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Summer Distribution and Diversity of Copepods in Upwelling Waters of the Southeastern East China Sea

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Cheng-Hsin Liao, Wan-Ju Chang, Ming-An Lee, and Kuo-Tien Lee (2006) Summer distribution and diversity of copepods in the upwelling waters of the southeastern East China Sea. *Zoological Studies* **45**(3): 378-394. We investigated the species composition and distribution of copepods in the East China Sea northeast of Taiwan during the summer of 1998. In total, 95 species of copepods belonging to 43 genera and 21 families were identified. Cluster analysis divided the sampling stations into 3 groups: A, B (comprised of subgroups B_1 and B_2), and C. Group A had the highest mean abundance but the lowest Shannon-Weaver species diversity and evenness index. Subgroups B_1 and B_2 had the lowest mean abundances but the highest values of species diversity and evenness index. Group C showed intermediate values for these factors. Satellite images of sea surface temperatures and in situ conductivity, temperature, and depth (CTD) data showed that group A stations were located in waters influenced by the Taiwan Strait Warm Current; those of subgroups B_1 and B_2 were distributed in waters near the continental slope in a cold-core eddy/upwelling area affected by the Kuroshio Current; and group C stations were in the northern part of the study area and were linked to continental mixed waters. Typical tropical copepod species, such as *Canthocalanus pauper*, *Undinula vulgaris*, *Acrocalanus gibber*, *Paracalanus aculeatus*, and *Temora turbinata* were highly abundant in waters linked to both the Kuroshio and Taiwan Strait Warm Currents. Copepods with low abundance, such as *Clausocalanus minor* and *Oithona plumifera* were consistently found in the cold-core eddy/upwelling area. These results suggest that the distribution, abundance, and species composition of copepods are associated with different water masses in the upwelling waters off northeastern Taiwan. http://zoolstud.sinica.edu.tw/Journals/45.3/378.pdf

Key words: Copepod, Diversity, Upwelling, Water mass, Kuroshio Current.

To date, oceanographic studies of the waters off northeastern Taiwan have focused primarily on physical and chemical flux characteristics (Chen et al. 1995, Liu et al. 1995, Shiah et al. 1995, Gong et al. 1996), and less so on fisheries and biology (Chiu 1991, Huang and Chiu 1998, Shih and Chiu 1998, Liao et al. 1999, Shih et al. 2000). Because these waters are a mixture of water masses from different sources and with different physical and chemical characteristics, the marine communities here are complex and vary according to local oceanographic conditions (Chiu 1991, Chen and Chen 1994, Liao et al. 1999).

Zooplankton comprise one of the most abundant and diverse marine communities and play an important role in energy transfer in marine ecosystems. They serve as the basic food source for larval and juvenile fishes and larger invertebrates (Suárez-Morales 1998, Zheng et al. 2000, Lan et al. 2004). The species composition, abundance, and distribution of zooplankton are, therefore, important factors to the formation of fishing grounds (Biggs et al. 1997, Liao et al. 1999). Recently, international organizations such as GLOBEC (Global Ocean Ecosystem Dynamics) have focused on the distributional characteristics of zooplankton as one of the key issues for monitoring changes in the marine ecosystems

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(USGLOBEC 1991, GLOBEC 1992).

Copepods are the most abundant, diverse, and widely distributed taxonomic group of marine zooplankton. The community structure of copepods is influenced by marine environmental conditions and the dynamics of water masses (Huang et al. 1991, Suárez-Morales 1998, Zheng et al. 2000, Hsieh et al. 2004). The main objective of our study was to investigate the relationship between copepod communities and the hydrographical structure in the upwelling area northeast of Taiwan in the northwestern Pacific Ocean.

Study Area

The waters off northeastern Taiwan are close to the continental slope of the southern East China Sea (Fig. 1), where the Kuroshio Current meets the Taiwan Strait Warm Current and coastal waters of China, resulting in the formation of a hydrographically complex area. There are coral reefs and several small islets, such as Keelung-Yu, Hwa-Ping Yu, Peng-Chia Yu, and Mian-Hwa Yu. In the vicinity of the Mian-Hwa Canyon (25.4°N 122.25°E), a cold-core eddy caused by upwelling of subsurface water associated with the Kuroshio Current persists throughout the year (Liu et al. 1992, Liao et al. 1997). In addition, there is an enormous input of runoff at an average volume of 28 x 10^3 m^3/s from the Yangtze River, the 4th longest river in the world, into the East China Sea (Cunningham and Cunningham 2002). The upwelling and runoff together maintain a constant supply of nutrients and, therefore, help sustain high primary productivity in the area (Liu et al. 1992 2000, Gong et al. 1995 1996 2000). This high primary productivity has made the waters off northeastern Taiwan one of the most productive neritic fishing grounds around Taiwan (Chiu 1991, Liao et al. 1997 1999).

MATERIALS AND METHODS

Prior to our sampling program being carried out, sea surface temperature (SST) data from the Advanced Very High Resolution Radiometers (AVHRR) of the National Oceanic and Atmospheric Administration's (NOAA) satellites nos. 14 and 15 were obtained from the archives of the Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University. They were used to produce a satellite SST image of the waters off northeastern Taiwan for 25 Aug. 1998

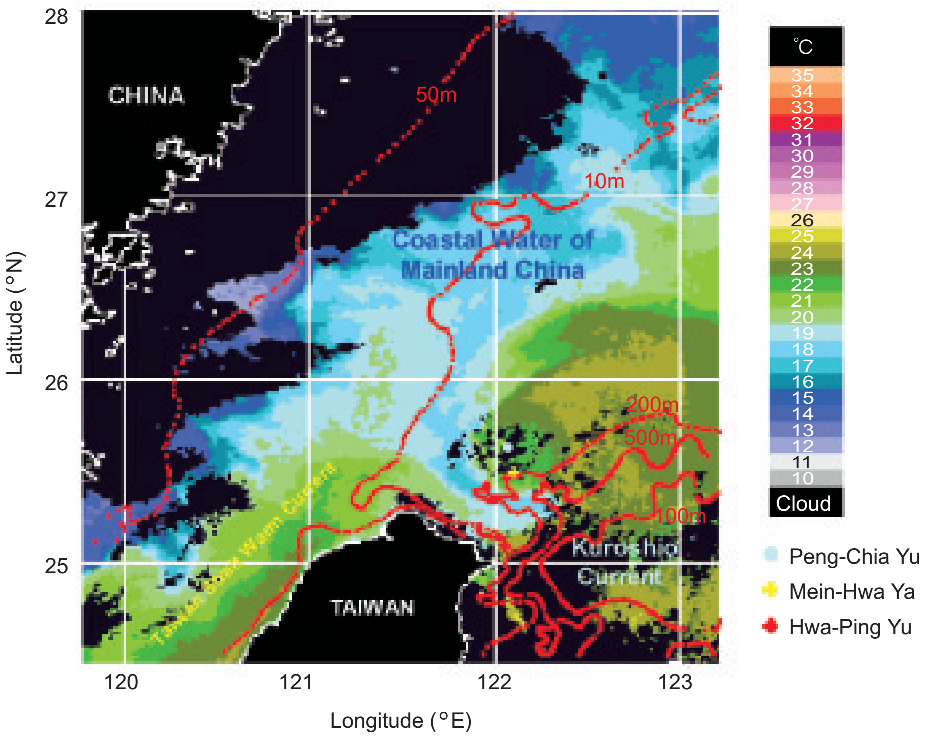


Fig. 1. Oceanographic conditions (sea surface temperatures (SSTs) are based on AVHRR satellite data of 12 Apr. 1995) and the topography of waters off northeastern Taiwan. The dashed red lines are bathymetric contours of 50, 100, 200, 500, and 1000 m.

(Fig. 2a). Based on this image, the transects and locations of sampling stations were chosen to include part of the cold eddy area, where upwelling of the subsurface Kuroshio water occurs, as well as areas where the warmer mixed waters of the continental shelf (< 200 m) predominate.

A sampling plan of 3 d (25-27 Aug. 1998) at 17 stations was carried out in the waters off northeastern Taiwan during cruise 486 of the *Ocean Research II* (Fig. 2). Zooplankton were collected using a Bongo net (with a mouth diameter of 60 cm and a mesh size of 335 μm) equipped with a flowmeter and a depth sensor. The net was towed obliquely from a depth near the bottom to the surface. Samples were preserved on board immediately after collection in 5%-10% formalin in seawater. Aliquots containing 300-500 specimens of copepods were obtained using a Folsom splitter. Copepods were sorted and identified to species, if possible, using major taxonomic references for the area (e.g., Chen and Zhang 1965, Chen et al. 1974, Chihara and Murano 1997). Immature specimens were recorded as copepodids.

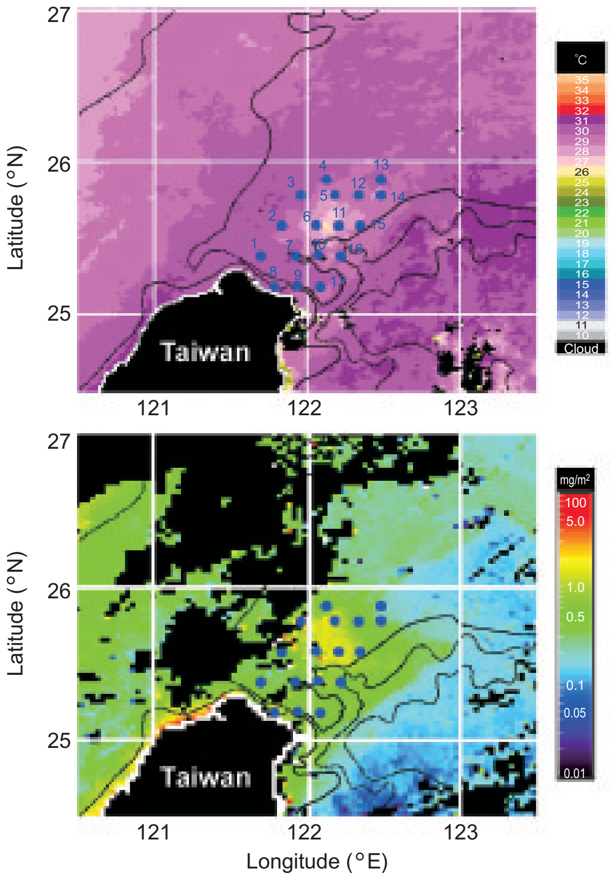


Fig. 2. Satellite images of the sea surface temperature (a) and chlorophyll-α (b) on 25 Aug. 1998, and locations of 17 zooplankton-sampling stations (blue circles) in the waters northeast of Taiwan.

For each copepod species in the sample, the number of individuals was counted, and the abundance was standardized to individuals (inds.)/m^3. Species diversity was estimated by Shannon's diversity index, and the relative abundance of species by Simpson's evenness. Cluster analysis with normalized Euclidean distances was used to measure the levels of similarity of species composition among sampling stations, and Ward's method was used to illustrate these relations in a dendrogram. Data used in the cluster analysis were the percentage compositions of copepods collected at each station (Lan et al. 2004).

Vertical observations of temperature (°C) and salinity (psu) from the sea surface to a depth near the bottom were recorded at each sampling station and between 2 neighboring stations, using a Sea-Bird Electronics (SBE) 911plus conductivity, temperature, and depth (CTD) system. These data were recorded each 10 m along the water column between 10 and 100 m; they were used to generate a 3D distributional contour map of the water masses using the linear interpolation method (Surfer for Windows; Golden Software, Inc. Golden, Colorado).

RESULTS

Hydrographic conditions

Satellite images of SST data and chlorophyll-α at the time of the present study (25 Aug. 1998) are shown in figure 2. This figure indicates that the summer SSTs in the waters northeast of Taiwan were mostly at or above 28°C, except in the vicinity of Mian-Hwa Canyon where a cold-core eddy was present. From figure 2b, 3 regions with different levels of chlorophyll-α concentration can be recognized: > 1 mg/m^3 in the cold eddy, 0.2-1 mg/m^3 over the continental shelf and outside the cold eddy, and < 0.2 mg/m^3 over the slope in an area influenced by the Kuroshio Current.

Figures 3 and 4 show that the water column between 50 and 100 m was composed of water masses with low temperature and high salinity, and variations in these factors within these depths were relatively small. The upper 50 m layer was a low-temperature, high-salinity cold-core eddy formed by the upwelling of the Kuroshio subsurface water. This cold water mixes with the surface water of high temperature and low salinity.

Table 1. Abundance (individuals (inds.)/m^3) and percentage composition of the total count of the 12 major taxonomic groups of zooplankton in samples taken from the 17 stations of the present study

Taxon	st01	st02	st03	st04	st05	st06	st07	st08	st09
Copepoda	73.64 69.24%	416.7 86.01%	348.26 79.18%	144.6 74.05%	176.14 80.09%	299.94 84.18%	681.75 83.69%	208.85 79.81%	69.2 74.93%
Decapoda	6.54 6.15%	28.85 5.96%	18.12 4.12%	11.74 6.01%	8.05 3.66%	20.13 5.65%	33.55 4.12%	17.61 6.73%	5.79 6.27%
Chaetognatha	14.93 14.04%	24.83 5.12%	25.16 5.72%	8.39 4.30%	10.57 4.81%	20.13 5.65%	33.55 4.12%	20.13 7.69%	8.81 9.54%
Appendicularia	1.01 0.95%	1.34 0.28%	14.09 3.20%	19.12 9.79%	11.07 5.03%	4.7 1.32%	4.03 0.49%	0.84 0.32%	3.02 3.27%
Medusae	1.85 1.74%	0 0%	11.07 2.52%	1.34 0.69%	2.01 0.92%	0 0%	2.68 0.33%	1.68 0.64%	1.51 1.63%
Pteropoda	2.18 2.05%	6.04 1.25%	10.07 2.29%	1.34 0.69%	3.02 1.37%	4.03 1.13%	8.05 0.99%	5.87 2.24%	0.25 0.27%
Ostracoda	0.34 0.32%	2.68 0.55%	2.01 0.46%	3.02 1.55%	4.03 1.83%	2.68 0.75%	1.34 0.16%	0 0%	0 0%
Thaliacea	1.01 0.95%	1.34 0.28%	6.04 1.37%	2.01 1.03%	0.5 0.23%	0.67 0.19%	6.71 0.82%	1.68 0.64%	1.26 1.36%
Amphipoda	1.85 1.74%	1.34 0.28%	3.02 0.69%	1.34 0.69%	2.01 0.92%	2.01 0.56%	38.92 4.78%	3.36 1.28%	0 0%
Heteropoda	1.51 1.42%	0.67 0.14%	1.01 0.23%	1.01 0.52%	2.01 0.92%	0.67 0.19%	2.68 0.33%	0 0%	0 0%
Fish larvae	0 0%	0 0%	0 0%	0 0%	0 0%	1.33 0.38%	1.34 0.16%	0 0%	0.25 0.27%
Other	1.51 1.42%	0.67 0.14%	1.01 0.23%	0.67 0.35%	0.5 0.22%	0 0%	0 0%	1.68 0.55%	2.26 2.45%
Sum	106.36 100%	484.47 100%	439.85 100%	195.27 100%	219.93 100%	356.31 100%	814.62 100%	261.7 100%	92.35 100%

Taxon	st10	st11	st12	st13	st14	st15	st16	st17	Average
Copepoda	108.37 82.61%	130.51 86.25%	117.09 61.23%	179.83 79.06%	84.55 67.74%	330.14 86.01%	60.89 79.61%	72.22 74.93%	206.04 78.15%
Decapoda	9.06 6.91%	5.7 3.77%	7.38 3.86%	4.03 1.77%	12.08 9.68%	13.42 3.50%	4.36 5.70%	9.31 9.66%	12.69 5.50%
Chaetognatha	5.37 4.09%	5.03 3.33%	13.76 7.19%	14.76 6.49%	12.75 10.22%	4.03 1.05%	2.85 3.73%	6.04 6.27%	13.59 6.08%
Appendicularia	1.01 0.77%	1.01 0.67%	30.87 16.14%	17.45 7.67%	7.05 5.65%	22.81 5.94%	2.01 2.63%	0.25 0.26%	8.33 3.79%
Medusae	1.68 1.28%	0.34 0.22%	3.36 1.75%	0 0%	1.01 0.81%	0 0%	0.34 0.44%	0.75 0.78%	1.74 0.81%
Pteropoda	2.01 1.53%	3.69 2.44%	5.37 2.81%	2.68 1.18%	0.67 0.54%	1.34 0.35%	1.17 1.54%	1.26 1.31%	3.47 1.41%
Ostracoda	0.34 0.26%	0.34 0.22%	4.03 2.11%	1.34 0.59%	3.36 2.69%	2.68 0.70%	0.67 0.88%	1.26 1.31%	1.77 0.85%
Thaliacea	0.67 0.51%	1.01 0.67%	6.37 3.33%	4.7 2.06%	1.01 0.81%	5.37 1.40%	0.17 0.22%	1.26 1.31%	2.46 1.01%
Amphipoda	0 0%	1.68 1.11%	1.01 0.53%	0 0%	0.67 0.54%	2.68 0.70%	3.69 4.82%	1.01 1.04%	3.80 1.16%
Heteropoda	2.01 1.53%	1.68 1.11%	0.67 0.35%	2.68 1.18%	0.67 0.54%	1.34 0.35%	0 0%	1.76 1.83%	1.20 0.63%
Fish larvae	0 0%	0.34 0.22%	0 0%	0 0%	0 0%	0 0%	0.34 0.44%	0.75 0.78%	0.25 0.13%
Other	0.67 0.49%	0 0%	1.34 0.71%	0 0.00%	1.01 0.79%	0 0%	0 0%	0.5 0.52%	0.70 0.46%
Sum	131.18 100%	151.31 100%	191.24 100%	227.48 100%	124.81 100%	383.82 100%	76.5 100%	96.37 100%	256.09 100%

Zooplankton composition

The 12 major taxonomic groups of animals in the present study are listed in table 1. Copepods constituted 61.2%-85.3% (with an average of 78.2%) of the total zooplankton numbers, with variable abundances (60.89-681.75 inds./m^3, with an average of 206.04 inds./m^3). Chaetognatha, Decapoda, and Appendicularia represented 6.1%, 5.5%, and 3.8% of the animals, respectively. Each of the other taxonomic groups represented less than 1.5% of the total count in the sample, with abundances below 4 inds./m^3.

Diversity and distribution of copepods

In total, 95 species of copepods, belonging to 43 genera, 21 families, and 4 orders were recognized (Table 2). Each station contained 15-45 species; diversity and evenness indices of each station were between 2.27 and 4.79 (with an average of 3.84) and 0.57 and 0.91 (with an average of 0.77), respectively. The top 6 dominant species of copepods were *Canthocalanus pauper*, *Undinula vulgaris*, *Centropages furcatus*, *Acrocalanus gibber*, *Paracalanus aculeatus*, and *Temora turbinata*. They occurred at every station and together contributed an average of 53.5% to the total copepod numbers.

The dendrogram resulting from the cluster analysis is shown in figure 5. Stations were divided into 3 groups: A, B, and C; at a Euclidean distance of 40, stations in group B were further divided into 2 subgroups: B_1 and B_2. The copepod taxa that contributed more than 1% to the total copepods and their respective abundances in each of these groups as well as the average diversity and evenness indices of each group are presented in table 3. Diversity and evenness indices were highest in subgroup B_2 (4.31 and 0.83, respectively) and lowest in group A (3.2 and 0.69, respectively). The number of taxa constituting over 1% of the copepods was highest (21) in subgroup B_2 and lowest in group A (15).

Based on a 3-dimentional structure of temperature (Fig. 3) and salinity (Fig. 4) and the satellite image of SSTs (Fig. 2), group A stations were mainly located in waters influenced by the Taiwan Strait Warm Current, which is characterized by relatively high temperatures and low salinities.

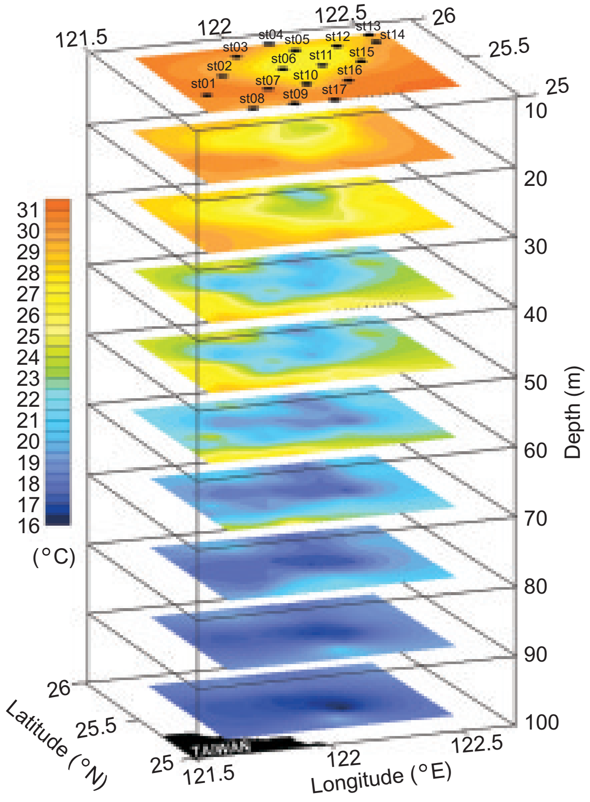


Fig. 3. Three-dimensional structure of temperature between the depths of 10 and 100 m in the study area.

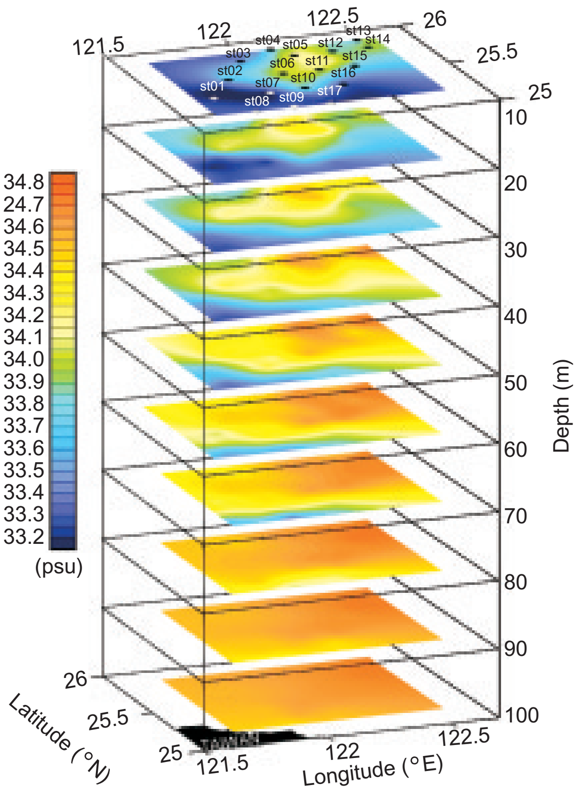


Fig. 4. Three-dimensional structure of salinity between the depths of 10 and 100 m.

Group B stations were distributed in waters associated with the Kuroshio Current and its adjacent waters, with subgroup B_1 stations along the 200 m contour line of the continental slope and the western margin of the Kuroshio with high temperatures and high salinities, and subgroup B_2 in the area of Kuroshio upwelling and the cold-core eddy typified by low temperatures and high salinities. Group C stations were scattered in the waters of the continental shelf in the northern part of the study area, were distinguished by high temperatures and low salinities, and were influenced by Chinese coastal waters.

The dendrogram resulting from the cluster analysis of the percentage composition of total copepods of the 20 most abundant copepod taxa is shown in figure 6. Three species classes, X, Y, and Z, were recognized from the dendrogram. Class X was formed by the 2 species, *Acrocalanus gibber* and *Temora turbinata*, both of which were above average in numerical and percentile abundances at nearly all stations (Table 2). These 2 species almost always contributed more than 10% to the total copepod abundance in all 3 station groups, but were greater in groups A and C, and subgroup B_1, and lowest in subgroup B_2.

Class Y included 4 species (*Paracalanus aculeatus*, *Canthocalanus pauper*, *Undinula vulgaris*, and *Subeucalanus mucronatus*) and unidentified species of *Acrocalanus* (as *Acrocalanus* spp.). These copepod species had an average abundance lower than class X species but higher than those in class Z (Fig. 6). Their relative abundances varied from 2.5% to 9.8% and were present in all groups (except *Acrocalanus* spp., which were absent from group C).

Class Z species contributed less to the total copepods; this class was subdivided into 2 subclasses, Z_1 and Z_2. The former contained 5 species and an unidentified taxon: *Subeucalanus* sp., *Oncaea venusta*, *Centropages furcatus*, *Acrocalanus gracilis*, *Temora discaudata*, and Eucalanidae copepodids. The average percentage contributions of these taxa in groups A, B, and C varied between 0.17% and 5.4%. Subclass Z_2 consisted of 5 species and 2 unidentified taxa: *Clausocalanus furcatus*, *Clausocalanus* sp., *Oithona plumifera*, Calanidae copepodids, copepodids, *Clausocalanus minor*, and *Calanus sinicus*. These taxa had the highest percentage contributions to total copepods in subgroup B_2.

DISCUSSION

The dynamics and coupling processes between physical oceanography and the marine biota of the northwestern Pacific Ocean to the northeast of Taiwan are due to the complexity caused by the presence of waters from several origins: the Taiwan Strait Warm Current, Chinese coastal waters of the Yellow and East China Seas, and in particular, the year-round cold-core eddy formed by upwelling of the Kuroshio Current (Figs. 3, 4). In the present study, our results of a cluster analysis of stations strongly suggested the presence of hydrographical partitioning, exemplified by the different structures of the copepod assem-

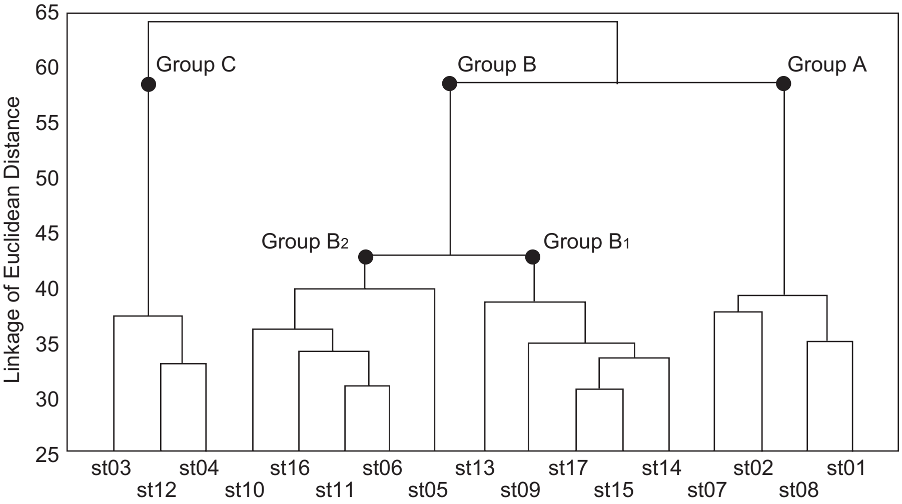


Fig. 5. Dendrogram resulting from cluster analysis based on the copepod communities of the 17 sampling stations in the waters northeast of Taiwan, 25-27 Aug. 1998.

Table 2. A list of species of copepods and their percentage compositions of total copepods in samples taken from the 17 stations in the waters northeast of Taiwan of the present study

Station:	st01	st02	st03	st04	st05	st06	st07	st08
Longitude (°E)	121°42'	121°50'	121°58'	122°07'	122°11'	122°03'	121°55'	121°47'
Latitude (°N)	25°21'	25°35'	25°47'	25°53'	25°47'	25°35'	25°23'	25°11'
Date (1998)	8/25	8/25	8/25	8/25	8/25	8/26	8/26	8/26
Sampling depth (m)	75	75	50	75	50	75	75	30
Abundance (inds./m^3)	73.6	417	348	145	176	300	682	209
Total number of species	36	37	30	39	39	32	29	15
Number of selected species	26	31	30	37	39	35	28	16
Shannon diversity index	3.86	3.65	3.78	3.25	4.4	4.11	3.14	2.27
Evenness	0.82	0.74	0.77	0.62	0.83	0.8	0.65	0.57
ORDER CALANOIDA								
ACARTIIDAE								
Acartia bifilosa Giesbrecht, 1881	0	0	0	0.46	0	0	0	0
Acartia danae Giesbrecht, 1889	0	0	0	0.23	0	0	0	0
Acartia erythraea Giesbrecht, 1889	0	0.16	0	0	0	0	0	0
Acartia longiremis Lilljeborg, 1853	0.68	0	0	0	0	0	0	0
Acartia negligens Dana, 1849	0	0	0	0	0.57	0.45	0	0
Acartia omorii Bradford, 1976	0.23	0	0	0	0	0	0	0
Acartia pacifica Giesbrecht, 1888	0.23	0.48	0	0	0	0	0	0
AETIDEIDAE								
Aetideus armatus Boeck, 1872	0	0.16	0	0	0	0	0	0
Aetideus bradyi A. Scott, 1909	0.23	0	0	0	0	0	0	0
Aetideus giesbrechti Cleve, 1904	0	0	0	0	0.29	0	0	0
AUGAPTILIDAE								
Haloptilus longicornis Claus, 1863	0	0	0	0	0.57	0	0	0
CALANIDAE								
Calanus sinicus Brodsky, 1965	2.05	1.15	1.16	0.46	0	1.79	0.98	0
Canthocalanus pauper Giesbrecht, 1888	4.33	4.35	9.25	4.64	5.43	3.58	13	6.02
Calanus spp.	0	0	0	0	0.29	0	0	0
Cosmocalanus darwini Lubbock, 1860	0	0.81	0.58	0.7	0	0.07	0	0
Nannocalanus minor Claus, 1863	0.46	0.16	0	0.23	0	0.22	0	0
Neocalanus gracilis Dana, 1849	0	0	0	0	0	0	0	0
Neocalanus spp.	0	0	0	0.23	0.57	0	0	0
Undinula vulgaris Dana, 1849	8.43	3.54	4.91	6.03	1.71	6.94	6.1	0.4
CALANIDAE copepodids	0	0	1.16	1.39	2.29	2.46	0.59	0
CALOCALANIDAE								
Calocalanus pavo Dana, 1849	0	0.81	0.58	0	2	0.67	0	0
Calocalanus plumulosus Claus, 1863	0	0	0	0	0	0	0	0
Calocalanus styliremis Giesbrecht, 1888	0.68	0.32	0	0	0	0	0	0
Calocalanus spp.	0	0	0	0	0	0	0	0
CANDACIIDAE								
Candacia bipinnata Giesbrecht, 1892	0	0	0	0	0.29	0	0	0
Candacia catula Giesbrecht, 1889	0.23	0	0	0	0.29	0	0	0
Candacia curta Dana, 1849	0	0	0	0	0	0	0	0
Candacia discaudata A. Scott, 1909	0	0.16	0	0	0	0	0	0
Candacia longimana Claus, 1863	0	0	0	0	0	0	0	0
Candacia turberculata A. Scott, 1902	0	0	0	0.46	0.29	0	0.39	0
Candacia spp.	0.23	0	0	0.23	0.29	0	0	0
Paracandacia simplex Giesbrecht, 1888	0	0	0	0	0	0	0	0
Paracandacia truncata Dana, 1849	0	0	0	0.23	0.29	0	0	0
CANDACIIDAE copepodids	0	0	0	0	0	0	0	0
CENTROPAGIDAE								
Centropages calaninus Dana, 1849	0	0	0	0	0	0	0	0
Centropages furcatus Dana, 1849	3.64	1.93	0.58	2.32	1.43	1.34	1.77	4.02

Table 2. (Cont.)

Station:	st01	st02	st03	st04	st05	st06	st07	st08
Centropages gracilis Dana, 1849	0.23	0	0	0	0	0	0	0
Centropages orsini Giesbrecht, 1889	1.14	0	0	0	0	0.22	0.98	0.8
Centropages spp.	0	0	0	0	0	0	0.59	0
CLAUSOCALANIDAE								
Clausocalanus farrani Sewell, 1929	0	0	0.29	0	0.86	0	0	0
Clausocalanus furcatus Brady, 1883	0.46	2.42	1.16	2.78	1.14	2.68	0.39	0.4
Clausocalanus lividus Frost and Fleminger, 1968	0	0.16	0	0.93	0	0	0	0
Clausocalanus mastigophorus Claus, 1863	0	0.16	0	0	0.29	0	0.39	0
Clausocalanus minor Sewell, 1929	1.59	1.13	1.16	1.39	0.57	1.12	0.2	0
Clausocalanus parapergens Frost and Fleminger, 1968	0	0	0	0	0	0	0	0
Clausocalanus spp.	0	0	0.58	5.34	4	0.89	0.39	0
EUCALANIDAE								
Pareucalanus attenuatus Dana, 1849	0	0	0.29	0.23	0	0	0	0
Rhincalanus rostrifrons Dana, 1852	0	0.16	0	0	0	0.22	0	0
Subeucalanus mucronatus Giesbrecht, 1888	7.29	5.31	16.8	0	5.43	9.84	0	1.2
Subeucalanus subcrassus Giesbrecht, 1888	0	0	0	0.93	0	0	0	0
Subeucalanus subtenuis Giesbrecht, 1888	0	0	0	0	0	0.45	0	0
Subeucalanus spp.	3.87	3.7	2.89	3.25	2	2.24	6.1	0
EUCALANIDAE copepodids	2.28	5.64	0	9.05	0	0	2.36	2.81
EUCHAETIDAE								
Euchaeta indica Wolfenden,1905	0	0	0	0.23	0	0	0	0
Euchaeta rimana Bradford, 1973	0.46	0.16	0.29	0	0.29	0.22	0	0
Euchaeta spp.	1.37	0.97	0	1.86	2.86	0.67	0.2	0
Paraeuchaeta spp.	0	0	0	0	0	0	0	0
LUCICUTIIDAE								
Lucicutia flavicornis Claus, 1863	0	0	0	0.7	1.43	0.67	0.39	0
Lucicutia gaussae Grice, 1963	0	0	0	0	0	0	0	0.4
METRIDIDIDAE								
Pleuromamma abdominalis Lubbock, 1856	0	0	0	1.16	0	0	0	0
Pleuromamma gracilis Claus, 1863	0	0.16	0	1.62	0.57	1.12	0	0
Pleuromamma spp.	0	0	0	2.32	0.57	0.89	0	0.4
Pleuromamma xiphias Giesbrecht, 1889	0	0	0	0	0.29	0	0	0
METRIDICIDAE copepodids	0.68	0.16	0	0	0	0	0	0
PARACALNIDAE								
Acrocalanus gibber Giesbrecht, 1888	22.1	16.4	19.7	16.5	16.9	8.28	22.8	39.8
Acrocalanus gracilis Giesbrecht, 1888	8.66	2.25	1.16	0.7	1.43	0.45	0.2	0
Acrocalanus monachus Giesbrecht, 1888	0	0	0	0.23	1.14	0	0	0
Acrocalanus spp.	0	0	5.49	0	6.29	5.15	0	0
Paracalanus aculeatus Giesbrecht, 1888	5.92	30.3	7.8	8.82	1.71	12.1	1.57	1.61
Paracalanus parvus Claus, 1863	0	0	0	0.46	0	0	0	0
Paracalanus spp.	0	0	2.31	0	0.86	4.7	0	0
PONTELLIDAE								
Calanopia elliptica Dana, 1849	0.46	0	0.58	0.46	0	0	0.39	0.8
Calanopia minor A. Scott, 1902	0.91	1.29	1.73	0.7	1.14	0.22	3.35	1.61
Calanopia spp.	0	0	0	0	0	0	0	0
Labidocera acuta Dana, 1849	0	0	0.29	0	0	0	1.77	0
Labidocera spp.	0	0	0	0	0.29	0	0	0
Pontellina plumata Dana, 1849	0	0	0	0.23	0	0	0	0
Pontellopsis spp.	0.46	0	0	0	0	0	0	0
PONTELLIDAE copepodids	0	0.16	0	0.23	0	0	0.79	0
SCOLECITHRICIDAE								

Table 2. (Cont.)

Station:	st01	st02	st03	st04	st05	st06	st07	st08
Scolecithricella dentata Giesbrecht, 1892	0	0	0	0	0	0	0	0
Scolecithricella spp.	0	0	0	0.23	0	0	0	0
Scolecithrix danae Lubbock, 1856	0	0.32	0.29	0.46	0	0	0.2	0
SCOLECITHRICIDAE copepodids	0	0.16	0	0.46	1.71	0.22	0	0
TEMORIDAE								
Temora discaudata Giesbrecht, 1889	5.47	1.13	0	3.25	0.86	2.24	0.98	2.01
Temora stylifera Dana, 1849	0.46	0	0	0	0	0	0	0
Temora turbinata Dana, 1849	4.33	5.48	10.4	11.8	13.7	19.7	29.9	36.5
Temoropia mayumbaensis T. Scott, 1894	0	0	0	0.46	0	0	0	0
ORDER CYCLOPOIDA								
OITHONIDAE								
Oithona atlantica Farran, 1908	0	0	0	0	0.29	0.22	0	0
Oithona fallax Farran, 1913	0	0	0	0	0	0	0	0
Oithona plumifera Baird, 1843	0.68	0.32	0.29	0.23	2.86	1.79	0.79	0
Oithona setigera Dana, 1849	0	0	0	0.93	1.14	0.22	0.39	0
ORDER HARPACTICOIDA								
EUTERPINIDAE								
Euterpina acutifrons Dana, 1847	0	0	0	0	0.29	0	0	0
MIRACIIDAE								
Macrosetella gracilis Dana, 1847	0	0	0	0	0.29	0	0	0
ORDER POECILOSTOMATOIDA								
CORYCAEIDAE								
C.(*Agetus*) *flaccus* Giesbrecht, 1891	0	0.16	0	0	0	0	0	0
C.(*Agetus*) *limbatus* Brady, 1883	0	0	0	0	0	0	0	0
C.(*Agetus*) *typicus* Kroeyer, 1849	0	0	0	0	0	0	0	0
C.(*Corycaeus*) *clausi* F. Dahl, 1894	0.23	0	0	0	0	0	0	0
C.(*Corycaeus*) *crassiusculus* Dana, 1849	0	0	0	0	0	0	0	0
C.(*Corycaeus*) *speciosus* Dana, 1849	0.23	0.64	0.29	0.46	0.29	0.45	0.2	0.4
C.(*Corycaeus*) spp.	0	0	0	0	0.57	0.22	0	0
C.(*Ditrichocorycaeus*) andrewsi Farran, 1911	0.46	0	0	0	0	0.22	0.39	0
C.(*Ditrichocorycaeus*) asiaticus F. Dahl, 1894	0.68	0	0	0	0	0	0.2	0
C.(*Onychocorycaeus*) agilis Dana, 1849	0	1.13	0.29	0.23	0	0	0.2	0
C.(*Onychocorycaeus*) catus F. Dahl, 1894	0.23	0.16	0	0	0.29	0	0	0
C.(*Onychocorycaeus*) pacificus M. Dahl, 1912	0.46	0.32	1.16	0.23	0.29	0.22	0	0.4
C.(*Urocorycaeus*) furcifer Claus, 1863	0.46	0	0	0	0	0	0	0
C.(*Urocorycaeus*) longistylis Dana, 1849	0	0.16	0	0	0	0	0	0
Farranula carinata Dana, 1847	0	0	0	0	0	0	0	0
Farranula gibbula Giesbrecht, 1891	2.51	1.29	1.16	0.46	0.57	1.12	0.39	0
Farranula spp.	0	0	0	0	0	0	0	0
ONCAEIDAE								
Oncaea conifera Giesbrecht, 1891	0	0	0	0	0.57	0	0	0
Oncaea mediterranea Claus, 1861	0	0	0.58	0.23	0.86	0.45	0	0
Oncaea venusta Philippi, 1843	4.1	3.38	3.18	2.32	4.86	1.57	0.2	0
SAPPHIRINIDAE								
Copilia mirabilis Dana, 1849	0	0.48	0.87	0	0	0	0.2	0
Sapphirina angusta Dana, 1849	0	0	0	0	0	0	0	0
Sapphirina gemma Dana, 1849	0	0	0	0	0	0	0	0
Sapphirina intestinata Giesbrecht, 1891	0	0	0.29	0	0	0	0	0
Sapphirina nigromaculata Claus, 1863	0	0	0	0	0	0	0.2	0
Sapphirina opalina Dana, 1849	0.46	0	0.29	0	0	0	0	0
COPEPODIDS	0	0	0.29	0.46	4	1.12	0	0.4

Table 2. (Cont.)

Station:	st09	st10	st11	st12	st13	st14	st15	st16	st17
Longitude (°E)	121°56'	122°04'	122°12'	122°20'	122°29'	122°29'	122°21'	122°13'	122°05'
Latitude (°N)	25°11'	25°23'	25°35'	25°47'	25°53'	25°47'	25°35'	25°23'	25°11'
Date (1998)	8/26	8/26	8/26	8/26	8/26	8/26	8/26	8/27	8/27
Sampling depth (m)	100	75	75	75	75	75	75	150	100
Abundance (inds./m^3)	69.2	108	131	117	180	84.5	330	60.9	72.2
Total number of species	31	32	38	38	31	45	27	43	26
Number of selected species	30	33	38	37	32	38	28	38	29
Shannon diversity index	3.5	4.42	4.3	4.27	4.06	4.79	3.32	4.32	3.89
Evenness	0.71	0.88	0.82	0.82	0.81	0.91	0.69	0.82	0.8
ORDER CALANOIDA									
ACARTIIDAE									
Acartia bifilosa Giesbrecht, 1881	0	0	0.51	0.29	0	0.4	0	0	0
Acartia danae Giesbrecht, 1889	0	0	0	0.29	0	0	0	0	0
Acartia erythraea Giesbrecht, 1889	0	0	0	0	0	0	0	0	0
Acartia longiremis Lilljeborg, 1853	0	0.31	0.51	0	0	0	0	0	0
Acartia negligens Dana, 1849	0.73	0	0	0	0	0	0	0	0
Acartia omorii Bradford, 1976	0	0	0	0	0	0	0	0	0
Acartia pacifica Giesbrecht, 1888	0	1.24	0.26	0	0	0	0	0.55	0
AETIDEIDAE									
Aetideus armatus Boeck, 1872	0	0	0	0	0	0	0	0	0
Aetideus bradyi A. Scott, 1909	0	0	0	0	0	0	0	0	0
Aetideus giesbrechti Cleve, 1904	0	0	0	0	0.37	0.79	0	0	0
AUGAPTILIDAE									
Haloptilus longicornis Claus, 1863	0	0	0.51	0	0.37	0.4	0	0	0
CALANIDAE									
Calanus sinicus Brodsky, 1965	0	4.95	2.31	0	1.12	0	0.41	3.58	1.05
Canthocalanus pauper Giesbrecht, 1888	6.55	4.02	5.9	4.87	7.09	1.59	8.94	4.68	5.57
Calanus spp.	0	0	0	0	0	0	0	0	0
Cosmocalanus darwini Lubbock, 1860	0.73	0	0	1.43	0.37	1.19	0.41	1.1	0.7
Nannocalanus minor Claus, 1863	0	0.31	0	0	0	0	0	0.28	0
Neocalanus gracilis Dana, 1849	0.36	0.31	0	0	0	0	0	0	0
Neocalanus spp.	0	0.62	0	0.57	1.49	1.19	0	0	0
Undinula vulgaris Dana, 1849	1.82	2.48	2.83	2.58	3.36	5.95	4.07	11	15
CALANIDAE copepodids	0.73	1.86	2.05	1.15	0	2.78	0	1.65	1.39
CALOCALANIDAE									
Calocalanus pavo Dana, 1849	0.36	0.62	0.51	0.86	1.12	1.98	0.41	0.55	0
Calocalanus plumulosus Claus, 1863	0	0	0	0	0	0.4	0	0	0
Calocalanus styliremis Giesbrecht, 1888	0.73	0	0	0	0	0	0	0	0
Calocalanus spp.	0	0	0	0	0	0.4	0	0	0
CANDACIIDAE									
Candacia bipinnata Giesbrecht, 1892	0	0	0	0	0	0.4	0	0	0
Candacia catula Giesbrecht, 1889	1.09	0	0	0	0.37	0	0	0	0
Candacia curta Dana, 1849	0	0	0	0	0	0.79	0	0	0
Candacia discaudata A. Scott, 1909	0	0	0	0	0	0	0	0	0.35
Candacia longimana Claus, 1863	0	0	0	0	0	0	0	0.28	0
Candacia turberculata A. Scott, 1902	0.36	0.31	0	0	0	0	0	0	0
Candacia spp.	0.36	0	0	2.29	0.37	0.79	0	0.28	0
Paracandacia simplex Giesbrecht, 1888	0	0	0	0	0.37	0	0	0.28	0
Paracandacia truncata Dana, 1849	0	0	0	0	0.37	0	0	0	0
CANDACIIDAE copepodids	0	0	0	0	0	0.4	0	0	0
CENTROPAGIDAE									
Centropages calaninus Dana, 1849	0	0.31	0	0	0	0	0	0.28	0
Centropages furcatus Dana, 1849	2.18	3.72	1.54	4.3	5.22	3.57	0.81	1.65	4.88
Centropages gracilis Dana, 1849	0	0	0	0	0	0	0	0	0

Table 2. (Cont.)

Station:	st09	st10	st11	st12	st13	st14	st15	st16	st17
Centropages orsini Giesbrecht, 1889	0.73	0	0.26	0	0.37	1.19	0	0.55	1.39
Centropages spp.	0	0	0	0	0	0.79	0	0	0
CLAUSOCALANIDAE									
Clausocalanus farrani Sewell, 1929	0	0	0.51	1.15	0	0.79	0	0.28	0
Clausocalanus furcatus Brady, 1883	0	8.98	1.54	2.29	0	3.57	2.44	1.1	2.09
Clausocalanus lividus Frost and Fleminger, 1968	0	0.31	0.51	0	0	0	0	1.1	0
Clausocalanus mastigophorus Claus, 1863	0	0	0	0.86	0	1.19	0	0.28	0
Clausocalanus minor Sewell, 1929	0	2.79	1.28	2.29	1.12	0.79	0.81	8.82	1.39
Clausocalanus parapergens Frost and Fleminger, 1968	0	0	0	0.29	0	0	0	0	0
Clausocalanus spp.	0.36	4.02	3.08	1.15	0.75	1.98	1.63	1.38	0
EUCALANIDAE									
Pareucalanus attenuatus Dana, 1849	0	0.93	0.26	0.57	0.37	0.79	0	0.55	0
Rhincalanus rostrifrons Dana, 1852	0	0	0	0.29	0	0	0	0.28	0
Subeucalanus mucronatus Giesbrecht, 1888	3.64	12.7	6.41	0	7.09	0	2.03	5.51	5.92
Subeucalanus subcrassus Giesbrecht, 1888	0	0	0	0.57	0	0	0	0	0
Subeucalanus subtenuis Giesbrecht, 1888	0	0	0.51	0	0	0	0	0	0
Subeucalanus spp.	1.45	6.81	3.33	4.3	4.85	1.19	4.47	0.83	3.83
EUCALANIDAE copepodids	0	0	0	7.16	0	1.98	0	0.83	0
EUCHAETIDAE									
Euchaeta indica Wolfenden,1905	0	0	0	0	0	0	0	0	0
Euchaeta rimana Bradford, 1973	0	0	0	0	0	0	0	0.28	0.35
Euchaeta spp.	0	1.86	1.54	0.86	2.61	1.59	0	1.1	1.05
Paraeuchaeta spp.	0	0	0.26	0	0	0	0	0	0
LUCICUTIIDAE									
Lucicutia flavicornis Claus, 1863	0.36	0	0.51	0.86	0.75	2.78	0.41	0.28	0
Lucicutia gaussae Grice, 1963	0	0	0	0	0	0	0	0	0
METRIDIDIDAE									
Pleuromamma abdominalis Lubbock, 1856	0	0	0.26	0.29	0	0.79	0	0	0
Pleuromamma gracilis Claus, 1863	0	0	0.26	0.29	0	1.19	0	2.75	0.35
Pleuromamma spp.	0	0	0	0.57	0	1.59	0	0	0
Pleuromamma xiphias Giesbrecht, 1889	0	0	0	0	0	0	0	0.28	0
METRIDICIDAE copepodids	0	0	0	0	0	0	0	0.28	0
PARACALNIDAE									
Acrocalanus gibber Giesbrecht, 1888	33.8	7.74	17.9	24.6	24.3	9.13	17.1	8.54	20.9
Acrocalanus gracilis Giesbrecht, 1888	5.09	1.55	1.03	1.15	1.87	0	2.44	1.93	2.44
Acrocalanus monachus Giesbrecht, 1888	0	0.31	0.26	0	0	0.79	0	0	0
Acrocalanus spp.	14.5	3.1	8.97	2.01	10.1	1.98	0	0	2.44
Paracalanus aculeatus Giesbrecht, 1888	2.91	5.26	8.72	8.6	2.61	2.78	6.5	9.09	9.06
Paracalanus parvus Claus, 1863	0	0	0	0.57	0	0.4	0	0	0.35
Paracalanus spp.	2.18	1.24	3.33	0	0	0	2.03	0.55	0.7
PONTELLIDAE									
Calanopia elliptica Dana, 1849	0.36	0.93	0	0.57	0	0.4	0.41	0.28	0
Calanopia minor A. Scott, 1902	1.09	0	0.26	2.58	0.75	1.19	0.41	0.28	0.35
Calanopia spp.	0	0.62	0.26	0	0.37	0	0	0	0
Labidocera acuta Dana, 1849	0	0.31	0	0	0.75	0	0	0	0.35
Labidocera spp.	0.36	0	0	0	0	0	0	0	0
Pontellina plumata Dana, 1849	0	0	0	0	0	0	0	0	0
Pontellopsis spp.	0	0	0	0	0	0	0	0	0
PONTELLIDAE copepodids	0	0	0	0	0	0.4	0	0	0
SCOLECITHRICIDAE									
Scolecithricella dentata Giesbrecht, 1892	0	0	0	0.29	0	0	0.41	0.28	0
Scolecithricella spp.	0	0	0	0	0	0	0	0	0

Table 2. (Cont.)

Station:	st09	st10	st11	st12	st13	st14	st15	st16	st17
Scolecithrix danae Lubbock, 1856	0.36	0	0	0.86	0	1.19	0	0.28	0
SCOLECITHRICIDAE copepodids	0.36	0.62	0	0.86	0	0.4	0.81	0	0.7
TEMORIDAE									
Temora discaudata Giesbrecht, 1889	2.18	0.31	0.77	0.86	1.87	1.98	0.41	0.28	2.44
Temora stylifera Dana, 1849	0	0	0	0	0	0	0	0	0
Temora turbinata Dana, 1849	7.27	3.1	7.44	1.43	5.6	9.13	35.8	13.8	9.76
Temoropia mayumbaensis T. Scott, 1894	0	0	0	0	0	0.79	0	0	0
ORDER CYCLOPOIDA									
OITHONIDAE									
Oithona atlantica Farran, 1908	0.36	0	0.77	0	0	0	0	0.83	0
Oithona fallax Farran, 1913	0	0	0	0.29	0	0.4	0	0	0
Oithona plumifera Baird, 1843	0.73	5.26	2.06	1.72	1.12	3.97	0.41	1.38	0.7
Oithona setigera Dana, 1849	0	1.86	1.8	2.29	0	1.98	0.41	0.83	0.35
ORDER HARPACTICOIDA									
EUTERPINIDAE									
Euterpina acutifrons Dana, 1847	0	0	0	0	0	0	0	0	0
MIRACIIDAE									
Macrosetella gracilis Dana, 1847	0	0	0	0	0	0	0	0	0
ORDER POECILOSTOMATOIDA									
CORYCAEIDAE									
C.(*Agetus*) *flaccus* Giesbrecht, 1891	0	0	0	0	0	0	0	0	0
C.(*Agetus*) *limbatus* Brady, 1883	0	0	0	0.29	0	0	0	0	0
C.(*Agetus*) *typicus* Kroeyer, 1849	0	0	0	0	0	0.4	0	0	0
C.(*Corycaeus*) *clausi* F. Dahl, 1894	0	0	0	0	0	0	0	0	0
C.(*Corycaeus*) *crassiusculus* Dana, 1849	0	0	0	0	0	0.4	0	0.28	0
C.(*Corycaeus*) *speciosus* Dana, 1849	0	0.31	0.26	0	0	1.19	0.41	0	0
C.(*Corycaeus*) spp.	0	0.31	0.26	0.57	1.12	0	0	0	0
C.(*Ditrichocorycaeus*) andrewsi Farran, 1911	0.36	0	0	0	0.37	0.4	0	0.55	0
C.(*Ditrichocorycaeus*) asiaticus F. Dahl, 1894	0	0	0.26	0	0	0.4	0	0	0
C.(*Onychocorycaeus*) agilis Dana, 1849	0.36	0	0.26	0.29	0.75	1.98	0	0.55	0
C.(*Onychocorycaeus*) catus F. Dahl, 1894	1.09	0.93	0	1.15	1.12	0	0	0.83	0.35
C.(*Onychocorycaeus*) pacificus M. Dahl, 1912	1.09	0	0.77	0	0.37	0	1.22	0	0.7
C.(*Urocorycaeus*) furcifer Claus, 1863	0	0	0	0	0	0	0.41	0	0.35
C.(*Urocorycaeus*) longistylis Dana, 1849	0	0	0	0	0	0	0	0	0
Farranula carinata Dana, 1847	0.36	0	0	0	0	0	0	0	0
Farranula gibbula Giesbrecht, 1891	0.36	0.62	0.26	0.86	0	0.79	0.41	1.38	0
Farranula spp.	0	0	0	0	0	0.79	0	0	0
ONCAEIDAE									
Oncaea conifera Giesbrecht, 1891	0	0	0	0	0	0.79	0	0	0
Oncaea mediterranea Claus, 1861	0	0	0.77	0.57	0.75	2.38	0.81	0.83	0
Oncaea venusta Philippi, 1843	0.36	4.64	2.31	4.87	3.36	7.14	0.81	1.1	1.39
SAPPHIRINIDAE									
Copilia mirabilis Dana, 1849	0.36	0.31	0	0	0	0.4	0	0	0
Sapphirina angusta Dana, 1849	0	0	0.26	0	0	0	0	0	0
Sapphirina gemma Dana, 1849	0	0	0	0	0	0.4	0.41	0	0
Sapphirina intestinata Giesbrecht, 1891	0	0	0	0	0	0	0	0	0
Sapphirina nigromaculata Claus, 1863	0	0.31	0	0	0	0	0	0	0
Sapphirina opalina Dana, 1849	0	0	0	0.29	0.37	0	0	0	0
COPEPODIDS	1.45	0.93	3.34	0	2.61	0.4	1.63	3.58	1.39

Table 3. Dominant species and percentage compositions of copepods in groups A, B$_1$, B$_2$, and C; and mean Shannon's diversity and Simpson's evenness indices of the group. Only species with a relative abundance exceeding 1% in each group are listed in this table

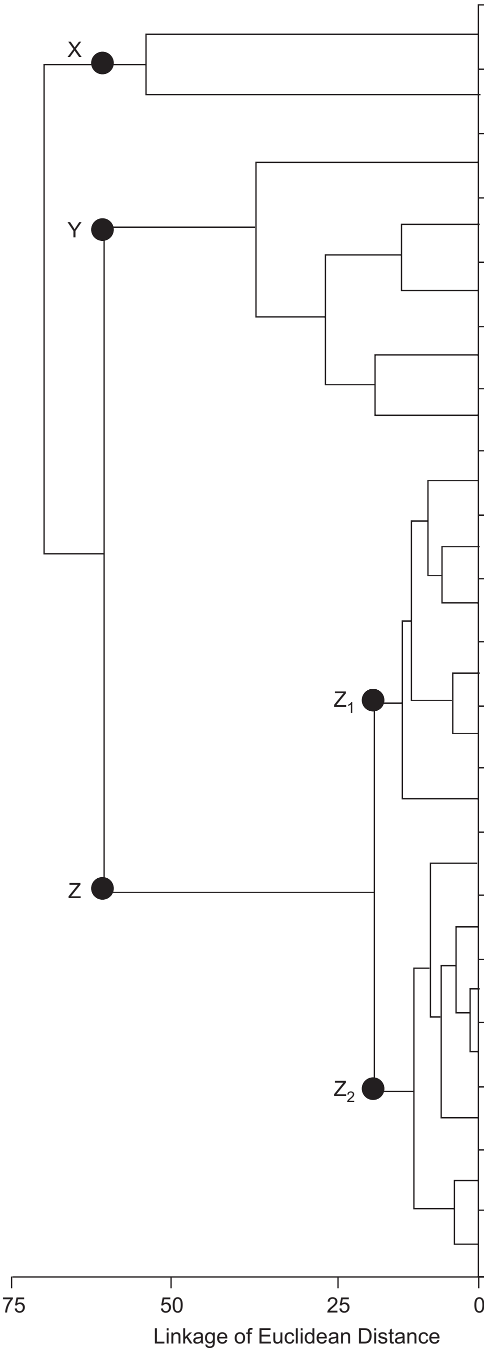
Group A (influenced by Taiwan Strait warm current water)			Group B$_1$ (influenced by Kuroshio current water)		
st01、st02、st07、st08			st09、st13、st14、st15、st17		
Species	inds./m^3	%	Species	inds./m^3	%
Acrocalanus gibber	80.86	23.42	*Temora turbinata*	29.59	20.10
Temora turbinata	76.58	22.18	*Acrocalanus gibber*	29.24	19.87
Paracalanus aculeatus	36.15	10.47	*Canthocalanus pauper*	10.43	7.09
Canthocalanus pauper	30.62	8.87	*Paracalanus aculeatus*	7.41	5.04
Undinula vulgaris	15.85	4.59	*Undinula vulgaris*	7.31	4.97
Subeucalanus spp.	14.97	4.34	*Acrocalanus* spp.	6.32	4.30
EUCALANIDAE copepodids	11.78	3.41	*Subeucalanus* spp.	5.65	3.84
Calanopia minor	8.05	2.33	*Subeucalanus mucronatus*	5.25	3.57
Centropages furcatus	7.80	2.26	*Centropages furcatus*	4.03	2.74
Subeucalanus mucronatus	7.51	2.17	*Acrocalanus gracilis*	3.34	2.27
Temora discaudata	4.91	1.42	*Oncaea venusta*	2.20	2.18
Oncaea venusta	4.61	1.34	*Clausocalanus furcatus*	2.52	1.71
Acrocalanus gracilis	4.28	1.24	COPEPODIDS	2.48	1.69
Calanus sinicus	3.56	1.03	*Temora discaudata*	1.93	1.31
Clausocalanus furcatus	3.48	1.01	*Paracalanus* spp.	1.74	1.19
			Clausocalanus spp.	1.73	1.17
			Oithona plumifera	1.54	1.05
Sum	311.01	90.09	Sum	122.71	84.07
Total abundance (inds./m^3)	345.24		Total abundance (inds./m^3)	147.19	
Mean Shannon diversity index	3.23 ± 0.71		Mean Shannon diversity index	3.9 ± 1.68	
Mean evenness	0.69 ± 0.11		Mean evenness	0.79 ± 0.33	

Group B$_2$ (influenced by upwelling water)			Group C (influenced by coastal waters of Mainland China)		
st05、st06、st10、st11、st16			st03、st04、st12		
Species	inds./m^3	%	Species	inds./m^3	%
Temora turbinata	20.94	13.49	*Acrocalanus gibber*	40.37	19.86
Acrocalanus gibber	18.32	11.81	*Subeucalanus mucronatus*	19.46	9.57
Subeucalanus mucronatus	12.92	8.32	*Temora turbinata*	18.34	9.02
Paracalanus aculeatus	12.38	7.98	*Paracalanus aculeatus*	16.66	8.20
Acrocalanus spp.	8.32	5.36	*Canthocalanus pauper*	14.87	7.32
Undinula vulgaris	7.38	4.76	*Undinula vulgaris*	9.62	4.73
Canthocalanus pauper	7.05	4.54	EUCALANIDAE copepodids	7.16	3.52
Clausocalanus furcatus	4.50	2.90	*Acrocalanus* spp.	7.16	3.52
Subeucalanus spp.	4.50	2.90	*Oncaea venusta*	6.71	3.30
Oncaea venusta	4.40	2.83	*Subeucalanus* spp.	6.60	3.25
Paracalanus spp.	4.33	2.79	*Clausocalanus* spp.	3.69	1.82
Oithona plumifera	3.93	2.53	*Clausocalanus furcatus*	3.58	1.76
Clausocalanus spp.	3.79	2.44	*Centropages furcatus*	3.47	1.71
COPEPODIDS	3.59	2.31	*Calanopia minor*	3.36	1.65
CALANIDAE copepodids	3.42	2.21	*Clausocalanus minor*	2.91	1.43
Calanus sinicus	3.19	2.05	*Paracalanus* spp.	2.68	1.32
Clausocalanus minor	2.89	1.86	CALANIDAE copepodids	2.46	1.21
Centropages furcatus	2.72	1.75	*Acrocalanus gracilis*	2.12	1.05
Euchaeta spp.	2.35	1.51			
Temora discaudata	1.95	1.25			
Acrocalanus gracilis	1.61	1.04			
Sum	134.48	86.64	Sum	171.22	84.21
Total abundance (inds./m^3)	155.17		Total abundance (inds./m^3)	203.32	
Mean Shannon diversity index	4.31 ± 0.12		Mean Shannon diversity index	3.77 ± 0.51	
Mean evenness	0.83 ± 0.03		Mean evenness	0.74 ± 0.10	

blages in each of the 3 station groups (Fig. 5). We were able to relate these station groups to hydrographical features.

The Taiwan Strait Warm Current flows northward through the Taiwan Strait and is mixed with nutrient-rich but less-stable runoff when passing estuarine areas of Taiwan. Stations of group A are located in the waters originating from the Taiwan Strait Warm Current (Fig. 2b), and their copepod compositions are therefore characterized by high abundances but low diversity and evenness.

Group C stations are distributed in the northern part of the study area which is strongly influenced by coastal waters of China, particularly the



	Group A	Group B_1	Group B_2	Group C
Acrocalanus gibber	80.86 ± 57.53 (25.28%)	29.24 ± 20.25 (21.04%)	18.32 ± 10.83 (11.88%)	40.37 ± 24.44 (20.26%)
Temora turbinata	76.58 ± 90.39 (19.07%)	29.59 ± 49.51 (13.51%)	20.94 ± 22.67 (11.55%)	18.34 ± 17.31 (7.89%)
Paracalanus aculeatus	36.15 ± 60.09 (9.84%)	7.41 ± 8.07 (4.77%)	12.38 ± 13.68 (7.38%)	16.66 ± 9.20 (8.41%)
Canthocalanus pauper	30.62 ± 39.13 (6.92%)	10.43 ± 11.49 (5.95%)	7.05 ± 3.36 (4.73%)	14.87 ± 15.02 (6.25%)
Undinula vulgaris	15.85 ± 18.10 (4.62%)	7.31 ± 4.82 (6.04%)	7.38 ± 7.67 (4.99%)	9.62 ± 7.09 (4.51%)
Subeucalanus mucronatus	7.51 ± 10.00 (3.45%)	5.25 ± 4.86 (3.74%)	12.92 ± 10.00 (7.98%)	19.46 ± 33.70 (5.59%)
Acrocalanus spp.	0 0	6.32 ± 7.67 (5.81%)	8.32 ± 6.40 (4.70%)	7.16 ± 10.43 (2.50%)
Subeucalanus spp.	14.97 ± 18.98 (3.42%)	5.65 ± 6.00 (3.16%)	4.50 ± 2.74 (3.04%)	6.60 ± 3.01 (3.48%)
Oncaea venusta	4.61 ± 6.44 (1.92%)	3.20 ± 2.73 (2.61%)	4.40 ± 2.90 (2.90%)	6.71 ± 3.96 (3.46%)
Centropages furcatus	7.80 ± 3.87 (2.84%)	4.03 ± 3.09 (3.33%)	2.72 ± 1.31 (1.94%)	3.47 ± 1.51 (2.40%)
Acrocalanus gracilis	4.28 ± 4.38 (2.78%)	3.34 ± 3.00 (2.37%)	1.61 ± 0.54 (1.28%)	2.12 ± 1.66 (1.00%)
Temora discaudata	4.91 ± 1.24 (2.40%)	1.93 ± 0.81 (1.78%)	1.95 ± 2.72 (0.89%)	1.90 ± 2.47 (1.37%)
EUCALANIDAE copepodids	11.78 ± 9.88 (3.27%)	0.34 ± 0.75 (0.40%)	0.10 ± 0.23 (0.17%)	7.16 ± 6.63 (5.40%)
Clausocalanus furcatus	3.48 ± 4.50 (0.92%)	2.52 ± 3.34 (1.62%)	4.50 ± 4.09 (3.09%)	3.58 ± 0.77 (2.08%)
Clausocalanus spp.	0.67 ± 1.34 (0.10%)	1.73 ± 2.15 (0.94%)	3.79 ± 2.29 (2.68%)	3.69 ± 3.50 (2.35%)
Oithona plumifera	1.80 ± 2.44 (0.45%)	1.54 ± 1.19 (1.38%)	3.93 ± 2.09 (2.67%)	1.12 ± 0.84 (0.75%)
CALANIDAE copepodids	1.01 ± 2.01 (0.15%)	0.77 ± 0.98 (0.98%)	3.42 ± 2.47 (2.06%)	2.46 ± 1.40 (1.23%)
COPEPODIDS	0.21 ± 0.42 (0.10%)	2.48 ± 2.36 (1.50%)	3.59 ± 2.31 (2.59%)	0.56 ± 0.51 (0.25%)
Clausocalanus minor	1.80 ± 2.02 (0.73%)	1.27 ± 1.07 (0.82%)	2.89 ± 1.69 (2.92%)	2.91 ± 1.02 (1.61%)
Calanus sinicus	3.56 ± 3.31 (1.12%)	0.82 ± 0.87 (0.51%)	3.19 ± 2.28 (2.53%)	1.57 ± 2.16 (0.54%)

Fig. 6. Cluster analysis: dendrogram of the 20 most abundant copepods at 17 sampling stations and related average abundances (individuals (inds.)/m^3) and composition (%) in groups A, B_1, B_2, and C.

East China Sea. The abundances of copepods in this group were lower than those of group A, but values of diversity and evenness were higher.

Station group B is centered on an area of cold-core upwelling of the Kuroshio Current. The strength of this upwelling, according to Gong et al. (1995 1996 2000), is dependent on seasonal variations in the velocity and volume of the Kuroshio, the direction and force of monsoon winds, and other climatic factors. As a consequence, the primary productivity, biomass of zooplankton, and fishing stocks are affected (Liao et al. 1999). Copepods of group B had the lowest abundances and highest diversity and evenness values among copepods of all station groups. The low numerical abundances of copepods recorded at stations of both subgroups of group B supports the results by Chen and Chen (1992) who claimed that low primary productivity and poor nutrient input were the main causes of the low abundance of marine biota in waters associated with the Kuroshio Current year round. The relatively high diversity and evenness indices of copepods found at stations of group B also support Shih and Chiu (1998) who believed that the relatively physical stability of the Kuroshio contributed to the existence of a more-diversified biota. Liao et al. (1999), using acoustic volume backscatter as an index of biomass, recorded the lowest value in the cold-core area and the highest value in the waters corresponding to mixed water of the warm continental shelf.

Upwelling plays an important role in copepod distribution. In a study on the planktonic copepod assemblages during spring upwelling off the Yucatan Peninsula in the Gulf of Mexico and Caribbean Sea, Suárez-Morales (1998) exhibited 4 distinct copepod assemblages. Three of these assemblages were related to upwelling. Each of these 3 assemblages had low diversity and was characterized by the dominance of 1 or 2 species. He further related the dominant species and the assemblage they represented to coastal, shelf, and outer shelf conditions. The 4th assemblage showed a strong oceanic affinity and high diversity values.

The waters of our study area are strongly influenced by ingress of the Kuroshio Current and Taiwan Strait Warm Current. Input from southerly transported tropical species into our area includes *Canthocalanus pauper*, *Undinula vulgaris*, *Centropages furcatus*, *Acrocalanus gibber*, *Paracalanus aculeatus*, and *Temora turbinata*. As a result, most dominant copepods in our study area are tropical species.

The 20 most abundant copepod taxa recorded herein were assembled into 3 classes (Fig. 6). Some of the species in classes X and Y, e.g., *Acrocalanus gibber*, *Temora turbinata*, *Paracalanus aculeatus*, and *Canthocalanus pauper*, are widely distributed in our study area. According to Chen and Zhang (1965) and Zheng et al. (1992), these species prefer habitats with high temperatures and are typically warm-water species, distributed widely in the tropical and subtropical waters of the world's oceans. The copepod taxa of subclass Z_1 were common in the present study but had relatively lower abundances and percentage compositions of the total copepods than those of classes X and Y. Their percentage compositions of the total copepods were, however, higher in waters with higher temperatures, e.g., at stations of groups A and C, and subgroup B_1. The copepod taxa of subclass Z_2 had the lowest abundances but their abundances and percentage compositions were highest in colder waters such as stations of subgroup B_2 (Fig. 6). Hsieh and Chiu (2002) and Hsieh et al. (2004) indicated that the occurrence of *Clausocalanus* spp. and *Clausocalanus minor* in waters influenced by the Kuroshio was significant in the northern Taiwan Strait. Lan et al. (2004) also indicated that *Oithona plumifera* develops in low-temperature, high-salinity waters in the northern Taiwan Strait. Species of subclass Z_2 had higher percentage compositions of total copepods in the cold-core eddy caused by upwelling of the Kuroshio subsurface water (Liu et al. 1992, Liao et al. 1997).

In the present study, *Calanus sinicus* occasionally occurred with low abundances and low percentage compositions of total copepods. Both Li and Fang (1990) and Chen (1992) previously pointed out that *C. sinicus* is a temperate species, with an optimal temperature range of 5-23°C. In autumn and winter when the northeasterly monsoon prevails, its population moves southward with Chinese coastal waters and reaches the waters northeast of Taiwan (Hsieh et al. 2004). In the following summer, when seawater is warmer and the coastal water recedes, *C. sinicus* also becomes scarce in our study area. According to a report issued by the Bureau of Oceanography of Fujian Province, China (1988), *C. sinicus* is present in the northern Taiwan Strait throughout the year, and its abundance slightly varies seasonally. As our study took place in summer, the abundance and percentage contribution to total copepods by *C. sinicus* were, therefore, consistently low.

The distribution pattern of each copepod species differed. An environment with different oceanographic features supports a copepod fauna with a different species composition. Some copepod species are more sensitive to changes in their surroundings and are likely to be indicator species of different water masses and oceanic currents (Suárez-Morales 1998, Zheng et al. 2000, Hsieh et al. 2004).

As our study clearly indicates, water masses of different origins that can be detected through remote sensing by satellite support different and characteristic copepod communities. This means that by studying satellite images, predictions can be made about the composition of the zooplankton in various areas. These conditions further imply that areas with a rich zooplankton community, that are thus, in principle, suitable nursery areas for fish, can be identified by satellite. In this way, our study and similar studies of this kind can considerably contribute to the planning, logistics, and management of commercial fisheries activities, particularly so in the area covered by this paper, i.e., around Taiwan and in the China Sea.

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