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# THE SEASONAL VARIATION AND DISTRIBUTION OF ZOOPLANKTON, FISH EGGS AND FISH LARVAE IN MALAMPAYA SOUND

by

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## ABSTRACT

**Some basic water parameters, and zooplankton, fish eggs and fish larvae biomasses were measured in Malampaya Sound between October 1977 and September 1978. The data were used to assess the seasonal changes that might have taken place in the plankton population of the area.**

**A comparison between the zooplankton biomass and the abundance of fish eggs and fish larvae of Malampaya's Outer and Inner Sounds is presented.**

## INTRODUCTION

Malampaya Sound is the second most productive fishing ground in the Philippines, accounting for about 19 percent of the total fish catch in 1973, and has always been the target of some big fishing companies since the early 1950's evidently because these operators have empirical data of its production potentials (Aprieto, 1975). In spite of its contribution to the national fish production, studies on the biology and ecology of the marine environment of this fishing ground are lacking. Until now, there is no published paper on the assessment of the fisheries, physico-chemical and biological studies done in Malampaya Sound, although there are some unpublished written reports based on field surveys in the area by several marine biologists.

The problem of the lack of biological studies to better understand the fishery resources has been recognized since 1973 by the Philippine Council for Agriculture and Resources Research and Development (PCARRD) Fisheries Commodity Research Team in several workshops. The need for biological studies in Malampaya Sound has been well emphasized by Aprieto (op. cit.).

The present study is concerned primarily with the seasonal distribution of zooplankton and variation in the abundance of major zooplankton groups, fish eggs and fish larvae together with the hydrographic condition in the

Malampaya Sound. The materials were collected during the six cruises of the research vessel "Researcher" conducted for a period of one year between October 1977 and September 1978, which was part of a comprehensive project entitled "Assessment of the Fisheries of Malampaya Sound" carried out by the Fisheries Research Division of the Bureau of Fisheries and Aquatic Resources.

The objective of the study was to obtain some baseline information on the physico-chemical and biological properties of Malampaya Sound and to determine their effects on the productivity of the area.

## The Study Area

"Malampaya Sound," on the northwestern part of Palawan, northeastward of Capoas Peninsula, is an extensive body of water 19 miles long in a southeasterly direction, varying in width from 2 to 4.5 miles (Figure 1). It is very irregular with bays and inlets along its shores capable of affording safe anchorage to a large number of deep-raft vessels. The sound has two basins separated by a number of islands. The northerly basin, or the Outer Sound, has depths of 20 to 12 fathoms (36.6 to 21.9 m) while the southeasterly basin, or the Inner Sound, is nine miles long and four miles wide with depths of three to nine fathoms (5.5 to 16.5 m) in the middle. The shoreline is generally steep with many rocky points and bold headlands backed by heavily wooded hills. The head of the sound is mostly shoal with mud flats. The shoreline is low bordered by mangroves and extensive swamps. A number of rivers empty in this part of the sound . . . . ".[1]

There are two entrances into the Malampaya Sound: Worcester Strait, the main entrance, which is deep in the fairway and has strong tidal streams, and Endeavor Strait, which has a depth of 8.7 meters (29 ft) in the fairway. The shores consist of mangroves and are fringed with drying coral reefs.

The bottom sediment of the Malampaya Sound is predominantly of soft fine mud from the closed end (southeast) to the open end (northwest). The former exhibited a dark green coloration while the latter showed a light green coloration (Olandez, unpublished data).

Climatically, the Sound belongs to a locality with two pronounced seasons (First Type): dry from November to April, and wet during the rest of the year. The rainy months are June to September; this period coincides with the southwest monsoon.

[1] *Philippine Coast Pilot. Part II, 4th ed., 1954, p. 252.*



## MATERIALS AND METHODS

### Stations

Plankton samples were taken at 18 stations; however, two more stations were added towards the end of the sampling period in September 1978 to represent the conditions at the head of the Inner Sound (Table 1). The two stations have depths of only 6.4 and 2.7 meters, respectively, so that sampling was carried out on board a fishing boat "Eastern Star-Jun". The map in Figure 1 shows the location of the sampling stations. The results were correlated with fluctuations of measured hydrographic conditions.

**Table 1. Position and depth of the sampling stations and depth of plankton hauls in Malampaya Sound.**

| Sampling Area | Locality | Station No. | Latitude | Longitude | Depth of Water (m) | Depth of Plankton Haul (m) |
|---|---|---|---|---|---|---|
| Outer Malampaya Sound | Endeavor Strait | 1 | 10° 57'48 "N | 119° 18'09" E | 32.2 | 27.5 |
| | Worcester Strait | 2 | 10° 56'54" N | 119° 16'36" E | 42.0 | 39.3 |
| | S of Tuluran Is | 3 | 10° 56'30" N | 119° 17'54" E | 39.0 | 35.5 |
| | Pirate Bay | 4 | 10° 55'48" N | 119° 17'06" E | 24.2 | 20.6 |
| | Northeast Bay | 5 | 10° 55'54" N | 119° 19'48" E | 28.0 | 25.0 |
| | Central part | 6 | 10° 54'54" N | 119° 18'54" E | 27.8 | 25.0 |
| | Taitai Bay | 7 | 10° 54'00" N | 119° 17'18" E | 19.4 | 16.0 |
| | N of Tacbolo Is. | 8 | 10° 53'33" N | 119° 18'48" E | 24.2 | 21.8 |
| | Passage Island Bay | 9 | 10° 53'20" N | 119° 20'06" E | 15.6 | 13.5 |
| | Turung Bay | 10 | 10° 52'45" N | 119° 17'13" E | 14.2 | 11.0 |
| Inner Malampaya Sound | N of Durangan Is. | 11 | 10° 52'03" N | 119° 19'06" E | 25.6 | 24.5 |
| | Alligator Bay | 12 | 10° 51'32" N | 119° 18'00" E | 14.0 | 12.0 |
| | N of Malaoton Is. | 13 | 10° 51'18" N | 119° 20'18" E | 21.8 | 19.3 |
| | Malipu Bay | 14 | 10° 50'12" N | 119° 20'06" E | 10.0 | 8.5 |
| | Central part (NE of Damao Is.) | 15 | 10° 50'45" N | 119° 21'54" E | 14.4 | 11.0 |
| | Off Pancol | 16 | 10° 51'18" N | 119° 23'30" E | 7.0 | 5.5 |
| | Central part | 17 | 10° 50'00" N | 119° 23'36" E | 9.2 | 7.5 |
| | Central part (E of Alcade Pt.) | 18 | 10° 49'06" N | 119° 22'33" E | 9.4 | 7.3 |
| | Innermost part (Head of the Inner Sound) | 19 | 10° 48'24" N | 119° 24'39" E | 6.4 | 5.0 |
| | Innermost part (Head of the Inner Sound) | 20 | 10° 46'24 N | 119° 25'42" E | 2.7 | 2.0 |

## HYDROGRAPHY

From each station occupied, water samples were collected at standard depth levels of 0, 10, 20, 30 and 50 meters with the use of Nansen reversing water bottles provided with protected thermometers.

Water samples were collected for the analysis of salinity and dissolved oxygen, after which temperature readings were taken and recorded at each depth level.

Water samples for salinity were analyzed on board the research vessel by the Knudsen-Mohr method and for dissolved oxygen by the modified Winkler method.

Atmospheric temperature was taken with an ordinary thermometer and the water visibility or transparency was measured with the use of a standard Secchi disc.

## ZOOPLANKTON

### Sampling Gear

The plankton samples were collected using the North Pacific (NORPAC) standard plankton net (Motoda, 1957, 1972), the sampling tool adopted by the conference on Pacific Oceanography in February 1956. The mouth diameter of the net was 45 cm, length 180 cm (conical) and mesh size 0.24 mm opening.

### Vertical Haul

The cod-end of the net was weighted to ensure the vertical position of the net. In each station, vertical haul was made from near the bottom to the surface.

A flowmeter was mounted in the mouth of the net to provide an estimate of the volume of water filtered. The calibration of the flowmeter and the estimation of the volume of water filtered by the net followed the procedure/calculation described by Estudillo (1979).

### Displacement Volume (Biomass)

The volume of plankton samples was measured on board ship at sea after sampling, using the "wet" displacement method (Ahlstrom, 1976),



to provide a rough measure of the zooplanktonic biomass (Smith and Richardson, 1977), and can be considered as an index to the amount of living matters present in the form of one or more of the various kinds of organisms comprising a plankton population (Beers, 1976).

The displacement volume was determined by filtering the plankton from the preserving fluid through a piece of bolting silk having a mesh size (0.24 mm) similar to the NORPAC net used. The bolting silk with the retained plankton was placed on blotting paper to allow most of the liquid to drain off. The sample was then placed into a 100-ml graduated cylinder containing a measured quantity of water. The increase in volume was recorded as the displacement and was assumed to be due entirely to the drained but still "wet" plankton.

For comparative purposes, the plankton volumes were expressed as the "wet" displacement volume, in ml per $m^3$ of water strained.

### Counting and Recording of Zooplankton, Fish Eggs and Fish Larvae

The samples were counted and classified into major zooplankton components. Phytoplankton and protozoans (radiolarians, foraminiferans, tintinnids, dinoflagellates) were not counted or considered in the determination of the total abundance of the plankton.

The counting procedure using an aliquot was identical with those described by Estudillo (1979). Samples were made up to 100 ml into a beaker (150 ml capacity) and stirred to evenly distribute the organisms. A 1-ml subsample was taken quickly, using a calibrated medicine dropper, before the organisms could resettle. This 1-ml subsample was placed into a Sedgewick-Rafter cell and spread with a needle. Counts were made from the whole 1-ml subsample. The counting procedure was done in triplicate and the values were averaged. The averaged value was then multiplied by 100 and expressed as the total number of individuals in the sample. Results from this enumeration have been expressed only in percentage relative abundance of the major zooplankton groups rather than in number per unit volume.

Fish eggs and fish larvae were counted directly from the whole sample and was transformed to number per $m^3$ of water strained.

# RESULTS AND OBSERVATIONS

## HYDROGRAPHIC CONDITIONS

Means and ranges of surface water temperature, salinity, dissolved oxygen and transparency values are shown in Table 2 and plotted in Figure 2. The hydrographic data were plotted so as to reveal the basic trend of seasonal processes rather than the exact state of the water masses at any particular period.

Table 2. Air temperature, and surface water temperature, salinity, dissolved oxygen and transparency values at each station in Malampaya Sound.

| Sampling Month / Parameter / Station No. | October 1977 | | | | | December 1977 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air Temp. (°C) | Water Temp. (°C) | Salinity (°/oo) | Dissolved Oxygen (ml/L) | Transpa-rency (m) | Air Temp. (°C) | Water Temp. (°C) | Salinity (°/oo) | Dissolved Oxygen (ml/L) | Transpa-rency (m) |
| 1 | 26.9 | 30.2 | 27.3 | 4.2 | 8 | 26.9 | 29.10 | 33.22 | 4.3 | 9 |
| 2 | 31.0 | 30.7 | 29.3 | 4.4 | 11 | 27.9 | 29.10 | 32.68 | 4.3 | 10 |
| 3 | 28.0 | 29.1 | 30.1 | 4.0 | 13 | 27.9 | 29.10 | 32.13 | 4.3 | 9 |
| 4 | 31.1 | 30.3 | 28.2 | 4.6 | 12 | 26.5 | 29.00 | 33.22 | 4.3 | 10 |
| 5 | 28.6 | 30.5 | 33.1 | 4.2 | 8 | 26.5 | 29.10 | 33.22 | 4.3 | 9 |
| 6 | 29.4 | 29.6 | 28.3 | 4.6 | 10.9 | 28.1 | 28.60 | 33.23 | 4.2 | 8 |
| 7 | 28.4 | 29.7 | 28.2 | 4.2 | 12 | 28.7 | 29.00 | 32.13 | 4.2 | 10.5 |
| 8 | 27.5 | 29.6 | 27.8 | 4.2 | 13 | 28.1 | 28.75 | 33.22 | 4.2 | 10 |
| 9 | 26.7 | 30.0 | 29.5 | 4.3 | 10 | 28.6 | 28.71 | 33.50 | 3.6 | 10 |
| 10 | 29.7 | 30.5 | 27.4 | 4.2 | 8 | 27.1 | 28.20 | 31.85 | 4.1 | 9 |
| 11 | 30.7 | 30.1 | 28.8 | 4.2 | 9 | 29.7 | 28.80 | 32.95 | 4.1 | 9 |
| 12 | 29.5 | 30.5 | 30.9 | 4.2 | 9 | 25.9 | 28.90 | 32.68 | 4.1 | 7 |
| 13 | 28.0 | 29.8 | 26.6 | 4.2 | 9 | 27.6 | 28.70 | 32.41 | 4.3 | 5 |
| 14 | 28.7 | 30.7 | 32.8 | 4.2 | 9 | 28.1 | 28.75 | 32.41 | 4.3 | 5 |
| 15 | 27.2 | 30.0 | 29.8 | 4.2 | 9 | 28.9 | 29.90 | 32.41 | 4.4 | 5 |
| 16 | 28.6 | 29.7 | 30.6 | 4.1 | 6 | 28.2 | 28.70 | 33.50 | 4.4 | 5 |
| 17 | 26.4 | 30.2 | 28.6 | 4.1 | 9 | – | 28.60 | 32.95 | 4.2 | 4 |
| 18 | 29.3 | 30.5 | 31.6 | 4.1 | 9.5 | 28.0 | 28.60 | 33.50 | 4.1 | 5 |
| **Mean** | 28.65 | 30.09 | 29.38 | 4.23 | 9.24 | 27.80 | 28.86 | 32.84 | 4.20 | 7.75 |



| Sampling Month / Parameter / Station No. | February 1978 | | | | | May 1978 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air Temp. (ºC) | Water Temp. (°C) | Salinity (°/oo) | Dissolved Oxygen (ml/L) | Transpa rency (m) | Air Temp. (°C) | Water Temp. (°C) | Salinity (°/oo) | Dissolved Oxygen (ml/L) | Transpa-rency (m) |
| 1 | 27.5 | 26.20 | 34.90 | 4.59 | 9.5 | 31.5 | 30.40 | 33.78 | 4.48 | 10 |
| 2 | 27.5 | 26.30 | 34.42 | 4.88 | 4 | 31.0 | 30.32 | 33.64 | 4.65 | 8 |
| 3 | 24.4 | 26.20 | 35.17 | 4.73 | 7 | 32.7 | 30.29 | 33.64 | 4.48 | 9 |
| 4 | 27.8 | 26.10 | 34.69 | 4.69 | 5 | 32.5 | 30.49 | 33.64 | 4.60 | 7 |
| 5 | 28.0 | 25.85 | 34.56 | 4.52 | 6 | 32.0 | 30.51 | 33.24 | 4.57 | 10 |
| 6 | 28.4 | 26.20 | 34.69 | 4.76 | 5 | 32.6 | 28.60 | 33.51 | 4.43 | 7 |
| 7 | 28.4 | 26.20 | 34.42 | 4.69 | 4 | 26.1 | 30.30 | 33.64 | 4.34 | 7 |
| 8 | 28.0 | 25.95 | 34.76 | 4.62 | 5 | 28.2 | 30.10 | 33.37 | 4.14 | 9 |
| 9 | 28.4 | 25.90 | 34.42 | 4.58 | 3 | 29.5 | 30.30 | 32.42 | 4.08 | 9 |
| 10 | – | 26.40 | 34.34 | 4.77 | 3 | 32.0 | 30.60 | 33.37 | 4.17 | 7 |
| 11 | 28.9 | 26.10 | 34.61 | 4.46 | 4 | 30.6 | 30.40 | 33.51 | 4.20 | 8 |
| 12 | 28.6 | 26.50 | 34.34 | 4.69 | 4 | 30.5 | 30.85 | 33.37 | 4.20 | 7 |
| 13 | 28.0 | 27.39 | 34.69 | 4.21 | 4.5 | 30.0 | 30.79 | 34.18 | 4.43 | 6 |
| 14 | 28.4 | 26.68 | 34.76 | 4.52 | 5 | 31.9 | 30.95 | 33.91 | 4.26 | 6 |
| 15 | 28.5 | 26.62 | 33.46 | 4.62 | 5 | 30.1 | 30.71 | 33.91 | 4.43 | 7 |
| 16 | 27.5 | 26.43 | 34.61 | 4.57 | 5 | 27.9 | 30.65 | 33.91 | 4.31 | 6 |
| 17 | 28.4 | 26.40 | 34.42 | 4.53 | 3 | 30.4 | 30.42 | 33.78 | 4.31 | 6 |
| 18 | 29.4 | 26.61 | 34.69 | 4.70 | 4 | 30.0 | 30.70 | 34.33 | 4.48 | 5 |
| Mean | 28.11 | 26.33 | 34.55 | 4.61 | 4.77 | 30.5 | 30.41 | 33.61 | 4.36 | 7.4 |

| Sampling Month / Parameter / Station No. | June 1978 Air Temp. (°C) | Water Temp. (°C) | Salinity (°/oo) | Dissolved Oxygen (ml/L) | Transparency (m) | September 1978 Air Temp. (°C) | Water Temp. (°C) | Salinity (°/oo) | Dissolved Oxygen (ml/L) | Transparency (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29.1 | 30.71 | 33.64 | 4.23 | 6 | 27.5 | 28.51 | 29.62 | 4.48 | 10 |
| 2 | 30.2 | 30.71 | 33.64 | 4.04 | 9 | 29.3 | 28.91 | 32.47 | 4.45 | 10 |
| 3 | 28.3 | 30.69 | 33.64 | 4.32 | 6 | 28.5 | 29.04 | 31.37 | 4.17 | 9 |
| 4 | 29.9 | 30.53 | 33.73 | 4.13 | 7 | 28.4 | 29.03 | 30.58 | 4.48 | 9 |
| 5 | 31.6 | 30.69 | 33.82 | 3.99 | 7 | 29.5 | 29.11 | 28.88 | 4.36 | 8 |
| 6 | 27.6 | 30.39 | 33.64 | 3.85 | 7 | 30.1 | 28.92 | 28.05 | 4.45 | 8 |
| 7 | 32.4 | 30.61 | 33.64 | 4.15 | 7 | 29.2 | 29.40 | 30.12 | 4.36 | 8 |
| 8 | 32.6 | 30.55 | 33.68 | 3.85 | 6 | 29.6 | 29.30 | 29.75 | 4.56 | 8 |
| 9 | 33.6 | 30.61 | 33.73 | 4.02 | 6 | 27.7 | 29.62 | 29.39 | 4.64 | 6 |
| 10 | 30.8 | 31.22 | 33.73 | 3.96 | 6 | 29.4 | 29.02 | 30.21 | 4.45 | 9 |
| 11 | 31.6 | 30.91 | 33.59 | 4.13 | 5 | 28.8 | 29.18 | 29.66 | 4.31 | 7 |
| 12 | 29.7 | 31.00 | 33.64 | 4.02 | 6 | 28.6 | 29.22 | 29.75 | 4.36 | 7 |
| 13 | 30.0 | 30.90 | 33.42 | 4.45 | 5 | 28.4 | 29.23 | 28.47 | 4.48 | 8 |
| 14 | 29.9 | 30.65 | 33.46 | 3.91 | 5 | 28.9 | 29.54 | 27.87 | 4.42 | 6 |
| 15 | 29.1 | 31.23 | 33.19 | 4.45 | 5 | 29.7 | 29.91 | 28.14 | 4.61 | 6 |
| 16 | 28.3 | 31.14 | 32.74 | 4.51 | 4 | 28.9 | 29.71 | 27.27 | 4.61 | 5 |
| 17 | 29.3 | — | 33.19 | 4.13 | 4 | 29.4 | 29.53 | 28.09 | 4.73 | 5 |
| 18 | — | 30.90 | 33.10 | 4.29 | 4 | 29.9 | 30.34 | 29.62 | 4.59 | 5 |
| Mean | 30.23 | 30.79 | 33.51 | 4.13 | 5.83 | 29.0 | 29.30 | 29.40 | 4.47 | 7.44 |



### Water Temperature

Surface water temperature showed a decreasing trend from the onset of the northeast monsoon season reaching its minimum values in February 1978. The temperature increased considerably in May 1978, attaining its peak in June then it showed a decreasing trend towards the end of the southwest monsoon period. Generally, the surface water temperature followed the pattern of the air temperature (Figure 2a).

The vertical profile of water temperature for October and December 1977 showed a water mass which appears to be an upwelling in the area of Station 8 (Figure 3). While an upwelling is taking place at Station 8 in December, a tongue-like water mass coming from outside Malampaya Sound tends to sink extending down to 30-m layer at Station 3 (Figure 3b).

### Salinity

Surface water salinity (Figure 2b) showed an inverse relationship with rainfall (Figure 4) and surface water temperature (Figure 2a), except during the end of the sampling period in September 1978 when both water temperature and salinity decreased. The decrease in values of the parameters possibly resulted from the effects of lowering of air temperature, amount of rainfall, diminished solar radiation and dilution from flood water.

As expected, the surface water had a general pattern of low salinity values during the southwest monsoon period and high values during the winter and summer months.

The occurrence of an upwelling which was noted from the water temperature profile in October and December 1977 was also noted for salinity during the same period (Figure 5).

### Dissolved Oxygen

Mean dissolved oxygen values were above 4 ml/l, and practically uniform throughout the survey period (Figure 2c). The maximum mean value in February and minimum mean value in June have a difference of only 0.48 ml/l .

From the vertical profile of dissolved oxygen values, however, minimum oxygen concentration of less than 2 ml/l was recorded beyond 20-m depth in October at Station 3 (Figure 6).

### Transparency

A big range was observed in the mean water transparency readings. The highest mean Secchi-depth reading was recorded at 9.2 m in October 1977 which declined to a relatively low mean of 4.7 m in February 1978 (Figure 2d).

## ZOOPLANKTON

### Biomass (Displacement Volume)

Variation in mean zooplankton biomass (expressed in ml/m$^3$) fluctuated during the sampling period, with tendency of increasing and decreasing as the cooler northeast monsoon and southwest monsoon (wet season) developed, respectively (Figure 7a). The highest volume was recorded in February 1978, followed by October 1977 with mean values of 7.62 ml and 5.47 ml per m$^3$, respectively. June 1978 was the time of lowest zooplankton crop with mean value of 1.06 ml per m$^3$ (Table 3).

### Comparison Between the Biomass of the Outer Sound and that of the Inner Sound

A comparison may also be drawn between the zooplankton biomass of the Outer Sound and the Inner Sound of the Malampaya Sound (Table 4 Figure 8a). The Inner Sound plankton biomass concentration was higher than that of the Outer Sound in all survey months, except in February 1978 when the mean volume of the latter was slightly higher (7.94 ml per m$^3$) than that of the Inner Sound (7.22 ml per m$^3$). This may be due to the increase in zooplankton volume at Station 1 (20.17 ml per m$^3$) which is located along the Endeavor Strait.

### Spatial Distribution

Figure 9 illustrates the spatial distribution of zooplankton biomass concentrations in Malampaya Sound during each of the survey cruises. The graduated shading in the figures clearly show that the distribution of biomass throughout the survey period was uneven except during the months of December 1977 and June 1978. In December 1977, the biomass was generally distributed evenly throughout the area which generally increased to a range of 3 to 10 ml per m$^3$ towards the Worcester and Endeavor Straits, Turung Bay and to the innermost part of the Inner Sound. In June 1978, the distribution was uniform throughout the survey area. Plankton collected during this period indicated concentrations of lower than 3 ml per m$^3$. Though the pattern of plankton biomass distribution varied cruise-by-cruise, the main concentrations were consistently found in sheltered bays such as Turung Bay, Taitai Bay and Passage Island Bay of the Outer Sound, and in the waters off Pancol and Malipu Bay of the Inner Sound.



**Table 3. Zooplankton displacement volumes and numbers of fish eggs and fish larvae collected by vertical hauls at each station in Malampaya Sound.**

| Sampling Month | October 1977 | | | December 1977 | | | February 1978 | | |
|---|---|---|---|---|---|---|---|---|---|
| Station No. | Zooplankton Volume (ml/m$^3$) | Fish Eggs (No./m$^3$) | Fish Larvae (No./m$^3$) | Zooplankton Volume (ml/m$^3$) | Fish Eggs (No./m$^3$) | Fish Larvae (No./m$^3$) | Zooplankton Volume (ml/m$^3$) | Fish Eggs (No./m$^3$) | Fish Larvae (No./m$^3$) |
| 1 | 3.20 | 1.77 | 1.77 | 4.11 | 0 | 0.91 | 20.17 | 7.01 | 0 |
| 2 | 1.88 | 0 | 1.34 | 3.13 | 1.25 | 2.50 | 2.50 | 0.37 | 4.81 |
| 3 | 0.97 | 0.21 | 1.29 | 1.73 | 1.73 | 3.11 | 11.50 | 0 | 0 |
| 4 | 2.09 | 0 | 1.90 | 2.34 | 0 | 0.78 | 6.62 | 1.20 | 12.04 |
| 5 | 1.20 | 0.89 | 2.69 | 1.20 | 2.01 | 0.40 | 7.51 | 6.76 | 6.76 |
| 6 | 3.94 | 4.56 | 0.41 | 1.88 | 1.25 | 0.63 | 6.71 | 4.02 | 0 |
| 7 | 4.40 | 2.19 | 0 | 1.24 | 0 | 1.86 | 2.17 | 2.17 | 5.43 |
| 8 | 1.84 | 5.52 | 0.31 | 2.07 | 3.63 | 2.07 | 5.37 | 7.52 | 6.98 |
| 9 | 5.45 | 1.81 | 1.21 | 0.92 | 4.41 | 0 | 13.75 | 10.00 | 8.75 |
| 10 | 12.66 | 1.26 | 0 | 8.33 | 33.33 | 25.00 | 3.14 | 2.09 | 0.69 |
| 11 | 3.23 | 0 | 0.27 | 1.87 | 4.21 | 0 | 6.82 | 2.92 | 1.46 |
| 12 | 6.82 | 0.76 | 0 | 2.58 | 1.29 | 1.29 | 4.72 | 4.05 | 0 |
| 13 | 3.70 | 2.31 | 0.46 | 2.83 | 0 | 1.21 | 6.86 | 4.90 | 0 |
| 14 | 1.26 | 27.67 | 1.25 | 1.51 | 0.38 | 0.75 | 12.98 | 19.48 | 5.19 |
| 15 | 15.46 | 9.87 | 0.65 | 3.77 | 8.49 | 1.89 | 2.75 | 5.50 | 1.83 |
| 16 | 10.42 | 3.12 | 6.25 | 3.66 | 21.95 | 1.22 | 10.52 | 29.82 | 5.26 |
| 17 | 7.44 | 1.65 | 0 | 3.70 | 0.93 | 0 | 5.81 | 5.81 | 1.16 |
| 18 | 12.64 | 12.08 | 3.29 | 7.53 | 1.08 | 2.15 | 7.30 | 7.86 | 7.86 |
| 19 | – | – | – | – | – | – | – | – | – |
| 20 | – | – | – | – | – | – | – | – | – |
| Mean | 5.47 | 4.20 | 1.28 | 3.02 | 4.77 | 2.54 | 7.62 | 6.74 | 3.79 |

| Sampling Month | May 1978 | | | June 1978 | | | September 1978 | | |
|---|---|---|---|---|---|---|---|---|---|
| Station No. | Zooplankton Volume (ml/m$^3$) | Fish Eggs (No./m$^3$) | Fish Larvae (No./m$^3$) | Zooplankton Volume (ml/m$^3$) | Fish Eggs (No./m$^3$) | Fish Larvae (No./m$^3$) | Zooplankton Volume (ml/m$^3$) | Fish Eggs (No./m$^3$) | Fish Larvae (No./m$^3$) |
| 1 | 2.97 | 3.46 | 5.94 | 0.06 | 0.03 | 4.86 | 0.53 | 0.79 | 8.44 |
| 2 | 0.53 | 1.14 | 0.26 | 0.45 | 1.42 | 1.42 | 0.47 | 3.55 | 0.47 |
| 3 | 2.11 | 5.01 | 2.37 | 0.74 | 2.46 | 4.91 | 0.23 | 3.79 | 2.56 |
| 4 | 3.23 | 12.26 | 4.51 | 0.47 | 6.13 | 9.91 | 1.00 | 9.34 | 5.14 |
| 5 | 2.16 | 5.63 | 9.09 | 0.98 | 2.46 | 10.83 | 1.66 | 9.95 | 4.97 |
| 6 | 4.83 | 8.96 | 6.20 | 1.36 | 3.77 | 5.88 | 2.35 | 15.14 | 4.96 |
| 7 | 7.30 | 46.06 | 4.49 | 1.72 | 37.09 | 7.75 | 3.96 | 27.75 | 3.08 |
| 8 | 4.39 | 25.67 | 11.49 | 0.97 | 9.66 | 5.31 | 3.64 | 12.72 | 4.09 |
| 9 | 5.38 | 43.01 | 8.60 | 1.27 | 22.93 | 15.29 | 5.43 | 3.80 | 4.89 |
| 10 | 8.72 | 111.62 | 13.95 | 0.92 | 98.59 | 11.57 | 2.12 | 8.51 | 3.54 |
| 11 | 5.22 | 11.19 | 5.97 | 0.66 | 8.94 | 2.65 | 5.42 | 11.33 | 4.92 |
| 12 | 2.33 | 4.19 | 6.05 | 1.49 | 24.63 | 17.16 | 5.70 | 14.20 | 14.20 |
| 13 | 5.00 | 6.66 | 8.33 | 0.96 | 3.72 | 3.19 | 2.07 | 12.03 | 10.79 |
| 14 | 12.50 | 33.33 | 12.50 | 0.95 | 11.42 | 2.85 | 3.61 | 16.86 | 18.07 |
| 15 | 5.00 | 5.00 | 15.83 | 0.74 | 30.15 | 10.29 | 9.70 | 61.94 | 7.46 |
| 16 | 5.26 | 5.26 | 5.26 | 1.12 | 1.12 | 4.49 | 5.56 | 27.77 | 23.41 |
| 17 | 1.60 | 1.59 | 3.19 | 2.91 | 32.03 | 10.67 | 3.36 | 4.20 | 15.96 |
| 18 | 9.84 | 21.31 | 8.19 | 1.32 | 6.57 | 15.78 | 10.43 | 28.70 | 1.74 |
| 19 | – | – | – | – | – | – | 2.22 | 24.44 | 22.22 |
| 20 | – | – | – | – | – | – | 2.94 | 2.94 | 5.88 |
| Mean | 4.90 | 19.51 | 7.34 | 1.06 | 16.84 | 8.04 | 3.62 | 14.98 | 8.33 |



**Table 4. Summary of the monthly mean zooplankton biomass and abundance of fish eggs and fish larvae of Malampaya's Outer and Inner Sounds. Data plotted in Figure 8.**

| Cruise/Month | Mean Value | |
|---|---|---|
| | Outer Malampaya Sound (Stations 1-10) | Inner Malampaya Sound (Stations 11-18) |
| R–77–5 (October 1977) | | |
| Zooplankton Volume* | 3.76 | 7.62 |
| Fish Eggs** | 1.82 | 7.01 |
| Fish Larvae*** | 0.92 | 1.52 |
| (Size range in mm) | (1.3–6.0) | (1.0–3.5) |
| R–77–6 (December 1977) | | |
| Zooplankton Volume | 2.70 | 3.43 |
| Fish Eggs | 4.76 | 4.79 |
| Fish Larvae | 3.72 | 1.06 |
| (Size range in mm) | (1.0–4.0) | (0.5–4.0) |
| R–78–1 (February 1978) | | |
| Zooplankton Volume | 7.94 | 7.22 |
| Fish Eggs | 4.11 | 9.68 |
| Fish Larvae | 4.55 | 2.85 |
| (Size range in mm) | (1.2–6.0) | (1.1–4.9) |
| R–78–6 (May 1978) | | |
| Zooplankton Volume | 4.16 | 5.84 |
| Fish Eggs | 26.28 | 11.06 |
| Fish Larvae | 6.69 | 8.16 |
| (Size range in mm) | (1.1–5.8) | (1.0–3.4) |
| R–78–7 (June 1978) | | |
| Zooplankton Volume | 0.92 | 1.26 |
| Fish Eggs | 18.45 | 14.82 |
| Fish Larvae | 7.77 | 8.38 |
| (Size range in mm) | (1.1–7.0) | (1.2–4.5) |
| R–78-8 (September 1978) | | (Stations 11-20) |
| Zooplankton Volume | 2.13 | 5.10 |
| Fish Eggs | 9.53 | 20.44 |
| Fish Larvae | 4.21 | 12.48 |
| (Size range in mm) | (1.3–8.5) | (1.0–6.3) |

* Displacement Volume in ml/m$^3$ *** Number per m$^3$

** Number per m$^3$

### Relative Abundance of Major Zooplankton Groups

Results of the zooplankton enumeration, in the form of percentage abundance, are presented in Table 5.

The composition of the zooplankton during the whole sampling period has been classified into 12 major groups as follows: copepod crustacea other crustacea, coelenterata, polychaeta, chaetognatha, mollusca, echinodermata, appendicularia, thaliacea, fish eggs, fish larvae and miscellaneous group (phoronidea).

The copepod crustaceans represented the bulk of the zooplankton population in the sea. In Malampaya Sound it ranged from 28.97 to 63.35 percent (averaging 46.50%) of the total zooplankton population. Calanoid copepods appeared to be the main constituent of the copepod crustacea composed mainly of the nearshore genera of different species. This is expected as this group is by far the most important constituent of marine zooplankton in biomass and number of individuals as well as in number of species (Tham, 1953; Brodskii, 1967). Cyclopoids and harpacticoids were the next most numerically abundant copepod groups. The other crustacean group ranked next to copepod in abundance forming 7.09 to 17.73% (averaging 13.57%). Chaetognaths and appendicularians (larvacean) followed with 6.79 to 15.13 percent (averaging 9.72%) and 3.86 to 13.02 percent (averaging 8.04%), respectively. Appendicularians outnumbered the chaetognatha in some samples particularly in October 1977 and September 1978 (see Table 5). Thaliaceans came next, their abundance forming 1.37 to 27.62 percent (averaging 7 percent). Polychaetes constituted 3.10 to 8.68 percent (averaging 4.87 percent), echinoderms 1.30 to 11.25 percent (averaging 4.66 percent), molluscs 0.15 to 7.81 percent (averaging 3.80 percent), and coelenterates 0.51 to 3.40 percent (averaging 1.24 percent). Fish eggs and fish larvae represented 0.07 to 0.72 percent and 0.04 to 0.27 percent of the total number, respectively. Together they formed a small proportion averaging only 0.14 percent of the catches. The miscellaneous group is solely represented in the samples by the actinotroch larvae (phoronidae) but never significant, averaging 0.19 percent. They were practically absent in the October and December 1977 samples.

The maximum abundance of copepod in February 1978 (63.35 percent) was due to the appearance of a large number of its larvae (nauplii). A secondary peak was recorded in December 1977 (56.33 percent), with low levels of copepod nauplii.

The minimum occurrence of copepods was noted in June 1978 (28.97 percent), which had considerable effect on zooplankton biomass. Larvae of copepods were not found in the samples.

The combined other crustaceans group represented in the samples included the cladocerans (*Evadne* and *Penilia*), ostracods (*Chonchoecia* and *Cypridina*), cirripedes (larvae), euphausiids (calyptopis larvae) and decapods (*Lucifer*,



**Table 5. Summary of the monthly mean abundance of the major zooplankton groups in Malampaya Sound.**

| Sampling Month | ZOOPLANKTON GROUPS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Copepod Crustacea | Other Crustacea | Coelenterata | Polychaeta | Chaetognatha | Mollusca | Echinodermata | Appendicularia | Thaliacea | Fish Eggs | Fish Larvae | Phoronidea (Actinotroch larvae) |
| Oct. 1977 | 41.88 | 7.09 | 0.99 | 1.48 | 6.81 | 2.16 | 1.54 | 10.16 | 27.62 | 0.20 | 0.07 | 0 |
| Dec. | 56.33 | 15.63 | 0.51 | 4.70 | 9.16 | 0.70 | 6.27 | 4.05 | 2.54 | 0.07 | 0.04 | 0 |
| Feb. 1978 | 63.35 | 13.73 | 0.53 | 4.94 | 8.65 | 0.15 | 2.66 | 4.49 | 1.37 | 0.07 | 0.06 | 0 |
| May | 49.68 | 16.17 | 3.40 | 3.10 | 11.78 | 7.53 | 1.30 | 3.86 | 2.54 | 0.36 | 0.14 | 0.14 |
| Jun. | 28.97 | 11.11 | 1.44 | 8.68 | 15.13 | 4.47 | 11.25 | 13.02 | 4.49 | 0.72 | 0.27 | 0.45 |
| Sept. | 38.82 | 17.73 | 0.57 | 6.36 | 6.79 | 7.81 | 4.94 | 12.71 | 3.23 | 0.28 | 0.18 | 0.58 |
| Mean | 46.50 | 13.57 | 1.24 | 4.87 | 9.72 | 3.80 | 4.66 | 8.04 | 7.00 | 0.28 | 0.13 | 0.19 |

mostly in larval stages, mysis and zoea; shrimp larvae and brachyuran zoea and megalopa larvae).

Cladocerans *Evadne* and *Penilia,* cirripede larvae ostracod *Conchoecia,* decapod *Lucifer* mysis and zoea larvae, shrimp larvae and brachyuran (crab) zoea and megalopa larvae accounted for the relatively high percentage of the other crustacean group in February 1978 (13.73 percent).

The maximum abundance of other crustaceans in September 1978 (17.73 percent) was entirely due to the zoea larvae of the decapod *Lucifer.* The adults and mysis larvae were only a very small proportion of the total zooplankton during this period. The secondary maximum abundance during the summer month of May 1978 (16.17 percent) was mainly due to the cladoceran *Penilia.* The percentage abundance of the other crustaceans in December 1977 (15.63 percent) was due to the ostracods *Conchoecia* and *Cypridina,* and decapods *Lucifer* adults, mysis and zoea larvae, and brachyuran zoea and megalopa larvae.

The plankton sample in June 1978 was distinguished from those of other months by the appearance of abundant echinoderm (echino-and ophioplutei) larvae which contributed 11.25 percent to the total number of zooplankton. Veliger larvae of molluscs were also noted in considerable proportion during this period.

Salps were present throughout the survey area. In much larger number in October 1977, they contributed greatly to the maximum abundance of thaliaceans (27.62 percent).

Abundant specimens of the smaller and less active calyptosis larvae of euphausiids were taken only in June 1978 and were restricted chiefly to the northwestern end (near the entrance) of Malampaya Sound (Station 3). They were found absent in all other areas throughout the sampling period. This suggests that this particular larval group is only an occasional visitor, and with the onset of the southwest monsoon season it was brought into the Malampaya Sound by water mass movements (ocean currents). The infrequent inshore occurrence of euphausiid larvae in the survey area indicates the entrance of oceanic waters in the Sound. This crustacean group is primarily oceanic and ranges through all depths (Fish, 1925 as cited by Estudillo, 1979).

## FISH EGGS

### Variation of Abundance

The mean abundance of fish eggs (in numbers per $m^3$) in Malampaya Sound increased progressively from the first month of sampling in October 1977 (4.20 fish eggs per $m^3$), and the trend continued to the greatest mean number in May 1978 (19.20 fish eggs per $m^3$). This was followed by a decline in June 1978 (16.84 fish eggs per $m^3$) until the end of the sampling period in September 1978 (14.98 fish eggs per $m^3$) (Table 3 and Figure 7a).



### Comparison Between the Abundance of Fish Eggs of the Outer Sound and that of the Inner Sound

Fish egg density in the Inner Sound was higher than that of the Outer Sound in all survey months, except in May and June 1978 when the mean number of the latter rose to 26.28 and 18.45 fish eggs per $m^3$, respectively (Table 4 and Figure 8b).

### Spatial Distribution

Fish eggs were taken in every sampling month but were absent in some samples collected in three months, *i.e.* October (Stations 2, 4 and 11), and December 1977 (Stations 1, 4, 7 and 13) and February 1978 (Station 3).

The distribution of fish eggs in the survey area throughout the sampling period, as shown in Figure 10, is unique in that numbers were more localized in small bays and coves bordering both the Outer and the Inner Sounds. In October 1977 (Figure 10a), the greatest number of fish eggs was found in the western part of the Inner Sound (Stations 14, 15 and 18). However, a tendency of fish egg concentration was also observed along the mid-section of the Outer Sound (Stations 6 and 8). In December 1977 (Figure 10b), the Outer Sound and the Inner Sound indicated similar pattern of distribution which correspond to almost the same amount of fish eggs with mean values of 4.76 and 4.79 per $m^3$, respectively. The highest concentration of fish eggs during this period was found in Turung Bay (Station 10) of the Outer Sound and in the waters off Pancol (Station 16) of the Inner Sound. In February 1978 (Figure 10c) there was an increase to the highest amount of fish eggs towards both sides of the Inner Sound, particularly in the waters of Malipu Bay (Station 14) and off Pancol (Station 16). Then in May 1978 (Figure 10d) when fish eggs were obtained in greatest quantities, the main concentrations were found in the waters of Taitai Bay (Station 7), Turung Bay (Station 10) and Passage Island Bay (Station 9) of the Outer Sound, and along the western part of the Inner Sound. In June 1978 (Figure 10c), the concentrations were again found in Taitai Bay (Station 7), Turung Bay (Station 10) and Passage Island Bay (Station 9) of the Outer Sound. Other areas of high fish egg concentrations during this period were found in Alligator Bay (Station 12) and in the mid-section of the Inner Sound (Station 15). In September 1978 (Figure 10f), the largest concentrations of fish eggs were found throughout the Inner Sound (Stations 15, 16 and 18) and also in Taitai Bay (Station 7) of the Outer Sound.

## FISH LARVAE

### Variation of Abundance

The mean abundance of fish larvae in Malampaya Sound increased steadily from the first sampling month in October 1977 (1.28 fish larvae/$m^3$) to the end of the sampling period in September 1978 (8.33 fish larvae/$m^3$) (Table 3 and Figure 7b). The total length of fish larvae caught throughout the sampling period ranged from 0.5 to 8.5 mm (Table 4).

### Comparison between the Abundance of Fish Larvae of the Outer Sound and that of the Inner Sound

Again, as with plankton biomass and numbers of fish eggs, the mean number of fish larvae in the Inner Sound was higher than that of the Outer Sound, except in December 1977 and February 1978 when the samples yielded 3.72 and 4.55 fish larvae per $m^3$, respectively (Table 4 and Figure 8c). The length of fish larvae measured in the Outer Sound was greater (1.0-8.5 mm) than that of the Inner Sound (0.5-6.3 mm) The largest larvae of 6.0 to 8.5 mm were found in most of the stations occupied in the Outer Sound.

### Spatial Distribution

Fish larvae were taken every sampling month but were absent in some samples collected during the months of October (Stations 7, 10, 12 and 17), December 1977 (Stations 9, 11 and 17) and February 1978 (Stations 1, 3, 6 and 12).

The spatial distribution of fish larvae was also found to be more localized in abundance. This was shown more clearly in October 1977 (Figure 11a) when the greatest number was found off Pancol (Station 16) in the Inner Sound; in December 1977 (Figure 11b) when the greatest number was found in Turung Bay (Station 10) of the Outer Sound; and in February 1978 (Figure 11c) when the greatest number was found in Pirate Bay (Station 4), Northeast Bay (Station 5), Taitai Bay (Station 7) and Passage Island Bay (Station 9) of the Outer Sound, and also off Pancol (Station 16) and Malipu Bay (Station 14) of the Inner Sound. In May 1978 (Figure 11d), the main concentrations were again found in Turung Bay (Station 10) of the Outer Sound and in Malipu Bay (Station 14) and the waters around Dumao and Micota Islands (Station 15) of the Inner Sound. Other areas of higher concentrations during this period were found along the eastern part of the Outer Sound and further down south in the entire waters of the Inner Sound; however, a decrease in abundance was noted in the innermost part of the Inner Sound (Station 17). In June 1978 (Figure 11c), the largest concentrations were found in the Passage Island Bay (Station 9) of the Outer



Sound and in Alligator Bay (Station 12) and north of Mangobabe Island (Station 18) of the Inner Sound. Low numbers, on the other hand, were found in the two openings of the sound (Worcester and Endeavor Straits), in the narrow entrance to the Inner Sound (Stations 11 and 13) and further down south to Malipu Bay (Station 14) and off Pancol (Stations 16 and 17). In September 1978 (Figure 11f), the concentrations of fish larvae were generally found in the Inner Sound. The largest numbers were found in Alligator Bay (Station 12), Malipu Bay (Station 14) and off Pancol (Station 16) and further down south of the waters east of Mangobabe Island (Station 19). A decrease in number was noted in the innermost part of the Inner Sound (Station 20). Other areas of relatively high concentrations during this period were observed in the Endeavor Strait (Station 1) and Pirate Bay (Station 4) of the Outer Sound.

## DISCUSSION

It is apparent that there is a somewhat considerable variation in the monthly means and ranges of values by cruise of the zooplankton standing crop (Figure 7a) and surface water temperature and salinity (Figure 2a, d). This could be due to the fact that Malampaya Sound is a small and shallow body of water, almost entirely surrounded by land and the very irregular shoreline is interrupted by sizeable estuaries and embayments (sheltered bays and coves), bordered by mangroves and swamps, and a number of rivers empty in especially the inner part of the sound, and therefore, subject to tidal and weather variations in which the general hydrographic conditions might undergo greater seasonal variation. Under such conditions it is not surprising to find a great variation in plankton standing crop. Tidal currents, tide height, and direction of water flow may affect the quality and quantity of zooplankton markedly in nearshore waters (Fleminger, 1981). Edra (1976) considered this situation in his study on the plankton succession off Changi Point, Singapore and concluded that tidal levels affect the hydrobiological parameters, such as salinity, $PO_4$–P concentration and the density of the plankton population. In the present study, however, there are no tidal observations made in coordination with the time of sampling to determine if correlation exists between the plankton abundance and distribution and a particular phase of tide.

The six-month collection within a period of one year showed that the zooplankton standing crop in Malampaya Sound is commonly of the order (on the monthly average) of 1.0 to 7.6 ml ( wet displacement volume ) of a cubic meter of water, which compares with a monthly mean of 0.3 to 1.7 ml for the Visayan Sea (Estudillo, 1979) an area sampled from July 1976 to March 1977 by means of the same collecting gear and processing methods used in Malampaya Sound. Based on these findings the plankton standing crop of Malampaya Sound is about six times as high as that of the Visayan

Sea. On the other hand, Bacuit Bay in the northwestern Palawan which was also sampled during the survey of Malampaya Sound using the same equipment and tow method, yielded 0.19 to 5.27 ml (Estudillo, unpublished data). Comparatively, Malampaya Sound is about two times more than that of Bacuit Bay. The large standing crop (annual mean of 4.4 ml per $m^3$) calculated for the duration of the sampling period in Malampaya Sound indicates high productivity and this may be attributed to the general geologic, geographic, climatic and hydrographic features of the Sound as already described earlier.

The seasonal variation pattern of zooplankton biomass of the three surveyed areas mentioned above which are geographically positioned in the same latitude between 10° and 12° (see Figure 2) are more or less similar, reaching their peak in February when their monthly mean temperature values are at the minimum (Estudillo, 1979, Figure 12). Brinton (1975) reported the same results in the area along the northern coastal waters of Vietnam (northern shelf area off Nhatrang Bay). Productive peaks occurred in February, when temperatures were coldest. A comparison of the monthly mean values of zooplankton biomass (Figure 7a) and water temperature (Figure 2a) in the present survey showed an apparent inverse relationship. Estudillo's findings in the Visayan Sea (1979) showed that there was also an inverse relationship between plankton abundance (biomass and total numbers of zooplankton) and water temperature, which are statistically significant at 1% level, indicating that the lower water temperature formed more plankton organisms.

It is of interest to note that the lowest zooplankton standing crop in Malampaya Sound in June 1978 almost coincided with the lowest fish catches (Malampaya Sound stock assessment survey, *In* Progress Report, unpublished). The catch in Malampaya Sound for the survey period was composed predominantly of foodfishes (the most common were *Leiognathus equulus, L. splendens, Nemipterus* spp., *Pomadasys hasta, P. argyreus, Saurida tumbil, Sphyraena jello, S. obstusata, Psettodes erumei, Caranx* spp., *C. djedaba, Gazza minuta, Lutjanidae, Stolephorus* spp., and *Scomberoides lysan*) ranging from 89.05 to 96.00 percent of the total catch. It was highest (average catch rate in kg/hr: 1,195 kg) in December 1977 and lowest (298 kg) in June 1978. Of the foodfishes, *L. equulus* dominated the catch in February, May and June 1978 while *Pseudosciaena anea* was predominant in December 1977. Tiews *et al.* (1973) found that all species of *Leiognathus* feed on a great variety of zooplankton and phytoplankton species. Pelagic copepods still predominated the food composition. All the species consumed a considerable amount of fish eggs. Tham (1953) states that many of the animal aggregations in nature have been found to be due to food, so that the above correlation may suggest that generally, fishes migrate into Malampaya Sound and are held there for sometime by the abundance of food. Thus, the relative abundance of one species over the other changes every survey month in which there appears a seasonality in species abundance in the area which corresponds more or less with the seasonality in the zooplankton.

Changes in zooplankton composition are mostly changes in relative



abundance within the neritic community which characterizes Malampaya Sound water. Changes within this community appear to follow a cyclic seasonal sequence. This is consistent with the hydrographical evidence that these waters develop their own characteristics and that variations of temperature and salinity are, for the most part, climatically controlled.

Comparatively, the Inner Sound must be regarded as richer than the Outer Sound with respect to its plankton biomass (as a measure of standing crop) and densities of eggs and larval fishes. The work on benthos by Olandez (unpublished data) which was also performed during the plankton survey of Malampaya Sound indicated the same results. The two basins differed much in benthos biomass (in gm) per 0.1 $m^2$. The Inner Sound, with 3.01 gm/0.1 $m^2$ has a much higher biomass than the Outer Sound's 0.33 gm/0.1 $m^2$. Both sub-areas, however, have almost the same population density: the former with 3.46 individuals/0.1 $m^2$ and the latter with 3.30 individuals/0.1 $m^2$. The role of mangroves and a large tropical swamp and a number of rivers which empty in this relatively shallow part (Inner Sound) of Malampaya Sound probably contributed greatly to its high productivity. Gabriel (1977) summarizes the uses and importance of the mangrove ecosystem, as revealed by earlier researchers. Some of the important uses of mangrove which have a direct bearing with the above findings are: it serves as nursery and spawning grounds for many economically important fishes; published studies show that the mangrove exports about 9-10 tons of carbon/ha/year, which are made available to both estuaries and marine organisms, and mangroves are important in the detritus-based food chain/food web and there is constant movement of living and non-living matter into and out of the mangrove, and the effect of such movement may be felt kilometers away. Leaf detritus from mangroves has been shown to contribute a major energy input into fisheries (Heald and W.E. Odum, 1970 as cited by E.P. Odum, 1971).

It is of interest to note that during the warmer months, a dinoflagellate bloom of *Noctiluca scintillans* was observed practically throughout the survey area. The samples for May 1978 contained about 3,760 to 189,260 individual cells per haul, while the samples for June 1978 were numerically the second largest, containing 460 to 105,260 individual cells per haul. In February 1978, on the other hand, the transparency became very low (mean value of 4.7 m) and clogging by phytoplankton was observed in the net. These phytoplankton were dominated by the diatoms *Rhizosolenia* and *Leptocylindrus* and by the dinoflagellate *Ceratium,* which coincided with the highest relative abundance (63.35 percent) of copepods including their larvae (nauplii). It has been observed by various workers (Dakin, 1908; Easterly, 1916; and Marshall, 1942 as cited by Tham, 1953) that phytoplankton formed a good proportion of the diet of copepods. As already pointed out, the surface water temperature in February 1978 was lowest (25.90-27.39°C), which coincided with the highest salinities (34.34-35.17 percent) and dissolved oxygen contents (4.21-4.88 ml/l). On the other hand, the lowest dissolved oxygen contents (3.85-4.51 ml/l) which were recorded in June 1978 coincided with the lowest mean zooplankton biomass (1.06 ml/m$^3$) and percentage of abundance of copepods (28.97 percent). Phytoplankton were practically negligible in the samples.

On the other hand, the larger zooplankton organisms such as the chaetognaths (15.13 percent) and appendicularians (13 percent) occured in greater abundance in June 1978 than in other sampling months (see Table 5). The explanation may be that the small zooplankton have been eaten by the larger zooplankton. A similar situation was observed in the Visayan Sea in August 1976 (Estudillo, 1979). Chaetognaths represented the third most important component (after appendicularians), forming 4.40 to 11.94 percent, of the zooplankton in the area. In Malampaya Sound, they also ranked third (after other curstacean group), forming 6.79 to 15.13 percent; appendicularians were only next in abundance to chaetognaths.

The drop in the relative abundance of copepods (Table 5) and zooplankton biomass (Figure 7a) in June 1978 may be related to the significant sudden change in the general weather conditions that had developed during the time of sampling (26-27 June). The southwest monsoon was observed to have started during the latter part of this month. Wind direction was southerly and wind force was at the minimum (1 knot), less sunshine than usual, and air temperature decreasing. However, monsoon rain (107.9 mm) occurred during this period resulting to decreased salinity values (Figure 2b). Lack of environmental stability was probably responsible for the rapid fluctuations in copepod numbers and zooplankton biomass (Bradford, 1972).

The high average of fish egg counts in May 1978 can be attributed by larger number of fish eggs caught in the Outer Sound. It should, however, be mentioned that over 90 percent of the fish eggs taken in May were anchovies (*Stolephorus* locally known as "dilis") and were more concentrated in Turung Bay (Station 10, 111.62 fish/m$^3$). In June 1978 over 50 percent of the egg catches were again dominated by anchovies, also taken in Turung Bay. This sheltered bay in the Outer Malampaya Sound is actually the area were fishing activities for anchovies are concentrated. *Stolephorus* spp. is one of the most common foodfishes caught in Malampaya Sound.

With reference to the above findings, anchovies in the survey area probably spawn in Turung Bay during the summer months. But this assumption is only supported by experimental catches with the NORPAC plankton net and no studies on the maturity stages of the gonads of the adult anchovies caught in Malampaya Sound have been made for this survey as an additional support to the plankton egg catches.

It will be noted that there was a steady increase in the mean numbers (and size ranges in mm) of fish larvae caught in May 1978, 7.34 larvae per m$^3$ (1.0-5.8 total length); in June 1978, 8.04 larvae (1.1-7.0 mm); and in September 1978, 8.33 larvae (1.3-8.5 mm). On the other hand, there was a decline in the mean numbers of fish eggs taken during the same months.

These considerations lead to the assumption that the large amount of fish eggs, mostly of anchovies, taken in May 1978 might have already been



hatched the following months. Thus, planktonic egg catches might indicate that the peak of spawning for anchovy might have taken place in May and hatching might have taken place in June. However, Tiews *et al.* (1971) noted that egg catches as a representative of spawning activity of fish in tropical waters might not be too conclusive because of the very speedy development of such eggs into larvae due to high temperature. In tropical areas, many eggs hatched within eight hours of spawning. Tham *et al.* (1970) reported that fish eggs hatched within 24 hours in Singapore Straits and other parts of Southeast Asia.

The greatest quantities of fish eggs, mostly in the developing stage, were obtained in surface water temperature of 30.41°C to 30.85°C which is in good agreement with the greatest number of anchovy eggs obtained in May 1978. Estudillo (1979) stated that the greatest occurrence of *Stolephorus* eggs in the eastern part of the Visayan Sea seemed to be associated with higher water temperature and salinity.

The increase in numbers of fish eggs and fish larvae in the Inner Sound during the rainy months from June through September (see Figure 8b, c) was probably associated with heavy rainfall. Eggs and larval/young fishes from the rivers and mangrove swamps (which serve as spawning and nursery grounds) were apparently carried by the floodwaters to the area.

## SUMMARY

Variations in the mean surface water temperature and salinity were inversely related and seem to be seasonal and were, for the most part, climatically controlled. However, the monthly individual values recorded for both parameters had greater range and variability, and can be directly related to long and short-term variations in air temperature and rainfall and also to the general geographic or physical features of this small, semi-enclosed body of water. The lowest (26.33°C) mean surface water temperature was observed in February 1978 which coincided with the highest mean surface water salinity (34.55°C) recorded for the same month.

The mean surface dissolved oxygen values were practically uniform throughout the study period. Mean values over 4 ml/l were recorded throughout the study period. The highest dissolved oxygen value (4.61 ml/l) was observed in February 1978, and since this is the period of dry-cooler northeast winds and much phytoplankton production which interestingly coincided with the lowest (4.7 m) mean water transparency reading, this high value may be due to the increased photosynthetic activity of phytoplankton.

Variation in zooplankton biomass in Malampaya Sound was observed to be increasing and decreasing as the cooler northeast monsoon (dry season) and southwest monsoon (wet season) developed, respectively. It was highest (7.62 ml/m$^3$) in February 1978 and lowest (1.06 ml/m$^3$) in June 1978. This low mean catch volume for June resulted from the very low number of cope-

pods, which made up only 28.97 percent of the total zooplankton. This drop in copepod numbers and zooplankton biomass may be related to the significant sudden change in the general weather conditions that had developed during the time of sampling.

Zooplankton biomass in Malampaya Sound was found to be about six times greater than in the Visayan Sea and twice greater than in the Bacuit Bay, northwestern Palawan. This high productivity could be attributed to the general geologic, geographic, climatic and hydrographic features of the Sound.

The Inner Sound was found to be richer than the Outer Sound with respect to its plankton biomass and abundance of fish eggs and fish larvae. The work on benthos biomass and population density in the same area indicated the same results (Olandez, unpublished data). The role of mangroves, large tropical swamps and a number of rivers which empty their waters into this shallow part (inner part) of the Sound probably contributed greatly to its high productivity.

Zooplanktons in Malampaya Sound were typically neritic. The copepod was the most dominant, comprising 46.50 percent, followed by other crustaceans (13.57 percent), chaetognaths (9.72 percent), appendicularians (8.04 percent) thaliaceans (7 percent), polychaetes (4.87 percent), echinoderms (4.66 percent), molluscs (3.80 percent), coelenterates (1.24 percent), fish eggs and fish larvae (0.41 percent) and actinotroch: larvae (0.19 percent).

Maximum abundance of copepods (63.35 percent) in February 1978 was due to the appearance of a large number of their larvae (nauplii) while the maximum abundance of other crustaceans (17.73 percent) in September 1978 was due to the zoea larvae of the decapod *Lucifer*. Other crustaceans which ranked next to copepod in abundance had a percentage composition of 16.17 percent in May 1978 which was mainly due to the cladoceran *Penilia.*

Large numbers of the relatively large salps, which contributed 27.62 percent to the total zooplankton, also helped to boost zooplankton volume in October 1977.

The distribution of fish eggs and fish larvae was found to be more localized. The main concentration was in the sheltered small bays and coves bordering both the Outer and Inner Sounds. Bigger larvae (the range being from 1.0 to 8.5 mm but the majority from 6.0 to 8.5 mm size) were obtained mainly from the Outer Sound, the smaller ones (the range being from 0.5 to 6.3 mm size) from the Inner Sound.

Anchovy was found to spawn in Turung Bay of the Outer Sound, and its main spawning period was estimated from May to June, with its peak in May, consisting over 90 percent of the total number of fish eggs. Turung Bay actually is the area where fishing activities for anchovy are concentrated.



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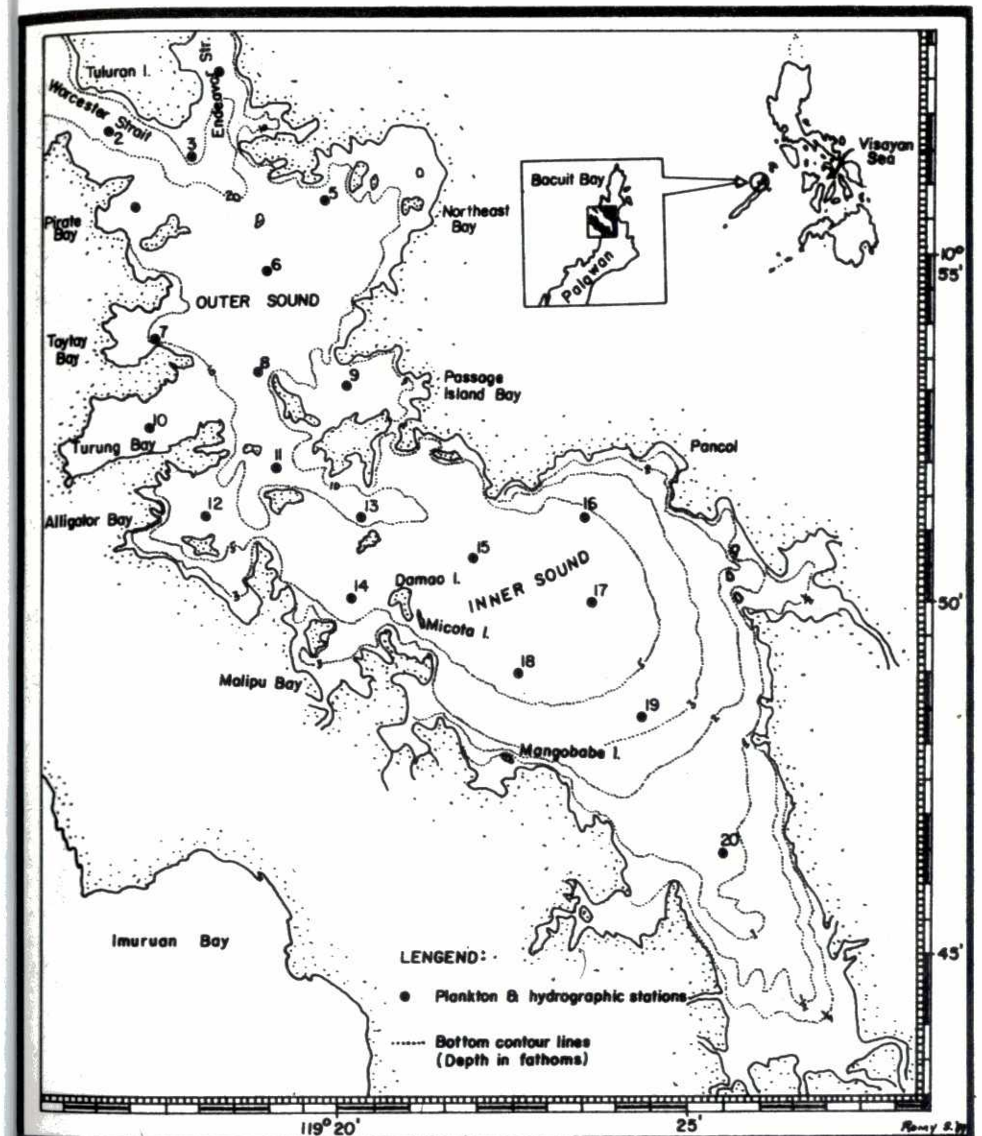



**Fig. 1** Map of Malampaya Sound showing depth contours and the location of hydrographic and plankton stations.

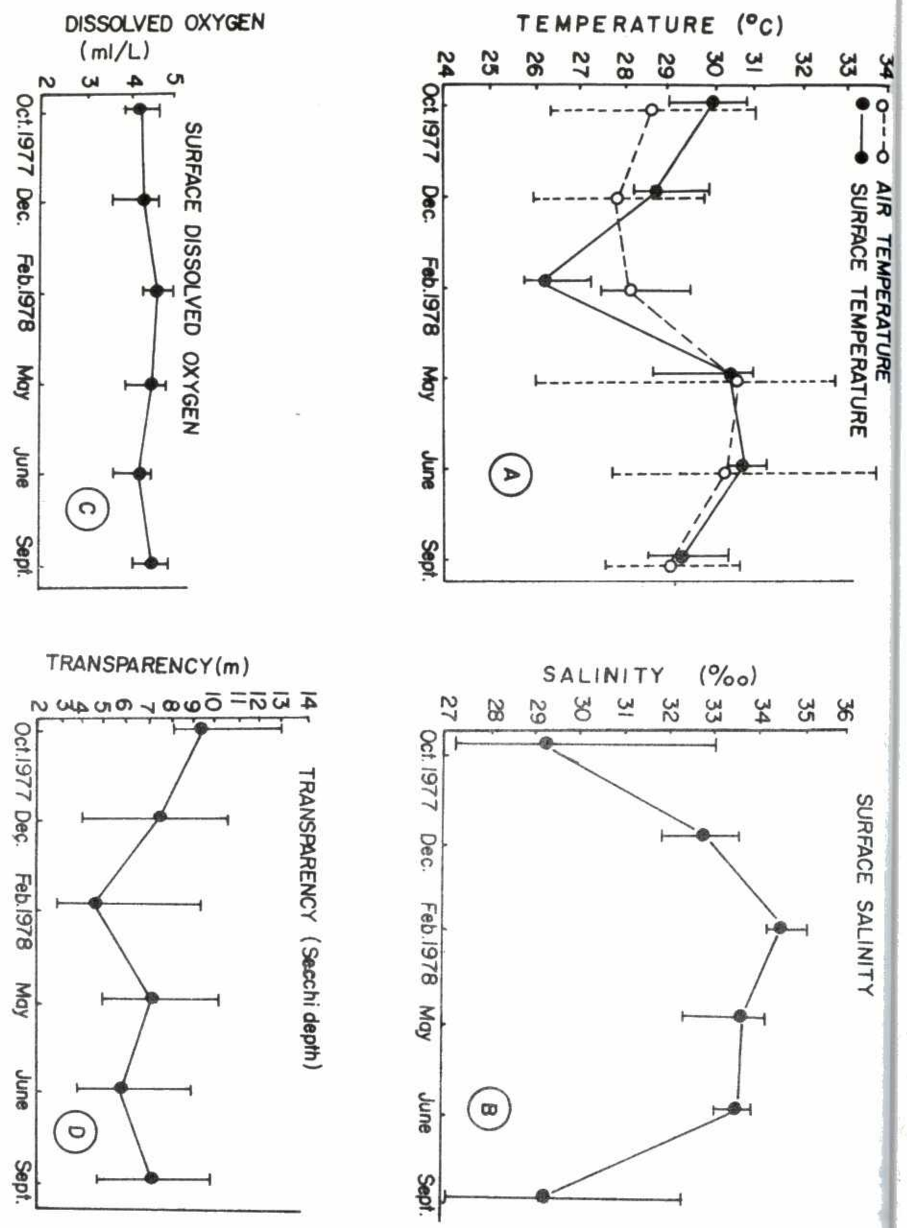



Fig. 2 Variations in the monthly means of a) air temperature and surface water temperature, b) surface salinity, c) surface dissolved oxygen and d) water transparency in Malampaya Sound. Vertical bars show ranges of values.



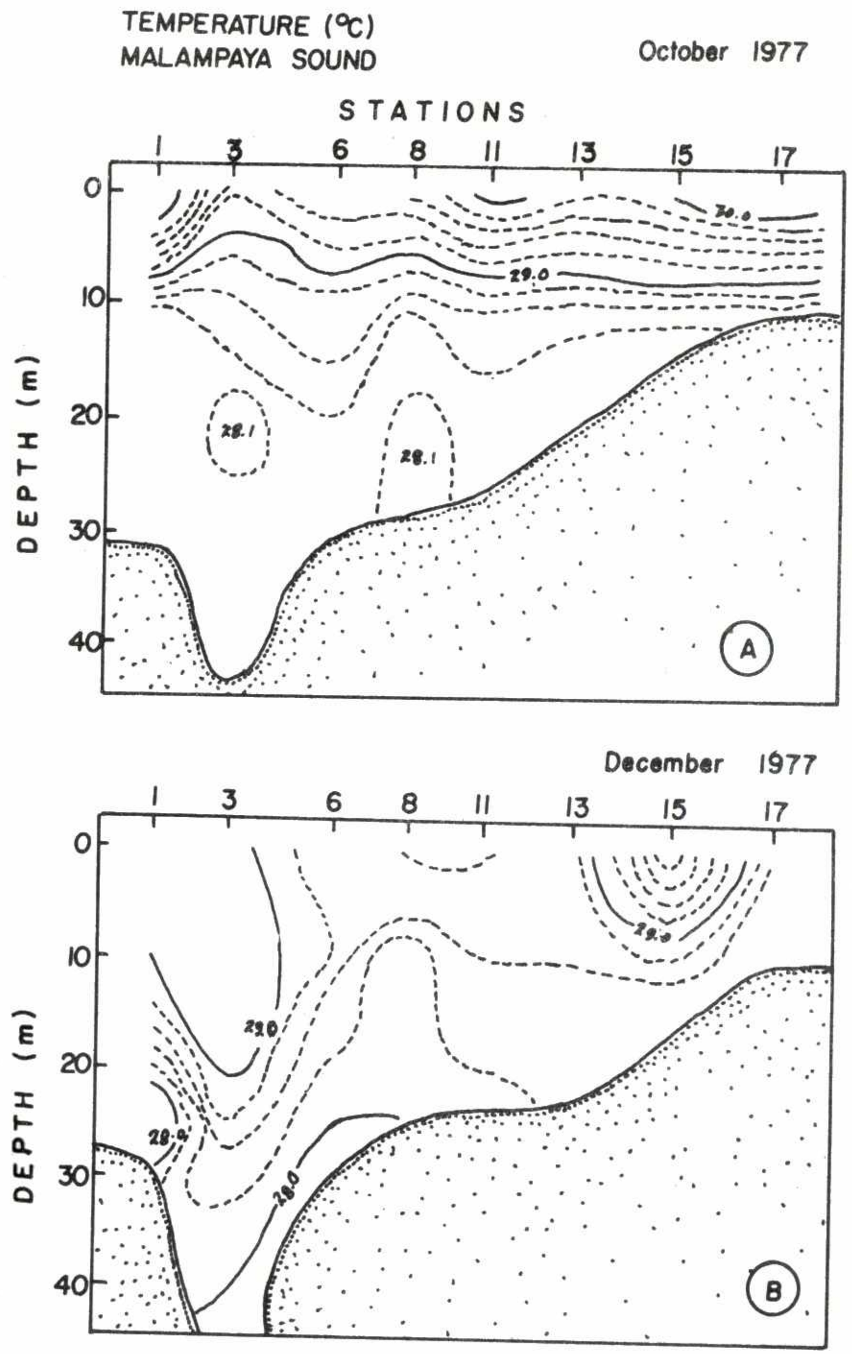
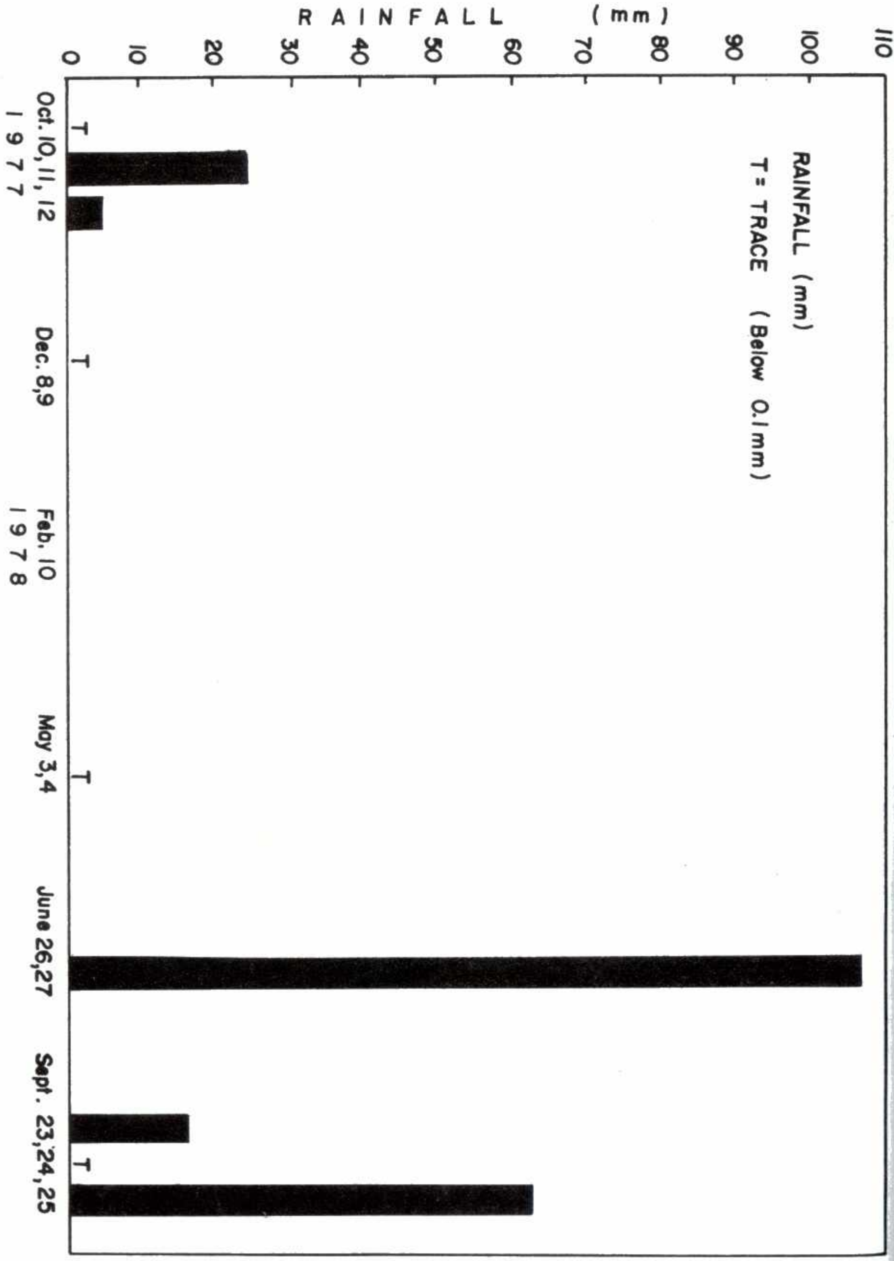



Fig. 3 Vertical temperature profiles in a) October 1977 and b) December 1977.

Fig. 4 Rainfall data for the inclusive dates of sampling during the period between October 1977 and September 1978, Puerto Princesa Weather Station, Palawan (from the records of the Philippine Atmospheric, Geophysical and Astronomical Services Administration, Quezon City, Metro Manila).





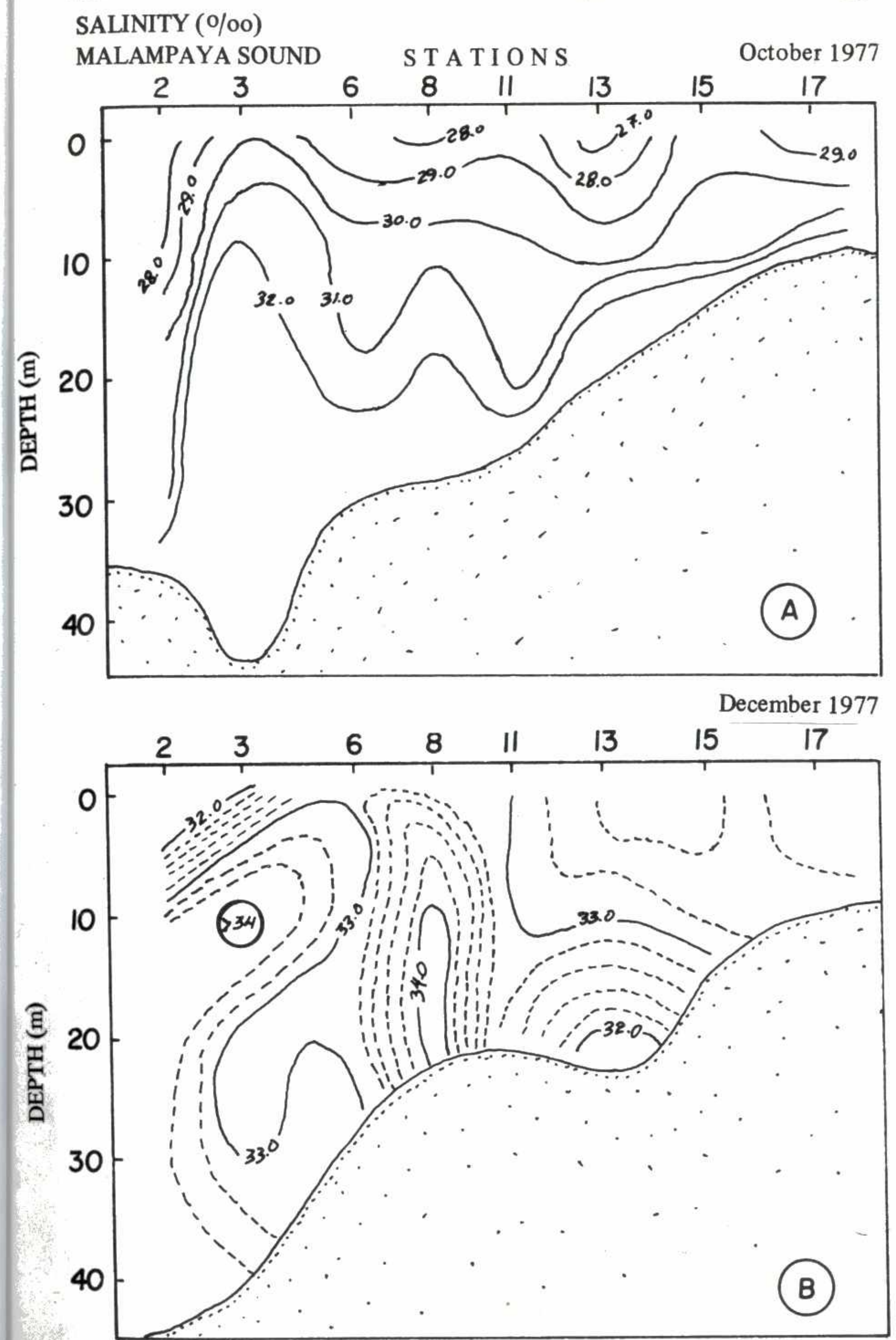




Fig. 3 Vertical salinity profiles in a) October 1977 and b) December 1977.

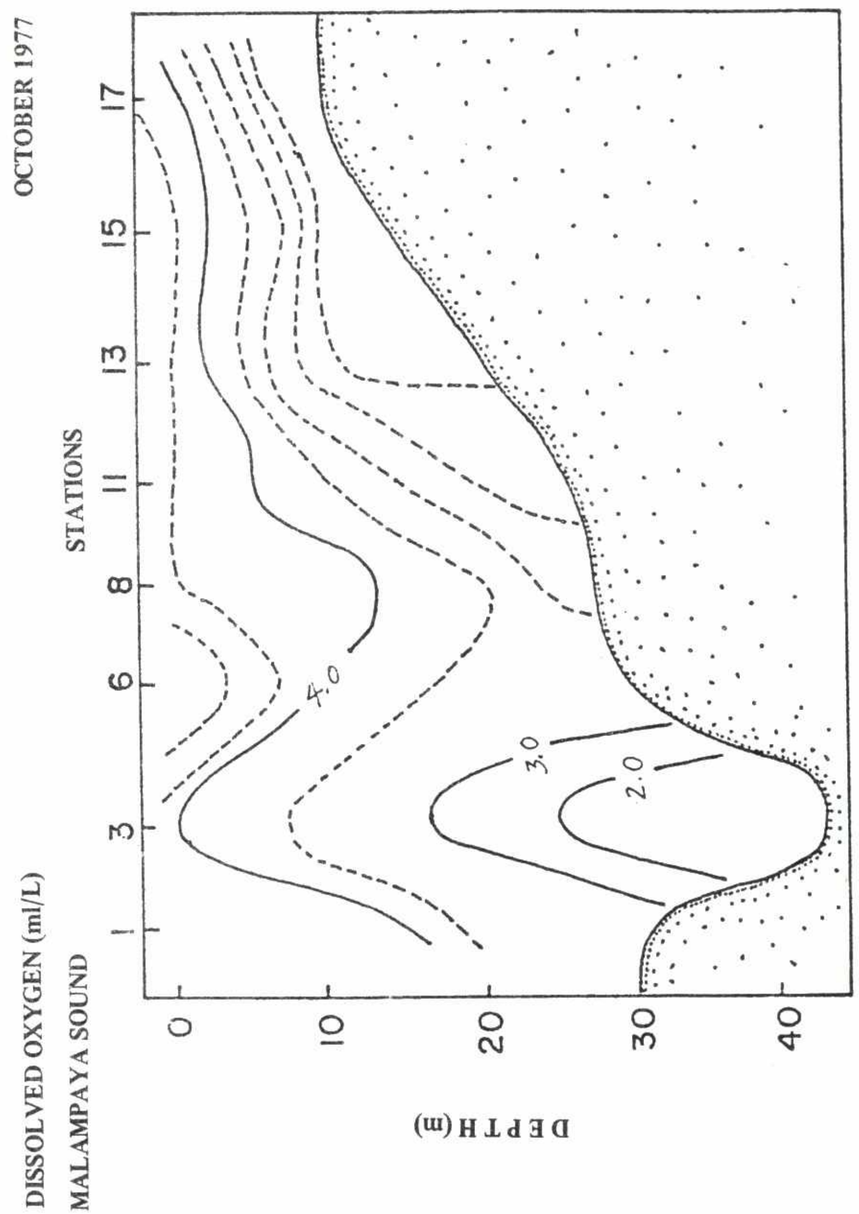



Fig. 6 Vertical dissolved oxygen profile in October 1977.



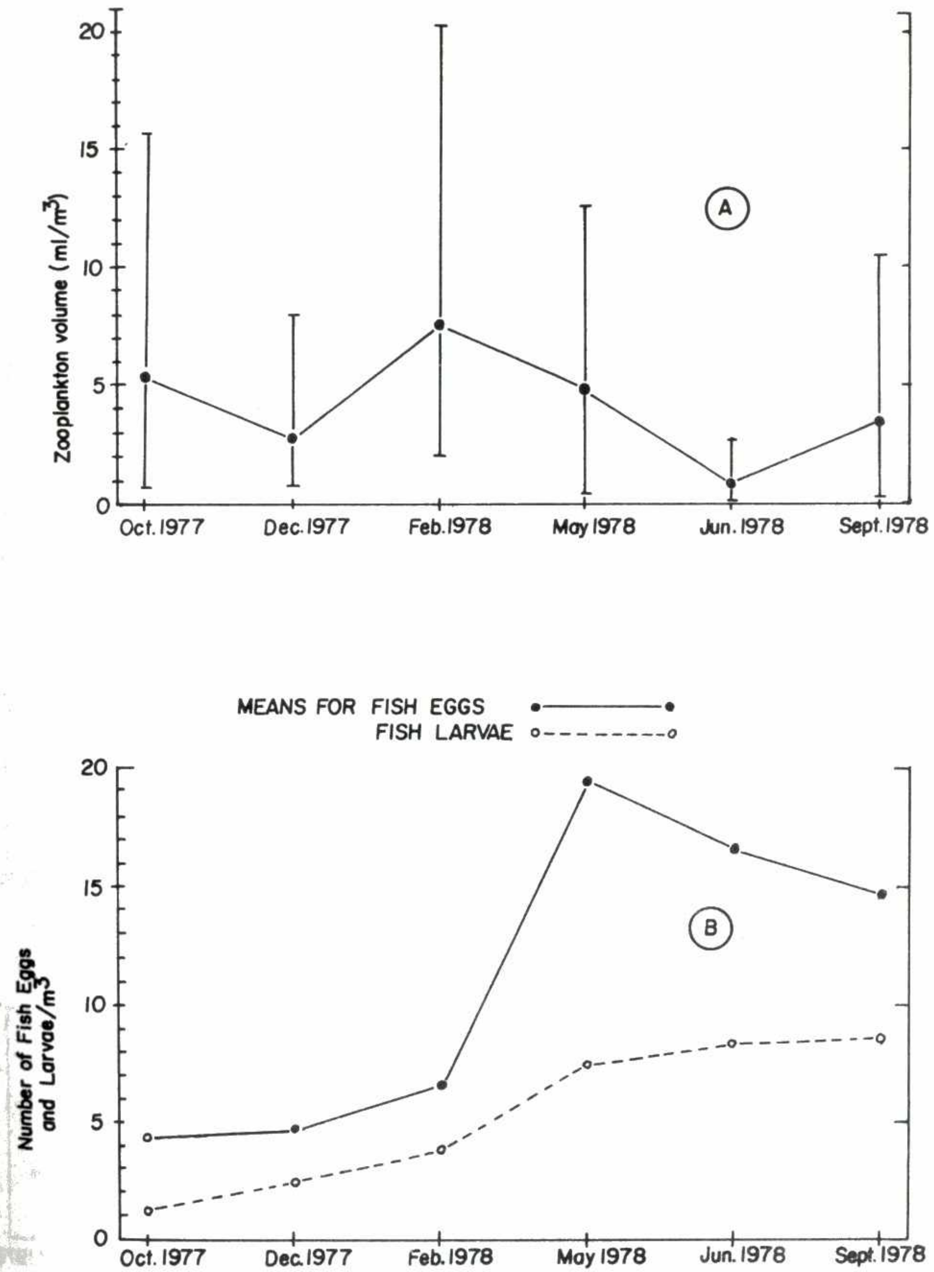



**Fig. 7** Variations in the monthly means of a) zooplankton biomass (vertical bars show ranges of values) and b) abundance of fish eggs and fish larvae in Malampaya Sound.

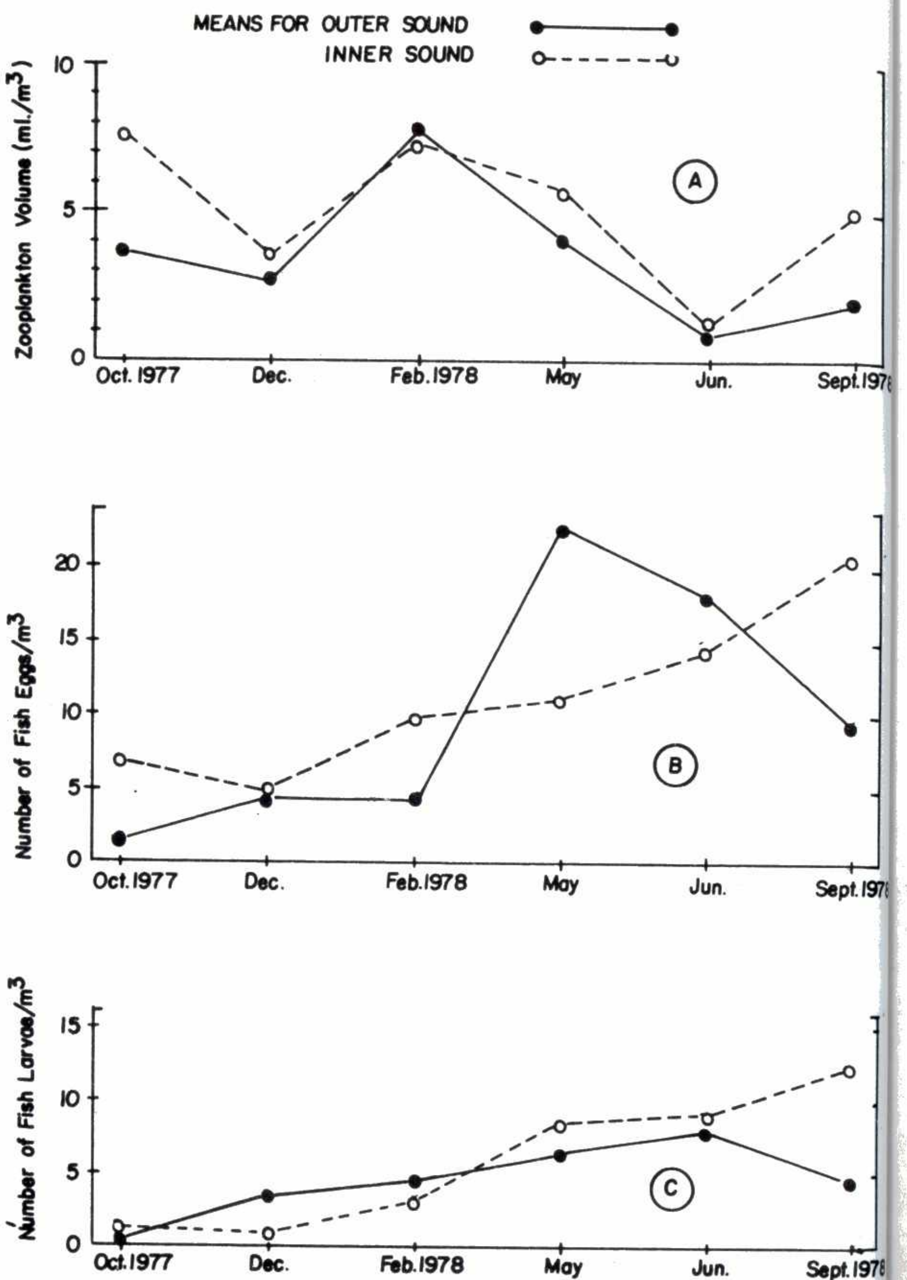
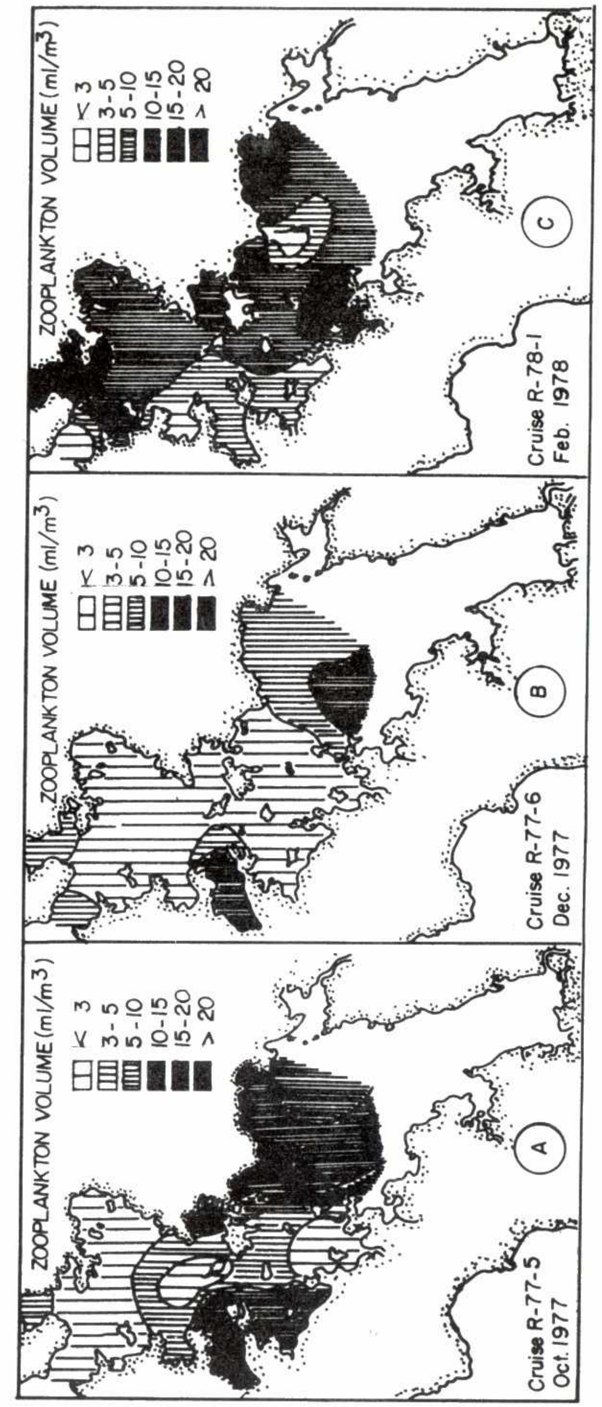



Fig. 8 Comparison between the variations of a) zooplankton biomass and the abundance of b) fish eggs and c) fish larvae of Malampaya's Outer and Inner Sounds.



Fig. 9 Distribution of zooplankton biomass during each of the sampling periods in Malampaya Sound.



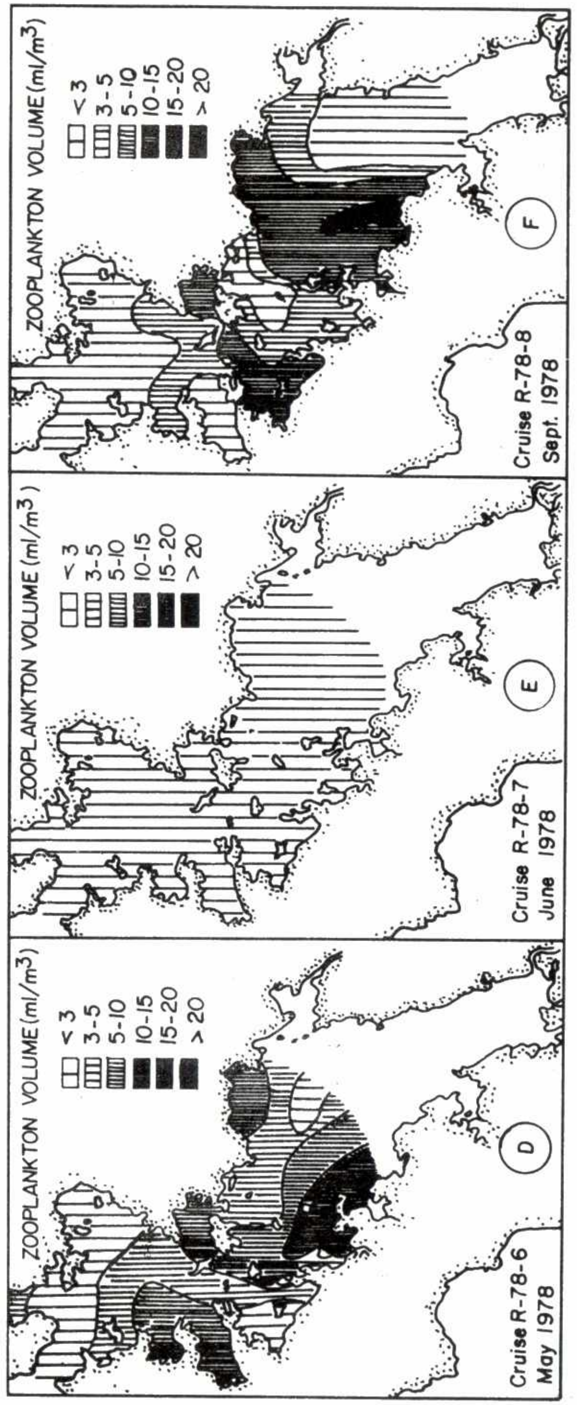



Fig. 9 (Cont'd) Distribution of Zooplankton biomass.



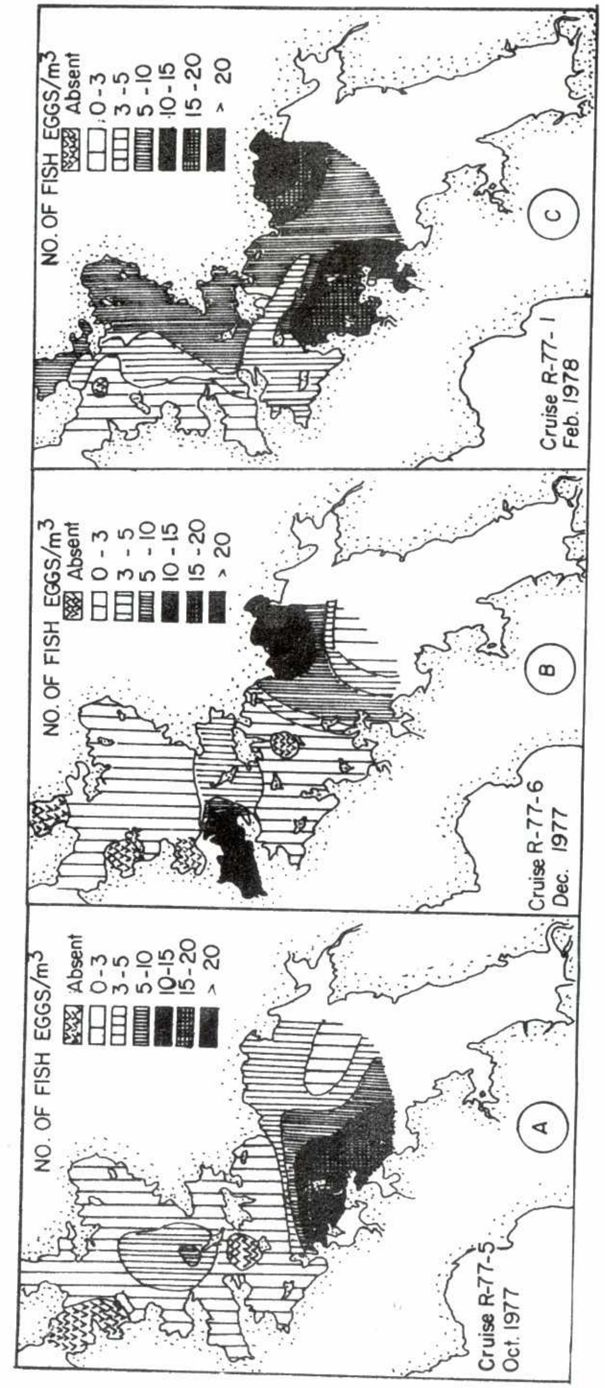



**Fig. 10** Distribution and abundance of fish eggs during each of the sampling periods in Malampaya Sound.

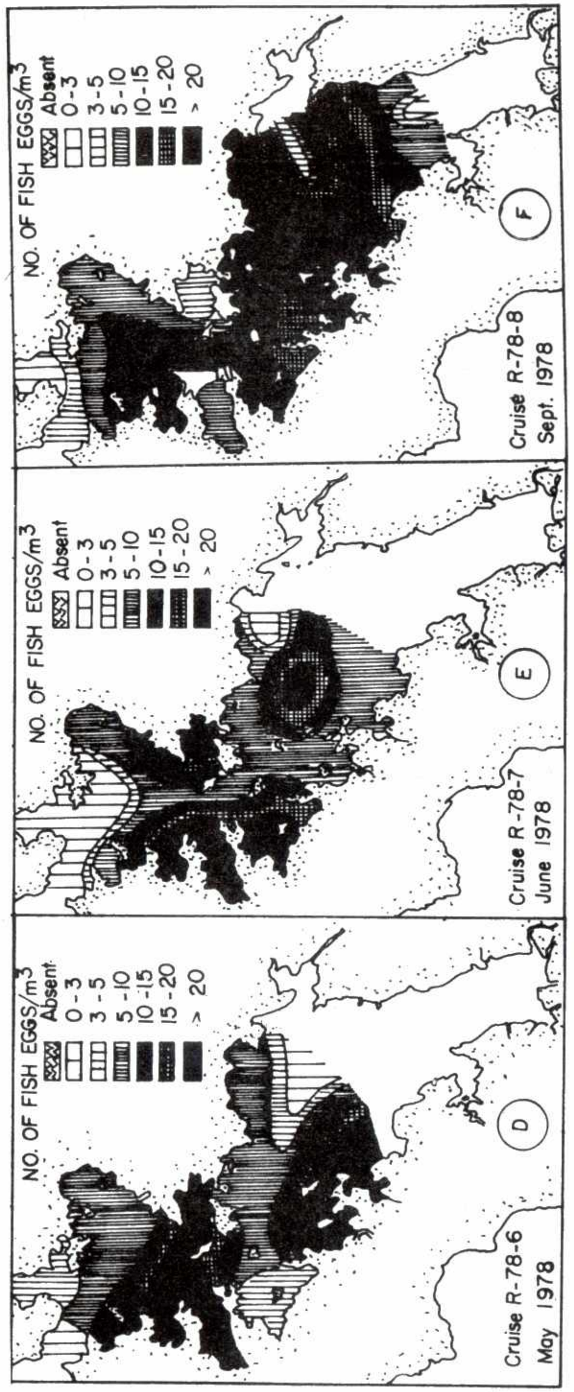



Fig. 10. (Distribution and abundance of fish eggs. .



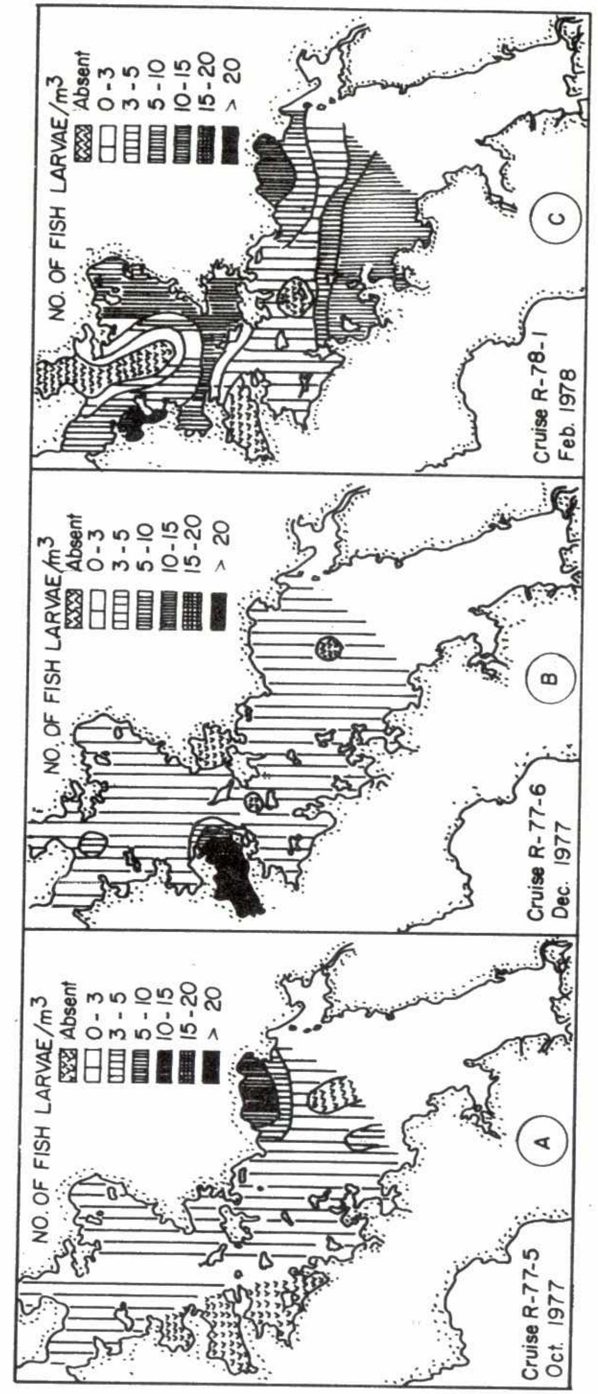



Fig. 11 Distribution and abundance of fish larvae during each of the sampling periods in Malampaya Sound.

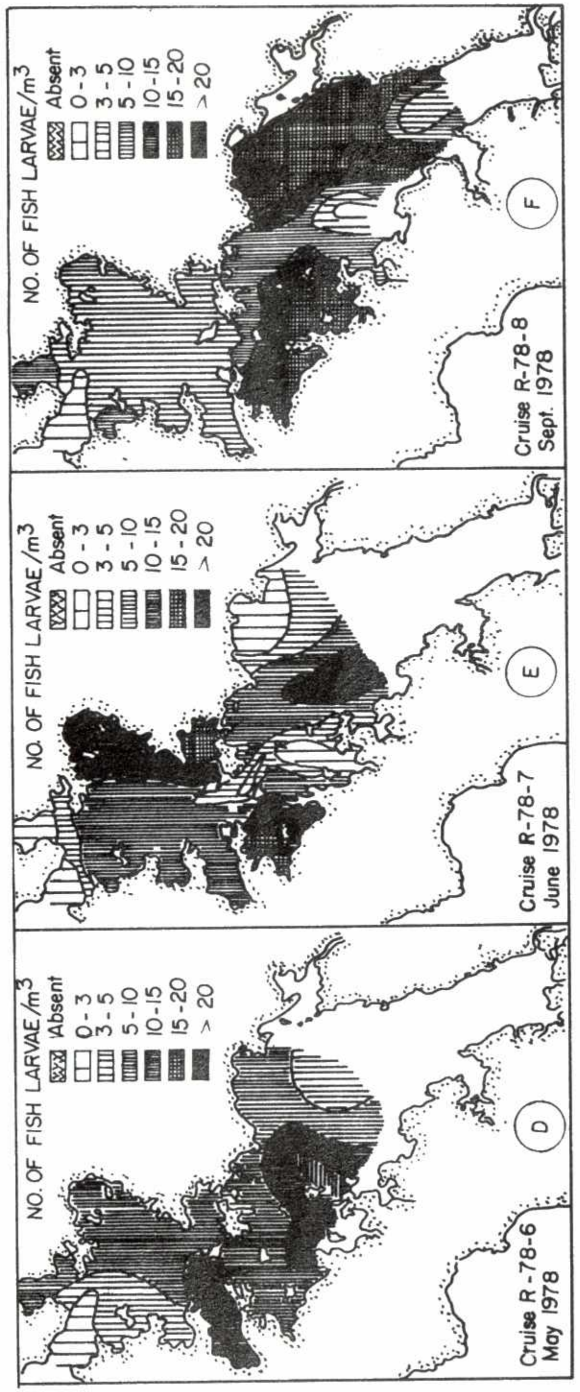



Fig. 11 (Cont'd) Distribution & abundance of fish larvae. . .



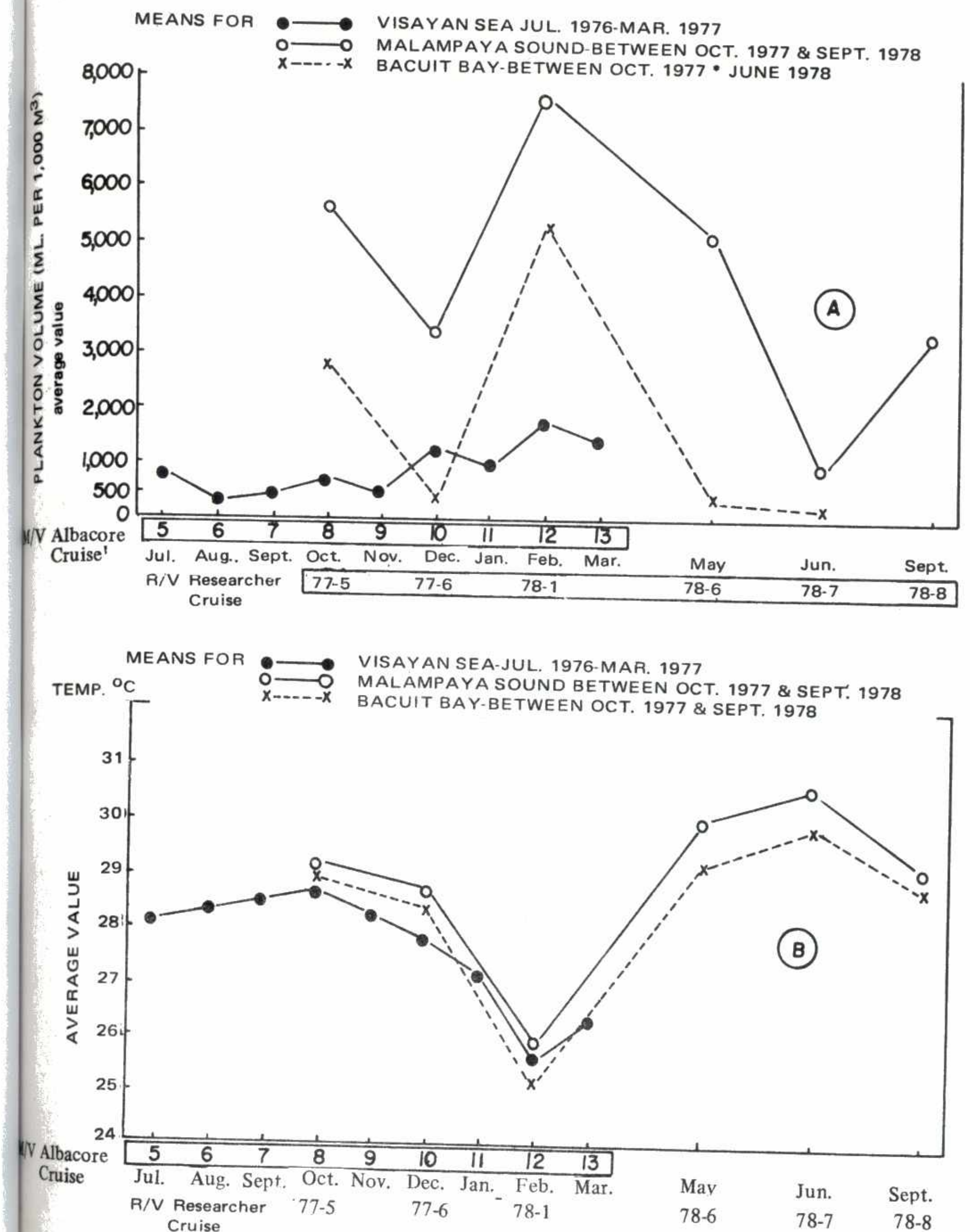



Fig. 12 Comparison of variations in a) zooplankton volumes and b) water temperature in Malampaya Sound with other localities where similar methods of analysis were used. Adapted from Figure 20 in Estudillo (1979).