Phuket mar. biol. Cent. Res. Bull. **64:** 53–63 (2002)

ZOOPLANKTON COMMUNITY IN SAPAM BAY, PHUKET ISLAND

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ABSTRACT

Zooplankton communities in Sapam Bay were studied during a 33-month period, January 1994–September 1996. Monthly samplings were performed using a 330-μm net. The total zooplankton densities were in the range of 84–5,859 (1,476 ± 1,142, mean ± SD) ind./m³ and the biomass in terms of ash free dry weight (AFDW) varied between 0.74–46.33 (8.18 ± 6.73) mg/m³. No clear seasonal pattern in either density or biomass was observed. Nevertheless, there was a trend of higher values late in the SW-monsoon season. Meroplankton contributed up to 40% of the zooplankton, and half of these were economically importance marine larvae. Total average zooplankton density showed no differences between years (1,450 ind./m³ in 1994, 1,548 ind./m³ in 1995 and 1,251 ind./m³ in 1996). Average AFDW declined gradually with 10.2, 8.1 and 6.1 mg/m³ in 1994, 1995 and 1996, respectively.

INTRODUCTION

The mangrove areas of Phuket Island are found mainly on the eastern coast. Satellite images in 1996 revealed the approximate land use of the mangrove area in Phuket (Charuppat and Charuppat, 1997). The mangrove forest remaining in 1996 was 15 km², which is a 66% reduction over a 35-year period (from 45 km² in 1961). The lost mangrove area was replaced by shrimp farms, land reclamation for urbanization, and other purposes.

Sapam Bay is located on the east coast of Phuket Island. The area has been disturbed mainly by mining and community development. It was originally surrounded by rich mangrove forests, from both its coastal plain and small islands in the western Phang-nga Bay (Boonruang and Janekarn, 1985). At present, even though shrimp farms and urbanization have replaced the major part of the mangrove forests, small-scale fisheries still exist in the bay and nearby areas. Small tributaries carry discharge from both the shrimp farms and domestic waste into Sapam Bay, especially during the rainy season. Concern has recently been voiced as whether this would affect the water quality and pelagic community in the bay. Hence, a monitoring program was set up in order to check and trace the ecosystem quality.

This study was carried out as part of the core project of monitoring and investigation of coastal fisheries resources and environment in Sapam Bay. Phytoplankton, zooplankton, benthos, and some basic environmental parameters were studied concurrently, *e.g.*, Sawangarreruks and Mokaratana (1999), Sawangarreruks, *et al.* (1999). This paper focuses on zooplankton communities in the bay during January 1994 and September 1996.

MATERIALS AND METHODS

Three sampling stations were established in Sapam Bay (Fig. 1). Monthly sampling (in replicate) was performed at each station during high tides. The depth of water recorded exceeded 4 m during every sampling period. The bottom sediment was mainly composed of silt-clay (< 63 μm) with a low organic content (Sawangarreruks and Mokaratana, 1999).

Prior to the zooplankton sampling, data on basic environmental parameters, *i.e.*, temperature,

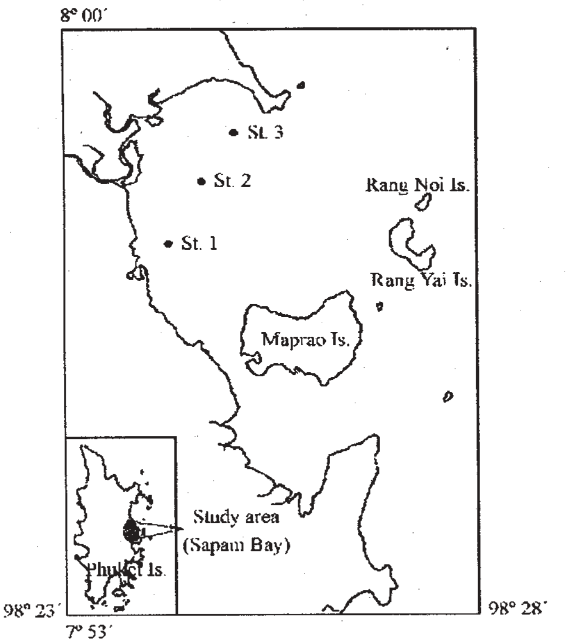

Figure 1 Location of the 3 replicate stations in the Sapam Bay, east coast of Phuket Island.

salinity, pH and dissolved oxygen, were recorded. Zooplankton was sampled at each station by using a 330-μm net towed for 5 minutes in the middle of the water column. Samples were preserved in 10% buffered formalin. Two hauls were taken at each station, one for enumeration and the other for biomass analysis. A TSK-type flow meter was mounted in the middle of the net to estimate the volume of water filtered through the net. Determination of biomass was done as displacement volume, wet weight, dry weight and ash free dry weight.

Statistical analysis was performed in Statistica 5.0. One-way ANOVA was applied to test seasonal effects on each variable of both environmental parameters and abundance of zooplankton taxa. Simple linear correlation was carried out between each environmental parameter and total zooplankton density. Cluster analysis was used to explore the assemblage patterns among zooplankton taxa through the sampling period. The original density data were double square root transformed (to minimize effects of spurious abundance) prior to the analysis.

RESULTS

Environmental parameters

Environmental parameters in the study area are summarized in Table 1. Temperature and salinity fluctuated noticeably during the study period. Higher values were observed during the NE-monsoon season as compared to the SW-monsoon season but differences were not statistically significant (temperature and salinity, $p>0.05$). The D.O. and pH values fluctuated widely but without any seasonal pattern. Data on chlorophyll-a concentration, only available for 1994 and 1995, showed higher values during the last quarter of the year (from late SW-monsoon season to early NE-monsoon season).

None of the parameters were significantly intercorrelated, and most of the correlation coefficients did not exceed 0.5. The total zooplankton density did not show any significant correlations with the environmental parameters. However, when the analysis was performed for each taxonomic group, minor taxa (platyhelminthes larvae and isopods) did show significant correlations with the total chlorophyll concentration ($p<0.05$).

Biomass

AFDW varied between 0.7–46.3 (average 8.2 ± 6.7) mg/m^3 (Table 1). The average annual AFDW gradually declined in the course of the study period with averages of 10.2, 8.1 and 6.1 mg/m^3 in 1994, 1995 and 1996, respectively. Monthly average biomasses (DW and AFDW) were high in late SW-monsoon season (August–October), and in the middle of NE-monsoon season (January and February) but the differences were not statistical significant.

Table 2 presents the monthly average of zooplankton biomass. The average ratio of AFDW to DW was 0.54 ± 0.21, while that of wet weight to dry weight was 0.08 ± 0.05.

Table 1 Some basic environmental parameters in Sapam Bay during January 1994–September 1996.

	Temp. (°C)	Salinity (ppt)	pH	D.O. (mg/l)	Chl-a (mg/m³)	Zoo. Dens. (ind./m³)	AFDW (mg/m³)
Range	25.7–33.9	30.6–33.6	7.1–9.0	5.9–8.2	0.3–10.1	84–5,859	0.7–6.3
Mean±SD	28.7±1.4	32.3±0.8	7.9±0.3	7.1±0.6	2.9±2.1	1,476±1,142	8.2±6.7

Abundance pattern

Zooplankton found in the samples belonged to 11 Phyla. Major taxa included *Lucifer* spp. (21% of the total density), barnacle larvae (20%), copepod (16%), crab larvae (13%), and larvaceans (13%).

The range of total zooplankton density was 84–5,859 (average 1,476 ± 1,142) ind./m³. There was no clear seasonal pattern in density although the highest abundances were noted in late SW monsoon season and during the NE monsoon season (Table 3, Fig. 2). Annual average zooplankton densities did not change during the study period (1,450 ind./m³ in 1994, 1,548 ind./m³ in 1995 and 1,251 ind./m³ in 1996).

Average density of zooplankton was high in August and September due to the higher contributions from various taxa (Table 3). The taxa with distinctively high densities in August were barnacle larvae, *Lucifer* spp., gastropods, bivalves, and fish larvae. Those that peaked in September were polychaetes, copepods, crustacean nauplii, bivalves, and chaetognaths. The brachyuran larvae showed relatively high densities in both August and September.

Several taxa peaked in occurrence during the NE-monsoon season, *e.g.*, amphipods, bivalve larvae, and echinoderm larvae in November, larvaceans and fish larvae in January, and fish larvae in February. For the rest of the year, density

Table 2 Biomass of zooplankton (mean±SD) in Sapam Bay during January 1994–September 1996.

Month	Volume, ml/m³	Wet weight, mg/m³	Dry weight, mg/m³	AFDW, mg/m³
January	0.6±0.4	502.9±324.2	48.3±17.5	11.0±8.4
February	0.3±0.3	221.4±189.3	18.3±15.0	8.1±2.8
March	0.2±0.3	164.0±247.4	8.5±8.7	4.8±2.3
April	0.2±0.1	175.9±136.9	11.6±7.3	7.1±5.5
May	0.1±0.0	41.3±33.1	3.4±2.4	2.2±1.7
June	0.2±0.2	48.9±215.2	15.2±14.8	6.9±4.2
July	0.2±0.2	306.7±343.1	11.4±9.1	5.2±2.9
August	0.3±0.1	394.4±191.3	22.9±11.0	11.4±3.9
September	0.7±0.7	798.2±761.2	33.2±32.1	12.1±13.5
October	0.3±0.2	299.1±196.0	16.5±16.0	10.0±11.2
November	0.1±0.1	118.8±51.5	10.8±5.0	8.3±3.9
December	0.3±0.2	265.3±171.6	15.7±10.6	7.7±5.0

Table 3 Zooplankton density (mean ± SD, ind./m³) in Sapam Bay during January 1994–September 1996.

Taxa	Jan	Feb	Mar	Apr	May
Hydromedusae	1.6±1.1	1.7±1.3	0.5±0.4	2.2±2.5	5.3±6.5
Siphonophora	12.9±18.3	10.3±9.2	12.9±12.1	8.3±8.2	9.3±14.2
Ctenophora	0.0	0.0±0.1	0.0	0.0	0.0±0.1
Platyhelminthes	0.1±0.1	0.0	0.0	0.0	0.0
Polychaeta	6.5±7.0	4.2±5.8	1.7±1.8	11.0±7.9	12.4±22.0
Cladocera	5.0±5.5	4.4±4.0	16.8±42.7	0.4±0.4	0.4±0.5
Ostracoda	3.4±3.4	1.3±2.0	1.3±1.6	1.4±1.9	2.0±2.3
Copepoda	205.2±152.7	214.0±254.9	243.5±325.4	181.4±113.9	68.8±78.4
Crustacean nauplii	0.8±1.2	3.4±5.7	0.1±0.3	2.0±2.4	0.5±0.7
Cerripidia	432.1±815.8	277.6±243.6	31.2±66.3	313.4±381.7	78.7±67.1
Amphipoda	0.0	0.1±0.4	0.1±0.3	0.2±0.5	0.0±0.1
Isopoda	0.0	0.0	0.0	0.0	0.0
Mysidacea	0.0±0.1	0.0	0.7±2.2	0.0	0.0
Shrimp larvae	11.6±7.9	7.9±7.8	4.1±4.9	22.3±24.6	5.6±6.8
Lucifer spp.	306.5±392.3	171.3±156.6	98.8±113.0	398.6±212.6	170.3±201.0
Stomatopoda	0.1±0.2	0.0±0.1	0.2±0.2	0.5±1.3	0.1±0.1
Anomura larvae	0.7±1.0	2.0±3.1	0.4±0.9	99.3±292.6	0.1±0.2
Brachyura larvae	126.7±145.0	229.4±172.5	81.2±111.2	304.2±327.5	35.3±28.5
Gastropod larvae	24.8±28.9	11.4±19.3	5.4±4.8	20.1±16.8	12.5±11.2
Bivalve larvae	7.3±6.2	2.1±2.1	2.5±4.1	3.3±3.4	5.9±8.8
Heteropod	0.0±0.1	0.2±0.4	0.0	0.1±0.4	0.2±0.4
Pteropod	1.4±2.5	0.7±0.9	0.3±0.4	0.7±1.8	0.7±0.7
Cyphonautes	0.2±0.4	0.4±0.7	0.1±0.2	0.0	0.0
Branchiopoda larvae	0.1±0.2	16.3±39.3	0.2±0.3	0.0±0.1	0.0
Chaetognatha	75.5±103.5	78.2±88.5	22.2±15.5	100.2±50.3	42.4±46.3
Echinoderm larvae	11.7±11.7	45.8±111.9	24.3±32.5	16.1±15.7	5.3±5.2
Larvacea	491.3±406.4	58.1±73.7	18.6±12.4	177.2±137.2	46.4±46.6
Thaliacea	0.1±0.1	3.8±9.1	0.0	0.3±0.8	0.0
Fish larvae	11.3±11.6	11.5±8.3	1.9±2.4	6.1±6.3	1.5±1.7
Fish eggs	9.6±6.4	10.4±8.5	14.8±18.7	17.7±22.0	7.0±7.1
Other	0.5±0.7	0.5±0.7	0.4±0.3	3.6±5.3	0.1±0.2
Total	**1747±1493**	**1167±481**	**584±394**	**1691±780**	**511±377**

Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.1±1.7	3.9±8.5	5.1±4.8	3.8±4.4	1.9±2.0	3.8±7.1	1.7±1.4
9.9±15.9	5.5±6.6	6.9±5.8	10.0±12.3	44.4±69.3	7.2±5.7	5.0±4.7
0.0	0.0	0.0	0.0	0.0	3.8±0.0	0.0
0.0	0.0	0.0	0.1±0.3	0.1±0.2	0.1±0.3	0.1±0.2
17.2±16.5	17.8±35.6	27.8±25.8	50.1±45.6	18.8±17.0	2.8±5.3	9.6±7.7
0.3±0.4	0.0	0.0	0.0	0.1±0.2	2.7±0.0	1.4±1.2
46.8±85.4	11.1±13.5	8.8±8.6	4.9±5.5	3.8±3.0	1.2±2.0	4.5±4.1
244.9±185.8	259.2±216.7	266.0±214.4	748.2±570.3	116.1±40.3	44.6±25.5	95.7±126.0
3.1±5.1	8.7±15.3	20.9±30.1	38.7±48.6	3.4±3.0	0.8±1.2	4.9±9.8
322.1±314.4	114.9±186.1	803.0±591.0	350.2±272.7	340.8±343.9	142.0±281.0	358.0±484.8
1.2±1.8	0.5±0.8	0.3±0.4	0.7±0.9	0.2±0.3	99.3±1.7	0.4±0.9
0.0	0.0	0.0	0.0	0.1±0.4	0.7±0.4	0.2±0.3
0.0	0.0	0.0	0.0	0.0	0.3±0.3	0.1±0.3
17.4±19.2	22.4±26.7	15.2±9.2	10.2±7.5	12.6±13.4	15.4±24.2	37.2±43.0
316.1±239.5	422.4±786.5	581.9±311.2	289.8±204.2	358.5±224.2	174.5±207.0	187.7±96.1
0.7±0.9	1.4±3.2	0.2±0.5	0.3±0.6	0.7±1.2	159.4±0.5	0.4±0.8
2.4±3.5	1.6±4.0	0.5±0.7	0.8±0.9	0.7±0.5	0.9±1.4	0.7±0.5
117.8±96.3	210.8±287.0	362.3±347.5	333.2±362.2	190.2±198.2	127.1±91.2	72.4±29.5
38.2±26.3	55.1±70.6	30.6±30.2	60.4±36.0	20.2±7.0	129.7±2.6	14.0±22.6
83.6±114.6	63.6±139.3	37.5±35.7	81.2±62.9	3.1±1.3	4.5±0.7	5.5±4.9
0.1±0.2	0.2±0.4	0.8±1.1	1.7±1.9	0.1±0.2	1.5±0.6	0.3±0.6
1.6±2.1	1.4±01.7	1.0±1.0	0.4±1.2	0.2±0.5	0.7±1.7	2.1±2.3
0.0	0.0	0.3±0.4	0.2±0.2	0.1±0.1	0.6±0.4	0.8±1.8
43.7±117.0	0.0±0.1	0.2±0.3	0.4±0.7	0.2±0.3	0.6±0.5	0.9±1.3
79.7±88.4	99.1±99.8	94.7±59.1	197.6±125.3	90.4±18.4	36.0±32.8	73.4±54.8
23.9±41.5	4.3±6.1	4.7±2.8	6.2±4.3	9.1±9.8	40.5±9.2	20.8±23.6
85.2±66.8	217.2±241.7	205.3±110.9	292.1±293.8	187.3±187.0	28.1±23.2	259.3±220.2
0.5±0.8	0.2±0.5	0.1±0.2	0.0	0.0	23.1±0.0	0.0
3.3±3.9	4.2±5.2	16.0±20.0	2.1±2.7	2.3±3.1	3.4±3.6	6.1±3.8
9.5±10.3	9.6±8.3	14.6±9.9	8.3±9.0	28.0±47.6	11.3±14.6	8.5±6.6
0.3±0.3	0.7±1.7	0.9±1.1	0.9±1.4	0.7±0.7	8.2±0.4	0.5±0.5
1471±717	**1535±1558**	**2505±1320**	**2492±1459**	**1434±699**	**538±387**	**1172±808**

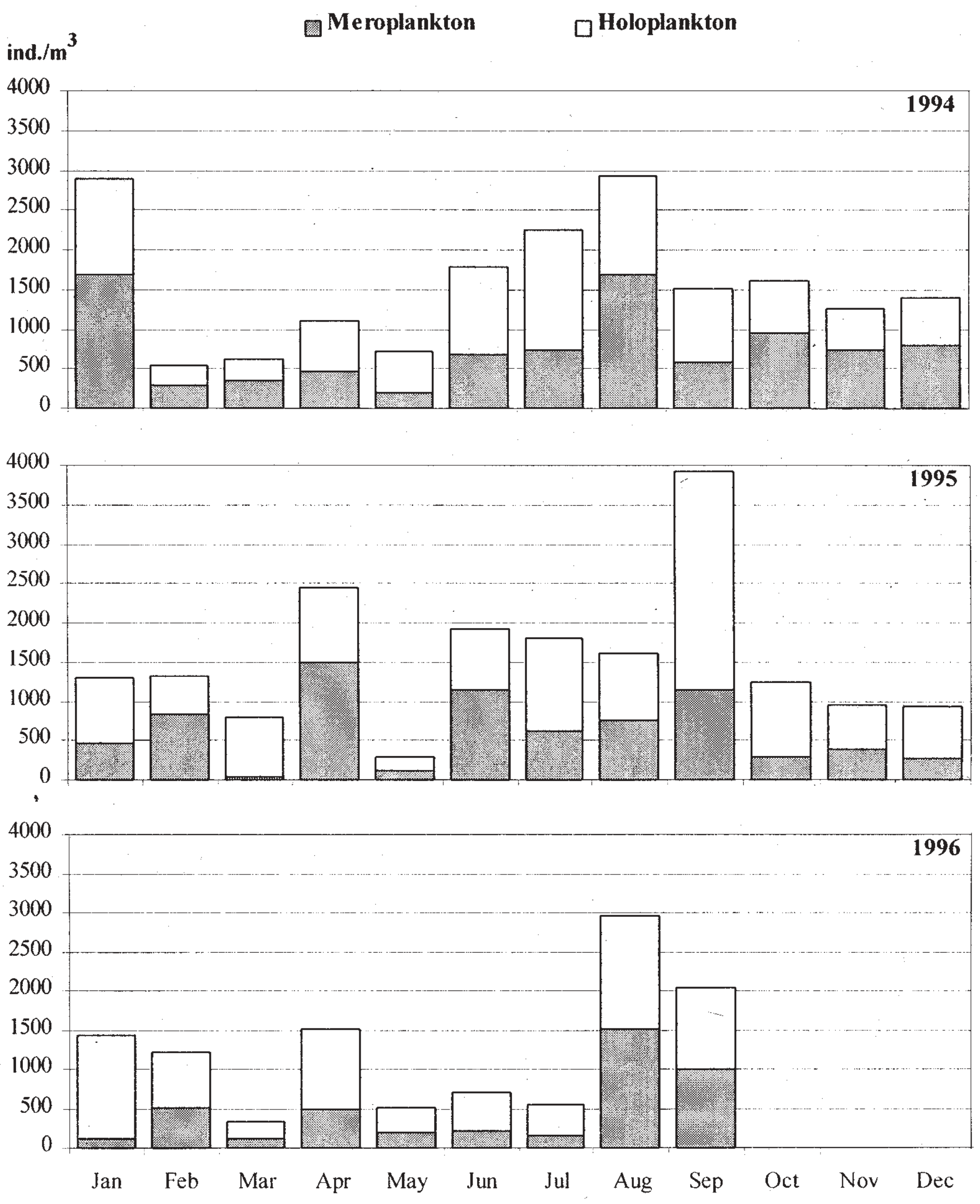

Figure 2 Zooplankton density (ind./m^3), averaged from the three stations in Sapam Bay during January 1994–September 1996.

of bivalve larvae and branchiopoda larvae were noticeably high in June.

Meropankton made up 1/3–1/2 in the total of zooplankton density (Fig. 2). Major groups of meroplankton comprised the larvae belonging to barnacles, crabs, mollusks, shrimps and fish, while *Lucifer* spp., copepods, larvaceans and chaetognaths dominated the holozooplankton portion. Merozooplankton, on average, contributed up to 40% of the total zooplankton, half of which were larvae of commercial importance marine fauna (*e.g.*, groups of shrimps, mollusks, crabs, and fish larvae).

Assemblage pattern

Cluster analysis on the composition of zooplankton abundance revealed 3 different groups (Fig. 3). The environmental data were only slightly different among clusters, except that the mean value of chlorophyll was lowest in cluster III (Table 4).

Cluster I and II were composed of samples mainly from the NE-monsoon season, while cluster III was dominated by SW monsoon samples.

Cluster III revealed the most distinctive assemblage of zooplankton by having highest mean total density. The characteristic groups found were barnacle larvae, copepod, *Lucifer* spp., crab larvae, bivalve larvae, gastropod larvae, polychaete larvae, and ostracod. The first four groups contributed up to 78% of the total density.

The assemblages represented by clusters I and II had similar mean total densities, which were lower than cluster III. The two assemblages shared various typical groups of taxa (*e.g.*, copepod, crab larvae, barnacle larvae). However, they contained different groups of predominant taxa, *i.e.*, *Lucifer* spp. in assemblage-cluster I, and larvacea in assemblage-cluster II.

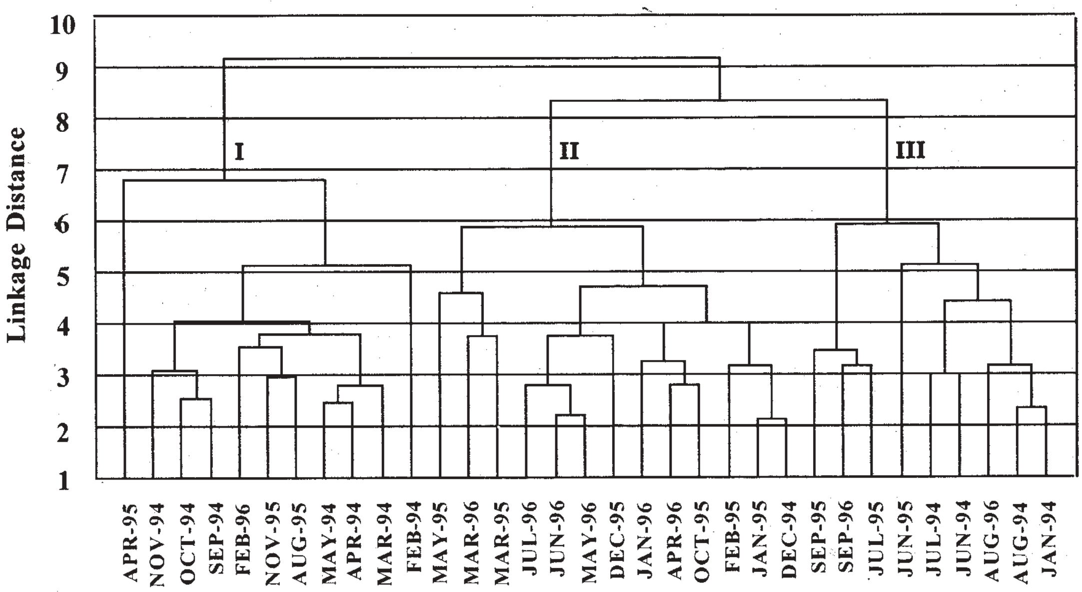

Figure 3 Dendrogram for cluster analysis of zooplankton in Sapam Bay during January 1994 –September 1996.

Table 4 Some characteristics of the clusters for zooplankton in Sapam Bay, January 1994–September 1996.

Cluster	Months	NE %	SW %	T ℃	S ppt	D.O. mg/l	pH	Chl-a mg/m^3	Meroplankton %	Total density ind./m^3
I	11	64	36	28.6±1.7	31.9±0.8	7.2±0.7	7.9±0.3	3.2±2.5	47±13	1,267±603
II	13	62	38	28.8±1.3	32.7±0.7	7.2±0.5	8.2±0.3	3.2±2.2	33±19	956±500
III	9	11	89	28.6±1.1	32.3±0.7	7.0±0.4	7.8±0.3	2.2±1.3	43±17	2,504±704

DISCUSSION

Sapam Bay contains a typical shallow water body, which is well mixed vertically. None of the environmental parameters differed between seasons. This is similar to that reported from Phuket Bay (Panutrakul, 1996).

Zooplankton density peaked simultaneously with chlorophyll concentration. However, from the statistical test, none of the correlations between zooplankton density and environmental parameters were significant.

Temporal variation of total zooplankton density in the Sapam Bay was noticed seasonally. The SW-monsoon provided a more productive assemblage of zooplankton, as reflected by higher densities of several dominant taxa (*i.e.*, barnacle larvae, copepod, and *Lucifer* spp.) and particularly a higher contribution of merozooplankton. Previous studies have shown corresponding periods of abundance peaks in certain taxa and of the late stages of shrimp and fish larvae. Boonruang and Janekarn (1985) found that all penaeid larvae were found in greater numbers during the SW-monsoon season (May–October). Janekarn and Boonruang (1986) reported that fish larvae in Sapam Bay (during 1979–1980) had two abundance peaks, during July–October and in February, similar to the findings of the present study.

Copepods were not the predominant taxa in our results. This group normally dominates in most samples from adjacent areas using the same mesh-size net, *e.g.*, in Phang-nga Bay (Boonruang, 1985) and in Ranong province (Satapoomin, 1999). Boonruang (1985) found that copepods dominated at all sampling stations and contributed up to 30–45% of the total zooplankton. Satapoomin (1999) also found that copepods always dominated, with an average of 61%. In the present study copepods only contributed 16% of the total zooplankton. Instead, meroplankton contributed a high percentage of the total community compared to what has been reported from other areas (see Table 5). Our results agree with several previous findings that Sapam Bay is an important nursery ground for penaeid shrimps (Boonruang and Janekarn, 1985) and fish larvae (Janekarn and Boonruang, 1986).

Boonruang (1985) surveyed the plankton in the western part of Phang-nga Bay (April 1981–April 1982) with one station in Sapam Bay, which allows a direct comparison. The present study showed higher average zooplankton density (1,476 ± 1,142, compared to 682 ± 279 ind./m^3 in Phang-nga Bay), and a higher conversion factor from DW to AFDW (0.54 ± 0.21, compared to 0.43). There were also differences in the timing of abundance peaks, *i.e.*, August–September in our study, compared to January–April, in the previous study. Certain changes in species composition were also noticed. It is unclear whether these changes are due to variability in zooplankton assemblage or caused by changes in predominant taxa over time. However, these data show that the zooplankton communities in Sapam Bay have not lost their productive characteristics over the past 12 years.

Table 5 Data on zooplankton density and AFDW, using similar mesh-size net, studied from different localities.

Range of Density ind./m³	AFDW mg/m³	Mesh µm	% mero-plankton	Study area	Sampling effort (number of station and cruise)	References
725–17,698	5.18–226.7	330	18	Phang-nga Bay, Andaman Sea	14 sts. 10 cruises Jan.–Dec. 84	Satapoomin and Boonruang (unpublished data)
303–1,047 (mean of all stations)	5.87–12.0 (mean of all stations)	330	18	Western part of Phang-nga Bay (east coast of Phuket Island), Andaman Sea	15 sts. 7 cruises Apr.81–Apr.82	Boonruang, 1985
35,345–959,873	–	334	–	Mangrove canal, Phang-gna Bay, Andaman Sea	6 sts. 2 cruises Sep.90 and Apr. 91	Angsupanich, 1994
1–30,707	0.33–5730.1	330	20	A mangrove canal, Ranong Province, Andaman Sea	7 sts. 13 cruises Jan.94–Jan.95	Satapoomin, 1999
84–5,859	0.7–46.3	330	40	Estuarine bay, Phuket Island, Andaman Sea	3 sts./33 cruises Jan.94–Sep 96	present study

Several groups of zooplankton are important food items for demersal fishes (Boonruang *et al.*, 1994; Poung-in, 1992; Boonruang and Satapoomin, 1997). The relatively high abundance level of zooplankton in Sapam Bay could well support a rich local fish assemblage within the Bay. This is highly relevant to the small-scale fisheries, which is still being operated in the area.

Regarding the high proportion of meroplankton in Sapam Bay, the area is likely to serve either one or both of the following ecological functions (under specific conditions): a) as a spawning ground (if the meroplankton production in the area is largely derived from the local reproductive output); and b) as a potential settlement and recruitment area. Existing information on macrobenthic community studied in the area seems to provide partial confirmation of our present results. Sawangarreruks *et al.* (1999) reported that crustaceans and mollusks were abundant groups in dredge samples. Several economically important groups, which were found in considerable amounts, included penaeid shrimps, portunid crab (*Portunus pelagicus*) and short-neck clam (*Paphia undulata*). Polychaetes dominated samples from van Veen grab both in terms of density and number of species (Sawangarreruks and Mokaratana, 1999). These findings are consistent with the present results as the major groups of meroplankton found in relatively high abundance included larvae of shrimps, crab, bivalves, mollusks and polychaetes.

Zooplankton abundance in the bay is typical of coastal waters. It is low when compared with the data from the productive mangrove areas, such as the inner part of Phang-nga Bay (Angsupanich, 1994; Satapoomin and Boonruang, unpublished data) or in Ranong province (Satapoomin, 1999). However, we found higher abundances compared to former records from the same area by Boonruang (1985). It is usually claimed that one might expect negative effects of waste effluences, particularly from shrimp farming and urbanization, on the quality of coastal ecosystem. Fortunately, such influences cannot so far be demonstrated on the zooplankton communities in the area. Nevertheless, to keep the natural purification process functioning, the remaining mangrove area has to be protected and a strict management of waste treatment is needed.

ACKNOWLEDGEMENTS

This study was supported by the Department of Fisheries. We are indebted to the staff of the Marine Biological Productivity Unit for their assistance during the field sampling. We thank Mr. Vitthaya Limtrakulvong and Mr. Prajuab Mokaratana who provided us with raw data on environmental parameters and Mrs. Pensri Boonruang for her advice on the study plan. Special gratitude is paid to Assoc. Prof. Nittharatana Paphavasit for her comments on the manuscript.

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manuscript received: 03 February 2001; accepted: 4 March 2002