CHAPTER IV

DISCUSSIONS

Environmental Variation

The present result showed pattern of seasonal variation in all parameters. Temperature had a broad peak during March to July with the maximum of 31.8 ^{o}C in April. Period of heavy rain in Phuket during the study occurred as long as eight months between April and November.

Chlorophyll concentration of both size fractions showed two distinct peaks, in February and July. The pelagic primary production during the study period also presented peaks in February and between April-July.

Since it is commonly assumed that primary production in the tropical nearshore water is elevated during the wet season due to nutrient enrichment of the euphotic zone caused by land runoff (Longhurst and Pauly, 1987 ; Qasim, 1974 ; Robertson et al., 1988). Because of quite long period of rainy season in Phuket, it may be expected that the region would be enriched by nutrients and that the primary production and chlorophyll concentration would be higher during the wet season than the dry season.

In this study, the result obtained was not according to the hypothesis stated above. Since primary production showed increasion in the beginning of the rainy period, April-June, when high amount of nutrients expected to be discharged into the area. But the primary production declined during the last half period of the heavy rain, this may also due to high turbidity caused by heavy land runoff which resulted in lowering the light intensity in sea water during the wet period. Positive correlation was only exist between primary production and temperature, Fig. 7c.

Data on temperature, pelagic primary production and light intensity at the PMBC pier were continuous recorded by Janekarn between 1981-1988 (personal communication). Temperature ranged from 25 ^{o}C to 30 ^{o}C, the lowest was during October to February, and the highest was presented between March and May. Light intensity was shown to be distinctly higher during November to April than the rest of the year. Average primary production during 1981-1988, ranged between 350-800 milligram carbon per cubic meter per day, peaked within the period according to high temperature and high light intensity. Variation of primary production and monthly rainfall also presented in the same pattern as resulted in this study, that the primary production was lower during the wet season than the dry season.

The pelagic primary production in the Phang-nga Bay and along the east coast and west coast of Phuket Island measured between 1981 and 1982 was lower in dry season in comparison to the wet season (Sundström et al., 1987). In their study, at PMBC pier station, the minimum, 201.6 milligram carbon per cubic meter of water per day,recorded in December, in dry season, and the maximum, 895.2 milligram carbon per cubic meter of water per day, recorded in June, in wet season. On the contrary, the present result showed the maximum, 156.85 milligram carbon per cubic meter of water per day, in February and the minimum, 19.17 milligram carbon per cubic meter of water per day, in November.

Janekarn and Kiørboe (1991) reported that the chlorophyll concentration in the Phang-nga Bay (in 1984) had no clear pattern in seasonal variation. But many study stations showed peaks in May and also the average concentration (all stations) showed a seasonal maximum, 3.4 milligram per cubic meter, in the same month. The primary production was reported as the seasonal pattern was not very pronounce nor consistent between stations, except for low production in August-September, which agreed with the present result.

Abundance, Biomass and Secondary Production

Abundance of zooplankton peaked in February, dry season, and May, wet season, 81.02×10^2 and 84.35×10^2 individuals per cubic meter of water, respectively. Peaks of copepods appeared in February, 44.93×10^2 individuals per cubic meter of water, and May, 40.42×10^2 individuals per cubic meter of water. For *A. gibber*, peaks were found in February, May and October with the density of 2.27, 1.48 and 1.60 individuals per cubic meter of water, respectively. Total copepods abundance at the PMBC pier was 58% of total zooplankton abundance. *A. gibber* was 2% of total zooplankton and 3.5% of all copepods abundance.

Density of zooplankton reported from the Phang-nga Bay between 1981-1982 (Boonruang, 1985) appeared to be highest during the north-east monsoon (dry) season, January-April 1982, with average was 962 individuals per cubic meter of water. Maximum in biomass presented in February which was 12 mg AFDW per cubic meter of water which was similar to the result of this study.

Chisholm and Roff (1990b) showed the result of their study during July 1985 and January 1987 at Lime Cay, Jamaica that the annual cycle of the copepods abundance was bimodals with one peaks in October-November and the other in May-June corresponding to the rainy season (temperature ranged between 27-29 ^{0}C). But the pattern of *A. gibber* and copepods abundance in this study were not corresponding to the heavy rain period.

Secondary production of *A. gibber* had significant relation in linear regression line with both chlorophyll concentration (>8 micrometers fraction) and primary production but the zooplankton production had no clear relationship with any of the environmental factors. Temperature did not appeared to be a limiting factor in secondary production of *A. gibber* and zooplankton at the PMBC pier. The finding follows what Burkill and Kendal (1982) suggested that production of copepods was influenced by food concentration.

Ecology of *Acrocalanus gibber*

Length-Weight Relationship

The length-weight equation of *A. gibber* at PMBC pier is :

$$W = 1.188 \times 10^{-9}\ L^{3.359}$$

Average weight of eggs measured in this study is 0.089, average egg diameter of 89 micrometers.

McKinnon (personal communication) worked with the samples obtained from the natural seawater of the Great Barrier Reef, at temperature 27-29 ^{0}C found the regression expressed as equation :

$$W = 3.635 \times 10^{-10}\ L^{3.515}$$

Weight of egg from McKinnon's samples was 0.07 microgram carbon for average egg diameters of 80 micrometers.

Huntley and Lopez (in press) showed relation between egg carbon (microgram carbon) and egg volume (V ; 10^6 cubic micrometer), by integrating data from various references, as follow :

$$W_e = 0.139\ (V) - 0.002$$

According to this equation, they assumed that egg weight are constant regardless of habitat temperature or location. This agreed with the data in the temperate region, for example, it was within 0.001 picogram per cubic micrometer of the value (Kiorboe et al., 1985.

Assuming that this is true also for tropical copepods, the average egg weight of *A. gibber* in this study would then be only 0.039

microgram carbon which is less than half of the actual value measured. The egg weight of *A. gibber* at Great Barrier Reef would be 0.037 microgram carbon. Hence, this equation still have not yet been applied for tropical region.

Egg Production Rate

In this study the rate of egg production was found to be related to food concentration which is consistent with numerous observations (Uye, 1981 ; Burkill and Kendal, 1982 ; Durbin et al., 1983 ; Runge, 1984,1985 ; Bellantoni and Peterson, 1987 ; Peterson, 1988). This implies that egg production is limited by food availability throughout the year.

Egg production of *A. gibber* in this study was found to be 6.3-52.0 eggs per female per day at 26.5-31.8 ^{0}C. For another species of *Acrocalanus*, *A. inermis*, reported from south Kaneohe Bay, Hawaii at 25-29 ^{0}C egg production ranged between 5-16.9 eggs per female per day (Kimmerer, 1984).

Most egg production from temperate region showed the temperature dependent (Landry, 1978 ; McLaren and Corkett, 1981 ; Uye, 1981 ; Runge, 1984,1985 ; Ambler, 1985) but for tropical region, temperature was not the most important factor (Chisholm and Roff, 1990b).

In this study, the egg production rate showed significantly related to pelagic primary production and both size fractions of chlorophyll concentration but not to temperature. Thus, it confirms that the most important factor effecting rate of egg production in tropical copepods, also of *A. gibber*, is food availability according to many studies (Uye, 1981 ; Burkill and Kendal, 1982 ; Durbin et al., 1983 ; Runge, 1984,1985 ; Bellantoni and Peterson, 1987 ; Peterson, 1988 ; Chisholm and Roff, 1990b).

The copepods preferred different size of food, dependent on morphology of the feeding appendages (Fernandez, 1979) and the mesozooplankton, for instance copepods, feed mainly on phytoplankton larger than 5-10 micrometers.

Kiørboe et al. (1990) presented that in situ fecundities of two copepods, *Temora longicornis* and *Acartia clausi*, increased linearly with the concentration of phytoplankton (chlorophyll-a) >8 micrometer. Bellantoni and Peterson (1987), studied weekly variation in egg production of *Acartia tonsa* in relation to several size fraction of chlorophyll, concluded that egg production was better related to the >10 µm chlorophyll size than to the total chlorophyll. But the result of egg production in relation to chlorophyll concentration in the present study was not different between >8 micrometer fraction and >1 micrometer fraction. The different between the two fractions was shown in the view of primary production, since primary production was only significantly correlated the >8 micrometers fraction of chlorophyll.

Acrocalanus gibber in the Pelagic Marine Food Web

From the results of fish stomach analysis, it appeared that at least 36.11% of the coral reef fish species around the PMBC pier consume copepods and other zooplankters. Even *A. gibber* was only a small fraction in the zooplankton community, they also could be recognized within the fishes stomachs. They were always found together with other copepods (Table 8). Average size, total length, of fish consumed *A. gibber* were within the range of 6.4-10.0 centimeters which most of them are plankton feeders.

The results of visual fish census around the PMBC pier recorded in 1991 by Satapoomin (personal communication) showed that the planktivorous fish, even though they occurred in small number of species, but composed of a major fraction about 64% of the total number of fishes observed in this area.

From personal observations of the living zooplankton samples from the PMBC pier, *A. gibber* was once to be found consumed by a medusa, diameter about 1 centimeter, and often found copepods, altogether *A. gibber*, inside Medusae, Siphonophores, Ctenophores, Salps and Chaetognaths in many preserved zooplankton samples. Of course, these occurrence could also very well happened once the plankton samples were collected, when they were together in high number they might eat each other even though they are usually not predator-prey related.

A. gibber, from the result of cluster analysis, was closely related to Ostracods population, both of them are herbivorous, and they were both then related to the carnivorous groups, Medusae, Siphonophores and Ctenophores, while other copepods was separated to other groups and showed less relation to *A. gibber* in this diagram.

From Spearman rank coefficience, *A. gibber* was closely correlated to six groups of zooplankton, in the trend of density changing, polychaete larvae, shrimp larvae, brachyura larvae, Mullusc larvae Ostracods and other copepods, which mean that all of these groups may require or response to the same environmental conditions.

Application

The average concentration of chlorophyll (>1 µm fraction) from field sampling was 595.6 microgram per cubic meter of water. By using the carbon to chlorophyll ratio of between 30 and 50 (Nicolajsen et al., 1983), the average (C:Chl = 40) concentration of the phytoplankton in the sea would be about 24 microgram carbon per liter.

From feeding experiments (Fig. 12) the ingestion rate of *A. gibber* in the sea at 24 microgram carbon per liter could then be estimated to be about 2 microgram carbon per female per day. The gross production efficiency in copepods was reported by some authors earlier to be approximately 33% (Kiorboe et al., 1985 ; Peterson, 1988) and since the average egg weight of *A. gibber* was 0.089 microgram carbon per egg (average egg diameter was 89 micrometers), hence, the estimated egg production rate corresponds to the ingestion rate of 2 microgram carbon per female per day is 7.5 eggs per female per day. Therefore, it is exist within the range of data from the experiment in this study, 6.3-52 eggs per female per day. So, it is still reasonable to use the gross growth efficiency as 1/3 (33%) for *A. gibber.*

The annual production of zooplankton, 1.3 gram carbon per cubic meter of water, was estimated by multiplying the average zooplankton production with 365. Zooplankton consumption was again roughly estimated by assuming 1/3 gross growth efficiency (Kiørboe et al., 1985 ; Peterson, 1988). So, the estimated consumption of zooplankton was about 4 gram carbon per cubic meter of water per year. The annual primary production during the study period was 25 gram carbon per cubic meter of water, then the zooplankton was expected to consume about 16% of the total primary production.

Since the pelagic fishes consumed the zooplankton, thus, even though it is not big fraction of the primary production which had been consumed by the zooplankton, from a fisheries point of view, it is important. This is the fraction of the primary production that is channelled to higher trophic levels in the pelagic food chain.

Thus, even the copepod, *A. gibber*, is only a small fraction in the whole zooplankton population at the PMBC pier, from many points of view in this study, it could be concluded that it is one of the species who plays an important linkage between the primary producer, within the zooplankton community, and the higher trophic level.