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MEIOFAUNA IN THALE SAP SONGKHLA, A LAGOONAL LAKE IN SOUTHERN THAILAND

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ABSTRACT

Quantitative samples of soft-bottom sediment meiofauna were collected from a lagoonal lake (Thale Sap Songkhla, southern Thailand). Eighteen taxa were encountered. Nematoda was the most abundant (62-64%) at all stations and Sarcomastigophora was the second (18-33%). Copepoda usually was not abundant, but it tended to be more common at seagrass beds. Total meiofauna densities varied among stations and seasons. The highest densities were found at stations adjacent to organic discharge areas and seagrass beds. The mean densities ranged from 65 to 1596 ind 10 cm^{-2}. Meiofauna was in high abundance during the transitional period between the SW monsoon and NE monsoon in October (36 to 2490 ind 10 cm^{-2}), while the low abundance was during the post NE monsoon in January (32 to 477 ind 10 cm^{-2}). The number of taxa increased slightly in October. Vertical distribution of each taxon occurred concurrently. The greatest abundance of meiofauna was noted in the upper 1 cm of sediment (32 to 6227 ind 10 cm^{-2}). Meiofauna was an important food supply for larger epibenthic fauna in the area. Although water temperature, salinity, particulate organic matter and particle grain size did not show positive correlation with meiofauna densities, the combination of those major factors may control the meiofauna population in Thale Sap Songkhla.

INTRODUCTION

Several studies have shown that meiofauna are a food source for larger macrofauna[1], epibenthic organisms such as shrimp[2-4] and juvenile fishes[4,5]. In a review of marine meiofaunal ecology, Coull and Bell[6] noted that meiofauna serve as food for higher trophic levels more in muds than in sands. Juvenile spot (Pisces) preferred to feed upon meiofauna in muddy substrata more than in sand substrata[4]. In comparison with previous research in soft bottom sediments of a lagoonal lake, Thale Sap Songkhla (personal observation) may also comprise a large number of meiofauna. The current investigation is the first study of meiofauna communities in the area.

The goal of this study was to investigate the distribution and abundance of meiofauna communities in Thale Sap Songkhla. Data from the study will be used as a database for management of the area which is important for seabass culture, commercial fisheries, and industrial development.

MATERIALS AND METHODS

Study area - Thale Sap Songkhla or the Outer Songkhla Lake is the lowermost part of Songkhla Lake, a shallow lagoonal lake in southern Thailand (Fig. 1). The average depth of Thale Sap Songkhla is 1.2 m. There are two small seagrass communities; one is 1300 m from the mouth of Songkhla Lake and the other is along the Ban Hua Hat shoreline[7]. Tidal currents and seasonal precipitation are important physical factors that govern seasonal variation of salinity[8]. Seven study stations were established. The five soft sediment stations (Sts. 2, 3, 4, 6, 7) are identical to those used by Angsupanich and Kuwabara[9] and the other two stations (Sts. 1 and 5) were in seagrass communities. Summary environment and habitat characteristics for each station are shown in Table 1.

Sampling - Meiofauna was sampled by coring with a 4.0 cm diameter plastic tube at all 7 stations. Five replicate core samples, usually to a depth of 10 cm, were taken at each station with a syringe style corer. Each core was sectioned in 1-, 2-, 3-, 4- and 5-cm slices from the top and each slice was separately preserved in 10% buffered formalin containing rose bengal stain for 48 hours. Quantitative extraction of meiofauna was done by decantation[10]. After multiple decantations all material retained on a 63 μm pore net were preserved in 70% alcohol. All materials were poured into a modified Bogorov tray for sorting under a stereo microscope. The density of each taxa in each centimeter of sediment was expressed as individuals 10 cm^{-2}.

Water temperature and salinity were measured routinely using bucket thermometer and Kagaku salinometer model 50. Sediments collected by Tamura's grab were used to determine grain size by the hydrometer method[11] and organic matter by the Walkey and Black technique[12].

Samples were taken during the daytime in July (the SW monsoon season), in October (the transitional period between SW monsoon and NE monsoon) and in January (the post NE monsoon season)[13].

RESULTS

Fauna

Table 2 lists meiofauna found by station and season. Eighteen taxa were encountered. Nematoda, Sarcomastigophora, Ostracoda, Copepoda, Nauplius of Copepoda, Ciliophora, Polychaeta and Turbellaria were found at all stations and seasons. Polychaeta and Turbellaria were found frequently, but not in high densities. At times Rotifera was found in greater abundance than either Polychaeta or Turbellaria.

Nematoda was the most abundant taxon at all seasons (62 to 64%). Sarcomastigophora was the second most abundant group (18 to 33%). Most major taxa were abundant in October. Although the number of taxa did not show much seasonal difference , the variety at each station tended to increase slightly in October. Moreover, the horizontal distribution of most taxa was wider in October than in July and January. The diversity of meiofauna showed slight variation among stations. The number of taxa, however, tended to be fewest at St. 2 which was near organic point sources.

Total meiofauna densities varied among stations and seasons (Fig. 2). Four different areas may be delineated using the average density of meiofauna : St. 4 (65 ind 10 cm^{-2}), Sts. 3 and 6 (246 to 316 ind 10 m^{-2}), Sts. 1, 2 (646 to 836 ind 10 m^{-2}) and the highest density area, Sts. 5, 7 (1081 to 1596 ind 10 cm^{-2}). The highest density was found at St. 7 followed by St. 5. Meiofauna was in high abundance during the transitional period between the SW monsoon season and the NE monsoon season in October (455 to 2490 ind 10 cm^{-2}) at almost all stations. Meiobenthos was most abundant at station 4 (126 ind 10cm^{-2}) during the SW monsoon season when salinity was highest. During the other two periods individuals ranged from 32 to 36 ind 10 cm^{-2})

The vertical distribution of total meiofauna at most stations was obvious. The number of individuals decreased with depth. The highest density ranged from 46 to 6227 ind 10 cm^2

Table 1 Summary environment and habitat characteristics for study stations.

Station	Environment / Habitat Characteristics
St. 1	adjacent to the sea, seagrass bed *(Halophila ovaris* and *Halodule piniforlia*), disturbed by ships
St. 2	adjacent to households and factory discharges
St. 3	adjacent to a small shrimp farm
St. 4	in front of the inlet from the middle lake; it is more affected by freshwater than other stations
St. 5	seagrass bed (*Halophila beccarii*)
St. 6	no activity
St. 7	adjacent to organic discharge from U-Taphao and Phawong Canal

Table 2 List of meiofaunal taxa found by month of sampling and station. Figures in parenthesis indicate average density (ind 10 cm-2).

Taxa	July 1995 (SW monsoon)	October 1995 (SW-NE monsoon)	January 1996 (NE-Dry season)
Nematoda	1-7 (389)	1-7 (715)	1-7 (127)
Sarcomastigophora	1-7 (228)	1-7 (213)	1-7 (36)
Ostracoda	1-7 (12)	1-7 (4)	1-7 (1)
Copepoda	1-7 (14)	1-7 (25)	1-7 (5)
Nauplius (Copepoda)	1-7 (9)	1-7 (7)	1-7 (4)
Ciliophora	1-7 (1)	1-7 (181)	1-7 (17)
Polychaeta	1-7 (2)	1-7 (1)	1-7 (< 1)
Turbellaria	1-7 (3)	1-7 (6)	1-7 (< 1)
Oligochaeta	1-7 (< 1)	2,3,4,6,7 (< 1)	1,2,5 (< 1)
Amphipoda	1,3,5,6,7 (< 1)	1,3,4,6,7 (< 1)	1,3,4,5 (< 1)
Gastropoda	1,7 (< 1)	1,2,6,7 (< 1)	1,3 (< 1)
Rotifera	1,4,5,6,7 (23)	1,2,3,5,6,7 (9)	3,4,5,6,7 (< 1)
Bivalvia	1,3,4,5,6,7 (< 1)	1,3,4,5,6,7 (< 1)	2,3,5,6,7 (< 1)
Kinoryncha	6 (< 1)	1,3,5,6,7 (1)	1,2,3 (< 1)
Halacaroidea	5,7 (< 1)	1,2,3,4,6,7 (< 1)	3,6,7 (< 1)
Pycnogonida	1 (< 1)	-	-
Tanaidacea	6 (< 1)	-	2,4 (< 1)
Unknown eggs	1,2,4,5,6,7 (7)	1-7 (1)	1,2,3,4,6,7 (2)

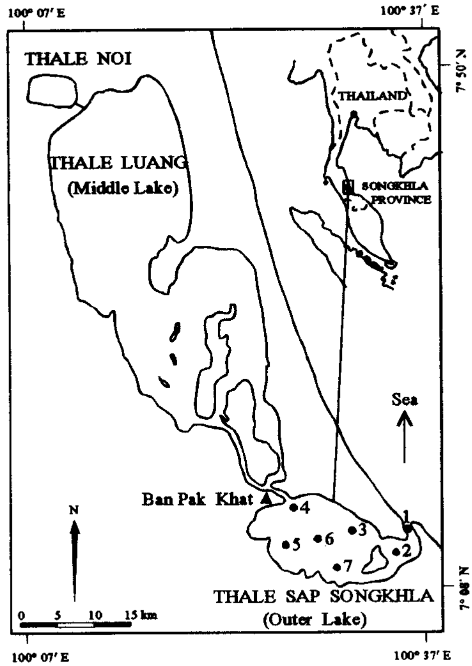

Fig. 1 Songkhla Lake and study area (Thale Sap Songkhla).

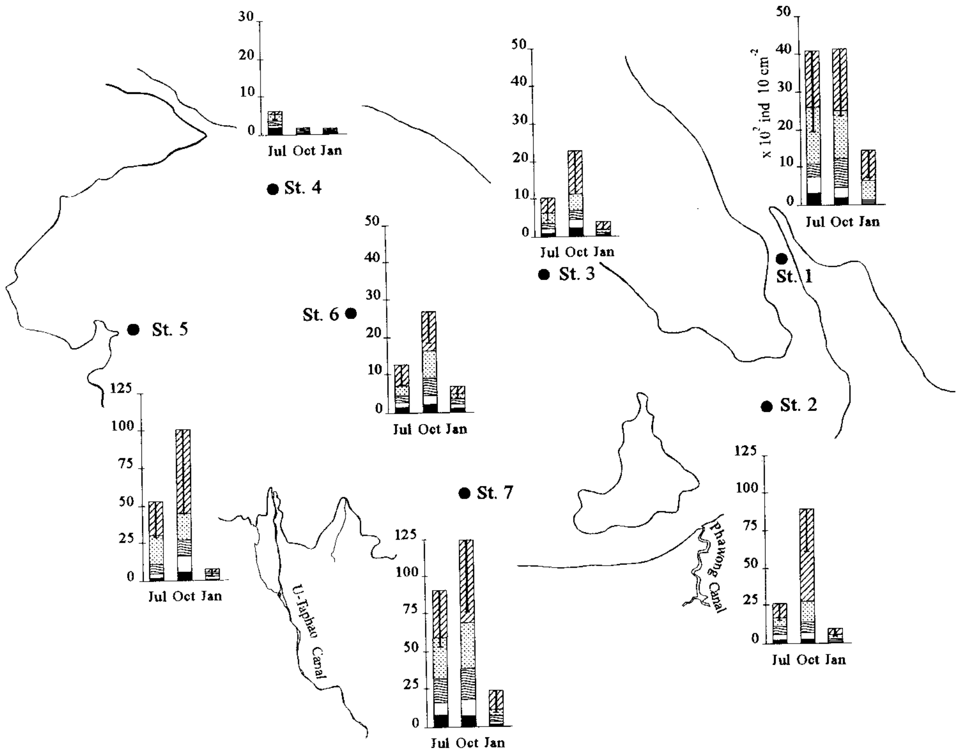

Fig. 2 Seasonal variation of total meiofauna densities (10^2 ind 10 cm^{-2}) and vertical distribution of 1-cm intervals from the surface (▨= 1, ░= 2, ≚= 3, □= 4, and ■ = 5). Bar show S.E.

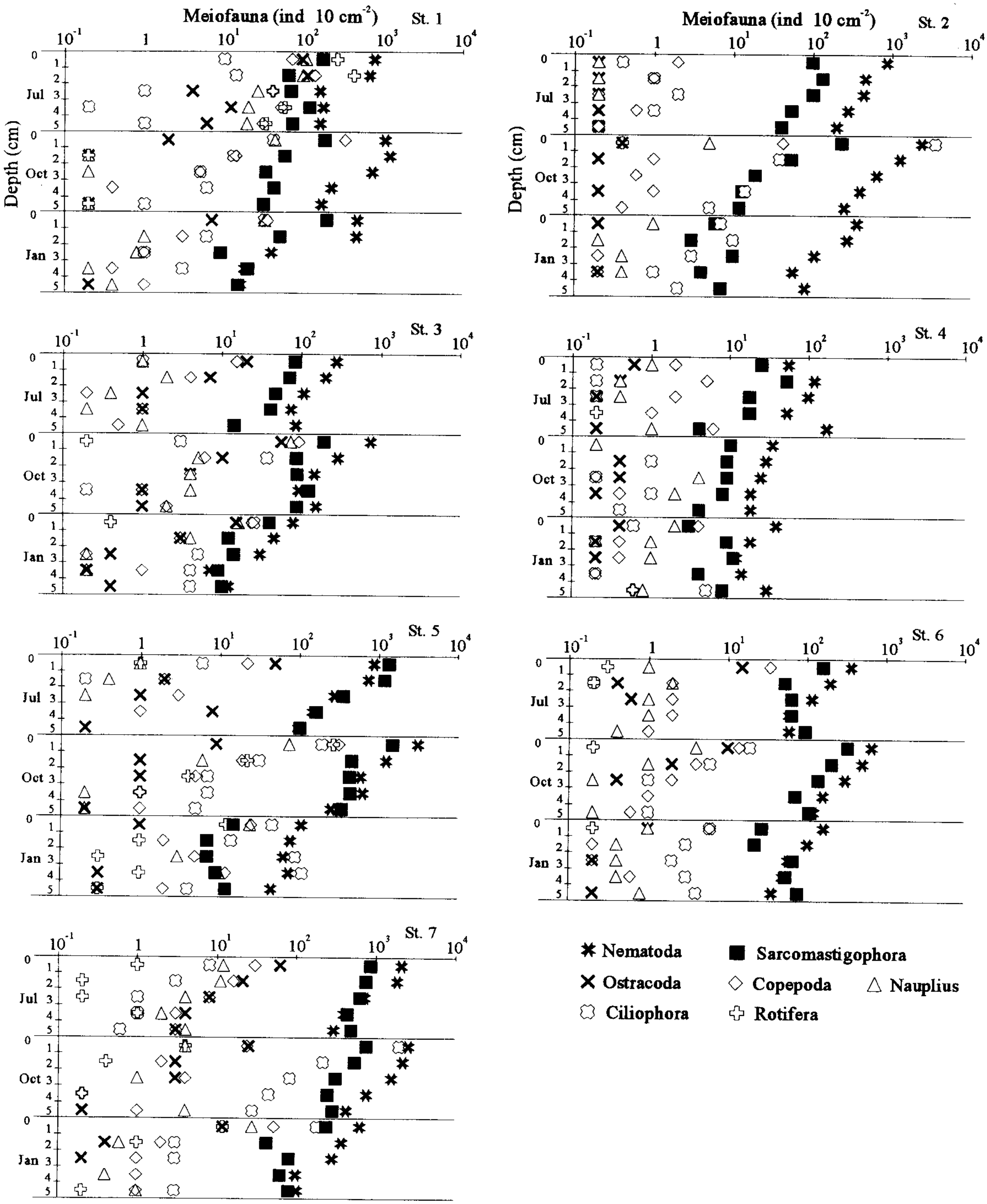

Fig. 3 Vertical distribution by centimeter (ind 10 cm-2) for the seven dominant meiofauna taxa in Thale Sap Songkhla.

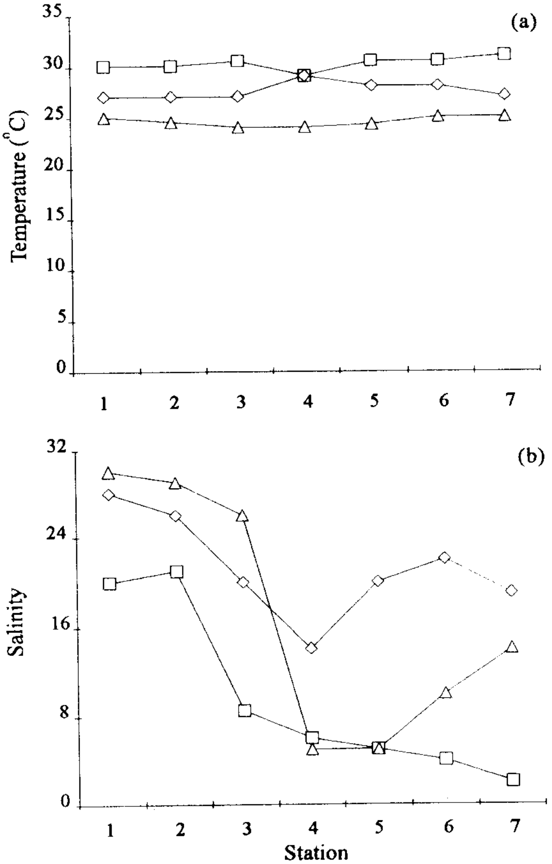

Fig. 4 (a) Water temperature and (b) water salinity during the sampling period (◇ = July, □ = October and △ = January).

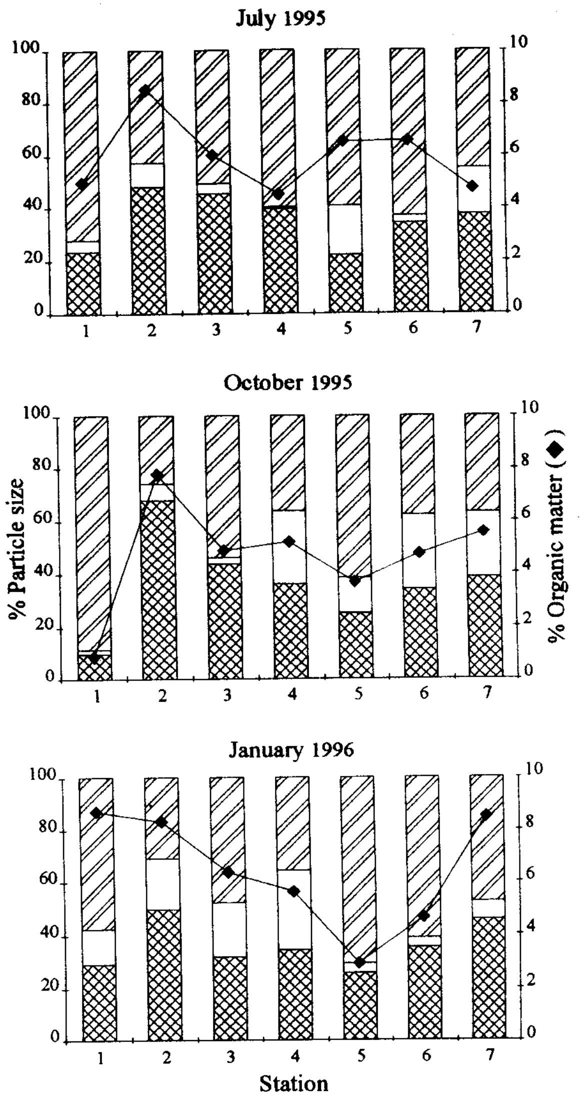

Fig. 5 Sediment size (▩ = % clay, □ = % silt and ▨ = % sand) and organic matter (%).

while the lowest densities were found at the fifth centimeter (12 to 431 ind 10 cm^{-2}). Except for St. 4, vertical distribution was rather irregular in every season. The highest density at the upper 1 cm (6227 ind 10 cm^{-2}) was found at St. 2 followed by St. 5 (5578 ind 10 cm^{-2}) and St. 7 (5558 ind 10 cm^{-2}) in October .

Fig. 3 shows the vertical distribution and densities of the seven major taxa of meiofauna at each station.

Nematodes, the most dominant taxon at all stations, ranged from 22 to 1537 ind 10 cm^{-2}. The highest density was found at St. 7 (977 ind 10 cm^{2}) in October, followed by St.5 (555 ind 10 cm^{-2}) and St.2 (535 ind 10 cm^{-2}). Most assemblages were found in the upper 1 cm and numbers decreased dramatically with depth. In January, when the total meiofauna counts decreased, the vertical distribution was indistinct.

Sarcomastigophora, was the second most dominant taxon at most stations. Most were soft-walled foraminifera. Numbers ranged from 6 to 634 ind 10 cm^{-2}, with exception at St. 5 in July when the density was higher than nematodes. The greatest abundance was found at Sts. 5 and 7, with the highest densities in July (622 ind 10 cm^{-2}) and October (634 ind 10 cm^{-2}). Their vertical distributions were obvious only in July and October. The largest assemblage was at the sediment surface.

Copepoda (mostly harpacticoid) were more abundant at St. 1 (65 ind 10 cm^{-2}) and St. 5 (69 ind 10 cm^{-2}) than other stations. The average density ranged from 0 to 69 ind 10 cm^{-2} and they were most abundant in October. Copepoda nauplii were most abundant in July especially at St. 1, and although vertically distributed, they were not found at every depth.

Ostracods were found at all stations, almost exclusively at the upper 1 cm of sediment. The greatest abundance, over one-hundred individuals were collected only once in July at St 1.

At times ciliates were very abundant such as at St. 2 (3534 ind 10 cm^{-2})and St. 7 (1987 ind cm^{-2}) in October. The greatest assemblage was at the upper 1 cm of sediment. Vertical distribution also occurred.

Rotifers were sparse, found only at St. 1 in July (116 ind 10 cm^{-2}) and St. 5 in October (59 ind 10 cm^{-2}).

Physico-chemical characteristics

Water temperature - Water temperature ranged from 24 to 31°C (Fig. 4a). The temperature in January was slightly lower. There was no temperature difference among stations.

Water salinity - Salinity varied greatly among stations and seasons (Fig. 4b). Salinities at the inner stations were lower than those at the mouth of Thale Sap Songkhla. In October, the salinity decreased to 2 PSU at St. 7.

Sediment particle size - The particle size distribution varied slightly among stations (Fig. 5). The mean coarse sand fraction was highest at St. 1 (59 to 89%) followed by St. 5 (59 to 71%). The highest clay fraction was found at St. 2 (48 to 68 %). The silt fraction was not dominant at any station. The percentages of these three fractions showed little seasonal change and sediment texture patterns were rather stable.

Organic matter in sediment - The organic matter (Fig. 5) ranged from 0.9 to 8.7% (St. 2). The seasonal variation did not change significantly except at St. 1.

DISCUSSION

Kjerfve[14] classified Songkhla Lake as a choked lagoon that is influenced by a single seawater entrance. The salinity of Thale Sap Songkhla water varies seasonally due to rainfall, land drainage and tides. During the rainy period in October the salinity gradually decreases and organic and inorganic input increases[15]. A dramatic increase in meiofauna density is noted in October (1.7 times more than in July and 6 times more than in January).

Although the overall mean meiofauna density per 10 cm^2 in Thale Sap Songkhla is lower than that in Chilka Lagoon, India[16], the number of Chilka taxa (14) is slightly lower. The significance of meiofauna as a food source for higher trophic levels contributes to their decline in July and October, especially at Sts. 1, 2, 5 and 7. The average meiofauna density found in the soft bottom of Thale Sap Songkhla is about 8 times higher than that of sandy beach in front of the area studied by Tochua *et al.*[17].

In muds and sediments heavy in detritus, meiofauna are often restricted to the upper few mm or cm of oxidized materials[6]. Vicente[18] found that the vertical distribution of meiofauna was significantly decreased at 2 cm intervals. Similarly, we found that all major taxa showed the greatest density at the upper 1 to 2 cm of sediments. In muddy sediments about 90% of the nematodes are confined to the top 5 cm[19]. At a depth of 5 cm Thale Sap Songkhla sediments still contained several nematodes and sarcomastigophorans, while other taxa were very rare.

Nematodes usually dominate over all meiofauna samples both in abundance and biomass, and represent the most common metazoans[20]. In marine sediments nematodes are the most abundant meiofauna organisms[19]. Aryuthaka[21] reported that nematodes were the most abundant taxon on the east coast of the Gulf of Thailand; our findings in Thale Sap Songkhla are similar.

Nematoda and Copepoda are the most abundant taxa in typical meiobenthic assemblages[6]. The percentages of nematodes of Thale Sap Songkhla (62 to 64%) were very similar to those of the central and southern sectors of Chilka lagoon of India (61 to 65%) as recorded by Sarma and Rao[22]. But, the copepod density found in Thale Sap Songkhla (2 to 8%) was quite low compare to Chilka lagoon (5 to 20%) where copepod were second in importance. Sarcomastigophorans were second in importance (18 to 33%) in Thale Sap Songkhla. Castel[23] suggested that nematodes and harpacticoid copepods are not always the most abundant taxa in lagoons because of variety of habitats. We noted that sarcomastigophorans were common at St. 5 and St. 7. The derived organic sources by leached and decayed seagrass materials[7] at St.5, and from Phawong Canal[24] and U-Taphao Canal[25] at St.7 support the abundance of forams[22]. Giere[20] reported that dissolved organic matter is favored by soft-bodied meiobenthos. Soft-walled forams, which are mostly found here, are nourished by enriched dissolved organic matter in the pore water. Fine-grained sediments at St.5 provide a better habitat for foraminiferans than the seagrass area at St.1 which contained more coarse sands. In general, foraminiferans are less abundant in coarse sands than in muds[26].

We attribute the luxuriant growth of Ciliophora in October at Sts. 2 and 7 to organic input by nearby households and frozen food factories. At that time precipitation increases and seawater intrusion decreases. This nutrient enriched water increases the high bacterial density that in turn supplies the major food for ciliates[27]. Stations covered with seagrasses are the best habitat for harpacticoid copepods[28] although they are not the predominant taxon in Thale Sap Songkhla. Epiphyte-covered decaying seagrass blades in October[7] and trapped detritus[29] increase copepod abundance[30,31].

Besides harpacticoid copepods, other meiofauna are also abundant in the seagrass system[32]. In our study the high abundance of meiofauna was not only found at seagrass beds but was more abundant at other stations affected by organic input. Shallow water and areas disturbed by long-tail fishing boats at St.1 created turbulence around seagrasses. This is sufficient to affect meiofauna density by suspending individuals above sediments[33,34]. The similar meiofauna densities of the upper 1 and 2 cm at St.1 supports this.

Our study showed no significant correlation between meiofaunal abundance and physico-chemical characteristics, but trends were observed. For example, the lowest densities of meiofauna were found in the low temperature season (January) at all stations, and the highest densities were found in October at most stations when the salinity declined. Data suggested that in general the decreased salinity was accompanied by an increased number of individuals. During the salinity decline in the transitional period in October the abundance of dissolved organic substances in fresh water runoff contributed much to the growth of organisms.

Euryhaline animals in saline lagoons and estuaries are physiologically adapted to withstand wide fluctuations in salinity[35]. The peaks of meiofauna in a brackish-water lagoon are influenced by their food supply (the growth of the Aufwuchs) or are affected by salinity and temperature[36]. In January, the meiofauna density was low although the salinity had increased. The long period of very low salinity (1 to 4 PSU) through Thale Sap Songkhla in December[8] inhibits meiofauna reproduction. Numbers of organisms were lowest in January when the salinity was low but gradually increasing. The food supplied by freshwater runoff during the heavy rainy season in November and December[8] seemed to be less important for inducing growth of all meiofauna taxa when salinity was very low. We attribute the decrease in meiofauna density in January to the grazing of larger macrofauna[1], such as juvenile fishes and shrimp[2,4,5,37]. The high density of mullet significantly decreased abundanes of total meiofauna[38]. The decline in total meiobenthic abundance at the muddy site was coincident with the annual arrival of many benthic feeding juvenile fishes in the estuary[39]. Therefore, The large number of macrofauna in October[9] and the large number of small fishes (Mugilidae and Clupeidae) collected in Thale Sap Songkhla during the heavy rainy season in December[40] also reduces the meiofauna . Zoobenthos production was reported to constitute a large proportion (86%) of secondary production in shallow lakes[41]. The meiobenthos supports not only benthic feeding juvenile fishes but also planktivorous fishes. Hicks[30] and Walters[42] discussed the diel vertical migration of meiofauna entering the water column; in Thale Sap Songkhla we suppose that the meiofauna organisms are subject to predation by fishes and shellfishes.

Other studies reported that the meiofauna distribution was positively correlated to organic matter in sediments[43,44]. Our study found no similar correlation. However, the major meiofauna assemblages occurred at stations affected by organic discharge (St.2 and St.7) and at seagrass stations (St.1 and St.5). The high content of particulate organic matter at all stations may not be the sole factor for governing the difference of meiofauna density among stations. Relexans et al.[45] found that the distribution of meiofauna abundance at the West Gironde mud patch (France) did not follow the same gradients as pigments and particulate organic carbon, and presumably depended on other environmental factors.

McLachlan *et al.* 1977 and Tietjen 1977 (cited in Ravenel and Thistle[46]) demonstrated that the importance of sediment types in controlling meiofauna composition was shown for subtidal sediments in studies which correlate faunal densities with sediment type. However, the different species (*e.g.* harpacticoid copepods) preferred different types of sediments which may be influenced by external characteristics[46]. Although sediment grain size is a primary factor effecting the abundance and species composition of meiofauna, other environmental factors must be considered e.g. temperature, salinity, water movement, oxygen content, seasonality and others[47]. Increased organic productivity is not always beneficial and at times the increased production is accompanied by a decrease in available oxygen. Due to their much wider oxygen tolerances, nematodes may be found in extremely low oxygen levels where fishes can not feed upon them. Additionally, oxidation of contaminants is curtailed by deoxygenation attributed to high meiobenthic consumption. At high levels of organic enrichment there is a decrease in both meiofaunal abundance and diversity of species, and an increase in species dominance[48].

Our results suggest that the meiofaunal fluctuation in brackish-water lagoon depends on the combination of salinity, food supply and temperature. The most influential factors may be the most extreme factors.

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บทคัดย่อ

ศึกษาสัตว์หน้าดินขนาดเล็กในดินตะกอนในทะเลสาบสงขลาซึ่งเป็นน้ำกร่อย พบสัตว์หน้าดินขนาดเล็ก 18 กลุ่ม Nematoda เป็นกลุ่มเด่นที่สุด (62-64%) ทุกสถานี และรองลงมา คือ Sarcomastigophora (18-33%) Copepod เป็นกลุ่มที่พบไม่บ่อย แต่มีแนวโน้มว่าชุกชุมในบริเวณที่เป็นหญ้าทะเล ปริมาณสัตว์หน้าดินขนาดเล็กทั้งหมดแปรผันตามสถานีและฤดูกาล โดยพบชุกชุมมากที่สุดที่สถานีที่อยู่ใกล้แหล่งปล่อยน้ำทิ้งและหญ้าทะเล พบเฉลี่ยอยู่ในช่วง 65-1596 ตัว ต่อ 10 ตารางเซนติเมตร สัตว์หน้าดินขนาดเล็กมีความชุกชุมในช่วงเปลี่ยนฤดู (เดือนตุลาคม) ระหว่างฤดูมรสุมตะวันตกเฉียงใต้และฤดูมรสุมตะวันออกเฉียงเหนือ (36-2490 ตัว ต่อ 10 ตารางเซนติเมตร) และชุกชุมน้อยในช่วงปลายฤดูมรสุมตะวันออกเฉียงเหนือในเดือนมกราคม (32-477 ตัว ต่อ 10 ตารางเซนติเมตร) ส่วนจำนวนกลุ่มเพิ่มขึ้นเล็กน้อยในเดือนตุลาคม การแพร่กระจายตามแนวดิ่งของสัตว์หน้าดินขนาดเล็กแต่ละกลุ่มเกิดขึ้นทำนองเดียวกัน โดยพบความชุกชุมมากที่สุดที่ผิวดินหนึ่งเซนติเมตรแรก (32-6227 ตัว ต่อ 10 ตารางเซนติเมตร) สัตว์หน้าดินขนาดเล็กจะเป็นแหล่งอาหารที่สำคัญของสัตว์หน้าดินขนาดใหญ่ในบริเวณนั้น แม้ว่าอุณหภูมิของน้ำ ความเค็ม สารอินทรีย์ในดิน และขนาดอนุภาคเม็ดดินตะกอน ไม่มีความสัมพันธ์กับปริมาณสัตว์หน้าดินขนาดเล็กอย่างมีนัยสำคัญ แต่การทำงานร่วมกันของปัจจัยเหล่านี้น่าจะเป็นตัวควบคุมประชากรสัตว์หน้าดินขนาดเล็กในทะเลสาบสงขลา