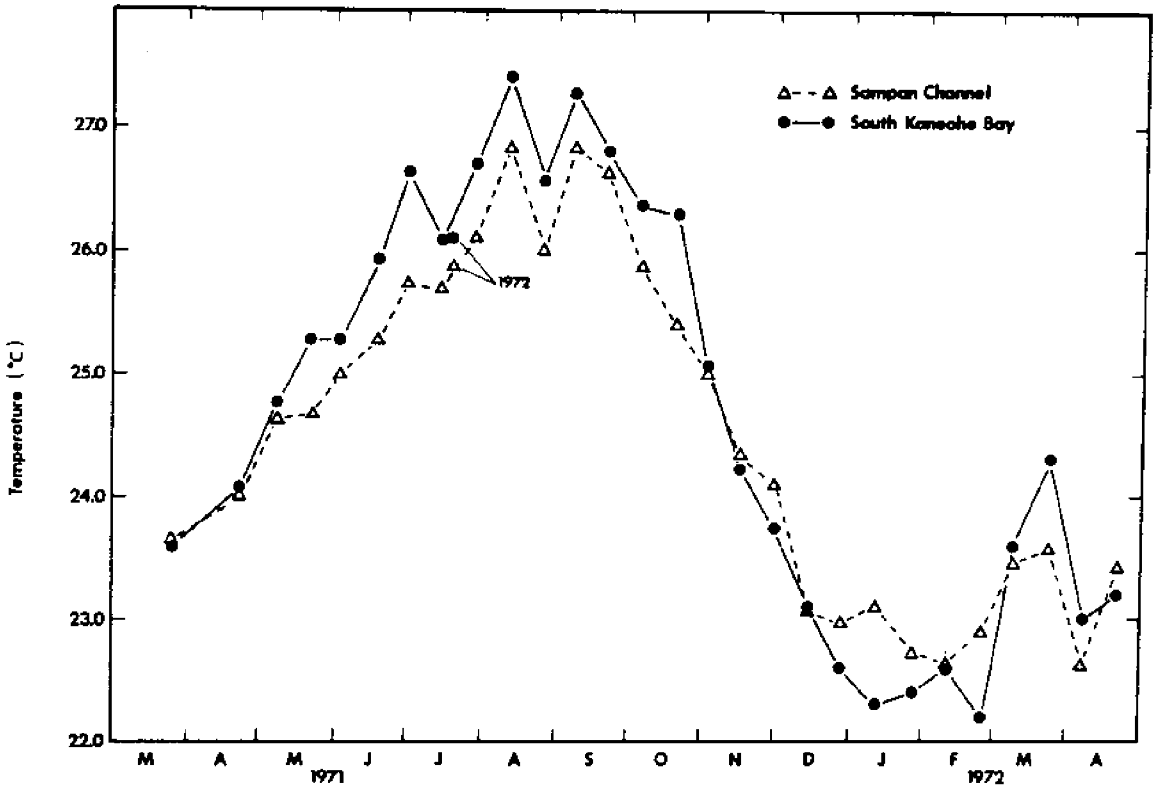

Figure 2. Surface water temperatures.

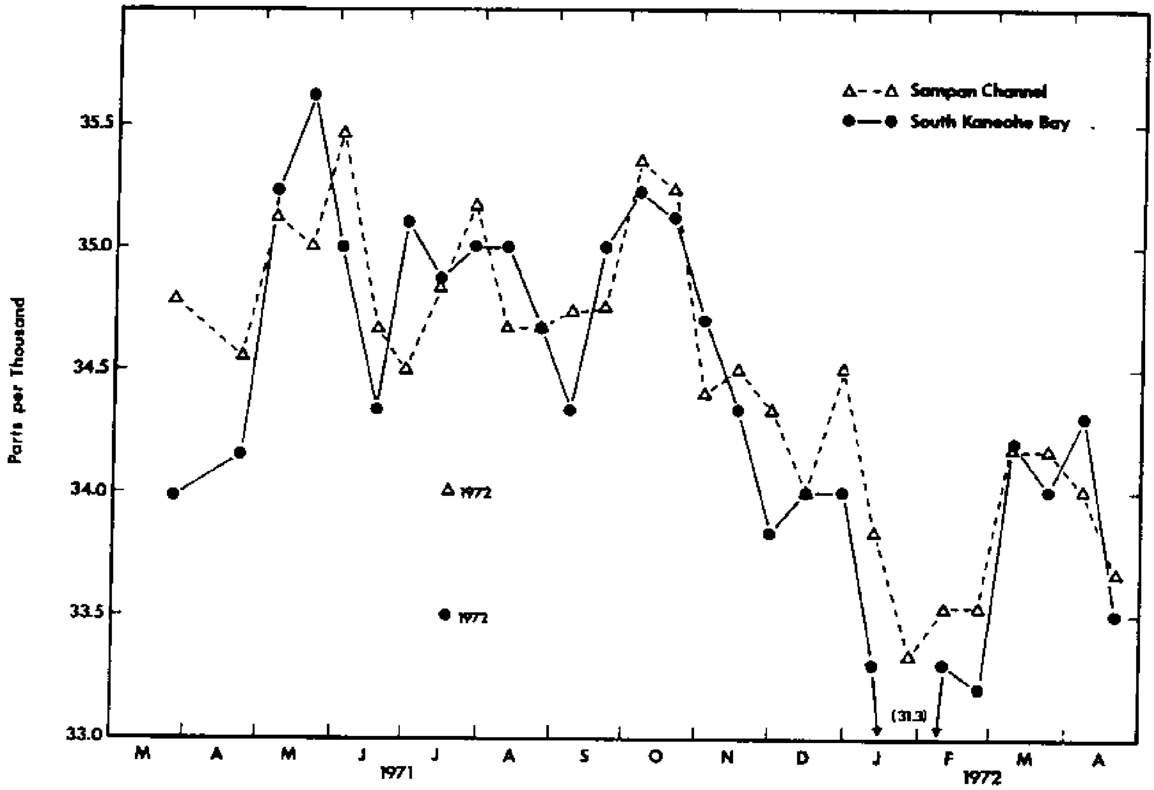

Figure 3. Surface salinities.

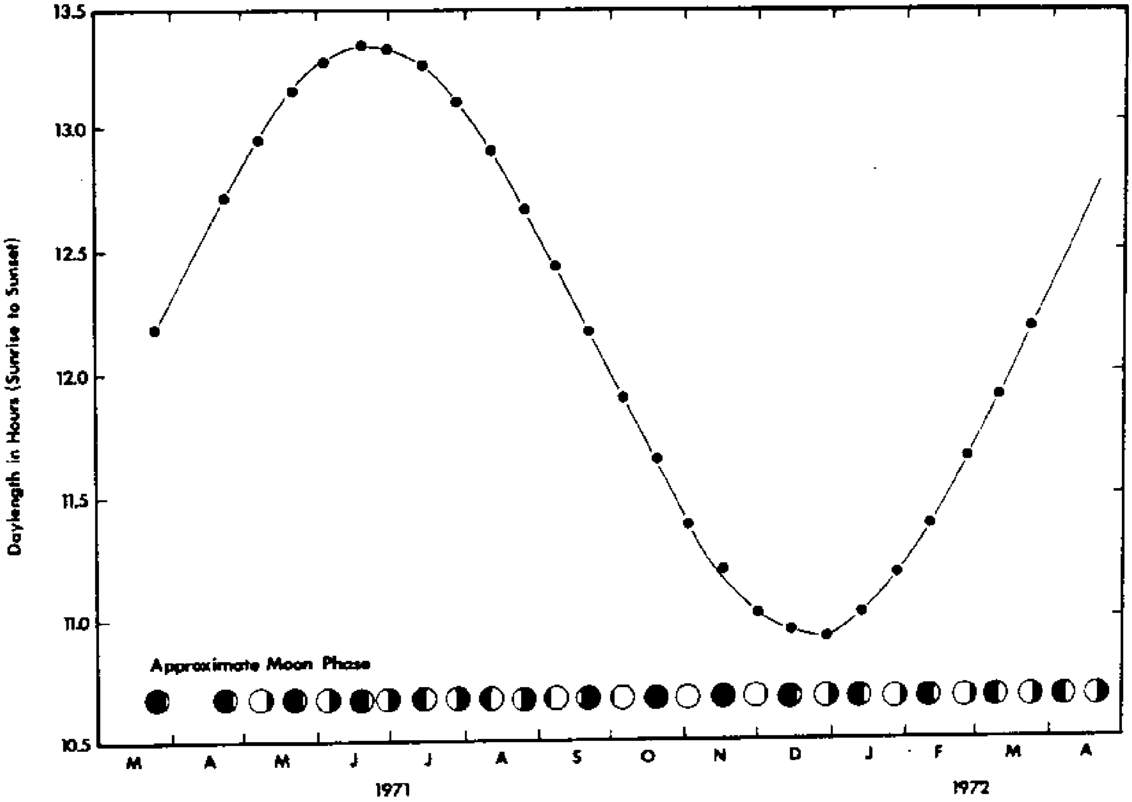

Figure 4. Day length and moon phase.

Among the four most abundant species, the carangids predominated from March through October, usually comprising between 60% and 95% of all the eggs collected on any day during this period, and clupeoids dominated from November through February, usually comprising between 60% and 99% of all the eggs on any day.

Between March and October, an average of nine of the twenty kinds of eggs were taken on each sampling day; from November through February the average dropped to six. The density of eggs changed similarly, averaging 4.81/m^3 per tow between March and October and declining to 0.77/m^3 between November and February.

In general, both the abundance and numbers of types of eggs increased at night:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)	Mean No. of Kinds
Morning	5.6	6.2	3.7
Afternoon	7.3	12.7	3.8
Night	8.9	9.9	3.9

Wilcoxon signed-ranks tests performed on the mean numbers of all eggs taken in each pair of replicates gave the following results:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	26	(-)151	$P > 0.052$
Morning-night	28	(+)145	$P > 0.052$
Afternoon-night	29	(+)145	$P > 0.050$

No significant overall differences were found, although the afternoon-night ranks-sum approached significance ($W_{0.05} = 141$). Consistent seasonal trends for day-night differences in abundance were not observed. Night tows contained more eggs more often than did either morning or afternoon tows, but each predominated at some time during the study.

Systematic accounts of the eggs taken from south Kaneohe Bay follow.

Carangidae (Omaka: *Caranx mate*)

Omaka eggs are very similar to 11 other kinds of fish eggs taken during the survey. The early confusion with these other eggs made it difficult to deal quantitatively with omaka eggs.

During the latter part of the survey (from about January of 1972) identification of the omaka egg became somewhat more certain, so that by the end only one other kind--a carangid called Type XLIII--was confused with it. Type XLIII differs from omaka only in that its diameter is somewhat smaller; whether it is a different species has not yet been determined with certainty. The name omaka, then, when used in this section will refer to *Caranx mate* plus Type XLIII.

From January through July of 1972, omaka constituted the major part of the combined complex of similar eggs, particularly when numbers were large. In addition, *C. mate* eggs were always much more numerous than Type XLIII when reasonably definite identifications could be made. Since the numbers in south Kaneohe Bay were often high and were probably omaka, the decision was made to extract omaka from the "Omaka Complex" data.

It was discovered that for the January through July of 1972 data, a logarithmic relationship existed between the daily mean number of "Omaka Complex" eggs (standardized to 1 m^3 of water filtered) and the percentage of omaka eggs contained in the "Omaka Complex" on that day. The least-squares fit curve was of the form:

$$\text{Percent omaka} = 92.68 \log (1 + \Sigma_i \bar{X}_i) - 17.50$$

where $\bar{X}_i$ = mean number of "Omaka Complex" eggs per m^3 in each pair of replicate tows

and i = number of pairs of replicates

($r = 0.67$ with 7 degrees of freedom; $P < 0.05$).

By applying this relationship to all the "Omaka Complex" data, mean numbers of omaka eggs per cubic meter of water filtered were generated for the sampling period (Figure 5). These values did not very accurately predict the actual counts of omaka eggs at low densities (January and February of 1972), but fit fairly well for higher densities (based on March and April of 1972 counts). A probable explanation for this result lies in the highly variable species composition of the "Omaka Complex" during winter months with a generally low and variable percentage of omaka eggs, as opposed to the spring and summer situation with variable species composition but a uniformly high percentage of omaka eggs. It is quite possible that when proper identifications are made, *Caranx mate* will be found to spawn only from early spring through fall (e.g., February or March through October). Based on an April through August gonad survey, Watarai (1973) suggested omaka spawning peaks in May and June of 1970, but stated that omaka breed from late March to late October.

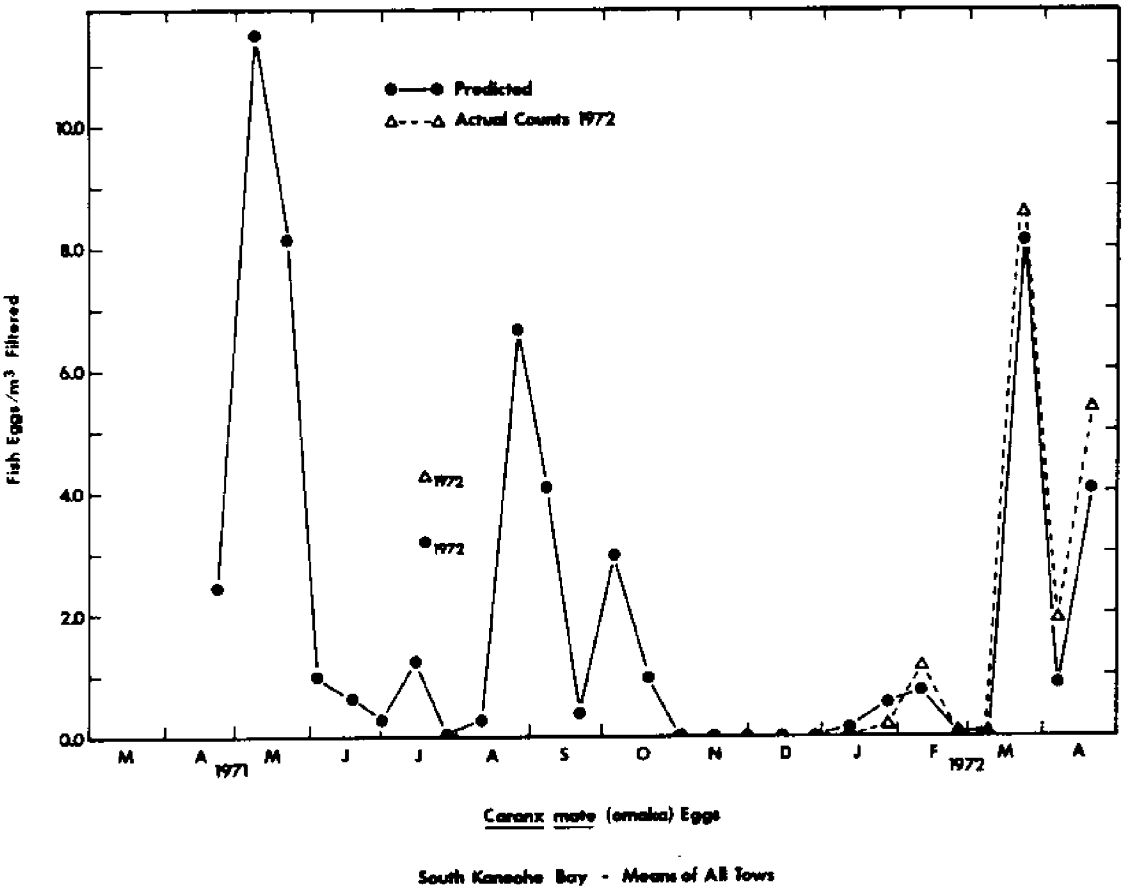

Figure 5. Predicted *Caranx mate* egg abundance.

Diurnal changes in abundance were not determined for the entire year; however, from January through July of 1972, means were as follows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	5.2	3.3
Afternoon	3.5	9.4
Night	3.2	5.7

Omaka apparently spawn during the late morning or early afternoon: most eggs taken during the afternoon between 1200 and 1600 hours were in the morula stage of development, while evening eggs, *ca* 2000 to 2200 hours, were in the blastula and gastrula stages and morning eggs, *ca* 0800 to 1000 hours, were in the tail-free and late stages. (Developmental stages are as given in Mansueti and Hardy, 1967.)

Omaka eggs were present throughout the year, possibly owing to misidentifications, except in November and December. Six peaks of abundance occurred: (1) in mid-February; (2) near the end of March; (3) in mid-May; (4) in mid-July; (5) in early September; and (6) in early October. These fell into two major periods of abundance during the spring and fall, separated by a much smaller summer peak. This suggests the possibility of a relationship between spawning and some variable such as change in day length with perhaps a day-length initiation and termination of spawning. Consideration of these possibilities must await further study, however, when more definitive identifications of omaka can be made.

Carangidae (Pa'opa'o: *Gnathanodon speciosus*)

Pa'opa'o eggs were taken from late February through mid-October including 15 pairs of replicate tows in the spawning season. Mean numbers of eggs for these were as follows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	1.30	1.60
Afternoon	0.41	0.62
Night	0.98	0.82

Wilcoxon signed-ranks tests performed on untied pairs of day-night mean catches gave the following results:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	15	(-)24	P < 0.024
Morning-night	13	(-)43	P > 0.050
Afternoon-night	14	(+)18	P < 0.025

A diel periodicity in pa'opa'o spawning is indicated. Pa'opa'o apparently begin spawning in the early evening hours and continue for some time into the night. After spawning, the eggs are dispersed by currents and perhaps lost to predators, etc. Consequently, mean catches averaged over the year could be expected to decline and variances to increase with time after spawning, assuming that sampling was done in the spawning area. This is consistent with the authors' observation that pa'opa'o eggs hatch within about 18 hours after being spawned.

About five peaks of pa'opa'o egg abundance at roughly one-month intervals were noted during the spawning period (Figure 6). All peaks occurred near the first and third quarters of the moon, suggesting the existence of a relationship. Too few samples were taken, however, to confirm or refute this possibility.

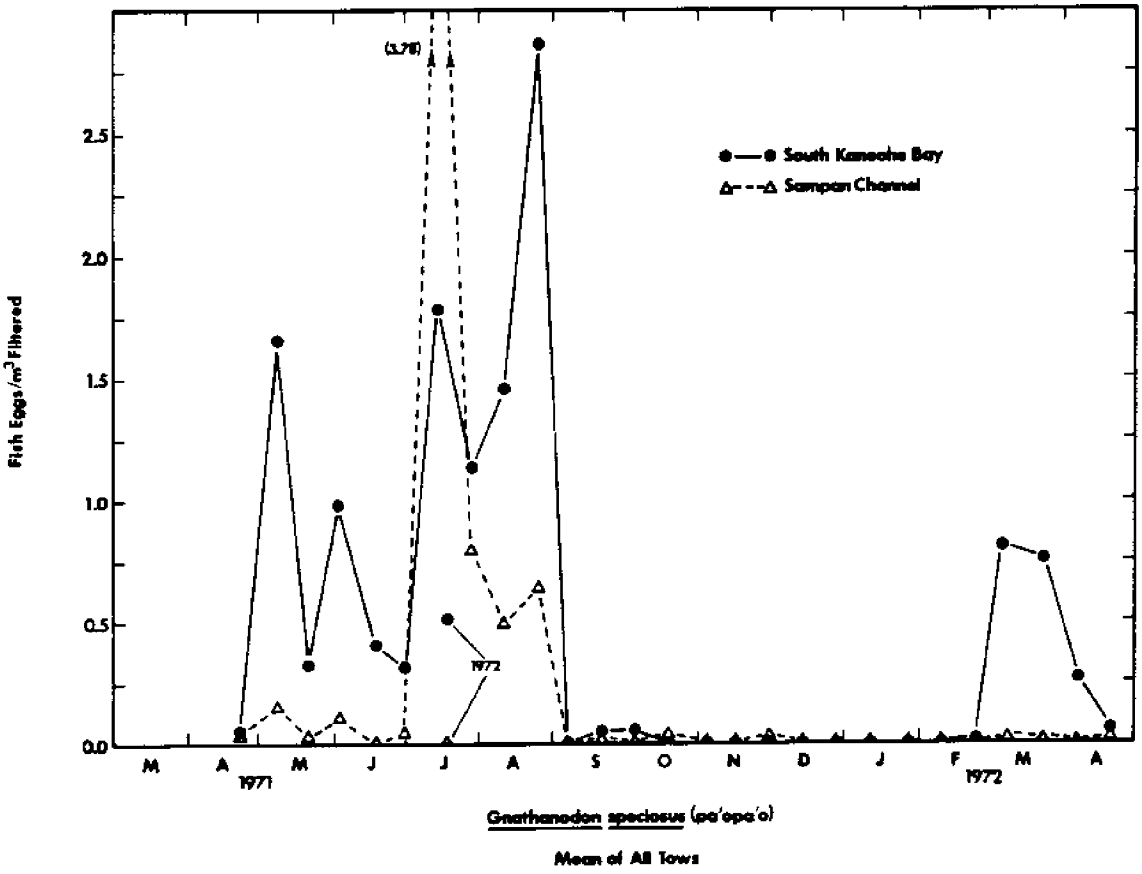

Figure 6. *Gnathanodon speciosus* egg abundance.

Application of a three-point moving average resolved the approximately one-month fluctuations into three broad peaks occurring in March, May, and August with relative minima in April and June. No eggs were taken during the winter and almost none in the fall.

Results of multiple regression analyses performed on the pa'opa'o data are given in Tables B2 and B12 of Appendix B. A number of relationships proved statistically significant, including regressions on day length, surface water temperature, and combinations of day length, water temperature, and salinity ($P < 0.050$ in all cases). Of these, day length was the most important single variable: its partial regression coefficient was significant at $P < 0.050$ in all cases, while for the other variables significance levels were greater than 0.050 in almost all cases. Since day length, water temperature, and salinity were well correlated with each other (Table B19 of Appendix B), it is reasonable to expect some degree of correlation with egg abundance for all of them. When the spawning season data alone were considered, no significant linear correlations were found.

During the data analysis, an almost all-or-nothing relationship between pa'opa'o egg abundance and day length was noted. At day lengths less than *ca* 11.5 hours (measured from sunrise to sunset; inclusion of twilight would add 40 to 50 min), no eggs were taken. Eggs were taken on all but one of the days which was longer than 11.5 hours, usually with higher catches on the longer days (Figure 7). Owing to a ± one week uncertainty in estimating occurrences on any date, the last eggs in fall may have been present as long as 13 more days and the first eggs in spring may have appeared up to 13 days earlier than the first catch. These would correspond to a possible last appearance at 11.33 hours day length and a first appearance at 11.22 hours day length. The actual last and first catches were on days of 11.65 hours and 11.38 hours, respectively. This suggests a day length dependence or dependence on some co-varying factor, such as mean light intensity, in spawning with a lower limit at about 11.5 hours. Above this limit the relationship between spawning and day length is yet to be determined.

Engraulidae (Nehu: *Stolephorus purpureus*)

Eggs of the nehu (*Stolephorus purpureus*) occurred throughout the year in both day and night tows in south Kaneohe Bay. For 28 pairs of replicate tows, mean catches were as follows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.27	0.38
Afternoon	0.19	0.42
Night	0.19	0.53

No day-night differences in abundance were apparent; Wilcoxon signed-ranks tests confirmed this observation. Results of the analysis were as follows:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	22	(-)93	P > 0.052
Morning-night	16	(-)52	P > 0.050
Afternoon-night	22	(-)96	P > 0.052

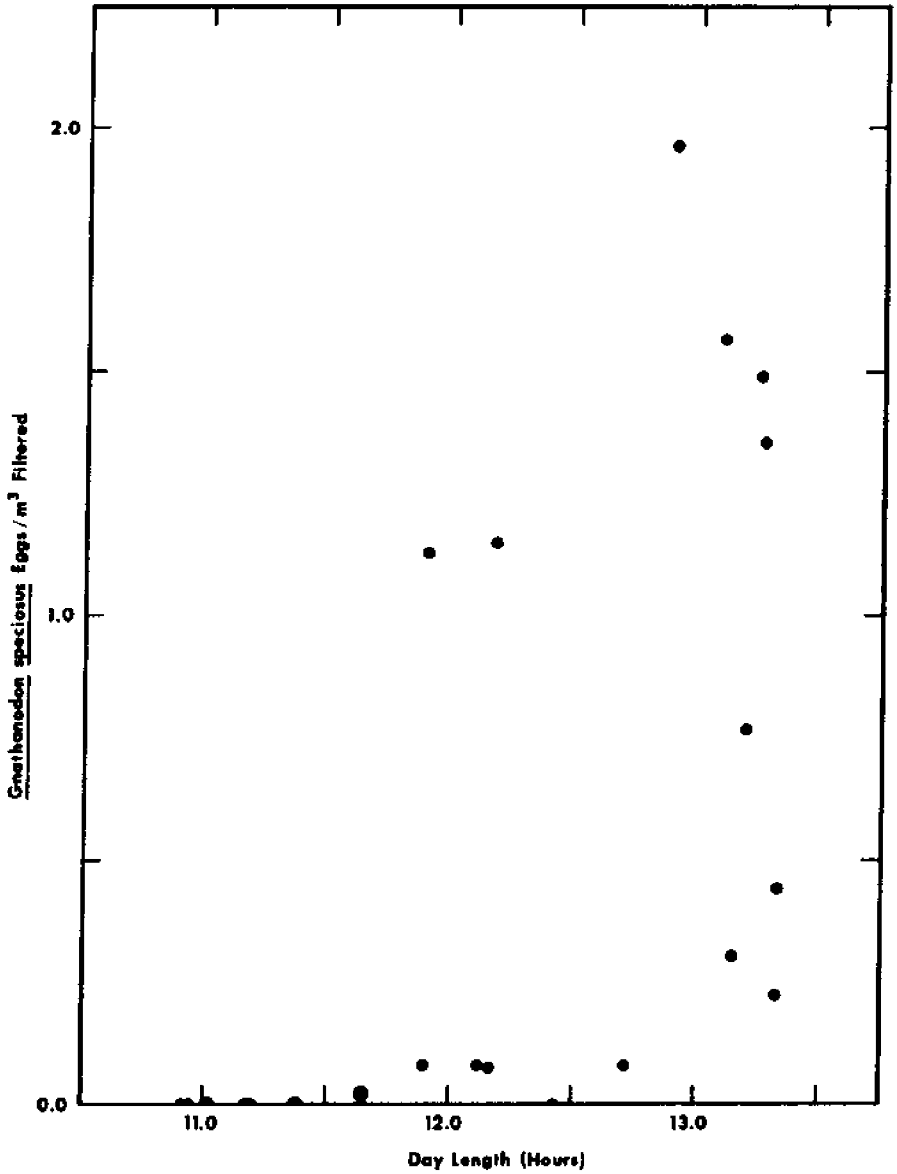

Figure 7. *Gnathanodon speciosus* egg abundance vs day length. (Large dot indicates two data points.)

Although the mean morning catch of eggs was not significantly greater than either afternoon or night mean catches, on 12 of the 28 occasions when eggs were taken, greater numbers were collected in the mornings as opposed to 8 of 28 occasions for both afternoons and nights. This contrasts with Yamashita's (1951) study in south Kaneohe Bay, where he found nearly five times as many eggs during the day (at 0800 and 1400 hours, corresponding approximately to the daytime sampling hours of this study) as at night (at 2000 hours, approximately the night sampling time). Since his data were collected over a period of only two days, however, quantitative comparisons were unjustified.

Nehu appeared to spawn year-round (see Tester, 1951) with four or, possibly, five peaks of abundance: (1) in February; (2) from late March through April; (3) in mid-July; (4) possibly from mid-August through early September; and (5) from mid-November through mid-December (Figure 8). The data from the present study indicated a seasonality completely different from that found by Tester (1951, 1955).

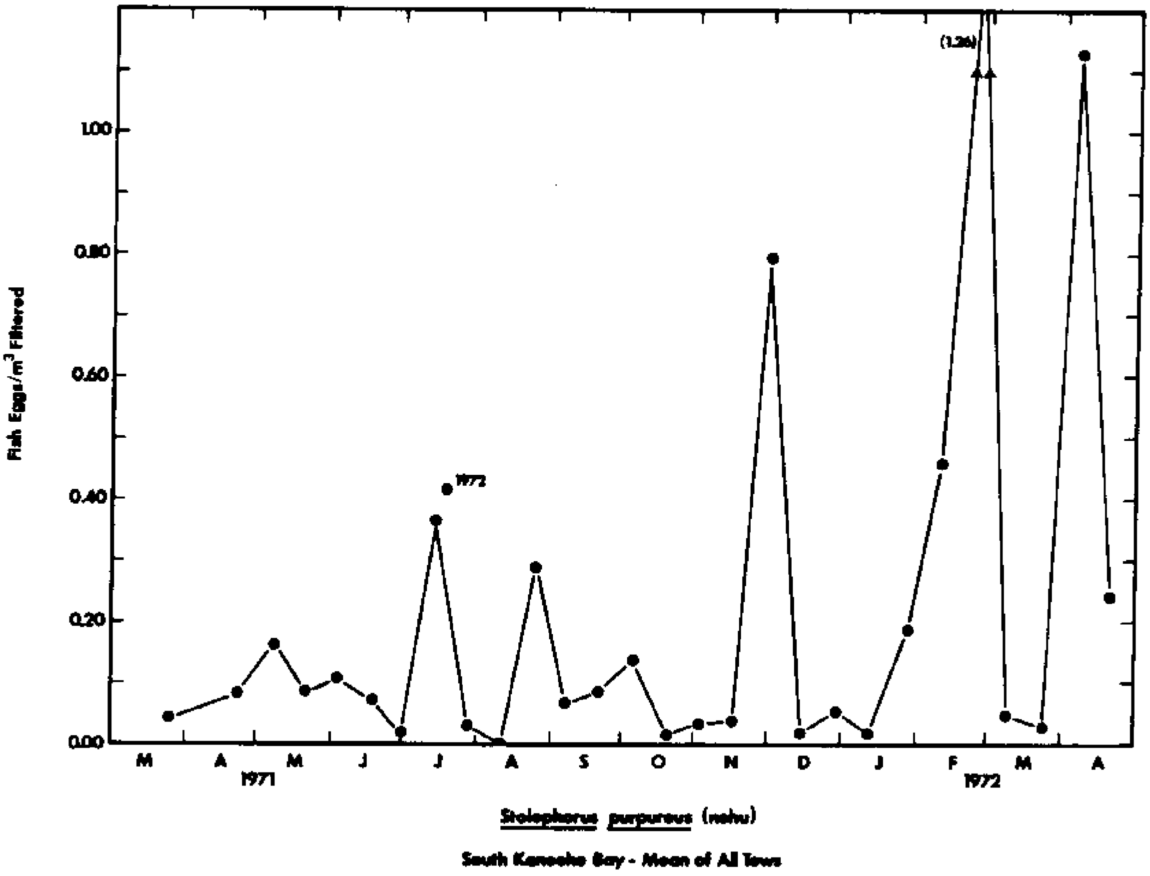

Figure 8. *Stolephorus purpureus* egg abundance.

Multiple regression analyses (Tables B3 and B11 of Appendix B) suggested that nehu egg abundance was weakly negatively correlated with surface water temperature, the probability level being near 0.050 (a t-test for significance of the regression coefficient gave a P ≈ 0.06). Combining the moon phase with water temperature improved the fit slightly.

Dussumieriidae (Makiawa: *Etrumeus micropus*)

Makiawa eggs were present in south Kaneohe Bay from mid-October through mid-July, but in high numbers only from late April. Peaks of abundance occurred during the first part of May and in mid-June with small fluctuations from November through March. Application of a three-point moving average resolved the May and June maxima into a single peak and suggested the presence of smaller peaks in mid-November and mid-December, with a continuous decline in abundance from January to mid-April. Between mid-July and mid-October no makiawa eggs were taken from south Kaneohe Bay (Figure 9).

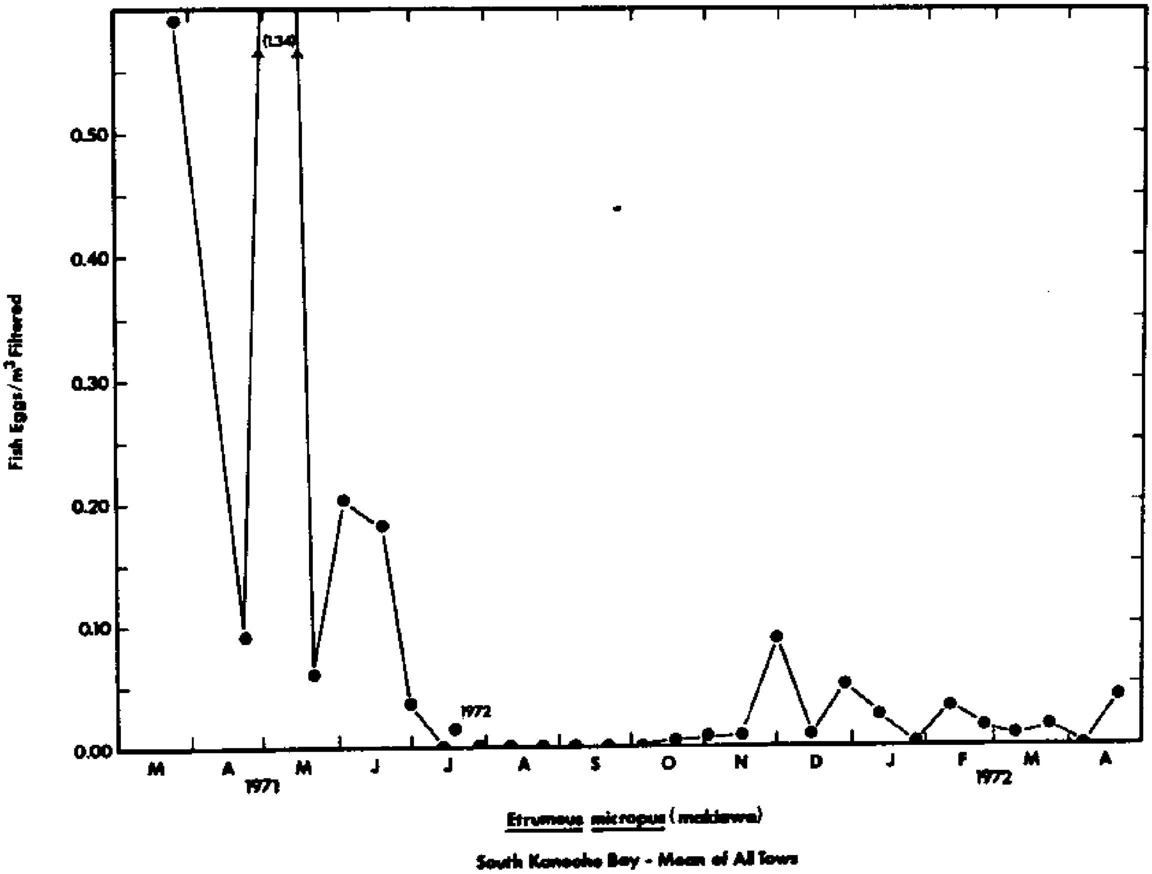

Figure 9. *Etrumeus micropus* egg abundance.

For 22 pairs of replicate tows taken during the spawning season (mid-October through June), mean catches were as follows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.06	0.09
Afternoon (21 replicates)	0.25	0.78
Night	0.09	0.12

The higher mean catch and larger standard deviation for the afternoons can be explained by two tows: March 25 and May 7, 1971, when makiawa eggs were present in densities of $1.02/m^3$ and $3.51/m^3$, respectively. Excluding these, the afternoon mean was 0.04 $eggs/m^3$ with a standard deviation of 0.07 $eggs/m^3$.

Wilcoxon rank-sum tests were applied to untied data from morning, afternoon, and night tows in order to test the hypothesis of equal numbers against the two-tailed alternative of greater numbers at any time. The null hypothesis was not rejected as is apparent from the test results below:

Times	N_1; N_2	Smaller Rank-Sum	Probability Level
Morning; Afternoon	13; 12	153	$P > 0.20$
Morning; Night	8; 7	54	$P > 0.20$
Afternoon; Night	5; 11	52	$P > 0.20$

Since makiawa have an approximately two-day incubation period (T.D. Cooney, 1973: personal communication), differences in numbers due to diel spawning behavior would tend to be obscure. However, makiawa clearly spawn during the evening: the majority of the eggs taken at night were in the morula stage of development, while daytime eggs were primarily in the tail bud and later stages.

Results of the multiple regression analyses are given in Tables B4 and B13 of Appendix B. Significant ($P \leq 0.050$) correlation coefficients were obtained from regression with (1) day length and change in day length and (2) day length, change in day length, and surface water temperature. T-tests for significance of the partial regression coefficients in every case gave two-tailed probability levels greater than 0.050. Only day length approached significance at $P \approx 0.07$ with 21 and 20 degrees of freedom in the two cases. In the first case, about 75% of the variability in makiawa egg abundance was not explained by the independent variables; in the second case 68% was not explained.

Inspecting only relative maxima and minima during spawning season, it was seen that four of the six peaks of abundance occurred in the second quarter of the moon and all minima in the first and fourth quarters. This suggested the possibility of a lunar periodicity, but was inadequate to show a causal relationship. Initiation and termination of spawning may be related to some combination of day length and change in day length; again, further study is necessary to clarify this relationship.

Labrid II (Hinalea)

Labrid II eggs were consistently confused with omaka during the first half of the survey. Since these eggs constituted the second largest component of the "Omaka Complex" in south Kaneohe Bay and were nearly always present when definite identifications were made, it was decided to attempt to extract them from the "Omaka Complex" as was done with omaka eggs.

A power function of the form:

$$\text{Percent Labrid II} = 7.68\ (\Sigma\ \text{Omaka Complex})^{-1.12}$$

$$(r = 0.64 \text{ with 7 degrees of freedom; } P > 0.050)$$

was found to best describe the relationship between Labrid II eggs and the "Omaka Complex" from January through July of 1972. However, this relation was not considered to be good enough to warrant generating numbers for the entire year. Labrid II eggs appeared to spawn year-round and in greater abundance during the winter months, but usually constituted only a small part of the south Kaneohe Bay fish egg catches.

Between January and July of 1972, when identifications were relatively certain, numbers were as follows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.36	0.86
Afternoon	0.19	0.34
Night	0.17	0.10

The high morning numbers were attributable to the catches of January 27, 1972, when an average of 2.64 eggs/m^3 were taken. Excluding this, the morning mean became 0.11 eggs/m^3 with a standard deviation of 0.08 eggs/m^3. Statistical tests were not performed and developmental stages were not noted; however, the numbers suggest a possibility of afternoon or night spawning.

Other Eggs

Infrequently-encountered fish eggs in south Kaneohe Bay include 14 kinds. They are as follows:

'Ulae (Synodont I). These appeared to be of one species. All were collected between October and December of 1971 in morning, afternoon, and night tows. All were taken on rising or high tides, suggesting tidal transport rather than spawning in the southern station. As previously mentioned, Synodont I were numerous on only two sampling dates. Aside from these two dates, the few samples with 'ulae eggs contained an average of 0.06 eggs/m^3.

Tetraodontiformes. Three or four species are included in this group (see Appendix A). They occurred sporadically throughout the year; five of the seven occurrences were at night.

The apparent lack of Tetraodontiform eggs at this station may have been an artifact attributable to their retention on the 1.5-mm sieve as a result of their large size and clogging of the sieve by the large numbers of zooplankters normally taken at this station. (On days when Tetraodontiform eggs were taken, zooplankton volumes were generally smaller than on days when they were not.)

Hinalea (*Thalassoma* sp.). These are most likely the eggs of *Thalassoma duperreyi*. Hinalea eggs were first noted on April 6, 1972 and then found on two succeeding sampling dates at an average density of 0.09 eggs/m^3. Prior to that time they were probably confused with the other "Omaka Complex" eggs, particularly Labrid II. All were taken in afternoon tows.

Type VIIIc. Type VIIIc is an unidentified egg and part of the "Omaka Complex." Beginning on September 21, 1971, VIIIc's were consistently distinguished from all but one--Type XIX, an uncommon egg--of the other "Omaka Complex" eggs. Thereafter, they occurred on 8 of the 17 sampling dates, averaging 0.30 eggs/m^3 per positive tow. Eggs were taken during mornings, afternoons, and nights, primarily on rising and high tides.

Trichonotidae (*Crystallodytes cookei*). These were taken from the southern station on four occasions (in February, April, June, and September), both during the day and night. Positive tows contained an average of 0.04 eggs/m^3.

Bothid I. These eggs were taken on the afternoon of September 7, 1971 (0.07 eggs/m^3 in one tow) and during the nights of October 19, 1971 and July 18, 1972 (0.04 eggs/m^3 and 0.02 eggs/m^3, respectively in one tow each).

Labrid IV. These eggs were collected on the morning of July 18, 1972 (0.19 eggs/m^3 in one tow) and night of March 9, 1972 (0.31 eggs/m^3 in one tow).

Type XXXVI. An average of 0.07 eggs/m^3 were taken in three of the four south Kaneohe Bay tows on the morning and afternoon of April 20, 1972 and 0.70 eggs/m^3 were taken in one tow on the morning of July 18, 1972.

Type XLII. On the mornings of April 20, 1972 and July 18, 1972, 0.05 eggs/m^3 were taken in one tow of each replicate pair.

Type VIIIb. On the night of September 21, 1971, 0.06 eggs/m^3 were taken in one tow.

Type XIX. On the morning of August 11, 1971, 0.16 eggs/m^3 were taken in the only tow.

Type XXX. On the afternoon of April 6, 1972, 0.20 eggs/m^3 were taken in one tow.

Type XXXIV. On the afternoon of March 23, 1972, 0.04 eggs/m^3 were taken in one tow.

Type XXXV. On the morning, afternoon, and night of July 18, 1972, an average of 0.19 eggs/m^3, 0.44 eggs/m^3, and 0.03 eggs/m^3, respectively were taken in each tow.

Sampan Channel

Thirty-nine kinds of pelagic fish eggs were distinguished at the Sampan Channel station; twenty occurred exclusively here. Twenty-six kinds could be identified to at least the familial level, thirteen others have not yet been identified.

The "Omaka Complex" eggs (including omaka, *Thalassoma* sp., Labrid II, VIIIb, VIIIc, XIX, XXXIV, XXXV, XLII, XLIII, and an acanthurid) comprised the largest group of eggs, amounting to 79.9% of the total Sampan Channel egg catch and reaching a single-day maximum of 97.3% on September 21, 1971. These eggs were not adequately separated before January of 1972, although VIIIb and VIIIc were distinct enough to be fairly consistently recognized from September 21, 1971. Labrid II and omaka were the major components of the "Omaka Complex," comprising about 84% and 8%, respectively from January through July of 1972. Other common Sampan Channel eggs included *Gnathanodon speciosus*, Tetraodontiformes, Synodontidae, *Crystallodytes cookei*, and *Stolephorus purpureus*. Bothids were numerous at times. These kinds of eggs, together with the "Omaka Complex," accounted for 89.1% of all the eggs taken from the Sampan Channel. Of the identifiable species, only *Gnathanodon speciosus* approached 5% of the total taken from this station. Its maximum was 74.9% of the catch on July 14, 1971.

Seasonal shifts in the composition of egg types were not as apparent in the Sampan Channel as in south Kaneohe Bay. Between March and October, an average of ten kinds of eggs were taken on a sampling date; from November through February, an average of nine kinds were taken. An average tow between March and October contained 4.98 eggs/m^3, while a November through February tow contained 2.74 eggs/m^3.

On the average fewer eggs were taken during the mornings than in either afternoon or night tows. Mean catches were:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	4.5	11.6
Afternoon	8.8	15.3
Night	12.7	12.0

Wilcoxon signed-ranks tests performed on the data gave the following results:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	27	(+)113	$P < 0.048$
Morning-night	28	(+) 30	$P < 0.005$
Afternoon-night	24	(+)104	$P > 0.051$

Morning tows contained fewer eggs throughout the year than did afternoon or night tows, except on two occasions, both in March, when the morning tows contained more eggs.

Systematic accounts of the eggs taken from the Sampan Channel station follow:

Labrid II (Hinalea)

The "Omaka Complex" constituted the major component of the Sampan Channel eggs; of this, Labrid II was by far the most abundant. For this reason, an attempt was made to extract Labrid II from the "Omaka Complex" using the data from January through July of 1972 during which time identifications were relatively certain.

Using the method of least-squares, Labrid II was found to be best related with the "Omaka Complex" by a hyperbolic relationship of the form:

$$\text{Percent (Labrid II)} = 114.62 - (653.46/\Sigma \text{ "Omaka Complex"})$$

where Percent (Labrid II) = the portion of the "Omaka Complex" represented by Labrid II eggs

and Σ "Omaka Complex" = the sum of the "Omaka Complex" eggs in all tows.

Unfortunately, this relationship was not a very good one: the correlation between the calculated percentage of Labrid II and the actual percentage for January through July of 1972 was 0.58 (with 7 degrees of freedom). This corresponds with a significance level (two-tailed) greater than 0.050. Consequently, little can be said concerning seasonality except that Labrid II apparently spawns year-round. The number of eggs declined slightly between January and July of 1972, suggesting that Labrid II may primarily be a winter-spawning fish (Figure 10a).

From January through July of 1972 more eggs were taken at night than during the day, in contrast with the southern station where similar numbers were usually taken during the day and night.

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	7.32	20.58
Afternoon	2.70	2.70
Night	9.20	6.90

The large mean and standard deviation for morning tows are attributable to samples from March 23, 1972, when an average of 31.09 eggs/m^3 were taken in each of the replicate tows. Excluding this catch, the mean and standard deviation became 0.47 eggs/m^3 and 0.44 eggs/m^3, respectively. Although developmental stages were not noted, the numbers suggest a possibility of late afternoon or night spawning which is consistent with the south Kaneohe Bay data.

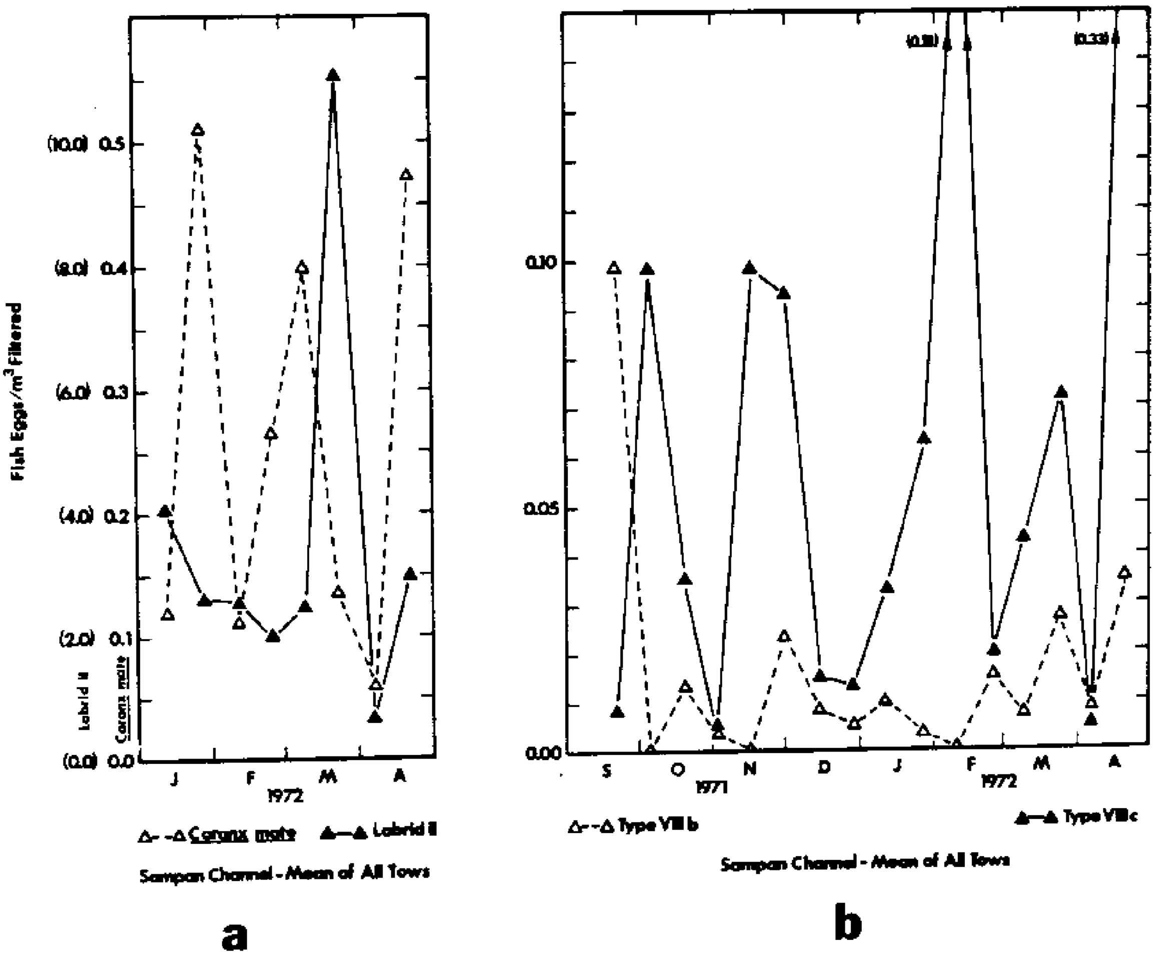

Figure 10. (a) *Caranx mate* and Labrid II egg abundance and (b) Type VIIIb and VIIIc egg abundance.

Carangidae (Omaka: *Caranx mate*)

Omaka (including *Caranx mate* and Type XLIII) eggs constituted the second largest part of the "Omaka Complex" in the Sampan Channel. Even so their numbers were always low: at most they comprised 19% of the "Omaka Complex" and 17% of the total egg catch on any day. Because of their low numbers and owing to the inaccuracies inherent in predicting numbers from a "best-fit" curve, no attempt was made to extract omaka from the "Omaka Complex" data. However, the data from January through July of 1972, when identifications of omaka eggs were reasonably certain, were available for analysis.

During the January through July period, morning and night tows generally contained more omaka eggs than did afternoon tows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.25	0.44
Afternoon	0.16	0.26
Night	0.26	0.37

Wilcoxon signed-ranks tests indicated that these differences were not significant ($P > 0.55$ in all cases).

Three peaks of abundance occurred during the first half of 1972 at six-week intervals (Figure 10a). These formed a single period of abundance which centered about mid-February through early March, corresponding well with the early spring omaka peak at the southern station.

Because of the consistently greater number of omaka eggs at the southern station, it seems likely that the omaka (*Caranx mate*) spawns in or near the southern sector of Kaneohe Bay.

Type VIIIc

Type VIIIc eggs have thus far resisted all attempts at rearing and identification. Prior to September 1971, they were recognized as a distinct egg type, but were often confused with the "Omaka Complex" owing to their similar appearance. After that time, it was possible to distinguish them consistently from most other eggs, except Type XIX, an uncommon egg which was occasionally confused with VIIIc throughout the survey. The discussion of Type VIIIc eggs, therefore, will be limited to the period extending from September 21, 1971 to July 18, 1972.

VIIIc's were present on all sampling dates and occasionally in fairly large numbers; e.g., 1.07 eggs/m^3 on the night of April 20, 1972. Peaks of abundance occurred at approximately one-month intervals, except during December and January (Figure 10b). This suggested the possibility of some lunar periodicity, but a direct relationship was not apparent.

Night tows usually contained more eggs than day tows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.05	0.07
Afternoon	0.02	0.04
Night	0.14	0.20

Wilcoxon signed-ranks tests confirmed the apparent higher number of eggs at night:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	13	(-)31	P > 0.055
Morning-night	13	(+)20	P < 0.047
Afternoon-night	10	(+) 2	P < 0.005

Because developmental stages were not noted, it cannot be conclusively determined whether these differences were the result of night-time spawning or the result of tidal input of offshore eggs. (Tides were generally rising during the morning and night tows and falling during the afternoon tows throughout much of the period dealt with here.)

Multiple regression analyses indicated significant relationships with no environmental variables other than tide (Tables B6 and B16 of Appendix B), using data for only half the year.

Regression of VIIIc abundance on the tidal factor based primarily on daytime tows showed a correlation of -0.389 (with 40 degrees of freedom; $0.01 < P < 0.05$) between the two. The slope of the regression line was significant at $P < 0.025$. This suggests that Type VIIIc is an offshore egg which was carried into the bay by tidal currents. The fact that VIIIc's were primarily, but not always, taken at the southern station near the peaks of rising tides lends some support to this hypothesis.

Carangidae (Pa'opa'o: *Gnathanodon speciosus*)

Pa'opa'o eggs were present throughout the year at the Sampan Channel station, although from mid-September through February few tows contained these eggs (Figure 6). This is not inconsistent with the March through August period inferred from the south Kaneohe Bay data. For the 16 sampling dates included between March and mid-September, mean numbers of eggs were as follows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.10	0.13
Afternoon	0.05	0.09
Night	1.01	2.76

During the night tows of July and August, relatively large numbers of eggs were taken. On the night of July 14, 1972 eggs were very numerous, amounting to 11.04 eggs/m^3. At all other times of the year, numbers were more similar for day and night samples.

Wilcoxon signed-ranks tests applied to the spawning season data gave the following results:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	11	(-)15	P > 0.051
Morning-night	16	(+)40	P > 0.052
Afternoon-night	15	(-)58	P > 0.054

It was thought that the lack of significant differences might be an artifact attributable to the fact that during 1972 fewer pa'opa'o eggs were present in the Sampan Channel (Figure 6). In view of this, Wilcoxon tests were applied to the 1971 data only, but the probability levels did not change.

During the spawning season, four approximately one-month periods of increased abundance occurred: (1) early May, (2) mid-June, (3) mid-July, and (4) late August. Of these, the July and August peaks were larger (Figure 6). Both occurred at night only; morning numbers formed a broad peak throughout this period, while afternoon tows contained very few pa'opa'o eggs. Peaks of abundance all occurred near the first and third quarters of the moon, but the data are insufficient to demonstrate a relationship.

Regression analyses applied to the pa'opa'o data showed a number of significant linear relationships between egg abundance and environmental variables including day length, surface water temperature, and various combinations of day length, surface water temperature, and salinity (all significant at $P < 0.50$; Table B15 of Appendix B). For single variables, the best linear fit was obtained with day length. T-tests for significance of the partial regression coefficients showed day length to be significant at $P \leq 0.050$ in most cases, while the others were usually not significant at the 0.050 level (Table B5 of Appendix B).

A dependent relationship between egg abundance and day length was suggested by the south Kaneohe Bay data; this was found to be applicable to the Sampan Channel as well, although the relationship was weaker. Here, the last eggs in the fall were taken on a day of 11.02 hours (sunrise to sunset); the first eggs in spring were taken on a day of 11.38 hours length. An uncertainty of ± one week in placing actual occurrences extended the last possible appearance to a 10.87-hour day and the first appearance to an 11.22-hour day.

Diel and seasonal changes in the abundance of pa'opa'o eggs at the Sampan Channel station generally paralleled changes in south Kaneohe Bay. The two major differences noted were: (1) much lower numbers at all times in the Sampan Channel, except on the night of July 14, 1971; and (2) a general lack of pa'opa'o eggs in the Sampan Channel during the 1972 segment of the study. Both of these differences could be explained by pa'opa'o spawning being localized in the southern sector of Kaneohe Bay, with eggs advected and concurrently dispersed toward the Sampan Channel by tidal currents.

The circulation pattern of south Kaneohe Bay shows a general outflow toward the Sampan Channel in the upper levels, on a falling tide. On a rising tide the pattern is reversed (Bathen, 1928), so that slightly positively buoyant eggs spawned in south Kaneohe Bay would be retained there.

It was previously suggested that pa'opa'o spawn during the early evening hours. Assuming they do, it follows that on an outgoing tide at night, eggs should be taken in the Sampan Channel tows; on an incoming tide they should not. For all 1971 night Sampan Channel tows taken during the spawning season, the tide was outgoing prior to and during tow time. As predicted, on all nights when eggs occurred at the southern station they also occurred in the Sampan Channel. For all 1972 night tows during spawning season, the tide was incoming prior to tow time; no eggs were taken at night in the Sampan Channel during this period, even though they were abundant in south Kaneohe Bay. This clearly suggests spawning inside Kaneohe Bay and provides a basis upon which further investigations can proceed.

Synodont I ('Ulae)

'Ulae eggs were present throughout the year in the Sampan Channel, although usually in small numbers. They accounted for 1.0% of all the eggs taken from the Sampan Channel, reaching a peak of 7.6% of the total catch on June 30, 1971.

A number of peaks of abundance were apparent throughout the year (Figure 11). Application of a three-point moving average resolved these into three periods of relatively high abundance: a major peak centered about mid-July, a smaller peak during March and April, and a very small peak in January.

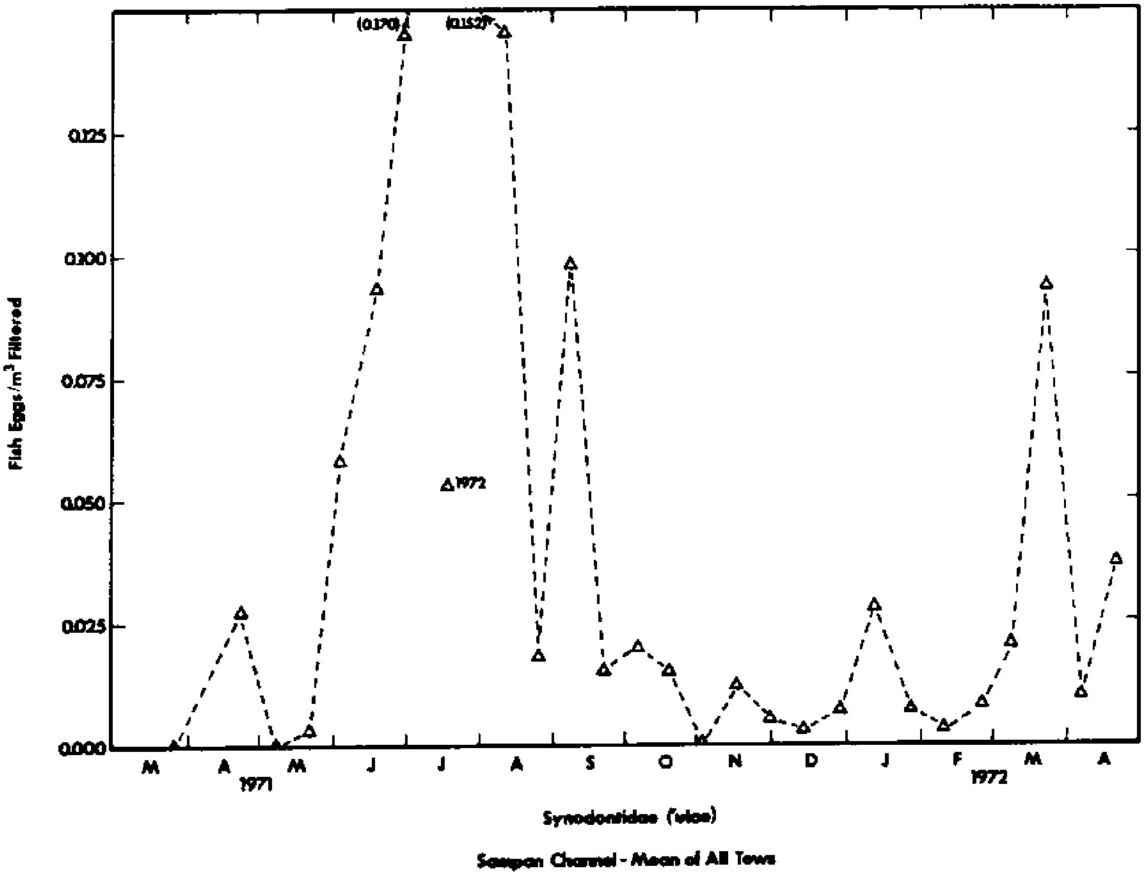

Figure 11. Synodont I egg abundance.

On the average, slightly more eggs were taken at night than during the day:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.04	0.08
Afternoon	0.03	0.06
Night	0.06	0.09

Application of Wilcoxon signed-ranks tests demonstrated no significant differences between times of day, however:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	14	(-)42	$P > 0.054$
Morning-night	13	(+)32	$P > 0.055$
Afternoon-night	13	(+)24	$P > 0.055$

Multiple regression analyses suggested significant relationships between egg abundance and a number of environmental variables, including day length, surface water temperature, and change in surface water temperature (Table B14 of Appendix B). As with other eggs, day length appeared to be the most important variable: t-tests for significance of the day-length partial regression coefficients gave probability levels (two-tailed) of less than 0.050 in all cases (Table B8 of Appendix B). The day-length regression alone explained 44% of the variability in 'ulae egg abundance; addition of other variables increased this by a maximum of only 9% (Table B8 of Appendix B). 'Ulae eggs were usually taken at or near high tide, although occasionally some were collected during low tide.

Tetraodontiformes

Although at least two and possibly four species (Ostraciontidae; Diodontidae: *Diodon* sp.; Tetraodontiformes II; and Type XXXIX) are included in this group, a reasonably well-defined seasonality was apparent. Eggs were present in only 3 of the 78 samples taken between October 5, 1971 and March 23, 1972 (Figure 12). During the April through September "spawning season," peaks of abundance occurred at roughly one-month intervals, corresponding approximately to the first quarters of the moon. In all cases but one, minima occurred during third quarters, suggesting the existence of a lunar periodicity. The several periods of abundance formed a single, broad, nearly symmetrical peak about late May and early June.

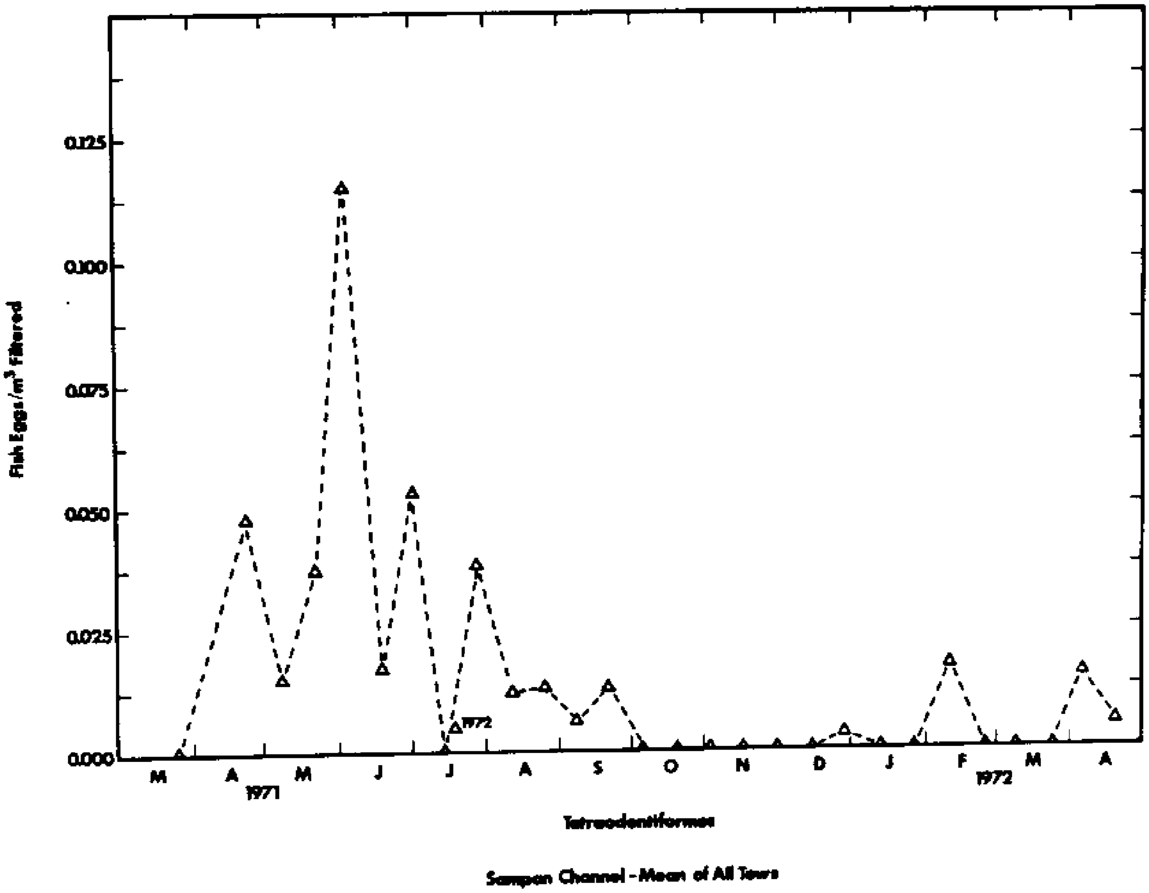

Figure 12. Tetraodontiform egg abundance.

Significant day-night differences of abundance on the 15 sampling dates included in the "spawning season" were not found:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.03	0.06
Afternoon	0.02	0.04
Night	0.02	0.03

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	9	(-)20	$P > 0.050$
Morning-night	12	(+)38	$P > 0.050$
Afternoon-night	7	(+)11	$P > 0.054$

Correlation analyses suggested significant relationships between Tetraodontiform egg abundance and day length, salinity, and combinations of day length, salinity, and water temperature. Considering "spawning season" alone, day length and salinity remained as the only variables significantly related with egg abundance (Table B17 of Appendix B).

T-tests for significance of the partial regression coefficients were performed in order to evaluate the relative importances of the single variables. Results are given in Table B7 of Appendix B, which shows that only the day-length coefficient remained significant at $P \leq 0.050$ in all cases.

The correlation analyses suggested a day-length initiation and termination of "spawning season," while during "spawning season" salinity, either per se or as a measure of another variable such as tide, became somewhat more important. Considering the entire year, 35% of the variability in Tetraodontiform egg abundance was explained by its linear regression on day length, while 20% was explained by salinity. For "spawning season" only, these were reversed: day length accounted for 26% of the variation while salinity accounted for 32%.

Advection of eggs by tidal currents into the Sampan Channel station from outside the bay was suggested. Eggs were often taken on or near high tide; they were less frequently taken near low tide.

Since more than one family of Tetraodontiform fishes is involved in this group, it is quite possible that they have different habits with respect to inshore or offshore spawning. This is suggested by the fact that most Tetraodontiform eggs taken from south Kaneohe Bay were collected on falling tides, while those in the Sampan Channel were more often captured on rising tides. Unfortunately, the Tetraodontiform eggs were not adequately distinguished from one another during the survey. Since the conclusion of sampling, qualitative evidence that the ostraciontid eggs are spawned in offshore waters has been obtained (Leis et al., *The pelagic eggs and larvae of three Hawaiian Tetraodontiform fishes*, in preparation).

Bothidae (Paku)

Three kinds of Bothid eggs were taken at the Sampan Channel station, but only two in any abundance. However, neither occurred in sufficient numbers to allow statistical analysis. Of the two, Bothid I was more numerous, occurring on 14 of the 29 sampling dates and accounting for 0.9% of the total egg catch in the Sampan Channel. Its maximum was 16.1% on June 3, 1971. Bothid II occurred on 15 of the 29 sampling dates, reaching a maximum of 2.7% of the catch on March 9, 1972 and accounting for 0.2% of the total catch. A total of four Bothid III eggs was taken on two sampling dates.

Bothids I and II displayed some evidence of seasonality in that they were absent from nearly all tows between November 1971 and mid-February 1972. The limits of any spawning season are rather difficult to fix, however, since eggs were scarce throughout the 1972 portion of the study.

Diel changes in abundance were apparent for both eggs, with day catches being larger than night catches. Mid-February through October means for Bothid I and Bothid II were as follows:

Time		Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	(Bothid I)	0.04	0.11
	(Bothid II)	0.08	0.01
Afternoon	(Bothid I)	0.11	0.43
	(Bothid II)	0.01	0.01
Night	(Bothid I)	0.01	0.02
	(Bothid II)	0.03	0.06

Bothid I eggs were apparently spawned outside Kaneohe Bay: most occurrences were at or near high tides. Since Bothid I eggs were collected primarily in afternoon tows, and in 1972 the afternoon tows were all taken on falling or low tides, no eggs were expected to be collected during 1972. In fact, only one afternoon tow during 1972 contained Bothid I eggs, while the frequency in morning tows (rising and high tides) was only slightly reduced below the 1971 level. Night tows rarely contained Bothid I eggs. Bothid I was taken three times at the southern station; twice on rising tides.

Bothid II seemed to spawn in the immediate vicinity of the Sampan Channel, since it was taken equally frequently on rising and falling tides; it was not taken in south Kaneohe Bay. Current patterns in Kaneohe Bay are such that spawning immediately north of the Sampan Channel would reduce the likelihood of an egg reaching the southern station, but would allow it to be taken into the Sampan Channel.

Bothid III was taken only in the Sampan Channel, both times on falling tides (morning of September 7, 1971 and afternoon of October 19, 1971).

Engraulidae (Nehu: *Stolephorus purpureus*)

Nehu eggs were relatively rare in the Sampan Channel, accounting for only 0.3% of all the eggs taken from this station during the study. On only three sampling dates did they account for more than 1.0% of the total catch, reaching a maximum of 3.3% on February 10, 1972.

Eggs occurred throughout the year in all tows except between mid-September and mid-November, when none were taken. Mean day and night catches were as follows:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.01	0.02
Afternoon	0.01	0.02
Night	0.01	0.02

Since all means and standard deviations were the same, statistical tests for differences were not performed.

Seasonal peaks of egg abundance in the Sampan Channel followed the south Kaneohe Bay peaks fairly well, but were consistently much smaller. The predicted tidal effects on nehu egg abundance were observed in the Sampan Channel catches, assuming that nehu spawn only inside the bay.

The data are insufficient for detailed analysis; they do not contradict any inferences based on south Kaneohe Bay data.

Trichonotidae (*Crystallodytes cookei*)

Crystallodytes cookei eggs were present throughout the year at the Sampan Channel station. About seven periods of increased abundance were noted (Figure 13). These were resolved by a three-point moving average into two broad periods of higher numbers; the larger centered in January and the smaller in June and July.

Multiple regression analyses indicated significant negative relationships of *C. cookei* abundance with (1) the tide factor and (2) surface water temperature (Table B18 of Appendix B). These suggested increased winter spawning outside Kaneohe Bay with eggs being advected into the sampling area on tidal currents. However, the tide and temperature correlations left 76% and 81%, respectively of the yearly variation in *C. cookei* abundance unexplained (Table B9 of Appendix B).

Fewer eggs were present during the afternoon tows than in either morning or night samples:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.08	0.10
Afternoon	0.05	0.12
Night	0.15	0.21

Application of Wilcoxon signed-ranks tests demonstrated that significantly more eggs were taken in the morning and at night:

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	21	(-)58	$P < 0.050$
Morning-night	18	(+)67	$P > 0.050$
Afternoon-night	19	(+)19	$P < 0.050$

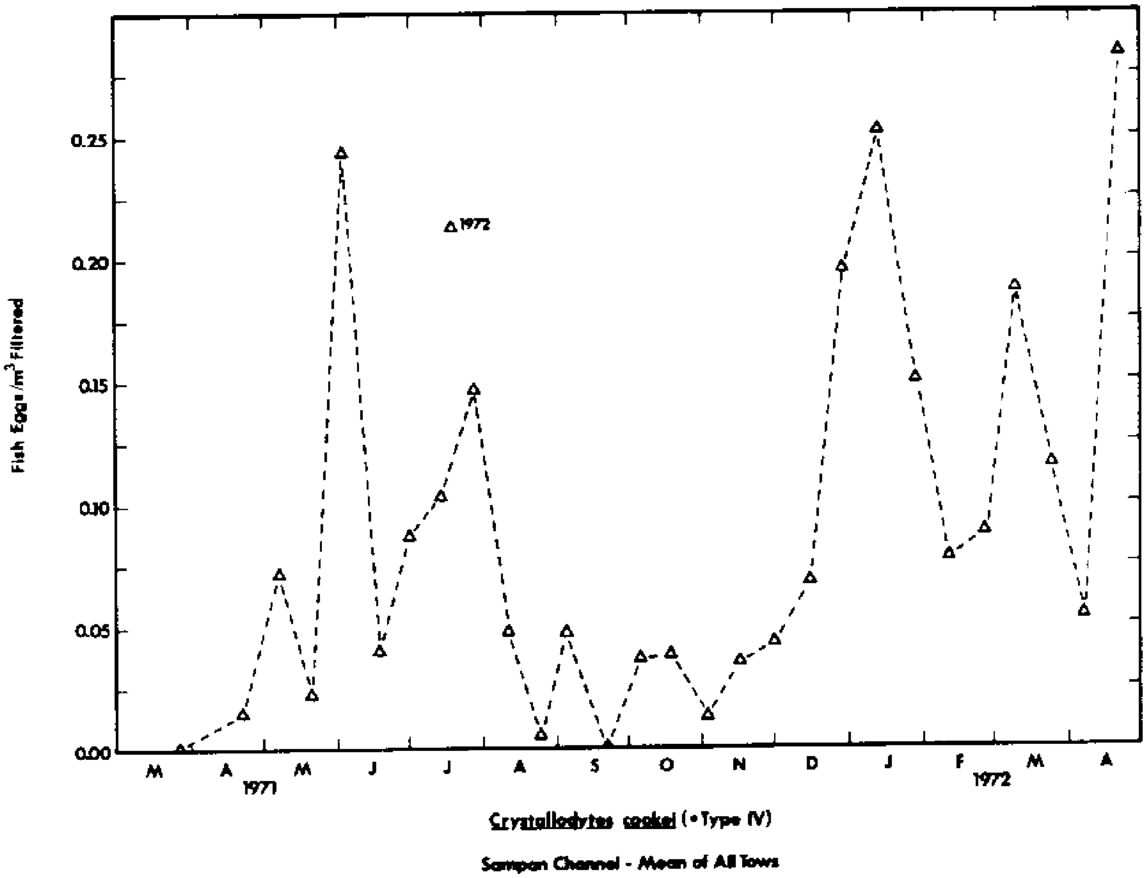

Figure 13. *Crystallodytes cookei* egg abundance.

Even though more eggs were taken at night, suggesting night time spawning, a distinct diel spawning periodicity was not apparent; various developmental stages were present in all tows when *Crystallodytes cookei* eggs were taken. This is explicable, however, in terms of the approximately three-day developmental period of *C. cookei* eggs which was observed in rearing experiments.

Other eggs

In addition to the common eggs already discussed, 24 others occurred in smaller numbers at the Sampan Channel station. Among these, the following two occurred most frequently.

Makiawa (Dussumieriidae: *Etrumeus micropus* and Fistulariidae: *Fistularia* sp.). Makiawa eggs were recorded on 12 of the 29 sampling dates, but on most of these occasions they were probably confused with fistulariid eggs. *Fistularia* sp. plus makiawa eggs accounted for 0.1% of all the eggs taken from the Sampan Channel. From the end of July through the end of October they were absent from all tows. Most were taken during the morning tows.

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.012	0.019
Afternoon	0.005	0.015
Night	0.003	0.008

Statistical tests for significant differences were not performed. The morning and evening catches were probably attributable primarily to *Fistularia* sp., which is known to be an offshore egg, since all tows containing eggs were made on rising tides. Afternoon tows containing eggs were all made on falling and low tides; these may primarily have been makiawa, which apparently is a bay-spawning species.

Type VIIIb. Type VIIIb's were confused with a number of other eggs during the early part of the study; beginning on September 21, 1971, they were consistently distinguished from the others. Thereafter, they occurred on 14 of the 18 sampling dates, generally in small numbers. Day-night differences were not apparent:

Time	Mean No. (eggs/m^3)	Standard Deviation (eggs/m^3)
Morning	0.02	0.06
Afternoon	0.02	0.03
Night	0.03	0.07

Type VIIIb was taken only once at the southern station; it might therefore be hypothesized as an offshore egg.

Other eggs occurring in the Sampan Channel include:

Puhi (Muraenidae, Ophichthidae, perhaps others). These were noted on eight occasions during the study. Because of the infrequency with which they were counted, however, nothing can be concluded about diel or seasonal variability. Puhi eggs were taken only from the Sampan Channel; it is known from other samples that they occur outside Kaneohe Bay in large numbers during the summer.

Synodont II (possibly *Bathysaurus* sp.). These eggs were taken from mid-March through mid-October, accounting for 0.1% of all the eggs taken in the Sampan Channel. A definite day-night difference in numbers was apparent; only one night tow contained Synodont II eggs as compared with 18 day tows containing eggs. Mean daytime numbers during spawning season were 0.02 eggs/m^3 for morning and 0.04 eggs/m^3 for afternoon. Synodont II eggs were not taken in south Kaneohe Bay, but did occur outside the bay. They were probably advected into the Sampan Channel station by tidal currents since most were taken on rising and high tides. The relative lack of eggs from November 1971 through the end of the survey may have been attributable in part to the fact that all afternoon tows during this period were made on falling and low tides.

Type XVII. Type XVII's occurred on five sampling dates spread over the year. They were taken almost exclusively in morning tows (averaging 0.06 eggs/m^3 per tow), although one egg was taken in an afternoon tow on August 11, 1971. Type XVII eggs were taken only from the Sampan Channel on both rising and falling tides.

Type XIX. Type XIX eggs are part of the "Omaka Complex." They occurred at least five times during the study; three times--in October and December 1971 and January 1972--after definite identifications could be made. All were taken during the day except on August 11, 1971, when identifications were uncertain, with both mornings and afternoons averaging 0.04 eggs/m^3 per positive tow.

Nenue (Kyphosidae: *Kyphosus cinerascens*). These eggs were first recognized on December 14, 1971. Thereafter they occurred on 8 of the 12 sampling dates. Nenue eggs were taken in three morning and three afternoon tows averaging 0.03 eggs/m^3 and 0.08 eggs/m^3 per positive tow, respectively and in five night tows averaging 0.15 eggs/m^3 per positive tow. They were encountered only in the Sampan Channel.

Scarid I. This egg was first recognized as a distinct type on January 27, 1972 and occurred on five of the eight following sampling dates. Eggs were taken almost exclusively at night although they occurred one time each in morning and afternoon tows, reaching a maximum of 12.4% of the night catch on January 27, 1972. Scarid I eggs were taken only in the Sampan Channel; six of the seven catches on rising and high tides.

Hinalea (Labrid IV). The eggs of Labrid IV were first recognized on February 10, 1972 and occurred on all six succeeding sampling dates. More eggs were taken in night tows (mean catch 0.22 eggs/m^3) than in afternoon tows (mean catch 0.11 eggs/m^3), which in turn contained more eggs than morning tows (mean catch 0.01 eggs/m^3). On July 18, 1972, Labrid IV eggs accounted for 10.7% of the total night egg catch. Most were taken from the Sampan Channel; on two dates they were also collected at the southern station on rising tides.

Type XXX. Type XXX eggs were recognized for the first time on February 25, 1972 and occurred on four of the six following sampling dates. They were taken primarily at night (averaging 1.64 eggs/m^3 per positive tow), but also occurred in afternoon tows (averaging 0.04 eggs/m^3 per positive tow).

On the night of March 23, 1972, they accounted for 31.5% of the total catch. Type XXX eggs occurred in both Sampan Channel and south Kaneohe Bay.

Type XXXV. Type XXXV is part of the "Omaka Complex." It was first distinguished on March 23, 1972 and found on the three succeeding dates during morning, afternoon, and night tows. Positive afternoon tows contained an average of 0.25 eggs/m^3, while positive morning and night tows both contained 0.06 eggs/m^3. Most XXXV's were taken from the Sampan Channel; they were also found at the southern station on one occasion.

Type XXXVI. Type XXXVI was recognized on April 6, 1972 and identified on both succeeding sampling dates. They were taken primarily at night, reaching a maximum of 1.80 eggs/m^3, which comprised 12.4% of the total Sampan Channel catch on the night of April 20, 1972. Type XXXVI occurred in the Sampan Channel and in south Kaneohe Bay.

Hinalea (Labridae: probably *Thalassoma duperreyi*). Hinalea eggs were first noted on April 6, 1972 and found on the two succeeding sampling dates. They were taken during morning, afternoon, and night tows, reaching a maximum of 2.32 eggs/m^3 and accounting for 57.7% of the Sampan Channel catch on the night of April 6, 1972. Hinalea eggs occurred at both the southern station and the Sampan Channel, but were much more numerous at the Sampan Channel station.

Prior to April 6, 1972, they were probably confused with Labrid II.

Schindleria sp. A few *Schindleria* eggs were taken on three sampling dates (March 9, April 6, and July 18, 1972) exclusively in night tows.

Eggs taken on only two sampling dates (all but the acanthurid and Type XLII exclusively on rising tides) included:

Acanthuridae. Acanthurid eggs were taken in one tow each on the afternoon and night of April 20, 1972 and morning of July 18, 1972. An average of 0.07 eggs/m^3 per positive tow was collected.

Labrid III. Labrid III eggs were taken in one tow each on the morning of February 10, 1972 (0.10 eggs/m^3) and night of March 9, 1972 (0.03 eggs/m^3).

Scarid II. Scarid II eggs were taken in one tow each on the morning and night of February 25, 1972 and in both night tows of April 20, 1972. Positive tows averaged 0.06 eggs/m^3.

Type XX. One afternoon tow on September 7, 1971 contained 0.02 eggs/m^3 and one morning tow on April 6, 1972 contained 0.03 eggs/m^3.

Type XLII. One afternoon tow and one night tow on April 20, 1972 contained 0.06 eggs/m^3 and 0.05 eggs/m^3, respectively, while one tow each on the morning, afternoon, and night of July 18, 1972 contained an average of 0.04 eggs/m^3.

Eggs taken on a single sampling date included:

Molidae (*Ranzania laevis*). One egg was taken on February 25, 1972; time unknown.

Type XXIX. Eggs were taken on morning, afternoon, and night tows of February 25, 1972, averaging 0.04 eggs/m^3 per positive tow.

Type XXXIV. Eggs were taken on morning, afternoon, and night of March 23, 1972, averaging 0.15 eggs/m^3 per positive tow.

Type XXXIX. Eggs were taken on April 6, 1972; time unknown.

Summary

The pelagic fish eggs could all be grouped into three very general categories: (1) eggs spawned within Kaneohe Bay; (2) eggs spawned in the open ocean adjacent to Kaneohe Bay; and (3) eggs for which definite spawning areas were not ascertainable.

The first category contains the following species: in the interior bay were the carangids *Caranx mate* and *Gnathanodon speciosus* and the clupeoids *Stolephorus purpureus* and *Etrumeus micropus*. Other species which might have spawned in the interior bay include Synodont I, one of the Tetraodontiformes, *Thalassoma duperreyi* which was observed spawning at the interior end of the Sampan Channel (J. Heiser, 1972: personal communication), Labrid II, and Type XXX. In the Sampan Channel area were the labrid *Thalassoma duperreyi* and Bothid II. Other species possibly spawning in or near the Sampan Channel include Labrid II, Synodont I, one or more of the Tetraodontiformes, Bothid III, Type XVII, and Type XXX.

The second category includes Bothid I (possibly), the various eels, *Fistularia* sp., *Ranzania laevis*, Scarid I, perhaps Synodont I, Synodont II, Tetraodontiformes III, *Crystallodytes cookei*, possibly Type VIIIb, and Type VIIIc.

The third category contains an acanthurid, Labrids III and IV, Scarid II, *Kyphosus cinerascens*, *Schindleria* sp., and egg Types XIX, XX, XXIX, XXXIV, XXXV, XXXVI, XXXIX, and XLII.

Concerning the seasonality among the pelagic fish eggs (Figure 14), most were not taken in sufficient numbers to allow inferences about spawning seasons. However, the few more abundant kinds seemed to fall into three general patterns: spring through fall spawning, fall through spring spawning, and year-round spawning.

The seasonal spawners are predominately fishes of the first category (see Patterns of Reproduction under the Summary of larvae where species in the first category are included in groups I and III). The spring through fall spawners include *Caranx mate* and *Gnathanodon speciosus* (February through October), Bothids I and II and Synodont II (March through October; Bothid I

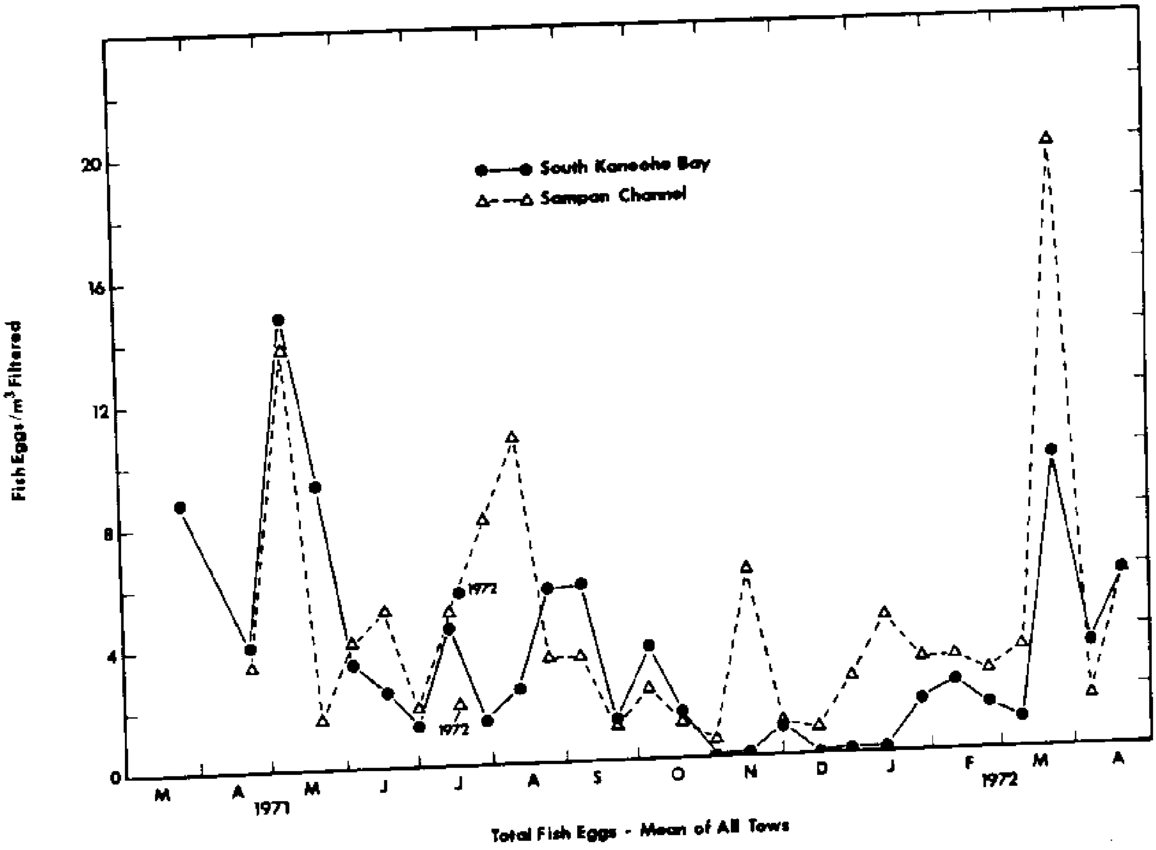

Figure 14. Total egg abundance.

and Synodont II are in the second category), and the Tetraodontiformes (April through October; first and second categories). Fall through spring spawners include *Etrumeus micropus* (October to July), Labrid II (winter), and *Fistularia* sp. (November to July; second category).

Year-round spawners are primarily of the second category, although *Stolephorus purpureus* clearly belongs to the first category and Synodont I may overlap between the two categories. In addition to these two, year-round spawners include *Crystallodytes cookei*, Type VIIIb, and Type VIIIc.

As can be seen in Appendix B, statistically significant relationships were most often found between fish egg abundance and (1) surface water temperature and (2) day length. Since these are the two major seasonal variables, this result is expected. Some of the offshore species were associated with rising tides, when currents were directed into the Sampan Channel from offshore. Although no statistical relationships with moon phase were detected, a relationship was suggested for several species including *Etrumeus micropus*, *Gnathanodon speciosus*, the Tetraodontiformes, and Type VIIIc. These were generally in the form of increased numbers of eggs during first quarters, or during first and third quarters.

FISH LARVAE: GENERAL CONSIDERATIONS

A total of 38,505 fish larvae were examined. Ninety-five percent were identified to at least the familial level, 3.6% remain unidentifiable or identifiable to a taxonomic level above family, and 1.4% were too severely damaged to be identified.

A total of 175 types of fish larvae was captured during the survey. Of these, 166 were taken from the Sampan Channel, while 100 were taken from south Kaneohe Bay. Only 89, approximately one half of the total, occurred in both areas (Appendix D).

In this analysis, the species of gobiids, pomacentrids, apogonids, and myctophids have been grouped in their respective families. This was done for several reasons: (1) the species were difficult to separate; (2) in gobiids especially, it became clear near the end of the study that several types were actually different developmental stages of the same species; and (3) late in the study it was recognized that several of the "species" were multispecific (apogonids, pomacentrids). However, in this case the "new" species were relatively minor components.

Having grouped these, the number of types of larvae was reduced to 145. Of these, only 20 comprised 0.5% or more of the total larvae per unit volume at either location. In south Kaneohe Bay, 13 types, each comprising at least 0.5% of the catch, in sum constituted 94.3% of the total south Kaneohe Bay larvae. At the Sampan Channel station there were 18 kinds, each of which composed at least 0.5% of the catch, constituting 93.9% when summed (Table 1).

Those 20 groups comprising at least 0.5% in either area were considered "important" and will be discussed in detail below. Of these, 11 were important in both areas, but their ranks of abundance differed markedly between the areas. For example, *Schindleria pietschmanni* was ranked second (15.7%) in the Sampan Channel, while in south Kaneohe Bay it ranked thirteenth (0.7%). (See Table 1.)

All but one of these groups (unidentified 142) could be identified to at least the familial level. Of the remaining 19 groups, 14 could be identified to species, including some of the apogonids and pomacentrids. One of the blenniids (Type 5) could not be identified with certainty, although the larvae have been reared through metamorphosis. It may represent a new species in Hawaiian waters. One of the carangids (C-5) also was unidentified. Most of the myctophids could be identified at least to genus. Two types of scarids could be identified when the larvae were relatively large, but at least 21 other types were recognized. It is unclear how many species these may represent. At least eleven species of marine gobiids and two of eleotrids are known from Kaneohe Bay (W.J. Baldwin, *An annotated checklist of fishes of Kaneohe Bay and tributaries*, in preparation) and at least nineteen from Hawaii (Gosline and Brock, 1960).

Two of the important types (*Schindleria* spp.) are not larvae, but are neotenous adults which are included here because they are the morphological and ecological equivalents of fish larvae in many respects.

TABLE 1. RANKS OF ABUNDANCE AND PERCENTAGES OF THE MOST ABUNDANT LARVAE

	Sampan Channel (all tows)				South Kaneohe Bay			
	Overall	Morning	Afternoon	Night	Overall	Morning	Afternoon	Night
	Rank (%)	Rank (%)	Rank (%)	Rank (%)	Rank (%)	Rank (%)	Rank (%)	Rank (%)
Gobiidae	1 (19.41)	1 (17.20)	3 (8.90)	1 (21.19)	2 (15.97)	3 (12.92)	6 (5.89)	1 (22.67)
Schindleriidae *Schindleria pietschmanni*	2 (15.72)	-*(0.33)	15 (0.72)	2 (20.44)	13 (0.68)	- (<0.10)	- (<0.10)	10 (1.28)
Apogonidae *Foa brachygrammus* and others	3 (10.32)	3 (11.92)	11 (3.41)	4 (11.03)	3 (14.16)	5 (11.01)	4 (6.53)	2 (19.56)
Eleotridae *Asterropteryx semipunctatus*	4 (9.72)	15 (0.52)	- (0.19)	3 (12.44)	7 (3.06)	- (<0.10)	- (0.14)	6 (5.83)
Engraulidae *Stolephorus purpureus*	5 (5.92)	10 (2.80)	8 (5.39)	5 (6.46)	1 (24.70)	2 (18.02)	1 (45.00)	3 (16.33)
Tripterygiidae *Tripterygion atriceps*	6 (4.89)	2 (12.72)	2 (10.61)	8 (2.90)	- (0.37)	- (0.46)	- (0.27)	- (0.38)
Schindleriidae *Schindleria praematurus*	7 (3.56)	- (<0.10)	- (<0.10)	6 (4.58)	- (0.12)	- (<0.10)	- (<0.10)	- (0.23)
Unidentified 142	8 (3.47)	8 (4.69)	13 (1.29)	7 (3.58)	12 (0.87)	9 (1.55)	- (<0.10)	11 (1.01)
Pomacentridae *Abudefduf* spp. and *Pomacentrus jenkinsi*	9 (3.26)	4 (9.54)	6 (6.40)	11 (1.87)	4 (12.46)	1 (21.98)	2 (12.73)	5 (8.53)
Carangidae *Caranx mate*	10 (3.19)	11 (2.68)	7 (5.82)	9 (2.90)	5 (11.30)	6 (8.06)	3 (11.54)	4 (12.45)
Blenniidae *Enchelyurus brunneolus*	11 (2.83)	5 (9.06)	4 (8.16)	12 (1.14)	- (0.33)	13 (0.79)	- (0.25)	- (0.18)
Atherinidae *Pranesus insularum*	12 (2.42)	13 (0.88)	14 (0.92)	10 (2.86)	11 (0.93)	12 (0.84)	- (0.20)	9 (1.35)
Blenniidae *Exallias brevis*	13 (2.01)	6 (9.05)	10 (4.88)	17 (0.54)	- (0.39)	11 (1.14)	- (0.27)	- (0.15)
Carangidae C 5	14 (1.91)	- (0.18)	1 (13.85)	18 (0.51)	- (0.31)	- (<0.10)	10 (0.69)	- (0.22)
Blenniidae *Omobranchus elongatus*	15 (1:87)	9 (3.86)	5 (7.40)	14 (0.79)	6 (4.33)	4 (11.15)	5 (5.92)	12 (0.73)
Myctophidae	16 (1.55)	7 (4.71)	9 (5.35)	16 (0.54)	- (0.42)	- (0.28)	- (0.40)	- (0.48)
Carangidae *Gnathanodon speciosus*	17 (1.28)	12 (1.25)	12 (2.67)	13 (1.08)	9 (2.09)	10 (1.34)	8 (2.06)	7 (2.40)
Scaridae	18 (0.58)	- (<0.10)	- (<0.10)	15 (0.75)	- (0)	- (0)	- (0)	- (0)
Callionymidae *Callionymus decoratus*	- (0.34)	14 (0.66)	16 (0.70)	- (0.25)	10 (1.42)	8 (1.79)	9 (1.18)	8 (1.41)
Blenniidae Type 5	- (0.26)	- (0.23)	17 (0.55)	- (0.22)	8 (2.28)	7 (4.26)	7 (4.02)	13 (0.53)

*Rank not assigned since abundance <0.5%.

The total catches largely represented the night tows, since more fish were captured at this time. On a per volume basis 2.0 and 7.1 times as many larvae were captured in night tows than in daytime tows in south Kaneohe Bay and Sampan Channel, respectively. Most types of larvae showed similar day-night patterns of abundance, with certain noteworthy exceptions:

1. At both stations, blenniids were much more abundant in both absolute number and percentage of the catch during daytime tows.
2. The two species of *Schindleria*, the eleotrid *Asterropteryx semipunctatus*, and the scarids were virtually absent during the daytime at both stations, but abundant at night in the Sampan Channel. *Asterropteryx semipunctatus* was the sixth most abundant fish larva in south Kaneohe Bay night samples; schindleriids and scarids were very minor components of south Kaneohe Bay fauna at all times.
3. Carangids generally showed an increase in number from morning through evening in both sampling areas.
4. Nehu abundance reached a peak in the afternoon in south Kaneohe Bay, but nehu were common only at night in the Sampan Channel.

The diel variations in catches of the various larvae described above could not be conclusively explained; however, they are under investigation. A combination of daytime net avoidance and vertical migration was probably involved; it is difficult to isolate the operative factors *a posteriori*.

Nevertheless, in certain cases tentative statements may be made to provide perspective for the following systematic account:

1. The blenniids, since less abundant at night, seemingly underwent a "reverse" vertical migration.
2. Since nehu in south Kaneohe Bay were less abundant at night, they may have migrated downward at night, but this does not explain the low numbers seen in the morning or the fact that most Sampan Channel nehu were taken at night.
3. *Schindleria* spp. and *Asterropteryx semipunctatus* probably migrated vertically in a "normal" fashion. Although net avoidance is a possible explanation, it seems unlikely that it could be so totally effective during the day. The Sampan Channel station is shallow (5 to 7 m) and generally turbulent. Consequently, vertical migration and maintenance of a subsurface daytime depth by fish larvae are difficult to imagine. It may well be that the *Schindleria* spp. and *Asterropteryx semipunctatus* maintain subsurface daytime depths outside the bay or in its calmer interior, being swept into the channel only when they migrate to their shallower night-time depths.

Little can be said about the other types, except those which were about equally abundant during the day and night, such as myctophids and tripterygiids. These probably did not migrate and avoided the net to only a small extent although other interpretations are possible.

Seasonal and Diel Abundance Patterns of Larvae: Systematic Accounts

The seasonal abundance of most fish larvae in Kaneohe Bay was bimodal (Figures 15 and 16). The first broad peak extended from February through mid-May, reaching an April maximum of 3800 fish/1000 m^3 in south Kaneohe Bay and nearly 2000 fish/1000 m^3 in the Sampan Channel night samples. The second period of higher numbers occurred in late summer and early fall, peaking in October in the Sampan Channel and in early September and mid-October in south Kaneohe Bay with peaks of 1700 and 700 fish/1000 m^3, respectively.

Except for nehu, larvae were generally scarce from November through February and most larvae, except carangids, were less abundant from mid-June through August (Figures 17 and 18).

Group-by-group accounts of seasonal and diel distributions follow.* Means and standard deviations are given in Appendix D.

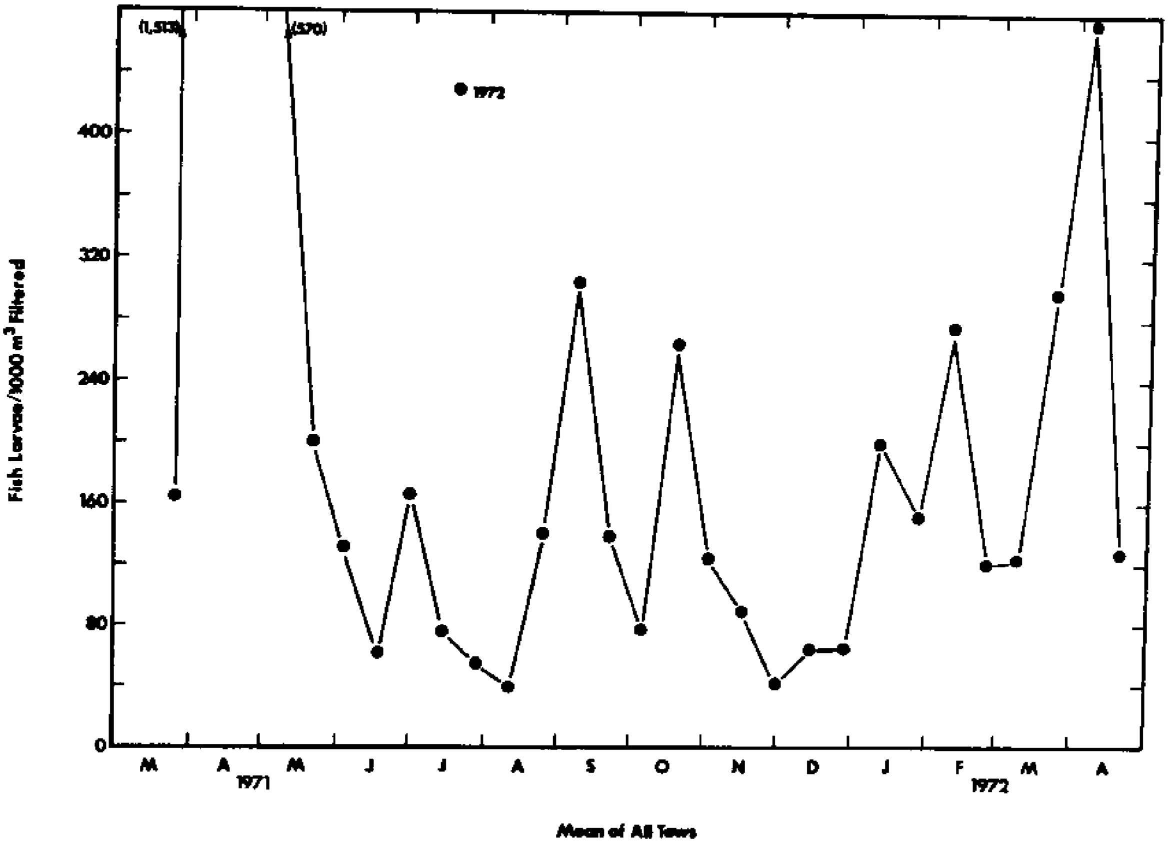

Figure 15. Total fish larvae of south Kaneohe Bay.

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*An occurrence is defined here as the presence of at least one larva in either of the paired tows at a station. Therefore, six occurrences were possible on a sampling date.

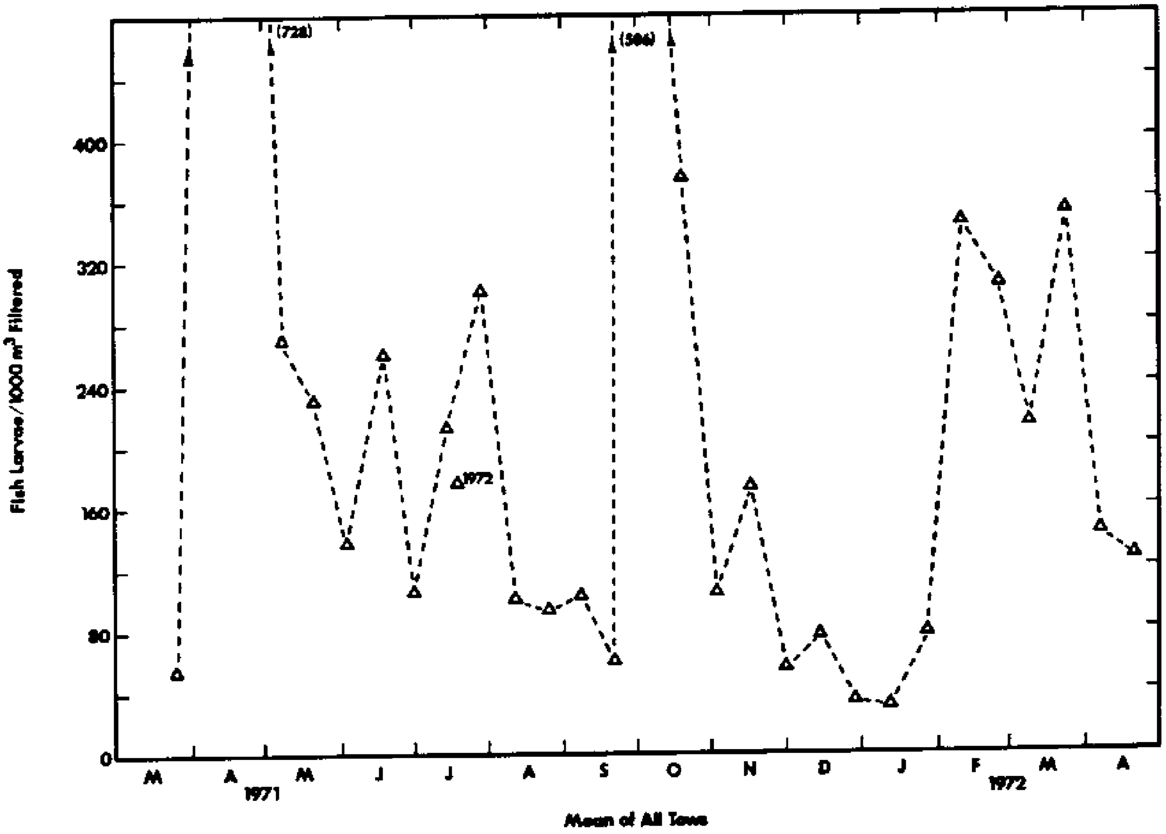


Figure 16. Total fish larvae of the Sampan Channel.

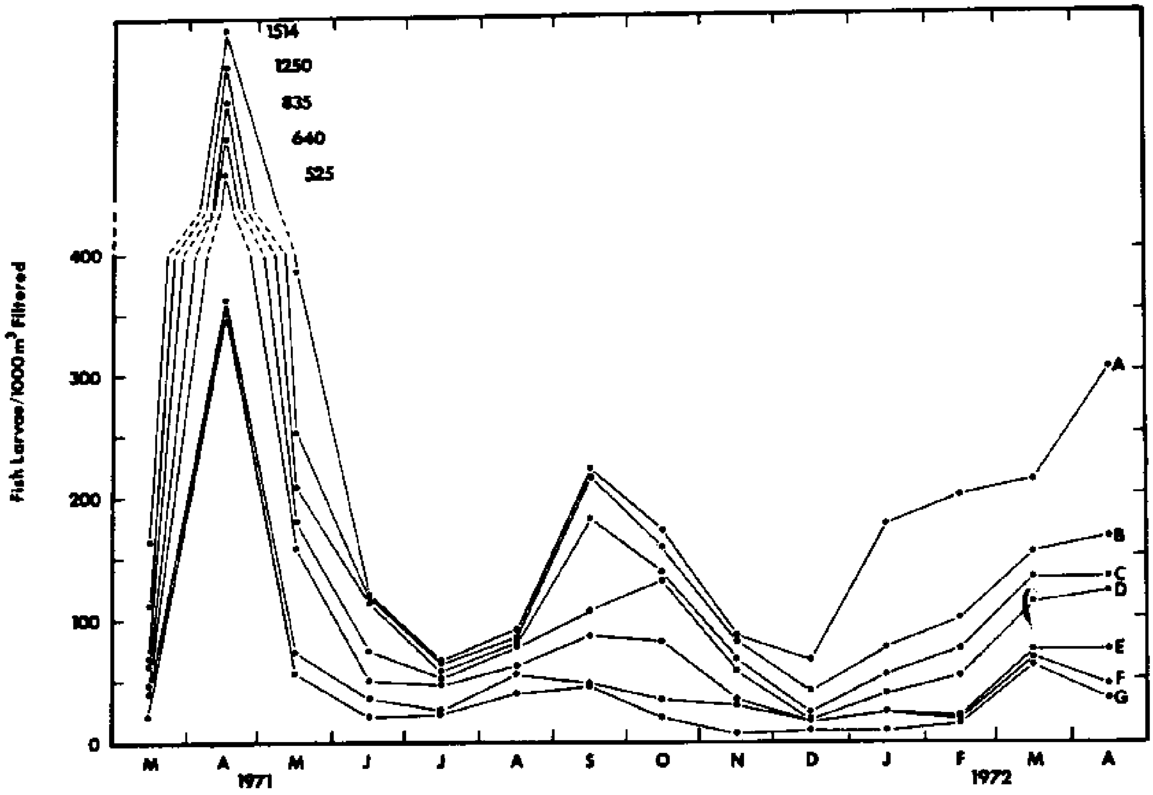


Figure 17. Monthly mean larval fish abundance of south Kaneohe Bay. Between lines A and B--*Stolephorus purpureus*; B and C--Gobiidae; C and D--Apogonidae; D and E--Pomacentridae; E and F--*Caranx mate*; F and G--*Omobranchus elongatus*; and below line G--others.

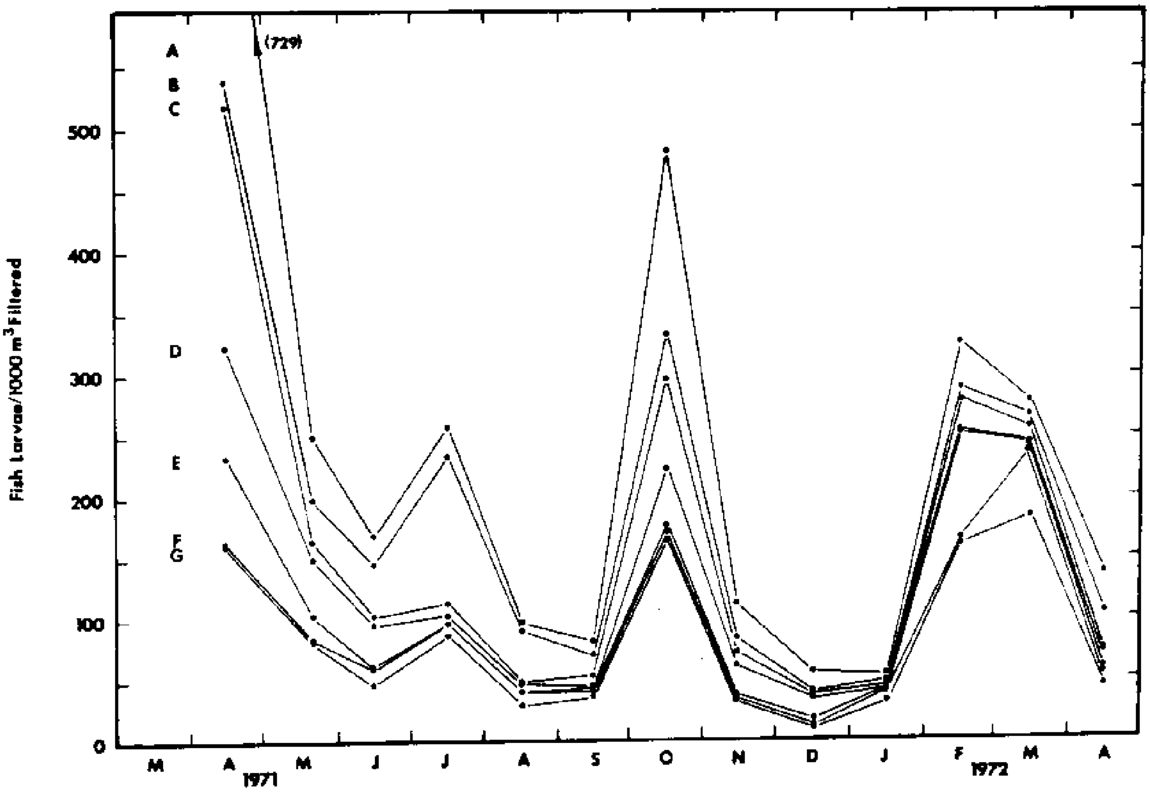


Figure 18. Monthly mean larval fish abundance of the Sampan Channel. Between lines A and B--Gobiidae; B and C--Schindleriidae; C and D--Apogonidae; D and E--*Asterropteryx semipunctatus*; E and F--*Stolephorus purpureus*; F and G--*Tripterygion atriceps*; and below line G--others.

Gobiidae ('O'opu)

In the Sampan Channel, gobiids, the most abundant larvae overall, were most abundant during the general spring and fall peaks (Figure 19). Only small numbers occurred from late December through March and from June through mid-September. They were much less abundant during the day than at night, but the daytime pattern of seasonal abundance generally paralleled the night pattern.

In south Kaneohe Bay, gobiids were somewhat less seasonal with spring peaks in April and May. The fall peak in September was very small (Figure 19). Again, during the day the gobiids were less common, but reflected the night pattern of seasonal abundance. (See the following Wilcoxon tests.)

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	24	(-)71	$P \simeq 0.013$
Morning-night	23	(+) 3	$P < 0.001$
Afternoon-night	23	(+) 0	$P < 0.001$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	22	(-)57	P ≃ 0.013
Morning-night	24	(+)86	P ≃ 0.035
Afternoon-night	25	(+)27	P < 0.001

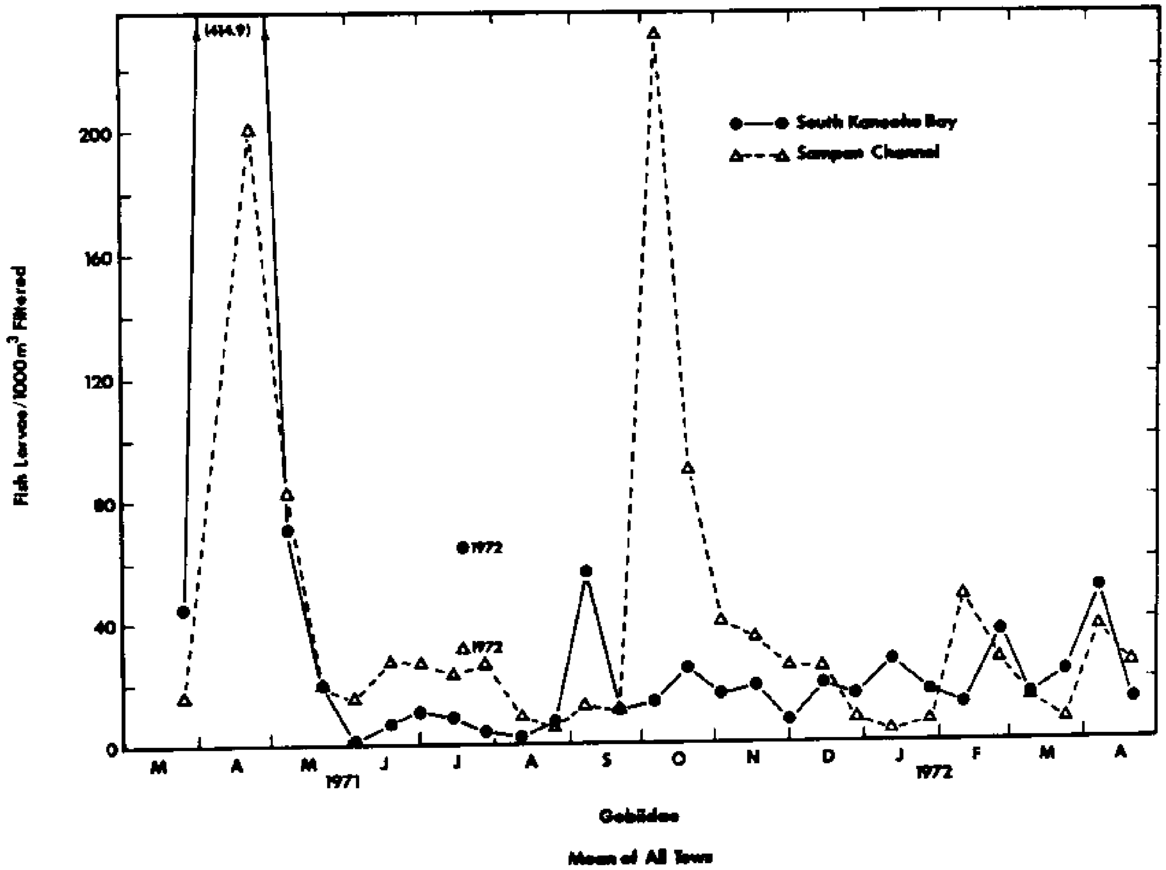


Figure 19. Gobiidae larval abundance.

While twenty-one types of gobiids were distinguished, only four were identifiable beyond the familial level and only relatively large specimens of those. The four identifiable types were *Psilogobius mainlandi*, *Oxyurichthys lonchotus*, *Bathygobius fuscus*, and *Bathygobius cotticeps*. It is likely that several of the "different types" of gobiids distinguished are merely different developmental stages of the same species.

Of the nine most common kinds of gobiids (Types 2, 5, 6, 8, 9, 11, 18, *B. fuscus*, and *O. lonchotus*), only Type 11 was taken more commonly from the southern station (46 south Kaneohe Bay versus 35 Sampan Channel occurrences). *B. fuscus*, *O. lonchotus*, and Type 2 were much more common in the Sampan Channel (5 to 11 times as many Sampan Channel as south Kaneohe Bay occurrences). The other common types, including 6, 8, and 9--the most abundant gobiids--were taken in approximately equal numbers from both stations. The other 12 less common types were taken predominately from the Sampan Channel.

Schindleriidae

From late spring to early fall *Schindleria pietschmanni* and *Schindleria praematurus* were the most abundant "larvae" in the Sampan Channel (Figure 20), constituting an average of 37% of all larvae in night samples. They were, however, virtually absent from all daytime and all south Kaneohe Bay samples. On July 28, 1971, they accounted for a maximum of 80% of the larvae taken in a single tow (627 *Schindleria*/1000 m^3; Sampan Channel, night tow). *S. pietschmanni* was more abundant than *S. praematurus* in all but one of the night tows.

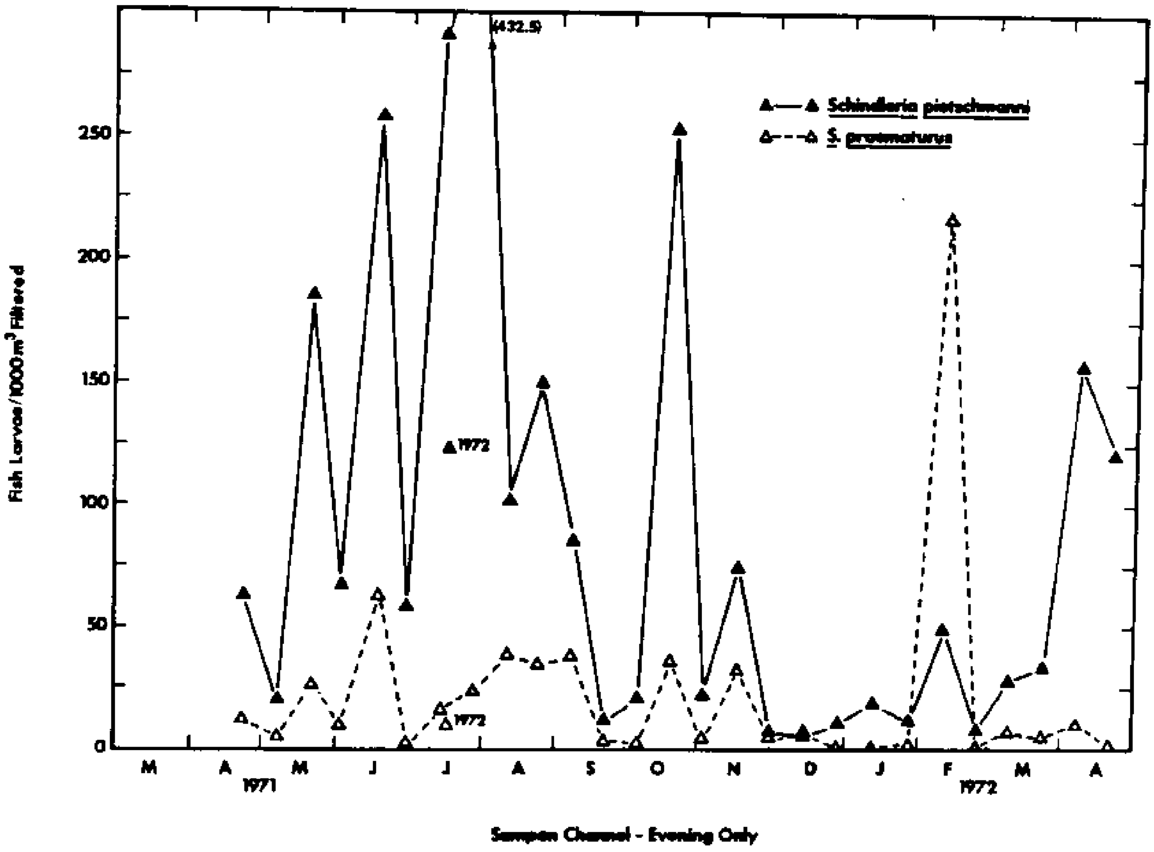
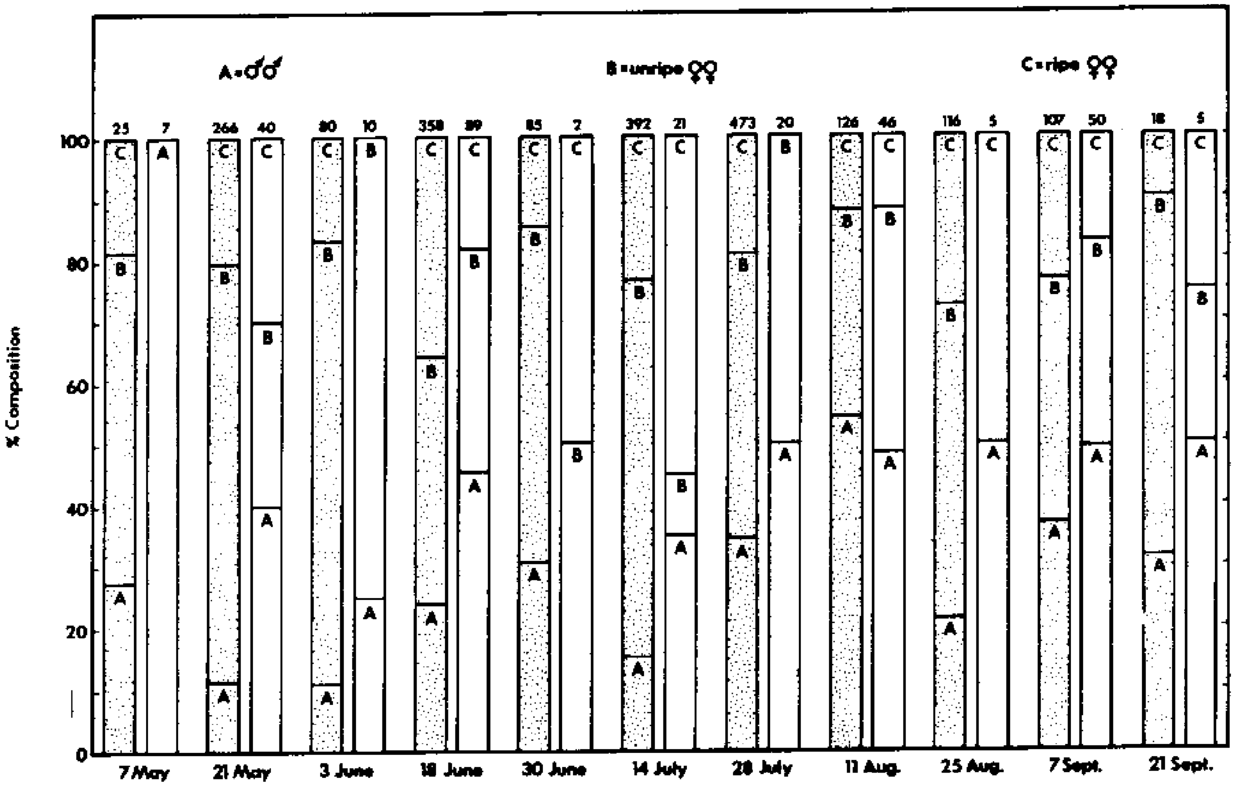


Figure 20. Schindleriidae larval abundance.

The sex of mature schindleriids was relatively easy to determine, as the ovarian eggs of the females were visible through the body wall. In addition, the males of *S. praematurus* possessed conspicuous genital papillae. During the time of maximum *Schindleria* abundance, female *S. pietschmanni* outnumbered males, except on one occasion, usually by 2:1. However, males generally outnumbered ripe females (Figure 21). Subadult *Schindleria* spp. were very rare in our samples.



Note: Numbers above bars indicate total number of specimens.

▨ S. pietschmanni ☐ S. praematurus

Figure 21. Schindleriidae sex ratios.

Apogonidae (Upapalu)

Although seven species are probably included here, *Foa (=Apogon) brachygrammus* was by far the most abundant larva (the others are unidentified). Its peaks of abundance in the Sampan Channel corresponded with the general spring and fall peaks, but continued for about a month longer. In south Kaneohe Bay the pattern was similar, except that the fall peak occupied only the beginning of the "all species" peak.

Apogonid larvae were present all year, but with decreased abundance in late summer and mid-winter (Figure 22). During the summer, even though abundance was reduced, they remained among the more common larvae.

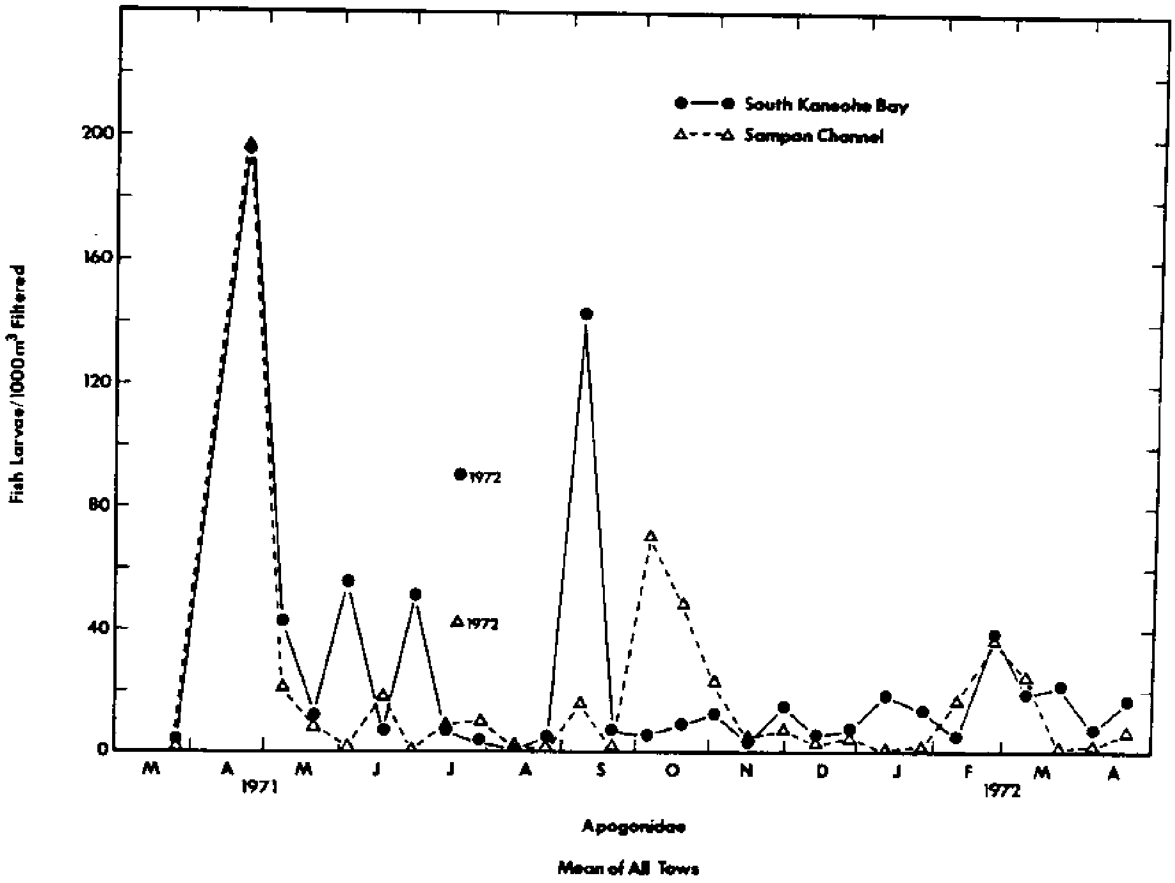


Figure 22. Apogonidae larval abundance.

Apogonids were another group of fish larvae which were more abundant at night than during the day, as can be seen below:

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	16	(-)20	$P \approx 0.053$
Morning-night	22	(+)43	$P \approx 0.004$
Afternoon-night	24	(+)15	$P < 0.001$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	22	(-)112	$P > 0.230$
Morning-night	25	(+)119	$P \approx 0.121$
Afternoon-night	27	(+) 57	$P < 0.001$

Eleotridae ('O'opu)

Asterropteryx semipunctatus, like the schindleriids, was another larva which was practically non-existent in daytime samples and more common in the Sampan Channel than in south Kaneohe Bay. In the Sampan Channel, its peaks of abundance occurred during the general spring and fall peaks, but were somewhat broader. In south Kaneohe Bay, the major occurrence coincided with the general spring peak with larvae present primarily from April through December. However, there were relatively few larvae between mid-July and September (Figure 23).

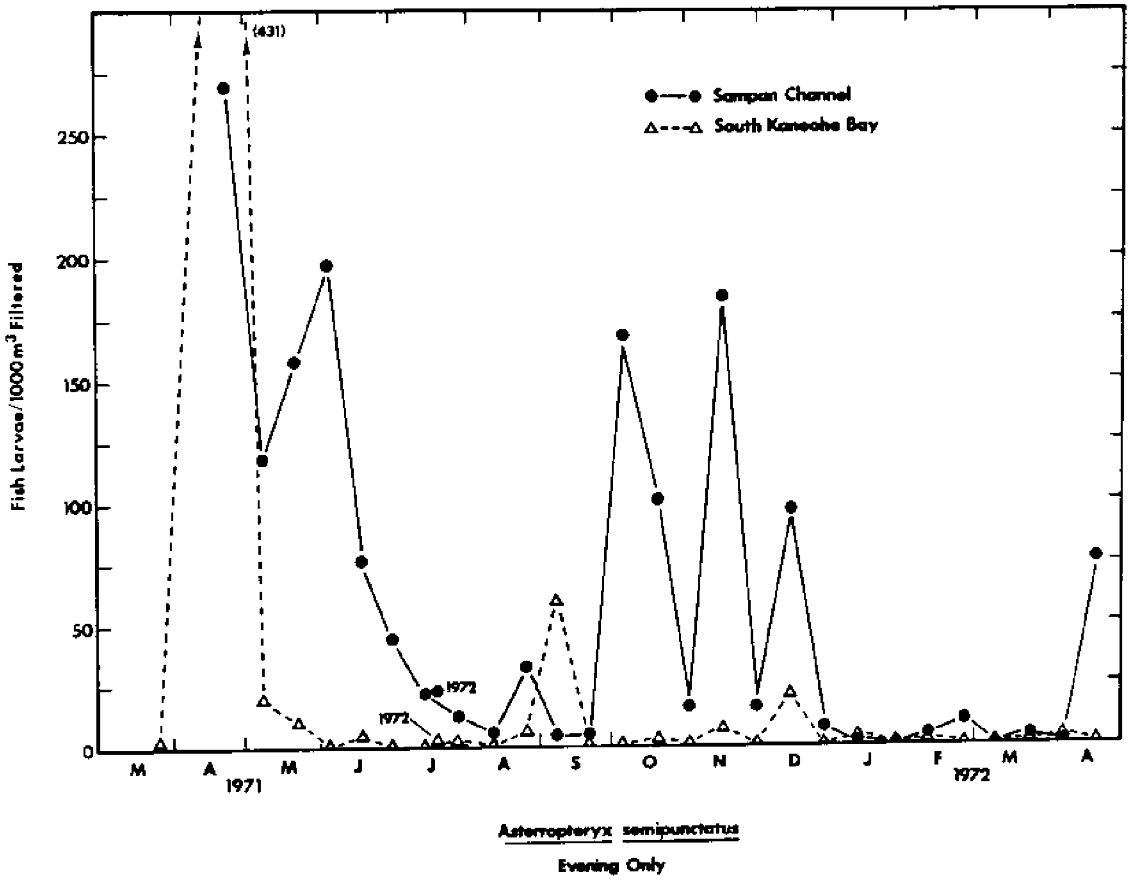


Figure 23. *Asterropteryx semipunctatus* larval abundance.

Eviota epiphanes, a very minor component of the Kaneohe Bay larval fish fauna, occurred year-round. Eighteen of the twenty occurrences of this fish were in Sampan Channel tows; all but one at night. Only 49 *E. epiphanes* larvae were captured.

Engraulidae (Nehu: *Stolephorus purpureus*)

Seasonally, the pattern of abundance of nehu larvae could be divided into four sections: (1) a peak extending from mid-December through mid-February; (2) a second, much larger peak extending from mid-March through mid-May; (3) a period of virtual absence extending from June through mid-August; and (4) a period of reduced but relatively regular abundance from late August through early December.

While this pattern was based on data from south Kaneohe Bay, the pattern was substantially the same in the Sampan Channel where far fewer nehu larvae were taken (Figure 24).

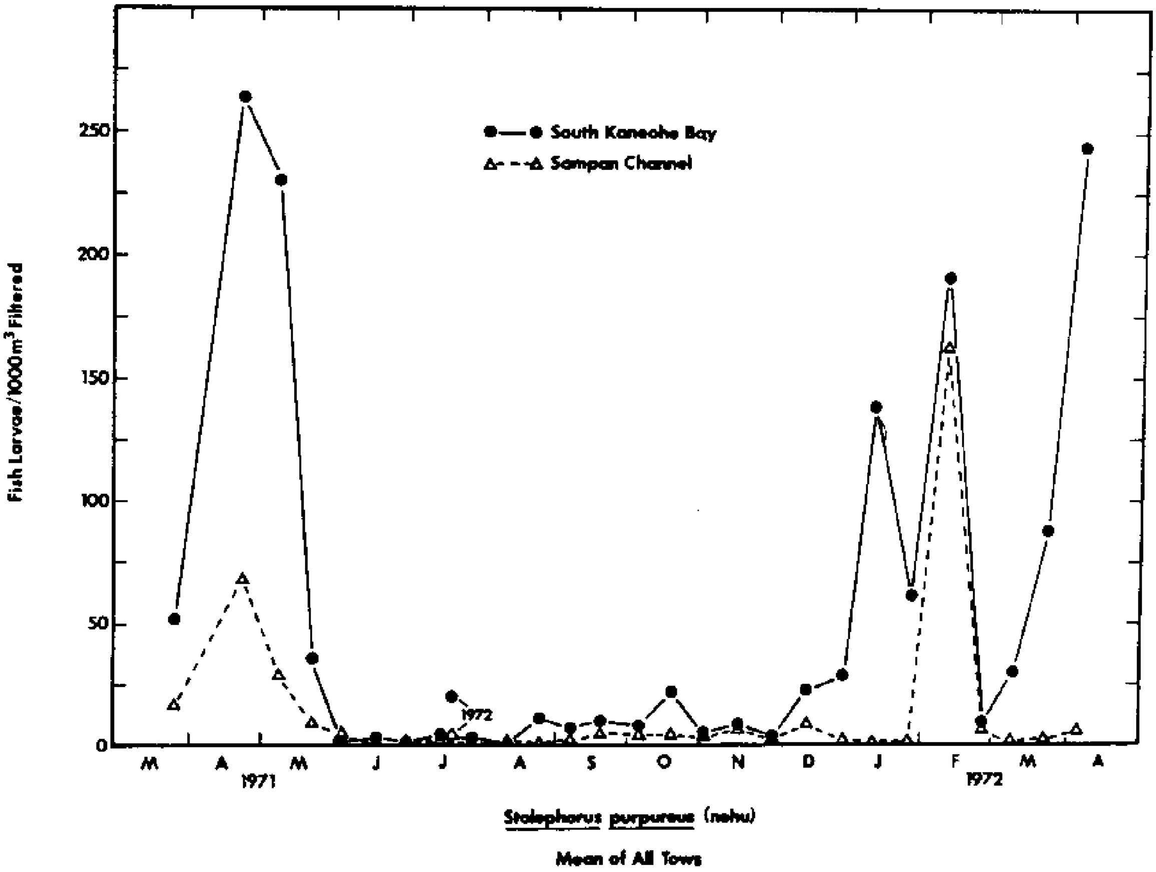


Figure 24. *Stolephorus purpureus* larval abundance.

In south Kaneohe Bay, the diel pattern of abundance was somewhat obscure. More nehu larvae were present in afternoon samples than in either morning or night samples and more were taken in night samples than in morning samples. However, only the morning-afternoon difference was statistically significant. On the other hand, the Sampan Channel samples contained significantly more nehu at night than during the day, but showed no significant difference between morning and afternoon counts.

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	14	(-)42	$P > 0.100$
Morning-night	20	(+)13	$P < 0.001$
Afternoon-night	21	(+) 8	$P < 0.001$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	20	(+) 17	$P < 0.005$
Morning-night	24	(+)109	$P > 0.050$
Afternoon-night	27	(-)142	$P > 0.050$

The diel pattern of abundance demonstrated by nehu larvae in south Kaneohe Bay stands in contrast to other studies of nehu larvae (Burdick, 1969; Murphy and Clutter, 1972) which indicate that larger larvae are undersampled by meter nets during the day. On the other hand, Sampan Channel samples seem to support the undersampling conclusion. Larvae in the present study were not measured, so comparisons on that basis are not possible. It may be noted that Burdick, who reported on the same samples used by Murphy and Clutter, used 333μ mesh in his net (505μ was used in the present study), although it is not clear how this would affect his results.

Tripterygiidae

Tripterygion atriceps was common in the Sampan Channel collections, but rare in south Kaneohe Bay samples.

In south Kaneohe Bay, most fish were taken from January through April, but some were also captured in May, June, and July (too few, however, to permit precise abundance estimates).

In the Sampan Channel, two periods of abundance were evident (Figure 25). The first and more important extended from late December through March; the second extended through the summer and fall (June through October).

Wilcoxon signed-ranks tests (below) indicated no significant day-night differences in abundance for this species in the Sampan Channel, although it was a more important component of the daytime fauna than of the night fauna; morning and afternoon ranks both equaled 2, night rank equaled 8.

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	23	(-)113	$P > 0.050$
Morning-night	21	(-) 82	$P > 0.050$
Afternoon-night	22	(-)112	$P > 0.050$

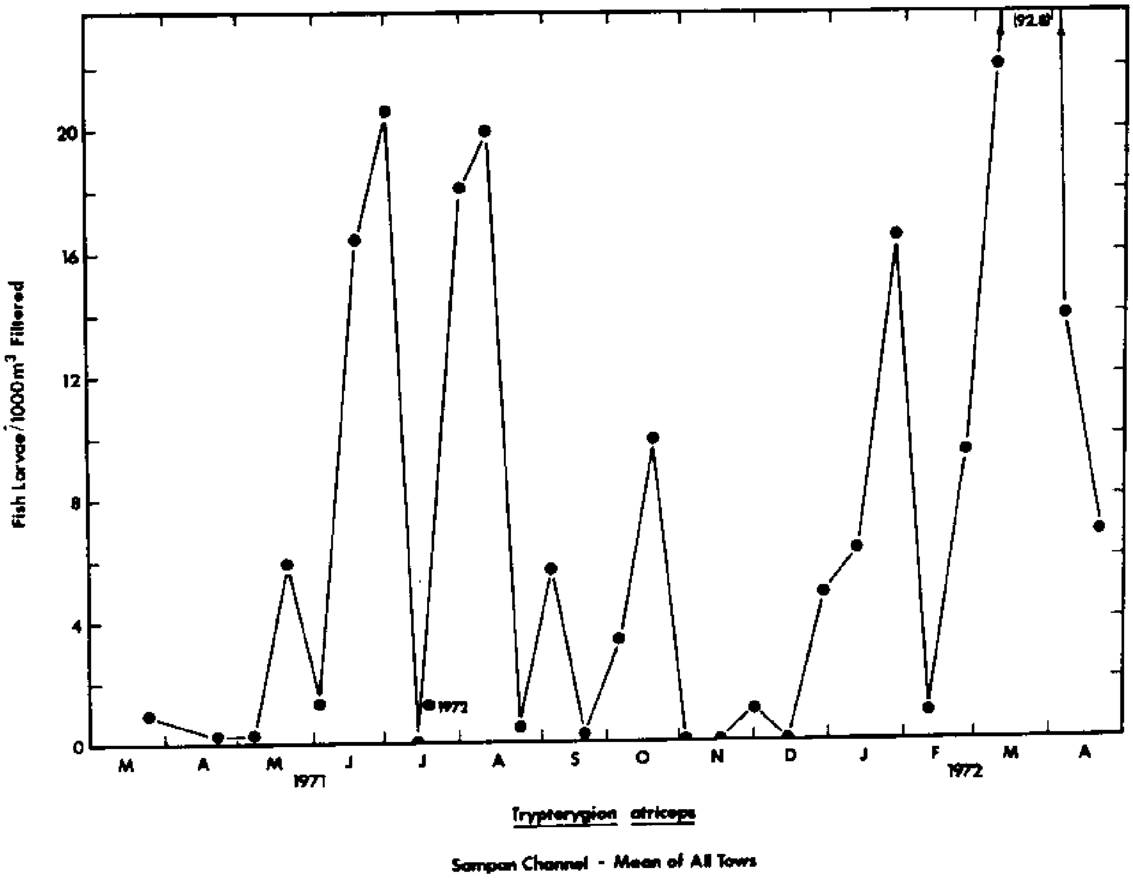


Figure 25. *Tripterygion atriceps* larval abundance.

The relatively great abundance of *Tripterygion atriceps* larvae was somewhat surprising in view of the apparent scarcity of the adults; however, it is likely that this very secretive fish is more common than has been supposed.

Unidentified 142

This larva (possibly an apogonid) composed a moderate proportion, approximately 3.5% of all Sampan Channel larvae and about 0.9% of all south Kaneohe Bay larvae taken, but was temporally very "patchy." It was taken on only 11 of the 29 sampling dates and was present in large numbers (> 20/1000 m^3 daily mean) on only two of these.

The peaks of unidentified 142 abundance apparently follow the general seasonal bimodality found for most species. Occurrence and abundance data are summarized in Table 2; numbers are means of daily tows. See Appendix D for a breakdown of diel occurrences.

TABLE 2. OCCURRENCES OF TYPE 142 LARVAE

Date	South Kaneohe Bay (Larvae/1,000 m^3)	Sampan Channel (Larvae/1,000 m^3)
22 Apr 1971	7.43	7.74
7 Sep 1971	11.44	0.64
5 Oct 1971	0.29	140.02
19 Oct 1971	0	26.27
27 Jan 1972	0	0.36
25 Feb 1972	0	5.37
9 Mar 1972	19.99	11.12
23 Mar 1972	0	2.52
6 Apr 1972	1.16	0
20 Apr 1972	1.45	0
18 Jul 1972	13.85	3.78

No diel changes in abundance were detected, perhaps due to the small number of occurrences.

Pomacentridae

The pomacentrids were almost exclusively *Abudefduf* spp. and *Pomacentrus jenkensi* with greater than 80% being *Abudefduf* spp.; most were *A. abdominalis*. Pomacentrid larvae occurred essentially year-round (Figure 26). In both sampling areas, a peak of abundance occurred between February and April with a smaller peak from late August through mid-November in the southern station and from October through mid-December in the Sampan Channel.

In south Kaneohe Bay, fewer larvae were present at night; in the Sampan Channel there was no clear pattern:

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	20	(-) 60	$P \simeq 0.049$
Morning-night	22	(+)120	$P \simeq 0.421$
Afternoon-night	21	(+) 40	$P \simeq 0.005$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	22	(-)112	P ≃ 0.290
Morning-night	24	(-) 90	P ≃ 0.044
Afternoon-night	21	(-) 74	P ≃ 0.076

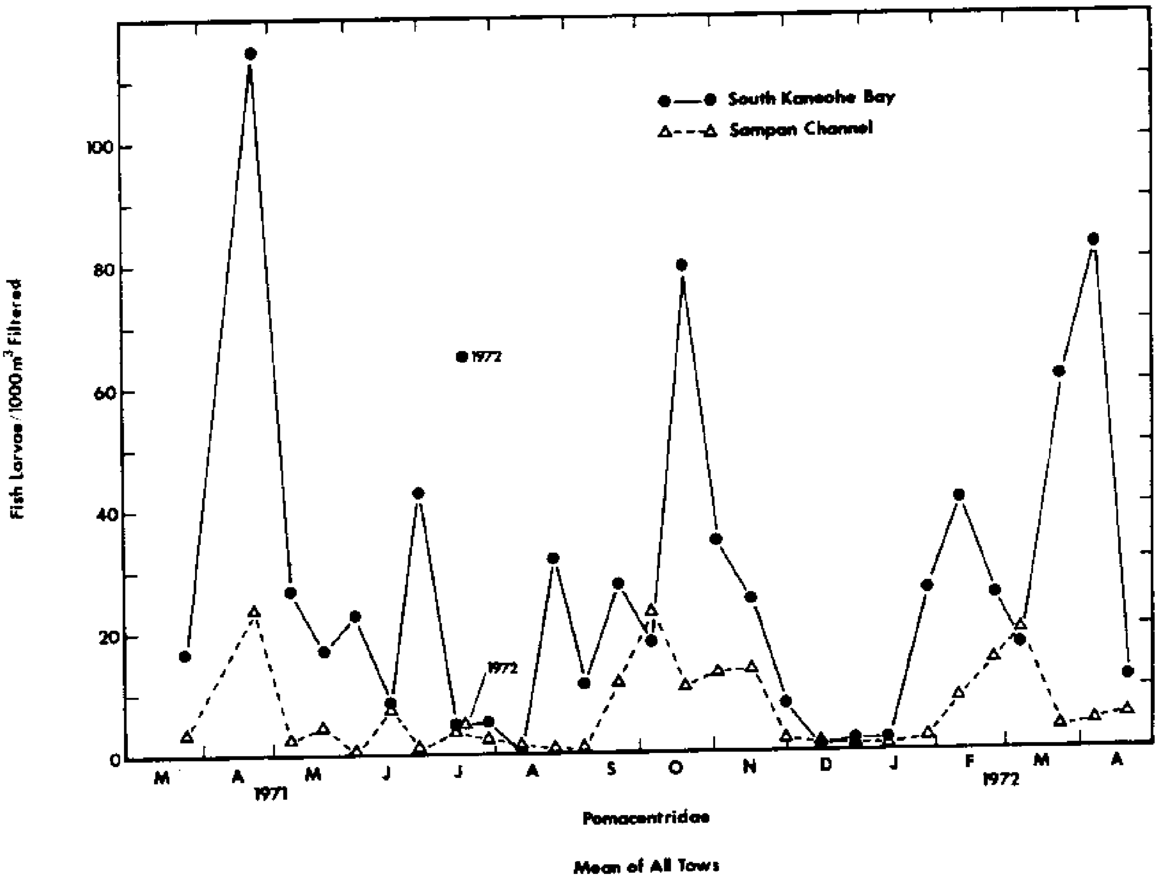


Figure 26. Pomacentridae larval abundance.

A third type of pomacentrid occurred in south Kaneohe Bay on February 25, 1972. This fish is unidentified and known from only one specimen.

Carangidae

Pa'opa'o (*Gnathanodon speciosus*). This carangid was present from mid-February through mid-November with a large peak of abundance in late April and early May. In south Kaneohe Bay, smaller monthly peaks occurred from June through October. A similar but less obvious pattern was apparent in the Sampan Channel with the August and October peaks lacking (Figure 27).

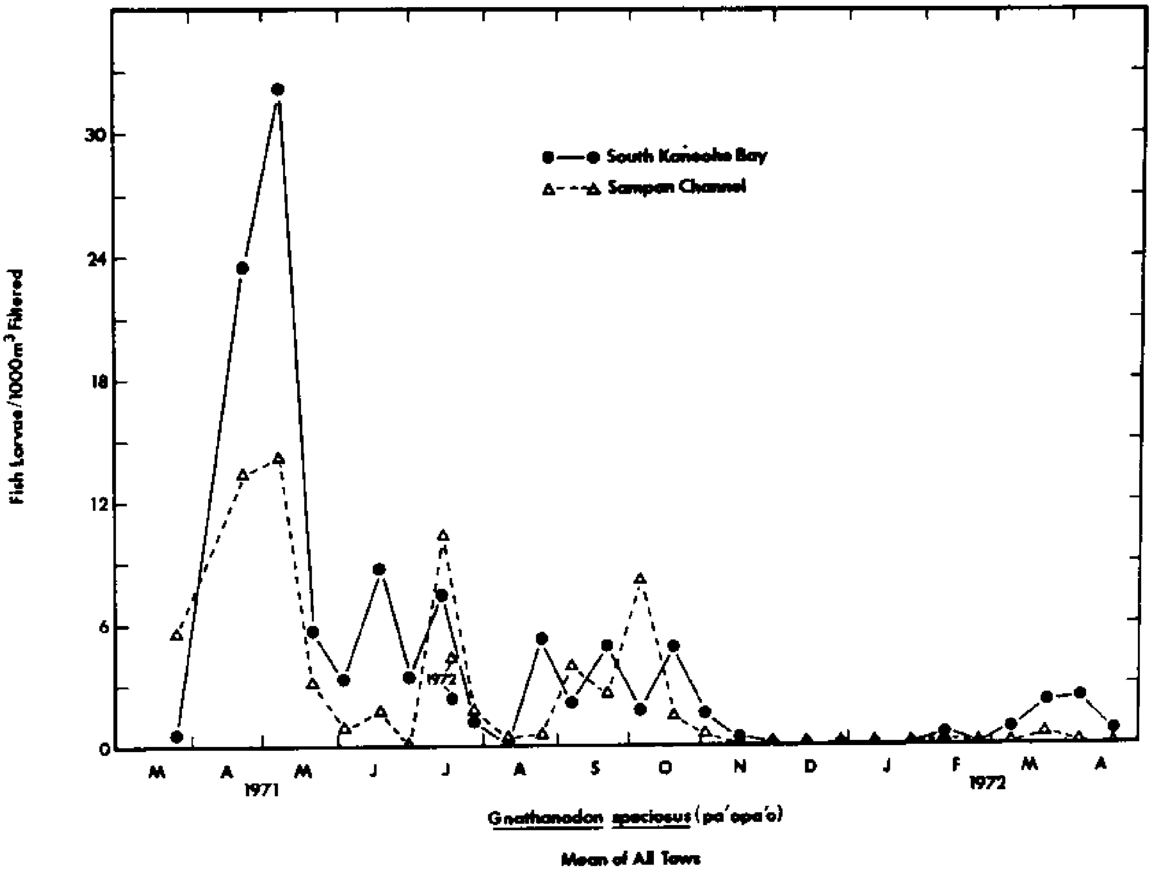


Figure 27. *Gnathanodon speciosus* larval abundance.

In both areas, more pa'opa'o larvae were taken at night than at either day station and more in the afternoon tows than in the morning tows. However, only the morning-night differences for both areas were statistically significant, as was the afternoon-night difference in the Sampan Channel:

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	12	(+)30	$P > 0.050$
Morning-night	17	(+) 3	$P < 0.005$
Afternoon-night	17	(+)15	$P > 0.005$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	16	(+)39	$P > 0.050$
Morning-night	15	(-)18	$P \simeq 0.010$
Afternoon-night	19	(+)76	$P > 0.050$

Omaka (*Caranx mate*). This fish was, by far, the most abundant carangid in all samples taken. Although it was found from late January through mid-November, substantial numbers occurred only between late March and early November.

The omaka exhibited a trimodal distribution of abundance with a very large peak from late March through mid-May, a second smaller peak in July, and a third peak in September and October (Figure 28). This pattern was somewhat different from the typical pattern of spring and fall peaks with an intervening summer minimum demonstrated by most of the other larvae.

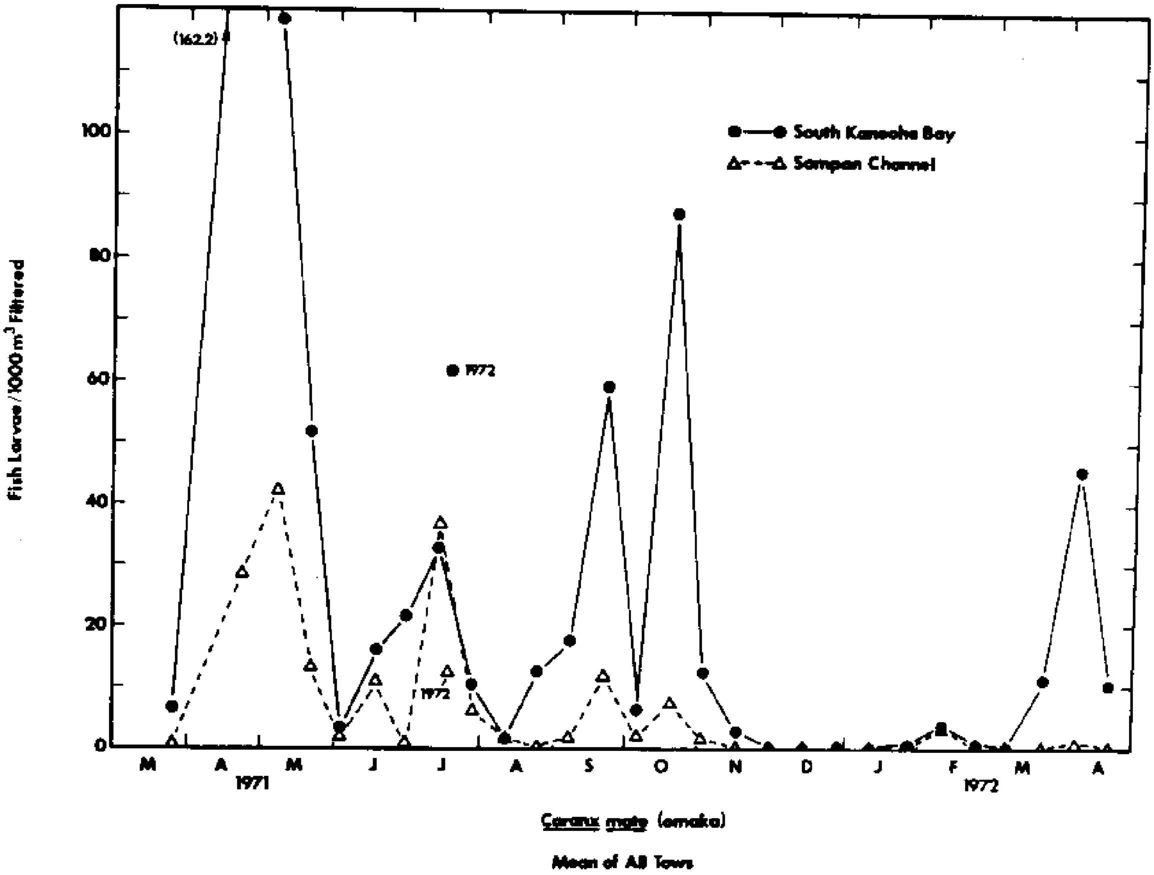


Figure 28. *Caranx mate* larval abundance.

Omaka showed a diel pattern similar to that of pa'opa'o, in that numbers of larvae increased from morning through evening. Significantly more larvae were present in the Sampan Channel night samples than in daytime samples. The morning-afternoon and morning-night differences were statistically significant in south Kaneohe Bay.

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	12	(+)33	$P > 0.050$
Morning-night	16	(+) 6	$P < 0.005$
Afternoon-night	17	(+)16	$P < 0.005$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	18	(+)31	$P \simeq 0.009$
Morning-night	19	(+)53	$P \simeq 0.048$
Afternoon-night	19	(+)94	$P > 0.050$

Type C-5. This carangid larva was included as an "important" fish almost entirely because it occurred in very large numbers (254 fish/1000 m^3) in the Sampan Channel on the afternoon of March 23, 1972. This catch, which accounted for all the Type C-5 larvae taken in Sampan Channel afternoon tows, was sufficient to make Type C-5 the most abundant larva in the Sampan Channel afternoon tows. Type C-5 was very rare in south Kaneohe Bay and uncommon in all other channel collections. This sudden great abundance of Type C-5 on March 23, 1972 was unexplained, but it is noteworthy that a similar, albeit smaller, burst of Type C-5's occurred in the night samples on that date. Nothing of this sort occurred in the morning. Other occurrences of Type C-5 in the Sampan Channel were April 22, 1971 (morning) and June 18, 1971 (morning). The few Type C-5's captured in south Kaneohe Bay were taken on March 23, 1972 in afternoon and evening samples.

Seriola sp. The larvae of this genus were rare (21 were captured), being taken only eight times, all in the Sampan Channel. Six of the occurrences were during daytime tows. The larvae were captured between late December and early May.

Five other species of carangids, all presently unidentified, occurred in the samples. These were generally taken during the "all species" peaks of February through April and September through October, but occurred in all months but November and December.

Type C-1. These larvae were captured in both south Kaneohe Bay and the Sampan Channel. Ten larvae were taken on six dates in January, February, May, June, August, and September.

Type C-2. These larvae were captured in April, July, September, and October; twelve larvae were taken.

Type C-3. These larvae were taken in February, April, June, and October; nine were captured.

Type C-4. These larvae were present in March, April, June, and October; seven were captured.

Type C-101. These larvae were present on only two sampling dates, one in June and one in September, and accounted for only three larvae.

Blenniidae

Omobranchus elongatus was the most common blenniid encountered during the study (Table 1), comprising 58% of all blenniid larvae in south Kaneohe Bay and 26% in the Sampan Channel. In south Kaneohe Bay, significantly more *O. elongatus* larvae were captured during the day than at night; in the Sampan Channel, no significant day-night differences were found.

An unidentified species, which was called Type 5, was the second most abundant blenniid larva (Table 1); it accounted for 3.7% and 32.8% of the Sampan Channel and south Kaneohe Bay blenniid catches, respectively. Type 5 was more common in south Kaneohe Bay day samples than in evening samples. Numbers taken in the Sampan Channel were too low to allow any analysis of diel changes.

The third most common blenniid larva was *Enchelyurus brunneolus* (Table 1). This species was rare in south Kaneohe Bay, constituting < 5% of the blenniids, but was the most common blenniid in Sampan Channel catches, totaling 39.6% of the blenniids there. *E. brunneolus*, too, was more common in daytime catches than in evening samples.

Exallias brevis was the only other blenniid larva taken in substantial numbers. It made up 28% of the Sampan Channel blenniid catch, but was very rare at the southern station. No significant day-night differences in *E. brevis* catches were detectable.

Two other species of blenniids--*Istiblennius zebra* and another unidentified species called Type 8--were taken almost exclusively from the Sampan Channel and together composed less than 3% of the blenniids captured there. Type 8 and *I. zebra* were present from late winter (February) through late spring (May).

Four other types of blenniid larvae captured during the study were:

Plagiotremus (=Runula) sp. (identification tentative). This species was taken twice from the Sampan Channel in June and July 1971 and once in October 1971 from south Kaneohe Bay.

Cirripectus sp. (identification tentative). This species occurred several times in both south Kaneohe Bay and the Sampan Channel, but not with any discernible pattern.

Type 9. This species occurred only once, on January 11, 1972, in the Sampan Channel.

Type 10. This species was encountered twice, on February 10 and March 23, 1972, both in south Kaneohe Bay and the Sampan Channel.

Blenniid larvae were taken throughout the year at both sampling stations (Figures 29, 30, and 31). For the four numerically important species, four periods of higher abundance occurred. While details vary for each species, the periods were generally: (1) February, (2) April through mid-June, (3) late July through early September, and (4) November through December.

The other blenniids were usually taken during these periods also, suggesting an approximately quarterly spawning periodicity for blenniids in general. This pattern is particularly evident for *Omobranchus elongatus* and *Exallias brevis*.

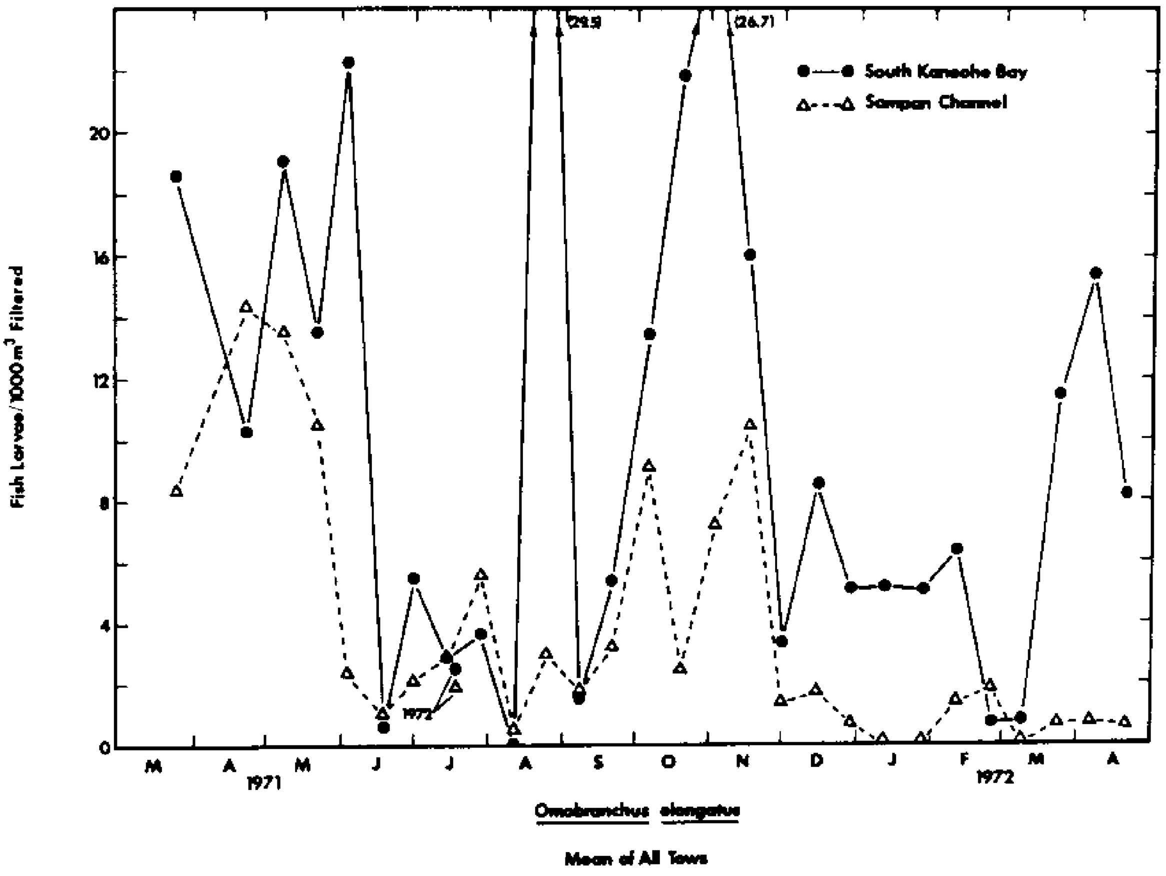


Figure 29. *Omobranchus elongatus* larval abundance.

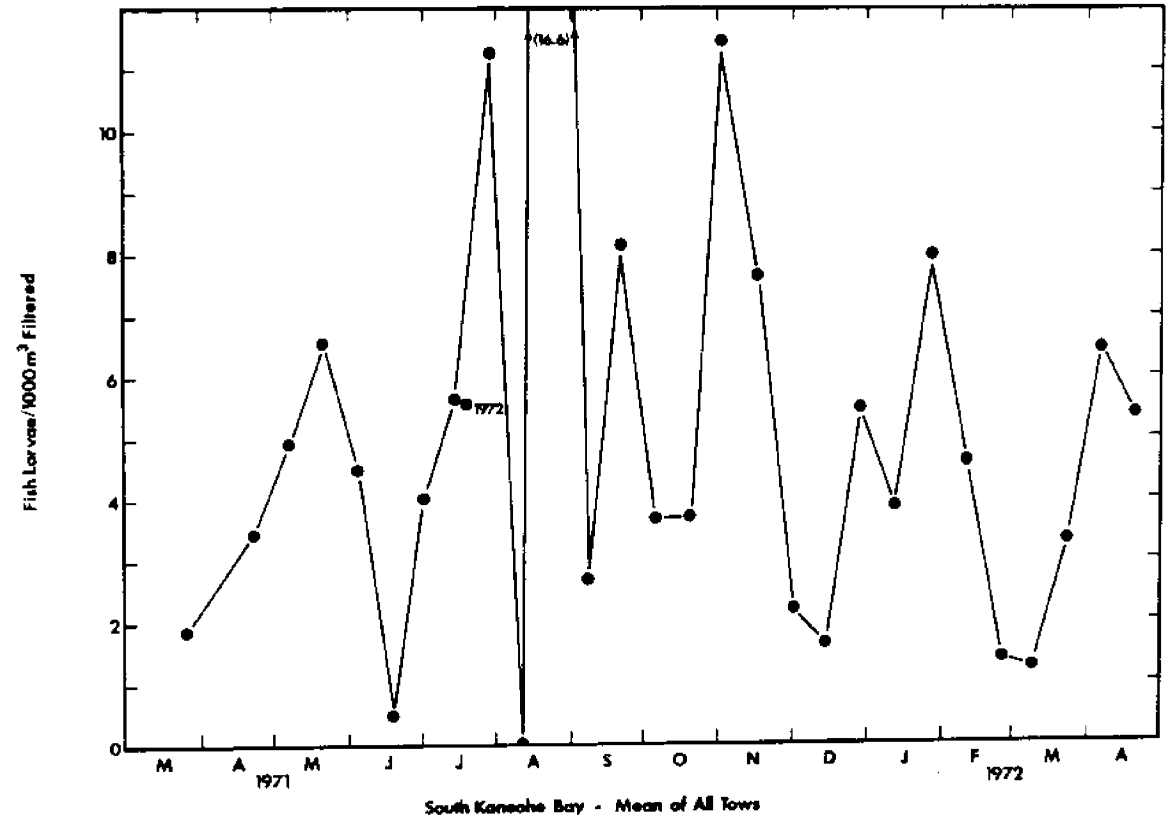


Figure 30. Blenny 5 larval abundance.

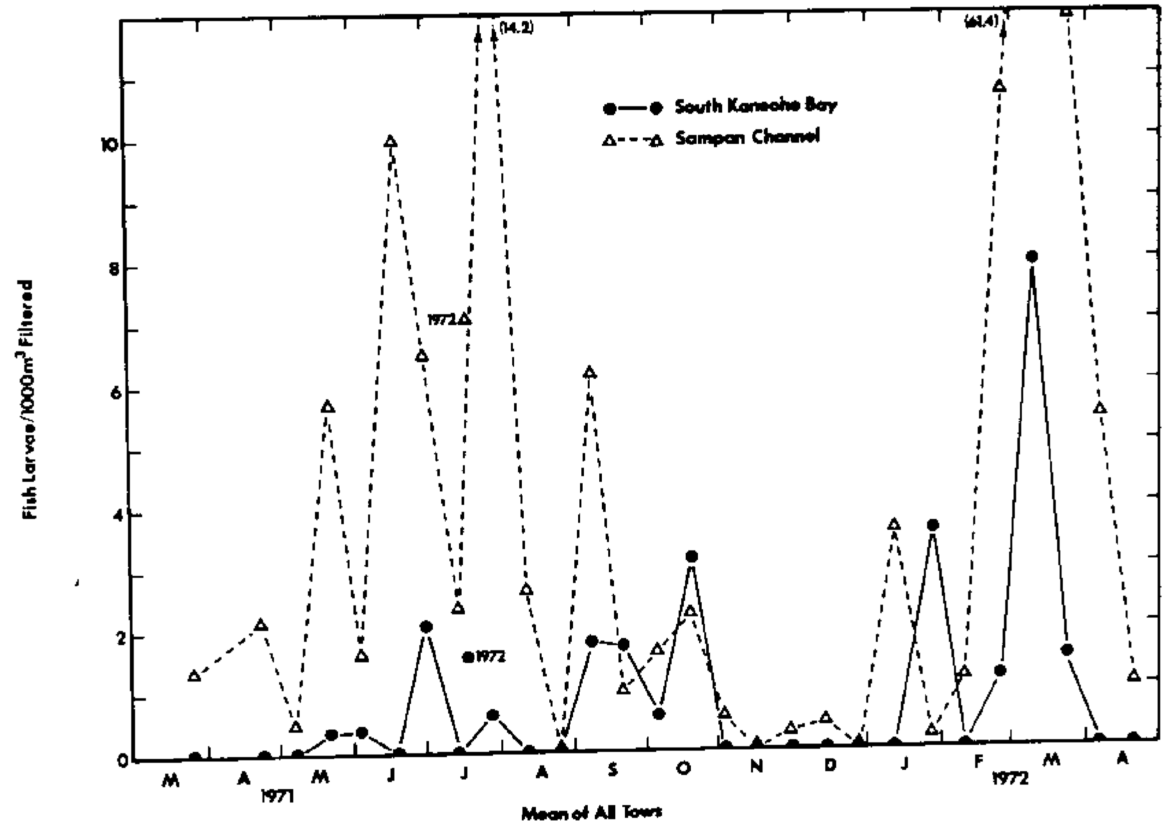


Figure 31. *Enchelyurus brunneolus* larval abundance.

The diel patterns of abundance demonstrated by these blenniids are currently under investigation.

Atherinidae (Iao: *Pranesus insularum*)

Larvae of this common schooling fish were present year-round, being absent from the catches only once, on December 28, 1971. A seasonality in abundance was indicated, however (Figure 32). A broad, bimodal peak of iao larvae was present from March through mid-November. The component peaks fell in late July and in October. Iao constituted 2.4% of all larvae taken from the Sampan Channel, but only 0.9% of those from south Kaneohe Bay.

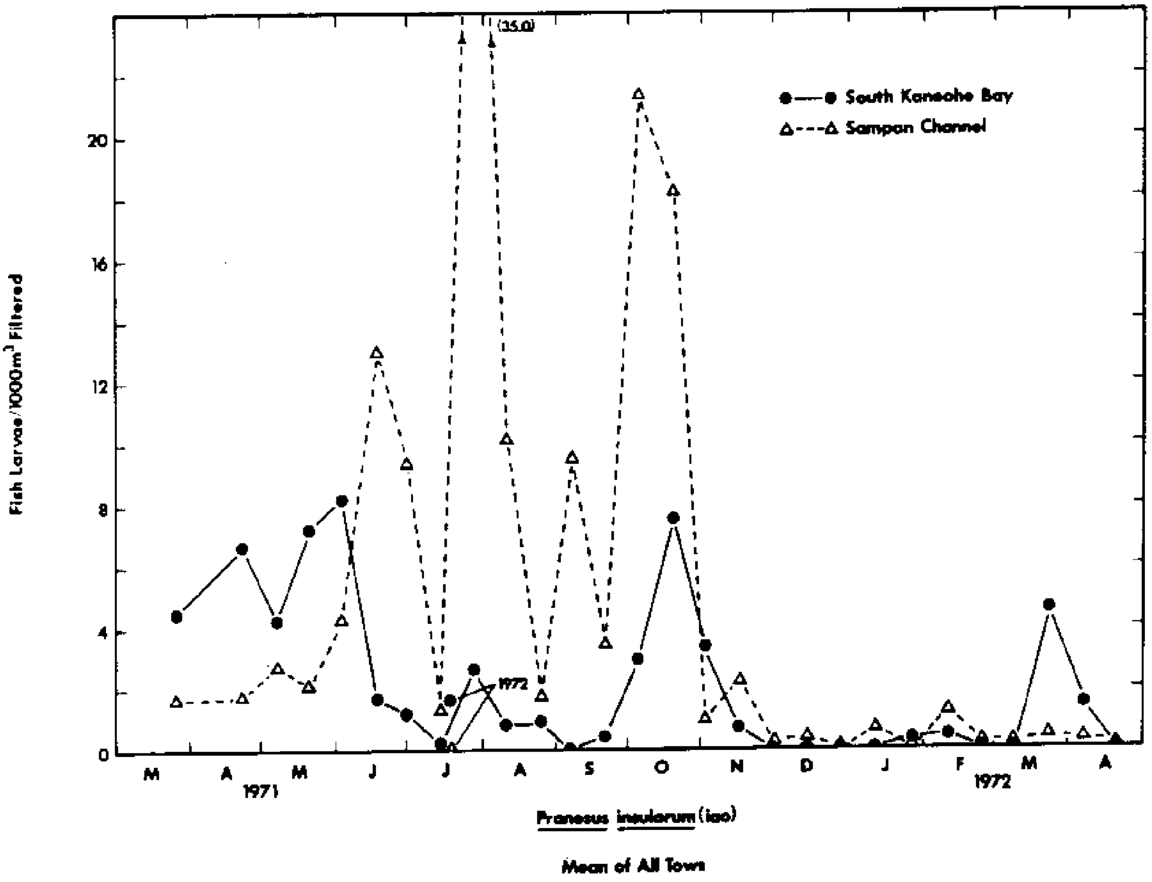


Figure 32. *Pranesus insularum* larval abundance.

There were more iao in the night tows than in the day tows in both areas. No significant morning-afternoon differences were found:

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	16	(-)59	$P > 0.050$
Morning-night	24	(+)21	$P < 0.005$
Afternoon-night	24	(+)11	$P < 0.005$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	12	(-)25	$P > 0.050$
Morning-night	21	(+)22	$P < 0.005$
Afternoon-night	24	(+) 4	$P < 0.005$

Larvae of *Iso hawaiiensis* occurred once in the Sampan Channel.

Myctophidae

The myctophids were a significant component of the larval fish fauna only in the Sampan Channel. There was no detectable diel variation in numbers, but any pattern may have been obscured by the small catches.

In the Sampan Channel, myctophids showed a strong seasonal pattern (Figure 33) with a single peak of abundance from January through March. None was taken in July or September and only two in August. They were found in small numbers in all other months.

At least sixteen species of ten genera were represented in the collections. Since most of the larvae could not be identified at the specific level, they will be discussed below by genus:

Ceratoscopelus (*townsendi*-complex)--107 larvae caught. These, along with the genus *Diaphus*, were the most abundant myctophids on a per volume basis. Except for two occurrences on August 11, 1971 and October 19, 1971, they were completely absent from all samples taken between late June and mid-February. Their peak of abundance was in late March.

Diaphus (3 spp.)--115 larvae caught. The peak of abundance occurred between late February and March. They were absent from all but four of the samples taken from May through mid-January.

Lampadena (3 spp. including *L. urophaos*)--124 larvae caught. This was the third most abundant genus and included the most abundant species (one of the unidentified). The peak of abundance was from late January through March; very few larvae were taken outside this period. No *Lampadena* larvae were taken between May and mid-November.

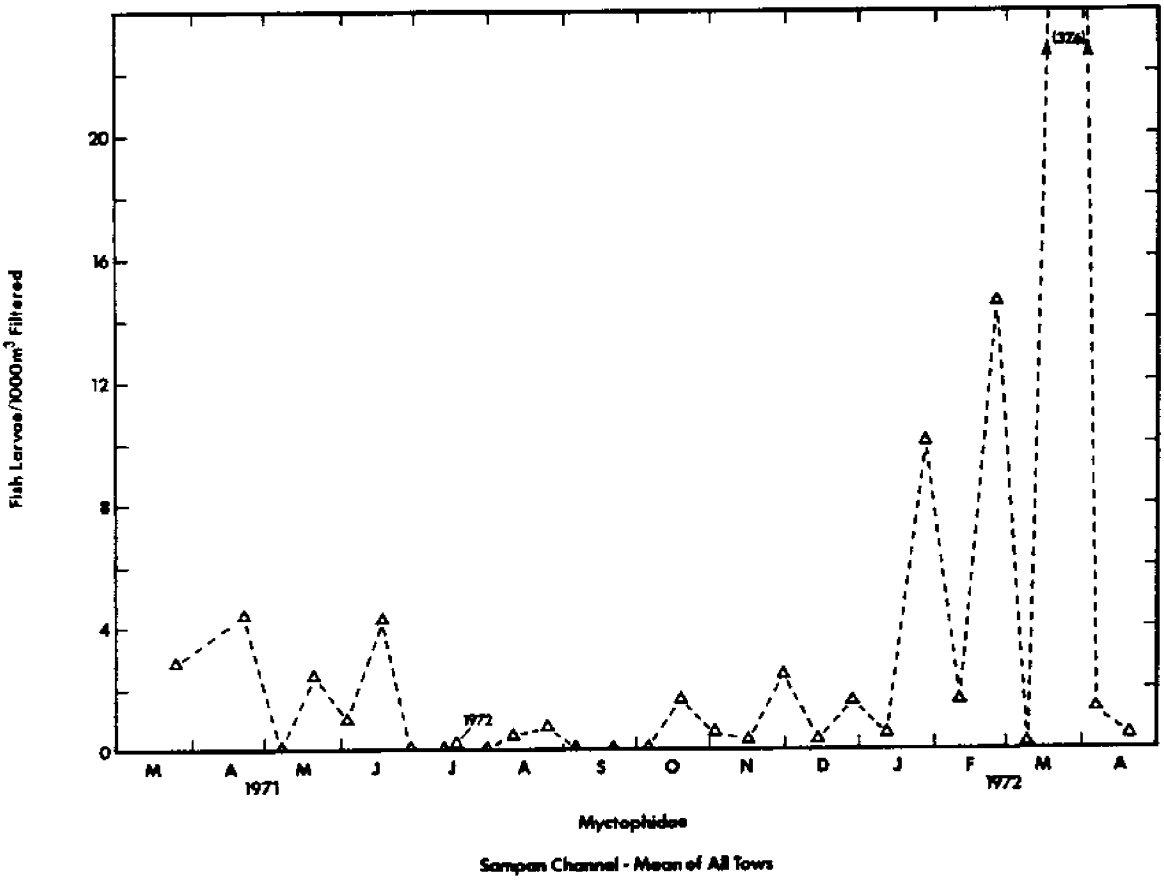


Figure 33. Myctophidae larval abundance.

The other myctophid genera were not common enough to warrant more than statements of occurrence. In order of decreasing abundance they are:

Bolinichthys (2 spp.)--52 larvae caught. These larvae were taken between late August and April with occurrences concentrated in November, January, and March.

Taaningichthys minimus--23 larvae caught. These larvae occurred from late October through February.

Triphoturus (2 spp. including *T. nigrescens*)--13 larvae caught. These larvae were taken between late February and mid-June.

Hygophum proximum--10 larvae caught. These larvae occurred from late February through June.

Lampanyctus (3 spp.)--8 larvae caught. These larvae also occurred from late February through June.

Diogenichthys (?) sp.--2 larvae caught. These larvae were taken twice, on April 22, 1971 and June 18, 1971.

Myctophum sp. (*prisilepis*?). One larva was collected on March 25, 1971.

The 52 myctophids collected from south Kaneohe Bay were all taken on 8 sampling dates, primarily between late March and June. Larvae were taken once in September and once in late January. Peak abundance was reached in late March.

Smoker and Pearcy (1970) determined from ovarian egg measurements that the myctophid *Stenobrachius leucopsarus* spawns off Oregon from December through March. Clarke (1973a), working off leeward Oahu, found that juveniles of several myctophids occurred seasonally. He took *Ceratoscopelus* spp. juveniles in March, June, and July. *Diaphus* and *Lampadena* spp. juveniles were caught in June, July, and September. Clarke's (1973a) findings are generally consistent with those of the present study.

Ahlstrom (1972), reporting on the EASTROPAC I and II collections, observed that larvae of most mesopelagic fish in the eastern tropical Pacific demonstrated relatively little seasonality in their abundance patterns. Most of the common larvae examined had a less than threefold seasonal range in relative abundance between the highest and lowest average number of larvae per haul. The EASTROPAC monitoring cruises upon which Ahlstrom was reporting were bimonthly, averaging 45 days, and thus may have tended to smooth any smaller-scale fluctuations somewhat; but comparatively little seasonality was evident. Whether the myctophids display a strong reproductive seasonality around Hawaii (as indicated by this study's collections) is difficult to determine, but Clarke's (1973a) data on the occurrence of juveniles seems to indicate that this is the case. Why a strong seasonal pattern of reproduction should exist near Hawaii, but not in the eastern tropical Pacific is puzzling.

Scaridae (Uhu)

A total of 143 uhu larvae of two unidentified species was collected only at night and, with the following exceptions, only in Sampan Channel samples: (1) one fish on May 7, 1971 in south Kaneohe Bay and (2) one fish on November 16, 1971 in south Kaneohe Bay.

Seasonally, scarids demonstrated a bimodal abundance pattern with peaks in April through June and November and December (Figure 34). Both species were present during the spring peak, but only one was represented in the smaller winter peak. Scarid Type SC-4 occurred only from March through June and was found only twice (April 22, 1971 and March 9, 1972) when not in the presence of the other species (Type SC-22). Scarid larvae were totally absent from July, January, and February samples.

It is significant that all the scarid larvae captured were relatively large, approximately 7 to 8 mm standard length. A noteworthy feature of their seasonal distribution is that the peaks in larval scarid abundance came approximately one month after the spring and fall peaks demonstrated by most other kinds of larvae. Finally, even though adult scarids are common in Kaneohe Bay, scarid eggs were virtually absent in our samples. This suggests that scarids move outside the bay to spawn and that their larvae develop outside the bay and return as relatively large ready-to-metamorphose individuals. Randall and Randall (1963) have reported such offshore spawning migrations for Caribbean scarids.

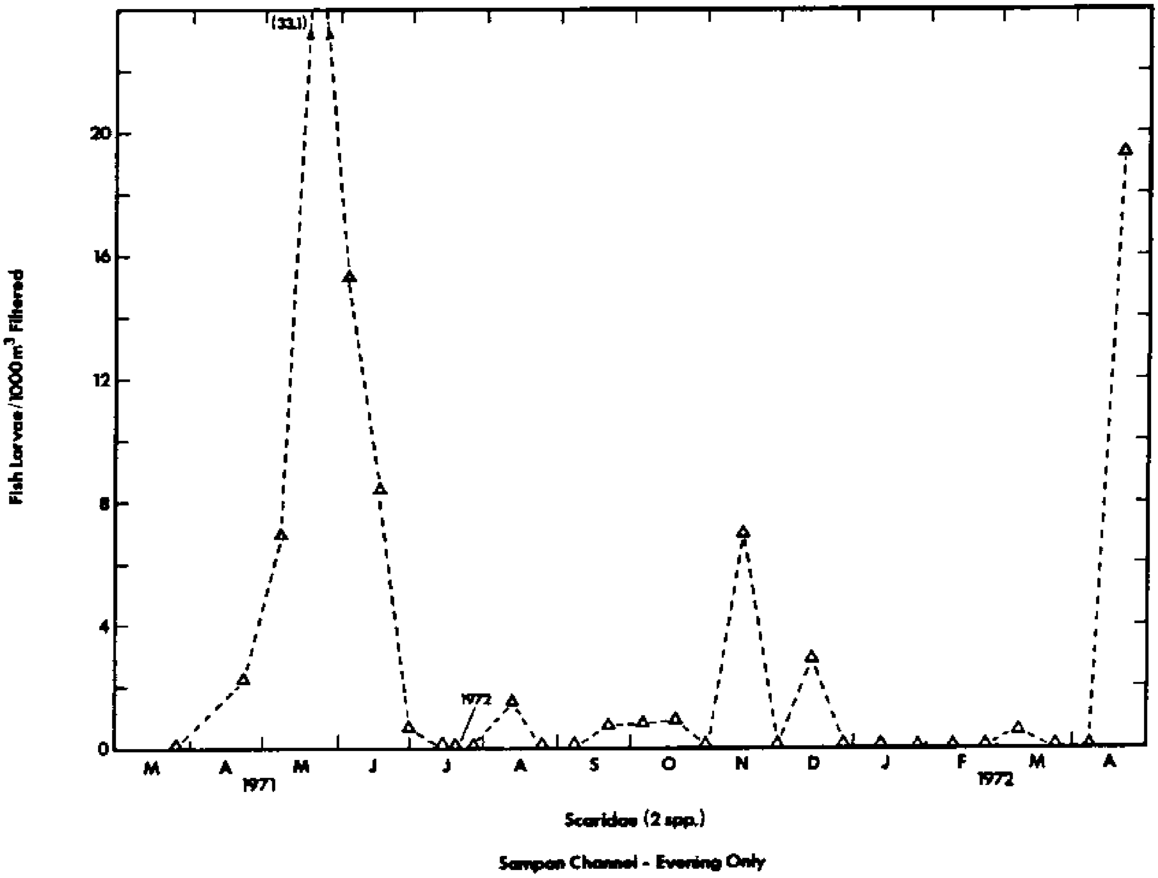


Figure 34. Scaridae larval abundance.

Callionymidae

Callionymus decoratus larvae were present year-round, except in December. Seasonality in abundance was evident: in the Sampan Channel, larvae were rare from August through January with a major peak of abundance in April and May and a second, very small peak in November. The south Kaneohe Bay samples revealed much broader peaks of abundance. The first extended from January through May, merging with the fall peak during the summer months (Figure 35).

In south Kaneohe Bay, substantially more *C. decoratus* larvae were captured at night than during the day. In the Sampan Channel also, more were captured at night, but here the difference was not statistically significant, possibly due to the low numbers of *C. decoratus* larvae captured.

Sampan Channel

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	12	(+)34	$P > 0.050$
Morning-night	14	(+)34	$P > 0.050$
Afternoon-night	13	(+)21	$P \simeq 0.047$

South Kaneohe Bay

Times Paired	No. of Pairs	Smaller Rank Sum	Probability Level
Morning-afternoon	19	(+)85	P > 0.050
Morning-night	22	(+)52	P < 0.010
Afternoon-night	23	(+)25	P < 0.005

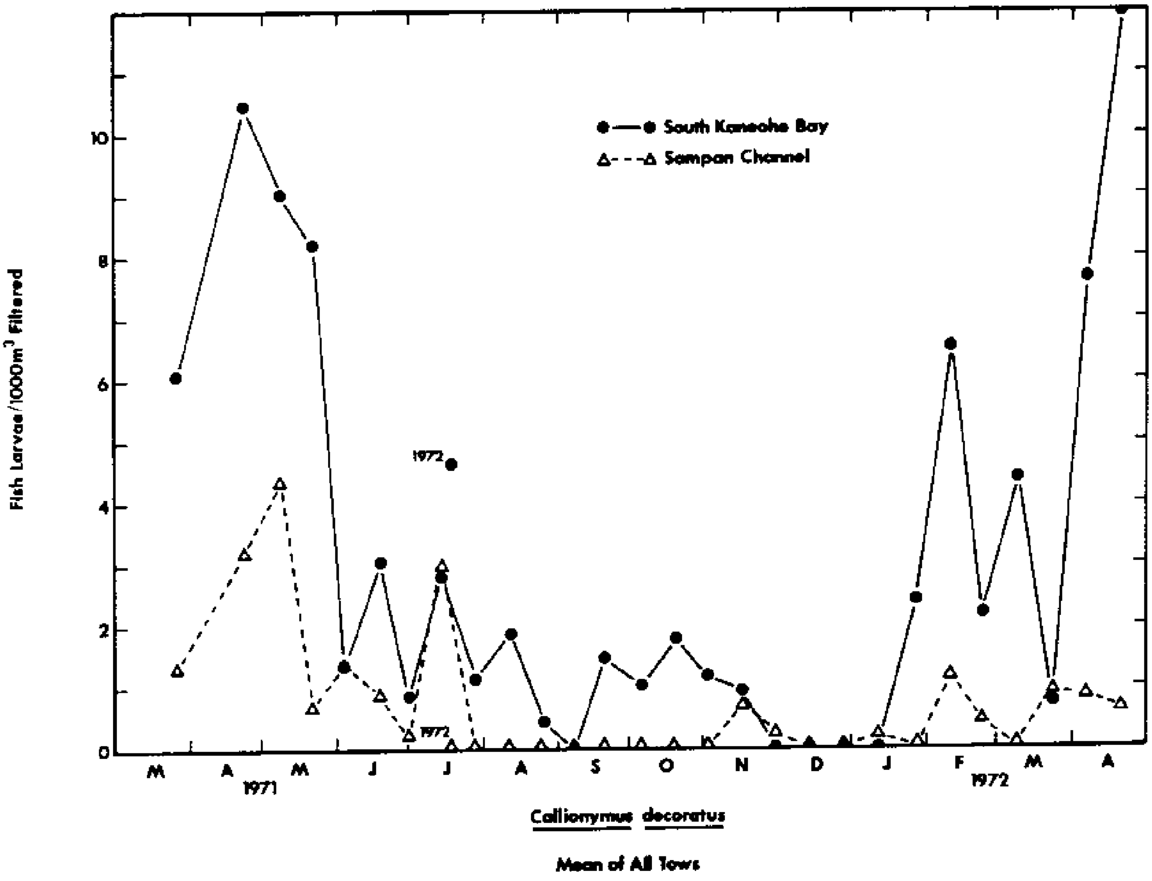


Figure 35. *Callionymus decoratus* larval abundance.

One other identifiable callionymid, *Pogonemus pogognathus*, occurred in the samples. It was taken once, on June 30, 1971, in the Sampan Channel.

A third callionymid which is unidentified at present occurred only once, on January 11, 1972, in the Sampan Channel.

Beloniformes

Belonidae (Aha'aha). Twelve larvae of the genus *Tylosurus* were taken in ten tows from March through June; nine of which were in daytime tows.

Hemirhamphidae (Iheihe). Five halfbeak larvae were encountered four times in both south Kaneohe Bay and the Sampan Channel between February and June.

Exocoetidae (Malolo). Seventy exocoetids of five (unidentified) species occurred 22 times in all months from January through mid-October, except August. Larvae were captured only three times in night tows. Eighteen of the occurrences were in the Sampan Channel, suggesting transport into the bay from the open ocean.

Myctophiformes

Synodontidae ('Ulae). Larvae of *Saurida gracilis* occurred twice in night Sampan Channel tows on November 30, 1971 and January 27, 1972. Both captured larvae were large individuals nearly ready to metamorphose. Two other synodonts, both probably *Synodus* sp., were taken in June and November of 1971 from the Sampan Channel.

Evermannellidae. A larval evermannellid was collected in south Kaneohe Bay on the afternoon of March 23, 1972.

Chlorophthalmidae. A single larval chlorophthalmid was captured on March 23, 1972 in the Sampan Channel.

Salmoniformes (Stomiatoidei)

Gonostomatidae. The following three genera were present in our samples:

Cyclothone. Larvae of this genus occurred eight times on three sampling dates, in February, March, and June. Five of the occurrences were in the Sampan Channel. A total of 108 *Cyclothone* sp(p?). were taken.

Vinciguerria nimbaria. Three larvae were present in an afternoon Sampan Channel sample on March 23, 1972.

Diplophos taenia. Two larvae of this genus were taken in the same sample as the *V. nimbaria*.

Finally, an unidentified gonostomatid, Type 140, occurred one time on March 23, 1972 in south Kaneohe Bay.

Melanostomiatidae (*Bathophilus* sp.). One larva of this family was captured on the afternoon of February 25, 1972 in the Sampan Channel.

Clupeiformes (Clupeoidei)

Unidentified clupeiform. Approximately 100 larvae of an unidentified clupeiform were captured, primarily from April through July and October through mid-November. Of the 14 occurrences, 13 were at night, and 10 were in the Sampan Channel. This unidentified larva may be the awa (Chanidae: *Chanos chanos*), but identification could not be confirmed.

Dussumieriidae (Makiawa: *Etrumeus micropus*). Makiawa larvae were taken year-round in small numbers, except in August, September, and early November when none was taken. Larvae occurred 34 times, 24 of these at night and 22 in the Sampan Channel. Approximately 200 makiawa larvae were captured.

Anguilliformes (Anguilloidei)

One muraenid leptocephalus was collected in the Sampan Channel during the night of November 16, 1971 and a single unidentified leptocephalus was collected in the Sampan Channel on the night of June 30, 1971.

Syngnathiformes (Syngnathoidei)

Syngnathidae. Both young seahorses and pipefishes occurred year-round. The only sampling date on which they were not encountered was December 14, 1971. Thirty-seven of the 82 occurrences were in the Sampan Channel. Tows rarely contained more than one individual. At least four species were encountered in the following numbers: *Hippocampus kuda* (38), *Syngnathus balli* (12), *Doryramphus melanopleura* (12), and *Micrognathus* sp. (2). In addition, 15 sea horses and 47 pipefish too small to be identified were present in the samples.

Scorpaeniformes

Scorpaenidae. Scorpion fish larvae of apparently nine species occurred eight times from December through June. All 35 individuals were taken from the Sampan Channel. Only one scorpaenid, *Pterois sphex*, was identifiable; it occurred on June 30 and December 14, 1971.

Perciformes (Acanthuroidei)

Acanthuridae. Larval acanthurids of at least two unidentified species occurred four times; twice on May 21, 1971 and twice on March 23, 1972. All eight individuals were taken during daytime samples in both south Kaneohe Bay and the Sampan Channel.

Perciformes (Scombroidei)

Scombridae. Thirteen larvae of *Thunnus albacares* (ahi) were taken five times; four in the Sampan Channel. Occurrences were in October, March, and July. *Euthynnus affinis* (kawakawa) larvae occurred one time, in the Sampan Channel on the afternoon of March 23, 1972 (16 larvae).

Gempylidae. *Gempylus serpens* (hauliuli-puhi) larvae were collected nine times from mid-October through May. Seven of the occurrences were in the Sampan Channel; eight were during the day (nine larvae).

Perciformes (Gobioidei)

Microdesmidae. Larvae of this family occurred twice, in June and August, in the Sampan Channel (two larvae).

Perciformes (Mugiloidei)

Sphyraenidae. *Sphyraena barracuda* (kaku) larvae were taken three times in September and March from the Sampan Channel.

Perciformes (Stromateoidei)

Nomeidae. *Cubiceps pauciradiatus* larvae occurred three times on June 18, 1971 in both the Sampan Channel and south Kaneohe Bay. Four larvae of *Cubiceps caeruleus* occurred once in March 1972 in the Sampan Channel.

Perciformes (Percoidei)

Labridae (Hinalea). Sixteen labrid larvae of four types were present in the samples. Two could be identified to genus, *Stethojulis* and *Cheilinus*. *Stethojulis* was encountered twice, once in May and once in December; a total of five larvae of this genus was captured. *Cheilinus* was encountered three times, in May, June, and April; three larvae of this genus were taken. Five larvae of *Cymolutes leclusei* were taken on three dates in February, May, and June and two specimens of an unidentified labrid (L-3) were taken in April of 1971. All labrid larvae were captured in the Sampan Channel and all but two (the L-3's) were taken at night. As with the scarids all these larvae were relatively large.

Coryphaenidae (Mahi-mahi). *Coryphaena hippurus* occurred throughout the year, in January, March, April, June, and October; six of the eight times in the Sampan Channel (25 larvae).

Kuhliidae (Ahole-hole). Two small juvenile *Kuhlia sandvicensis* were captured, one in December and one in June.

Kyphosidae (Nenue). Nine larval and one juvenile *Kyphosus cinerascens* were taken on six dates. Nenue were captured in January, April, and March; only two were in south Kaneohe Bay samples.

Kyphosid complex. Two types of generalized percoid larvae are included under this classification. Eight larvae were captured during March and May, primarily in the Sampan Channel.

Mullidae. Eighteen larval mullids of two species were captured in the Sampan Channel on five sampling dates; once in December, once in January, once in March, and twice in April.

Pleuronectiformes

Bothidae. A small, unidentified bothid larva was captured on August 11, 1971 in the Sampan Channel.

Tetraodontiformes

Three larvae of this order, too small to be further identified, were taken on three dates in April and October.

Ostraciontidae (Moa). Two boxfish larvae were captured on March 23, 1972.

Tetraodontidae (Kēkē). Puffers occurred seven times in our samples, in March, April, June, and October. Only 11 larvae and juveniles were captured. The one juvenile identifiable to genus was *Arothron* sp.

Diodontidae ('O'opu kawa). Three *Diodon* sp. larvae were sampled on March 23, 1972 in the Sampan Channel.

Lophiiformes

Seven larvae, identifiable only to order were taken on two dates: February 25 and March 23, 1972.

Antennariidae. A single antennariid was captured on March 9, 1972.

Unidentified Larvae

Aside from unidentified 142 which was discussed earlier, the unidentified larvae (34 kinds) usually occurred in the Sampan Channel. Below is a summary of the occurrences of the unidentified larvae. (Identifications in parentheses were made while this paper was still in production; thus, they are also included.)

Larvae which occurred only once (one fish unless noted otherwise):

M-13	Oct	Sampan Channel
28	Jan	Sampan Channel
62	Oct	Sampan Channel
64	Apr	Sampan Channel
67	Apr	Sampan Channel (two fish)
71	Oct	Sampan Channel
81	Jun	Sampan Channel (two fish)
124	Sep	South Kaneohe Bay (five fish)
131 (Blenniidae)	Mar	South Kaneohe Bay (two fish)
143	Feb	Sampan Channel
152 (Brotulidae)	Jan	Sampan Channel
153	Dec	Sampan Channel
157	Mar	Sampan Channel
161 (Trichonotidae: *Crystallodytes cookei*)	Mar	Sampan Channel (two fish)
162	Mar	Sampan Channel
163 (Scombridae: *Auxis* sp.)	Mar	South Kaneohe Bay
164	Apr	Sampan Channel
165	Apr	Sampan Channel

Larvae which occurred twice (two fish unless noted otherwise):

58	Feb and Apr	South Kaneohe Bay and Sampan Channel
79	Apr and Dec	Sampan Channel
90	Jun and Sep	South Kaneohe Bay and Sampan Channel (five fish)
135	Mar	South Kaneohe Bay and Sampan Channel (four fish)
136	Mar	South Kaneohe Bay and Sampan Channel (ten fish)
151	Jan and Mar	South Kaneohe Bay and Sampan Channel
156	Mar	Sampan Channel (four fish)

Larvae which occurred three or more times (number of occurrences and fish noted):

51	three occurrences	Apr, Sep and Oct	South Kaneohe Bay and Sampan Channel (three fish)
61	four occurrences	Apr, Sep and Dec	South Kaneohe Bay and Sampan Channel (nine fish)
113	three occurrences	Apr and Jul	South Kaneohe Bay and Sampan Channel (fourteen fish)
129	three occurrences	Mar, Apr and Sep	South Kaneohe Bay and Sampan Channel (four fish)
154	three occurrences	Mar, Apr and Dec	Sampan Channel (three fish)

Summary

Patterns of Reproduction

Neglecting Schindleriidae, fish larvae obtained during this study could be divided into four groups on the basis of their adult habitat and mode of reproduction (Table 3): (1) the first group was composed of species of inshore, pelagic fish which spawn pelagic eggs; (2) the second group consisted of reef-associated fish with non-pelagic eggs, including those species with demersal eggs, as well as those which brood their eggs; (3) group III was made up of those reef-associated species which spawn pelagic eggs; and (4) group IV represented offshore, oceanic, pelagic species, all of which presumably spawn pelagic eggs.

TABLE 3. REPRODUCTIVE GROUPINGS

GROUP I

Carangidae (especially *Caranx mate* and *Gnathanodon speciosus*)
Engraulidae
Dussumieriidae
Atherinidae*

GROUP II

Gobiidae
Pomacentridae
Blenniidae
Apogonidae (mouth brooders)
Eleotridae
Syngnathidae
Tripterygidae

GROUP III

Labridae
Scorpaenidae
Acanthuridae
Scaridae
Diodontidae
Chaetodontidae
(and Pomacanthidae**)
Mullidae
Bothidae
Eels
Holocentridae
Synodontidae
Antennariidae
Fistulariidae
Ostraciontidae
Trichonotidae

GROUP IV

Myctophidae
Gonostomatidae
Scombridae
Gempylidae
Exocoetidae**

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*This family is included in group I in spite of the fact that atherinids have demersal eggs; it may actually fit better in group II, however, atherinids are pelagic fish in the sense that nehu are.

**Mode of spawning (i.e., pelagic or non-pelagic eggs) assumed, based on taxonomic considerations.

***Although exocoetids do not have pelagic eggs in the same sense as carangids, the eggs are not brooded or demersal.

On the basis of larval abundance, the seasonality of spawning of these groups could be determined. Although larvae of most of the group II species were present throughout the year, two peaks of abundance were evident. The first extended from late March through mid-May, while the second extended from late September through October. Relatively few larvae of group II were present in the winter or summer, with the exception of some of the blennioids. However, *Omobranchus elongatus* and blenny 5 are almost exclusively bay species (see below).

The larvae of group I were more seasonal in occurrence than those of group II: carangid larvae, for example, were virtually absent from collections made from mid-November through late February. This group containing both summer and winter spawners was not as coherent as group II in its spawning habits.

Carangid eggs and larvae demonstrated trimodal abundance patterns with spring, summer, and fall peaks, rather than the bimodal, spring-and-fall pattern exhibited by the group II larvae.

Atherinids showed June and October abundance peaks. Dussumieriidae larvae were relatively rare in the samples, but a spring-and-fall spawning pattern was indicated. However, makiawa (*Etrumeus micropus*) eggs suggested a unimodal spring-spawning pattern, although a small winter peak of abundance was also noted.

The other important component of group I, the nehu (Engraulidae: *Stolephorus purpureus*) displayed increased numbers of larvae during winter and spring with a peak period from January through May. Nehu eggs were also present in greatest numbers between January and May, but the seasonal pattern differed somewhat from that of the larvae.

Group III was more difficult than the others to characterize because these larvae were extremely rare in the samples: only 232 were taken. Scarids, the most abundant component of this group, were represented by only 143 individuals of the 38,505 total larvae examined. The scarids did, however, exhibit a spring-and-fall pattern similar to that of group II but with a one-month delay (see section on scarids). The limited data suggest a spring-and-fall pattern for the other members of this group as well.

Only 672 group IV larvae were captured, with myctophids being the only family abundant enough (500) to give substantial information on seasonality. Myctophids displayed one large peak of abundance from January through March, but larvae were present in all months except July and September. (The large peak may actually have extended through June.)

The members of both groups I and II are very common in Kaneohe Bay as adults and, as evidenced by these collections, spawn and complete their life cycles within the bay. The larvae of these two groups constituted greater than 90% of all larvae collected (excluding Schindleriidae) at both stations. Of the remaining larvae, 5% were unidentified for various reasons, leaving fewer than 5% of all the larvae in groups III and IV.

The adults of group III are also very abundant members of the Kaneohe Bay ecosystem. Labrids, scarids, and acanthurids are among the most abundant families of reef fishes in Kaneohe Bay. Many of these may spawn in the bay: scarid, acanthurid, synodontid, bothid, scorpaenid, ostraciontid, diodontid, eel, trichonotid, and especially labrid eggs were taken in south Kaneohe Bay or Sampan Channel samples. The larvae of group III, however, were virtually absent from the bay: no fistulariids, 2 ostraciontids, 4 synodontids, 1 bothid, 2 eels, no chaetodontids, 35 scorpaenids, 18 mullids, 8 acanthurids, 143 scarids, no trichonotids and 16 labrids were present among the 38,505 larvae taken. The scarids made up of 0.6% of all Sampan Channel larvae on a per volume basis. Larvae of group IV were also rare.

The larvae in these samples were, almost without exception,[1] either reef fish with demersal eggs (group II) or inshore pelagic fish with pelagic eggs (group I). The eggs were primarily of group I with smaller numbers from group III. Considerably fewer larvae of group III were taken than would be expected, on the basis of adult abundance and egg catches.

The members of group III apparently do not complete their life cycles within the day; on the contrary, their larvae are often found in offshore mid-water trawl samples (Leis and Watson, unpublished data) and several have specialized pelagic pre-juvenile stages. Larvae of lutjanids and chaetodontids were present in these offshore collections, contrary to the statement by Munro et al. (1973) that these families as well as scarids must have a brief planktonic existence.

Thus it seems that for reef fish, the pelagic egg is an adaptation allowing the young to reach oceanic waters where further development takes place. In fact, many of the group III eggs were found to be associated with rising tides when currents are directed into the bay from offshore. Additional support is lent by the observation that the group III larvae, also taken primarily from the Sampan Channel, were generally large individuals nearing metamorphosis (after returning from the open ocean?).

This is not surprising and perhaps should be expected for those species with highly specialized pelagic pre-juvenile or juvenile stages such as eels, chaetodonts, holocentrids, acanthurids, and mullids. It is, however, somewhat unexpected for the labrids, scarids, scorpaenids, ostraciontids, and diodontids. The eggs of those fish with specialized pre-adult stages, except eels, were either very rare or not recognized in the collections, while the eggs of the other members of group III (those without highly specialized stages) were commonly encountered. The former group may migrate out of the bay to spawn.

It is generally agreed that fish larvae are at the mercy of currents. This is a particularly important aspect of the study of Hawaiian fish, since the currents around the Hawaiian Islands may sweep larvae away, leaving them several hundred kilometers from the site of spawning (and land) by the time of metamorphosis.

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[1] The only apparent exception is *Callionymus decoratus*, a reef associated species, which may have pelagic eggs, and made up about 1.5% of all the larvae sampled in south Kaneohe Bay.

The spring-and-fall pattern demonstrated by most species may be an adaptation to the current system present in Hawaii (see Bathen, 1971). The current pattern, on Oahu at least, apparently shifts from a predominately northeast direction in winter to a predominately southeast direction in summer. These shifts, which should be associated with periods of weaker currents, occur with the spring and fall spawning peaks. Synchronization of spawning with periods of reduced current flow would allow development and metamorphosis of the pelagic larvae before they were swept far out to sea. Wourms and Bayne (1973) observed that the brotulid *Dinematichthys ilucoeteoides* spawned during at least one of the calm periods between monsoon cycles in the Indian Ocean and cited this as an advantage to an inshore species.

The fish of group I, which spawn at times other than the shift, are bay species (Clarke, 1973b) which complete their life cycles within the sheltered confines of areas such as Pearl Harbor and Kaneohe Bay and are thus at least partially protected from the dispersing effects of currents. While the larvae of group II would be protected within the bays in the same manner as those of group I, large populations of these species exist in exposed areas of the Hawaiian Islands, where no such protection is afforded. A slack-current synchronization would be especially important for the larvae of group III, which apparently undergo larval development away from embayments. Being swept away from the islands would probably be less detrimental to larvae of group IV, since they are oceanic species.

Current gyres in the lee of Oahu may also prevent larvae from being swept away (Sale, 1970) but this does not exclude the utility of slack-current synchronization, especially on windward coasts such as the Kaneohe area.

Seasonal patterns in primary and secondary productivity in Hawaiian waters are poorly documented, but data available on primary productivity (Krasnick, 1973; S.A. Cattell, Hawaii Institute of Marine Biology, unpublished data) do not parallel the fish spawning pattern indicated by this study's data. Krasnick (1973) demonstrated a peak in Kaneohe Bay primary productivity in November, with a minimum in March. Cattell, working 20 miles north of Oahu, reported a marked spring bloom with a productivity minimum in November. It might be argued that fall-spawning fish are responding to the fall bloom in Kaneohe Bay, while the spring spawners are responding to the spring bloom offshore. However, this would require that the spring larvae move offshore, while the fall larvae stay in the bay. There is no evidence for these movements; indeed, the present study's data indicate that the offshore movement or non-movement of larvae is a function of the mode of spawning rather than the time of year.

Seasonal microcopepod biomass variations in Kaneohe Bay (Bartholomew, 1973) also do not correspond to any of the fish spawning peaks.

From the foregoing it is concluded that: (1) the pelagic egg of reef species may represent a mechanism allowing their larvae to reach open waters; (2) those nearshore species which do not complete their life cycles exclusively in embayments may time their spawning peaks to coincide with times of reduced currents associated with a seasonal shift in current directions; and (3) bay species spawn in a pattern that is less dependent upon seasonal current shifts.

Long-term Changes in the Seasonal Abundance of Nehu

Since the nehu is the major baitfish for the Hawaiian aku (Scombridae: *Katsuwonus pelamis*) fishery, many studies directed at estimating its abundance have been undertaken over the past 20 years. At least four studies were concerned with nehu eggs or larvae in Kaneohe Bay (Yamashita, 1951; Tester, 1951, 1955; Murphy and Clutter, 1972), and two of these (Tester, 1951, 1955) were sufficiently similar to this study so that comparisons of abundance and seasonality could be made.

Tester's initial sampling program consisted of daytime tows at 23 stations throughout Kaneohe Bay (Tester, 1951). One of these stations (#4) is essentially the same as the south Kaneohe Bay station occupied during this study. Comparisons are complicated by the fact that Tester did not measure volumes of water sampled, used a net with two different mesh sizes (.81 and .47 mm), and sampled only four times at station four (in September and December of 1949 and March and June of 1950). If it is assumed, however, that comparable volumes were filtered in both Tester's 10-min meter-net tows and the 10-min tows of the present study, then a rough comparison can be made. For this comparison, the daytime samples of this study taken within ± two weeks of the anniversaries of Tester's tows have been averaged. The results are presented in Table 4.

Subject to the above assumptions, it can be seen (in Table 4) that very similar numbers of larvae (per unit volume) were taken, while during 1971 and 1972 fewer eggs were found. This suggests the possibility of higher egg-to-larval survival in 1971 and 1972. A more interesting feature, however, is the apparent shift in seasonality: Tester obtained the greatest number of larvae in September and December, while during 1971 and 1972 peaks of abundance were found in December and March. June 1971 estimates made by this study were much smaller than Tester's.

More rigorous comparisons were possible with Tester's 1950 to 1952 data (Tester, 1955). In this study, daytime samples at station four (Tester, 1973: personal communication) were taken semi-weekly for two years using a half-meter Hensen egg net with .47 mm mesh. From these, numbers of nehu eggs and larvae per 100 m^3 filtered were calculated, and the data were presented as monthly geometric means. For the purposes of comparison, 1971 and 1972 daytime data was converted to monthly geometric means (see Figures 36 and 37 and Tables 5 and 6).

From both figures, it appears that a definite shift has occurred in the major spawning season: from May through August (1950 to 1952) to February through May (1971 to 1972). However, numbers of eggs and larvae were similar: an average tow in 1950 to 1952 contained 22.72 eggs/100 m^3 and 1.21 larvae/100 m^3, while during the present study an average of 20.33 eggs/100 m^3 and 3.76 larvae/100 m^3 were caught. These differences were not statistically significant, although the difference in number of larvae approached significance at the 0.050 level ($P = 0.10$ for larvae, $P >> 0.050$ for eggs; Cochran modified t-test; Snedecor and Cochran, 1967). Tester took more eggs during his earlier study and similar numbers of larvae in both studies. Thus, in spite of a shift in season, the year-round abundance of larvae apparently has not changed significantly.

TABLE 4. NEHU EGG AND LARVAL ABUNDANCE: 1949-50 AND 1971-72

	EGGS (No. per m^3)	LARVAE (No. per 1000 m^3)
Fall (Sep)		
Tester: 6-8 Sep 1949	3.90	62.10
Leis & Watson: 25 Aug 1971; 7 & 21 Sep 1971	0.20	8.11
Winter (Dec)		
Tester: 27-29 Dec 1949	1.18	24.30
Leis & Watson: 14 & 28 Dec 1971; 11 Jan 1972	0.03	48.19
Spring (Mar)		
Tester: 16-18 Mar 1950	12.11	10.80
Leis & Watson: 25 Mar 1971;	0.06	61.50
9 & 23 Mar 1972	0.05	71.43
Summer (Jun)		
Tester: 21-23 Jan 1950	0.57	16.20
Leis & Watson: 18 & 30 Jun 1971	0.04	0.92
Total		
Tester	17.76	113.40
Leis & Watson	0.33	118.72

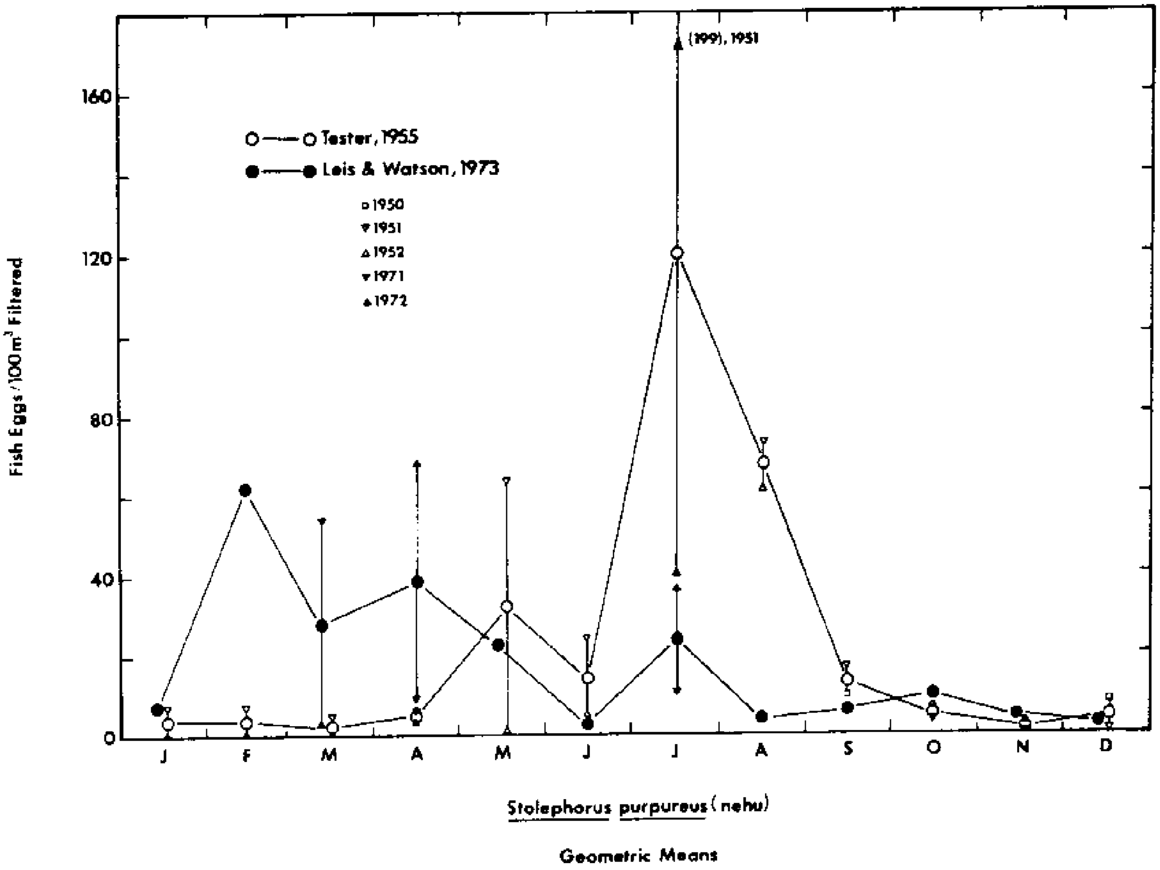

Figure 36. Geometric means of nehu egg abundance.

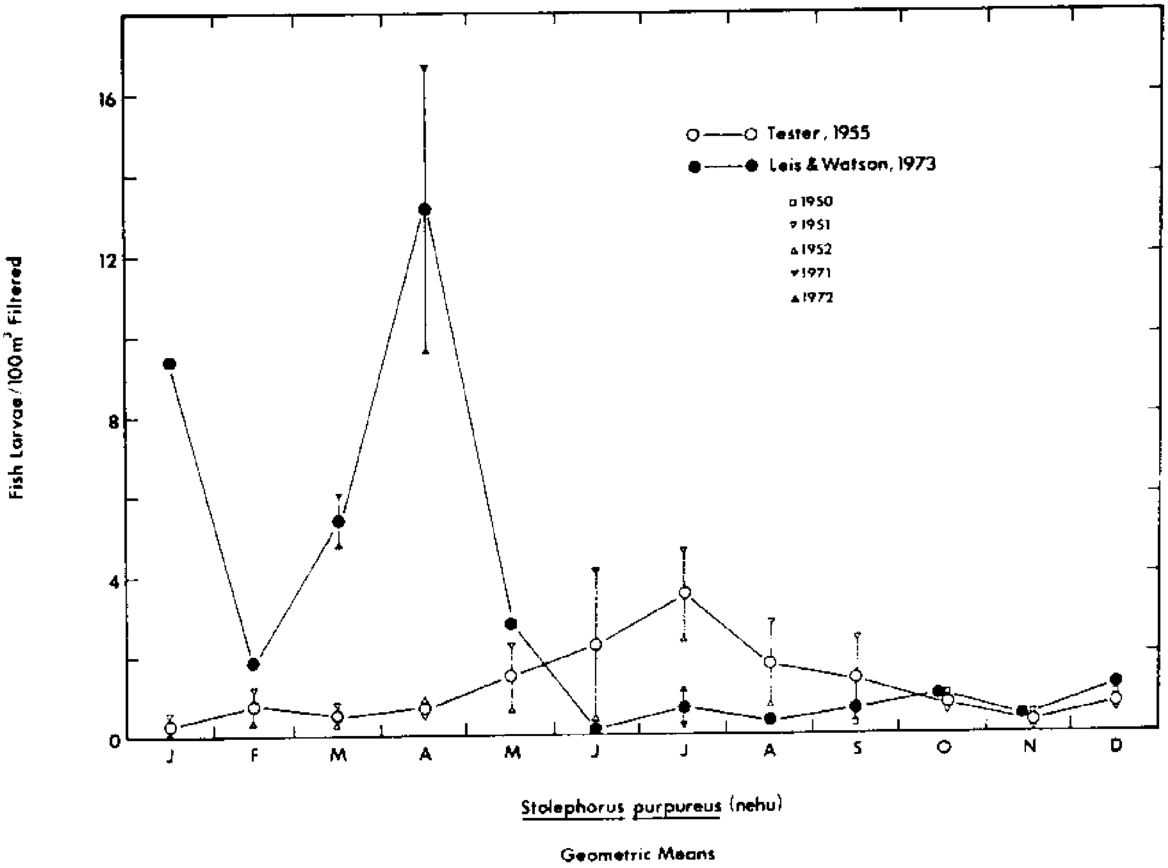

Figure 37. Geometric means of nehu larval abundance.

TABLE 5. NEHU EGG ABUNDANCE: 1950-52 AND 1971-72

	GEOMETRIC MEANS (No. per 100 m^3)		GEOMETRIC MEANS (No. per 100 m^3)	
Month	Leis & Watson	Year	Tester	Year
Jan	7.36	1972	7.38	1951
			0.08	1952
Feb	62.09	1972	7.49	1951
			0.06	1952
Mar	54.20*	1971	4.04	1951
	2.84	1972	0.40	1952
Apr	9.64	1971	5.70	1951
	68.08	1972	4.35	1952
May	23.23	1971	64.30	1951
			0.65	1952
Jun	3.14	1971	24.20	1951
			4.34	1952
Jul	10.96	1971	199.10	1951
	37.58*	1972	40.70	1952
Aug	3.81	1971	73.40	1951
			61.87	1952
Sep	6.21	1971	9.53	1950
			16.40	1951
Oct	8.93	1971	6.09	1950
			4.25	1951
Nov	4.28	1971	2.06	1950
			0.64	1951
Dec	2.54	1971	7.88	1950
			0.38	1951
	Σ = 304.89		Σ = 545.29	
	$\overline{x}$ = 20.33		$\overline{x}$ = 22.72	
	$\hat{\sigma}$ = 23.34		$\hat{\sigma}$ = 43.50	

*only one sampling date during month

TABLE 6. NEHU LARVAL ABUNDANCE: 1950-52 AND 1971-72

Month	GEOMETRIC MEANS (No. per 100 m^3) Leis & Watson	Year	GEOMETRIC MEANS (No. per 100 m^3) Tester	Year
Jan	9.44	1972	0.58 0.14	1951 1952
Feb	1.84	1972	1.13 0.38	1951 1952
Mar	6.07* 4.79	1971 1972	0.70 0.37	1951 1952
Apr	16.67* 9.66	1971 1972	0.58 0.78	1951 1952
May	2.79	1971	2.22 0.65	1951 1952
Jun	0.12	1971	4.10 0.35	1951 1952
Jul	0.24 1.12*	1971 1972	4.61 2.19	1951 1952
Aug	0.36	1971	2.85 0.68	1951 1952
Sep	0.64	1971	0.30 2.47	1950 1951
Oct	0.99	1971	0.96 0.59	1950 1951
Nov	0.45	1971	0.42 0.25	1950 1951
Dec	1.22	1971	1.15 0.50	1950 1951
	$\Sigma = 56.40$ $\bar{x} = 3.76$ $\hat{\sigma} = 4.81$		$\Sigma = 28.95$ $\bar{x} = 1.21$ $\hat{\sigma} = 1.23$	

*only one sampling date during month

The small differences detected in overall egg and larval abundance might be attributable to "good" or "bad" years, but the shifts in seasonality cannot be so explained.

Application of a three-point moving average to our data resolved the seasonal pattern of abundance into a series of peaks of varying magnitudes, but of fairly regular intervals of ten + two weeks (Figure 38). From the above, it was hypothesized that this is the approximate period required for attainment of sexual maturity after hatching. Yamashita (1951) estimated metamorphosis at six to seven weeks after hatching, at a length of about 30 mm SL--the approximate size of the smallest ripe females. Each peak of egg abundance, then, would be primarily the result of spawning by nehu produced during the previous spawning peak. It should be pointed out that integer multiples of the 10-week periodicity work as well. For example, a 20-week maturation period with a separate fraction of the fish spawning during alternate peaks leads to the same result as a 10-week periodicity.

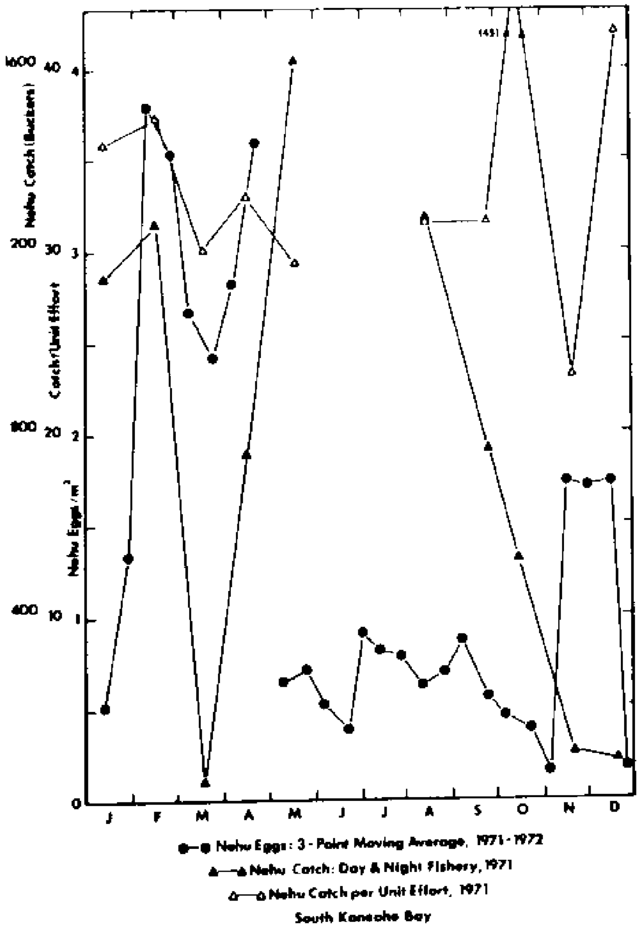

Figure 38. Total monthly commercial nehu catch, catch per unit effort, and moving average of nehu egg catches.

In addition, both Tester's studies and the data presented here suggest the possibility of a larger periodicity, shown by higher peaks of egg abundance at about 56-week intervals. If it is assumed that this is real, then in 20 years the major peak will have advanced approximately 28 weeks, placing the 1971-72 peak in February and March, five months earlier than the 1951-52 peak. The observed period of greatest abundance during 1971 and 1972 extended from February through May, not inconsistent with this projection.

Bachman (1963) noted that commercial nehu catches suggest a long-term cyclic fluctuation in numbers, but with a period roughly twice as long as that suggested by the egg and larval data: see Bachman's Figure 1 for Kaneohe Bay. This longer period, assuming that it is about 112 weeks, would lead to the same predicted timing for the 1971-72 peak.

Superposition of an 8 to 12 week maturation period (a short cycle) on a (Bachman's) slightly longer than two-year period (a long cycle) might explain the 56-week periodicity apparent in the two-year sampling programs. Since the long cycle is somewhat longer than two years and an integer number of short cycles will not fit in two years, both would be in different phases at a given time in the second year relative to their phases at that same time during the first year. If these cycles are assumed to be simple sinusoidal functions and are added as such, then a peak in the first year will not occur at the same time in the second year. If the phases were such that a four-week offset occurred during Tester's studies, then 20 years later the phases should again be in approximately the same relative positions, leading again to a roughly four-week offset which would appear as a 56-week major periodicity.

This explanation was not pursued in any depth; however, it might be informative to make simulations of this situation, varying the periods of the cycles and comparing the results with observed fluctuations in numbers. From the present data, it would also be possible to generate confidence intervals using the small-scale fluctuations.

Tester (1973: personal communication) has suggested that a change in the timing of maximum fishing pressure on the nehu population could account for the seasonal shift by temporarily reducing the size of the spawning population. If this were the case, then periods of high nehu catches should coincide with or immediately precede periods of low egg abundance. Linear correlations of monthly means of this study's egg data on 1971 monthly nehu catches in Kaneohe Bay (Figure 39) indicate no significant relationships with either total catch or catch per unit effort ($R = 0.22$ and -0.01 respectively, with 8 degrees of freedom; $P > 0.050$). Bachman (1963) also found no correlation between fishing effort and the two-year abundance cycle. This suggests that periods of high egg abundance are not a function of fishing pressure; however, the data are somewhat ambiguous (see Figure 38) and more detailed analyses of data covering a longer span of time will be required to resolve this question.

A third possibility is that the environmental degradation in Kaneohe Bay over the last 20 years has progressed to the point that summer survival of larvae is reduced, with a compensatory increase in winter survival. Bachman (1963) also suggested that environmental degradation was involved in a gradual decline in the nehu population between 1948 and 1960.

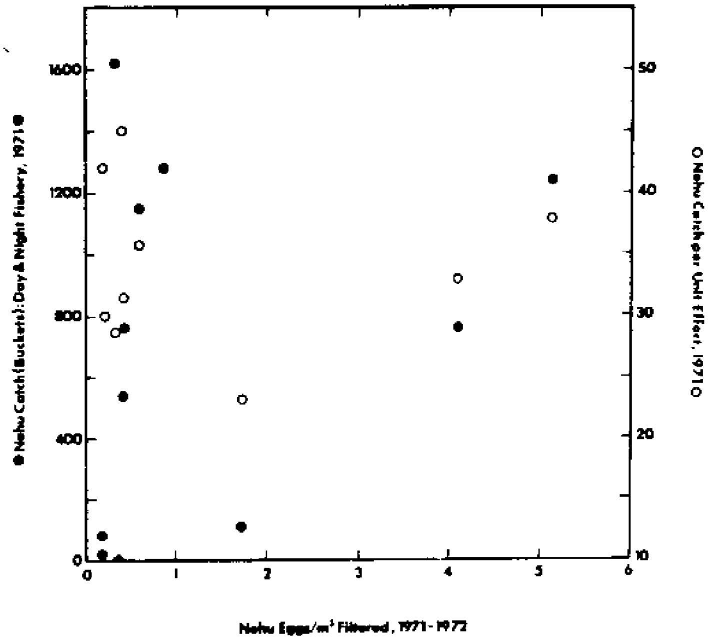

Figure 39. Total commercial nehu catch and catch per unit effort vs 1971 egg catches.

Stress associated with elevated water temperatures, combined with sewage inputs and urban runoff, might reduce survival of summer-spawned larvae, shifting peaks of abundance from summer to spring. If this is occurring, and assuming no seasonal differences in growth rates, the ratio of nehu larvae to nehu eggs should be reduced in summer and fall compared with winter and spring. For this study's data, the average May through October ratio was 0.47 larvae/egg, while for November through May the ratio was 1.38 larvae/egg. This difference approached significance at the 0.050 level ($t = 2.016$; $t_{.05} = 2.166$). Tester's 1951-52 ratios were: summer-fall, 0.018; winter-spring, 0.003. Consequently, this should be considered a real possibility.

In summary, it appears that over the past 20 years a shift in peak spawning from May through August to February through May has occurred, possibly as a function of a 56-week cycle of abundance of unknown origin, with a superimposed 10-week maturation period, or alternatively, as a result of a difference in the season of maximum fishing pressure, or a reduction in summer survival caused by increased stress.

No significant changes in overall abundance of either eggs or larvae were detected. Data from the nehu fishery support the observation that a large-scale change in numbers has not occurred: during Tester's studies (1950-52) the Kaneohe Bay fishery yielded yearly catches of between 5157 and 11,825 buckets (Bachman, 1963), while during 1971 the total catch was 7575 buckets. The catch per unit of effort varied between 26.05 and 39.84 buckets/boat-day during the years of Tester's studies; it was 33.22 during 1971 and 1972.

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APPENDICES

APPENDIX A. EGG IDENTIFICATION

APPENDIX A. EGG IDENTIFICATION

To aid in identifying the many types of pelagic fish eggs encountered during the course of this study, an artificial key was constructed (see page 101). The key includes all types of eggs encountered in the samples, as well as a few others (noted below) not in the samples but which occurred close to the study area (i.e., just outside Kaneohe Bay).

When this project was initiated, the only pelagic fish egg from Kaneohe Bay identifiable with any certainty was the engraulid, *Stolephorus purpureus* (Yamashita, 1951). Mr. David Hashimoto of the Hawaii Institute of Marine Biology had also tentatively distinguished the eggs of the carangids, *Caranx mate* and *Gnathanodon speciosus*, and the dussumieriid, *Etrumeus micropus*--all from south Kaneohe Bay. Hashimoto's identifications of *G. speciosus* and *E. micropus* were confirmed during this study. However, several kinds of eggs closely resemble those of *C. mate* (the omaka), and identification of this egg is not yet certain.

Pelagic fish eggs of 43 types were distinguished from Kaneohe Bay. Of these, 30 were identified to some taxonomic level, although some identifications were tentative: 27 were identified at least to the familial level, 13 to the generic level, and 8 to the specific level. The purpose of this section is to discuss the methods used in identifying the eggs encountered during the study and to provide some notes on those eggs.

During counting (see Methods), whenever an unfamiliar egg was encountered, it was described using observations made with a stereoscopic dissecting microscope fitted with an optical micrometer. The new egg was usually photographed. Later the description was checked and, if necessary, synonymized with previously recognized eggs. New eggs were assigned roman numerals until more specific names could be assigned.

It was possible to adequately identify eggs only before they were preserved. Upon preservation eggs usually cloud and shrink obscuring interior details, the chorions may become deformed, and oil droplets shatter and change positions. De Sylva (1970) also encountered this problem. Preserved specimens of most eggs have been retained for reference but have proved to be of little use. It is likely that the key will be of limited value for identifying preserved eggs of less than 1 mm diameter.

Egg Diameter. This is one of the most useful characteristics. Ranges of greater than 100 microns in diameter for any egg type were rare. Also, little seasonal change in egg diameter was found. This contrasts with conditions found in temperate regions (e.g., Hiemstra, 1962), possibly due to the relative constancy of temperature and salinity and, therefore, density in Kaneohe Bay when compared with temperate waters.

Oil Droplets. The presence or absence, color, size, and positioning of oil droplets are very valuable characteristics. In some types of eggs (e.g., omaka) the position of the oil droplet relative to the developing embryo is constant.*

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*It cannot be overemphasized that this key was developed for live eggs floating freely in seawater. In dead eggs and those restricted in movement

In other eggs the oil droplets appear to move relative to the embryo, when actually the embryo is growing past the stationary droplets (e.g., egg Type XX). Finally, several eggs contain droplets or clusters of droplets which actually do move ontogenetically (e.g., *Crystallodytes cookei*). Knowledge of these movements or the lack of them is essential in identifying eggs of different ages.

Very little variation (typically $< 50\mu$) in the size of oil droplets in eggs with only one droplet was found. In eggs with clusters of droplets, both the size and the number of droplets may vary among eggs and within the same egg during development.

Most of the oil droplets seen are colorless or slightly yellow, but some may be red (e.g., Labrid III) or bright yellow (e.g., Egg Mass C).

Egg Shape. Most pelagic eggs are spherical; however, some are ovoid and the scarid eggs are spindle-shaped.

Chorion. A few types of eggs have bumps or ornamentation on the chorion which are taxonomically significant (e.g., Bothid II, Synodontidae).

Pigment. Embryonic pigment was of limited value since it is absent in the early developmental stages, varies greatly with the age of the egg, and is generally not distinctive. However, several types of carangid eggs as well as some others have melanophores and/or white pigment granules on the yolk sac or on the oil droplet which are useful taxonomically.

Egg Masses. Several types of eggs occur only in gelatinous masses of 100 or more eggs. This serves to distinguish them from single, free-floating eggs.

Embryo Shape. This characteristic, like embryonic pigment, is of limited utility for many of the same reasons as pigmentation. However, for some eggs it is a helpful supplement (e.g., Tetraodontiformes).

Yolk Configuration. The width of the perivitelline space is useful for some eggs such as eels, but in most it is very narrow and non-distinctive. Although some authors (e.g., Uchida et al., 1958) have used segmented yolk as a diagnostic characteristic, this was not used in the present study, since the counting technique did not facilitate easy determination of this difference.

The most useful procedure for identifying, as opposed to differentiating, eggs is rearing them in a laboratory situation. This procedure was used to identify eggs whenever sufficient numbers were available to make the attempt worthwhile. All eggs were reared in seawater from Kaneohe Bay at ambient temperatures which varied from 22° to 27.5°C. Many authors have commented on the difficulties of rearing marine fish larvae from eggs (e.g., May, 1970,

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the droplets will often move to unnatural positions. For example, when an egg is placed in a shallow watch glass the droplet(s) often migrates to the top of the egg, regardless of natural positioning.

1971) and most of these difficulties were encountered in this study. Although most attempts were less than successful, if more effort had been put into this subsidiary phase of the study, better results probably could have been obtained.

Short discussions for most of the eggs which were distinguished are given below. No attempt was made to provide complete descriptions for the eggs; rather this section should be used in conjunction with the key and its accompanying table as information contained there is not repeated here. Where possible, papers are cited which describe the eggs of the species or closely related species involved; the reader is referred to these papers and figures of this paper for more details.

Eel Eggs. (See Figure A2 of Appendix A.) Several species and at least two families are included under this heading. This class of eggs was originally identified through rearing. These eggs resemble Eldred's (1969) descriptions of muraenid eggs. The size range (2.4 to 3.8 mm) is extremely large compared with other eggs discussed here; this is probably due to the large number of species represented. More than 50 shallow water eel species of six families are known in Hawaii (Gosline and Brock, 1960). Rearing revealed that muraenids and perhaps ophichthids and congrids were present. It was not possible to differentiate types due to the size continuum among the eggs (Figure A1 of Appendix A) and the lack of oil droplets or color; some yolks were slightly yellowish, but this was not helpful. However, the size-frequency graph suggests that at least six species may have been taken.

An interesting result of the rearing attempts was the discovery that, a few days after being collected (in the blastula stage), the eel eggs would sink. They then remained on the bottom of the rearing container until they hatched. This may represent a mechanism for reaching deeper water layers and may also explain why only young (i.e., gastrula or earlier stage) eel eggs were present in the samples. Incubation time was typically 10 to 14 days with the eggs sinking on about the fourth day. Some leptocephali lived for 12 days after hatching.

Elopomorpha (Offshore A). (See Figure A3 of Appendix A.) This egg, like the Offshore B egg, is one which did not occur in these samples, but it is known from the area just seaward of the Sampan Channel. One rearing attempt ended when the larvae died while attempting to break out of the egg membrane. The embryo was developed enough at that point, however, to be identified as that of an eel, or at least a fish with a Leptocephalus larvae--for example, eel, Albulidae or Elopidae. In the blastula stage, the yolk sac fills most of the egg but, as development proceeds, the yolk sac shrinks markedly.

Dussumieriidae: *Etrumeus micropus* (makiawa). (See Figure A4 of Appendix A.) This clupeoid egg was identified by rearing. The eggs and larvae match published descriptions of makiawa (Uchida et al., 1958), except that *E. micropus* eggs in Kaneohe Bay are somewhat larger (1.40 to 1.50 mm) than those from Japan (1.32 mm).

Engraulidae: *Stolephorus purpureus* (nehu). (See Figure A5 of Appendix A.) The eggs and larvae of the nehu are described by Yamashita (1951); his figures were published by Nakamura (1970).

Synodontidae: Synodont I. (See Figure A6 of Appendix A.) These eggs were identified by rearing. The characteristic hexagonal pattern of the chorion distinguishes these eggs from all others found in Kaneohe Bay.

Kuthalingam (1959) described the eggs of *Saurida tumbil* from India. Synodont I eggs are similar to those of *S. tumbil* although somewhat larger--1.25 vs 1.12 mm diameter. They may be those of *Saurida gracilis*, a common Hawaiian synodont. Mito (1961) described seven synodonts of three genera; Synodont I most closely resembles those eggs attributed by Mito (1961) to *Saurida* spp.

Synodont II. (See Figure A7 of Appendix A.) These were the most spectacular eggs encountered during the course of the study. Delsman (1938) has described what are apparently synodont eggs from Java with an oil droplet and similar chorion ornamentation, although he could not attribute them to any genus. Mito (1961) illustrated as "Myctophida No. 1" an egg similar to Synodont II, but larger in size with smaller spikes; the hatched larvae are also similar. This identification must be considered tentative.

Fistulariidae: *Fistularia* sp. (See Figures A8 and A9 of Appendix A.) This egg was identified by rearing. The egg hatches in five to six days from the early blastula stage, and the larvae were kept alive for two weeks after hatching.

Kaneohe Bay *Fistularia* sp. eggs correspond closely with those described for *Fistularia villosa* (=*serrata*) by Delsman (1921). There are slight differences, however: (1) *Fistularia* sp. is slightly larger (1.65 to 1.75 mm) than *F. villosa* (1.50 to 1.70 mm); and (2) *Fistularia* sp. does not develop pigment on the yolk sac before hatching as does *F. villosa*.

Unfortunately, Delsman gave no reason for attributing the egg (collected from the plankton) to *Fistularia villosa* rather than *Fistularia petimba* (=*depressa*), which also occurs in the area. In fact, Delsman (1921) stated "the differences between both species are evidently too slight to allow us to distinguish them [*F. petimba* and *F. villosa*] in such young stages as described in the present article" (p. 104). Later he (Delsman, 1930) seemed to hedge on his previous identification in his re-publication of some of the same figures of *Fistularia villosa*, calling them *Fistularia*, but not attributing them to either species.

More recently, Mito (1961) described the eggs of *F. petimba* from Japan which he obtained from ripe females and from the plankton, and included a condensed version of Delsman's description of *F. villosa* eggs. *F. petimba* eggs were described as large (1.80 to 2.10 mm) and lacking the "double chorion" of both *Fistularia* sp. and *Fistularia villosa*.

Kaneohe Bay *Fistularia* sp. eggs are evidently not *F. petimba*, but could very well be *F. villosa* or those of a third *Fistularia* sp. (undescribed?), which was not attributable to either of the previously recorded Hawaiian species.

Labridae: *Thalassoma duperreyi* (and other species?). Stripped and fertilized eggs of this common labrid were provided by John Heiser of Cornell, a visiting investigator at the Hawaii Institute of Marine Biology. There are currently seven recognized species of this genus in Hawaiian waters (L.R. Taylor, 1973: personal communication), and it is likely that at least some of them have eggs sufficiently similar to *T. duperreyi* as to make them very difficult to distinguish. See Mito's (1962) figures of *Stethojulis kalosoma* eggs; these eggs are very similar to those of *T. duperreyi*. Incubation time is about 24 hours. Reared larvae lived only a few days.

Labrid II (Type VIIIa). (See Figure A10 of Appendix A.) This tentative identification is based on the similarity of both egg and yolk sac larvae of Labrid II to those of *Thalassoma duperreyi*. (See also Mito, 1962.) Incubation time is about 24 hours. Larvae lived four days in rearing experiments.

Labrid III (Type XXV). This tentative identification is based on yolk sac larvae (field specimens) which are almost certainly labrids. Since the oil droplets of the eggs and larvae were of the same color (red) and diameter, the larvae were assumed to have hatched from this egg. The egg was not reared since it was encountered only once and in small numbers. The egg is similar to one described by Bolin (1930) from *Oxyjulis californicus*; this genus does not occur in Hawaii (Gosline and Brock, 1960).

Labrid IV (Type XXVII). This identification is also tentative, being based on reared yolk sac larvae which resemble other labrids (Mito, 1962) and on the general appearance of the egg. The larvae hatched in about 24 hours and lived two days in the single rearing attempt.

Scaridae. (See Figures A11, A12, and A13 of Appendix A.) Two types of scarid eggs, both probably of the genus *Scarus*, were taken. These eggs were rare in the samples. In both types of eggs the oil droplets were positioned either centrally or at one end of the egg, possibly the result of an ontogenetic change or a change due to death and disorganization of the egg. Mito (1962) and Winn and Bardach (1960) described similar eggs. Mito's figures of *Scarus chlorodon* (=*Callyodon ovifrons*) are very similar to Scarid I.

One rearing attempt was carried out but ended in failure when the eggs died before hatching.

Scorpaenidae. (See Figure A14 of Appendix A.) Two types of scorpaenid egg clusters were taken. Rearing attempts were not successful in identifying these eggs. A Type II cluster took two days to hatch. Larvae have never lived longer than four days. Many authors have described egg masses similar to these, and attributed them to scorpaenids (e.g., Mito and Uchida, 1958; David, 1939).

A *Scorpeonodes guamensis* caught handlining off Maui extruded clusters very similar to Type II.

Carangidae: *Gnathanodon speciosus* (pa'opa'o). (See Figure A15 of Appendix A.) The egg of *G. speciosus* was identified by rearing larvae hatched from field-caught eggs. The oil droplet in this egg is always opposite the center of the developing cell disc or embryo regardless of the age of the egg. The yolk and embryo have a yellowish cast due to white or yellow pigment granules which appear about midway during development. Hatching takes place approximately 18 hours after spawning (see section on *G. speciosus* eggs). Maximum age of reared larvae was greater than 30 days.

Caranx mate (omaka). The egg of the omaka is very similar to that of *G. speciosus*, but smaller and without the yellow color. The egg is typically carangid. Incubation time is approximately 24 hours. Reared larvae lived for as long as 60 days. See Miller and Sumida (1974) for a more complete description of omaka development.

Type XLIII. (See Figure A16 of Appendix A.) This carangid egg, almost certainly of the genus *Caranx*, is so similar to the omaka egg that it is still not certain that it is not *C. mate*. It is differentiated from omaka primarily by its slightly smaller size (see Key to the Pelagic Fish Eggs of Kaneohe Bay on page 101). Attempts at rearing this egg were complicated by its similarity to the omaka and by the fact that omaka and Type XLIII co-occurred. Since separating Type XLIII eggs for rearing was virtually impossible, rearing attempts have been inconclusive. In addition to *C. mate*, *C. sexfasciatus*, *C. ignobilis*, and *C. melampygus* are known to occur in substantial numbers in Kaneohe Bay, although it is not known if any of them spawn in the bay.

Bothidae: Bothid I. (See Figures A17 and A18 of Appendix A.) This egg was also identified by rearing. The incubation time is two to three days. Several of the larvae survived for 10 days. It is possible that this is the egg of some other type of flatfish (i.e., Pleuronectidae) but since bothids are by far more common in Kaneohe Bay, this seems to be the best identification and the presence of oil droplets on the yolk supports this identification. The migration of the oil droplets from a tight cluster (Figure A17) to being scattered over the yolk (Figure A18) takes about four hours.

Bothid II. (See Figure A19 of Appendix A.) Also identified by rearing, this unique egg hatched in two to three days. Larvae from this egg lived for as long as nine days. Mito (1960a) illustrated a very similar egg as "Bothidae No. 8," but this egg was about 100μ larger and had a single oil droplet, while Bothid II had four or five oil droplets.

Bothid III. In all respects but size, including yolk sac larvae, this egg resembled Bothid I; however, the difference in size is sufficient, in the authors' opinion, to differentiate them. They occurred together in the samples. Although the earliest stage of this egg has not been seen during this study, it is likely to be similar to Bothid I with the droplets clustered.

Acanthuridae. (See Figure A30 of Appendix A.) These eggs, surprisingly rare in these samples considering the number of adult acanthurids in Kaneohe Bay, were identified by rearing. On only one occasion were more than a few eggs taken. During rearing attempts one larva from which the identification was made was kept alive for four days. The larvae hatched in less than two days. The eggs and larva were similar to those described for *Acanthurus triostegus sandvicensis* by Randall (1961).

Diodontidae: *Diodon* sp. (See Figures A20 and A21 of Appendix A.) This egg was identified by rearing. The oil droplets are clustered opposite the developing cell disc early in development and spread out somewhat caudad, clustering again at the posterior portion of the yolk sac by hatching. The eggs hatched in four days and the reared larvae lived for one month. This egg will be more fully described in a future publication (Leis et al., *The pelagic eggs and larvae of three Hawaiian Tetraodontiform fishes*, in preparation). A similar, but larger (2.1 mm) egg has been found near Moku Manu Island (near Kaneohe Bay) and may be the other local *Diodon* sp. This egg is not included in the key.

Ostraciontidae. (See Figure A22 of Appendix A.) Also identified by rearing, this egg took four to five days to hatch. The larvae have lived for one week in several experiments. The slightly oblong shape, combined with the easily missed rough patch, is unusual and serves to distinguish this egg along with Tetraodontiformes II from all others. This egg will be more fully described in the future (Leis et al., *The pelagic eggs and larvae of three Hawaiian Tetraodontiform fishes*, in preparation).

Tetraodontiformes II. (See Figure A23 of Appendix A.) This egg, similar in many respects to the Ostraciontidae egg, may be that of the cowfish *Lactoria* (Ostraciontidae). It and the ostraciontid were not common in the samples.

Molidae: *Ranzania laevis*. The eggs of this molid were present in only one sample during the survey. However, subsequent to the survey, a large number were secured and reared. The egg hatched in five days and lived for more than a week afterward. This egg will also be more fully described in the future (Leis et al., *The pelagic eggs and larvae of three Hawaiian Tetraodontiform fishes*, in preparation).

Schindleriidae: *Schindleria* spp. (See Figure A24 of Appendix A.) Two species of this neotenous family, both members of the type genus, are known from Hawaii and both occurred in the samples. The eggs appeared rarely in the samples. Adult *Schindleria* spp. were often taken, with many running ripe females among them. Upon dissection the distinctive eggs are readily visible. The authors are unsure whether the specimens of these eggs taken in their samples are pelagic or are actually demersal when fertilized and were merely extruded by the ripe females after capture.

Trichonotidae: *Crystallodytes cookei*. (See Figures A25, A26, A27, and A29 of Appendix A.) This very unusual egg has extensive ontogenetic movements of the oil droplets. These movements are so radical that seven of the stages were described as different eggs at one point in the study. In the early cleavage stage the droplets are arranged on the periphery of the equatorial plane of the egg. As the egg develops the droplets move toward the vegetal pole, riding the edge of the germ ring to eventually coalesce into a cluster at the caudal end of the now developed embryo. The embryo then grows past the oil droplets which are at the belly just prior to hatching. In spite of repeated attempts to rear the larvae of this egg, none have lived longer than six days after hatching. However, a size series of larvae has been built from other plankton collections, allowing identification of this egg as that of the trichonotid, *Crystallodytes cookei*. *C. cookei* eggs take approximately two days to hatch from specimens at the earliest stage described.

Type VIIIb. (See Figure A28 of Appendix A.) This egg is a smaller version of *Crystallodytes cookei*. The two eggs undergo the same development and give rise to similar larvae, but larvae from Type VIIIb eggs have approximately 10 fewer myomeres. This egg has tentatively been attributed to the other Hawaiian trichonotid, *Limnichthys donaldsoni*.

Types VIIIc and XIX. (See Figure A31 of Appendix A.) These two eggs are very similar with overlapping size ranges. Except for the fact that they give rise to two very different types of larvae, they are nearly undistinguishable. Larvae have not lived long enough (approximately four days) in rearing experiments to be identified.

Type XVII. This unidentified egg was very rare.

Type XIX. (See Type VIIIc.)

Type XX. (See Figure A32 of Appendix A.) This is one of the various types of eggs in which the embryo grows past the oil droplet as it develops. This results in an apparent migration of the oil droplet. In spite of the fact that the larvae from this egg have survived more than two weeks after hatching, they have not yet been identified.

Kyphosidae: *Kyphosus cinerascens*. (See Figure A33 of Appendix A.) This egg was uncommon in the regular samples, but was very abundant off Moku Manu Island. Subsequent to this study, a large number of these eggs were secured and reared for more than a month; they proved to be the eggs of the nenue, *Kyphosus cinerascens*.

Types XXIX and XXX. These eggs have been encountered infrequently and have always been dead when seen. They are possibly damaged omaka (*Caranx mate*) eggs.

Type XXXIV. Rare in the samples (see Key to the Pelagic Fish Eggs of Kaneohe Bay on page 101).

Type XXXV. This egg resembles that of an acanthurid. The one attempt at rearing was inconclusive in attempting to identify the egg. Type XXXV hatched in 24 hours; the larvae lived for only two days.

Type XXXVI. (See Key to the Pelagic Fish Eggs of Kaneohe Bay on page 101.)

Type XXXIX. (See Figure A34 of Appendix A.) This rare egg resembles the Tetraodontiformes II egg; however, since sufficient numbers could not be obtained for rearing, it is not certain that they are the same.

Type XLII. (See Figure A35 of Appendix A.) This is the smallest egg encountered during the study and the smallest the net would retain. One attempt at rearing failed when the eggs did not hatch.

Offshore B. This egg was encountered twice, but not in the regular samples as discussed in this report. It is probably an eel.

Egg Mass C. This very large mass of eggs was encountered only once, but not in the samples and is described from a preserved specimen.

Egg Sizes. The distribution of sizes among the eggs was unusual in that it was not a continuum as might be expected. The eggs are distinctly grouped into diameter categories (Figure A36 of Appendix A).

The first category extended from 550µ to 900µ with many types at or about 750µ.

No single eggs were between 900µ and 1000µ in diameter.

A second size group extended from 1000µ to 1200µ and a third from 1250µ to 1300µ. Only one egg was found in the 1300µ to 1400µ range. Several eggs were between 1400µ and 1750µ diameter and only the eels and Offshore B were larger (2400µ to 3800µ).

The reasons for these size groupings are obscure. In general, larger eggs have a longer incubation time than smaller ones, although this is not exclusively true. For example, the small Type VIIIb's and Type VIIIc's take two to three days to hatch, as do the larger makiawa eggs, while the small carangid eggs require only one day.

It would be interesting to examine in more detail the relationships between egg size, amount of oil in the droplets, yolk size, incubation time, and state of development at hatching.

KEY TO THE PELAGIC FISH EGGS OF KANEOHE BAY

A. Eggs in gelatinous clusters - B

Eggs single, not clustered - C

B. Clustered eggs (A)

1. A single yellow oil droplet present in each egg - Egg Mass C
   No oil droplet present in eggs - 2
2. Eggs in cluster "tightly packed," eggs not spherical (800 to 850 x 600 to 650 microns) - Scorpaenid Egg Mass I
   Eggs in cluster "loosely packed," eggs spherical (725 to 750 microns) - Scorpaenid Egg Mass II

C. Single, non-clustered eggs (A)
Egg spherical or nearly so - E
Egg oblong; (major axis $\geq$ 2 x minor axis) - D

D. Oblong eggs

1. Egg without oil droplets - 2
   Egg with a single oil droplet - 3
2. Egg approximately 1.75 x 0.65 mm; no "cap" on one end - *Stolephorus purpureus*
   Egg approximately 1.30 x 0.50 mm; a "cap" on one end - Schindleriidae
3. Egg approximately 1.50 x 0.50 mm - Scarid I
   Egg approximately 1.70 x 0.50 mm - Scarid II

E. Spherical eggs (C)

1. Chorion smooth with no bumps, facets or "spikes"; may have a small rough patch at one pole - 5
   Chorion with facets, spikes, bumps or having a pockmarked appearance - 2
2. Chorion with hexagonal or pentagonal facets, no oil droplet present - Synodontidae I
   Chorion without facets - 3
3. Chorion with "spikes" projecting radially, an oil droplet present - Synodontidae II
   Chorion without spikes - 4
4. Chorion smooth except for a single, large projection (i.e., bump) - Bothid II
   Egg membrane rough, pockmarked with no bump above - Type XXIX
5. Egg diameter greater than 950 microns - F
   Egg diameter less than 950 microns - G

F. Large, smooth, spherical single eggs (E,5)

1. Egg diameter greater than 1400 microns - 2
   Egg diameter less than or equal to 1400 microns - 11

2. Egg diameter greater than 2000 microns - 3
   Egg diameter less than 2000 microns - 5

3. Oil droplet(s) present - 4
   Oil droplet(s) lacking - Eel (Anguilloidei)

4. A single, yellow oil droplet present - Elopomorpha (Offshore A)
   Many colorless oil droplets scattered over yolk sac - Offshore B

5. No oil droplets present - 6
   Oil droplet(s) present - 7

6. Egg diameter 1.65 to 1.75 mm - *Fistularia* sp.
   Egg diameter 1.45 to 1.53 mm - *Etrumeus micropus*

7. Egg diameter approximately 1.60 mm or greater; having fewer than 20 oil droplets; no or few melanophores on yolk - 8
   Egg diameter less than 1.60 mm; approximately 20 yellowish oil droplets either clustered in the early stage or widely scattered over yolk in the late stage, in later stages with melanophores scattered on yolk - *Ranzania laevis*

8. Only two oil droplets (may coalesce--one much smaller than the other), both opposite embryo - Type XXXIX
   Egg with from 5 to 15 oil droplets, either clustered or scattered - 9

9. Egg spherical with no rough patches - *Diodon* sp.
   Egg slightly oblong with a small rough patch which may be easily overlooked at one pole - 10

10. Egg 1.6 x 1.9 mm, one or two oil droplet clusters - Ostraciontidae
    Egg 1.6 x 1.7 mm, only one cluster of oil droplets - Tetraodontiformes II

11. No oil droplet or clusters present - Type XVII
    Oil droplets or clusters present - 12

12. Only one oil droplet present - 13
    More than one oil droplet present - 14

13. Egg diameter 1.0 to 1.1 mm, droplet position varies ontogenetically but is directly opposite embryo in early stages - *Kyphosus cinerascens*
    Egg diameter 1.25 to 1.35 mm, droplet position varies, but never directly opposite embryo - Type XX

14. Egg diameter greater than 1.2 mm - Bothid I
    Egg diameter less than 1.2 mm - 15

15. Oil droplets randomly scattered over yolk sac, not clustered - Bothid III
    Position of oil droplets varies ontogenetically, but never randomly scattered over yolk sac - *Crystallodytes cookei*

G. Small, smooth, spherical single eggs (E,5)

1. No oil droplets or clusters present - 2
   Oil droplet(s) or clusters present - 6

2. Egg diameter greater than 600 microns - 3
   Egg diameter approximately 550 microns - Type XLII

3. Chorion somewhat rough (pockmarked) - Type XXIX
   Chorion smooth - 4

4. Egg diameter 850 to 875 microns - Type XXXIV
   Egg diameter 700 to 800 microns - 5

5. Egg diameter 700 to 750 microns - Type VIIIc
   Egg diameter 750 to 800 microns - Type XIX

6. Egg with a single droplet - 7
   Egg with two droplets approximately 150 and 125 microns diameter - Type XXX

7. Egg with a single oil droplet directly opposite cell disc or center of embryo - 9
   Oil droplet not directly opposite, but at side of cell disc - 8

8. Egg diameter 700 to 750 microns - Type XXXV
   Egg diameter approximately 600 microns - Acanthuridae

9. Oil droplet colorless or slightly yellow - 10
   Oil droplet red-brown in color - Labrid III

10. Oil droplet 150 to 250 microns in diameter - 13
    Oil droplet less than 150 microns in diameter - 11

11. Egg less than 700 microns in diameter - 12
    Egg diameter 700 to 725 microns; oil drop 100 to 125 microns in diameter - Labrid IV

12. Egg diameter approximately 550 microns, oil droplet 100 microns in diameter - *Thalassoma* spp.
    Egg diameter 600 to 650 microns, oil droplet 100 to 125 microns in diameter - Labrid II

13. Egg diameter greater than 780 microns; one oil droplet, 225 to 300 microns in diameter - *Gnathanodon speciosus*
    Egg diameter 750 microns or less; oil droplet diameter less than 200 microns - 14

14. Oil droplet approximately 200 microns diameter - 15
    Oil droplet approximately 150 microns diameter - Type XXXVI

15. Egg slightly oblong (650 x 680 microns) - *Caranx* sp. (Type XLIII)
    Egg spherical, 700 to 750 microns in diameter - *Caranx mate*

TABLE A1. SUMMARY OF KEY CHARACTERISTICS

Egg Type	Diameter (mm)	Egg Membrane	Oil Droplet(s) & Diameter (μ)	Position of Droplets	Remarks
Eel (various spp.)	2.4 to 3.8	smooth	none	---	large perivitelline space
Elopomorpha (Offshore A)	2.90 to 2.95	smooth	1 (400) yellow	on opposite side of yolk sac from embryo	captured only twice just beyond buoy 4, Sampan Channel; reared once, embryo died while hatching; resembled eel
Etrumeus micropus (Makiawa)	1.45 to 1.525	smooth	none	---	embryo somewhat whitish
Stolephorus purpureus (Nehu)	oblong 1.75 x 0.65	smooth	none	---	segmented yolk
Synodontid I	1.25	covered with hexagonal facets	none	---	egg may appear cloudy or with reddish band due to diffraction of light by facets
Synodontid II	0.80 to 0.90	covered with spike-like projections	1 (150)	opposite embryo	λ spine cross-section
Fistularia sp.	1.65 to 1.75	smooth	none	---	embryo in late stages long; length > egg circumference; early egg looks empty
Thalassoma (*duperreyi?*)	0.550	smooth	1 (100)	opposite embryo	embryo with scattered black pigment
Labrid II	0.575 to 0.625	smooth	1 (125)	opposite embryo	egg resembles *Thalassoma* egg in all respects except it is slightly larger
Labrid III	0.75 to 0.80	smooth	1 (100) red-brown	opposite embryo	have found yolk sac larvae with red droplet which resemble labrid larvae and whose size suggest they came out of this egg; (oil droplets *ca* equal size)
Labrid IV	0.70 to 0.75	smooth	1 (100)	opposite embryo	can be distinguished from Labrid II by diameter of egg, from omaka by diameter of oil droplet; yolk sac larvae from this egg resemble labrids
Scarid I	oblong 1.50 x 0.50	smooth	1 (100)	variable, either opposite embryo or polar in position	only very few observed--more pointed on ends than nehu
Scarid II	oblong 1.65 to 1.70 x 0.50	smooth	1 or 2 (50 and 125)	large drop as Scarid I; small drop as a satellite to large	described from preserved specimens taken only once--spindle shaped
Scorpaenid I	slightly oblong 0.800 to 0.850 x 0.600 to 0.650	smooth	none	---	eggs tightly packed; 180 to 360 eggs/cluster
Scorpaenid II	0.725 to 0.750	smooth	none	---	eggs loosely packed; 100 to 124 eggs/cluster; size of whole cluster variable
Gnathanodon speciosus	0.78 to 0.90	smooth	1 (225 to 300)	opposite embryo	whitish-yellow "granules" scattered on yolk sac and on embryo; embryo with scattered dorsal melanophores; oil droplet with melanophores at later stages
Caranx mate (Omaka)	0.70 to 0.75	smooth	1 (190 to 200)	opposite embryo	embryo tends to have white granules; black pigment as in *Gnathanodon*
Caranx sp. (Type XLIII)	may be slightly oblong 0.65 to 0.68	smooth	1 (200)	directly opposite from embryo	very similar to omaka; rearing experiments inconclusive as to identity (i.e., omaka or not)

TABLE A1. SUMMARY OF KEY CHARACTERISTICS (continued)

Egg Type	Diameter (mm)	Egg Membrane	Oil Droplet(s) & Diameter (µ)	Position of Droplets	Remarks
Bothid I	1.2 to 1.3	smooth	15 to 20 (50 to 100)	randomly scattered over surface of yolk sac; no apparent relation to embryo; in early stages of development, drops clustered about 60° from cell disc; droplets may move around rather easily	
Bothid II	slightly oblong 1.150 to 1.200 x 1.250	smooth except for a protrusion (stalk?) dorsal to embryo	4 or 5 (~100)	scattered opposite embryo	
Bothid III	1.0 to 1.1	smooth	many	randomly scattered over surface of yolk sac; no apparent relation to embryo	egg greatly resembles Bothid I and gives rise to a similar larva
Acanthuridae	0.575 to 0.625	smooth	1 (100 to 125)	at side of cell disc	
Ranzania laevis	1.55	smooth	~20 (50 to 150) yellowish	scattered over surface of yolk sac (may actually be inside yolk sac)	yolk sac with many scattered brown chromatophores in late stages; embryo with black pigment in branchial region; in early stage droplets clustered opposite embryo and dispersed as development proceeds
Diodon sp. (Tetraodontiformes I)	1.7 to 1.8	smooth	10 to 25 cluster (75 to 200)	variable either opposite embryo in early stages; at caudal in later stages	late-stage embryo with "wide" head
Ostraciontidae (Tetraodontiformes III)	slightly oblong (see remarks) 1.6 x 1.9	smooth except small rough patch on one end	1 or 2 cluster(s)	varies; either at caudal or opposite; number of drops/cluster varies	floats so only measurable dimensions equals 1.6 when viewed from above
Tetraodontiformes II	slightly oblong 1.70 to 1.75	smooth except small rough patch on one end	15 (100 to 200)	varies with development but only one cluster present	
Schindleriidae *Schindleria* sp.	oblong 1.30 x 0.50	smooth	none	---	egg with a "cap" on one end; may be another type with a short stalk connecting cap to egg (Schind. II?)
Crystallodytes cookei	1.00 to 1.10	smooth	several small clusters or very small oil droplets	varies (see remarks)	in very early eggs, clusters arranged on equatorial plane; they move from cell disc as development proceeds and ultimately coalesce in a large cluster at the caudal end of embryo; embryo grows past the cluster as development proceeds
Type VIIIb	0.700 to 0.800	smooth	cluster	varies (see remarks)	position varies exactly as in *Crystallodytes cookei*; hatched larvae are somewhat smaller versions of *C. cookei* larvae
Type VIIIc	0.70 to 0.75	smooth	none	---	extremely easy to confuse with Type XIX; but are different as they give rise to different types of larvae
Type XVII	1.1 to 1.2	smooth	none	---	rare
Type XIX	0.75 to 0.80	smooth	none	---	see Type VIIIc

TABLE A1. SUMMARY OF KEY CHARACTERISTICS (continued)

Egg Type	Diameter (mm)	Egg Membrane	Oil Droplet(s) & Diameter (μ)	Position of Droplets	Remarks
Type XX	1.25 to 1.35	smooth	1 (200)	varies	clear, long, skinny embryo which wraps around egg; oil droplet starts at 60° angle from cell disc but embryo grows past it so that in late stage it is on belly
Kyphosus cinerascens	1.0 to 1.1	smooth	1 (250)	varies	again, embryo grows past oil droplet but oil droplet is directly opposite cell disc in earliest stages; ends up near position of future anus at hatching
Type XXIX	0.75	rough, pockmarked	none	---	probably a dead, damaged Type VIIIc or Type XIX egg; one occurrence only
Type XXX	0.75	smooth	2 (150 and 125)	opposite embryo; drops touching	perhaps a dead omaka, oil droplets often fragmented in preserved eggs
Type XXXIV	0.850 to 0.875	smooth	none(?)	two small patches seen in some	"patches" seen in some eggs probably not oil droplets
Type XXXV	0.700 to 0.750	smooth	1 (150)	varies	oil droplet position varies in same manner as Type XX, i.e., embryo grows past the droplet
Type XXXVI	0.700 to 0.725	smooth	1 (150 to 165)	directly opposite from embryo	very similar to omaka until late stages when the embryo becomes very long and head and tail almost touch oil droplet
Type XXXIX	may be slightly oblong 1.75	smooth except for small rough patch at one end	2 (300 and 100)	both opposite embryo	patch similar to patches of ostraciontid
Type XLII	0.550	smooth	none	---	embryo small even for size of egg
Offshore B	3.30	smooth	many	scattered over surface of yolk	captured once just beyond buoy 4 and once at Moku Manu
Egg Mass C	*ca* 0.85	smooth	1 (250)	varies from side to edge of cell disc	very large egg mass, 500 to 600 eggs

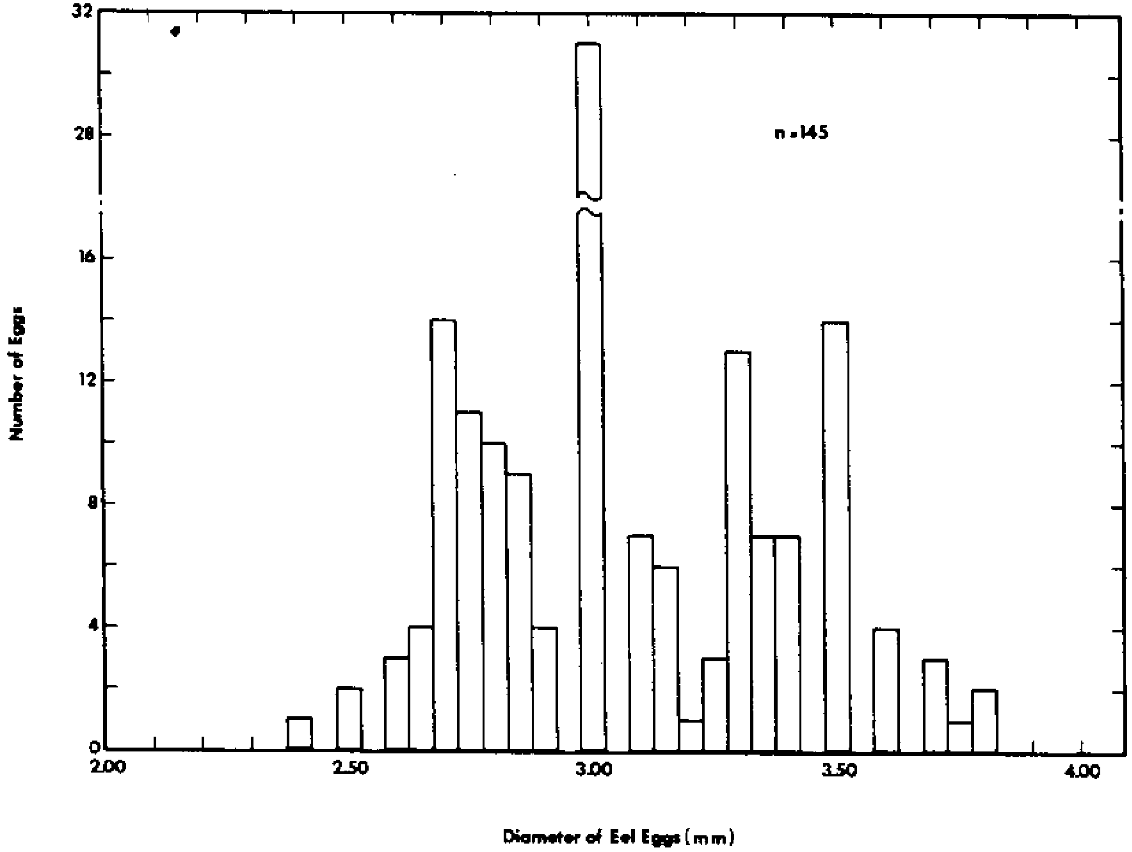

Figure A1. Distribution of eel egg sizes.

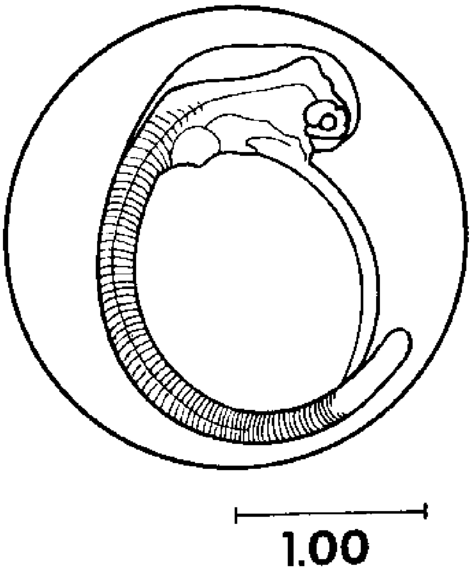

Figure A2. Eel egg.

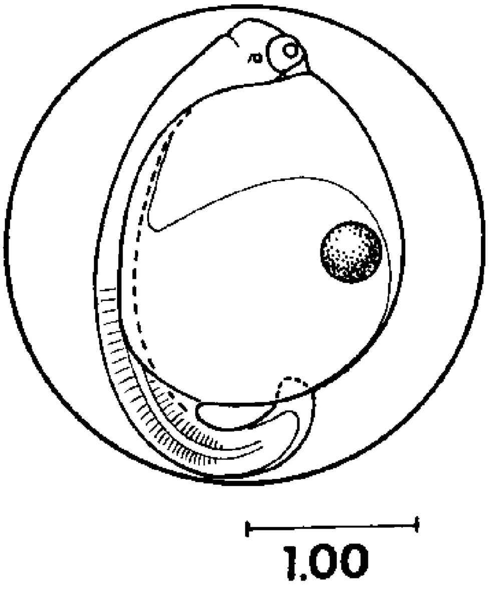

Figure A3. Elopomorpha egg.

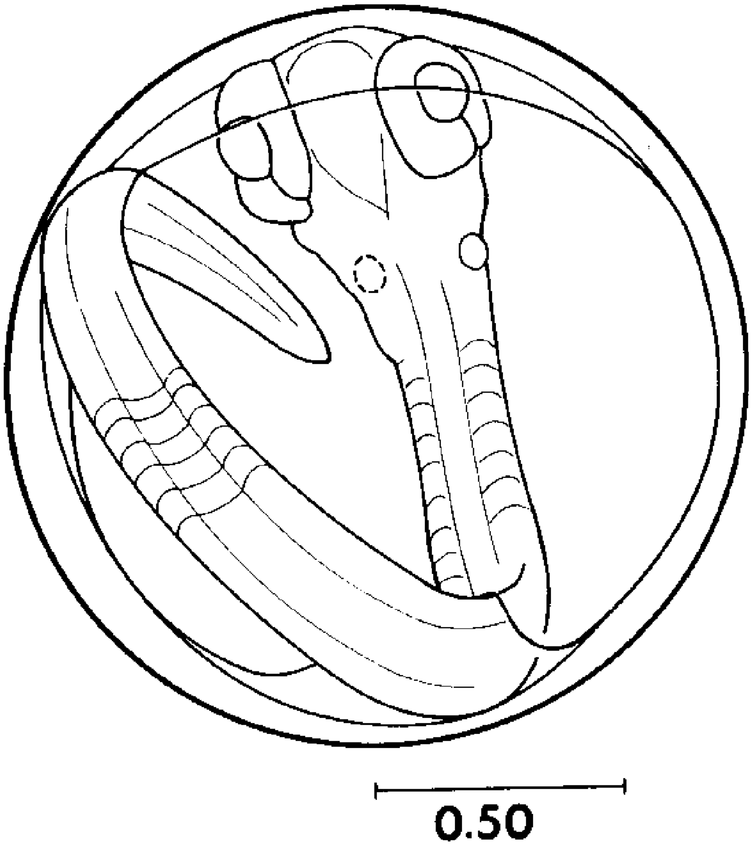

Figure A4. *Etrumeus micropus* egg.

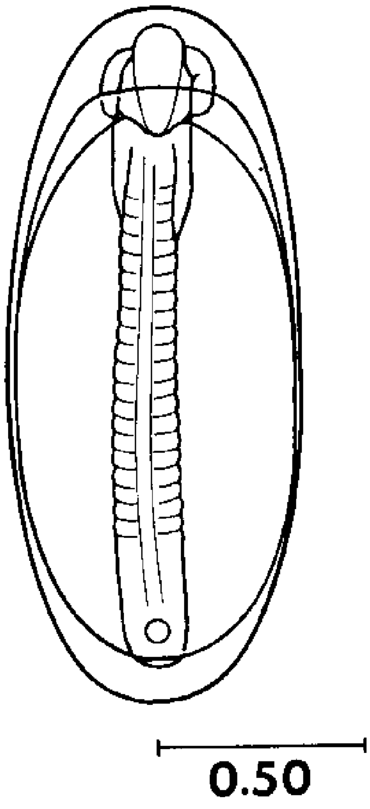

Figure A5. *Stolephorus purpureus* egg.

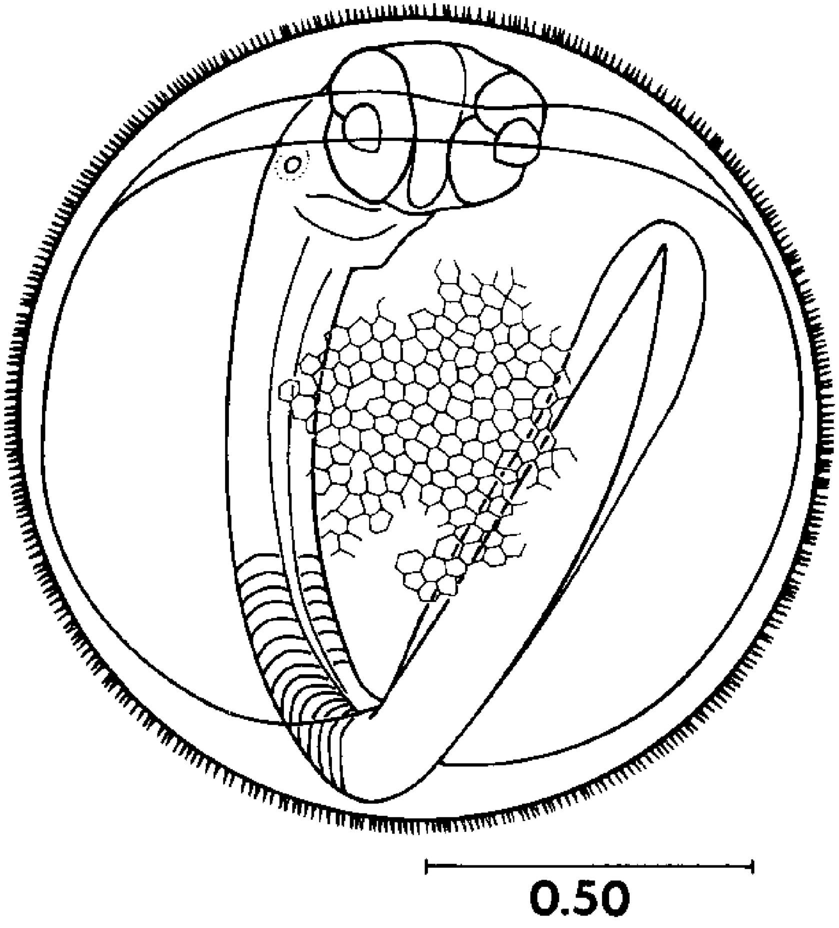

Figure A6. Synodont I egg.

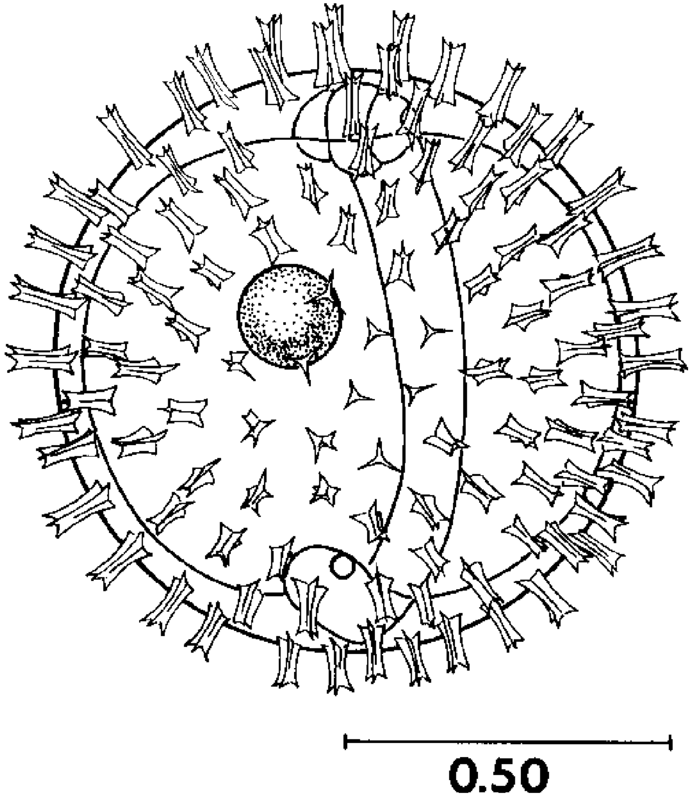

Figure A7. Synodont II egg.

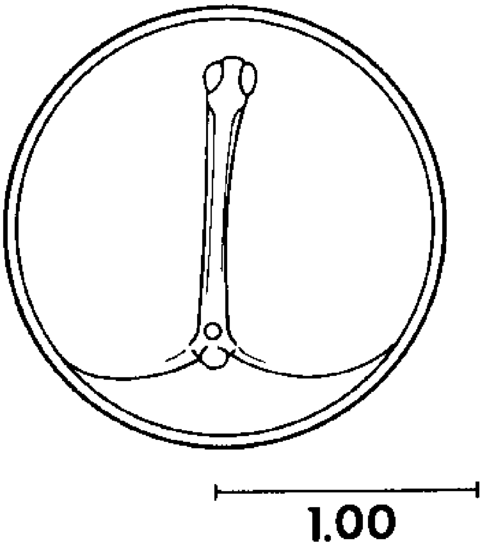

Figure A8. *Fistularia* sp. egg (early).

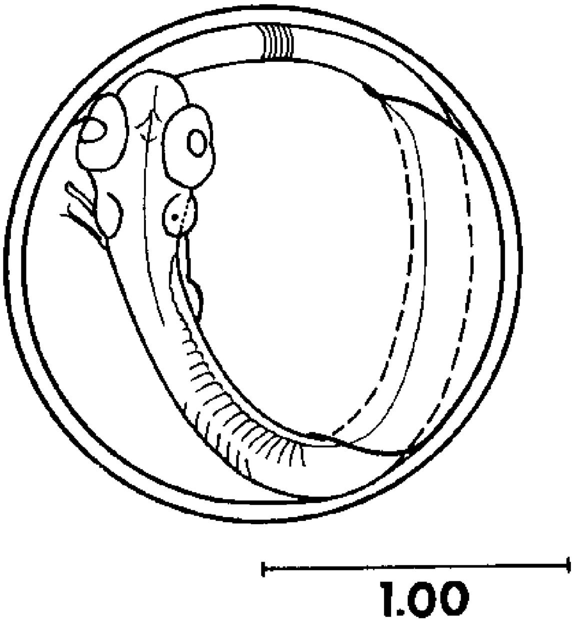

Figure A9. *Fistularia* sp. egg (late).

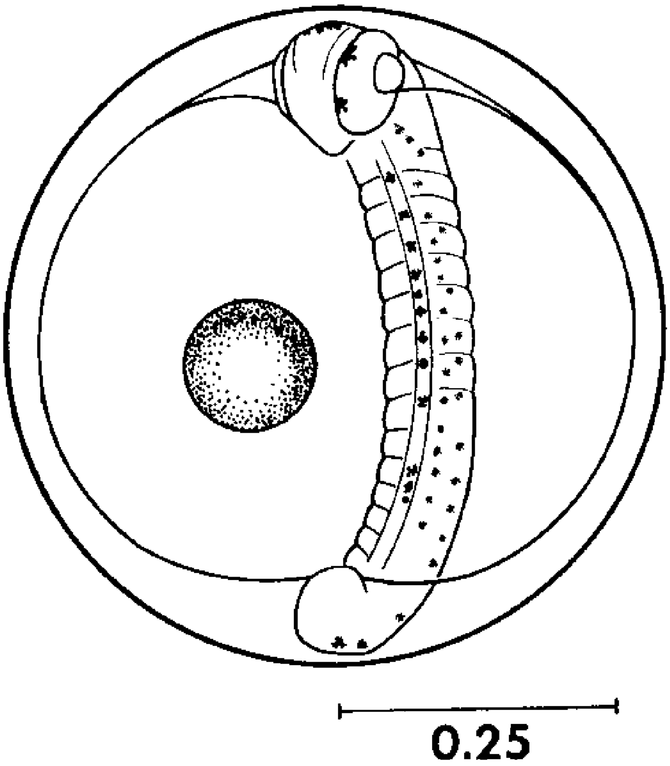

Figure A10. Labrid II egg.

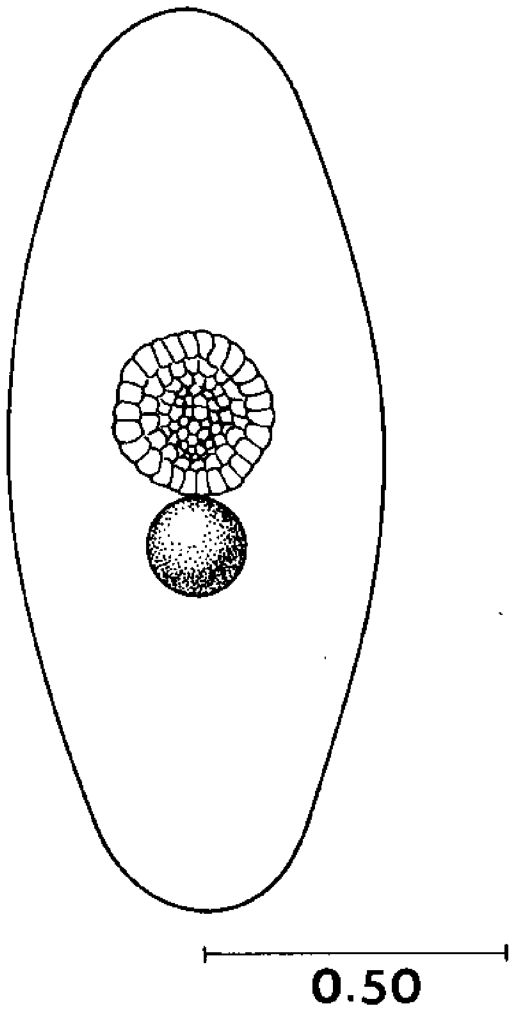

Figure A11. Scarid I egg (early).

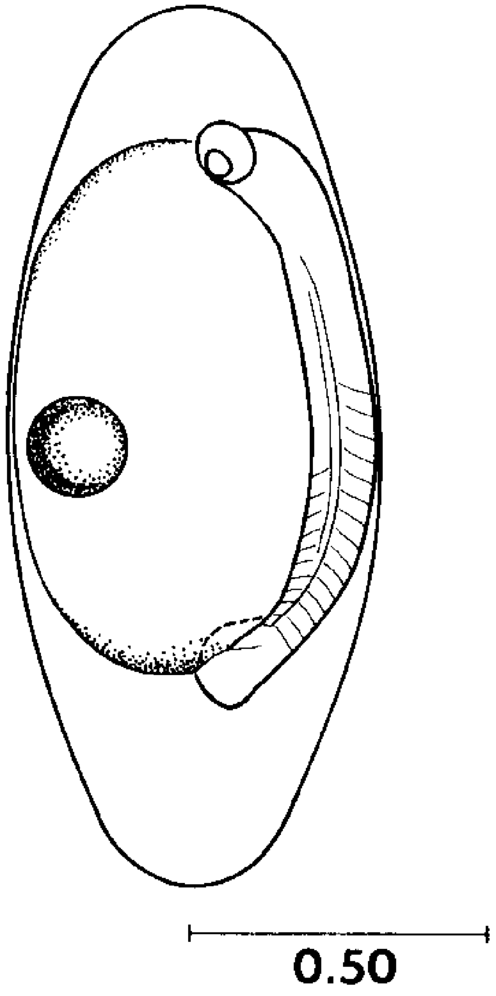

Figure A12. Scarid I egg (late).

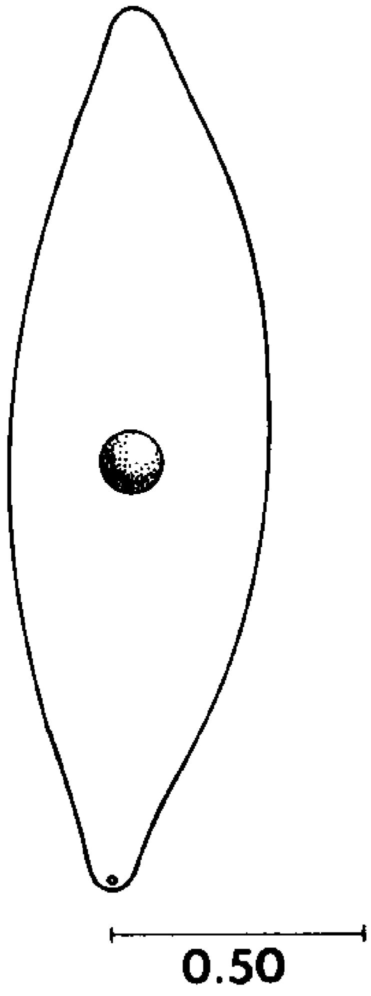

Figure A13. Scarid II egg.

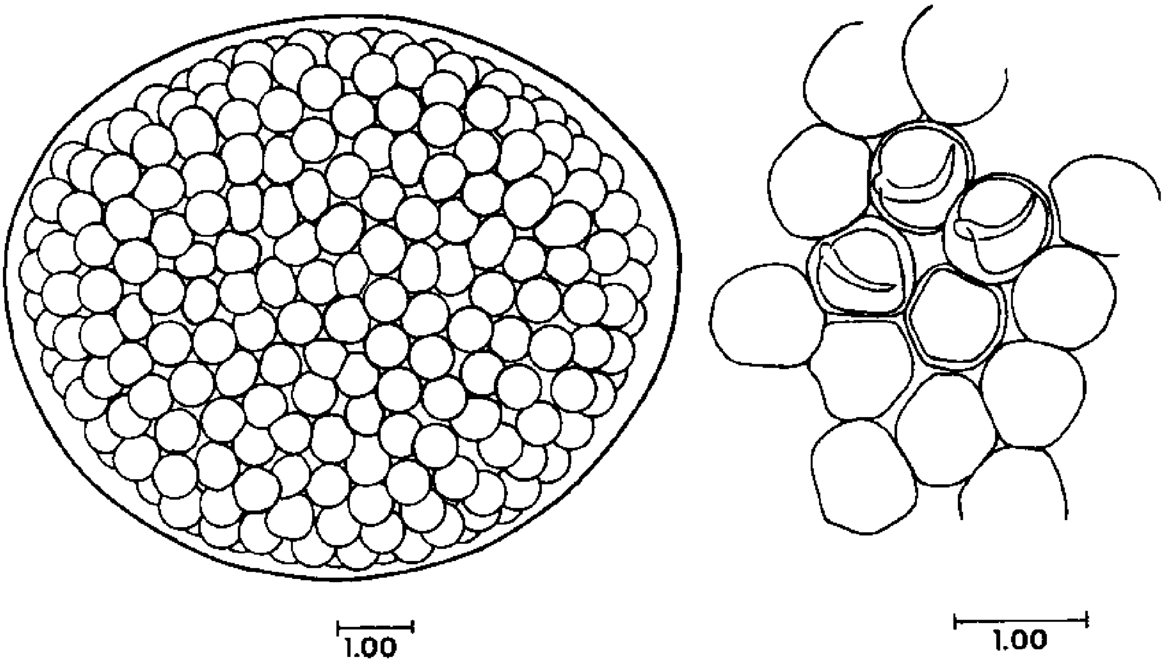

Figure A14. Scorpaenid A eggs.

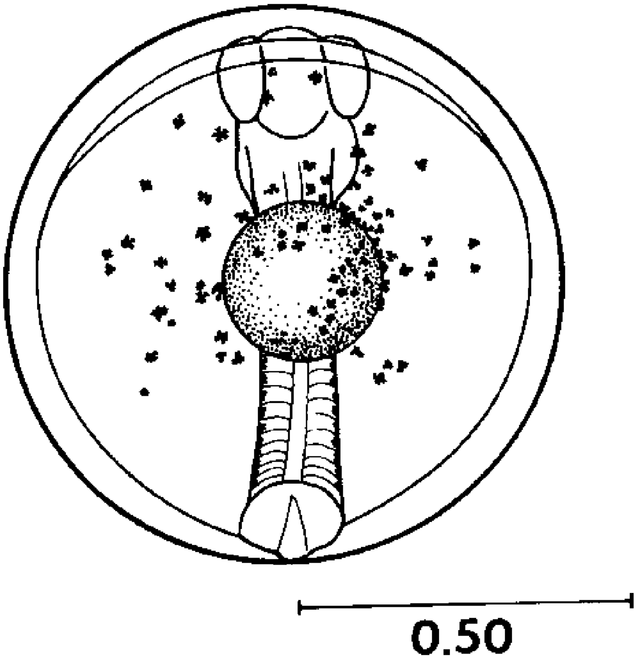

Figure A15. *Gnathanodon speciosus* egg.

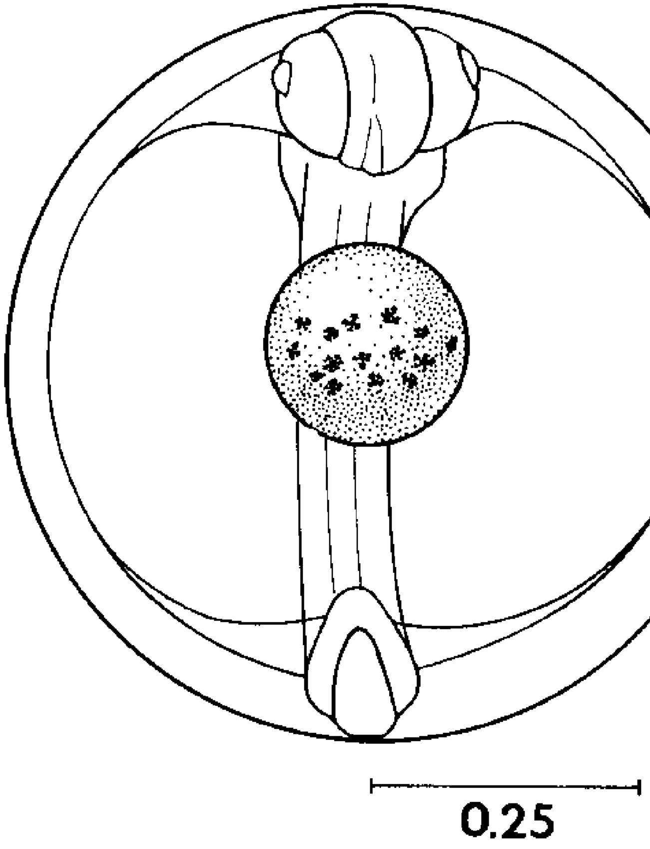

Figure A16. Type XLIII (*Caranx*) egg.

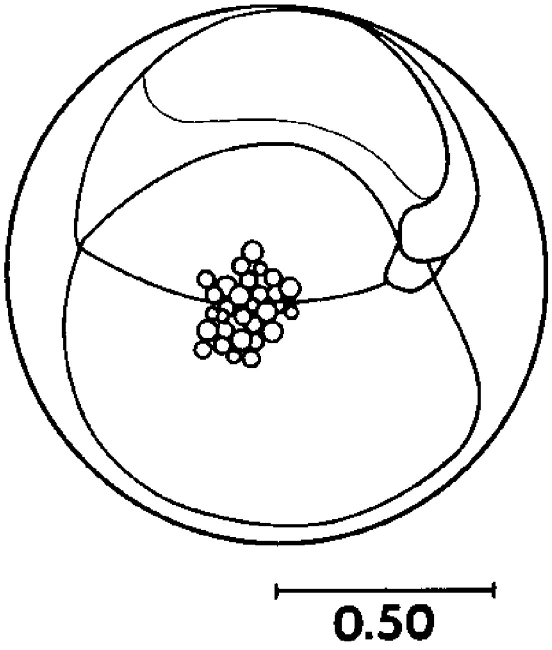

Figure A17. Bothid I egg (early).

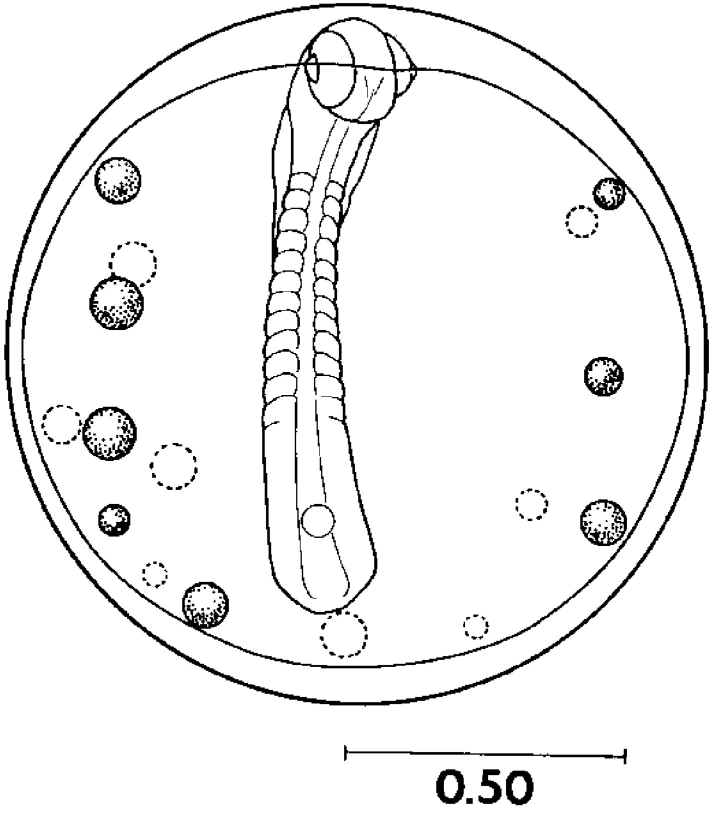

Figure A18. Bothid I egg (late).

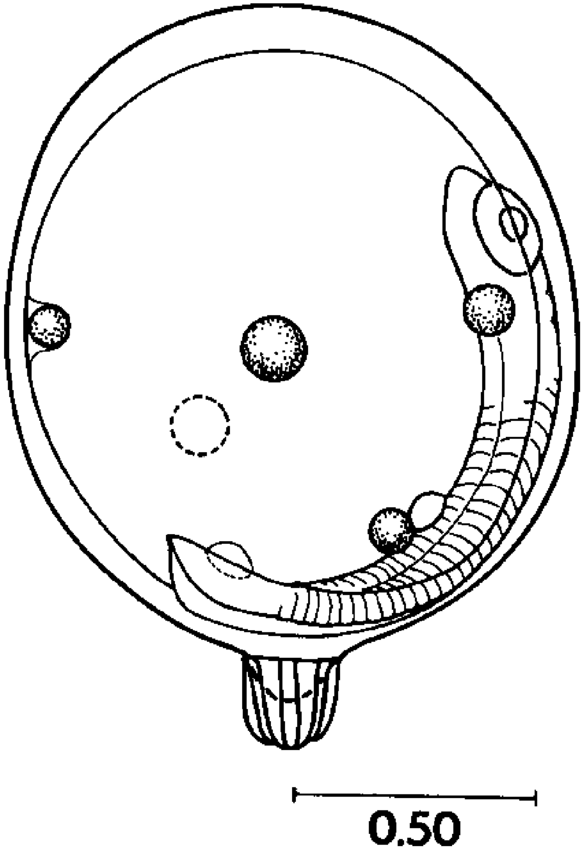

Figure A19. Bothid II egg.

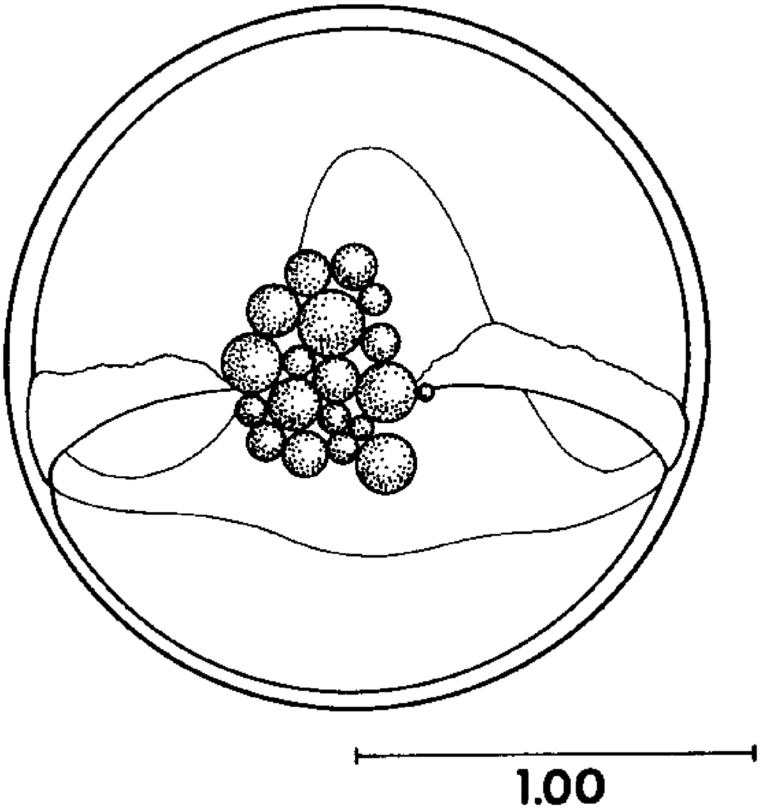

Figure A20. *Diodon* sp. I egg (early).

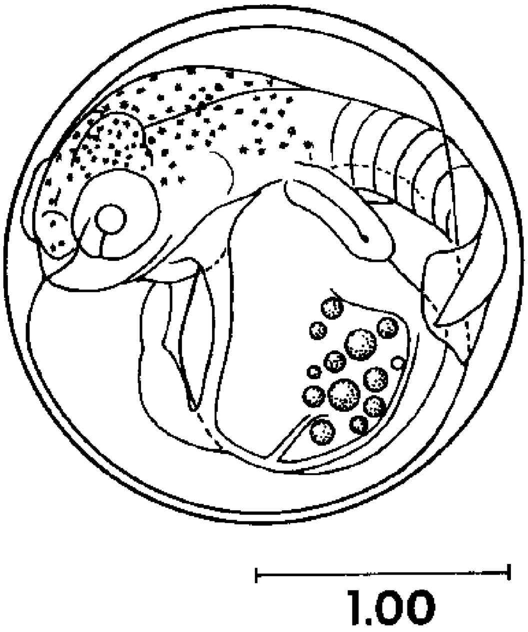

Figure A21. Diodontid II egg (late).

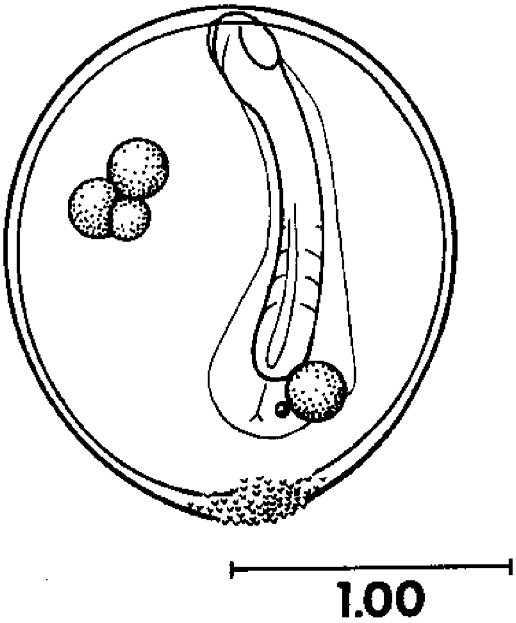

Figure A22. Ostraciontid egg.

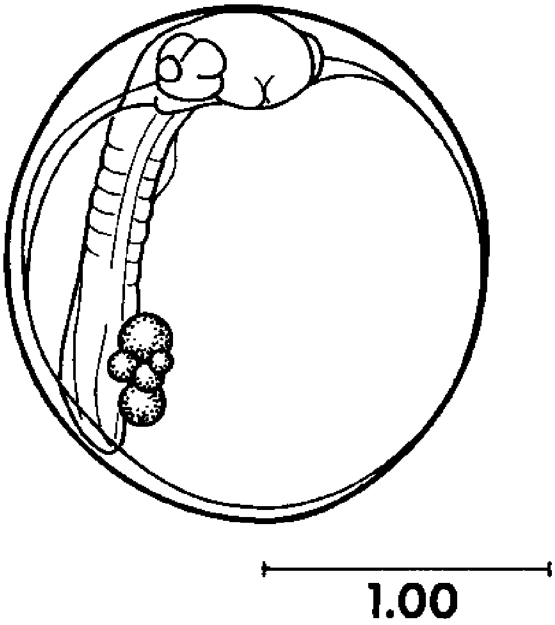

Figure A23. Tetraodontiform II.

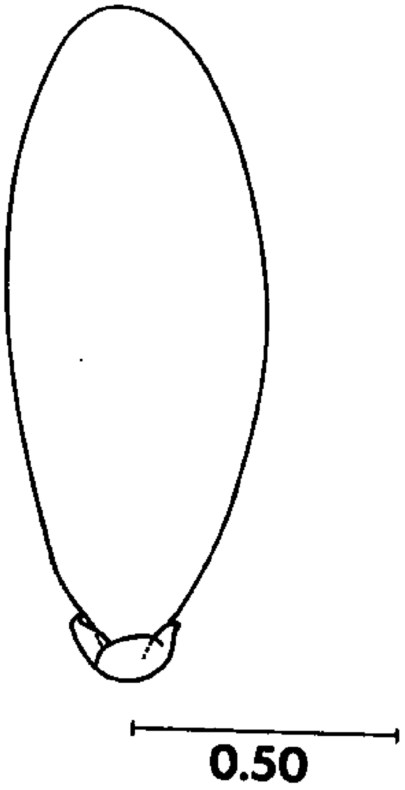

Figure A24. *Schindleria* sp. egg.

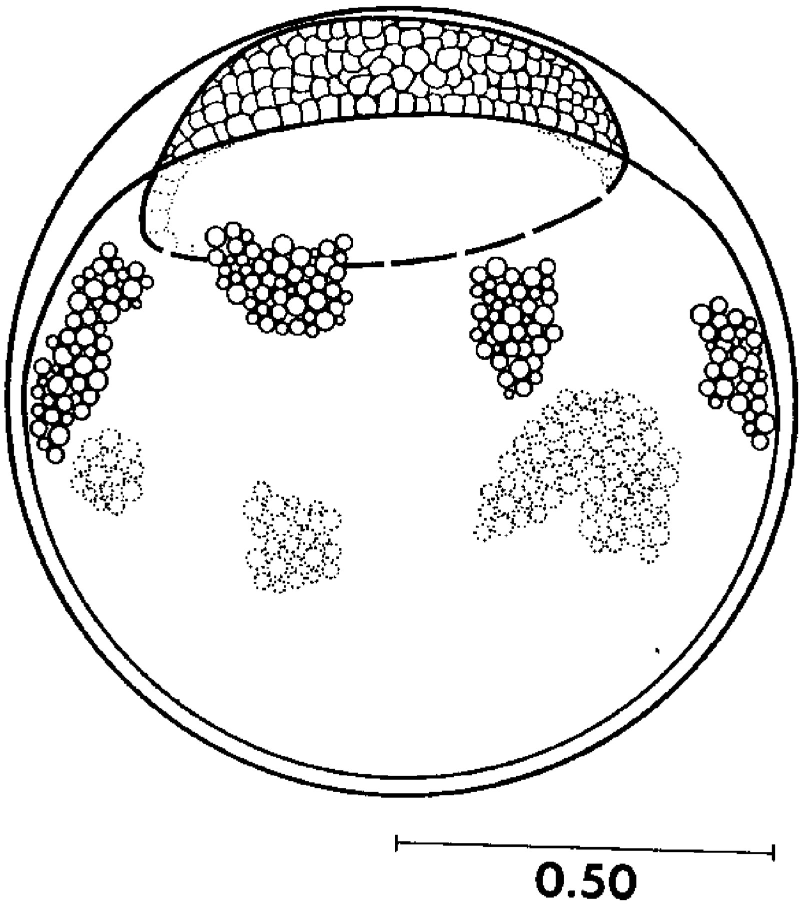

Figure A25. *Crystallodytes cookei* egg (very early).

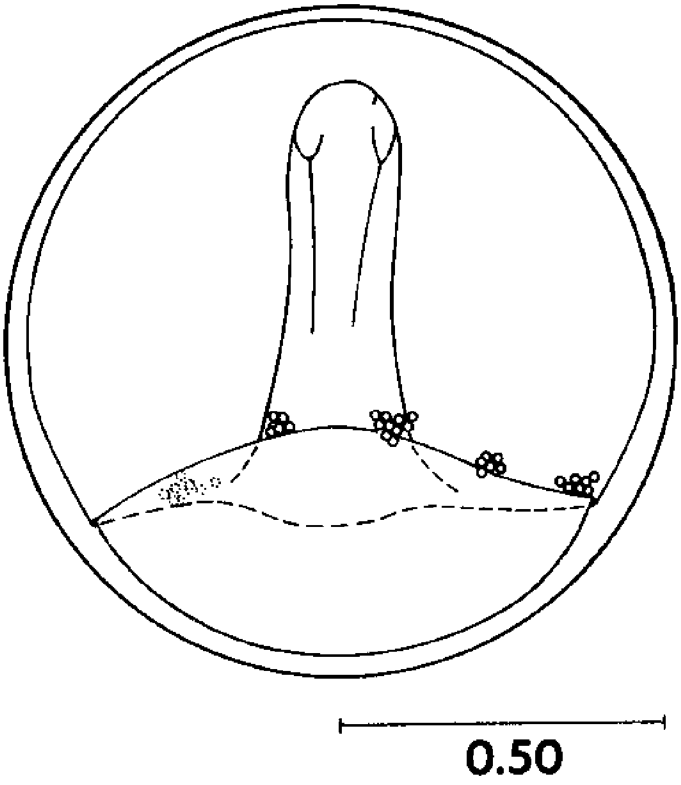

Figure A26. *Crystallodytes cookei* egg (gastrula stage).

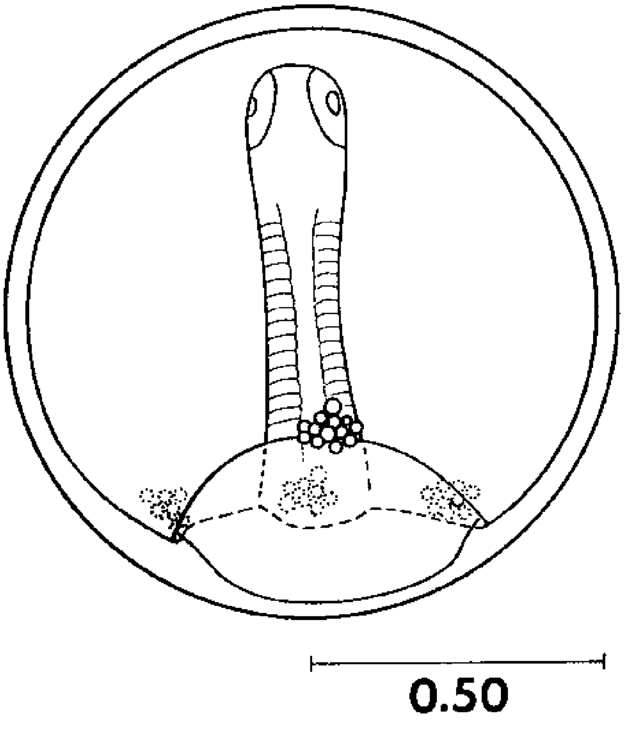

Figure A27. *Crystallodtyes cookei* egg (gastrula stage).

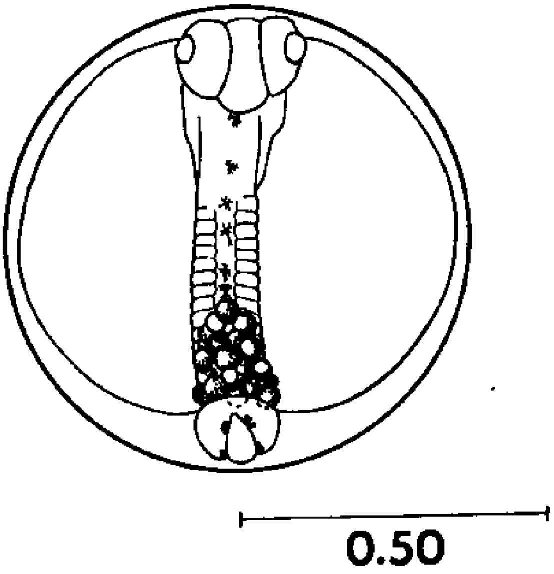

Figure A28. Type VIIIb egg shortly after blastopore closure.

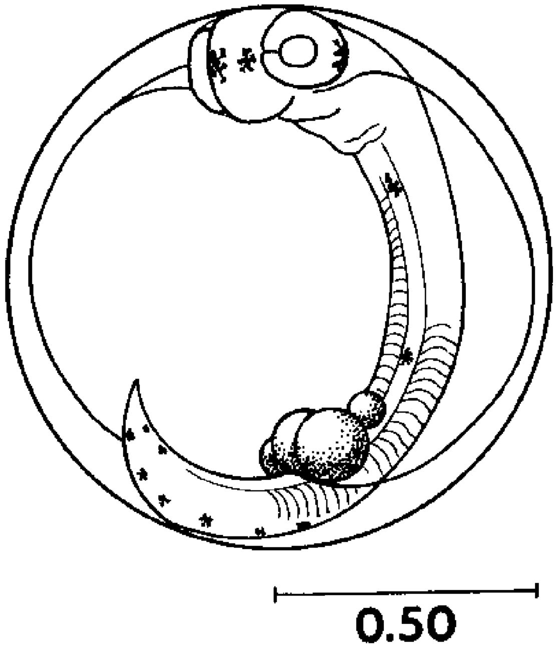

Figure A29. *Crystallodytes cookei* egg (late).

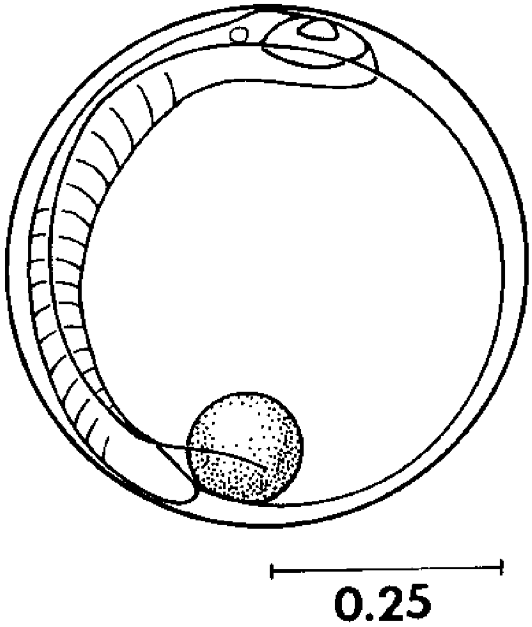

Figure A30. Acanthurid egg.

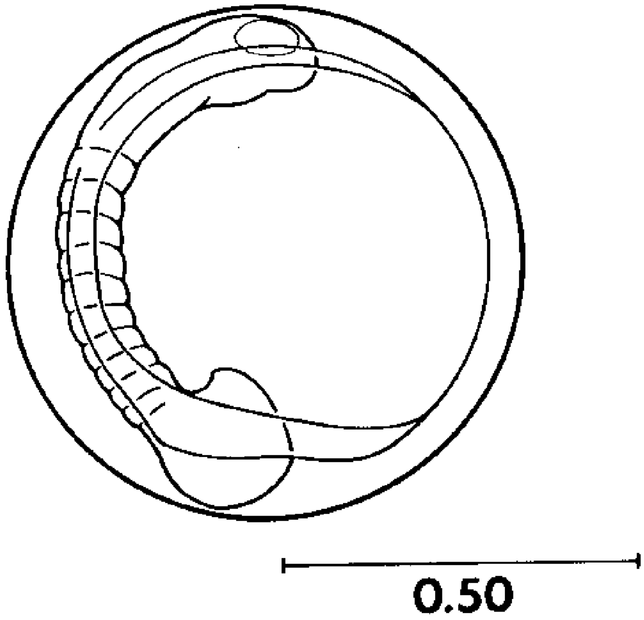

Figure A31. Type VIIIc egg.

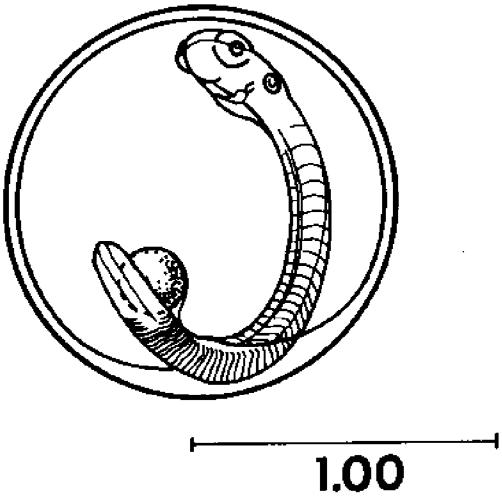

Figure A32. Type XX egg.

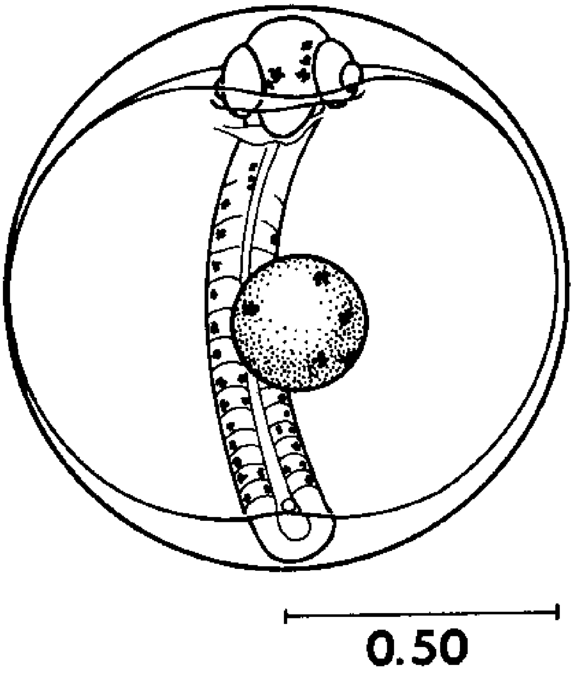

Figure A33. *Kyphosus cinerascens* egg.

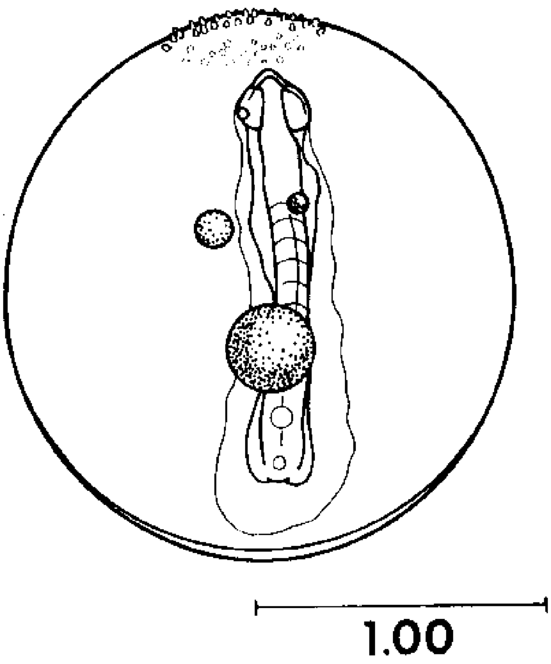

Figure A34. Type XXXIX egg.

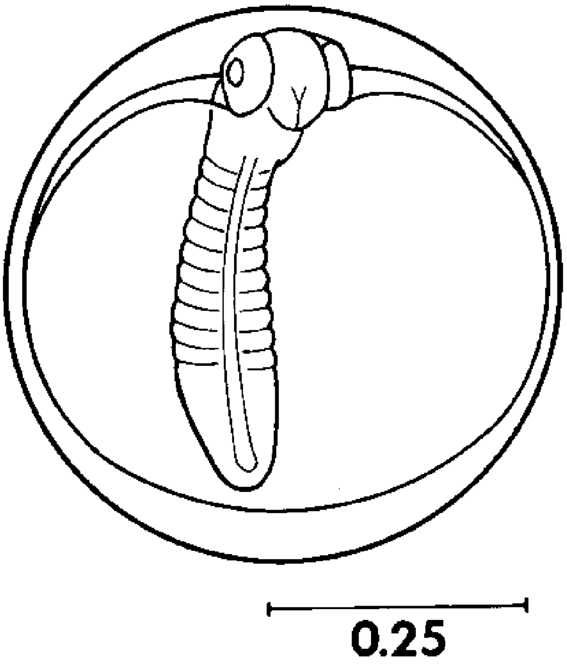

Figure A35. Type XLII egg.

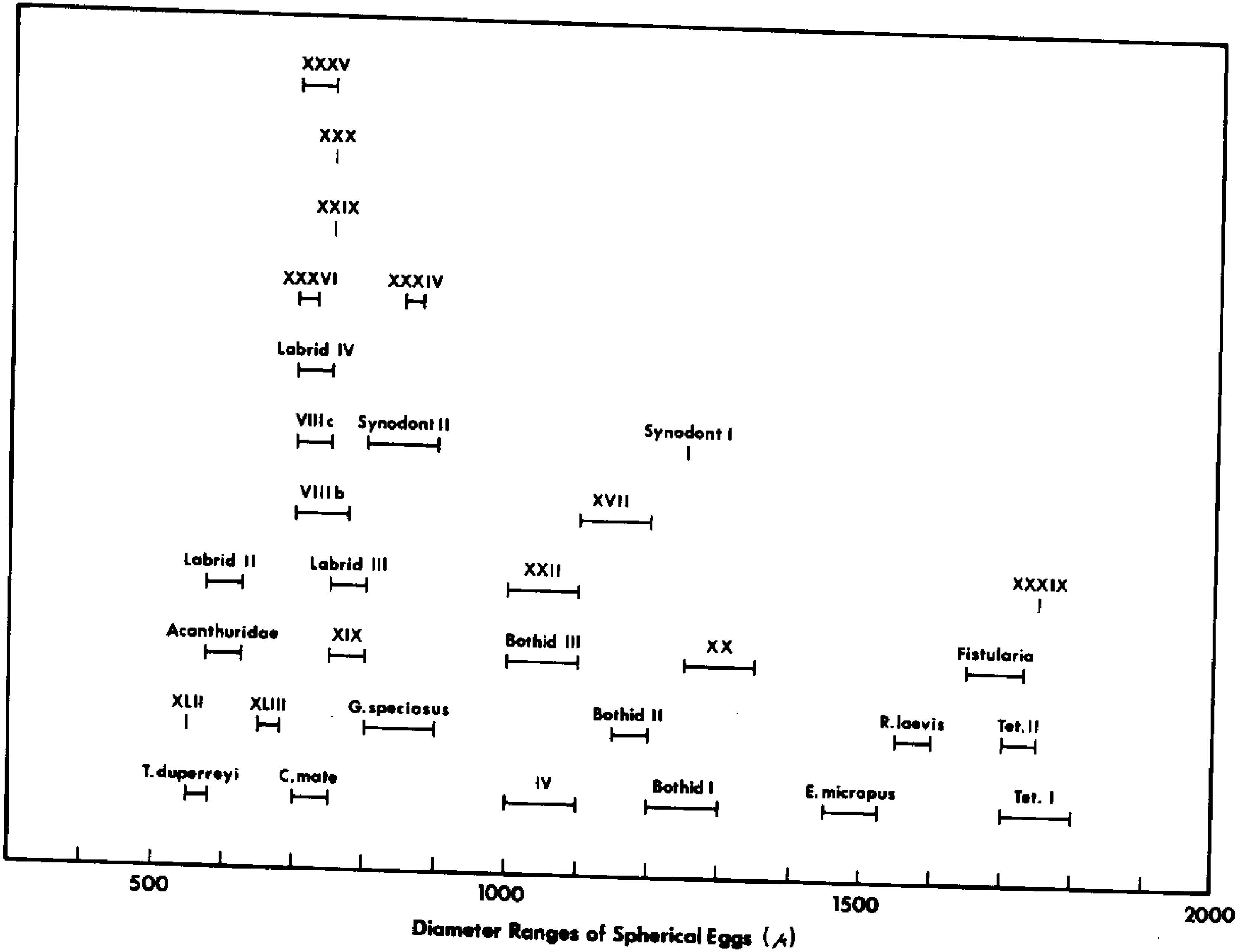

Figure A36. Range of egg sizes.

APPENDIX B. REGRESSION ANALYSIS

SYMBOLS FOR TABLES B1 THROUGH B19.

D = day length

ΔD = change in day length

$|\Delta D|$ = absolute change in day length

T = water temperature

ΔT = change in water temperature

$|\Delta T|$ = absolute change in water temperature

S = salinity

MN = moon phase (new and full)

MQ = moon phase (second and third quarters)

TF = tide factor

|TF| = absolute tide factor

d.f. = degrees of freedom of regression

$1 - R^2$ = percentage of the variability in the dependent variable not explained by its regression on the independent variable(s)

* = statistical significance at the 0.050 level

TABLE B1. *CARANX MATE* (OMAKA) EGGS IN SOUTH KANEOHE BAY

Regression	d.f.	$1 - R^2$ (%)	$\lvert t_{\text{Partial Regression Coefficient}} \rvert$	$t_{.05}$ (Two-tailed)
D	24	85.5	2.015	2.064
$\lvert \Delta D \rvert$	24	89.9	1.646	2.064
T	24	97.6	0.772	2.064
$\lvert \Delta T \rvert$	24	99.6	0.295	2.064
S	24	93.0	1.346	2.064
MN	24	98.8	0.530	2.064
MQ	24	100.0	0.048	2.064
D, MN	23	83.8	2.034, 0.694	2.069
$\lvert \Delta D \rvert$, MN	23	89.3	1.566, 0.371	2.069

TABLE B2. *GNATHANODON SPECIOSUS* (PA'OPA'O) EGGS IN SOUTH KANEOHE BAY

Regression	d.f.	$1 - R^2$ (%)	$\lvert t_{\text{Partial Regression Coefficient}} \rvert$	$t_{.05}$ (Two-tailed)
D	25	72.2	3.105*	2.060
ΔD	23	100.0	0.018	2.069
$\lvert \Delta D \rvert$	23	99.2	0.429	2.069
T	25	84.3	2.161*	2.060
ΔT	23	94.4	1.169	2.069
$\lvert \Delta T \rvert$	23	95.8	1.007	2.069
S	25	87.4	1.900	2.060
MN	25	100.0	0.043	2.060
D, T	24	71.9	2.032, 0.302	2.064
ΔD, ΔT	22	92.8	0.618, 1.308	2.074
$\lvert \Delta D \rvert$, $\lvert \Delta T \rvert$	22	95.2	0.358, 0.960	2.074
D, S	24	71.5	2.311,* 0.485	2.064
T, S	24	83.2	1.102, 0.561	2.064
T, MN	24	84.2	2.124,* 0.162	2.064
S, MN	24	87.1	1.891, 0.309	2.064
D, T, S	23	71.5	1.941, 0.039, 0.373	2.069
D, T, MN	23	71.6	2.010, 0.295, 0.310	2.069
D, S, MN	23	71.0	2.274,* 0.514, 0.368	2.069
T, S, MN	23	83.0	1.062, 0.579, 0.242	2.069
D, T, S, MN	22	71.0	1.920, 0.009, 0.412, 0.358	2.074

TABLE B3. *STOLEPHORUS PURPUREUS* (NEHU) EGGS IN SOUTH KANEOHE BAY

Regression	d.f.	$1 - R^2$ (%)	$\lvert t_{\text{Partial Regression Coefficient}} \rvert$	$t_{.05}$ (Two-tailed)
D	26	95.6	1.098	2.056
ΔD	23	94.4	1.171	2.069
$\lvert \Delta D \rvert$	23	96.8	1.007	2.069
T	26	87.0	1.967	2.056
ΔT	23	94.8	1.119	2.069
$\lvert \Delta T \rvert$	23	93.4	1.278	2.069
S	26	90.3	1.679	2.056
MN	26	91.2	1.589	2.056
MQ	26	99.9	0.203	2.056
D, T	25	86.9	0.229, 1.583	2.060
ΔD, T	22	85.7	0.007, 1.492	2.074
D, S	25	89.9	0.286, 1.253	2.060
T, $\lvert \Delta T \rvert$	22	82.2	1.732, 0.972	2.074
T, S	25	86.5	1.041, 0.407	2.060
T, MN	25	78.5	2.010, 1.653	2.060
D, T, S	24	86.2	0.256, 1.013, 0.417	2.064

TABLE B4. *ETRUMEUS MICROPUS* (MAKIAWA) EGGS IN SOUTH KANEOHE BAY

Regression	d.f.	$1 - R^2$ (%)	$\lvert t_{\text{Partial Regression Coefficient}} \rvert$	$t_{.05}$ (Two-tailed)
D	25	94.6	1.193	2.060
ΔD	22	86.8	1.832	2.074
$\lvert \Delta D \rvert$	22	96.7	0.865	2.074
T	25	98.4	0.629	2.060
ΔT	22	95.5	1.020	2.074
$\lvert \Delta T \rvert$	22	96.1	0.942	2.074
S	25	99.9	0.165	2.060
MN	25	97.9	0.736	2.060
MQ	25	95.2	1.128	2.060
D, ΔD	21	74.9	1.820, 1.732	2.080
D, T	24	80.5	2.315,* 2.053	2.064
D, S	24	93.4	1.292, 0.558	2.064
T, S	24	95.4	1.057, 0.868	2.064
T, MN	24	96.4	0.610, 0.715	2.064
T, MQ	24	94.3	0.468, 1.027	2.064
D, ΔD, T	20	67.8	2.004, 0.694, 1.456	2.086
D, T, S	23	79.0	2.187,* 2.046, 0.651	2.069
D, T, MN	23	79.5	2.210,* 1.970, 0.527	2.069

TABLE B5. *GNATHANODON SPECIOSUS* (PA'OPA'O) EGGS IN SAMPAN CHANNEL

Regression	d.f.	$1 - R^2$ (%)	$\lvert t_{\text{Partial Regression Coefficient}} \rvert$	$t_{.05}$ (Two-tailed)
D	23	75.4	2.741*	2.069
ΔD	23	91.7	1.446	2.069
T	23	75.4	2.737*	2.069
ΔT	23	99.3	0.407	2.069
S	23	87.5	1.811	2.069
TF	34	99.1	0.593	2.034
$\lvert TF \rvert$	34	99.0	0.593	2.034
D, ΔD	22	64.8	3.023,* 1.900	2.074
D, T	22	70.0	1.307, 1.300	2.074
ΔD, T	22	75.0	0.347, 2.209*	2.074
D, ΔT	22	71.9	2.897,* 1.038	2.074
D, S	22	74.7	1.943, 0.448	2.074
T, ΔT	22	75.4	2.640,* 0.106	2.074
T, S	22	75.4	1.880, 0.097	2.074
D, T, S	21	69.6	1.328, 1.245, 0.364	2.080
D, ΔD, T	21	59.4	2.350,* 1.935, 1.375	2.080
D, T, ΔT	21	68.4	1.469, 1.035, 0.707	2.080
ΔD, T, ΔT	21	74.9	0.384, 1.773, 0.208	2.080
D, ΔD, T, ΔT	20	58.3	2.388,* 1.863, 1.476, 0.628	2.086

TABLE B6. TYPE VIIIc EGGS IN SAMPAN CHANNEL

Regression	d.f.	$1 - R^2$ (%)	$\lvert t_{\text{Partial Regression Coefficient}} \rvert$	$t_{.05}$ (Two-tailed)
D	14	93.7	0.967	2.145
$\lvert \Delta D \rvert$	14	97.6	0.592	2.145
T	14	98.3	0.496	2.145
$\lvert \Delta T \rvert$	14	99.2	0.345	2.145
S	14	93.2	1.010	2.145
MN	14	100.0	0.116	2.145
TF	40	84.8	2.673*	2.021
D, T	13	88.0	1.234, 0.923	2.160
D, S	13	83.9	1.202, 1.235	2.160
D, T, S	12	83.8	1.022, 0.124, 0.774	2.179

TABLE B7. TETRAODONTIFORM (KĒKĒ) EGGS IN SAMPAN CHANNEL

Regression	d.f.	$1 - R^2$ (%)	t_{Partial} Regression Coefficient	$t_{.05}$ (Two-tailed)
D	24	65.3	3.573*	2.064
|ΔD|	24	95.6	1.049	2.064
T	24	94.5	1.177	2.064
|ΔT|	24	98.6	0.592	2.064
S	24	80.2	2.430*	2.064
MN	24	99.7	0.249	2.064
D, T	23	62.1	3.463,* 1.078	2.069
D, S	23	63.6	2.449,* 0.767	2.069
D, MN	23	65.3	3.486,* 0.075	2.069
D, T, S	22	53.6	3.173,* 2.030, 1.872	2.074
D, T, S, MN	21	53.6	3.085,* 1.981, 1.829, 0.053	2.080

TABLE B8. SYNODONTIDAE ('ULAE) EGGS IN SAMPAN CHANNEL

Regression	d.f.	$1 - R^2$ (%)	t_{Partial} Regression Coefficient	$t_{.05}$ (Two-tailed)
D	23	55.5	4.290*	2.069
ΔD	23	98.3	0.634	2.069
|ΔD|	23	91.5	1.457	2.069
T	23	70.9	3.076*	2.069
ΔT	23	77.4	2.592*	2.069
|ΔT|	23	100.0	0.064	2.069
S	23	92.3	1.387	2.069
D, T	22	53.4	2.685,* 0.948	2.074
D, S	22	53.9	3.961,* 0.829	2.074
T, ΔT	22	54.5	3.043,* 2.572	2.074
T, S	22	67.7	2.827,* 1.014	2.074
D, T, ΔT	21	58.8	1.555, 1.311, 1.393	2.080
D, T, S	21	56.2	3.123,* 1.864, 1.802	2.080

TABLE B9. *CRYSTALLODYTES COOKEI* EGGS IN SAMPAN CHANNEL

Regression	d.f.	$1 - R^2$ (%)	$\lvert t_{\text{Partial Regression Coefficient}} \rvert$	$t_{.05}$ (Two-tailed)
D	24	99.4	0.40	2.064
$\lvert\Delta D\rvert$	24	93.3	1.31	2.064
T	24	81.1	2.36*	2.064
$\lvert\Delta T\rvert$	24	97.7	0.75	2.064
S	24	92.9	1.36	2.064
MN	24	98.0	0.69	2.064
TF	40	75.8	3.57	2.021
D, T	23	76.0	1.38, 2.73*	2.069
D, S	23	92.1	0.45, 1.35	2.069
T, S	23	80.5	1.89, 0.44	2.069
D, T, S	22	74.9	1.28, 2.25,* 0.17	2.074

TABLE B10. *CARANX MATE* (OMAKA) EGGS IN SOUTH KANEOHE BAY

Independent Variable(s)	Correlation Coefficient (R)	d.f.	$R_{.05}$ (Two-tailed)
D	0.380	24	0.388
$\lvert\Delta D\rvert$	0.319	24	0.388
T	0.156	24	0.388
$\lvert\Delta T\rvert$	0.060	24	0.388
S	0.265	24	0.388
MN	0.108	24	0.388
MQ	0.010	24	0.388
D, MN	0.403	23	0.479
$\lvert\Delta D\rvert$, MN	0.327	23	0.479

TABLE B11. *STOLEPHORUS PURPUREUS* (NEHU) EGGS IN SOUTH KANEOHE BAY

Independent Variable(s)	Correlation Coefficient (R)	d.f.	$R_{.05}$ (Two-tailed)
D	-0.210	26	0.374
ΔD	0.237	23	0.396
|ΔD|	0.206	23	0.396
T	-0.360	26	0.374
ΔT	-0.227	23	0.396
|ΔT|	-0.257	23	0.396
S	-0.313	26	0.374
MN	0.297	26	0.374
MQ	0.040	26	0.374
D, T	-0.362	25	0.462
ΔD, T	-0.378	22	0.488
D, S	-0.317	25	0.462
T, |ΔT|	-0.422	22	0.488
T, S	-0.368	25	0.462
T, MN	0.464*	25	0.462
D, T, S	-0.371	24	0.523

TABLE B12. *GNATHANODON SPECIOSUS* (PA'OPA'O) EGGS IN SOUTH KANEOHE BAY

Independent Variable(s)	Correlation Coefficient (R)		d.f.		$R_{.05}$ (Two-tailed)	
	A	B	A	B	A	B
D	0.528*	0.331	25	17	0.381	0.456
ΔD	-0.004		23		0.396	
|ΔD|	0.089		23		0.396	
T	0.397*	0.191	25	17	0.381	0.456
ΔT	0.237		23		0.396	
|ΔT|	0.206		23		0.396	
S	0.355	0.233	25	17	0.381	0.456
MN	0.009		25		0.381	
D, T	0.530*	0.338	24	16	0.470	0.550
ΔD, ΔT	0.269		22		0.488	
|ΔD|, |ΔT|	0.219		22		0.488	
D, S	0.534*	0.353	24	16	0.470	0.559
T, S	0.410	0.242	24	16	0.470	0.559
T, MN	0.398		24		0.470	
S, MN	0.360		24		0.470	
D, T, S	0.534*		23		0.532	
D, T, MN	0.533*		23		0.532	
D, S, MN	0.538*		23		0.532	
T, S, MN	0.413		23		0.532	
D, T, S, MN	0.538		22		0.580	

A = correlation with eggs/1000 m^3 of water filtered
B = correlation with eggs/1000 m^3 of water filtered during "spawning season"

TABLE B13. *ETRUMEUS MICROPUS* (MAKIAWA) EGGS IN SOUTH KANEOHE BAY

Independent Variable(s)	Correlation Coefficient (R)	d.f.	$R_{.05}$ (Two-tailed)
D	0.232	25	0.381
ΔD	0.364	22	0.404
|ΔD|	-0.181	22	0.404
T	-0.125	25	0.381
ΔT	0.212	22	0.404
|ΔT|	-0.197	22	0.404
S	0.033	25	0.381
MN	-0.146	25	0.381
MQ	0.220	25	0.381
D, ΔD	0.501*	21	0.498
D, T	0.442	24	0.470
D, S	0.257	24	0.470
T, S	0.213	24	0.470
T, MN	-0.190	24	0.470
T, MQ	0.239	24	0.470
D, ΔD, T	0.568*	20	0.563
D, T, S	0.458	23	0.532
D, T, MN	0.453	23	0.532

TABLE B14. SYNODONTIDAE ('ULAE) EGGS IN SAMPAN CHANNEL

Independent Variable(s)	Correlation Coefficient (R)		d.f.		$R_{.05}$ (Two-tailed)	
	A	B	A	B	A	B
D	0.667*	0.307	23	10	0.396	0.576
ΔD	-0.131	-0.258	23	10	0.396	0.576
|ΔD|	0.291		23		0.396	
T	0.540*	0.282	23	10	0.396	0.576
ΔT	0.475*	0.379	23	10	0.396	0.576
|ΔT|	0.013		23		0.396	
S	0.278	0.234	23	10	0.396	0.576
D, T	0.683*		22		0.488	
D; ΔT		0.447		9		0.697
D, S	0.679*		22		0.488	
T, ΔT	0.675*		22		0.488	
T, S	0.568*		22		0.488	
D, T, ΔT	0.715*		21		0.522	
D, T, S	0.733*		21		0.522	

A = correlations with eggs/m^3 of water filtered
B = correlations with eggs/m^3 of water filtered during "spawning season"

TABLE B15. *GNATHANODON SPECIOSUS* (PA'OPA'O) EGGS IN SAMPAN CHANNEL

Independent Variable(s)	Correlation Coefficient (R)	d.f.	$R_{.05}$ (Two-tailed)
D	0.496*	23	0.396
ΔD	-0.289	23	0.396
T	0.496*	23	0.396
ΔT	0.085	23	0.396
S	0.353	23	0.396
TF	0.095	34	0.325
|TF|	0.101	34	0.325
D, ΔD	0.594*	22	0.488
D, T	0.548*	22	0.488
ΔD, T	0.500*	22	0.488
D, ΔT	0.530*	22	0.488
D, S	0.503*	22	0.488
T, ΔT	0.496*	22	0.488
T, S	0.496*	22	0.488
D, T, S	0.552*	21	0.522
D, ΔD, T	0.637*	21	0.522
D, T, ΔT	0.562*	21	0.522
ΔD, T, ΔT	0.501	21	0.522
D, ΔD, T, ΔT	0.646*	20	0.604

TABLE B16. TYPE VIIIc EGGS IN SAMPAN CHANNEL

Independent Variable(s)	Correlation Coefficient (R)	d.f.	$R_{.05}$ (Two-tailed)
D	0.250	14	0.497
|ΔD|	0.156	14	0.497
T	-0.131	14	0.497
|ΔT|	0.092	14	0.497
S	-0.261	14	0.497
HN	0.031	14	0.497
TF	-0.389*	40	0.304
D, T	0.347	13	0.608
D, S	0.401	13	0.608
D, T, S	0.403	12	0.683

TABLE B17. TETRAODONTIFORM (KĒKĒ) EGGS IN SAMPAN CHANNEL

Independent Variable(s)	Correlation Coefficient (R)		d.f.		$R_{.05}$ (Two-tailed)	
	A	B	A	B	A	B
D	0.589*	0.507*	24	15	0.388	0.482
|ΔD|	-0.209	-0.311	24	15	0.388	0.482
T	0.234	0.170	24	15	0.388	0.482
|ΔT|	-0.120	-0.140	24	15	0.388	0.482
S	0.444*	0.564*	24	15	0.388	0.482
MN	0.051	0.011	24	15	0.388	0.482
D, T	0.615*	0.550	23	14	0.479	0.590
D, S	0.603*	0.568	23	14	0.479	0.590
D, MN	0.589*	0.508	23	14	0.479	0.590
D, T, S	0.681*	0.666*	22	13	0.542	0.664
D, T, S, MN	0.681*		21		0.592	

A = correlations with eggs/m^3 of water filtered
B = correlations with eggs/m^3 of water filtered during "spawning season"

TABLE B18. *CRYSTALLODYTES COOKEI* EGGS IN SAMPAN CHANNEL

Independent Variable(s)	Correlation Coefficient (R)	d.f.	$R_{.05}$ (Two-tailed)
D	-0.081	24	0.388
|ΔD|	-0.259	24	0.388
T	-0.434*	24	0.388
|ΔT|	-0.152	24	0.388
S	-0.267	24	0.388
MN	0.140	24	0.388
TF	-0.492*	40	0.304
D, T	0.500*	23	0.479
D, S	0.282	23	0.479
T, S	0.442	23	0.479
D, T, S	0.501	22	0.542

TABLE B19. PHYSICAL VARIABLES AND CORRELATION COEFFICIENTS

SOUTH KANEOHE BAY

	Day Length	Water Temperature	Salinity	Change in Day Length	Change in Water Temperature
Day Length	.999981	.694124	.601155	.067477	.499827
Water Temperature	.694124	1.00001	.755174	-.620759	.174872
Salinity	.601155	.755174	.999902	-.408338	.085133
Change In Day Length	.067477	-.620759	-.408338	1.00000	.476793
Change in Water Temperature	.499827	.174872	.085133	.476793	1.00000

(20 Degrees of Freedom)

SAMPAN CHANNEL

	Day Length	Water Temperature	Salinity	Change in Day Length	Change in Water Temperature
Day length	.999981	.639412	.575826	.073164	.498421
Water Temperature	.639412	.999947	.737193	-.677559	.131369
Salinity	.575826	.737193	1.00015	-.472097	.007870
Change In Day Length	.073164	-.677559	-.472097	1.00000	.441325
Change In Water Temperature	.498421	.131369	.007870	.441325	1.00000

(23 Degrees of Freedom)

APPENDIX C. PHYSICAL DATA

TABLE C1. SAMPAN CHANNEL PHYSICAL DATA

Date	Water Temperature (°C)			Salinity (°/oo)			Dissolved Oxygen (parts per million)			Surface Light Intensity (foot-candles)*	
	Morning	Afternoon	Night	Morning	Afternoon	Night	Morning	Afternoon	Night	Morning	Afternoon
25 Mar 1971	23.8	23.5	-	34.6	35.0	-	7.5	7.7	-	-	-
8 Apr 1971	-	-	-	-	-	-	-	-	-	-	-
22 Apr 1971	23.9	24.1	24.0	-	35.0	34.1	6.7	7.5	7.0	3200	2200
7 May 1971	24.5	24.9	24.5	35.0	35.0	34.6	7.7	8.2	7.8	5200	2300
21 May 1971	24.0	25.1	24.9	35.0	35.0	35.0	5.5	7.8	7.4	6000	2400
3 Jun 1971	24.7	25.2	25.1	35.4	35.4	35.7	7.3	7.9	8.0	1600	2800
18 Jun 1971	24.6	25.7	25.5	34.5	34.5	35.0	7.9	7.9	8.6	3900	5800
30 Jun 1971	25.2	26.2	25.8	33.0	35.0	35.5	7.4	8.7	7.8	4400	5400
14 Jul 1971	24.9	26.4	25.8	34.5	35.0	35.0	7.9	-	-	2800	1600
28 Jul 1971	25.4	26.5	26.4	34.5	35.0	36.0	6.2	5.6	6.4	3000	5500
11 Aug 1971	25.5	27.0	28.0	34.5	35.0	34.5	6.6	6.6	6.8	4600	5000
25 Aug 1971	26.0	26.0	26.0	35.0	34.5	34.5	6.0	6.1	6.6	3600	2000
7 Sep 1971	26.6	27.2	26.7	35.0	34.2	35.0	-	6.2	7.0	7000	2800
21 Sep 1971	26.5	26.7	26.7	34.6	34.0	35.7	6.1	6.4	7.0	4500	5600
5 Oct 1971	25.7	26.0	25.9	35.0	35.7	35.4	6.0	6.9	6.8	3600	8000
19 Oct 1971	26.3	26.2	25.7	35.0	35.4	35.4	6.5	6.3	7.1	4000	1600
2 Nov 1971	24.8	25.2	25.0	34.1	34.6	34.6	6.5	6.6	6.5	2600	1000
16 Nov 1971	24.3	24.4	24.3	34.5	34.5	34.5	6.2	7.0	7.0	6000	2200
30 Nov 1971	23.7	24.2	24.4	34.0	34.5	34.5	6.2	6.5	7.0	2000	1800
14 Dec 1971	22.9	23.4	22.9	34.0	34.0	34.0	7.0	7.5	6.5	1400	7000
28 Dec 1971	22.9	23.2	22.8	34.5	35.0	34.0	6.9	7.1	7.8	4000	2200
11 Jan 1972	23.1	23.2	23.0	33.5	34.0	34.0	6.6	6.1	7.2	3200	2000
27 Jan 1972	22.9	22.8	22.5	33.5	33.0	33.5	6.6	7.0	6.9	4000	800
10 Feb 1972	22.4	22.9	22.6	33.3	34.1	33.3	6.3	6.6	7.4	3200	3200
25 Feb 1972	21.9	23.3	23.5	33.3	34.1	33.3	6.8	6.6	7.1	-	4800
9 Mar 1972	23.0	23.8	23.6	33.0	34.5	35.0	6.3	7.0	7.3	3200	5400
23 Mar 1972	23.9	23.6	23.3	33.0	35.5	34.0	6.6	6.9	6.8	4400	3200
6 Apr 1972	22.6	22.5	22.8	33.5	35.0	33.5	6.1	6.8	6.6	1600	2300
20 Apr 1972	23.2	23.8	23.3	33.0	35.0	33.0	6.4	6.3	6.7	2200	4200
18 Jul 1972	25.3	25.9	26.2	35.5	35.0	33.5	-	-	-	4200	6000

*The values given must be multiplied by 1.25 to obtain the true light intensity.

TABLE C2. SOUTH KANEOHE BAY PHYSICAL DATA

Date	Water Temperature (°C)			Salinity (°/₀₀)			Dissolved Oxygen (parts per million)			Surface Light Intensity (foot-candles)*	
	Morning	Afternoon	Night	Morning	Afternoon	Night	Morning	Afternoon	Night	Morning	Afternoon
25 Mar 1971	23.7	23.6	23.5	33.3	34.1	34.6	8.2	8.0	7.7	-	-
8 Apr 1971	-	-	-	-	-	-	-	-	-	-	-
22 Apr 1971	23.9	24.1	24.0	-	35.0	34.1	6.7	7.5	7.0	1080	940
7 May 1971	24.5	24.9	24.5	35.8	35.0	34.6	7.9	8.2	7.8	8000	9100
21 May 1971	25.2	25.4	25.2	35.7	36.6	34.6	5.5	7.6	7.5	7600	320
3 Jun 1971	25.2	25.4	25.2	35.0	35.0	35.0	7.7	8.2	8.3	6800	1400
18 Jun 1971	25.8	26.3	25.7	34.5	34.5	34.0	8.8	9.2	8.3	7000	5000
30 Jun 1971	26.5	26.9	26.5	35.5	35.5	34.5	8.0	9.2	10.1	5200	1600
14 Jul 1971	25.9	26.2	26.1	35.1	35.0	34.5	8.7	8.6	9.5	2600	1400
28 Jul 1971	26.7	26.9	26.5	35.0	35.5	34.5	6.4	6.2	6.2	4800	2000
11 Aug 1971	27.2	27.5	27.5	35.0	35.5	34.5	6.7	6.9	7.4	5900	1800
25 Aug 1971	26.5	27.0	26.2	34.5	35.0	34.5	6.6	6.8	7.1	3000	2000
7 Sep 1971	27.0	27.7	27.1	34.0	35.0	34.0	6.4	6.8	7.3	5600	4600
21 Sep 1971	26.7	26.9	26.8	35.0	35.0	35.0	6.2	6.0	6.8	4500	5600
5 Oct 1971	26.2	26.7	26.2	35.7	35.0	35.0	7.0	6.9	7.9	5600	9000
19 Oct 1971	26.5	26.3	26.1	35.4	35.0	35.0	6.3	7.7	7.1	3000	800
2 Nov 1971	24.9	25.3	25.0	35.0	34.6	34.6	6.2	6.1	6.3	7800	1400
16 Nov 1971	24.1	24.4	24.2	34.0	34.5	34.5	6.0	7.2	6.8	4000	1600
30 Nov 1971	23.6	24.0	23.7	34.0	34.0	33.5	6.7	7.4	7.1	1200	6200
14 Dec 1971	23.1	23.2	23.0	34.0	34.0	34.0	6.9	9.0	-	3200	5000
28 Dec 1971	22.6	22.8	22.3	34.5	34.0	33.5	6.4	7.0	6.8	4400	3700
11 Jan 1972	22.2	22.7	22.2	33.5	33.5	33.0	6.4	6.2	7.2	5400	3600
27 Jan 1972	22.3	22.7	22.3	31.5	32.0	30.5	6.5	7.3	7.0	4000	600
10 Feb 1972	22.5	23.0	22.3	33.3	33.3	33.3	6.3	6.6	6.6	4200	4800
25 Feb 1972	21.9	22.5	22.3	33.3	33.3	32.9	7.2	6.6	7.6	-	6000
9 Mar 1972	23.4	24.0	23.3	34.5	34.0	34.0	6.7	6.7	7.0	4600	5400
23 Mar 1972	24.1	24.6	24.2	34.0	34.5	33.5	6.2	6.7	6.5	2200	1000
6 Apr 1972	23.1	23.0	22.9	34.0	35.0	34.0	5.7	6.9	6.4	3500	800
20 Apr 1972	23.2	23.4	23.1	32.5	34.0	34.0	6.3	6.9	6.8	1500	2600
18 Jul 1972	25.6	26.6	26.0	33.5	34.0	33.0	-	-	-	4600	4800

*The given values must be multiplied by 1.25 to obtain the true light intensity.

APPENDIX D. TABULATED DATA FOR FISH EGGS AND LARVAE

TABLE D1. TOW DATES LACKING DATA

Date	Location	Time	Reason
25 Mar 1971	Sampan Channel	Afternoon	Only one tow taken between buoys 6 and 8 due to high waves in channel
	Sampan Channel	Night	No tows taken due to high waves in channel
8 Apr 1971	Sampan Channel South Kaneohe Bay	All times	Data sheets listing volumes filtered were lost
7 May 1971	Sampan Channel	Afternoon	Only one tow taken due to current meter malfunction
14 Jul 1971	South Kaneohe Bay	Morning	Only one tow taken due to boat schedule conflict
	Sampan Channel	Afternoon	One sample not properly preserved
28 Jul 1971	South Kaneohe Bay	Morning	Only one tow taken due to boat schedule conflict
11 Aug 1971	South Kaneohe Bay	Morning	No tows due to boat schedule conflict and one sample improperly preserved
25 Aug 1971	South Kaneohe Bay	Morning	Only one tow taken due to boat schedule conflict
	Sampan Channel	Night	Only one tow taken due to current meter malfunction
	South Kaneohe Bay	Night	Only one tow taken due to current meter malfunction
7 Sep 1971	South Kaneohe Bay	Morning	Only one tow taken due to boat schedule conflict
21 Sep 1971	South Kaneohe Bay	Afternoon	One sample spilled
19 Oct 1971	South Kaneohe Bay	Afternoon	No tows due to equipment failure
16 Nov 1971	Sampan Channel	Morning	One sample spilled
14 Dec 1971	Sampan Channel	Night	Tows between buoys 6 and 8 due to high waves in channel
27 Jan 1972	Sampan Channel	Night	Tows between buoys 6 and 8 due to high waves in channel
10 Feb 1972	Sampan Channel	Night	Tows between buoys 6 and 8 due to high waves in channel
6 Apr 1972	Sampan Channel	Morning	Tows between buoys 6 and 8 due to high waves in channel
	Sampan Channel	Night	Tows between buoys 6 and 8 due to high waves in channel
18 Jul 1972	Sampan Channel	Morning	Only one tow taken due to equipment failure
	South Kaneohe Bay	Night	Only one tow taken due to current meter malfunction

Summary

360 tows scheduled
-31 tows not included

329
-11 tows in slightly different locations

318 tows in scheduled location with data included

TABLE D2. PELAGIC FISH EGGS TAKEN FROM SOUTH KANEOHE BAY

												Unidentified Eggs							
Date	Bothid I	Carangidae: *Caranx mate* and Type XLIII	Carangidae: *Gnathanodon speciosus*	Dussumieriidae: *Etrumeus micropus*	Engraulidae: *Stolephorus purpureus*	Labridae: *Thalassoma* sp.	Labrid II*	Labrid IV	Synodont I	Tetraodontiformes I	Trichonotidae: *Crystallodytes cookei*	Type VIIIb*	Type VIIIc*	Type XIX	Type XXX	Type XXXIV	Type XXXV	Type XXXVI	Type XLII
25 Mar 1971		X		X	X														
8 Apr 1971	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22 Apr 1971		X	X	X	X		(X)			X		(X)	(X)						
7 May 1971		X	X	X	X		(X)			X		(X)	(X)						
21 May 1971		X	X	X	X		(X)			X		(X)	(X)						
3 Jun 1971		X	X	X	X		(X)					(X)	(X)						
18 Jun 1971		X	X	X	X		(X)			X		(X)	(X)						
30 Jun 1971		X	X	X	X		(X)					(X)	(X)						
14 Jul 1971		X	X		X		(X)					(X)	(X)						
28 Jul 1971		X	X		X		(X)					(X)	(X)						
11 Aug 1971		X	X				(X)					(X)	(X)	X					
25 Aug 1971		X	X		X		(X)			X	X	(X)	(X)						
7 Sep 1971	X	X			X		(X)					(X)	(X)						
21 Sep 1971		X	X		X							X							
5 Oct 1971		X	X		X		X		X				X						
19 Oct 1971	X	X	X	X			X						X						
2 Nov 1971				X	X														
16 Nov 1971		X		X	X				X										
30 Nov 1971				X	X		X		X	X			X						
14 Dec 1971				X	X				X										
28 Dec 1971				X	X		X						X						
11 Jan 1972				X	X		X												
27 Jan 1972		X		X	X		X				X	X	X						
10 Feb 1972		X		X	X		X			X			X						
25 Feb 1972		X	X	X	X		X												
9 Mar 1972		X	X	X	X		X	X											
23 Mar 1972		X	X		X		X				X	X				X			
6 Apr 1972		X	X		X	X	X								X				
20 Apr 1972		X	X	X	X	X	X						X					X	X
18 Jul 1972	X	X	X	X	X	X	X	X					X				X	X	X

* Prior to 21 September 1971, Labrid II, Type VIIIb, and Type VIIIc were not adequately distinguished.

TABLE D3. PELAGIC FISH EGGS TAKEN FROM THE SAMPAN CHANNEL*

Date	Acanthuridae (Type XLIV)	Anguilliformes	Bothid I	Bothid II	Bothid III	Carangidae: *Caranx mate* and Type XLIII	Carangidae: *Gnathanodon speciosus*	Dussumieriidae: *Etrumeus micropus*	Engraulidae: *Stolephorus purpureus*	Fistulariidae	Labridae: *Thalassoma* sp.	Labrid II**	Labrid III	Labrid IV	Molidae: *Ranzania laevis*	Scarid I	Scarid II	Schindleriidae: *Schindleria* sp.	Synodont I	Synodont II (*Bathysaurus* sp.)	Tetraodontiformes I	Tetraodontiformes II	Trichonotidae: *Crystallodytes cookei*	Unidentified Eggs												
																								Type VIIIb**	Type VIIIc**	Type XVII	Type XIX	Type XX	Type XXII***	Type XXIX	Type XXX	Type XXXIV	Type XXXV	Type XXXVI	Type XXXIX	Type XLII
25 Mar 1971						X		X																												
8 Apr 1971	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22 Apr 1971			X	X		X	X	X	X			(X)							X		X		X	(X)	(X)											
7 May 1971		X				X	X					(X)									X		X	(X)	(X)											
21 May 1971		X		X		X	X		X			(X)							X	X	X		X	(X)	(X)											
3 Jun 1971			X	X		X	X	X	X			(X)							X		X		X	(X)	(X)											
18 Jun 1971		X		X		X	X		X			(X)							X	X	X		X	(X)	(X)											
30 Jun 1971		X	X	X		X	X	X				(X)							X	X	X		X	(X)	(X)											
14 Jul 1971				X		X	X		X			(X)							X				X	(X)	(X)											
28 Jul 1971		X	X	X		X	X	X	X			(X)							X	X	X		X	(X)	(X)											
11 Aug 1971		X	X	X		X	X		X			(X)							X	X	X		X	(X)	(X)	X	X									
25 Aug 1971			X			X	X		X			(X)							X		X		X	(X)	(X)		X									
7 Sep 1971		X	X	X	X	X	X		X			(X)							X		X		X	(X)	(X)	X		X								
21 Sep 1971			X			X						X							X		X			X	X											
5 Oct 1971				X		X						X							X	X			X		X		X									
19 Oct 1971			X	X	X	X						X							X				X	X	X											
2 Nov 1971						X		X				X											X	X	X											
16 Nov 1971			X			X	X					X							X				X		X											
30 Nov 1971						X	X	X	X			X							X				X	X	X											
14 Dec 1971						X						X							X				X	X	X	X			X							
28 Dec 1971						X			X			X							X		X		X	X	X	X	X									
11 Jan 1972						X			X			X							X				X	X	X	X	X		X							
27 Jan 1972						X		X	X			X				X			X				X	X	X				X							
10 Feb 1972		X				X	X	X	X			X	X	X							X		X		X				X							
25 Feb 1972			X	X		X	X	X	X			X		X	X	X	X		X				X	X	X				X	X	X					
9 Mar 1972			X	X		X	X	X				X	X	X		X		X	X				X	X	X				X		X					
23 Mar 1972				X		X	X			X		X		X					X	X			X	X	X				X		X	X	X			
6 Apr 1972			X	X		X			X		X	X		X		X		X	X		X	X	X	X	X	X							X	X	X	
20 Apr 1972	X					X	X	X	X		X	X		X		X	X		X	X	X		X	X	X						X		X	X		X
18 Jul 1972	X		X			X					X	X		X				X	X	X	X		X	X	X				X				X	X		X

*Scorpaenids I and II are not included.

**Not adequately distinguished prior to 21 September 1971.

***Identified as *Kyphosus cinerascens* after the study had ended.

TABLE D4. BOTHIDAE (BOTHID I)

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	(0)*	-	0	0	0
8 Apr 1971	-	-	-	-	-	-
22 Apr 1971	0	0	0.065	0	0	0
7 May 1971	0	0	0	0	0	0
21 May 1971	0	0	0	0	0	0
3 Jun 1971	0.045	1.925	0	0	0	0
18 Jun 1971	0	0.050	0	0	0	0
30 Jun 1971	0.045	0.055	0	0	0	0
14 Jul 1971	0	0	0	(0)	0	0
28 Jul 1971	0.075	0.005	0	(0)	0	0
11 Aug 1971	0.015	0	0	(0)	0	0
25 Aug 1971	0	0.030	(0)	(0)	0	(0)
7 Sep 1971	0	0.010	0.015	(0)	0.035	0
21 Sep 1971	0	0.010	0	0	(0)	0
5 Oct 1971	0	0	0	0	0	0
19 Oct 1971	0	0	0.050	0	-	0.020
2 Nov 1971	0	0	0	0	0	0
16 Nov 1971	(0)	0	0.030	0	0	0
30 Nov 1971	(0)	0	0	0	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	0	0	0	0
27 Jan 1972	0	0	0	0	0	0
10 Feb 1972	0	0	0	0	0	0
25 Feb 1972	0	0.010	0	0	0	0
9 Mar 1972	0.015	0	0	0	0	0
23 Mar 1972	0	0	0.015	0	0	0
6 Apr 1972	0.010	0	0	0	0	0
20 Apr 1972	0	0	0	0	0	0
18 Jul 1972	(0.510)	0.069	0.012	0	0	0.024

*Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D5. BOTHIDAE (BOTHID II)

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay* (Eggs/m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	(0)**	-			
8 Apr 1971	-	-	-			
22 Apr 1971	0	0	0			
7 May 1971	0	0	0			
21 May 1971	0.025	0	0			
3 Jun 1971	0.015	0.015	0.055			
18 Jun 1971	0	0.015	0.015			
30 Jun 1971	0.015	0.015	0.115			
14 Jul 1971	0.010	0	0			
28 Jul 1971	0.055	0	0			
11 Aug 1971	0	0.005	0.030			
25 Aug 1971	0	0	(0)			
7 Sep 1971	0.020	0	0			
21 Sep 1971	0	0	0			
5 Oct 1971	0.015	0.015	0.015			
19 Oct 1971	0.015	0	0			
2 Nov 1971	0	0	0			
16 Nov 1971	(0)	0	0			
30 Nov 1971	(0)	0	0			
14 Dec 1971	0	0	0			
28 Dec 1971	0	0	0			
11 Jan 1972	0	0	0.015			
27 Jan 1972	0	0	0			
10 Feb 1972	0	0	0			
25 Feb 1972	0.015	0	0.025			
9 Mar 1972	0	0	0.270			
23 Mar 1972	0	0.055	0			
6 Apr 1972	0	0.010	0			
20 Apr 1972	0	0	0			
18 Jul 1972	(0)	0	0			

*Bothid II eggs were not taken from the southern station.
**Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D6. CARANGIDAE (*CARANX MATE* AND TYPE XLIII)*

Date	Sampan Channel (Eggs/m³ filtered) Morning $\overline{X}$	Sampan Channel (Eggs/m³ filtered) Afternoon $\overline{X}$	Sampan Channel (Eggs/m³ filtered) Night $\overline{X}$	South Kaneohe Bay (Eggs/m³ filtered) Morning $\overline{X}$	South Kaneohe Bay (Eggs/m³ filtered) Afternoon $\overline{X}$	South Kaneohe Bay (Eggs/m³ filtered) Night $\overline{X}$
11 Jan 1972	0.035	0	0	0	0	0
27 Jan 1972	0.290	0.775	0.465	0.215	0.150	0.115
10 Feb 1972	0.180	0.080	0.075	0.195	0.710	2.485
25 Feb 1972	0.150	0.390	0.255	0.020	0.045	0.040
9 Mar 1972	0.050	0	1.145	0	0.115	0.020
23 Mar 1972	0.060	0.135	0.210	13.856	8.530	3.580
6 Apr 1972	0.055	0.065	0.055	3.105	2.005	0.570
20 Apr 1972	1.400	0.015	0	2.540	1.605	1.985
18 Jul 1972	(0)**	0	0.087	1.250	0.885	3.995

*These eggs were not adequately distinguished from the "Omaka Complex" prior to 11 Jan 1972.

**Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D7. CARANGIDAE (*GNATHANODON SPECIOSUS*)

Date	Sampan Channel (Eggs/m³ filtered) Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	South Kaneohe Bay (Eggs/m³ filtered) Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971*						
8 Apr 1971	-	-	-	-	-	-
22 Apr 1971	0	0.110	0.030	0.155	0	0
7 May 1971	0.045	0.355	0.075	3.235	0.125	1.620
21 May 1971	0.080	0.015	0	0.020	0.380	0.585
3 Jun 1971	0.160	0.120	0.065	2.250	0.225	0.465
18 Jun 1971	0	0	0	0.365	0.350	0.520
30 Jun 1971	0.090	0.030	0.025	0.415	0.500	0.030
14 Jul 1971	0.295	0.010	11.035	(1.550)**	2.360	1.425
28 Jul 1971	0.315	0.005	2.050	(1.630)	0.205	1.505
11 Aug 1971	0.370	0	1.100	(1.570)	0.440	2.355
25 Aug 1971	0.180	0.030	(1.720)	(5.940)	1.190	(1.470)
7 Sep 1971	0.015	0.010	0	(0)	0	0
21 Sep 1971	0	0	0.045	0	(0)	0.150
5 Oct 1971	0	0	0	0.160	0	0
19 Oct 1971	0	0.010	0.035	0	-	0.045
2 Nov 1971	0	0	0	0	0	0
16 Nov 1971	(0)	0.015	0	0	0	0
30 Nov 1971	(0.015)	0.010	0.020	0	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	0	0	0	0
27 Jan 1972	0	0	0	0	0	0
10 Feb 1972	0	0	0.020	0	0.040	0
25 Feb 1972	0	0	0.010	0	0	0.045
9 Mar 1972	0.025	0.015	0	0.355	0.170	1.905
23 Mar 1972	0	0.030	0	0.230	0	2.065
6 Apr 1972	0	0	0	0.160	0.045	0.605
20 Apr 1972	0	0.010	0	0.115	0	0.060
18 Jul 1972	(0)	0	0	1.534	0.159	0

**Gnathanodon* eggs were not adequately distinguished from the "Omaka Complex" on this date.

**Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D8. DUSSUMIERIIDAE (*ETRUMEUS MICROPUS*)

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	0.045	(0.070)*	-	0.290	1.020	0.470
8 Apr 1971	-	-	-	-	-	-
22 Apr 1971	0.030	0	0.015	0.160	0.060	0.060
7 May 1971	0	0	0	0.260	3.510	0.270
21 May 1971	0	0	0	0.010	0.020	0.160
3 Jun 1971	0	0	0.015	0.200	0.240	0.180
18 Jun 1971	0	0	0	0.040	0.210	0.310
30 Jun 1971	0.030	0.025	0.030	0.080	0	0.030
14 Jul 1971	0	0	0	(0)	0	0
28 Jul 1971	0	0.010	0	(0)	0	0
11 Aug 1971	0	0	0	(0)	0	0
25 Aug 1971	0	0	(0)	(0)	0	(0)
7 Sep 1971	0	0	0	(0)	0	0
21 Sep 1971	0	0	0	0	(0)	0
5 Oct 1971	0	0	0	0	0	0
19 Oct 1971	0	0	0	0	-	0.020
2 Nov 1971	0.015	0.008	0	0	0	0.020
16 Nov 1971	(0)	0.030	0	0	0	0
30 Nov 1971	(0.015)	0.110	0	0	0.060	0.100
14 Dec 1971	0	0	0	0	0.030	0
28 Dec 1971	0	0	0	0.050	0.100	0
11 Jan 1972	0	0	0	0.050	0	0.030
27 Jan 1972	0.025	0	0	0.050	0	0
10 Feb 1972	0.015	0	0	0.070	0.030	0
25 Feb 1972	0.015	0	0	0	0	0.050
9 Mar 1972	0.075	0	0	0	0	0.030
23 Mar 1972	0	0	0	0	0	0.050
6 Apr 1972	0	0	0	0	0	0
20 Apr 1972	0.010	0	0	0	0.030	0.090
18 Jul 1972	(0)	0	0	0	0.030	0.024

*Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D9. ENGRAULIDAE (*STOLEPHORUS PURPUREUS*)

Date	Sampan Channel (Eggs/m^3 filtered) Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	South Kaneohe Bay (Eggs/m^3 filtered) Morning X	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	(0)*	-	0.090	0.025	0.010
8 Apr 1971	-	-	-	-	-	-
22 Apr 1971	0	0	0.015	0.020	0.060	0.165
7 May 1971	0	0	0	0.220	0.250	0.015
21 May 1971	0	0.095	0.025	0.040	0.080	0.130
3 Jun 1971	0.015	0	0.050	0.065	0	0.260
18 Jun 1971	0	0	0.015	0.150	0	0.060
30 Jun 1971	0	0	0	0	0.025	0.015
14 Jul 1971	0	0.010	0.075	(0.910)	0.130	0.055
28 Jul 1971	0.015	0	0.030	(0.060)	0.020	0
11 Aug 1971	0.015	0.015	0	(0)	0	0
25 Aug 1971	0.015	0	(0)	(0.840)	0.025	(0)
7 Sep 1971	0	0	0.035	(0)	0.100	0.090
21 Sep 1971	0	0	0	0.165	(0.090)	0
5 Oct 1971	0	0	0	0.340	0.070	0
19 Oct 1971	0	0	0	0.030	-	0
2 Nov 1971	0	0	0	0	0.050	0.045
16 Nov 1971	(0)	0	0	0	0.025	0.090
30 Nov 1971	(0)	0	0.010	0.185	0.265	1.930
14 Dec 1971	0	0	0	0	0	0.055
28 Dec 1971	0.040	0.010	0	0.055	0.075	0.025
11 Jan 1972	0	0.015	0.015	0	0.050	0
27 Jan 1972	0.010	0	0	0.285	0.205	0.070
10 Feb 1972	0.280	0.035	0.020	1.095	0.240	0.030
25 Feb 1972	0.120	0	0	0.810	0.695	2.275
9 Mar 1972	0	0	0	0	0.145	0
23 Mar 1972	0	0	0	0	0.045	0.040
6 Apr 1972	0	0.010	0	1.055	2.220	0.110
20 Apr 1972	0.025	0	0	0.330	0.275	0.115
18 Jul 1972	(0)	0	0	1.085	0.130	0.024

*Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D10. LABRIDAE (LABRID II)*

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
11 Jan 1972	0.060	3.175	9.030	0	0.205	0.025
27 Jan 1972	0.405	3.500	2.390	2.640	0.985	3.950
10 Feb 1972	0.480	2.635	4.565	0.065	0.220	0.285
25 Feb 1972	0.585	0.750	4.640	0.040	0	0.480
9 Mar 1972	0	0.205	7.195	0	0	0.125
23 Mar 1972	31.090	0.450	1.600	0.325	0.110	0
6 Apr 1972	0.070	0.450	1.385	0.090	0	0
20 Apr 1972	0.135	0.090	9.930	0	0.025	0
18 Jul 1972	(0.127)**	0.797	0.530	0.095	0	0.010

*These eggs were not adequately distinguished from the "Omaka Complex" prior to 11 Jan 1972.

**Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D11. SYNODONTIDAE (SYNODONT 1)

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	0	(0)*	-	0	0	0
8 Apr 1971	-	-	-	-	-	-
22 Apr 1971	0	0.080	0	0	0	0
7 May 1971	0	0	0	0	0	0
21 May 1971	0.010	0	0	0	0	0
3 Jun 1971	0.145	0	0.030	0	0	0
18 Jun 1971	0.070	0.065	0.145	0	0	0
30 Jun 1971	0.185	0.095	0.155	0	0	0
14 Jul 1971	0.160	0	0.350	(0)	0	0
28 Jul 1971	0.270	0.005	0.180	(0)	0	0
11 Aug 1971	0.190	0.020	0.225	(0)	0	0
25 Aug 1971	0.025	0	(0.030)	(0)	0	(0)
7 Sep 1971	0.080	0.200	0.015	(0)	0	0
21 Sep 1971	0	0	0.045	0	(0)	0
5 Oct 1971	0	0.060	0	0	0.025	0
19 Oct 1971	0	0.010	0.035	0	-	0
2 Nov 1971	0	0	0	0	0	0
16 Nov 1971	(0)	0.035	0	0	0	0.030
30 Nov 1971	(0.015)	0	0	0.015	0	0
14 Dec 1971	0	0.010	0	0	0	0.065
28 Dec 1971	0	0.010	0.010	0	0	0
11 Jan 1972	0	0.030	0.055	0	0	0
27 Jan 1972	0.010	0.010	0	0	0	0
10 Feb 1972	0.010	0	0	0	0	0
25 Feb 1972	0.015	0.010	0	0	0	0
9 Mar 1972	0	0.010	0.050	0	0	0
23 Mar 1972	0	0.280	0	0	0	0
6 Apr 1972	0	0.030	0	0	0	0
20 Apr 1972	0	0.010	0.100	0	0	0
18 Jul	(0)	0	0.158	0	0	0

*Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D12. SYNODONTIDAE (SYNODONT II)

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay* (Eggs/m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	0	(0)**	-			
8 Apr 1971	-	-	-			
22 Apr 1971	0	0	0			
7 May 1971	0	0	0			
21 May 1971	0.025	0	0			
3 Jun 1971	0	0	0			
18 Jun 1971	0.075	0.050	0			
30 Jun 1971	0.045	0.015	0.015			
14 Jul 1971	0	0	0			
28 Jul 1971	0.015	0.040	0			
11 Aug 1971	0	0.005	0			
25 Aug 1971	0	0	(0)			
7 Sep 1971	0	0	0			
21 Sep 1971	0	0	0			
5 Oct 1971	0	0.030	0			
19 Oct 1971	0	0	0			
2 Nov 1971	0	0	0			
16 Nov 1971	(0)	0	0			
30 Nov 1971	(0)	0	0			
14 Dec 1971	0	0	0			
28 Dec 1971	0	0	0			
11 Jan 1972	0	0	0			
27 Jan 1972	0	0	0			
10 Feb 1972	0	0	0			
25 Feb 1972	0	0	0			
9 Mar 1972	0	0	0			
23 Mar 1972	0	0.020	0			
6 Apr 1972	0	0	0			
20 Apr 1972	0	0.030	0.015			
18 Jul 1972	(0.102)	0.029	0.510			

*Synodont II eggs were not taken from the southern station.
**Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D13. TETRAODONTIFORMES (TYPES I, II, AND III)

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	(0)*	-	0	0	0
8 Apr 1971	-	-	-	-	-	-
22 Apr 1971	0	0.080	0.065	0	0	0.080
7 May 1971	0.045	0	0	0	0	0.485
21 May 1971	0.125	0	0	0	0	0.025
3 Jun 1971	0.135	0.135	0.075	0	0	0
18 Jun 1971	0	0.050	0	0	0	0.060
30 Jun 1971	0.145	0	0.015	0	0	0
14 Jul 1971	0	0	0	(0)	0	0
28 Jul 1971	0	0	0.115	(0)	0	0
11 Aug 1971	0	0	0.035	(0)	0	0
25 Aug 1971	0.010	0	0.030	(0)	0	(0.050)
7 Sep 1971	0	0	0.020	(0)	0	0
21 Sep 1971	0.015	0.025	0	0	(0)	0
5 Oct 1971	0	0	0	0	0	0
19 Oct 1971	0	0	0	0	-	0
2 Nov 1971	0	0	0	0	0	0
16 Nov 1971	(0)	0	0	0	0	0
30 Nov 1971	(0)	0	0	0.130	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	0.010	0	0	0	0	0
11 Jan 1972	0	0	0	0	0	0
27 Jan 1972	0	0	0	0	0	0
10 Feb 1972	0.010	0	0.040	0.065	0	0
25 Feb 1972	0	0	0	0	0	0
9 Mar 1972	0	0	0	0	0	0
23 Mar 1972	0	0	0	0	0	0
6 Apr 1972	0	0.015	0.030	0	0	0
20 Apr 1972	0	0.015	0	0	0	0
18 Jul 1972	(0)	0	0.015	0	0	0

*Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D14. TRICHONOTIDAE (*CRYSTALLODYTES COOKEI*)

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	(0)*	-	0	0	0
8 Apr 1971	-	-	-	-	-	-
22 Apr 1971	0.015	0.030	0	0	0	0
7 May 1971	0.140	0	0.075	0	0	0
21 May 1971	0.065	0	0	0	0	0
3 Jun 1971	0.080	0.580	0.070	0	0	0
18 Jun 1971	0.045	0	0.080	0	0	0
30 Jun 1971	0.230	0	0.030	0	0	0
14 Jul 1971	0.165	0	0.145	(0)	0	0
28 Jul 1971	0.370	0.025	0.045	(0)	0	0
11 Aug 1971	0.145	0	0	(0)	0	0
25 Aug 1971	0.015	0	(0)	(0)	0	(0.100)
7 Sep 1971	0.060	0.020	0.060	(0)	0	0
21 Sep 1971	0	0	0	0	(0)	0
5 Oct 1971	0	0.095	0.015	0	0	0
19 Oct 1971	0.115	0	0	0	-	0
2 Nov 1971	0.015	0.008	0.015	0	0	0
16 Nov 1971	(0.020)	0	0.085	0	0	0
30 Nov 1971	(0.070)	0.010	0.050	0	0	0
14 Dec 1971	0.065	0.095	0.045	0	0	0
28 Dec 1971	0.170	0.135	0.280	0	0	0
11 Jan 1972	0.060	0.040	0.655	0	0	0
27 Jan 1972	0.010	0	0.440	0.075	0	0
10 Feb 1972	0.035	0	0.195	0	0	0
25 Feb 1972	0.060	0.035	0.160	0	0	0
9 Mar 1972	0.010	0.050	0.500	0	0	0
23 Mar 1972	0.025	0.280	0.040	0	0.045	0
6 Apr 1972	0.045	0.030	0.085	0	0	0
20 Apr 1972	0	0	0.085	0	0	0
18 Jul 1972	(0.330)	0.135	0.173	0	0	0

*Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D15. TYPE VIIIb*

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
21 Sep 1971	0	0.035	0.260	0	(0)**	0.030
5 Oct 1971	0	0	0	0	0	0
19 Oct 1971	0.040	0	0	0	-	0
2 Nov 1971	0	0.008	0	0	0	0
16 Nov 1971	(0)	0	0	0	0	0
30 Nov 1971	(0)	0	0.070	0	0	0
14 Dec 1971	0	0.025	0	0	0	0
28 Dec 1971	0.015	0	0	0	0	0
11 Jan 1972	0	0.030	0	0	0	0
27 Jan 1972	0.010	0	0	0	0	0
10 Feb 1972	0	0	0	0	0	0
25 Feb 1972	0	0.045	0	0	0	0
9 Mar 1972	0	0.010	0.010	0	0	0
23 Mar 1972	0.015	0.065	0	0	0	0
6 Apr 1972	0	0.010	0.085	0	0	0
20 Apr 1972	0.025	0.055	0.025	0	0	0
18 Jul 1972	(0.254)	0.124	0.033	0	0	0

*These eggs were not adequately separated from the "Omaka Complex" prior to 21 Sep 1971.

**Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D16. TYPE VIIIc*

Date	Sampan Channel (Eggs/m^3 filtered)			South Kaneohe Bay (Eggs/m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
21 Sep 1971	0.011	0	0.010	0	(0)**	0
5 Oct 1971	0	0.070	0.225	0	0.050	0
19 Oct 1971	0.045	0	0.060	0.025	-	0.020
2 Nov 1971	0	0	0.015	0	0	0
16 Nov 1971	(0)	0.035	0.255	0	0	0
30 Nov 1971	(0.035)	0.010	0.235	0	0	0.035
14 Dec 1971	0.045	0	0	0	0	0
28 Dec 1971	0.025	0.015	0	0	0.025	0
11 Jan 1972	0	0.100	0	0	0	0
27 Jan 1972	0.175	0.015	0	0.025	0	0.025
10 Feb 1972	0.045	0	0.505	0.125	0	1.500
25 Feb 1972	0	0	0.060	0	0	0
9 Mar 1972	0	0.015	0.115	0	0	0
23 Mar 1972	0.045	0.105	0.065	0	0	0
6 Apr 1972	0.015	0	0	0	0	0
20 Apr 1972	0.230	0.025	0.730	0	0	0.055
18 Jul 1972	(0.102)	0	0.074	0	0.033	0.049

*These eggs were not adequately separated from the "Omaka Complex" prior to 21 Sep 1971.

**Data enclosed in parenthesis ( ) indicate no replicate tow.

TABLE D17. KINDS OF FISH LARVAE SAMPLED IN KANEOHE BAY*

	South Kaneohe Bay	Sampan Channel
Acanthuridae		
A 1**	X	
A 2	X	X
Antennariidae		X
Anguilliformes		
(unidentified leptocephalus)		X
Apogonidae		
Foa brachygrammus	X	X
A 2	X	X
A 3		X
A 4	X	X
A 5	X	X
Type 80	X	X
Atherinidae		
Pranesus insularum	X	X
Iso hawaiiensis		X
Belonidae		
Tylosurus sp.	X	X
Blenniidae		
Enchelyurus brunneolus	X	X
Exallias brevis	X	X
Istiblennius zebra		X
Omobranchus elongatus	X	X
Type 5	X	X
Type 8	X	X
Type 9		X
Type 10	X	X
Plagiotremus sp.?	X	X
Cirripectus sp.? (Type 112)	X	X
Bothidae		X
Callionymidae		
C 1		X
Callionymus decoratus	X	X
Pogonemus pogognathus		X
Carangidae		
Caranx mate	X	X
Gnathanodon speciosus	X	X
Seriola rivoliana		X
Seriola (Type 26)		X
C 1	X	X
C 2	X	X

*Larvae are listed under the most specific identification which was possible to make.

**Numbers refer to the Hawaii Institute of Marine Biology classification system for unidentified larvae.

TABLE D17. KINDS OF FISH LARVAE SAMPLED IN KANEOHE BAY (continued)

	South Kaneohe Bay	Sampan Channel
C 3	X	X
C 4	X	X
C 5	X	X
Type 25 (*Seriola?*)		X
Type 101	X	X
Chloropthalmidae		
Chloropthalmus sp.		X
Clupeiformes	X	X
Coryphaenidae		
Coryphaena hippurus	X	X
Diodontidae		
Diodon sp.		X
Dussumieriidae		
Etrumeus micropus	X	X
Eleotridae		
Asterropteryx semipunctatus	X	X
Eviota epiphanes		X
Engraulidae		
Stolephorus purpureus	X	X
Exocoetidae		
Ex 0		X
Ex 1		X
Type 5		X
Type 23		X
Type 56	X	X
Evermannellidae		
Evermannella sp.	X	
Gempylidae		
Gempylus serpens	X	X
Gonostomatidae		
Cyclothone spp.	X	X
Diplophos taenia		X
Vinciguerria nimbaria		X
Type 140	X	
Gobiidae		
Bathygobius cotticeps		X
Bathygobius fuscus	X	X
Psilogobius mainlandi	X	X
Oxyurichthys lonchotus	X	X
Type 66		X
Type 91	X	X
Type 2	X	X
Type 3	X	X
Type 5	X	X
Type 6	X	X
Type 7		X
Type 8	X	X
Type 8A	X	X

TABLE D17. KINDS OF FISH LARVAE SAMPLED IN KANEOHE BAY (continued)

	South Kaneohe Bay	Sampan Channel
Type 9	X	X
Type 9A	X	X
Type 10		X
Type 11	X	X
Type 12	X	X
Type 13		X
Type 16		X
Type 18	X	X
Hemiramphidae	X	X
Kuhliidae		
Kuhlia sandvicensis (juvenile)	X	X
Kyphosid complex		
Type 77		X
Type 158	X	
Kyphosidae		
Kyphosus cinerascens	X	X
Labridae		
Cymolutes leclusei (L 1)		X
Cheilinus sp. (L 2)		X
L 3		X
Stethojulis sp. (L 6)		X
Lophiiformes	X	X
Melanostomiatidae		
Bathophilus sp.		X
Microdesmidae		
Gunnellichthys sp. (Type 73)		X
Mullidae		
Type 75		X
Type 115		X
Muraenidae		
Uropterygius (?) sp.		X
Myctophidae		
Ceratoscopelus townsendi - complex	X	X
Diaphus (Type 60)	X	X
Diaphus (Type 85)	X	X
Diaphus (Type 114)	X	X
Diogenichthys (?) sp.	X	X
Hygophum proximum	X	X
Lampadena urophaos		X
Lampadena (Type 65)	X	X
Lampadena luminosa	X	X
Lampanyctus (Type 70a)	X	X
Lampanyctus (Type 70b)		X
Lampanyctus (Type 70c)		X
Bolinichthys (Type 46)	X	X
Bolinichthys (Type 55)		X
Myctophum sp.		X

TABLE D17. KINDS OF FISH LARVAE SAMPLED IN KANEOHE BAY (continued)

	South Kaneohe Bay	Sampan Channel
Taaningichthys minimus		X
Triphoturus (Type 109)	X	X
Triphoturus nigrescens (Type 99)	X	X
Nomeidae		
Cubiceps pauciradiatus	X	X
Cubiceps caeruleus		X
Ostraciontidae		X
Pomacentridae		
Abudefduf spp.	X	X
Abudefduf abdominalis	X	X
Pomacentrus jenkensi	X	X
P 10	X	
Scaridae		
Sc 22	X	X
Sc 4	X	X
Scombridae		
Euthynnus affinis		X
Thunnus albacares	X	X
Scorpaenidae		
Pterois sphex		X
Type 57		X
S 3	X	X
S 5	X	X
S 6	X	X
S 7		X
S 8	X	X
S 9	X	
S 10		X
Schindleriidae		
Schindleria pietschmanni	X	X
Schindleria praematurus	X	X
Sphyraenidae		
Sphyraena barracuda		X
Syngnathidae		
Doryrhamphus melanopleura	X	X
Hippocampus kuda	X	X
Micrognathus spp.		X
Syngnathus balli		X
Synodontidae		
Saurida gracilis		X
Synodus sp. (Type 98)		X
Tetraodontiformes	X	X
Tetraodontidae	X	X
Arothron meleagris		X
Tripterygiidae		
Tripterygion atriceps	X	X

TABLE D17. KINDS OF FISH LARVAE SAMPLED IN KANEOHE BAY (continued)

	South Kaneohe Bay	Sampan Channel
Unidentified larvae[***]		
Type 28		X
Type 51	X	X
Type 58	X	X
Type 61	X	X
Type 62		X
Type 64		X
Type 67		X
Type 71		X
Type 79		X
Type 81		X
Type 90	X	X
Type 113	X	X
Type 124	X	X
Type 129	X	X
Type 131 (Blenniidae)	X	
Type 135	X	
Type 136	X	X
Type 142	X	X
Type 143		X
Type 151	X	X
Type 152 (Brotulidae)		X
Type 153		X
Type 154		X
Type 156		X
Type 157		X
Type 161 (Trichonotidae: *Crystallodytes cookei*)		X
Type 162		X
Type 163 (Scombridae: *Auxis* sp.)	X	
Type 164		X
Type 165		X
M 13		X
Total	100[†]	166[††]
Total number of species in all samples	175	

[***] Some "unidentified" larvae were identified while this paper was still in production. These identifications are given in parentheses.

[†] Seventy-five species which occurred in Sampan Channel did not occur in south Kaneohe Bay.

[††] Nine species which occurred in south Kaneohe Bay did not occur in Sampan Channel.

TABLE D18. TOTAL FISH LARVAE

Date	Sampan Channel (Larvae/1000 m^3 filtered) Morning $\overline{X}$	Sampan Channel Afternoon $\overline{X}$	Sampan Channel Night $\overline{X}$	South Kaneohe Bay (Larvae/1000 m^3 filtered) Morning $\overline{X}$	South Kaneohe Bay Afternoon $\overline{X}$	South Kaneohe Bay Night $\overline{X}$
25 Mar 197	30.05	113.43	-	295.50	106.59	90.81
22 Apr 1971	74.78	117.28	1993.97	181.19	531.69	3828.12
7 May 1971	103.68	97.50	607.84	19.39	919.18	771.00
21 May 1971	71.92	26.47	589.45	95.09	213.61	292.15
3 Jun 1971	11.21	7.72	395.00	146.30	110.39	140.44
18 Jun 1971	68.97	68.33	645.27	42.99	50.60	91.65
30 Jun 1971	34.74	14.12	267.59	263.71	186.35	48.73
14 Jul 1971	24.68	124.13	490.08	81.82	59.44	89.55
28 Jul 1971	124.61	8.02	774.79	20.34	79.62	67.00
11 Aug 1971	69.57	9.93	224.34	-	9.09	70.09
25 Aug 1971	7.26	13.27	259.72	97.88	78.33	248.50
7 Sep 1971	12.80	43.87	256.45	17.52	179.22	718.61
21 Sep 1971	31.74	74.54	71.10	57.58	172.54	187.76
5 Oct 1971	68.94	25.01	1668.67	89.75	49.73	94.46
19 Oct 1971	313.22	70.37	743.78	203.14	-	324.84
2 Nov 1971	27.94	40.37	246.46	129.86	136.30	111.03
16 Nov 1971	90.34	37.83	395.36	136.58	53.74	80.52
30 Nov 1971	19.17	19.64	128.15	26.93	49.85	48.39
14 Dec 1971	18.20	9.36	206.12	53.65	12.98	130.90
28 Dec 1971	40.77	14.99	46.18	66.96	63.35	69.50
11 Jan 1972	49.06	10.71	30.56	132.36	232.64	235.61
27 Jan 1972	49.12	98.79	85.86	195.31	203.55	55.20
10 Feb 1972	53.04	27.57	954.15	79.72	400.61	346.72
25 Feb 1972	316.90	54.35	137.44	201.60	79.02	84.33
9 Mar 1972	95.47	143.24	400.86	218.35	59.09	92.75
23 Mar 1972	13.50	500.41	543.45	262.99	400.65	232.74
6 Apr 1972	111.90	23.83	293.70	469.92	715.68	242.74
20 Apr 1972	38.78	26.96	318.22	142.96	128.18	112.10
18 Jul 1972	43.25	17.11	468.61	212.54	95.41	982.60
Mean	69.50	63.42	472.90	140.80	192.05	332.36
Standard Deviation	75.13	93.31	452.10	103.00	217.21	711.06

TABLE D19. APOGONIDAE

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0.65	2.64	-	8.17	0.90	3.56
22 Apr 1971	11.47	15.33	560.81	5.81	13.55	566.92
7 May 1971	11.99	2.38	48.22	2.95	15.05	108.34
21 May 1971	0	0	25.59	1.35	12.21	22.83
3 Jun 1971	0	0	4.94	81.15	12.43	73.73
18 Jun 1971	0	0	54.99	5.61	2.60	11.90
30 Jun 1971	0	0.70	0	105.11	30.86	18.28
14 Jul 1971	1.41	5.91	19.75	0	7.73	12.10
28 Jul 1971	0	0	30.37	8.72	0	0
11 Aug 1971	0	0	4.07	-	1.52	0
25 Aug 1971	2.12	0	0.80	3.50	3.48	8.19
7 Sep 1971	1.48	0	46.56	0	83.75	393.99
21 Sep 1971	2.11	2.59	0	0	3.50	15.71
5 Oct 1971	3.49	0.66	210.98	0	0	17.38
19 Oct 1971	58.23	3.29	83.90	0	-	18.15
2 Nov 1971	0	1.75	65.36	18.28	8.59	11.08
16 Nov 1971	7.97	0.82	4.49	0	1.32	7.27
30 Nov 1971	5.26	0.63	17.39	7.04	9.42	28.14
14 Dec 1971	0	0	2.14	7.23	1.10	8.42
28 Dec 1971	6.19	4.35	4.58	3.93	11.39	8.29
11 Jan 1972	0	0	0	6.60	40.27	9.13
27 Jan 1972	1.91	1.69	1.64	15.48	11.44	14.19
10 Feb 1972	7.95	3.64	38.79	6.37	2.62	5.49
25 Feb 1972	89.06	1.45	19.52	63.99	10.44	41.76
9 Mar 1972	15.87	9.64	47.45	36.46	5.97	15.40
23 Mar 1972	0	0	0.98	10.52	26.36	28.79
6 Apr 1972	2.96	0.74	0.71	7.57	10.31	3.20
20 Apr 1972	9.65	4.53	6.19	21.11	8.79	21.42
18 Jul 1972	0	0	116.83	7.11	15.67	498.64
Mean	8.27	1.63	50.61	15.50	12.55	68.01
Standard Deviation	19.08	2.36	109.94	25.82	16.88	148.22

TABLE D20. ATHERINIDAE (*PRANESUS INSULARUM*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	0.65	2.64	-	12.25	0	1.19
22 Apr 1971	0	0	5.32	4.39	0	15.63
7 May 1971	0	0	8.23	0	1.27	11.42
21 May 1971	3.78	0	2.53	2.69	0	18.71
3 Jun 1971	0.73	0	12.00	2.23	1.79	20.59
18 Jun 1971	0.64	0	38.35	0	0	5.10
30 Jun 1971	0.75	0	27.53	0	0	3.66
14 Jul 1971	0	0	0.64	0	2.18	1.85
28 Jul 1971	2.77	1.35	100.92	5.81	0	2.23
11 Aug 1971	0.72	0.68	29.08	-	0	2.58
25 Aug 1971	0.57	0	4.78	0	0	2.73
7 Sep 1971	0	0	28.48	0	0	0
21 Sep 1971	4.29	0	6.01	1.27	0	0
5 Oct 1971	0.70	0	63.27	0	0	5.87
19 Oct 1971	0	9.11	45.44	1.40	-	13.71
2 Nov 1971	0.77	0.82	1.34	0	2.38	7.76
16 Nov 1971	0	0	6.96	0	0	2.15
30 Nov 1971	0.85	0	0	0	0	0
14 Dec 1971	0	1.22	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	1.97	0	0	0
27 Jan 1972	0	0	0	1.14	0	0
10 Feb 1972	0	0	3.93	0	0	1.44
25 Feb 1972	0	0	0.78	0	0	0
9 Mar 1972	0	0	0.68	0	0	0
23 Mar 1972	0	0.79	0.49	0.96	1.08	11.70
6 Apr 1972	0.62	0.48	0	1.14	2.38	1.07
20 Apr 1972	0	0	0.58	0	0	0
18 Jul 1972	0	0	0	0	0	4.89
Mean	0.61	0.58	13.90	1.14	0.41	4.63
Standard Deviation	1.10	1.74	23.65	2.56	0.82	6.09

TABLE D21. BLENNIIDAE (*ENCHELYURUS BRUNNEOLUS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	1.38	1.32	-	0	0	0
22 Apr 1971	0.75	5.06	0.68	0	0	0
7 May 1971	0	1.19	0	0	0	0
21 May 1971	15.85	0.57	0.56	0	1.00	0
3 Jun 1971	3.20	1.54	0	1.11	0	0
18 Jun 1971	8.90	16.80	4.20	0	0	0
30 Jun 1971	4.37	7.56	7.54	1.45	4.75	2.00
14 Jul 1971	7.05	0	0	0	0	0
28 Jul 1971	36.95	2.67	3.02	0	1.88	0
11 Aug 1971	4.32	2.84	0.88	-	0	0
25 Aug 1971	0	0	0	0	0	0
7 Sep 1971	5.79	12.68	0	2.92	0	1.79
21 Sep 1971	0	2.92	0	5.09	0	0
5 Oct 1971	4.88	0	0	1.67	0	0
19 Oct 1971	5.87	2.01	0	5.49	-	0.77
2 Nov 1971	0.79	0.82	0	0	0	0
16 Nov 1971	0	0	0	0	0	0
30 Nov 1971	0	0	0.89	0	0	0
14 Dec 1971	0	1.22	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	6.74	4.03	0	0	0	0
27 Jan 1972	0	0	0.55	6.10	0	4.64
10 Feb 1972	1.96	1.50	0	0	0	0
25 Feb 1972	15.61	12.97	3.56	0	3.45	0
9 Mar 1972	30.19	54.39	99.53	16.41	2.81	4.62
23 Mar 1972	0	12.14	23.65	0	1.15	3.22
6 Apr 1972	10.11	0.72	5.45	0	0	0
20 Apr 1972	2.42	0.59	0	0	0	0
18 Jul 1972	15.27	5.29	0.70	4.73	0	0
Mean	6.28	5.20	5.40	1.60	0.55	0.54
Standard Deviation	9.03	10.51	19.03	3.48	1.23	1.35

TABLE D22. BLENNIIDAE (*EXALLIAS BREVIS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	0	0	-	0	0	0
22 Apr 1971	0	0	2.41	0	0.95	5.96
7 May 1971	0	0	0	0	0	0
21 May 1971	0	0	0	0	0	0
3 Jun 1971	0	0	0	0	0	0
18 Jun 1971	1.51	4.66	0	0	0	0
30 Jun 1971	0	0	0	0	0	0
14 Jul 1971	0	0	0	0	0	0
28 Jul 1971	24.31	0	0	0	0	0
11 Aug 1971	2.16	0	0	-	0	0
25 Aug 1971	0	0	0	0	0	0
7 Sep 1971	0	0	0	5.84	3.43	0
21 Sep 1971	0	0	0	0	0	0
5 Oct 1971	0	1.40	2.31	1.67	0	0
19 Oct 1971	37.96	3.06	0	1.40	-	0
2 Nov 1971	0.77	0	0.67	0	0	0
16 Nov 1971	0	0	0	0	0	0
30 Nov 1971	0	0	1.77	0	0	0
14 Dec 1971	0.56	0	0	1.21	0	0.40
28 Dec 1971	7.01	1.46	1.86	0	1.29	0.43
11 Jan 1972	5.53	0.67	0	0	0	0
27 Jan 1972	3.98	46.05	38.33	10.72	5.19	4.78
10 Feb 1972	0	0	1.77	0	0	0
25 Feb 1972	68.03	8.93	3.99	7.46	1.15	1.18
9 Mar 1972	1.97	16.27	7.03	2.86	1.58	1.33
23 Mar 1972	0	5.69	4.75	0	0	1.08
6 Apr 1972	25.78	0.97	0.71	0	0	0
20 Apr 1972	0	1.38	6.96	0	0	4.03
18 Jul 1972	2.54	0	0	4.73	0	0
Mean	6.27	3.12	2.48	1.11	0.35	0.63
Standard Deviation	14.99	8.97	7.32	2.61	1.05	1.55

TABLE D23. BLENNIIDAE (*OMOBRANCHUS ELONGATUS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	9.76	6.59	-	47.81	2.30	5.72
22 Apr 1971	11.47	13.91	17.75	12.01	18.46	1.68
7 May 1971	0	26.16	14.28	0	40.08	17.29
21 May 1971	3.78	22.64	5.06	16.51	21.80	2.37
3 Jun 1971	1.28	1.54	4.31	22.20	43.51	1.16
18 Jun 1971	0	3.08	0	1.84	0	0
30 Jun 1971	1.44	0.70	4.10	9.47	7.13	0
14 Jul 1971	1.72	5.91	0.64	4.55	2.18	1.85
28 Jul 1971	1.39	0	15.37	0	6.56	4.45
11 Aug 1971	0	1.42	0	-	0	0
25 Aug 1971	1.69	5.59	1.59	48.94	17.85	21.85
7 Sep 1971	1.35	1.64	2.45	2.92	1.72	0
21 Sep 1971	4.89	4.85	0	6.91	9.33	0
5 Oct 1971	4.88	4.63	17.79	32.02	7.00	1.38
19 Oct 1971	2.90	2.39	2.26	41.46	-	2.30
2 Nov 1971	4.67	8.98	8.13	39.14	33.25	7.77
16 Nov 1971	18.60	12.76	0	28.51	17.91	1.49
30 Nov 1971	0	3.70	0.57	5.66	4.45	3.37
14 Dec 1971	1.49	2.90	0.72	24.47	1.28	0
28 Dec 1971	0	1.21	0.93	3.85	10.19	1.33
11 Jan 1972	0	0	0	14.36	1.25	0
27 Jan 1972	0	0	0	9.92	5.33	0
10 Feb 1972	0.55	2.37	1.17	0	17.66	1.44
25 Feb 1972	3.73	0.59	1.22	0.96	1.18	0
9 Mar 1972	0	0	0	2.36	0	0
23 Mar 1972	0.82	0.71	0.49	26.78	6.68	1.08
6 Apr 1972	0.78	0	1.31	24.98	21.25	0
20 Apr 1972	0.61	1.18	0	9.68	15.03	0
18 Jul 1972	0	0.73	4.85	2.37	5.22	0
Mean	2.68	4.69	3.74	15.70	11.38	2.52
Standard Deviation	4.17	6.55	5.60	15.32	12.01	5.11

TABLE D24. BLENNIIDAE (TYPE 5)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	0	-	0	5.60	1.87
22 Apr 1971	0	0	6.06	1.04	8.69	3.47
7 May 1971	0	0	0	0	10.09	4.63
21 May 1971	0	1.70	0	8.07	10.26	1.37
3 Jun 1971	0	0	0	7.28	6.22	0
18 Jun 1971	0	0	0	0	1.22	0
30 Jun 1971	0	0	0	8.54	3.57	4.04
14 Jul 1971	0	1.48	0.77	13.64	3.37	0
28 Jul 1971	0	0	9.51	2.91	30.91	0
11 Aug 1971	0	0	0	-	0	0
25 Aug 1971	0	0	1.59	3.50	10.82	35.50
7 Sep 1971	0	0	0	2.92	5.14	0
21 Sep 1971	0	1.68	0.70	3.53	20.98	0
5 Oct 1971	1.39	0	2.20	0	9.69	1.38
19 Oct 1971	0	0	0	5.58	-	1.83
2 Nov 1971	0	1.40	3.48	16.07	16.16	2.21
16 Nov 1971	1.33	0.82	0	19.01	3.94	0
30 Nov 1971	0.85	2.45	0	2.14	4.45	0
14 Dec 1971	0.56	0	2.14	2.47	2.38	0
28 Dec 1971	0	0	0	3.76	11.43	1.33
11 Jan 1972	0	0	0	7.76	3.83	0
27 Jan 1972	0	0	0	7.64	15.17	1.13
10 Feb 1972	0	0	1.12	0	17.66	1.44
25 Feb 1972	0	0	0.78	1.81	2.33	0
9 Mar 1972	0	0	0	1.18	2.45	0
23 Mar 1972	0	0	0	7.78	2.15	0
6 Apr 1972	0	0	0	8.77	10.63	0
20 Apr 1972	0.61	0.59	0	8.40	6.11	1.60
18 Jul 1972	0	0	1.39	15.34	1.99	2.44
Mean	0.16	0.34	1.10	5.83	7.72	1.86
Standard Deviation	0.39	0.69	2.17	5.27	6.75	6.55

TABLE D25. CALLIONYMIDAE (*CALLIONYMUS DECORATUS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	2.64	-	17.28	0	0.98
22 Apr 1971	4.60	0	5.01	4.14	11.75	15.49
7 May 1971	1.33	0	11.76	0	4.96	22.08
21 May 1971	1.51	0	0.56	6.80	6.16	11.61
3 Jun 1971	0	0.76	3.39	1.11	1.79	1.16
18 Jun 1971	0	1.23	1.38	1.84	2.60	4.77
30 Jun 1971	0	0	0.66	1.45	1.19	0
14 Jul 1971	2.42	4.43	2.06	0	1.68	6.76
28 Jul 1971	0	0	0	0	0	3.42
11 Aug 1971	0	0	0	-	0	3.78
25 Aug 1971	0	0	0	0	0	1.37
7 Sep 1971	0	0	0	0	0	0
21 Sep 1971	0	0	0	0	0	4.43
5 Oct 1971	0	0	0	1.67	0	1.38
19 Oct 1971	0	0	0	2.79	-	0.77
2 Nov 1971	0	0	0	0	1.28	2.24
16 Nov 1971	1.33	0.82	0	0	1.32	1.49
30 Nov 1971	0.71	0	0	0	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	0.65	0	0	0
27 Jan 1972	0	0	0	5.90	1.33	0
10 Feb 1972	0	0	3.50	6.37	3.06	10.19
25 Feb 1972	0.75	0	0.61	0.96	2.30	3.27
9 Mar 1972	0	0	0	2.61	4.39	6.18
23 Mar 1972	0.66	2.15	0	0	1.15	1.08
6 Apr 1972	0	0	2.63	2.15	10.63	10.11
20 Apr 1972	0	0.79	1.16	11.34	7.83	17.13
18 Jul 1972	0	0	0	4.13	0	9.78
Mean	0.45	0.44	1.19	2.51	2.30	4.80
Standard Deviation	1.00	1.01	2.45	4.01	3.24	5.86

TABLE D26. CARANGIDAE (*CARANX MATE*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	0	1.32	-	1.01	15.94	3.35
22 Apr 1971	6.09	2.06	77.62	10.58	72.32	403.76
7 May 1971	40.39	14.27	71.40	8.85	138.57	207.73
21 May 1971	0	0.79	38.63	21.22	49.37	84.56
3 Jun 1971	0.64	0.76	4.16	0	4.90	4.65
18 Jun 1971	0	0.80	31.32	11.21	18.85	18.40
30 Jun 1971	0	0	2.86	20.90	35.36	8.53
14 Jul 1971	1.21	62.06	47.45	31.82	25.86	40.75
28 Jul 1971	0	0	18.76	0	17.80	13.50
11 Aug 1971	0	0	3.92	-	3.04	0
25 Aug 1971	0	0	0	1.75	14.14	21.85
7 Sep 1971	1.42	2.00	1.28	0	37.95	15.41
21 Sep 1971	0	18.99	16.88	25.56	32.64	120.12
5 Oct 1971	3.48	0	2.09	1.30	4.39	12.97
19 Oct 1971	0	0	22.21	13.80	-	151.36
2 Nov 1971	0	2.57	1.47	13.06	17.44	6.68
16 Nov 1971	0	0	0	3.57	4.92	0
30 Nov 1971	0	0	0	0	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	0	0	0	0
27 Jan 1972	0	0	0	1.34	0	0
10 Feb 1972	0	0	9.18	0	6.33	5.10
25 Feb 1972	0	0	0	1.81	0	0
9 Mar 1972	0	0	0	0	0	0
23 Mar 1972	0	0	0	3.83	11.14	18.17
6 Apr 1972	0.78	0	0	47.80	53.92	35.85
20 Apr 1972	0	0	0	7.02	14.22	10.16
18 Jul 1972	1.27	1.46	34.86	91.53	41.60	48.89
Mean	1.88	3.69	13.71	11.35	22.17	42.47
Standard Deviation	7.51	12.01	21.99	19.59	29.84	85.70

TABLE D27. CARANGIDAE (*GNATHANODON SPECIOSUS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	10.55	-	0	1.79	0
22 Apr 1971	5.36	0	34.76	8.91	13.50	48.27
7 May 1971	3.72	11.89	26.89	0	25.01	71.61
21 May 1971	0	0	9.05	1.35	9.38	6.29
3 Jun 1971	0.73	0	1.70	2.15	1.79	5.87
18 Jun 1971	0	0	5.15	11.30	5.11	9.54
30 Jun 1971	0	0	0	4.34	4.75	1.22
14 Jul 1971	1.72	19.21	10.00	4.55	10.61	6.98
28 Jul 1971	0	0.65	4.44	0	1.88	1.71
11 Aug 1971	0	0	0.88	-	0	0
25 Aug 1971	0	0	1.59	5.25	2.40	8.19
7 Sep 1971	0.68	2.00	9.00	0	6.36	0
21 Sep 1971	1.43	2.34	3.70	1.27	9.33	4.17
5 Oct 1971	2.09	0	22.30	4.26	0	0.87
19 Oct 1971	2.07	0	2.06	2.76	-	6.87
2 Nov 1971	0	0.82	0.80	0	3.66	1.12
16 Nov 1971	0	0	0	0	1.23	0
30 Nov 1971	0	0	0	0	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	0	0	0	0
27 Jan 1972	0	0	0	0	0	0
10 Feb 1972	0	0	0.59	0	0	1.83
25 Feb 1972	0	0	0	0	0	0
9 Mar 1972	0	0	0	1.18	1.23	0
23 Mar 1972	0.82	0	0.80	0	1.15	5.33
6 Apr 1972	0	0	0	1.14	1.11	4.61
20 Apr 1972	0	0	0	0	2.20	0
18 Jul 1972	1.27	1.82	9.79	4.73	8.46	53.77
Mean	0.68	1.76	5.12	1.89	3.96	8.21
Standard Deviation	1.27	4.50	8.86	2.93	5.63	17.72

TABLE D28. ELEOTRIDAE (*ASTERROPTERYX SEMIPUNCTATUS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	0	-	0	0	2.17
22 Apr 1971	0	2.69	269.06	0	1.94	430.96
7 May 1971	0	0	117.94	0	0	20.06
21 May 1971	0	0	158.34	0	0	10.83
3 Jun 1971	0	0	197.09	0	0	0
18 Jun 1971	0	0	76.63	0	0	4.77
30 Jun 1971	0	0	44.28	0	0	0
14 Jul 1971	0	0	22.07	0	0	0
28 Jul 1971	0	0	12.53	0	0	2.23
11 Aug 1971	0	0	5.82	-	0	0
25 Aug 1971	0	0	33.46	0	0	5.46
7 Sep 1971	0	0	4.11	0	3.43	59.80
21 Sep 1971	0	0	4.71	0	0	0
5 Oct 1971	5.58	0	168.37	0	0	0
19 Oct 1971	0	0	100.74	0	-	2.14
2 Nov 1971	1.56	0	11.64	0	0	1.12
16 Nov 1971	0	0	183.86	0	1.23	6.85
30 Nov 1971	0	0	15.51	0	0	0
14 Dec 1971	2.60	0.94	96.62	1.21	0	20.81
28 Dec 1971	0	0	7.04	0	0	0
11 Jan 1972	0	0	0.79	0	0	2.64
27 Jan 1972	0	0	0	0	0	0
10 Feb 1972	0	0	3.98	0	0	1.83
25 Feb 1972	0	0	9.54	0	1.18	0
9 Mar 1972	0	0	0	0	0	0
23 Mar 1972	0	0	3.38	0	0	1.08
6 Apr 1972	0	0	0.66	0	0	2.31
20 Apr 1972	0.80	0	76.39	0	0	0
18 Jul 1972	0	0	23.01	1.76	0	2.44
Mean	0.36	0.13	58.84	0.11	0.27	19.91
Standard Deviation	1.15	0.54	74.90	0.40	0.77	79.93

TABLE D29. ENGRAULIDAE (*STOLEPHORUS PURPUREUS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0.65	31.65	-	51.59	71.49	32.93
22 Apr 1971	8.42	17.87	178.33	99.20	279.87	610.20
7 May 1971	9.82	28.54	48.22	1.55	641.53	47.22
21 May 1971	0	0	27.10	14.86	40.67	52.11
3 Jun 1971	0	0	10.93	1.04	0	0
18 Jun 1971	0	0	0	1.84	1.84	4.10
30 Jun 1971	0	0	0.79	0	0	1.22
14 Jul 1971	1.72	0	0.77	4.55	1.68	5.56
28 Jul 1971	0	0	0	0	4.68	2.23
11 Aug 1971	0	0	1.60	-	0	0
25 Aug 1971	0	0	0	3.50	12.98	16.38
7 Sep 1971	0	1.45	1.28	2.92	11.75	4.47
21 Sep 1971	1.35	5.10	7.09	3.53	13.99	9.80
5 Oct 1971	0.70	0.74	10.32	10.92	7.92	2.75
19 Oct 1971	0	0	10.69	11.07	-	32.49
2 Nov 1971	0	0.82	6.96	2.13	7.23	4.43
16 Nov 1971	1.33	1.44	15.48	13.06	5.09	7.03
30 Nov 1971	0	0	6.02	1.38	5.82	1.29
14 Dec 1971	2.42	0	21.33	7.37	4.76	55.45
28 Dec 1971	2.46	0.61	0.93	35.94	17.63	30.81
11 Jan 1972	0	1.33	0	76.20	161.97	176.69
27 Jan 1972	0.62	0.57	0.55	55.68	115.61	11.66
10 Feb 1972	16.11	5.78	466.09	6.74	294.84	270.99
25 Feb 1972	5.86	1.72	8.76	2.89	19.84	2.23
9 Mar 1972	0	0	2.31	26.84	19.81	42.11
23 Mar 1972	2.96	0.71	0.49	53.56	185.50	24.36
6 Apr 1972	2.02	0.97	14.12	185.31	436.76	110.88
20 Apr 1972	0.61	0	6.38	22.48	47.99	19.56
18 Jul 1972	0	0.73	9.98	14.20	8.82	36.66
Mean	1.96	3.44	32.94	25.36	86.42	55.68
Standard Deviation	3.69	8.15	94.97	40.42	154.36	121.76

TABLE D30. GOBIIDAE

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	1.94	44.84	-	101.48	5.09	27.78
22 Apr 1971	14.50	13.29	542.99	18.47	76.43	1149.78
7 May 1971	33.76	0	212.70	3.02	8.82	200.45
21 May 1971	5.91	0.79	49.39	0.82	5.22	53.71
3 Jun 1971	0.64	0	42.95	1.04	0	2.28
18 Jun 1971	6.00	0.62	76.66	5.61	0	14.97
30 Jun 1971	0	0.68	77.99	18.30	13.06	2.44
14 Jul 1971	7.16	2.96	57.57	9.10	4.36	12.10
28 Jul 1971	1.42	0	76.96	2.91	4.68	4.45
11 Aug 1971	2.21	0.68	23.55	-	1.52	4.47
25 Aug 1971	0	3.49	12.74	3.50	2.32	16.38
7 Sep 1971	0.68	4.90	32.23	2.92	13.72	153.98
21 Sep 1971	11.20	9.45	10.81	2.55	9.32	21.08
5 Oct 1971	22.98	0	609.20	11.29	3.53	26.73
19 Oct 1971	101.15	8.51	158.31	11.01	-	38.31
2 Nov 1971	6.19	10.62	102.81	11.80	7.23	28.86
16 Nov 1971	23.92	12.96	65.39	14.27	7.80	33.70
30 Nov 1971	3.70	7.48	64.07	2.14	7.48	10.12
14 Dec 1971	9.10	1.68	61.75	7.26	3.48	46.22
28 Dec 1971	6.78	2.07	13.21	10.54	11.43	23.80
11 Jan 1972	5.85	0	4.99	18.28	22.80	39.30
27 Jan 1972	7.80	0.57	12.26	27.62	14.11	8.01
10 Feb 1972	9.91	8.09	125.46	6.37	8.29	21.67
25 Feb 1972	18.02	2.64	58.61	74.24	12.74	21.54
9 Mar 1972	6.31	5.52	34.08	31.99	4.39	10.79
23 Mar 1972	1.98	5.72	11.40	31.56	16.52	20.21
6 Apr 1972	25.98	5.86	80.34	50.19	43.45	56.79
20 Apr 1972	7.24	9.44	56.25	14.04	9.41	16.04
18 Jul 1972	3.81	0.91	89.86	17.11	0	175.98
Mean	11.93	5.64	98.73	18.50	11.32	77.30
Standard Deviation	19.17	8.60	142.97	22.66	15.41	212.28

TABLE D31. MYCTOPHIDAE

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	5.62	0	-	0	0	0
22 Apr 1971	4.58	8.75	0	3.36	0	9.93
7 May 1971	0	0	0	0	0	0
21 May 1971	6.82	0	0.56	1.64	0	0.98
3 Jun 1971	1.28	1.54	0	0	0	1.16
18 Jun 1971	8.30	3.82	0.69	0	0	1.70
30 Jun 1971	0	0	0	1.19	0	0
14 Jul 1971	0	0	0	0	0	0
28 Jul 1971	0	0	0	0	0	0
11 Aug 1971	1.49	0	0	-	0	0
25 Aug 1971	0	2.10	0	0	0	0
7 Sep 1971	0	0	0	0	1.72	2.45
21 Sep 1971	0	0	0	0	0	0
5 Oct 1971	0	0	0	0	0	0
19 Oct 1971	0	5.00	0	0	-	0
2 Nov 1971	0	0.59	0	0	0	0
16 Nov 1971	0	0.82	0	0	0	0
30 Nov 1971	1.70	0.58	5.01	0	0	0
14 Dec 1971	0	0.94	0	0	0	0
28 Dec 1971	1.22	0	3.66	0	0	0
11 Jan 1972	1.39	0	0	0	0	0
27 Jan 1972	20.81	7.98	1.35	4.02	0	0
10 Feb 1972	3.71	0	1.12	0	0	0
25 Feb 1972	34.15	8.18	1.39	0	0	0
9 Mar 1972	0	0.65	0	0	0	0
23 Mar 1972	0.76	54.34	57.80	0.96	19.90	32.09
6 Apr 1972	2.64	1.48	0	0	0	0
20 Apr 1972	0	0.79	0.58	0	0	0
18 Jul 1972	0.64	0	0	0	0	0
Mean	3.14	3.25	2.48	0.41	0.77	1.66
Standard Deviation	7.19	9.99	10.70	1.03	3.76	6.15

TABLE D32. POMACENTRIDAE

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	2.77	3.96	-	47.81	0	2.17
22 Apr 1971	0.75	10.91	58.94	4.39	27.33	312.51
7 May 1971	0	4.76	1.35	3.02	32.59	45.32
21 May 1971	0	0	13.70	6.80	30.73	12.99
3 Jun 1971	0	0	0	23.74	34.39	9.22
18 Jun 1971	16.51	2.38	2.20	1.84	20.23	3.40
30 Jun 1971	0.75	0	2.20	44.94	71.21	12.18
14 Jul 1971	0.51	7.39	2.31	13.64	0	0
28 Jul 1971	1.45	0	5.06	0	4.68	10.60
11 Aug 1971	0	0	3.05	-	0	0
25 Aug 1971	0	0	1.59	17.48	11.90	65.54
7 Sep 1971	0.74	0.54	0.64	5.84	8.57	18.74
21 Sep 1971	5.80	24.65	3.86	8.03	67.62	5.64
5 Oct 1971	17.41	0	50.96	21.66	15.44	15.87
19 Oct 1971	15.09	15.83	0.62	105.01	-	53.86
2 Nov 1971	13.20	8.41	17.21	28.52	39.12	35.53
16 Nov 1971	31.88	4.73	3.00	52.24	8.95	13.05
30 Nov 1971	2.14	1.83	1.77	2.14	17.68	2.59
14 Dec 1971	1.49	0	0.70	1.24	0	0
28 Dec 1971	2.88	0	0	5.10	0	0
11 Jan 1972	2.20	0.67	0	5.18	0	0
27 Jan 1972	0	3.12	2.15	47.30	26.21	4.92
10 Feb 1972	8.94	3.41	13.11	40.40	58.45	23.50
25 Feb 1972	35.49	1.22	6.68	40.16	23.26	12.02
9 Mar 1972	2.12	15.89	40.16	25.84	14.03	11.02
23 Mar 1972	4.78	1.44	3.87	128.15	36.42	18.13
6 Apr 1972	10.28	1.70	0.66	133.21	107.18	6.75
20 Apr 1972	10.45	2.37	3.86	10.45	10.92	13.10
18 Jul 1972	12.54	2.55	9.29	42.46	17.64	134.43
Mean	6.55	4.06	8.89	30.94	24.44	25.63
Standard Deviation	9.25	5.93	15.36	36.53	25.63	61.08

TABLE D33. SCARIDAE

Date	SC-4 (Larvae/1000 m^3 filtered)*		SC-22 (Larvae/1000 m^3 filtered)*	
	Sampan Channel $\bar{X}$	South Kaneohe Bay $\bar{X}$	Sampan Channel $\bar{X}$	South Kaneohe Bay $\bar{X}$
25 Mar 1971	-	0	-	0
22 Apr 1971	2.04	0	0	0
7 May 1971	5.54	1.59	1.34	0
21 May 1971	2.78	0	30.28	0
3 Jun 1971	8.03	0	7.40	0
18 Jun 1971	2.07	0	6.33	0
30 Jun 1971	0	0	0.66	0
14 Jul 1971	0	0	0	0
28 Jul 1971	0	0	0	0
11 Aug 1971	0	0	1.45	0
25 Aug 1971	0	0	0	0
7 Sep 1971	0	0	0	0
21 Sep 1971	0	0	0.70	0
5 Oct 1971	0	0	0.77	0
19 Oct 1971	0	0	0.82	0
2 Nov 1971	0	0	0	0
16 Nov 1971	0	0	7.03	1.08
30 Nov 1971	0	0	0	0
14 Dec 1971	0	0	2.85	0
28 Dec 1971	0	0	0	0
11 Jan 1972	0	0	0	0
27 Jan 1972	0	0	0	0
10 Feb 1972	0	0	0	0
25 Feb 1972	0	0	0	0
9 Mar 1972	0.58	0	0	0
23 Mar 1972	0	0	0	0
6 Apr 1972	0	0	0	0
20 Apr 1972	18.96	0	0.58	0
18 Jul 1972	0	0	0	0
Mean	1.43	-	5.92	-
Standard Deviation	3.92	-	2.15	-

*Night samples only; no scarid larvae were taken during the day

TABLE D34. SCHINDLERIIDAE (*SCHINDLERIA PIETSCHMANNI*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	0	-	0	0	0
22 Apr 1971	0	0	61.86	0	0	2.98
7 May 1971	0	0	19.83	0	0	4.63
21 May 1971	0	0	185.52	0	0	6.29
3 Jun 1971	1.45	0	67.14	0	0	1.12
18 Jun 1971	0	0	257.78	0	0	11.90
30 Jun 1971	0	0	57.72	0	0	0
14 Jul 1971	0	0	291.44	0	0	0
28 Jul 1971	0	0	432.16	0	0	11.12
11 Aug 1971	2.98	1.49	102.21	-	1.50	59.27
25 Aug 1971	0.78	1.40	149.78	0	0	21.85
7 Sep 1971	0	0	85.86	0	0	0
21 Sep 1971	0	0	11.41	0	0	2.96
5 Oct 1971	0.70	0	20.54	0	0	0
19 Oct 1971	0	0.60	254.04	0	-	0
2 Nov 1971	0	2.80	22.21	0	0	0
16 Nov 1971	0	0	74.11	0	0	2.15
30 Nov 1971	0	2.40	7.28	0	0	0
14 Dec 1971	0	0	5.02	0	0	0
28 Dec 1971	0	0.73	10.30	0	0	0
11 Jan 1972	0	0	19.29	0	0	0
27 Jan 1972	0	0	11.65	1.14	0	0
10 Feb 1972	0	2.14	49.14	0	0	0
25 Feb 1972	0	0	7.55	0	0	0
9 Mar 1972	0	0	28.50	0	0	0
23 Mar 1972	0	0	33.84	0	0	3.22
6 Apr 1972	0.78	0	157.03	0	0	0
20 Apr 1972	0	1.77	121.00	0	0	0
18 Jul 1972	0	0	123.39	0	0	0
Mean	0.23	0.45	95.26	-	-	4.39
Standard Deviation	0.63	0.85	105.66	-	-	11.63

TABLE D35. SCHINDLERIIDAE (*SCHINDLERIA PRAEMATURUS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$	Morning $\bar{X}$	Afternoon $\bar{X}$	Night $\bar{X}$
25 Mar 1971	0	0	-	0	0	0
22 Apr 1971	0	0	12.12	0	0	6.02
7 May 1971	0	0	5.38	0	0	0
21 May 1971	0	0	26.14	0	0	0
3 Jun 1971	0	0	8.90	0	0	0
18 Jun 1971	0	0	63.77	0	0	0
30 Jun 1971	0	0	4.32	0	0	0
14 Jul 1971	0	0	15.90	0	0	0
28 Jul 1971	0	0	24.70	0	0	0
11 Aug 1971	0	0	38.11	-	0	0
25 Aug 1971	0	0	35.05	0	0	16.38
7 Sep 1971	0	0	37.28	0	0	0
21 Sep 1971	0	0	3.16	0	0	0
5 Oct 1971	0	0	1.54	0	0	0
19 Oct 1971	0	0	35.97	0	-	0
2 Nov 1971	0	0	3.06	0	0	0
16 Nov 1971	0	0	32.98	0	0	1.08
30 Nov 1971	0	0.58	3.48	0	0	0
14 Dec 1971	0	0	7.14	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	0	0	0	0
27 Jan 1972	0	0	1.09	0	0	0
10 Feb 1972	0	0	217.74	0	0	0
25 Feb 1972	0	0	0	0	0	0
9 Mar 1972	0	0	7.23	0	0	0
23 Mar 1972	0	0	5.34	0	0	0
6 Apr 1972	1.24	0	10.04	0	0	0
20 Apr 1972	0	0	0.97	0	0	0
18 Jul 1972	0	0	9.32	0	0	0
Mean	-	-	21.68	0	0	0.80
Standard Deviation	-	-	41.67	-	-	3.19

TABLE D36. TRIPTERYGIIDAE (*TRIPTERYGION ATRICEPS*)

Date	Sampan Channel (Larvae/1000 m^3 filtered)			South Kaneohe Bay (Larvae/1000 m^3 filtered)		
	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	1.94	0	-	0	0	0
22 Apr 1971	0	0	0.68	0	0	1.99
7 May 1971	0	0	0.84	0	0	0
21 May 1971	17.22	0	0.56	0	0	1.19
3 Jun 1971	0.64	1.58	1.70	0	0	0
18 Jun 1971	9.84	31.78	7.70	0	0	0
30 Jun 1971	24.56	2.03	35.20	11.96	0	0
14 Jul 1971	0	0	0	0	0	0
28 Jul 1971	48.70	2.69	2.84	-	0	6.67
11 Aug 1971	58.54	1.35	0	0	0	0
25 Aug 1971	0.78	0.70	0	0	0	0
7 Sep 1971	0	15.23	1.81	0	0	0
21 Sep 1971	0.68	0	0	0	0	0
5 Oct 1971	0	10.15	0	0	0	0
19 Oct 1971	9.70	17.20	3.08	0	-	0
2 Nov 1971	0	0	0	0	0	0
16 Nov 1971	0	0	0	0	0	0
30 Nov 1971	2.41	0	0.89	0	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	9.67	3.14	1.86	1.25	0	0
11 Jan 1972	14.87	4.03	0	0	1.29	2.62
27 Jan 1972	4.60	33.76	11.14	0	7.99	4.78
10 Feb 1972	1.96	0.64	0	0	0	0
25 Feb 1972	13.85	11.78	2.78	0	0	1.18
9 Mar 1972	1.97	10.75	53.33	2.86	1.23	0
23 Mar 1972	0.82	39.32	238.25	0	4.45	16.06
6 Apr 1972	23.47	5.84	12.60	0	0	2.14
20 Apr 1972	5.83	3.55	9.87	0	0	1.60
18 Jul 1972	3.82	0	0	2.37	0	0
Mean	8.82	6.73	13.75	0.65	0.53	1.31
Standard Deviation	14.36	10.93	45.55	2.32	1.70	3.24

TABLE D37. UNIDENTIFIED 142

Date	Sampan Channel (Larvae/1000 m^3 filtered) Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$	South Kaneohe Bay (Larvae/1000 m^3 filtered) Morning $\overline{X}$	Afternoon $\overline{X}$	Night $\overline{X}$
25 Mar 1971	0	0	-	0	0	0
22 Apr 1971	0	1.58	21.64	0	0	22.28
7 May 1971	0	0	0	0	0	0
21 May 1971	0	0	0	0	0	0
3 Jun 1971	0	0	0	0	0	0
18 Jun 1971	0	0	0	0	0	0
30 Jun 1971	0	0	0	0	0	0
14 Jul 1971	0	0	0	0	0	0
28 Jul 1971	0	0	0	0	0	0
11 Aug 1971	0	0	0	-	0	0
25 Aug 1971	0	0	0	0	0	0
7 Sep 1971	0	0	1.92	0	0	34.33
21 Sep 1971	0	0	0	0	0	0
5 Oct 1971	0	0	420.07	0	0	0.87
19 Oct 1971	74.29	0	4.53	0	-	0
2 Nov 1971	0	0	0	0	0	0
16 Nov 1971	0	0	0	0	0	0
30 Nov 1971	0	0	0	0	0	0
14 Dec 1971	0	0	0	0	0	0
28 Dec 1971	0	0	0	0	0	0
11 Jan 1972	0	0	0	0	0	0
27 Jan 1972	0	0	1.09	0	0	0
10 Feb 1972	0	0	0	0	0	0
25 Feb 1972	13.75	0	2.35	0	0	0
9 Mar 1972	0	21.23	12.12	59.97	0	0
23 Mar 1972	6.47	1.08	0	0	0	0
6 Apr 1972	0	0	0	0	3.49	0
20 Apr 1972	0	0	0	1.43	1.31	1.60
18 Jul 1972	0	0	11.33	0	0	41.55
Mean	3.37	0.82	16.96	2.27	0.16	3.47
Standard Deviation	14.18	3.94	79.15	11.53	0.68	10.47