THE MARINE BIOGEOGRAPHY OF RAGAY GULF AND BURIAS PASS, PHILIPPINES

by

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INTRODUCTION:

The Philippines is an archipelago of 7,700 islands. Living along the coasts of these islands are more than half a million Filipinos to whom fishing is one of the most important sources of livelihood (Smith, et al., 1980). The last two decades witnessed the unprecedented growth of Philippine population as well as the rapid technological development of the local commercial fishing industry, especially in the urban areas (Jamir, 1989; Smith, et al., 1980). However, these did not happen without some serious setbacks. As the commercial fishery sector expanded to meet the population's growing demand for fishery products, more and more fishing grounds became overexploited, leaving behind their wake thousands of displaced and disgruntled sustenance fishermen (Callanta, 1988). The seriousness of the situation demanded that the government formulate policy initiatives that counter the depletion of the remaining fishery resources while easing the growing tension and open conflict between the urban-based commercial fishermen and the rural-based sustenance coastal workers. However, this requires that adequate, timely, and reliable information about the resource and its users be made available to policy makers. Scientific research provides some of the answers to these questions (Marr, 1982).

The literature abounds with numerous recommendations on how to effectively approach fishery resource management (e.g., Tietenberg, 1988; Gulland, 1982; Saeger, 1981; Gulland, 1969). One common strategy is to establish fish sanctuaries subject to permanent or seasonal closures in an effort to protect spawning stocks from fishing pressures (Smith, et al., 1980). However, although this approach is reasonable, lack of adequate data and scientific research have led well-meaning policy makers in the

Philippines to declare specific water bodies or portions thereof as fish sanctuaries without any sound scientific basis at all. For example, during the Marcos era, a number of traditional fishing grounds within 7 fathoms deep or 7 kilometers from the shore were declared either as exclusive sustenance (municipal fisheries) fishing zones or fish sanctuaries based on Presidential Decree No. 704 (Smith, et al., 1980). This was not based on any scientific reasons, but simply because the mystical number 7 happened to be the former president's lucky number.

Ragay Gulf and Burias Pass are among the traditional fishing grounds of the country being considered by the government for an integrated approach to fishery management (Smith, et al., 1980; Samson, et al., 1977, World Bank, 1976). The Department of Marine Fisheries, College of Fisheries, University of the Philippines in the Visayas (UPV) in cooperation with the German Technical Cooperation Agency (GTZ), and under the financial auspices of the National Science and Technology Authority (NSTA) and the Ministry of Natural Resources (MNR), was awarded a contract to do a multidisciplinary research survey of the area from November, 1981 to February, 1983 under the aegis of the NSTA-MNR-UPVCF Project no. 8203 Ag. "Assessment of Trawlable Areas in the Philippines II - Ragay Gulf, Burias Pass, Ticao Pass, and Waters North of Samar Sea." To date, much of what remains to be done involves the processing and analyses of the volumes of research data accumulated by this project. The main objective of the above research was to assess the status of the fishery resources of the area for the rational management of the commercial and subsistence fishing industry. However, much of the basic information generated by this multidisciplinary research can be used for other purposes as well. This paper is a contribution to this extensive research effort. Specifically, the objectives of this research are as follows:

1) to understand the seasonal monsoons and local topography and how they affect the environmental processes and patterns in Ragay Gulf and Burias Pass,

2) to determine the biogeographic distribution of ichthyoplankton in the Ragay Gulf-Burias Pass area and their relationship with their fluid environment, and

3) based on the above findings, identify potential sites that are suitable for the establishment of fish sanctuaries.

MATERIALS AND METHOD:

From November, 1981 to February, 1983 thirteen oceanographic and nine ichthyoplankton stations (Figure 1) were sampled at regular intervals using TRV Sardinella, the 410 gross ton training and research vessel of the UPV College of Fisheries. At each oceanographic station, water samples were collected at standard depths using Nansen bottles fitted with reversing thermometers. These were analyzed for salinity using a Tsurimi-Seiki induction salinometer model TSE2 calibrated at regular intervals using the Mohr-Knudsen procedure (Grashof, 1976). Dissolved oxygen concentrations were measured using a Horiba water quality checker model U-7 which in turn was calibrated using the modified Winkler procedure (Grashof, 1976). Water temperature were determined using deep sea reversing thermometers corrected for errors using the procedures of Sverdrup, et al. (1947), and La Fond (1951).

Wind velocity and barometric pressure were measured using the ship's anemometer and aneroid barometer respectively. The Philippine Weather Bureau's Masbate station was used as the reference station for this study. Soundings were made using the ship's Furuno scientific echosounder model Fe D824, 1060 KHz with a depth range of 0 m to 1,600 m (single frequency) and 28/200 KHz frequency with variable gain. Ship positions were determined using SATNAV and radar fixes.

Ichthyoplankton samples were collected using Bongo nets with a mouth diameter of 0.6 m. Two of these frames were fitted with 2.2 m long Nitex cylindrical-conic nets. The principal ichthyoplankton sampling net has a 0.500 mm mesh size while the other has

0.335 mm mesh size. A centrally mounted flow meter is used to provide data on the volume of water filtered during each tow. The net is lowered to the bottom down to a maximum depth of 100 m. A neuston katamaran with a 0.5 mm. mesh size and a rectangular mouth of 0.30 m x 0.15 m was used to collect fish eggs and larvae from the surface water layer. The upper net effectively samples 0-10 cm strata while the lower one samples from 20-35 cm strata. The gear was towed 4 meters from broadside at 3 knots for 15 minutes.

All plankton samples were immediately preserved in a 4% buffered seawater and formalin solution before being stored. Biomass and biovolumes were determined using the methods of Hermes and Dizon (1982), Estudillo (1981), and Smith and Richardson (1977).

RESULTS AND DISCUSSION:

Marine Geography of the Ragay Gulf Basin:

Ragay Gulf and Burias Pass make up a basin located in the Bicol Region southeast of Luzon, Philippines (Figure 1), between latitudes 13° 00' N and 14° 00' N and longitudes 122° 25' E and 123° 20' E. It has a maximum width of about 25 nautical miles and a longitudinal length of about 75 nautical miles with the main axis oriented along the northwest-southeast axis. It is bordered on the east by the Sierra Madre mountain range and on the west by Bondoc Peninsula. Situated on its northern tip is Vinas River, a relatively wide but short river with limited watershed. Ragay Gulf is connected to Sibuyan Sea to the west through the narrow gaps of Burias Pass and between Bondoc Peninsula and Burias Island.

Using nautical chart no. 4715 published by the Philippine Coast and Geodetic Survey as base map, together with the echo sounder track data collected by TRV Sardinella, the bathymetric map shown in Figure 2 was created. The resulting map shows Ragay Gulf to be a relatively isolated basin with two wide and shallow sills connecting it to

Sibuyan Sea. The shallower sections of the basin are located in the vicinity of Vinas River to the northeast while the deepest, with a recorded depth of 539 m, lies in the central section. Figure 3 shows the cross section of the basin along this mid-section as revealed by echo sounding. The sill of the basin is relatively wide (23 nautical miles) with an average depth of about 150 m. Coming from the sill, the bottom plunges rapidly, down to a depth of about 550 m, and then steeply rises as one nears the coast of Bicol.

If we lower the water level to the 150 m isobath relative to the present sea level, Ragay Gulf Basin will assume a triangular lake structure with limited connection to the open sea. Lowering the water some more to 200 m (down to the edge of the insular shelf) will make the basin look like an elongated lake that is totally isolated from the other bodies of water.

Hypsometric curves of volume and area (Figure 4) were constructed based on the updated chart. The surface area of the basin measures about 4,500 km^2 with a mean depth of 125 m. Of this, 27% of the land lie submerged between 0 - 50 m, 47% between 50 - 200 m, and only 26% of the total land area lie below the insular shelf. In terms of volume, the estimated capacity of the Ragay Gulf is about 520 km^3 of which, 50% are contained in the upper 120 m layer (i.e., half of the waters lie above the sill and the other half below). Volume development index of the basin (Welch, 1952) was calculated to be equal to 0.625 indicating convex configuration.

Observed Meteorological Conditions:

The Philippines has three distinct "seasons," i.e., the northeast monsoon (occurs during northern hemisphere winter) characterized by cool, dry winds coming from the northeast; the southwest monsoon (occurs during northern hemisphere summer and early fall) characterized by winds coming from the southwest, frequent tropical storms, and cloudy skies; and the dry, often windless summer months (occurs during northern hemisphere spring and early summer) (Pauly and Navaluna, 1983; Dickerson, 1928).

The wind velocity pattern (based on Masbate weather station) during the survey period are shown in Figures 5 and 6. The 15-day average wind velocity profile shows wide fluctuations in observations indicating variability in wind pattern. The 5-day moving average curve smoothed out the fluctuations in the observations and clearly shows a bimodal wind velocity pattern corresponding to the two monsoon seasons mentioned earlier. Peak winds occurred during the months of January to February and August to September. The low wind velocity months indicate the intermonsoon shifts in the direction of the wind as the intertropical convergence zone (ITCZ) moves towards the equator (Critchfield, 1979). The plot of the variation in the frequency of occurrence of the northeast and southwesterly winds (Figure 6) clearly shows the directional shift of this bimodal wind structure.

The seasonal variation of precipitation closely followed the above variations in wind pattern (Figure 7). General trends in the actual daily observed rainfall pattern were consistent with the annual average rainfall cycle for the area, i.e., reaching peak precipitation values during the southwest monsoon period and low rainfall during summer. Superimposed on the graph is the monthly variation in observed sea surface salinity. As precipitation increased, the sea surface salinity of the Ragay Gulf decreased significantly and vice versa, indicating the strong influence of meteorological factors on the oceanographic properties of this body of water.

The seasonal variation of temperature and cloudiness also showed distinct patterns (Figure 8). Air temperature followed an annual cycle with minimum values (26.5°C) recorded during the months of December to February. This was followed by increasing temperatures, reaching its peak (29.9°C) during the months of May to June in response to changing levels of insolation. Beyond this point, air temperature fell and settled to a thermal plateau of about 28°C as increased cloudiness decreased the amount of solar radiation able to reach the earth's surface. Average sea surface temperatures followed the air temperature pattern but with a lag of about 2 - 3 months due to the high specific heat of water. The temporal variation in cloudiness agreed well with the average observed climatological characteristics of the region, i.e., clear sky conditions prevailed with the development of the high pressure cell in the Asiatic mainland during the northern hemisphere winter while the reverse happened during the northern hemisphere summer (Critchfield, 1979).

The Oceanography of the Ragay Gulf Basin:

Spatial and Temporal Variation of Temperature:

The observed thermal structure of Ragay Gulf Basin during the different cruises are shown in Figures 9a to 9i. The general seasonal trend in the thermal pattern can be summarized as follows:

a) The northeast monsoon months were characterized by rapid cooling of the basin waters as indicated by the disappearance of the warmer isotherms. As the months progressed, the mixed layer depth (MLD) thickened, thermal stratification weakened, and the thermocline almost disappeared altogether.

b) The onset of the summer months resulted in the reversal of this trend, i.e., the waters in the basin started to warm up, thermal stratification became more pronounced, the MLD decreased, and once again, the thermocline started to develop.

c) With the coming of the rainy southwest monsoon months, the waters in the basin remained warm and the MLD boundaries became more distinct as the thermocline layer became well formed at depths of about 100 m to 150 m.

The coolest sea surface temperatures occurred during the northeast monsoon months while the warmest occurred during late summer. Along the vertical, the highest temperatures were observed at the surface and near surface layer of the MLD. When thermal stratification was well developed, a deep thermocline was present marked by a rapid decrease in temperature with depth. Below this (at about 150 m) is the permanent thermocline where the temperature continues to fall but at a much more gradual rate. As expected, water temperature at the permanent thermocline remained almost the same throughout the year.

Spatial and Temporal Variation of Salinity:

The spatial and temporal patterns of salinity in the Ragay Gulf Basin are shown in Figures 10a to 10i. In general, the seasonal trends in salinity distribution throughout the survey areas can be summarized as follows:

a) During the northeast monsoon months, the salinity of seawater generally increased while salinity stratification decreased as indicated by the deviation of the isohaline surfaces from the horizontal. Water samples taken during the month of January showed the Ragay Gulf Basin waters to be almost isohaline from the surface down to the bottom with a salinity of about 34.5 $^o/oo$.

b) Summer months were characterized by the return of salinity stratification in the basin. However, vertical salinity gradients remained weak. Observed salinity values did not differ much from the previous months.

c) The onset of the rainy southwest monsoon season considerably lowered the surface salinity of the whole basin and resulted in intense salinity stratification. A strong halocline developed and a lens of low salinity water started to form near the mouth of Vinas River.

The ranges of observed salinities were largest during the rainy season and least during the dry northeast monsoon months. Salinities were lowest (33.4$^o/oo$) near the mouth of Vinas River and highest at deeper waters far from freshwater sources (34.5$^o/oo$ for waters deeper than 200 m).

Spatial and Temporal Variation in Dissolved Oxygen Concentration:

The analysis of the spatial and temporal changes in dissolved oxygen (DO) concentration (Figures 11a to 11i) is not as straightforward as those for salinity and temperature since a number of factors influence its distribution, e.g., temperature, mixing, nutrient levels, respiration and primary production, etc. However, a few generalizations can be derived from the observations.

DO concentrations were generally high at or near the seasurface (about 6.0 mg/L) and decreased rapidly with depth (<3.0 mg/L for waters deeper than 150 m). This is to be expected as most of the increase in DO is mediated by phytoplankton living in the photic zone as well as through diffusion and mixing at the air-sea interface (Valiela, 1984). Shallow coastal waters often have less DO concentrations compared to offshore waters at the same depth. This difference may be explained by high animal biomass in the shallow coastal waters compared to the deeper areas (Smith, et al., 1980; Tait, 1968) and therefore, more respiration relative to oxygen production. DO values were generally lower during the northeast monsoon months and highest during summer. This may be related to the seasonal cycle in phytoplankton production, i.e., peak primary production during early summer and low primary production during winter (northeast monsoon season), which influences the concentration of oxygen in the water column.

Abundance and Seasonality of Fish Eggs and Larvae:

The percentage composition of the dominant fish family found in Ragay Gulf Basin is shown in Figure 12 (Villoso, 1984). Members of the family Mullidae or goat fishes comprise the bulk of the samples (38%); followed by the silverfishes, family Atherinidae (14.1%); flying fishes, family Exoceotidae (8%); theraponids, family Theraponidae (6%); gray mullets, family Mugillidae (5.3%); cardinal fishes, family Apogonidae (5.3%); silver breams/sea breams, family Sparidae (5%); herrings and sardines, family Clupeidei (4.23%), and the rest making up 14.2 %.

The seasonal fluctuations in species composition of fish larvae caught by the neuston katamaran (0 to 10 cm) are shown in Figure 13. Family Mullidae was consistently the dominant species throughout the year with peak abundance during the months of May to November (1982). Family Atherinidae follows closely with peak abundance registered during the months of January to May. The rest of the species followed the general trend, i.e., minimum abundance during January and maximum during the summer months of March to May with some extending up to July.

The abundance of fish egg and larvae per cruise is shown in Figures 14 and 15. Fish egg abundance showed a bimodal distribution pattern with peaks around the months of May and November-December. Fish eggs were most abundant in the surface layers and abundance decreased rapidly with depth. Fish larval abundance also showed a bimodal distribution with peaks around the months of May and November-December. However, their abundance pattern was more widely spread in time compared to the pattern for the fish eggs.

The monthly variation in larval fish density of the five most abundant families in Ragay Gulf is show in Figure 16. Although each family exhibited local density peaks, in general, larval fish density distribution was bimodal. The largest concentration of fish larvae were observed during the summer months while the least occurred during the northeast monsoon months.

The above data seem to indicate the presence of two spawning seasons (indicated by the time when large amounts of eggs are laid in the water) in Ragay Gulf Basin. The first (and major) spawning season occurs during the summer months and the second during the months of November to December following wind shifts from the southwest to the northeast. Bakun, et al. (1981; 1982) and Pauly and Navaluna (1983) believe that most tropical fishes spawn continuously throughout the year but survive only when they chance to spawn during the times when the "environmental windows" are open. These environmental windows are periods when the environmental conditions are favorable for the growth, feeding, and survival of the hatchlings and fish larvae, e.g., during periods of large and sustained phytoplankton blooms; low turbulence; optimal temperature, salinity, dissolved oxygen concentration, etc.). For Ragay Gulf and Burias Pass, these ideal conditions seem to occur during the summer months as well as during the lulls in the monsoons. A similar conclusion was arrived at by Pauly and Navaluna (1983) in their study of the recruitment patterns of Philippine demersal fishes using NORMSEP (Abrahamson, 1971), ELEFAN I and ELEFAN II programs (Pauly and David, 1981; Pauly and Ingles, 1982).

Geographic Distribution of Zooplankton:

Isopleths of zooplankton biovolumes (ml/1,000 m^3) were constructed for each cruise and shown in Figures 17a to 17h. This approach will give us a good idea of the general geographic location and time of spawning of the different aquatic fauna that comprise the ichthyoplankton samples taken from Ragay Gulf and Burias Pass (MacCall, 1990; Lasker, 1978; Cushing, 1969; Tait, 1968). To a certain extent, the general circulation pattern can also be ascertained using the same data (Parish, et al., 1983).

The geographic pattern of zooplankton distribution during the months of November and December are shown in Figures 17a, 17b, and 17h. There were large zooplankton concentrations sampled around the northern section of Ragay Gulf as well as in the vicinity of Burias Pass. Separating these two local peaks was a band of water within central Ragay Gulf with low zooplankton biovolume. This pattern remained almost the same for the months of January to March (Figures 17c and 17d) except for the significant increase in zooplankton concentrations throughout the basin. In both cases, Burias Pass and northern Ragay Gulf consistently exhibited the most dense zooplankton concentrations.

The spatial distribution of zooplankton during the month of May (Figure 17e) showed intense concentrations in the northern Ragay Gulf section and slightly less so, but with a wider areal coverage, in Burias Pass. The deeper, central section of Ragay Gulf showed thinning out of zooplankton concentration. This general reduction in the concentration of zooplankton in the water becomes even more widespread in the succeeding months (Figure 17f and 17g). Except for the large pocket of dense zooplankton laden waters in northern Ragay Gulf, the zooplankton density of the whole basin dropped significantly during the rainy month of July. The pattern for September is almost the same, although it seems that at this point, recovery of the zooplankton population was already underway.

In general, the greatest concentration of zooplankton can be found most consistently in the northern section of Ragay Gulf while the least can be found in the deeper, central section of the Ragay Basin. Burias Pass also exhibited large zooplankton concentrations but not throughout the year and with a slightly smaller magnitude than northern Ragay Gulf. Seasonality of zooplankton abundance was also evident, i.e., highest concentrations were found (for both northern Ragay Gulf and Burias Pass) during the warm summer months of March and May and also during the month of January, 1982 while low concentrations were observed during the rainy season.

The underlying mechanism for this zooplankton population cycle looks similar to those occurring in the mid-latitudes (Valiela, 1984; Raymont, 1980) and can be explained in conjunction with the observed physico-chemical processes that took place in the basin during different times of the year. The cool, dry northeast monsoon winds resulted in the intense mixing of the basin waters (as shown earlier by the dissipation of thermal and salinity stratification) which enabled the system to recycle the nutrients that have settled to the bottom. However, the mixing process itself not only increased water turbidity, (hence, significantly lowering the amount of light able to penetrate the water column), but it also decreased the time phytoplankters can stay above the compensation depth (Sverdrup, 1953). This resulted in low primary production and the observed depression in zooplankton concentration throughout the basin.

With the approach of summer, the waters calm down, the suspended materials in the water settles out allowing more light to enter, and as a consequence, phytoplankton blooms became frequent. This enabled the zooplankton biomass to increase rapidly as more food became available and physical stress related to water turbulence was minimized (Raymont, 1980; Tait, 1968). However, with increasing (thermal) stratification, nutrient replenishment is reduced resulting in its eventual depletion and the corresponding collapse of the phytoplankton and zooplankton populations (Valiela, 1984; Sverdrup, 1953). The rainy southwest monsoon season further increases the stability of the water column thereby making the situation worse for the primary producers and, subsequently, to organisms higher in the food web. Although freshwater runoffs from land also bring some nutrients to the system (San Diego, 1985), they are usually localized and can be availed only by euryhaline or brackishwater species (e.g., family Mullidae). This may explain the presence of high zooplankton concentrations in northern Ragay Gulf, just a little distance off Vinas River, during the rainy season.

IMPLICATIONS FOR CONSERVATION AND RESEARCH:

Status of the Fishery:

The rapid increase in Philippine population during the latter half of this century created a large market demand for fish and other fishery products. As a consequence, the domestic fishing industry rapidly modernized (beginning in the 1960's and continued on to the 1970's), initially through the adoption of motor power which later led to the massive build-up of modern commercial trawlers and purse seiners (Jamir, 1989). Typical of most open-access fisheries, these developments resulted in the eventual depletion of major commercial fish stocks in most of the traditional fishing grounds of the country (Smith, et al., 1980) including the Ragay Gulf basin (J. Ingles, pers. comm.). The increasing number of idle commercial fishing vessels as well as fishing companies going bankrupt are good indicators that the fishery has already gone beyond the level maximum sustainable yield (MSY) (Taitenberg, 1988).

Some Major Issues and Concerns:

From the stand point of absolute numbers, optimum economic rent, and sustainable yields, fishery biologists, resource economists, and population dynamicists are keenly aware of and worried about the overfishing problems confronting most tropical regions of the world, e.g., Pauly (1979; 1982), Pauly and Murphy (1982). During the rapid growth stage of the fishing industry, much emphases were placed by Philippine fishery scientists and technologists on exploratory fishing and development of more efficient and effective fishing gears and methods for exploiting the fishery. There was little or no concern at all for the rational management or conservation of the fishery resources. Numerous fishery development programs were initiated by the Philippine government with only one major purpose -- increase the present level of fish production (see Smith, et al., 1980). Concern and interest in stock assessment and fishery management started only in the late 1970's (and at present is the "big thing" in most Philippine fishery institutions) as problems about overfishing started to surface. As a result, government fishery agencies shifted from production-oriented to fishery management-oriented programs and policies in the 1980's (see Samson, 1985).

While fish population dynamics is the current "fad" in the Philippines as well as in other Southeast Asian nations as well, there is very little interest or even awareness among local fishery scientists of a much bigger problem, i.e., those that relate to the loss of genetic diversity. This is an important issue because fish usually exhibit high levels of phenotypic variations within populations but posses lower heritabilities which indicate that they are highly affected by environmental fluctuation, e.g., pollution, plankton failure, typhoons, etc. (Allendorf, et al., 1987). Hence, while fish population dynamicists will generally be satisfied knowing that a large population of a given species exist, albeit of low genetic diversity, population geneticists will not since they know that, given the uncertainty and fluctuation of environmental conditions, the future, long-term sustainability and survival of this genetically homogenous population is low compared to a similar population with a more diverse genetic composition.

Often, what is considered as rational fishery management policies may actually turn out to be detrimental to the fishery from the genetic point of view. Nelson and Soule (1987) gave examples where loss of genetic diversity were often done due to "Partial

Knowledge and Good Intentions" rather than "Ignorance and Greed." Loss of stocks have resulted from attempts to fish at the MSY (or maximum economic rent, MEY), a simplistic management concept which failed to take into account fluctuations in recruitment and differences between stock components. They also pointed out that, *size limitations often encourage a reduction in the number of breeding year classes to a destabilizing one or two and produce powerful size-selective forces with as yet unknown consequences. And well-intentioned but injudicious temporal closures may produce selective pressures on sex ratio or on the timing of the breeding season, again with unknown consequences.*

Minimum Viable Populations and Minimum Area Requirements:

From the genetic point of view, the main idea for setting aside some land or water areas as sanctuaries is to enable a minimum number of individuals to survive and in the process, preserve the genetic diversity of the population. The minimum viable population (MVP) concept emerged in recognition of the fact that extinction is a stochastic phenomena and that the probability of survival of populations can be evaluated only within a given time frame and some objective level of security (Schaffer, 1987). Although there is no universal concensus on the standard meaning of MVP, scientists generally agree that it refers to the levels of genetic diversity necessary to maintain adaptation and evolution. Schaffer (1987) listed four classes of uncertainties that affect the dynamics of populations (and likelihood of extinction), i.e., demographic uncertainty, environmental uncertainty, natural catastrophes, and genetic uncertainty. These factors not only interact with one another, they also increase in importance with decreasing population size. However, for single, isolated, unsubdivided population, genetic considerations will not always, perhaps not often, set the lower limit to acceptable population size (Shaffer, 1987).

The relationship between the first three classes of uncertainties is illustrated in Figure 18. Several observations can be made regarding this model (Shaffer, 1987):

(1) Under the effects of demographic uncertainty, average persistence times increases geometrically with increasing population size and is a hazard only for relatively small populations (on the order of 10s to 100s).

(2) Under the effects of environmental uncertainty, persistence times increases linearly with increases in population size and there is no population size that, once reached, ensures a high level of long-term security. To achieve very long retention of species, depending on the degree of environmental variability and population growth rate, numerous population or very large population sizes (100s to 1,000,000s) are needed.

(3) Under the effects of catastrophic uncertainty, persistence times increase only with the natural logarithm of population size and depends not only on the population growth rate but also on the severity and frequency of catastrophes. This curve points to the inevitability of extinction.

Although there are only few data on life histories and demographic parameters, Belovsky (1987) points out that there is a general relationship between size of an individual organism and certain population parameters, e.g., density and population growth rate. Figure 19 shows Belovsky's initial estimates of MVP size and minimum area requirements (MAR) for various body sizes ranges of mammals using a 95% probability of persistence for two time frames: 100 and 1,000 years. This approach is worth pursuing in greater detail and for other major taxa, especially with respect to accurate measures of environmentally-induced variation in population growth rates (Schaffer, 1987).

Assumming that these "ball park" figures can be applied to the common size range of roundscads, *Decapterus macrosoma* (200 grams) found in Ragay Gulf, one gets for the 100 year persistence, an MVP size of about 100,000 individuals and an MAR ranging from 10 km^2 to 1,000 $km.^2$ The latter amounts to a maximum of 22% of the total water surface area of the basin. However, optimal environments are patchy in nature and as a result, a population distributed over such an environment will also be patchy (Gilpin, 1987). In island biogeography theory, a collection or sets of these local populations are called "metapopulation" (Gilpin, 1987). Based on the previous discussions, two major areas in the Ragay Gulf Basin were identified as potential breeding/nursery grounds for most fishes: Burias Pass and the shallow portions of northern Ragay Gulf. Also, two peak spawning season were exhibited in those two areas, mainly during the summer months and during the months of November to December. Both seems to be affected by the monsoonal nature of the Philippine climate system. These "spawning/nursery" areas correspond to about 1,500 sq. km., or roughly 30% of the total water surface area. Of this patch, about 65% needs to be set apart as marine sanctuaries -- quite a sizeable and potentially controversial amount considering that most productive commercial as well as subsistence fishing activities are also being conducted in the same place.

However, even assumming that the above solution is feasible and enforceable, it is not necessary to close off a large portion of these productive fishing grounds in order to protect the fishery for future Filipino generations. If the object is to enable as many sub-populations or breeding classes to be represented in the metapopulation (thus achieve greater genetic diversity), then, a more viable alternative would be to declare the whole area or sub-areas closed to fishing only at intermittent periods of time. There are several combinations and ways of doing this, e.g.,

(1) Permanently closed season, variable protected areas. Selection of the areas to be closed may be achieved by subdividing the spawning/nursery area into smaller sized grids (e.g., 10 km x 10 km), each with an identifying number. Selection of the grids that will be subject to closure for the given month or season can then be made using a random number generator or table. Due to ecological reasons a random, stratified (by depth) "sample" is prefered over a simple random "sample." How the area will be subdivided will depend on the local conditions and consensus between planners and representatives of the fishing communities affected.

(2) Permanent protected areas, variable closed seasons. The closed season schedule can also be selected using the same procedure. Because of the continous, year-round

spawning habits of most tropical fishes, it may be necessary to have periodic closed and open seasons spread throughout the year. However, known peak spawning months should have longer average closed season times than the rest in order to protect pulse spawners.

(3) A combination of (1) and (2) above depending on the situation.

Because of the fluctuations in the timing and intensity of the monsoons, there is also a corresponding irregularity in the start or end of the spawning seasons. To expedite the scheduling process outlined above, it may be necessary to establish a local fish/plankton monitoring station(s) with personnel assigned to gather data, analyze trends, and give timely advise to whoever is responsible.

The above scenario implies that, if we want to effectively tackle the growing problems of fisheries management and rural development, traditional educational and research institutions should now shift its efforts towards the development of awareness and expertise in the fields of population genetics, rural sociology, and natural resource management. This means that, contrary to World Bank (1976) recommendations, fishery education and training should veer away from the specialist-technocentric mode that is characteristic of present day fishery institutions and curricula. Instead, it should move towards a broader, more open and inter-disciplinary mode that emphasizes the close inter-relationship between the social sciences, technology, management, and education.

SUMMARY/CONCLUSION:

From the geographic distribution and concentration of zooplankton, the time and place of spawning and feeding of fishes can be satisfactorily determined (MacCall, 1990; Lasker, 1978; Cushing, 1969; Tait, 1968) The above findings indicate that the shallow waters of northern Ragay Gulf is the major spawning and feeding ground for most fishes in the area with Burias Pass acting in a secondary role. Summer seems to be the peak season for spawning in the Ragay Gulf Basin. Except for the goat fishes (family Mullidae), the rainy, southwest monsoon season seems to be the least productive time of the year with respect to zooplankton (and also fish) concentration.

Based on the above findings, a general mechanism for the delineation, establishment, and operation of a fish sanctuary(ies) was proposed with the primary objective of conserving genetic diversity. Because of the large estimated area that is needed for conservation purposes, a variable closed season/permanent sanctuary, permanent closed season/variable santuary, or their combination was proposed depending on the situation and the consensus of the fishery planners, managers, fishermen, and other affected groups. This may be a more promising and workable solution since these same areas, identified in this research as primary and secondary fish spawning/nursery grounds, are also the prime fishing grounds of the commercial and municipal fishermen as well.

The need to re-orient the fishery education policies and programs of the country was also emphasized. A more open, wider based, and inter-disciplinary educational system is advocated in lieu of the present day technocentric, specialist education.

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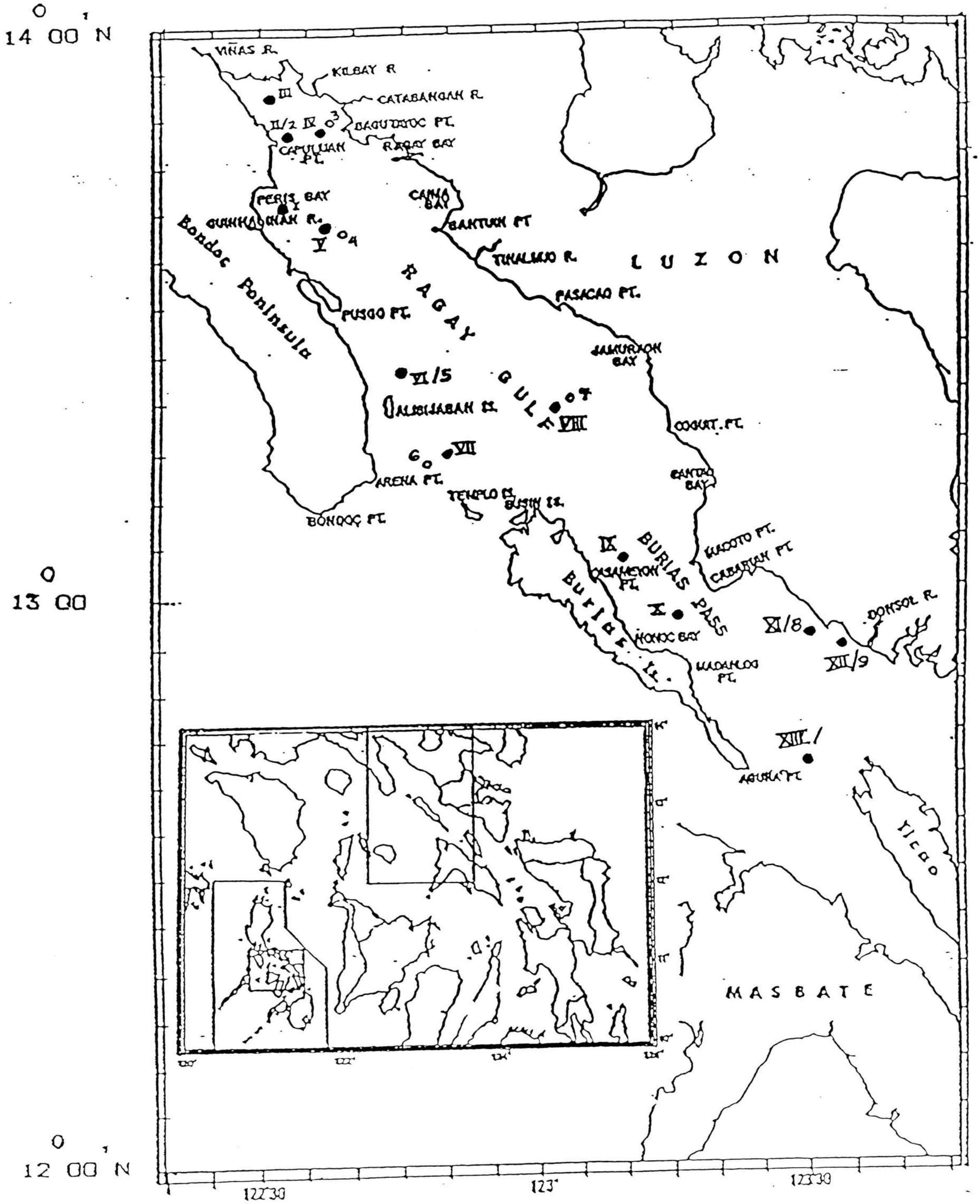


Figure 1. Geographic location of the survey areas. o 4 Ichthyoplankton stations, ● VI Oceanographic Stations.

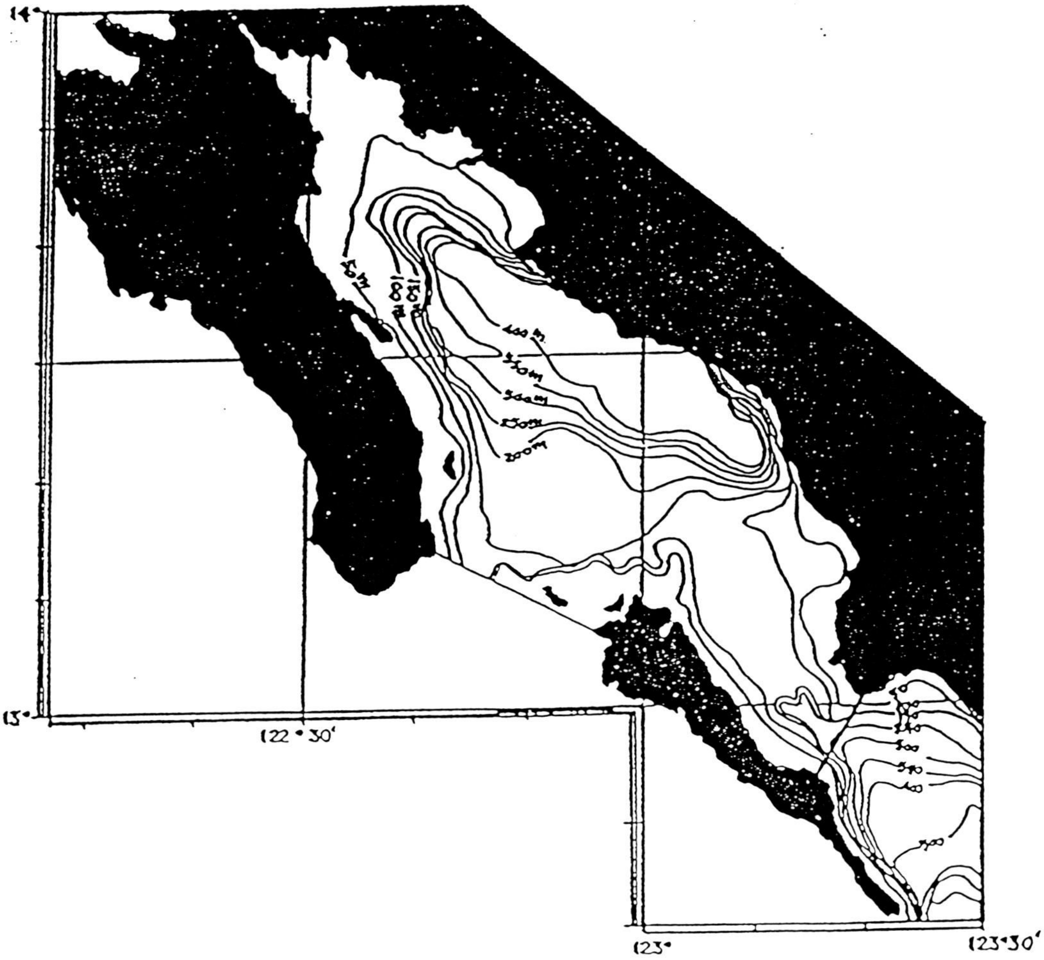


Figure 2. Updated bathymetric map of Ragay Gulf and Burias Pass, Philippines; depth are in meters (adapted from Jamir, 1984).

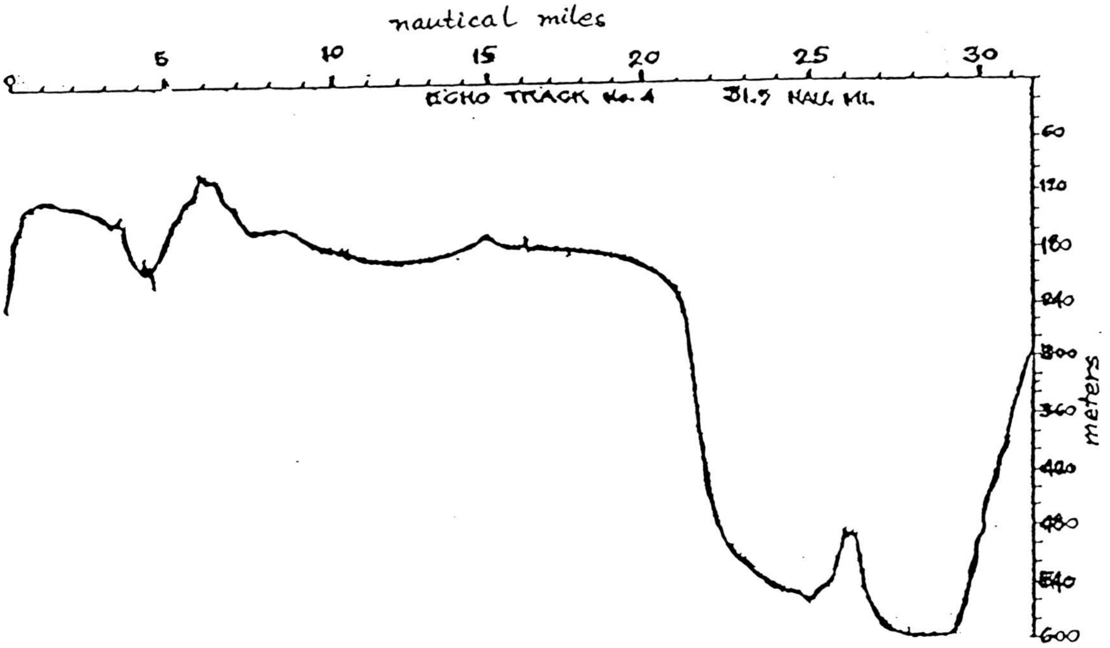


Figure 3. Echo-track no. 4 running northeast to southwest along the mid-section of Ragay Gulf Basin.

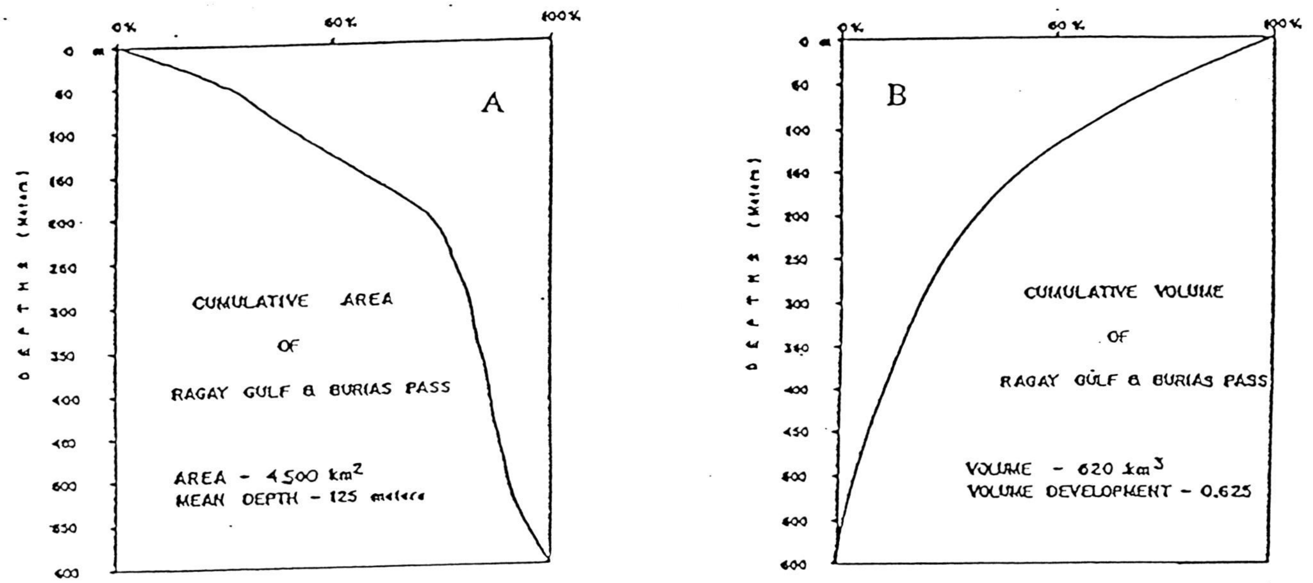


Figure 4. a. Hypsometric curve of area for Ragay Gulf and vicinity,
b. Hypsometric curve of volume for Ragay Gulf and vicinity (adapted from Jamir, 1984).

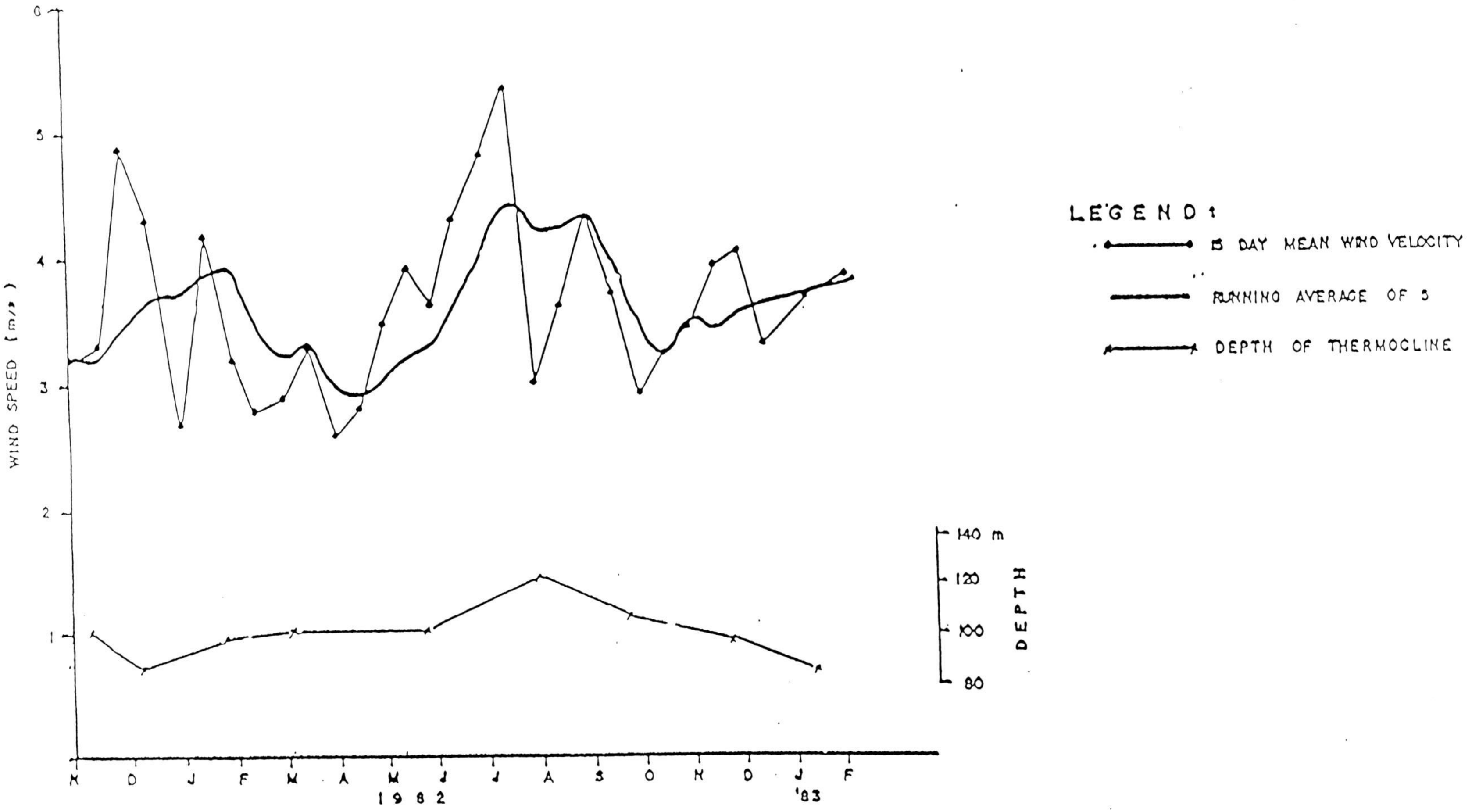


Figure 5. Seasonal variation of wind velocity from November, 1981 to February, 1983 and average depth of the thermocline for Ragay Gulf Basin (adapted from Jamir, 1984).

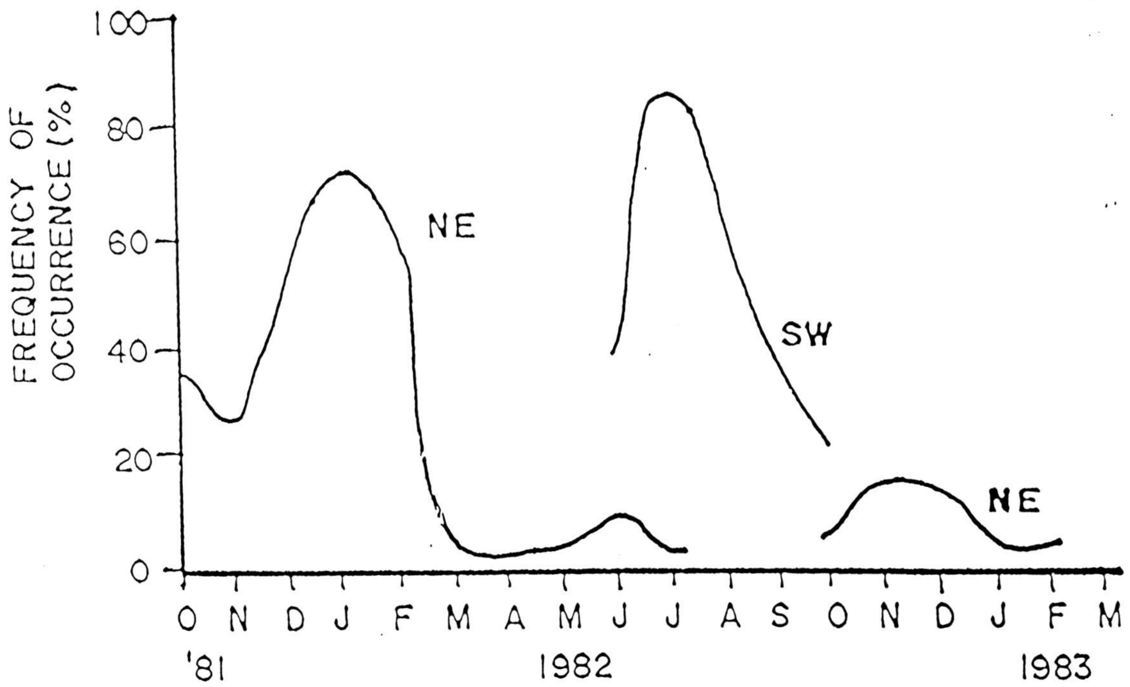


Figure 6. Frequency of occurrence of the northeast and southwest winds in the Ragay Gulf Basin, November, 1981 to February, 1983 (adapted from Jamir, 1984).

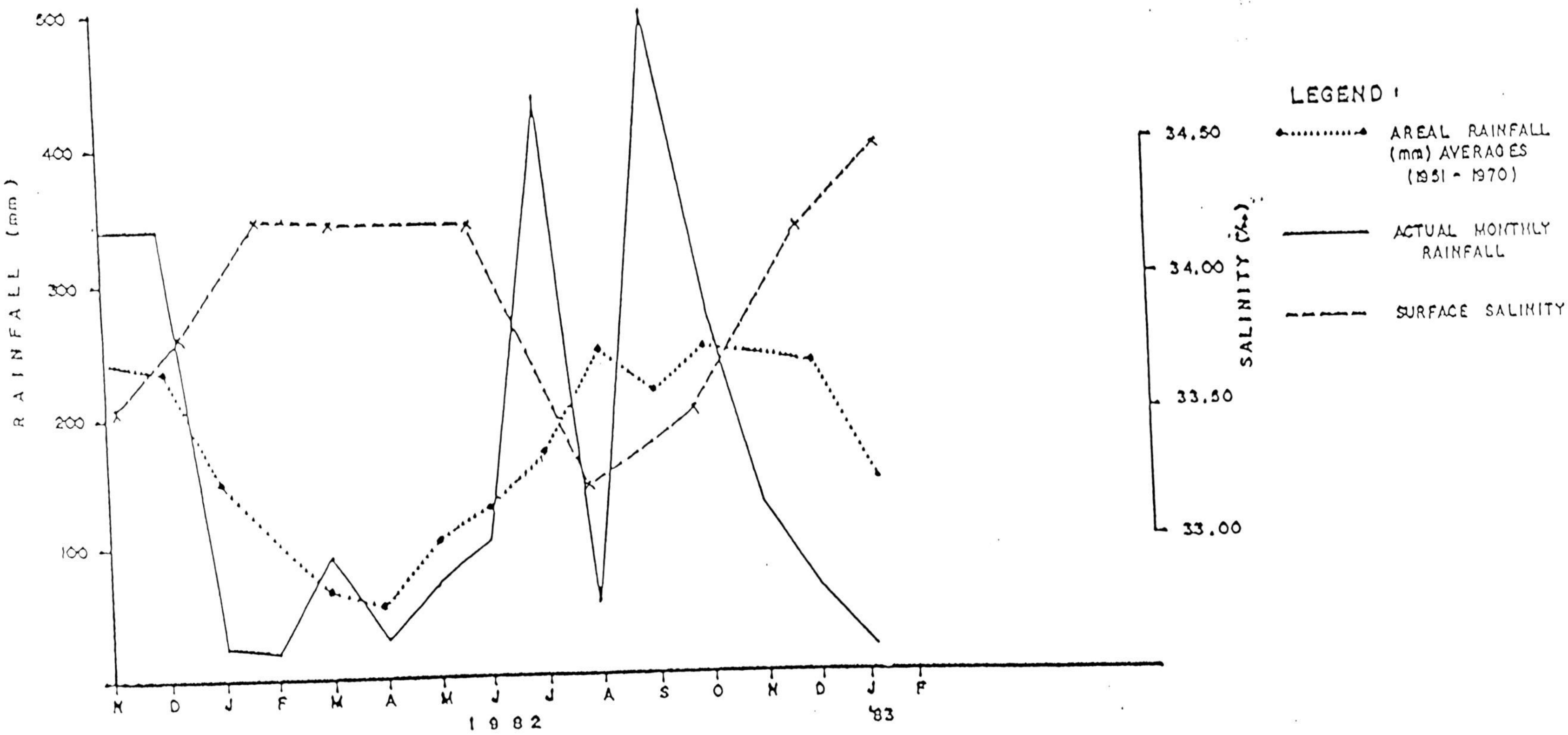


Figure 7. Seasonal variation of precipitation and sea surface salinity in the Ragay Gulf Basin, November, 1981 to February, 1983 (adapted from Jamir, 1984).

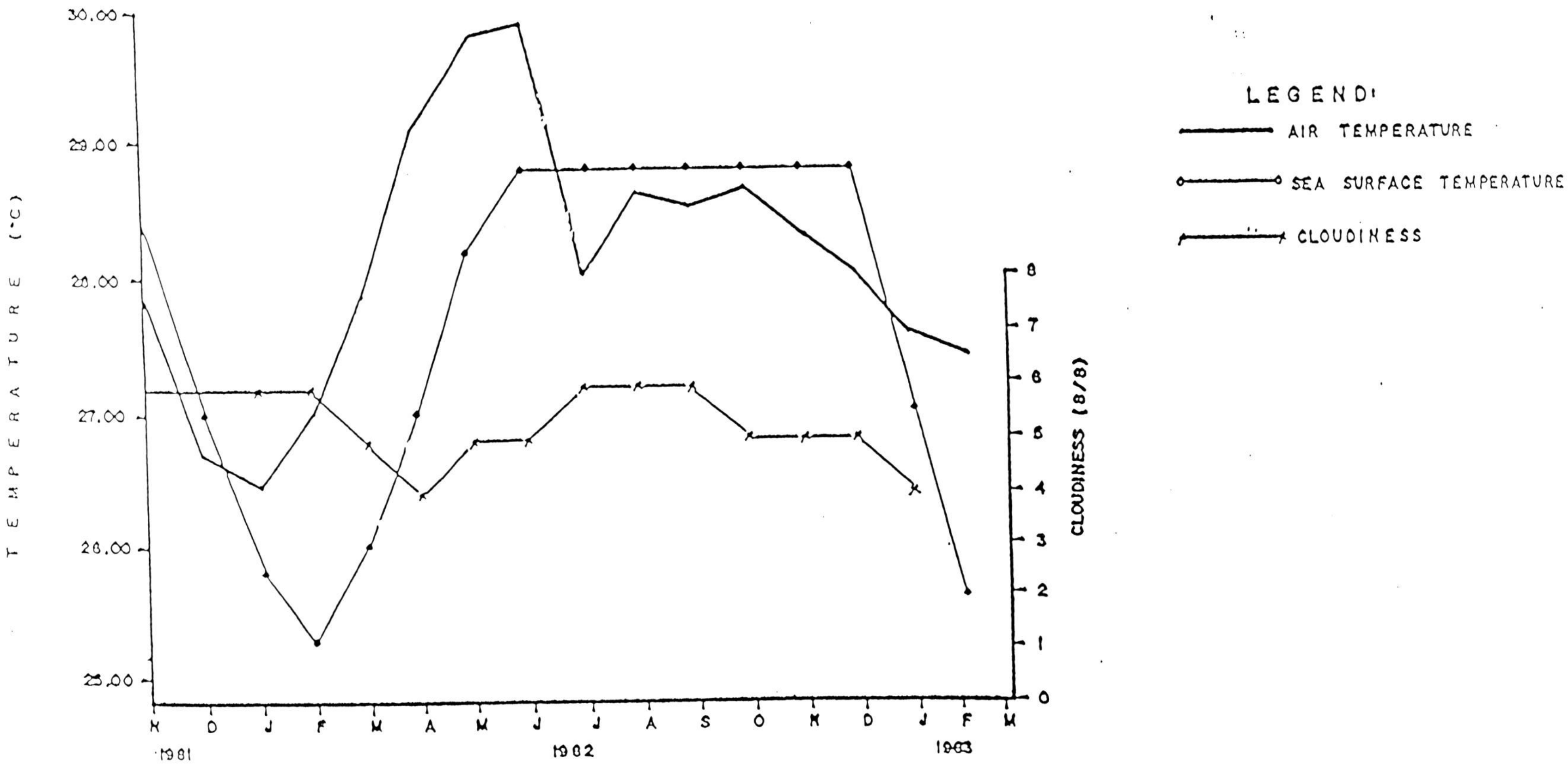
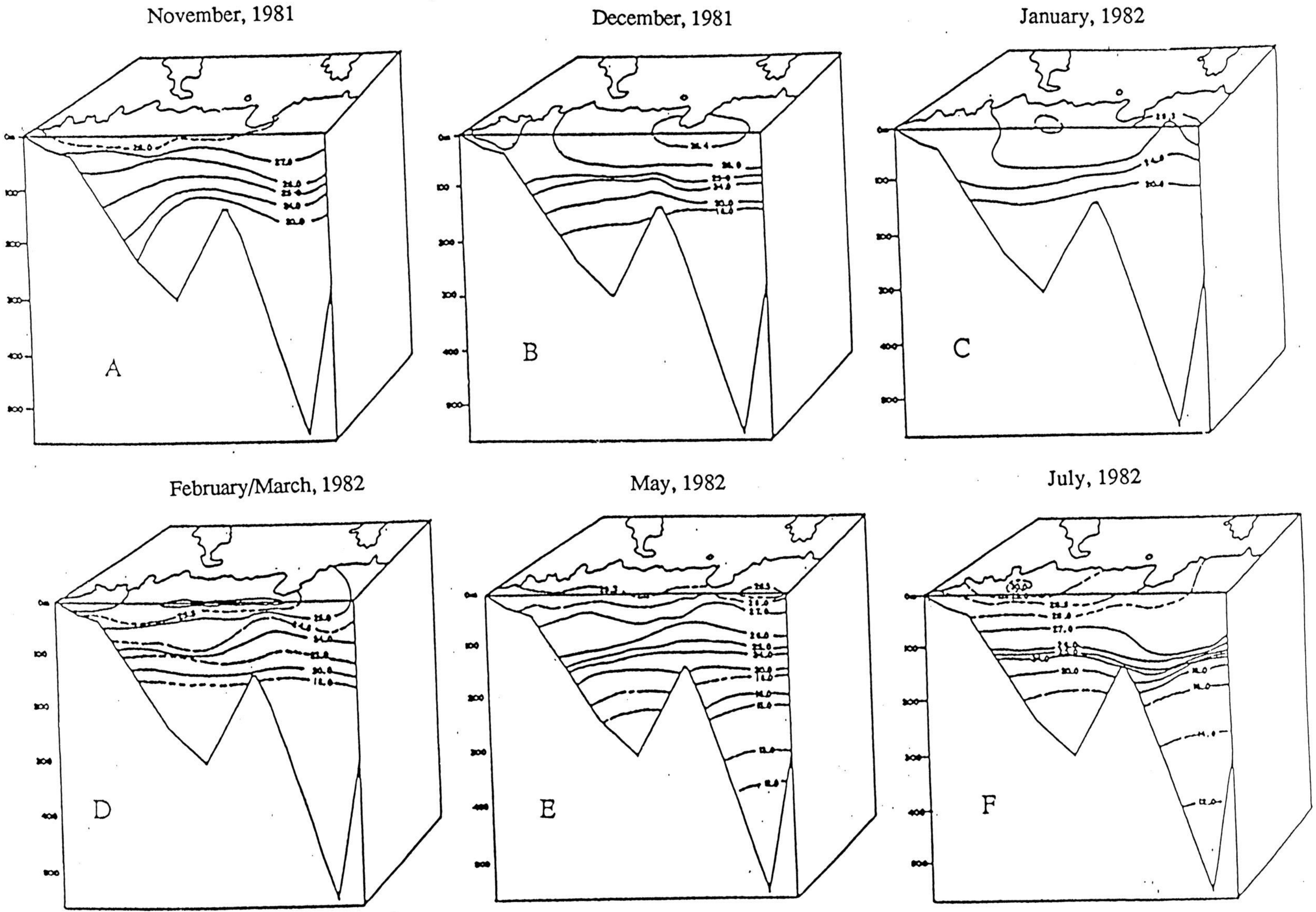


Figure 8. Seasonal variation of air and sea surface temperature and cloudiness in the Ragay Gulf Basin, November, 1981 to February, 1983 (adapted from Jamir, 1984).



November, 1981

December, 1981

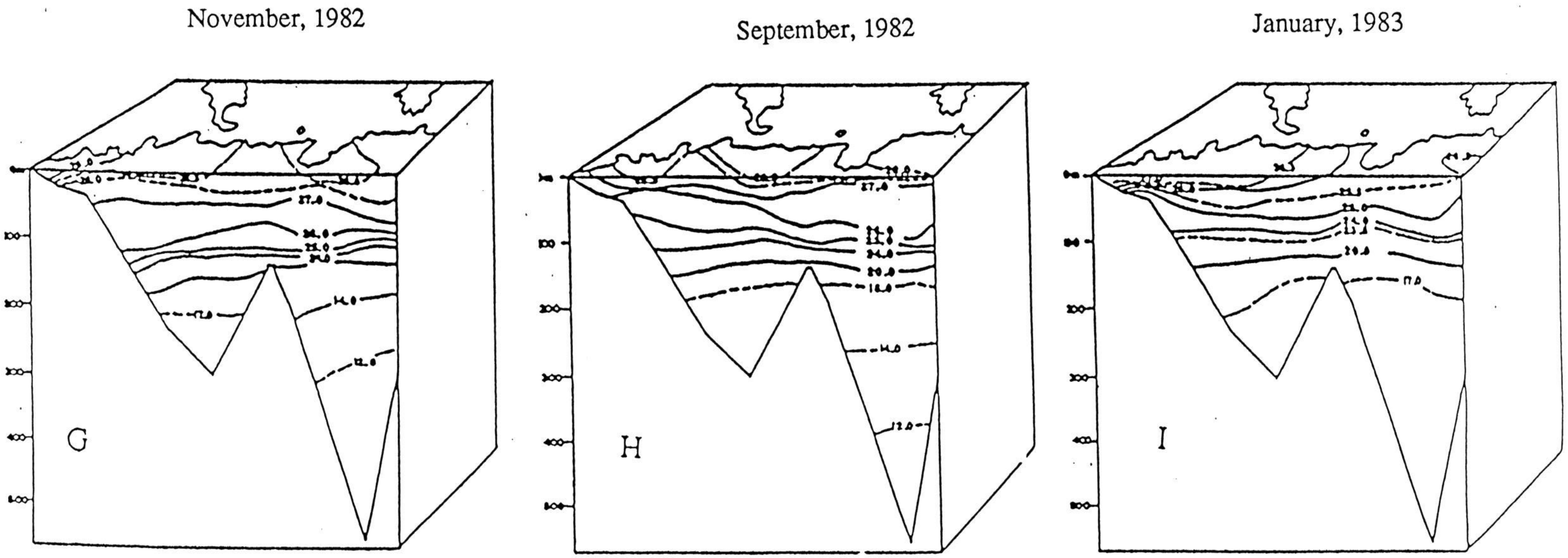
January, 1982

February/March, 1982

May, 1982

July, 1982

Figure 9. Thermal pattern for Ragay Gulf Basin from November, 1981 to January, 1983 (adapted from Jamir, 1984).

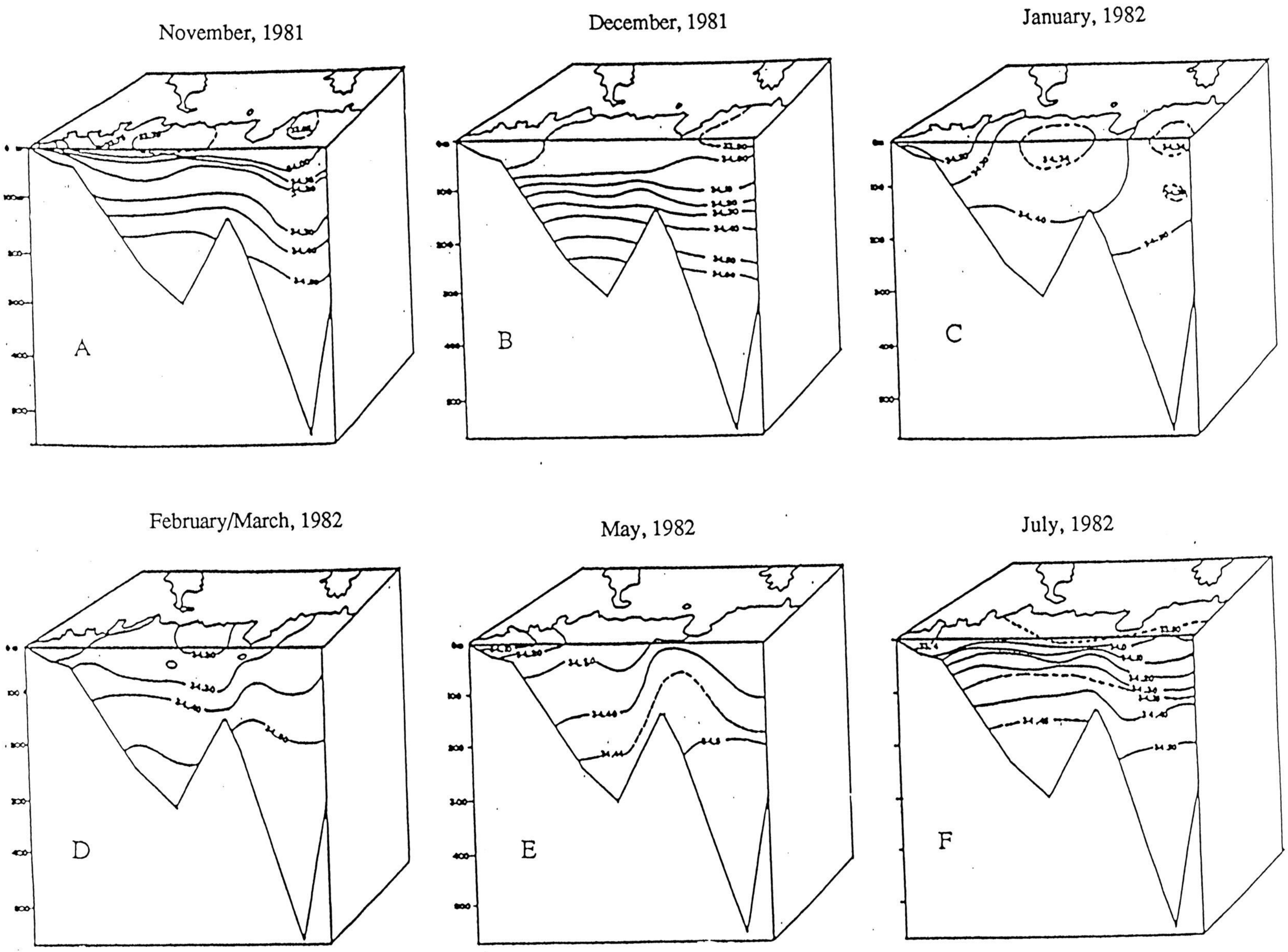


November, 1982

September, 1982

January, 1983

Figure 9. Thermal pattern for Ragay Gulf Basin from November, 1981 to January, 1983 (adapted from Jamir, 1984).


November, 1981

December, 1981

January, 1982

February/March, 1982

May, 1982

July, 1982

Figure 10. Salinity structure of Ragay Gulf Basin from November, 1981 to January, 1983(adapted from Jamir, 1984).

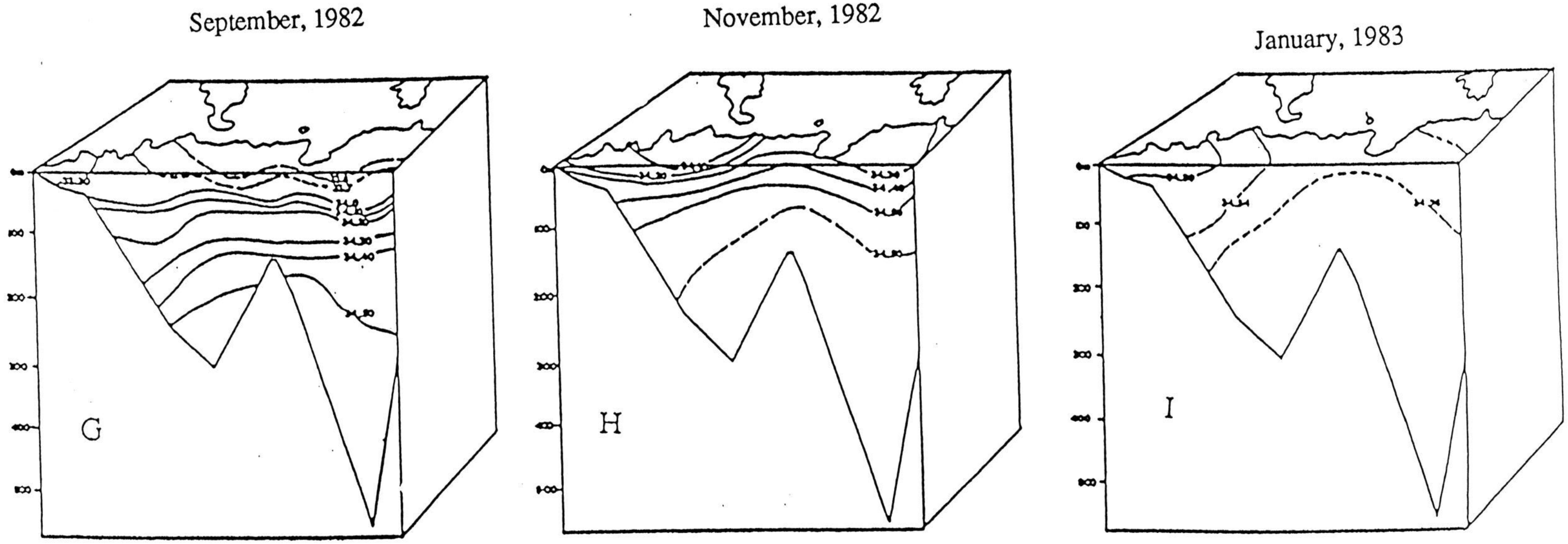
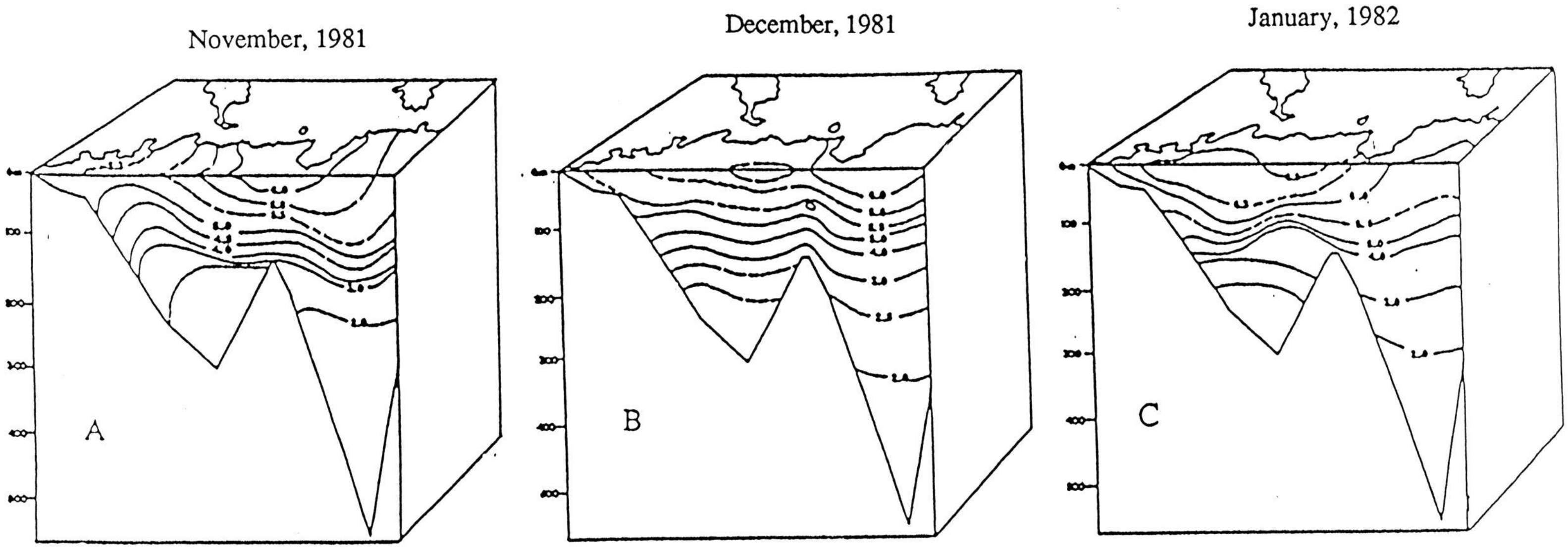
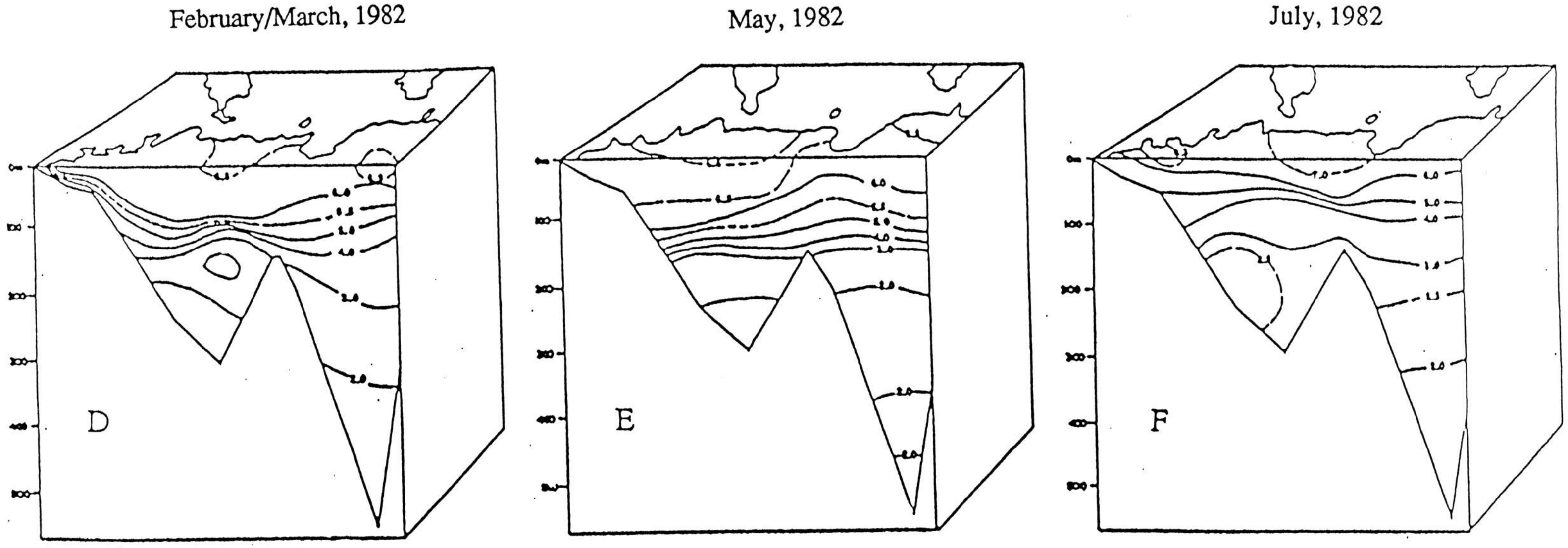


Figure 10. Salinity structure of Ragay Gulf Basin from November, 1981 to January, 1983(adapted from Jamir, 1984).


November, 1981

December, 1981

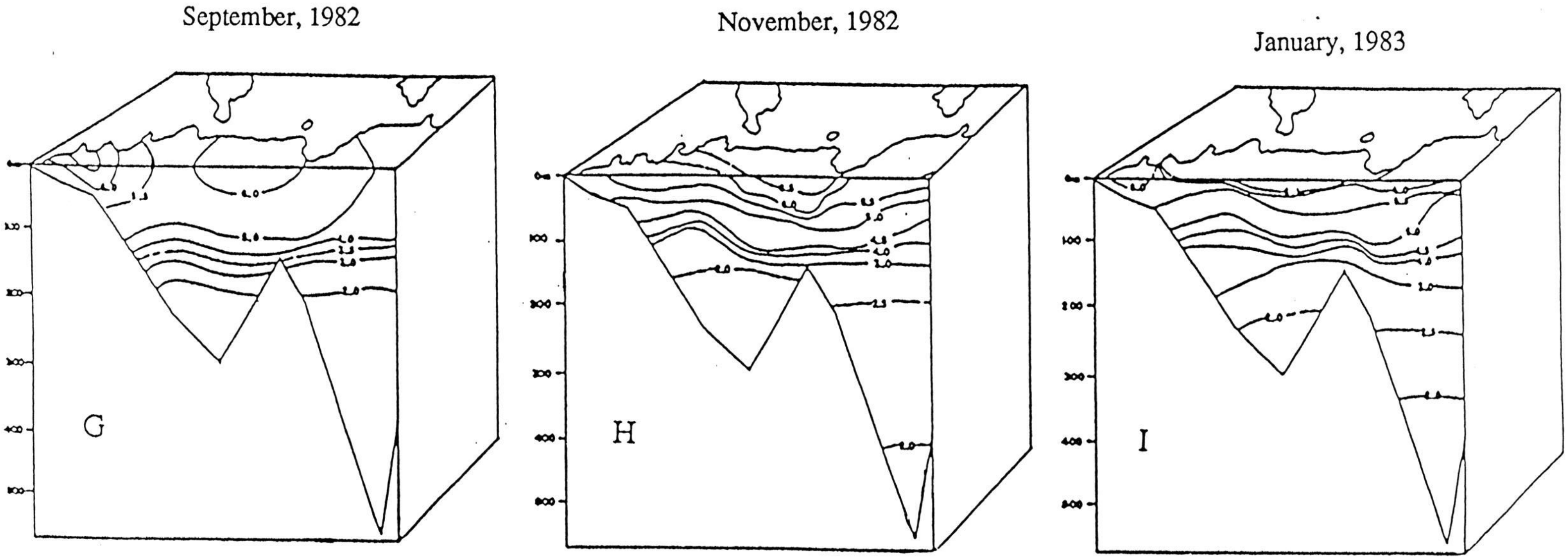
January, 1982


February/March, 1982

May, 1982

July, 1982

Figure 11. Dissolved oxygen concentration pattern of Ragay Gulf Basin from November, 1981 to January, 1983 (adapted from Jamir, 1984).


September, 1982

November, 1982

January, 1983

Figure 11. Dissolved oxygen concentration pattern of Ragay Gulf Basin from November, 1981 to January, 1983 (adapted from Jamir, 1984).

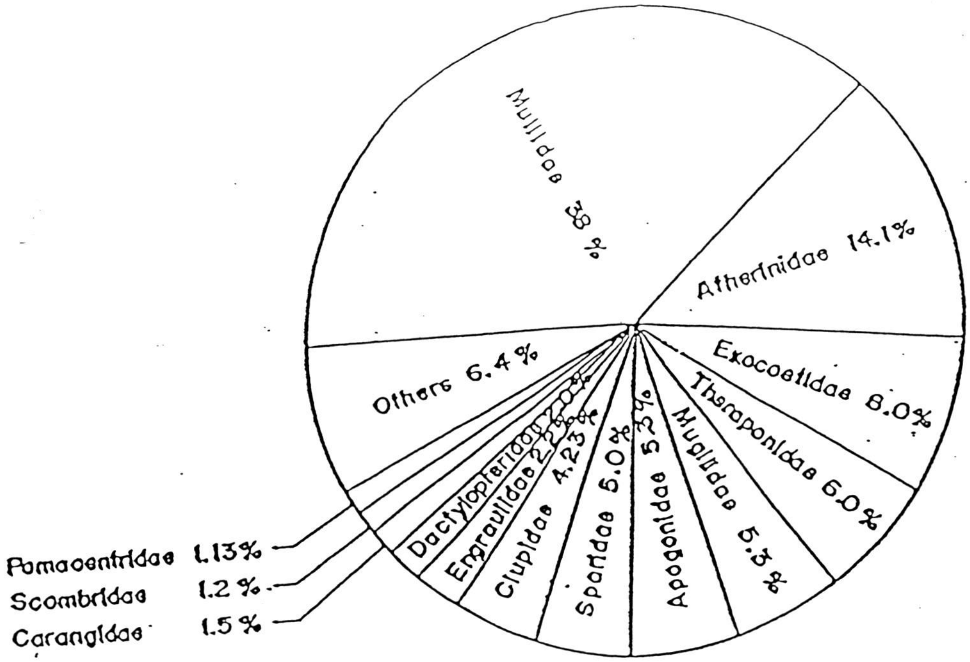


Figure 12. Relative abundance of larval fish families collected by neuston katamaran in Ragay Gulf and adjacent waters, November, 1981 to November, 1982 (adapted from Villoso, 1984).

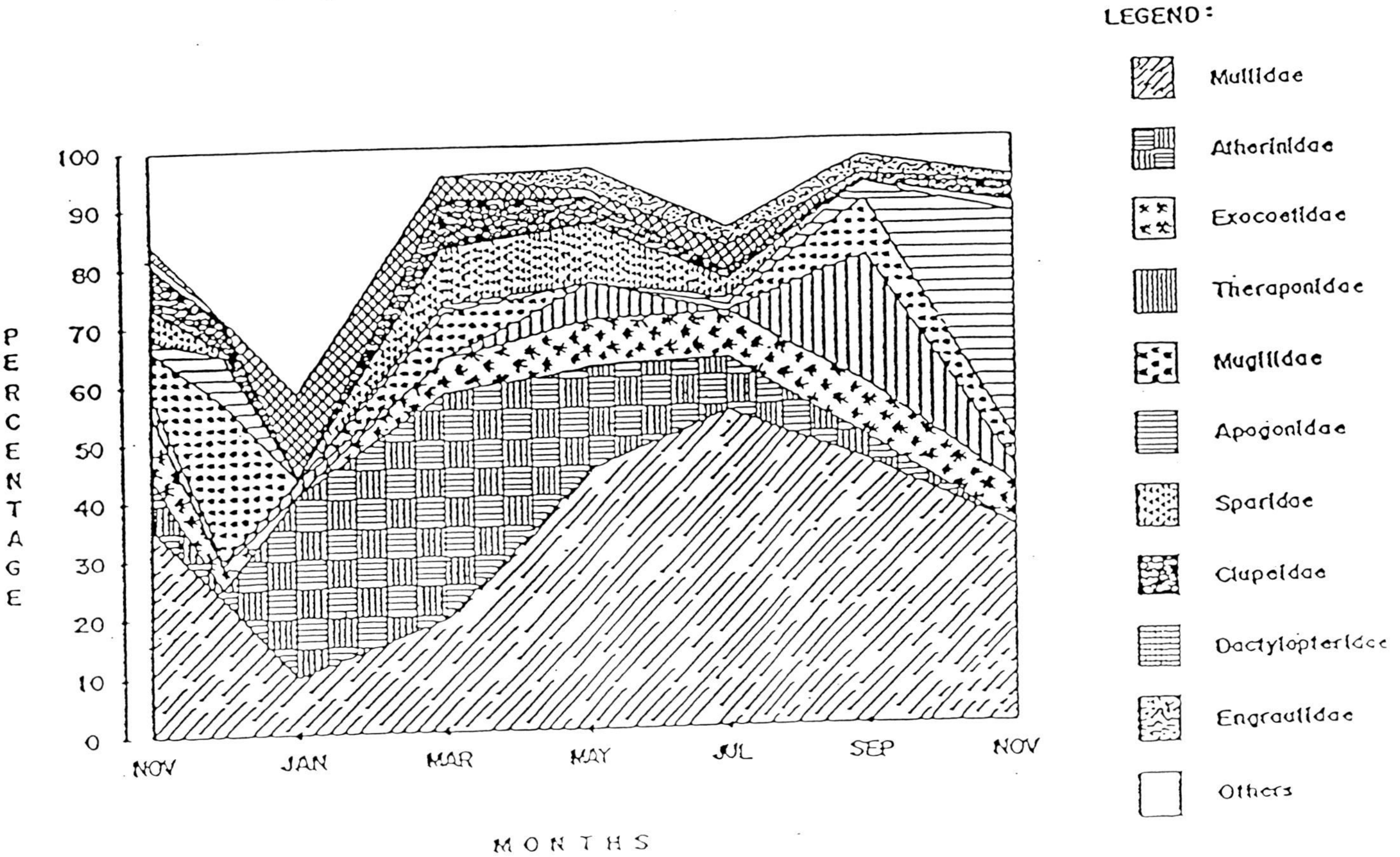


Figure 13. Seasonal fluctuations in the percentage relative share of major families of fish larvae caught by neuston katamaran between 0-10 cm of surface water in Ragay Gulf and adjacent waters from November, 1981 to November, 1983 (adapted from Villoso, 1984).

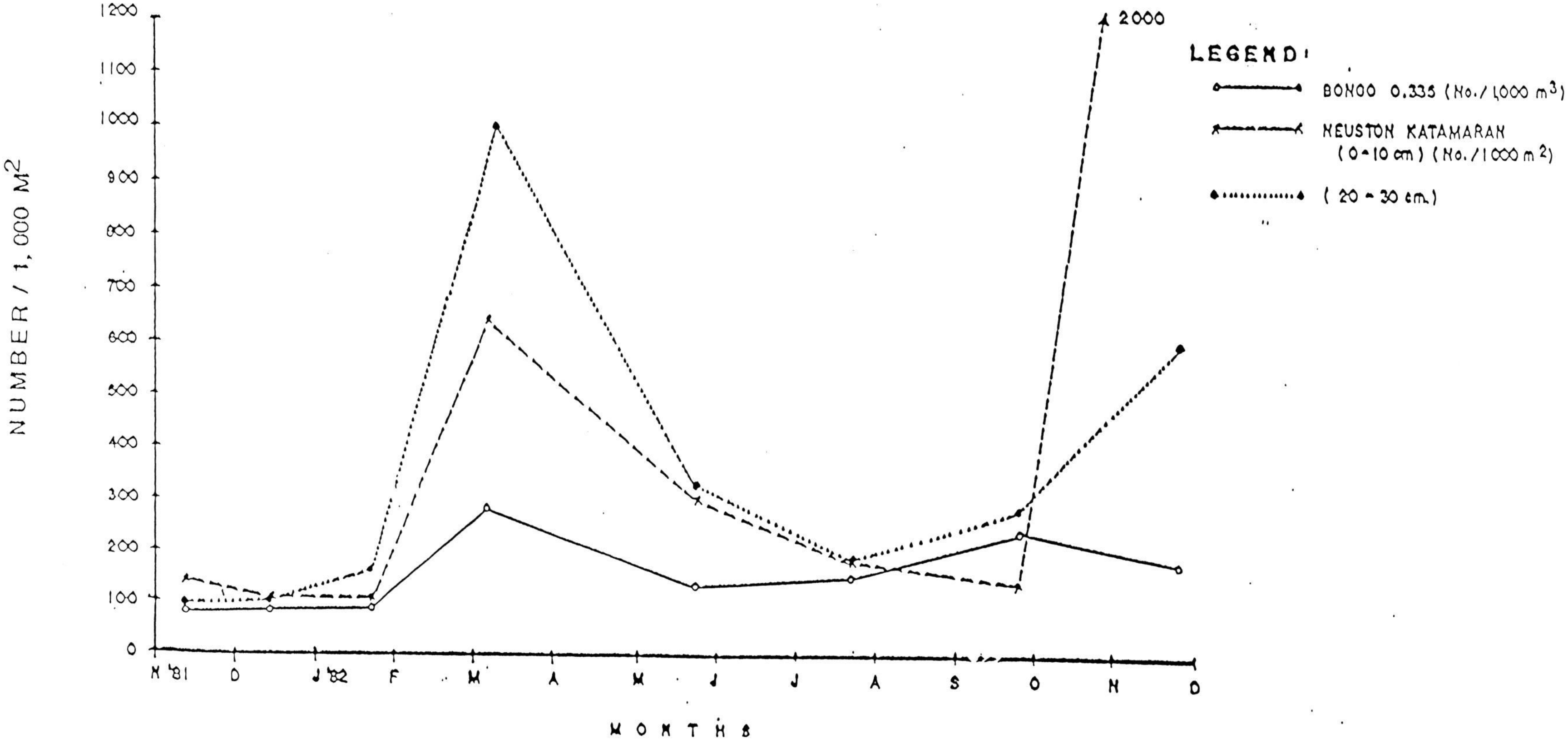


Figure 14. Fish egg abundance per cruise as collected by bongo and neuston katamaran.

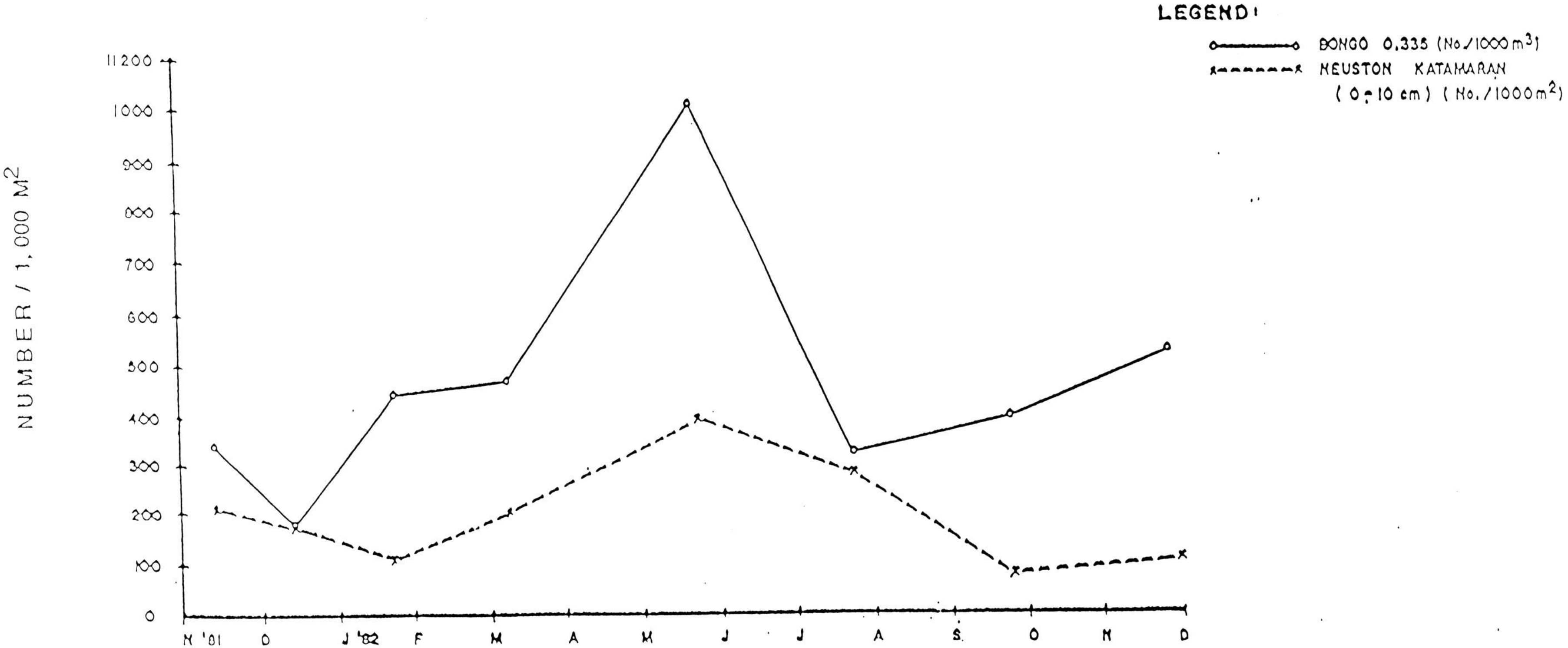


Figure 15. Fish larval abundance per cruise as collected by bongo and neuston katamaran.

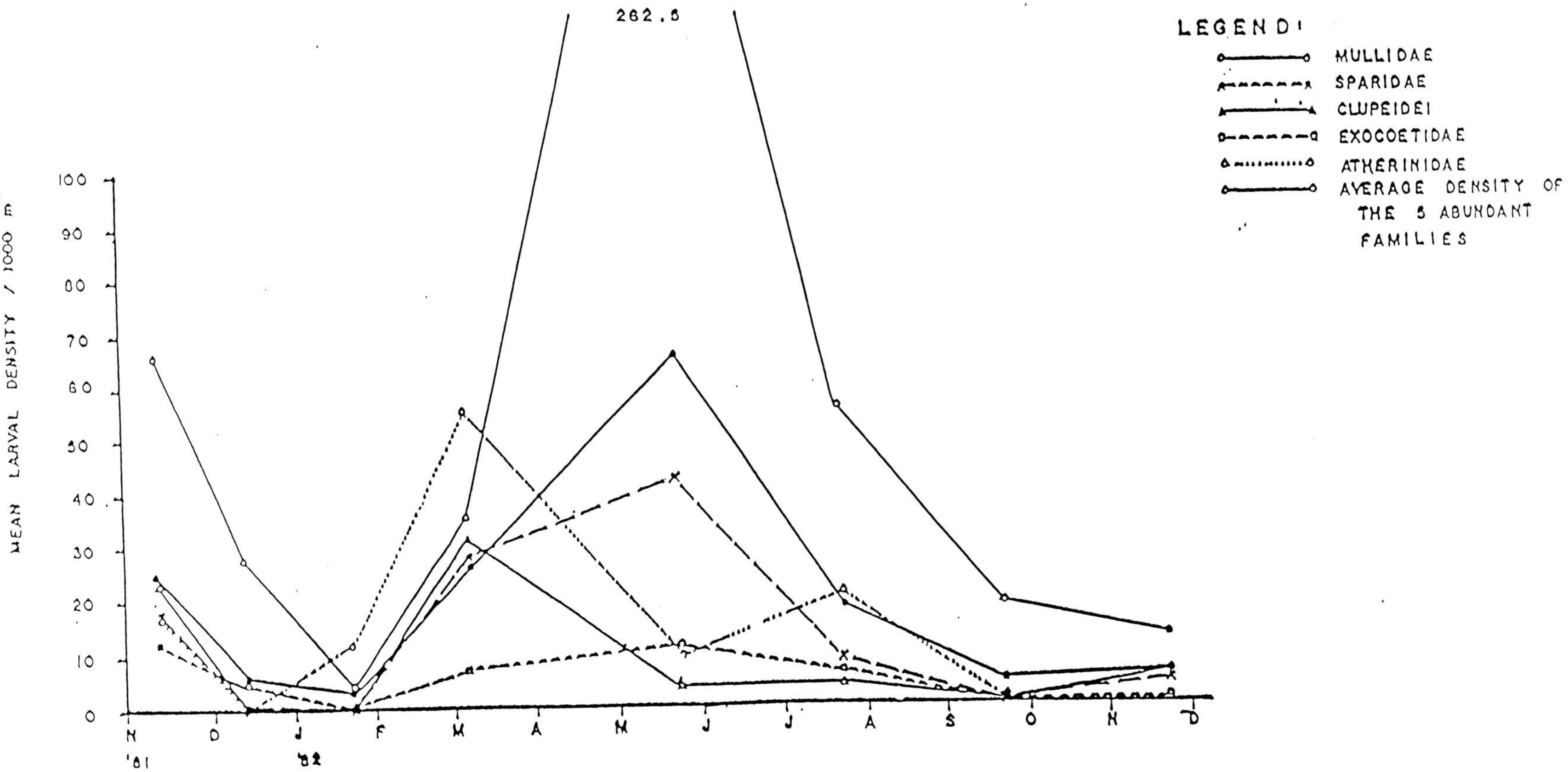


Figure 16. Larval fish density (per 1,000 sq.m.) of the five most abundant fish families in Ragay Gulf and vicinity collected using neuston katamaran (0-10 cm layer).

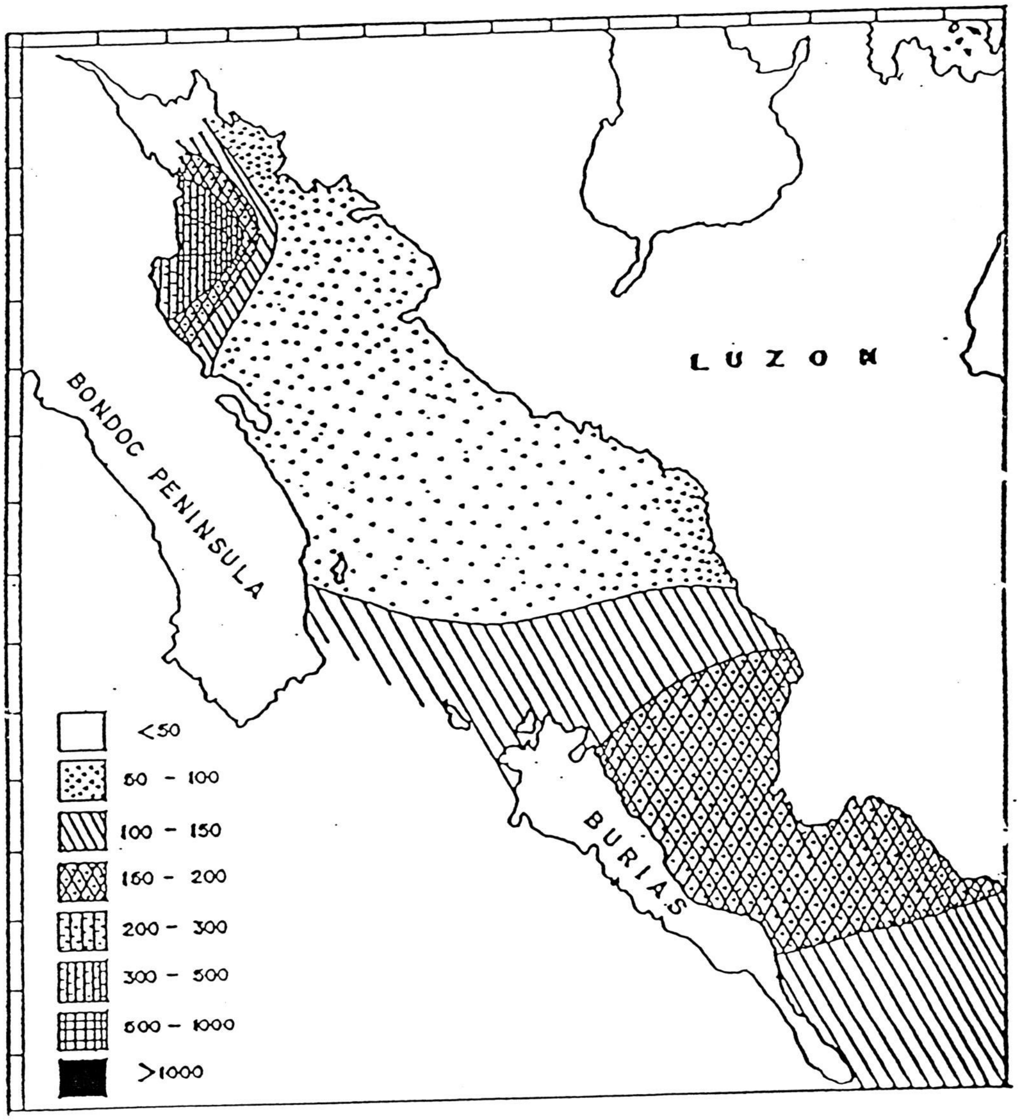


Figure 17a. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (November, 1981).

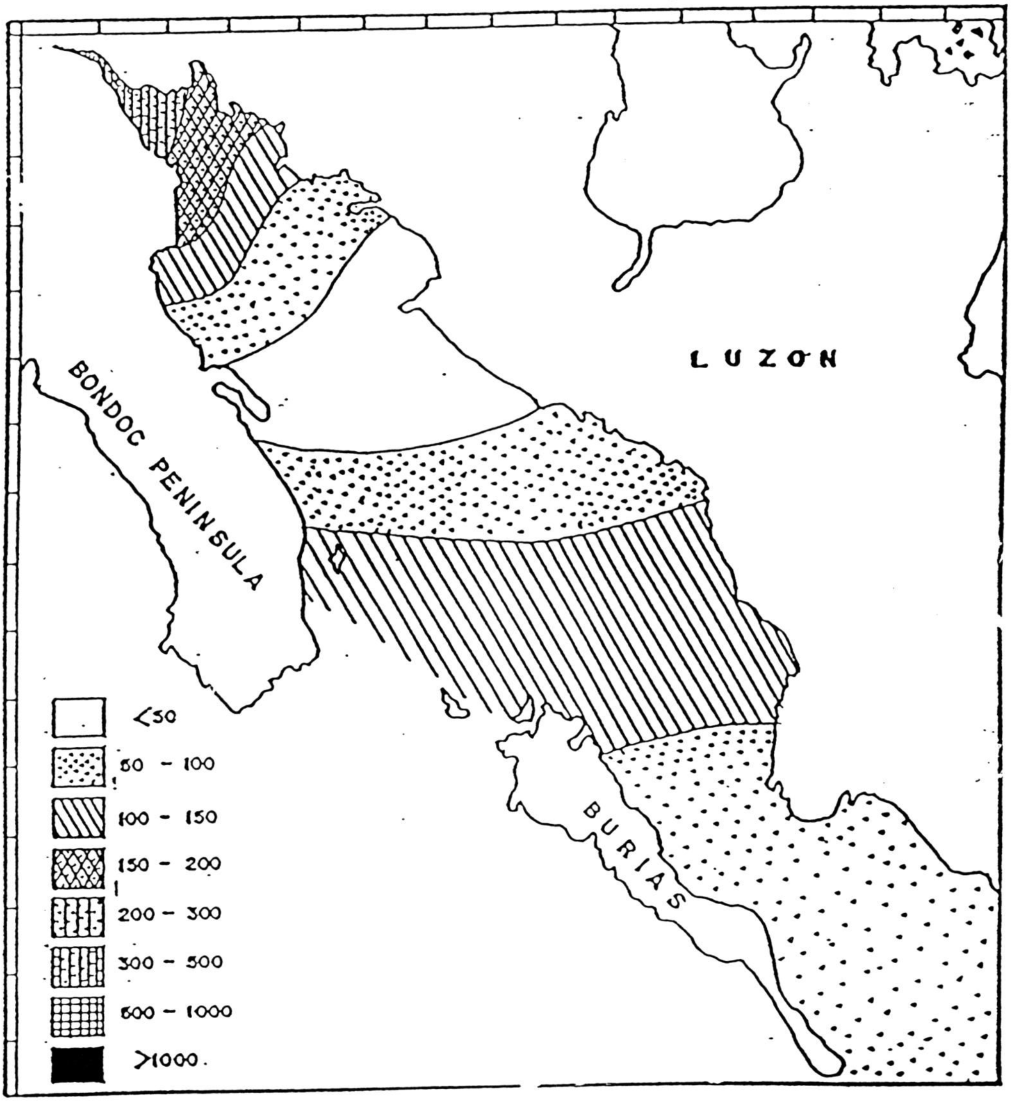


Figure 17b. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (December, 1981).

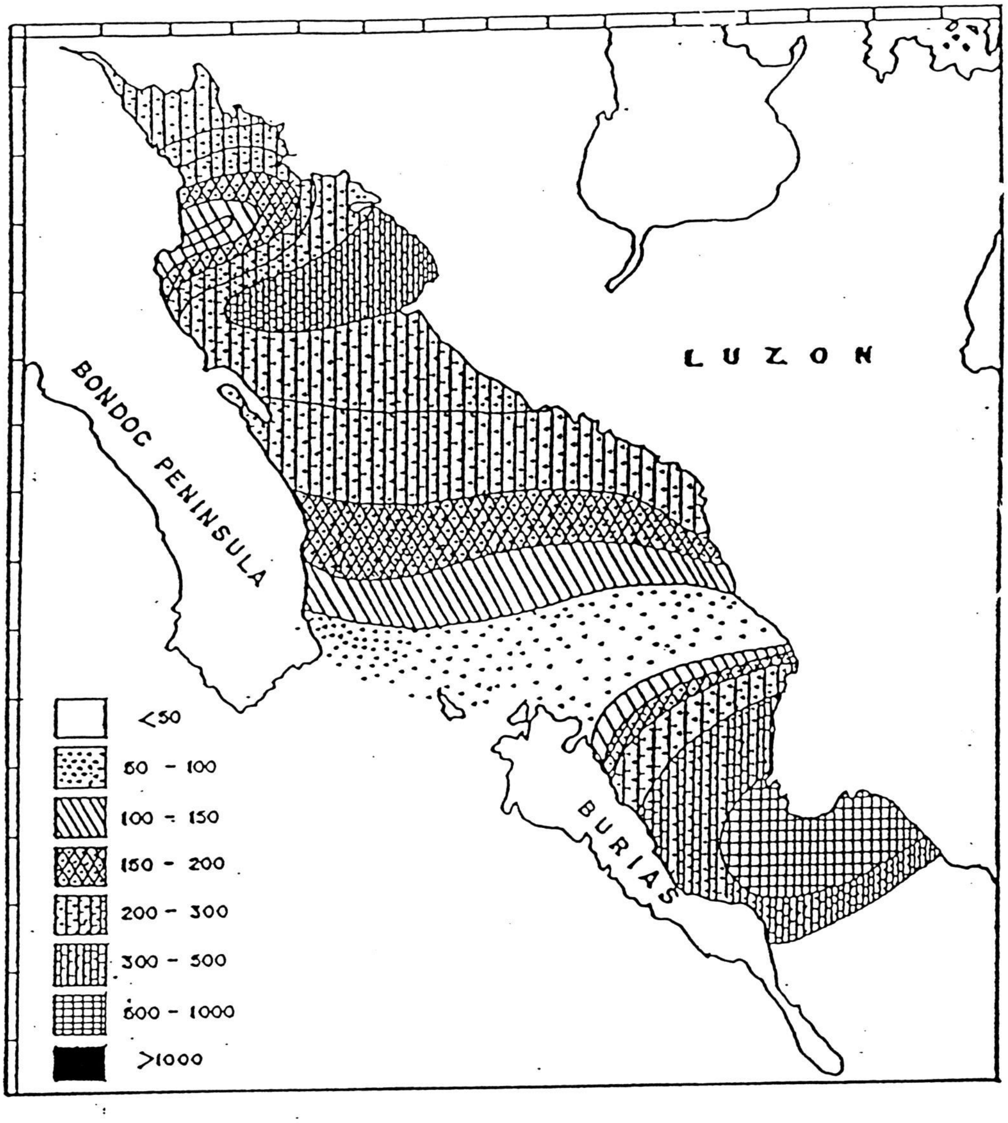


Figure 17c. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (January, 1982).

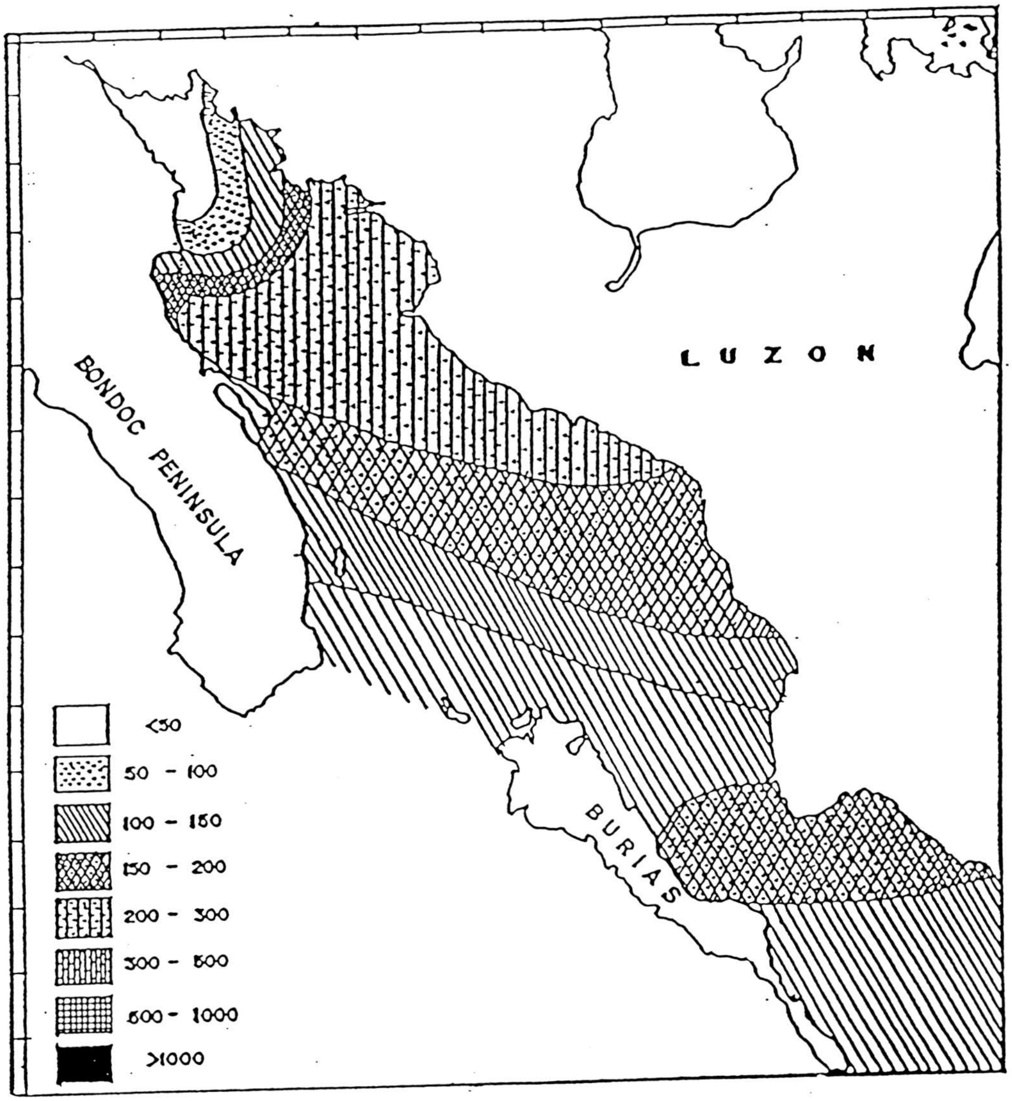


Figure 17d. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (February-March, 1982).

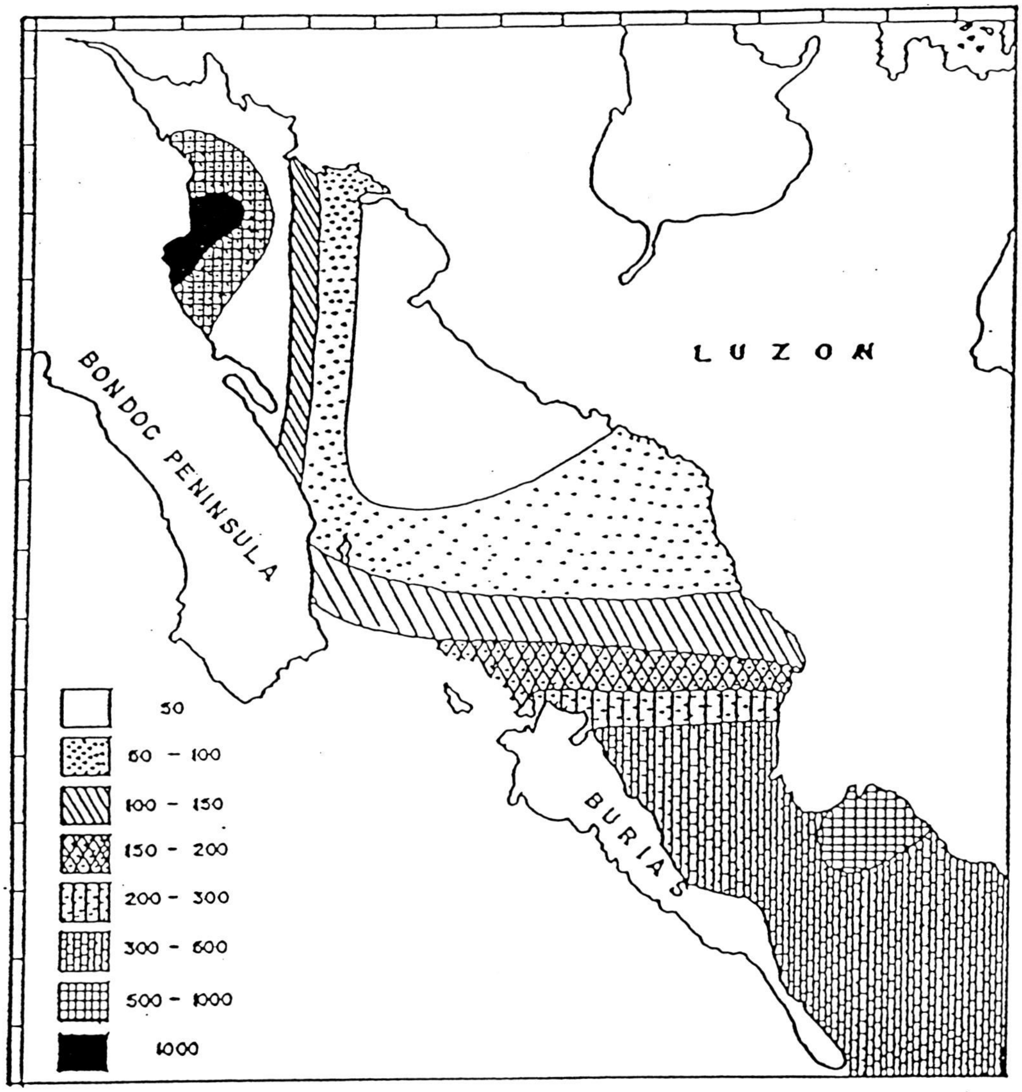


Figure 17e. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (May, 1982).

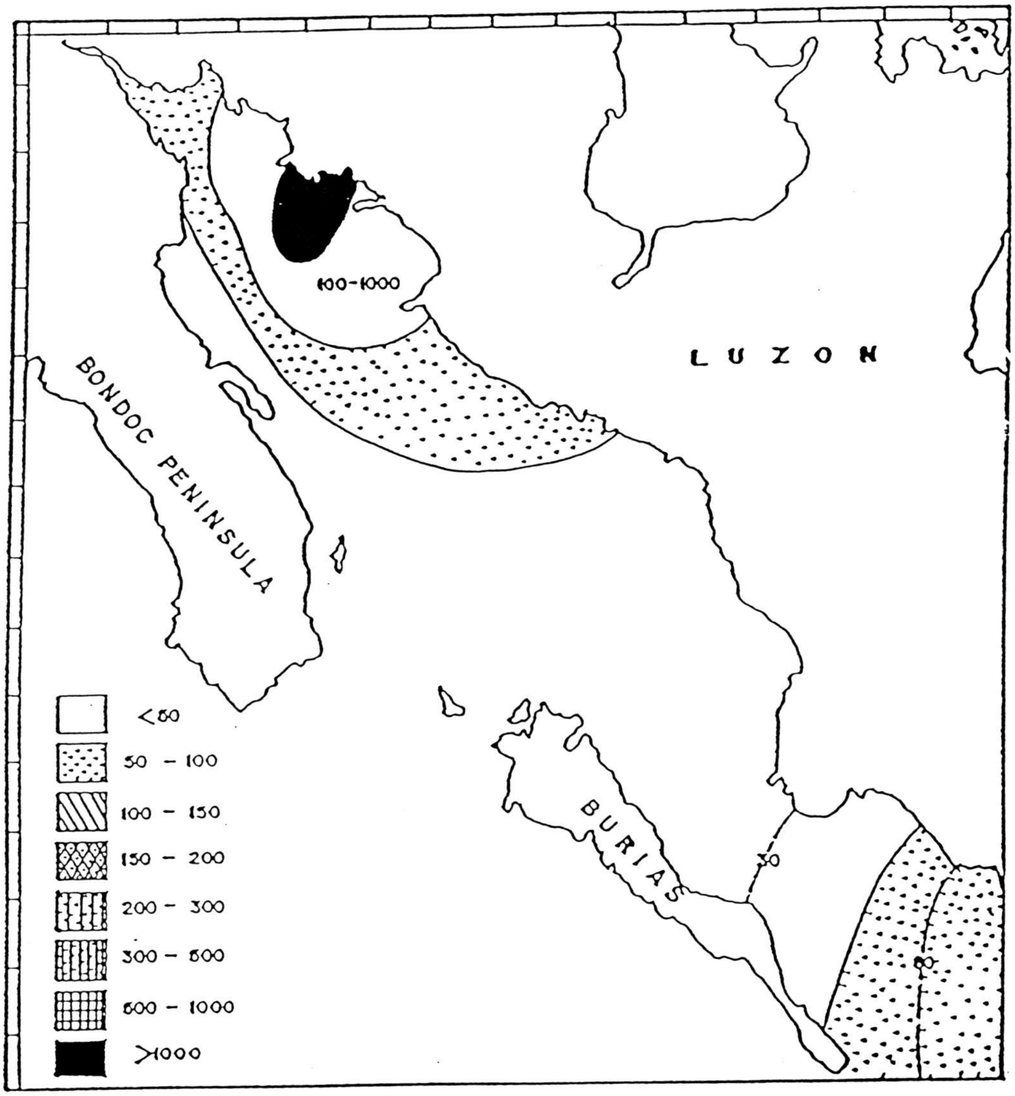


Figure 17f. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (July, 1982).

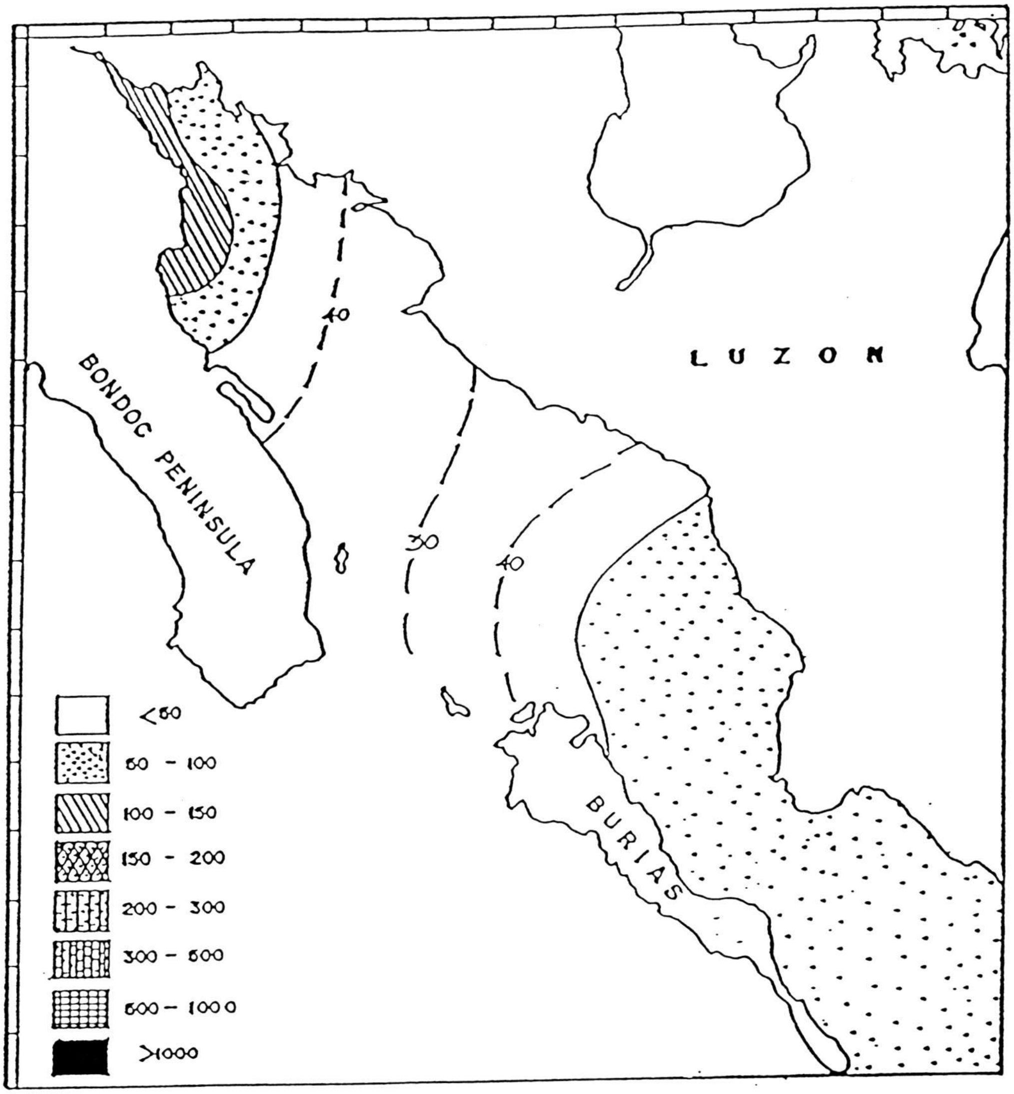


Figure 17g. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (September, 1982).

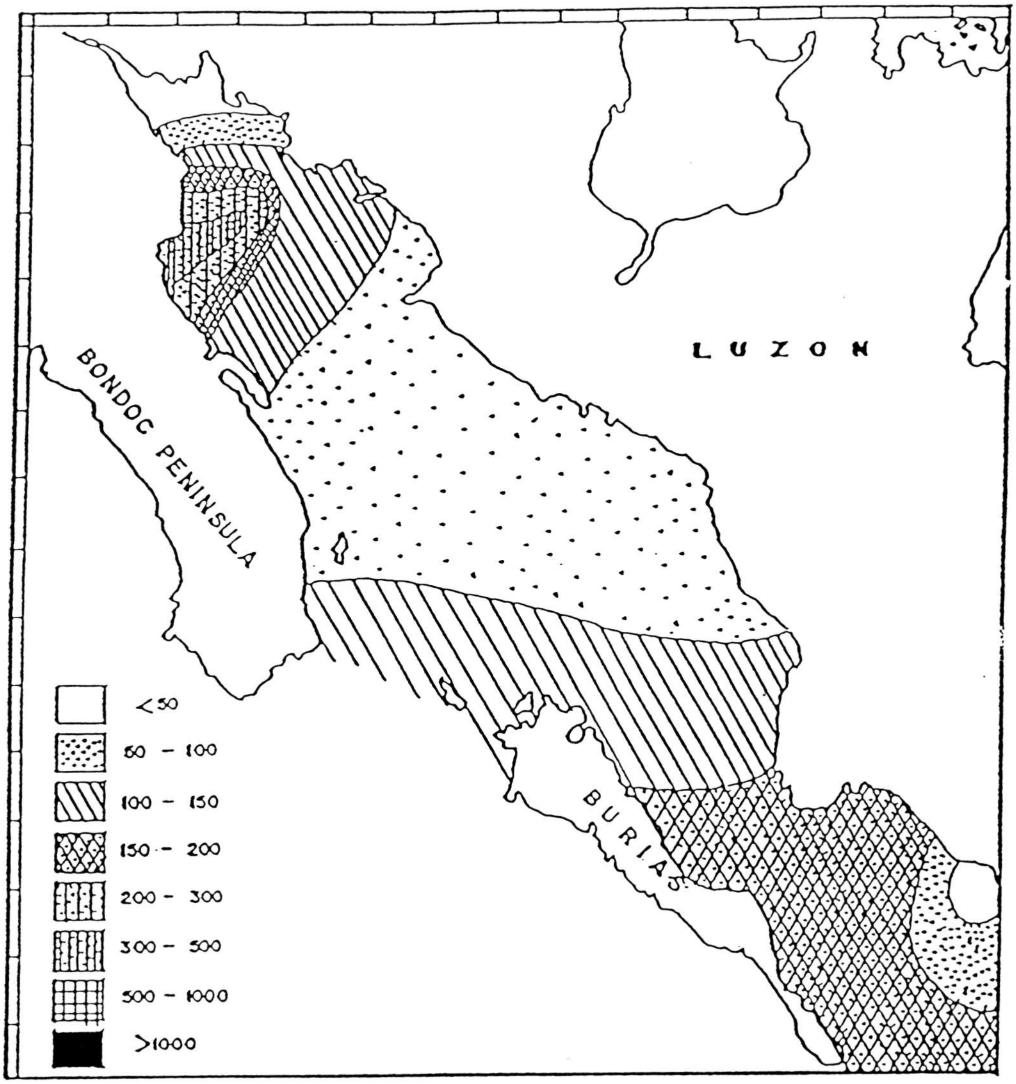


Figure 17h. Geographic distribution of zooplankton (biovolumes expressed as ml/1,000 cubic meters) in Ragay Gulf and vicinity (November, 1982).

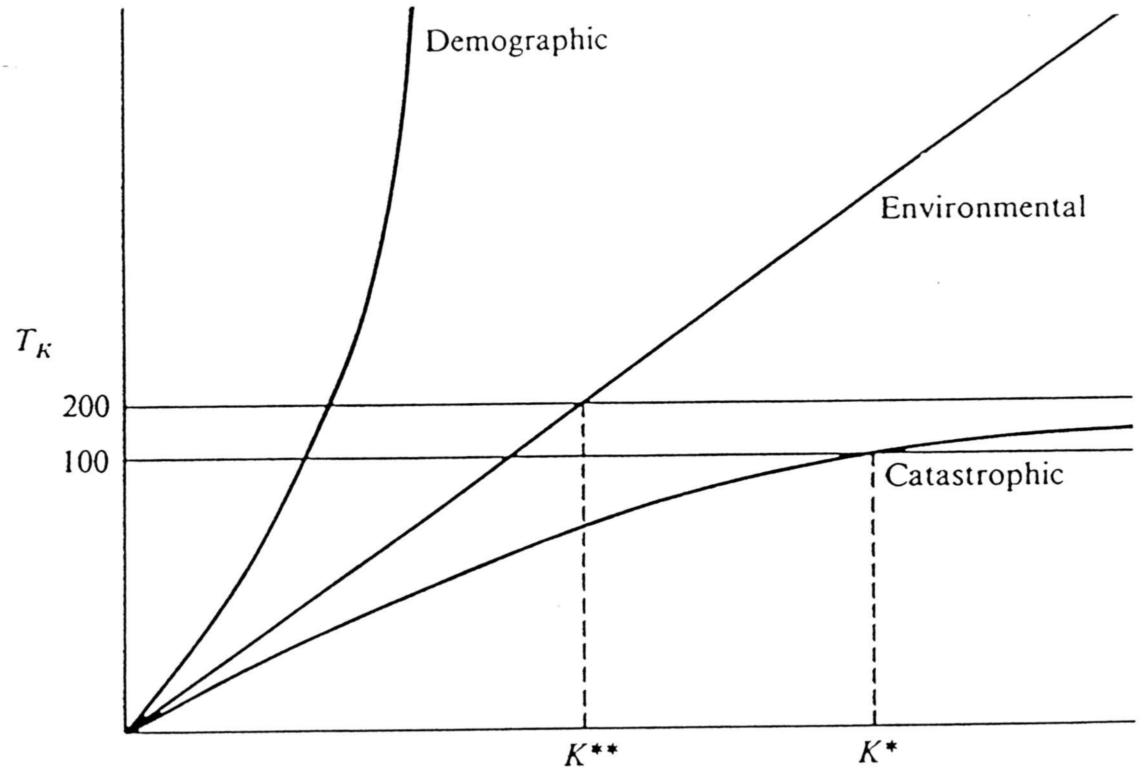


Figure 18. Functional forms of the relationship of the expected time to extinction, or average persistence time (T_K), to population size (K) for three classes of uncertainty (adapted from Shaffer, 1987).

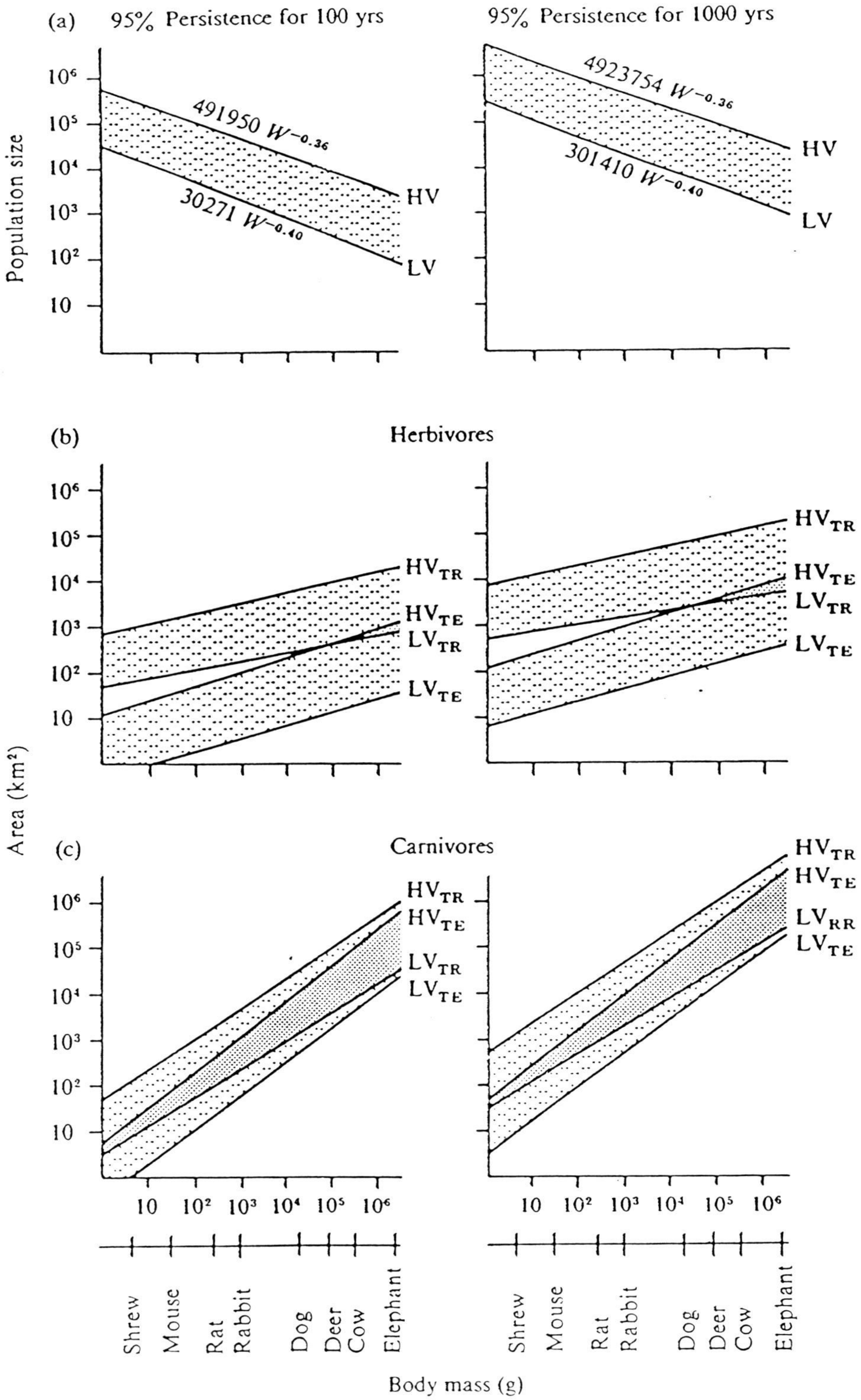


Figure 19. (a) population size needed to persist 100 or 1,000 years with a 95% probability for mammals of different body masses. HV and LV refers to high and low variance values that should bound the majority of "real world" values (shaded region).
(b) conversion of the predicted maximum population number, N_m values for herbivorous mammals of different body masses into the necessary habitat area needed to sustain that population size. TR refers to tropical environments and TE refers to temperate environments. The shaded regions represent the expected "real world" values bounded by HV and LV.
(c) presents a simila conversion of N_m into habitat area for carnivores.