Asian Marine Biology 8 (1991): 45-56

AN ECOLOGICAL STUDY OF THE ZOOPLANKTON IN WESTERN XIAMEN HARBOUR, CHINA

Dai Yanyu, Lin Jinghong, Lin Mao, Chen Luixing and Huang Yijing

Third Institute of Oceanography, State Oceanographic Administration, Xiamen, China

Abstract

This report analyses zooplankton species composition and abundance and their relationship with water masses that influence Western Xiamen Harbour and are based on samples obtained between April 1989 and March 1990. The results show that of the 112 species collected, the most abundant were *Labidocera euchaeta, Pleurobrachia globosa, Pseudeuphausia sinica, Centropages tenuiremis, Sagitta bedoti, Calanopia thompsoni* and *Lensia subtiloides* which are low salinity neritic species characteristic of zooplankton communities dominated by neritic species, in subtropical estuaries. Species abundance and biomass are closely related to water temperature and salinity. In high temperature and high salinity summer, zooplankton species composition and biomass reached highest values while in low temperature winter, they were lowest. Horizontal distribution data suggest that the zooplankters were subject to the influences of the Jiulong River and other currents outside the harbour. In the mouth of the harbour, where various water currents have a stronger influence, both species and biomass were higher than in the inner harbour. Zooplankton of this region can be divided into four ecological groups, e.g., neritic warm-water, neritic warm-temperate, estuarine and oceanic eurywarm-water. The former could be recognized everywhere whereas the estuarine group only occurred at stations where salinity was < 26‰, that is, under the influence of the Jiulong River. The oceanic eurywarm-water species could only be obtained occasionally at stations in the harbour mouth. Zooplankton distribution reflects the environmental characteristics of Western Xiamen Harbour.

Introduction

The study of zooplankton in Xiamen Harbour has a long history (Zhen 1955; Huang 1983), but has mainly focussed on the Jiulong River estuary. Western Xiamen Harbour has become semi-enclosed since a causeway was built in 1956, and the natural environment has changed subsequently. In recent years, the discharge of domestic sewage and factory effluents due to the rapid development of industry along the coast has influenced aquaculture farms and sometimes created red tides (Zhang *et al.* 1988). This investigation of the environmental capacity of the harbour was conducted between April 1989 and March 1990. The paper mainly describes the zooplankton composition and biomass and their variations in relation to environment factors.

Materials and methods

The data used in this paper is obtained from analysis of zooplankton samples collected from 7 stations in Western Xiamen Harbour (Fig. 1). Samples were collected every month at the time of high tide. Two extra samples were taken in both early May and late June during the red tide season, making a total of 16 sampling cruises for the year. All of the 112 obtained samples were hauled vertically from bottom to surface in shallow water with a plankton net (50 cm mouth diameter, 145 cm long, 0.2m^2 mouth area, 0.505–0.507 mm mesh aperture) and were preserved in 5% formalin. The zooplankton samples were subsequently filtered and weighed. After medusae and Thaliacea had been isolated, such values then transformed into wet weight (w.w.)·m^{-3} as follows:

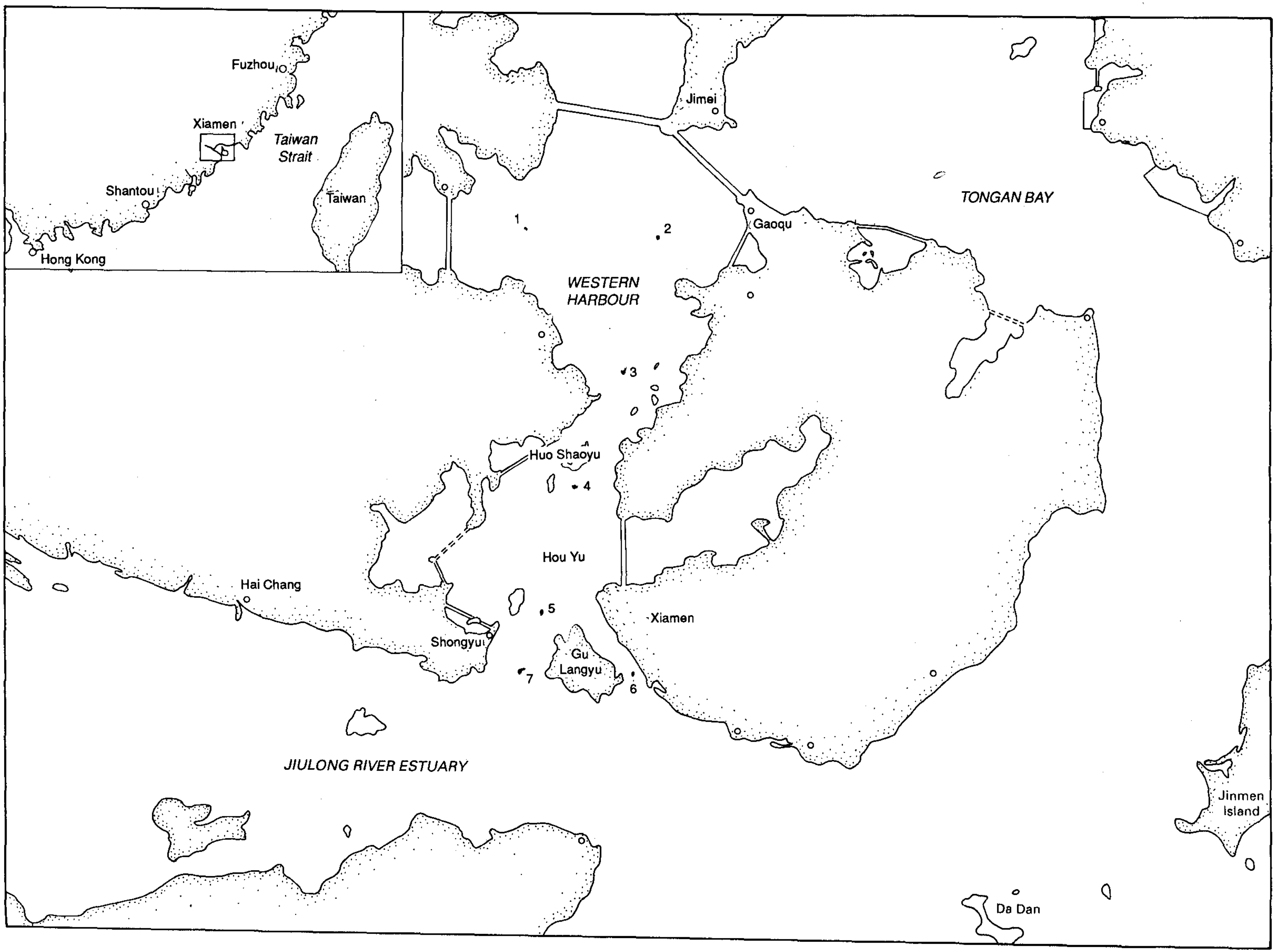

Fig. 1. Stations in Western Xiamen Harbour where zooplankton samples were collected from April 1989 to March 1990.

$$A = \frac{a}{c \times b}$$

where A is the total zooplankton biomass,
a is the zooplankton w.w. (mg·haul = –1)
c is the net mouth area (m^2), and
b is the length of the haul cable (m).

Water temperature and salinity data were obtained by averaging surface values at every station.

Results

Species composition and seasonal distribution of zooplankton

One hundred and ten species of zooplankton were identified (Table 1). These comprised Copepoda (43), Hydromedusae (34), Siphonophora (4), Ctenophora (2), Chaetognatha (7), Mysidacea (4), Decapoda (4), Pteropoda (2), Thaliacea (1), plus fish eggs and larval fishes as well as pelagic larvae. Dominant species were as follows: *Labidocera euchaeta, Pleurobrachia globosa, Pseudeuphausia sinica, Centropages tenuiremis, Sagitta bedoti, Calanopia thompsoni, Lensia subtiloiodes* and *Calanus sinicus*. The majority of the above are neritic eurywarm-water, a minority were warm-temperate. In addition to the neritic species which occur in both Xiamen and Hong Kong, more euryhaline warm-water species and oceanic species such as *Sagitta pacifica, Diacria quadridentata, Candacia bradyi, Undinula vulgaris* and *Chelophyes contorta* occur in Hong Kong (Chen 1982), the latter species also occurring in the centre of the South China Sea. In Xiamen Harbour, the majority of species are neritic low salinity species rather than oceanic. Except for the less oceanic eurywarm-water species, the dominant species in Xiamen Harbour are basically the same as those which occur in Dongsan Bay, from where data were collected during May 1988 and January 1989. The zooplankton of this region of the southern coast of China can thus be characterized as neritic species typical of a subtropical estuary.

Table 1. A list of zooplankton species recorded from Western Xiamen Harbour.

Hydromedusae
Dipurena ophiogaster Heackel
Sarsia sp.
Rumus xiamenensis Zhang and Wu
Euphysora bigelowi Mass
Turritopsis lata von Lendenfeld
Podocoryne apicata Kramp
Podocoryne minima (Trinci)
Rathkea octopunctata (Forbes)
Bougainvillia ramosa (van Beneden)
Phialella macrogona Xu and Huang
Phialidium chengshanense (Ling)
Phialidium folleatum (McCrady)
Phialidium hemisphaericum (Linneaus)
Eucheilota macrogona Zhang and Lin
Eucheilota ventrcularia McCrady
Eucheilota tropica Kramp
Lovenella asimilis (Browne)
Blackfordia manhattensis (Mayer)
Octophialucium indicum (Kramp)
Phialucium carolinae (Mayer)
Eirene ceylonensis Browne
Eirene kambara Agassiz and Mayer
Eirene pyramidalis (L. Agassiz)
Helgicirrha malayensis (Stiasny)
Helgicirrha brevistyla Xu and Huang
Eutima modesta (Hartlaub)
Eutima japponica Uchida
Aequorea australis Uchida
Triaricodon coeruleus Browne
Proboscidactyla ornata (McCrady)
Liriope tetraphylla (Chamisso and Eyseuhardt)
Petasiella asymmetrica Uchida
Aeginura grimaldii Mass
Solmundella bitentaculata (Quoy and Gaimard)

Siphonophora
Physophora hydrostatica Forskal
Diphyes chamissonis Huxley
Lensia subtiloides Len and van Riemsdijk
Muggiaea atlantica Cunningham

Ctenophora
Pleurobrachia globosa Moser
Beroe cucumis Fabricius

Chaetognatha
Sagitta nagae Alvarino
Sagitta enflata Grassi
Sagitta bedoti Beraneck
Sagitta neglecta Aida
Sagitta ferox Doncaster
Sagitta pulchra Doncaster
Sagitta delicata Tokioka

Table 1 (cont.)

Pteropoda	
Creseis acicula Rang	
Hyalocylix striata (Rang)	
Cladocera	
Penilia avirostris Dana	
Evadane tergestina Claus	
Ostracoda	
Euconchoecia aculeata (Scott)	
Cypridina dentata (Muller)	
Cycloleberis similis (Brady)	
Copepoda	
Calanus sinicus Brosky	
Canthocalanus pauper (Giesbrecht)	
Eucalanus crassus Giesbrecht	
Eucalanus subcrassus Giesbrecht	
Paracalanus parvus (Claus)	
Paracalanus aculeatus Giesbrecht	
Paracalanus crassirostris Dahl	
Bestiola amoyensis Li and Huang	
Acrocalanus gibber Giesbrecht	
Euchaeta concinna Dana	
Euchaeta plan Mori	
Temora turbinata (Dana)	
Temora discaudata Giesbrecht	
Centropages tenuiremis Thompson	
Centropages furcatus (Dana)	
Pseudodiaptomus marinus Sato	
Schmackeria poplesia Shen	
Calanopia thompsoni A. Scott	
Calanopia elliptica (Dane)	
Labidocera bipinnata Tanaka	
Labidocera euchaeta Giesbrecht	
Labidocera pavo Giesbrecht	
Labidocera acuta (Dana)	
Pontella chierchiae Giesbrecht	
Pontella latifurca Chen and Zhang	
Pontellopsis tenuicauda (Giesbrecht)	
Acartia pacifica Steuer	
Acartia erythraea Giesbrecht	
Acartia spinicauda Giesbrecht	
Acartiella sinensis Shen and Lee	
Tortanus forcipatus (Giesbrecht)	
Tortanus gracilis (Brady)	
Tortanus derjugini Smirnov	
Tortanus dextrilobatus Chen and Zhang	
Oithona similis Claus	
Oithona nana Giesbrecht	
Oithona simplex Farran	
Oithona brevicornis Giesbrecht	
Corycaeus speciosus Dana	
Corycaeus dahli Tanaka	
Microsetella rosea (Dana)	
Microsetella horvegica (Dana)	
Euterpina acutifrons (Dana)	
Amphipoda	
Lestrigonus macrophthalmus (Vosseler)	
Lestrigonus bengalensis Gilos	
Mysidacea	
Gastrosaccus kejimeansis Nakazawa	
Acanthomysis sinensis Di	
Acanthomysis laticauda Liu and Wang	
Acanthomysis crossispinosa Liu and Wang	
Euphausiacea	
Pseudeuphausia sinica Wang and Chen	
Decapoda	
Lucifer hanseni Nobili	
Acetes japonicus Kishinouye	
Leptochela gracilis Stimpson	
Leptochela aculeocaudata Paulson	
Thaliacea	
Dolialetta gegenbauri Uljanin	
Larvae	
Polychaeta	
Macrura	
Porcellana zoea	
Brachyura zoea	
Brachyura megalopa	
Ophiopluteus	
Bipinnaria	
Fish eggs	
Fish larva	

Seasonal changes in zooplankton numbers in Western Xiamen Harbour showed a maximum in summer and a minimum in winter (Fig. 2). Only 24 species were recorded in April. Because of an increase in the number of Hydromedusae and Copepoda, the total number of species obtained in May increased to 56. In June, the number of zooplankton species recorded was 64, mainly due to the appearance of large numbers of Copepoda and other zooplankters. In July and August, the number of zooplankton species fell to between 50–56. This resulted from a decrease in the numbers of Copepoda and Hydromedusae. In September and October, the number of Hydromedusae species was 50% that seen in August. In November, the numbers of zooplankton species increased before falling to only 19 species in December. Such a figure persisted until March of the following year. Only 14 species were recorded from outside the harbour at this time, the lowest for the year.

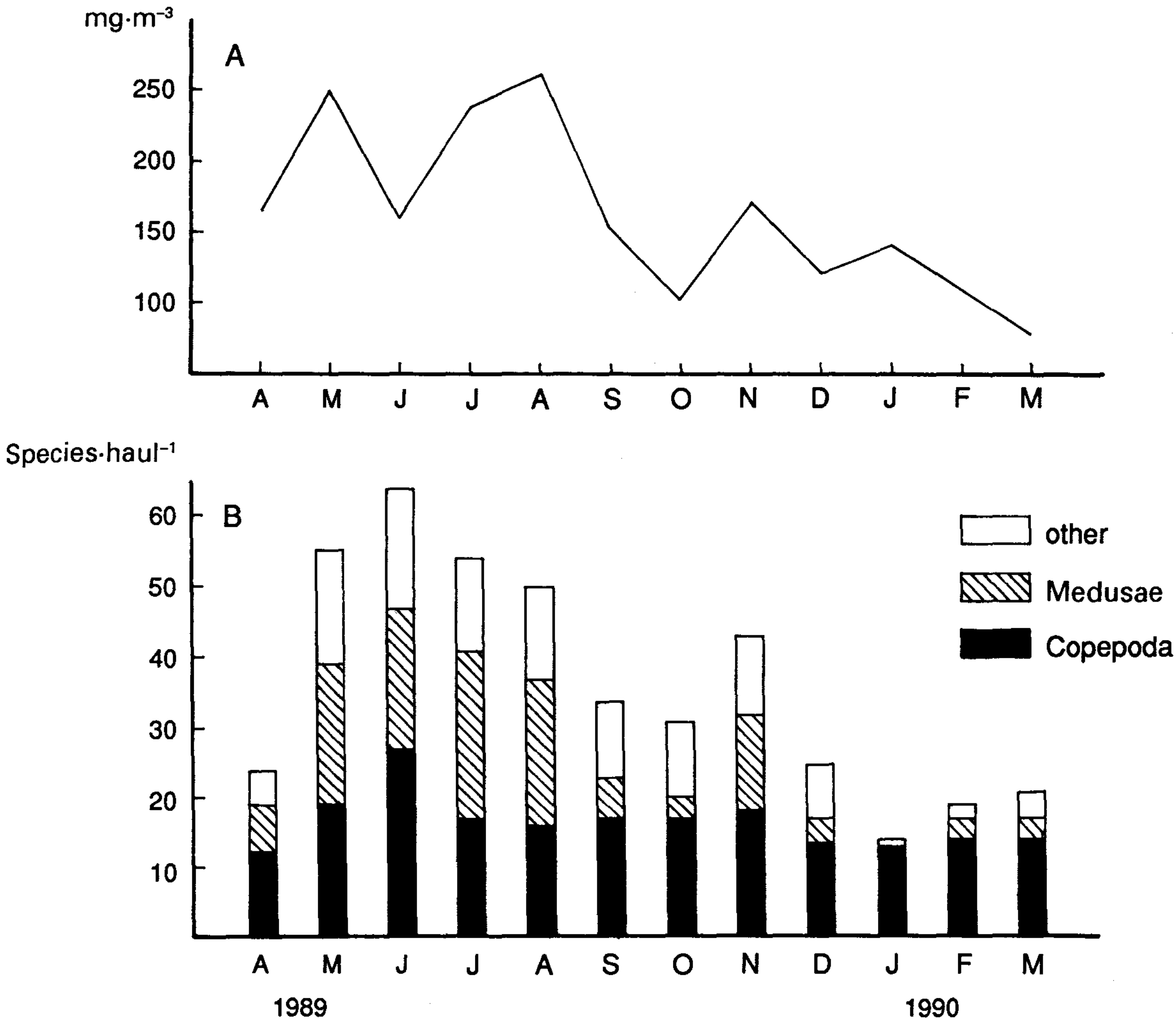

Fig. 2. Seasonal changes in *A*, zooplankton biomass and *B*, numbers, throughout the year in Western Xiamen Harbour.

The horizontal distribution of zooplankton species varied seasonally. Basically, more species occurred outside the harbour (68) than within (27) (Table 2). Water outside the harbour is affected by different currents.

Seasonal variation in and horizontal distribution of the total zooplankton biomass

Seasonal changes in the total zooplankton biomass are distinct in Xiamen Harbour and values were highest (260 mg·m^{-3}) in August 1989, followed by

Table 2. Numbers of zooplankton species recorded from Western Xiamen Harbour.

Station	Species numbers (Annual totals)
1	47
2	52
3	60
4	66
5	61
6	61
7	68

May 1989. During the period from December 1989 to March 1990, zooplankton biomass was low, with the lowest figure being recorded for March (80 mg·m^{-3}) (Fig. 2). Seasonal changes in zooplankton biomass can be related to an alternation in dominance by different species.

In April and May 1990, total zooplankton biomass increased gradually from 160 mg·m^{-3} to 250 mg·m^{-3}. During this time, the most abundant species were *Pseudeuphausia sinica, Sagitta nagae, Calanus sinicus, Centropages tenuiremis* and Brachyura zoea. In June, total zooplankton biomass decreased with the decline of the dominant species, especially *P. sinica*, whose abundance decreased from 23.32 individuals·m^{-3} in May to 0.5 individuals·m^{-3}. In July–August, warm water species appeared in high densities and can be correlated with rising water temperature and salinity.

At this time, the total numbers of chaetognaths, copepods and zooplankton larvae reached a peak, resulting in a peak in total zooplankton biomass. The most abundant species were *Labidocera euchaeta, Sagitta bedoti, Lucifer hanseni, Calanopia thompsoni* and pelagic larvae. In September–October, the density of the species mentioned above decreased greatly with a concomitant decrease in zooplankton biomass. In November, biomass increased rapidly, mainly due to an increase in the abundance of *Pseudeuphausia sinica* and other species. In December–March, the abundance of various zooplankters fell to the annual low in total biomass.

Horizontal distribution

The horizontal distribution of total zooplankton biomass varied from season to season. The distribution of the annual and monthly average biomass values indicate that a high biomass occupies the bay entrance, south of Huo Shaoyu. This may be related to the strong influence here of various external water bodies. The variations in different months can be described as follows. In April, a high total biomass occurred between Hou Yu and Huo Shaoyu, reaching 250 mg·m^{-3}. In May, biomass increased over the whole area but was especially high south of Huo Shaoyu. Biomass values as high as 680 mg·m^{-3} were obtained from Xiagu Channel (Fig. 3), where *Calanus sinicus, Sagitta nagae, Centropages tenuiremis* and Brachyura zoea were dominant. In June, total biomass decreased quickly, with relatively high values occurring only on both sides of Gu Langyu at the bay entrance. In July and August, total biomass everywhere reached 300–400 mg·m^{-3}, except at Bao Zhuyu in the bay head, where the biomass was relatively low (Fig. 4).

In September and October, the overall biomass decreased. In November, biomass increased again and reached 420 mg·m^{-3} in a small area between Huo Shaoyu and Hou Yu (Fig. 5). From December 1989 to March 1990, total biomass decreased, with decreasing water temperature, to a low of 160 mg·m^{-3}.

The distribution of zooplankton in relation to environmental factors

The area surveyed is a semi-enclosed shallow estuary, bordering the Taiwan Straits and close to the outflow of the Jiulong River. As a result, the hydrology of the harbour is influenced by water masses outside the bay and by variations in climate and runoff from the mainland. The environmental factors mentioned above regulate zooplankton diversity and abundance. An analysis of the year-round hydrological data suggests the following interpretation. In spring (March–May), zooplankton species numbers and biomass increase due to temperature and salinity rises though, overall, temperature and salinity remain low in early spring. In March, when the average temperature is 15.1 °C and salinity 25‰, neritic warm-temperate species and low-temperature adapted species occur throughout the harbour while neritic warm-water species, usually occurring in great numbers, become rare, thereby accounting for the lowest recorded total zooplankton biomass at this time. In April, large numbers of neritic, low-salinity, species, such as *Pseudeuphausia sinica, Acartia pacifica* and *Centropages tenuiremis* appear when average water temperature rises to 19.4 °C. In addition to the mass reproduction of warm-temperate species, e.g., *Calanus sinicus* and *Sagitta nagae*, some neritic warm-water species enter the area following the summer rise in water temperature.

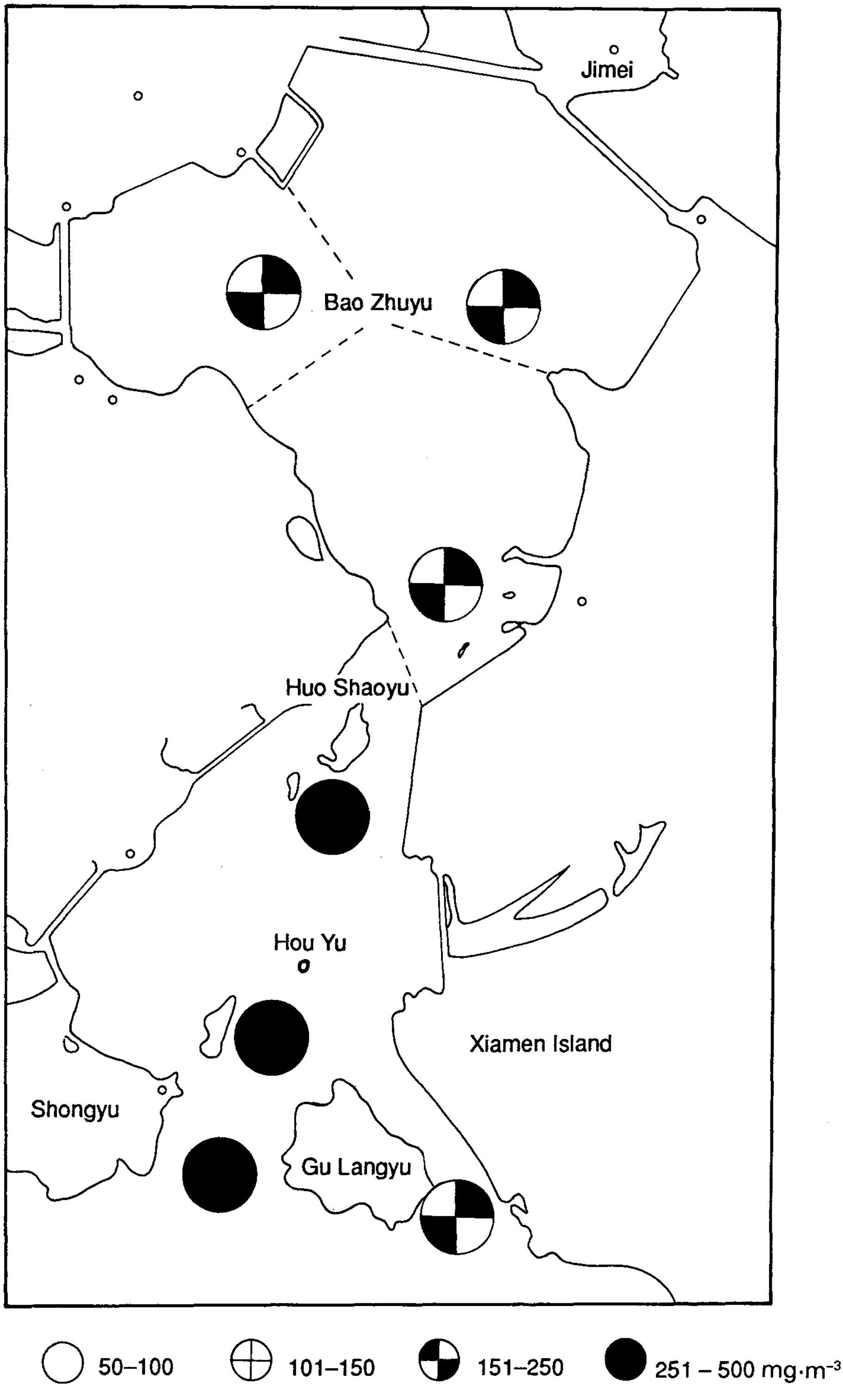

Fig. 3. Horizontal distribution of total zooplankton biomass in Western Xiamen Harbour in spring (May).

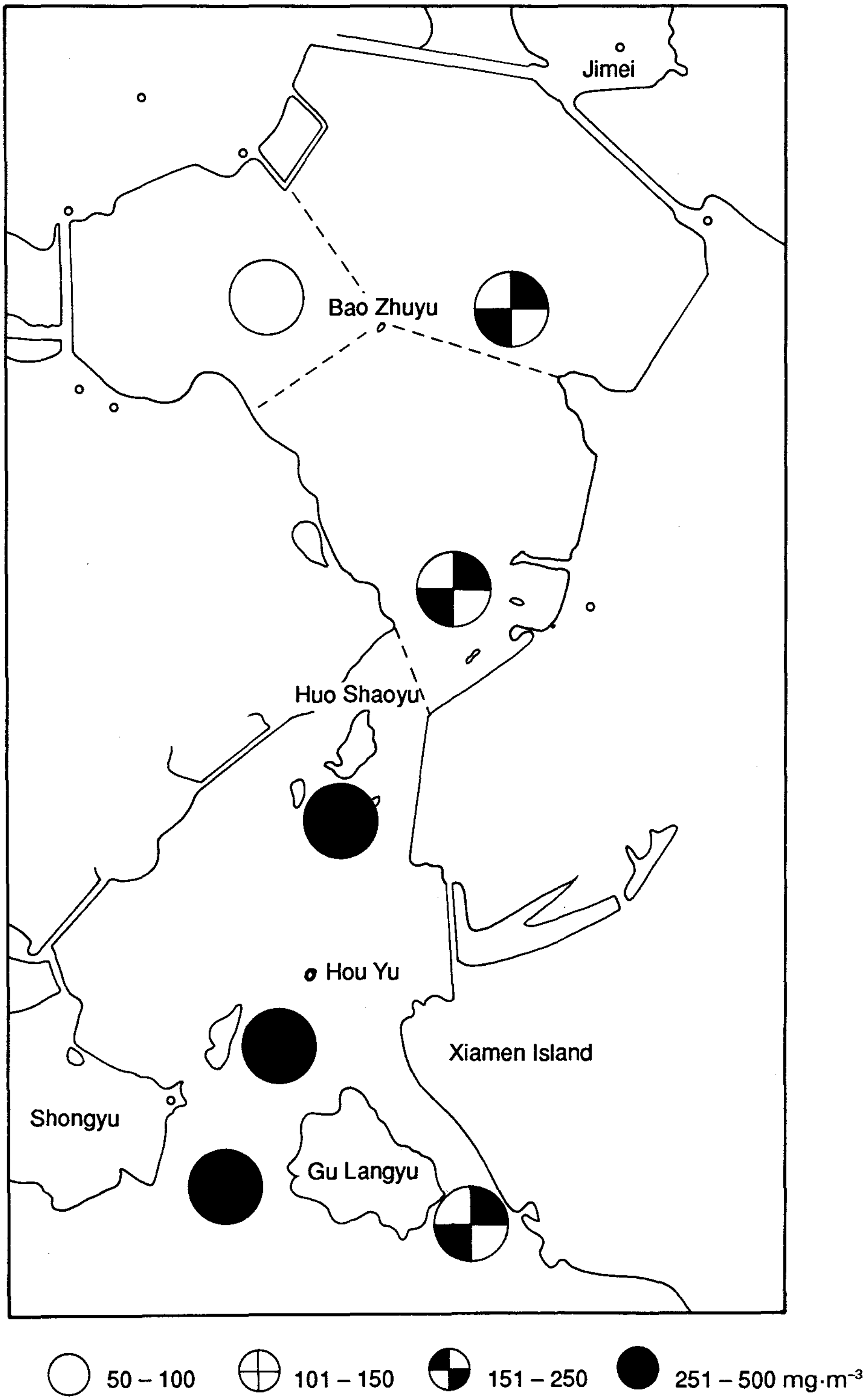

Fig. 4. Horizontal distribution of total zooplankton biomass in Western Xiamen Harbour in summer (August).

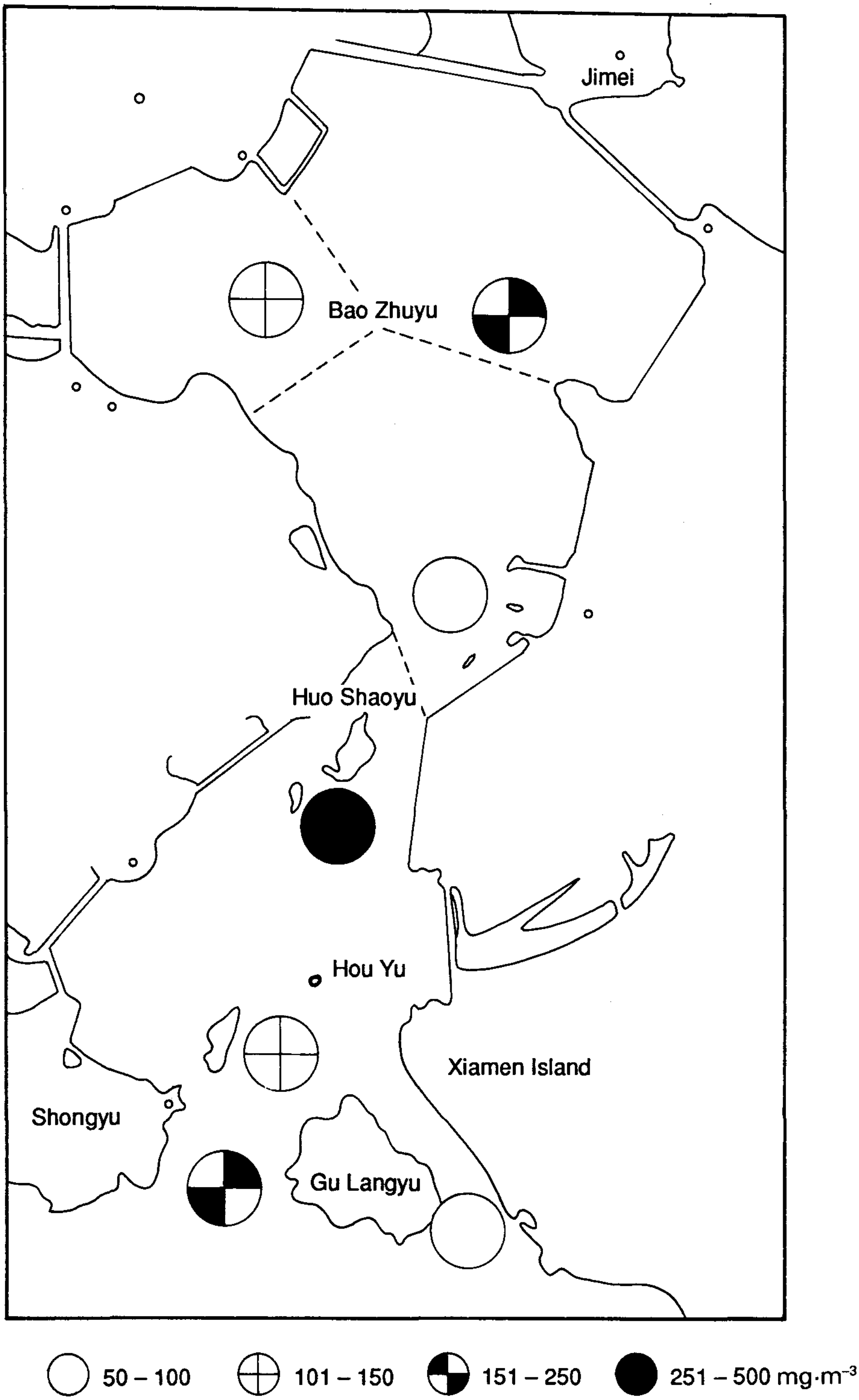

Fig. 5. Horizontal distribution of total zooplankton biomass in Western Xiamen Harbour in autumn (November).

In April, some estuarine low salinity species, e.g., *Triaricodon coeruleus, Schmackeria poplesia, Acartiella sinensis, Tortanus dextrilobatus* and *T. derjugini*, also appear when the discharge from the Jiulong River and surface runoff increases during this rainy month.

In May, the importance of warm-temperate species decreased due to the reduced influence of nearshore water and rising temperatures. In early May, when the average temperature reached 20.5 °C, the dominant zooplankters comprised warm-temperate and neritic low temperature species. They decreased numerically with distance from the shore, especially in the area of Bao Zhuyu, when the average temperature reached 23.2 °C. It is concluded that the distribution of the zooplankton is related to the waxing and waning influence of coastal currents along the coasts of Fujian and Zhejiang Provinces. In contrast, warm water species doubled both in terms of numbers and biomass.

Zooplankton species numbers and biomass reach a peak in summer (June–August) with increased warming of the water. In June, when temperature and salinity reached 26.3 °C and 26.76‰, respectively, estuarine low salinity species disappeared. Warm-temperate species and low-temperature and low-salinity adapted species also declined to a few, and were observable until early June; they disappeared offshore in late June. Warm-water species, however, increased at this time, both in terms of numbers and biomass. Eventually, the number of zooplankton species reached a maximum as high temperature and salinity adapted oceanic warm water species, such as *Eucalanus subcrassus, Physophora hydrostatica* and *Sagitta ferox*, associated with warm currents, entered the area. The strongest warm water influence upon the area occurs in July and August when highest temperatures and salinities are recorded, i.e., 29.9 °C and 30.1 °C and 30.60‰ and 28.03‰, respectively. Important zooplankton species, such as copepods, medusae and chaetognaths, attain maximal numbers at this time. They keep neritic warm water species dominant, at high species numbers and peak biomass. Conversely, with ebbing coastal currents and low salinity water, the number of species decreased, as compared with June, due to the disappearance of some warm-temperate species, low-temperature adapted neritic species and low-salinity estuarine species.

In Autumn (September–November), the wind turns direction. With the north-east wind prevailing at this time, the coastal currents of Fujian and Zhejiang Provinces gradually influence the Taiwan Strait and approach Xiamen. At the same time, the northwesterly wind weakens and the warm water mass that controlled the area in summer recedes while the now prevailing low temperature and salinity environment leads to either a decline or the disappearance of warm-water zooplankton. Species numbers and biomass in September and October were less than half that of August. In November, driven by the north-east wind, coastal currents influence the area and water temperature falls to 21.4 °C. As the warm water species are eliminated, some low salinity estuarine species, absent in high salinity and temperature summer, either enter or increase in numbers in the harbour. A small peak in species numbers and biomass is therefore formed.

In winter (December–February), water temperature in the harbour is significantly lower due to the influence of low radiation, the prevailing north-east wind and cold water arising from the estuary. Since all warm water species have disappeared, the zooplankton numbers species and the total biomass fall to lowest levels in the year. The distribution of zooplankton in this area is, thus, closely related to variations in environmental factors (Table 3).

Ecological groups

According to their ecological and distribution characteristics, the zooplankters obtained from Western Xiamen Harbour can be divided into four categories.

1. *Estuarine, low salinity group.* This group comprises a few species and is distributed in the low salinity water created by runoff from the Jiulong River, during spring and autumn. Typical species are *Schmackeria poplesia, Tortanus dextrilobatus, T. derjugini* and *Triaricodon coeruleus.*
2. *Neritic warm-water group.* As a major group in the survey area, the zooplankton of this

Table 3. **The relationship between temperature and zooplankton species and numbers.**

Season (Month)	Spring (Mar.–May)	Summer (June–Aug.)	Autumn (Sept.–Nov.)	Winter (Dec.–Feb.)
Temperature (°C) (Mean)	18.2	27.8	24.3	16.2
Total numbers of zooplankton species	53	86	57	34
Total numbers of zooplankton (Individuals·m^{-3})	355	824	466	128

category has more species and a higher biomass and is present during all seasons, but especially summer and autumn. A majority of the dominant species belong to this category and include *Labidocera euchaeta, Temora turbinata, Sagitta bedoti, Pleurobrachia globosa* and *Phialidium chengshanense.*

3. *Neritic warm-temperate group.* Although the numbers of species comprising this group are small, they are individually dominant because they are largely influenced by the offshore currents prevailing in winter and spring. Typical species are *Muggiaea atlantica, Sagitta nagae* and *Calanus sinicus.*
4. *Oceanic eurywarm-water group.* This group is adapted to wide variations in salinity and temperature and is widely distributed in oceanic waters. It intrudes into the investigated area, along with warm-water from the sea in summer and autumn and is represented by low individual numbers and a low species occurrence. Representative species are *Eucalanus crassus, E. subcrassus, Dolialetta gegenbauri* and *Sagitta ferox.*

Discussion

The zooplankton biomass and species numbers in Xiamen Harbour show some variation, following the broad pattern of a summer maximum and a winter minimum.

Some warm-temperate species, such as *Sagitta nagae, Muggiaea atlantica* and *Calanus sinicus*, appear in the investigated area, in the western Taiwan Strait and the South China Sea and are an indication of the effects of offshore currents from Fujian and Zhejiang upon this area.

Additionally, a few species usually inhabiting river mouths, such as *Schmackeria poplesia, Triaricodon coeruleus* and *Blackfordia manhattensis* have been recorded to be relatively more abundant when low salinity water influences the area. For this reason, the occurrence of the above species in the investigated area may be related, respectively, to the effects of offshore currents and surface runoff.

Following summer and autumn when higher temperatures and salinities prevail, some eurytopic species, occurring in low numbers, such as *Solmundella bitentaculata, Physophora hydrostatica, Eucalanus subcrassus, Dolialetta gegenbauri* and *Sagitta ferox*, are recorded from the area of southern Huo Shaoyu. High temperature and salinity species are not found, indicating that the warm-water oceanic influence is only weakly felt in this area of mixed water.

Variation in water temperature is an important factor positively influencing zooplankton biomass, abundance and species numbers. Maximum biomass followed periods of high water temperature (August) because the zooplankton can reproduce and grow. A few species inhabit low temperature and salinity water.

References

Chen, Q. C. 1982. The marine zooplankton of Hong Kong. In *The marine flora and fauna of Hong Kong and southern China* (ed. B. Morton and C. K. Tseng), 789–99. Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong, 18 April–10 May 1980. Hong Kong: Hong Kong University Press.

Huang, J. Q. 1983. The species composition and distribution of the middle zooplankton in Jiulong Jiang estuary. *Journal of Xiamen University* 22:88–95 (in Chinese).

Zhang, S. J. *et al.* 1988. Observations of red tide in Western Xiamen Harbour. *Acta Oceanologica Sinica* 10:602–8 (in Chinese).

Zhen, Z. 1955. A preliminary study on marine zooplankton in Xiamen Harbour. *Journal of Xiamen University* 5:1–16 (in Chinese).