Copepod diversity in the water masses of the southern East China Sea north of Taiwan

Chang-tai Shih^{a,b,*}, Tai-Sheng Chiu^b

^a *Research Division, Canadian Museum of Nature, Ottawa, K1P 6P4, Canada*

^b *Department of Zoology, National Taiwan University, Taipei 106, Taiwan*

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Abstract

The warm oceanic current Kuroshio and the continental shelf water of the East China Sea meet in the western North Pacific, north of Taiwan and form an upwelling when they converge. The intrusion of the Kuroshio westward over the East China Sea shelf thus results in complicated exchanges of waters between these two water masses. We studied the copepods in the plankton collection taken from an east–west transect crossing these waters in April 1995 when the intrusion of the Kuroshio over the East China Sea shelf was beginning to retreat. The taxonomy of copepods was carefully treated and erroneous species records reported in the literature were guarded against. We evaluated the copepod diversity, the association of copepod species, and the association of stations in these water masses. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: water masses; zooplankton; Copepoda; East China Sea; Kuroshio; species association

1. Introduction

The present study is a part of the interdisciplinary research (KEEP-II) on the oceanographic exchange processes between the Kuroshio and the East China Sea shelf water. The KEEP-II study area is boxed approximately by the coordinates 26°10'N 121°50'E, 24°50'N 123°10'E, 25°50'N 121°30'E, and 24°40'N 122°40'E.

The Kuroshio, a North Pacific warm current, originates from the North Equatorial Current east of the

Philippines and flows northward along the east coast of Taiwan. Northeast of Taiwan, it approaches a sharply curved break at the boundary of the East China Sea shelf where a year-round upwelling is formed before the Kuroshio runs northeastward along the shelf edge (Chern et al., 1990; Liu et al., 1992). The location of the upwelling varies, dependent on the degree of the Kuroshio intrusion onto the East China Sea shelf (Chern and Wang, 1989). The waters of the Kuroshio (KUR) and East China Sea (ECS) exchange and mix (MIX, the upwelling) vertically in the KEEP-II study area (Chern et al., 1990).

Some reports on the biological oceanography of the KEEP-II area, including ichthyoplankton (Chiu, 1991; Chiu and Hsyu, 1994), biomass and biochemi-

* Corresponding author. Present address: Institute of Oceanography, National Taiwan University, Taipei, Taiwan 106. Fax: +886 (2) 363-6837. E-mail: ctshih@ccms.ntu.edu.tw

cal composition of zooplankton (Chen and Chen, 1992), phytoplankton (Chen, 1995), and primary productivity (Shiah et al., 1995), have been published lately. The taxonomy of copepods is, however, relatively unknown despite the dominance of these animals in zooplankton, both by species diversity and numerical abundance. Tan (1967) reported 42 copepod species from his northern stations near our transect. Tseng (1972) studied Candaciidae taken from north of Taiwan, superimposing with our stations. A list of the copepods collected from the Kuroshio downstream of our sampling sites was given by He and Yang (1990).

Our objectives were to examine the copepod species diversity in the study area, to evaluate the species association among the copepods, and to correlate the copepod distribution with the areal water masses.

2. Material and methods

Our samples were collected from eight stations on a transect extending from 25°10'N and 122°51'E to 26°18'N and 120°29'E during cruise 416 in April 1995 on board the *Ocean Research I* (Fig. 1). This transect passed through the water masses KUR, MIX, ECS, and the coastal water of the East China Sea

Fig. 1. Localities of stations of *Ocean Research I* cruise 416 in April 1995 with depth contours of 200, 500, and 1000 m.

(COAST), and crossed various depths from the Okinawa Trough (> 1000 m) to the continental slope (200–1000 m) to the East China Sea shelf (< 200 m).

We collected the samples with a Bongo plankton net of 60 cm mouth diameter and 500 μ m mesh. A flowmeter was mounted at the centre of the mouth opening. The net was towed obliquely from near the bottom to the surface if the bottom depth was 200 m or less, and from 200 m to the surface if the depth was more than 200 m. The samples were preserved in seawater with 5% formalin. At each station prior to plankton tow, temperature and salinity as functions of depth were obtained from lowering a Sea-Bird conductivity–temperature–depth (CTD) instrument from surface to near bottom.

In the laboratory, each sample was split by a Folsom splitter until the subsample contained 300–500 specimens. Copepods were sorted and identified to species. The number, sex, and copepodite stage of the specimens of each species in the sample were recorded. General references for identification were Chen and Zhang (1965) and Chen et al. (1974), but original and revisional references were consulted.

We used the Shannon diversity index to check the species diversity and Simpson's evenness to measure the relative abundance of species in each station, and in stations of a water mass. The species association of the twenty most abundant species was measured by normalized Euclidean distances. The Spearman rank correlation coefficient between the stations with the UPGMA method was used to illustrate station association. All of the above statistical analyses followed Rholf (1989). We selected the species (hereafter the selected species) which accounted for 1% or more of the total number of specimens in at least one station to calculate the Shannon diversity index, Simpson's evenness and Spearman's rank correlation coefficients.

3. Results

3.1. Water masses

The temperature–salinity curves of the stations are shown in Fig. 2 and four types of waters are

Fig. 2. The temperature–salinity curves of cruise 416 stations showing four different types of water masses.

readily recognized. Stations 1 and 3 have low temperature and salinity, typically of the COAST. Stations 7 and 10 are the ECS characterized by moderate temperature and salinity. Stations 15 and 20 belong to the KUR marked by high temperature and salinity. Stations 11 and 12 exhibit temperatures and salinity intermediate between the KUR and ECS, signifying the MIX

3.2. Systematics and species diversity

We found from the samples 113 species of copepods belonging to 43 genera and 22 families: 79 species of Calanoida, 5 species of Cyclopoida, 1 species of Harpacticoida, and 28 species of Poecilostomatoida. *Calanus sinicus*, *Paracalanus aculeatus*, *Temora discaudata*, and *Oncaea venusta* occurred in all stations. 33 species were found only once, including eight of the ten species of Scolecithricidae. Number of the selected species (boldfaced species in Table 1) and Shannon diversity index

varied from 16 and 1.3904 in station 1 to 36 and 3.1315 in station 20. When the stations were lumped according to the water masses where they were located, the Shannon diversity index and Simpson's evenness increased eastward from the COAST to ECS, MIX and KUR (Shannon diversity index: 2.2502, 2.6668, 2.8752, and 3.2750; Simpson's evenness: 0.6375, 0.7513, 0.8332, and 0.9504).

3.3. Species association

The species association of the twenty most abundant species was measured by normalized Euclidean distances. A dendrogram showing the species association is illustrated in Fig. 3. Species with similar horizontal distribution formed a cluster or close clusters. For instance, *Oncaea venusta* and *Temora discaudata* form a cluster, to which *Calanus sinicus* is joined. These three species are common to all water masses. Several species, absent from or rare in the COAST and/or ECS but relatively common and abundant in MIX and KUR, e.g., *Oithona setigera*, *Pleuromamma gracilis*, *Lucicutia flavicornis*, *Corycaeus (Agetus) flaccus*, and *Clausocalanus lividus*, are joined to close clusters at the bottom of the dendrogram.

3.4. Station association

Stations 1 and 15 are at the two ends of the dendrogram (Fig. 4) indicating most dissimilar copepod compositions between these two stations. It is apparent that in general the farther the stations are located from each other, the larger the distance is between them in this dendrogram, being a strong reflection of the association between the copepod faunas and water masses.

4. Discussion

Results of the biological studies in the KEEP-II program have shown a correlation between the biotic abundance and the water masses. Chiu (1991) and Chiu and Hsyu (1994) found that the abundance of

Table 1

Copepod species, % of the total number of specimens in the station, and other collection data

Station:	416-01	416-03	416-07	416-10	416-11	416-12	416-15	416-20
Latitude (N)	26°18'	26°10'	25°51'	25°35'	25°29'	25°40'	25°10'	25°39'
Longitude (E)	120°29'	120°49'	121°29'	121°59'	122°11'	122°51'	122°51'	122°17'
Date (1995–04–)	16	16	15	17	17	19	20	19
Starting time of haul	16:40	13:20	21:37	17:13	14:52	02:19	19:45	12:49
Water depth (m)	53	74	76	119	255	699	1953	112
No. of specimens	1336	1648	1342	23072	2544	15344	2256	9808
Water filtered (m ³)	76.47	60.70	67.74	87.41	145.57	140.90	199.91	236.11
Specimens/m ³	18.62	27.15	19.81	263.95	17.48	108.90	11.29	41.54
CALANOIDA								
ACARTIIDAE								
<i>Acartia bifilosa</i> (Giesbrecht, 1888)✓	1.12	0.24	0	0.43	0.31	0	1.71	0
<i>Acartia danae</i> Giesbrecht, 1889	0	0	0.45	0.29	0	0	1.02	0.65
<i>Acartia erythraea</i> Giesbrecht, 1889	0	0	0	0	1.26	0	0	0
<i>Acartia negligens</i> Dana, 1849	0	0	1.49	0	0	0	0	0.81
<i>Acartia pacifica</i> Steuer, 1915✓	0.56	0	0	0	0	0	0	0
AETIDEIDAE								
<i>Aetideus giesbrechti</i> Cleave, 1904	0	0	0.15	0	0.63	0.21	0	0.16
<i>Gaetanus</i> sp.	0	0	0	0	0	0.10	0	0
AUGAPTILIDAE								
<i>Haloptilus longicornis</i> (Claus, 1865)	0	0	0	0	1.86	0	0	1.63
<i>Haloptilus oxycephalus</i> (Giesbrecht, 1892)	0	0	0	0	0.31	0	0	0
CALANIDAE								
* <i>Calanus sinicus</i> Brodsky, 1962	52.25	11.17	6.71	29.19	9.12	31.91	4.44	0.33
<i>Canthocalanus pauper</i> (Giesbrecht, 1888)	0.56	0.73	0.75	0.58	0.63	1.46	0	0.65
* <i>Cosmocalanus darwinii</i> (Lubbock, 1860)	0	0.97	2.83	0.58	0.94	3.65	7.51	1.14
<i>Mesocalanus tenuicornis</i> (Dana, 1849)	0	0	0	0	3.77	0	0	0
* <i>Nannocalanus minor</i> (Claus, 1863)	0	2.18	1.34	1.59	1.26	2.92	1.71	3.26
<i>Neocalanus gracilis</i> (Dana, 1849)	0	0.24	0	0	0	0	0	1.31
<i>Undinula vulgaris</i> (Dana, 1849)	0	1.46	0	0	0	0.63	1.02	0
CANDACIIDAE								
<i>Candacia bipinnata</i> Giesbrecht, 1892	0	0	0.15	0	0.94	0.10	0.34	0.49
<i>Candacia catula</i> (Giesbrecht, 1889)	0	0.24	0.15	0.14	0.31	0.31	0	0
<i>Candacia curta</i> (Dana, 1849)	0	0	0.15	0	0	0.10	0.34	0
<i>Candacia discaudata</i> Scott, 1909	0	0.24	0	0.14	0	0	0	0
<i>Candacia pachydactyla</i> (Dana, 1849)	0	0	0	0	0	0	0	0.16
<i>Paracandacia bispinosa</i> (Claus, 1863)	0	0	0	0	0	0.31	0.68	0.49
<i>Paracandacia simplex</i> (Giesbrecht, 1888)	0	0	0.15	0	0	0	0	0.16
<i>Paracandacia truncata</i> (Dana, 1849)	0	0.24	0	0	0	0.10	0.68	0.33
CENTROPAGIDAE								
<i>Centropages furcatus</i> (Dana, 1849)	0.56	0	0	0.43	0.31	0	0	0
<i>Centropages longicornis</i> Mori, 1932✓	0	0	0	0.14	0	0	0	0
CLAUSOCALANIDAE								
* <i>Clausocalanus arcuicornis</i> (Dana, 1849)	0	5.58	1.19	0.14	3.46	4.48	1.02	1.79
<i>Clausocalanus farrani</i> Sewell, 1929	0	0	0.45	0	0.63	0.73	1.37	0.81
<i>Clausocalanus furcatus</i> (Brady, 1883)	0	0	0.30	0.87	0.94	0.83	1.02	0.33
* <i>Clausocalanus lividus</i> Frost & Fleminger, 1968✓	0	0	0	0.29	4.40	0	0.34	0.16

Table 1 (continued)

Station:	416-01	416-03	416-07	416-10	416-11	416-12	416-15	416-20
<i>Clausocalanus mastigophorus</i> (Claus, 1863)✓	0	0	0.15	0	0	1.15	0	1.79
* <i>Clausocalanus minor</i> Sewell, 1929✓	0	0	5.07	1.30	0	1.15	2.39	1.79
EUCALANIDAE								
<i>Eucalanus elongatus</i> (Dana, 1849)	0	0	0	0	0.31	0	0	0
<i>Paraeucalanus attenuatus</i> Dana, 1849	0	0	0.15	0.29	0	0.21	0.68	0
<i>Rhincalanus nasutus</i> Giesbrecht, 1888	0	0	0	0.14	0	0.42	0	0.98
<i>Rhincalanus rostrifrons</i> (Dana, 1852)	0	3.15	1.19	0.29	0.31	0.31	0	1.47
<i>Subeucalanus crassus</i> (Giesbrecht, 1888)	0	0.24	0.60	0.14	0.31	0.10	0	0.33
* <i>Subeucalanus mucronatus</i> (Giesbrecht, 1888)	0.56	4.13	3.28	3.03	0.63	0.83	0	7.01
<i>Subeucalanus pileatus</i> (Giesbrecht, 1888)	0	0	0	1.83	0.31	0	0	0
<i>Subeucalanus subcrassus</i> (Giesbrecht, 1888)	0	0.73	0	0	0.31	0.31	0	1.31
<i>Subeucalanus subtenuis</i> (Giesbrecht, 1888)	2.81	0	0	0	0.31	0	0	0
EUCHAETIDAE								
<i>Euchaeta concinna</i> Dana, 1849	0	0.24	0.30	0	0	0	0	0
<i>Euchaeta indica</i> Wolfenden, 1905	0	0	0.15	0	0	0	0	0
<i>Euchaeta longicornis</i> (Giesbrecht, 1888)	0	0	0.45	0	0	0	0	0
<i>Euchaeta media</i> Giesbrecht, 1888	0	0	0	0	0	0.21	0	0
<i>Euchaeta plana</i> Mori, 1937	0	0.73	0.45	0	0	0	0	0
* <i>Euchaeta rimana</i> Bradford, 1974	0	1.46	1.19	0.58	1.89	0.10	2.73	0.65
<i>Pareuchaeta russelli</i> (Farran, 1936)	0	0	0	0.14	0	0	0	0
HETERORHABDIDAE								
<i>Heterorhabdus papilliger</i> (Claus, 1863)	0	0	0	0	0.94	0.10	0.68	0.98
LUCICUTIIDAE								
* <i>Lucicutia flavicornis</i> (Claus, 1863)	0	0.24	1.04	0.14	3.14	1.04	5.80	2.77
MECYNOCERIDAE								
<i>Mecynocera clausi</i> Thompson, 1888)	0	0	0.15	0	0	0	0.34	0
METRIDINIDAE								
<i>Pleuromamma abdominalis</i> (Lubbock, 1856)	0	0	0	0	0.63	0.31	3.07	0
* <i>Pleuromamma gracilis</i> (Claus, 1863)	0	0	0	0	0.63	3.55	5.80	0.81
<i>Pleuromamma robusta</i> (Dahl, 1893)	0	0	0.15	0	0.31	0.10	0.68	0.16
<i>Pleuromamma xiphias</i> (Giesbrecht, 1889)	0	0	0	0	0	0	4.10	0
PARACALANIDAE								
<i>Acrocalanus gibber</i> Giesbrecht, 1888	0	1.21	1.49	0.72	0.31	0.42	0	0.98
<i>Acrocalanus gracilis</i> Giesbrecht, 1888	0.56	0.24	0	0.87	0	0.73	0	1.96
<i>Acrocalanus monachus</i> Giesbrecht, 1888	0	0	0	0.14	0	0	1.02	0
<i>Calocalanus pavo</i> (Dana, 1849)	0	0	0	0	0.31	0.10	0.34	0.49
* <i>Paracalanus aculeatus</i> Giesbrecht, 1888	1.69	6.55	0.60	7.65	1.26	4.28	1.71	0.65
<i>Paracalanus parvus</i> (Claus, 1863)	1.12	0	0	0	0	1.15	0	0
<i>Paracalanus serrulus</i> Shen & Lee, 1963✓	0	0	0	0	0.31	0	0	0
PONTELLIDAE								
<i>Calanopia elliptica</i> (Dana, 1849)	0	0.24	0	0	0	0	0	0
<i>Calanopia minor</i> Scott, 1902	0	0.24	0.30	0	0	0	0	0
<i>Labidocera acuta</i> (Dana, 1849)	0.56	0.24	0	0.14	0	0.31	0	0
<i>Labidocera minuta</i> Giesbrecht, 1889	0	0.24	0	0	0	0.10	0	0
<i>Pontellina plumata</i> (Dana, 1849)	0.56	0	0.30	0.14	0	0	0	0.16
SCOLECITHRICIDAE								
<i>Scaphocalanus echinatus</i> Farran, 1905	0	0	0	0	0	0	0	0.16
<i>Scolecithricella abyssalis</i> (Giesbrecht, 1888) ✓	0	0	0	0	0	0	0	0.16
<i>Scolecithricella bradyi</i> (Giesbrecht, 1888)	0	0	0	0	0.63	0	0	0.16
<i>Scolecithricella dentata</i> (Giesbrecht, 1892)	0	0	0	0	0	0	0	0.16
<i>Scolecithricella longispinosa</i> Chen & Zhang, 1965	0	0	0	0	0	0.10	0	0
<i>Scolecithricella tenuiserrata</i> (Giesbrecht, 1892)	0	0	0	0	0	0	0	0.49

Table 1 (continued)

Station:	416-01	416-03	416-07	416-10	416-11	416-12	416-15	416-20
* <i>Scolecithrix danae</i> (Lubbock, 1856)	0.56	1.46	2.68	0.29	0	0.31	0	0.16
<i>Scolecithrix nicobarica</i> Sewell, 1929	0	0	0	0	0	0	0	0.32
<i>Scottocalanus helenae</i> Scott, 1909	0	0	0	0	0	0	0.34	0
<i>Scottocalanus securifrons</i> (Scott, 1893)	0	0	0	0	0	0.42	0	0
TEMORIDAE								
* <i>Temora discaudata</i> (Giesbrecht, 1889)	0.56	0.73	0.45	2.60	0.31	0.52	0.34	0.49
* <i>Temora turbinata</i> (Dana, 1849)	7.30	6.07	5.96	2.17	0.94	2.50	0	4.89
CYCLOPOIDA								
OITHONIDAE								
<i>Oithona longispina</i> Nishida, 1976✓	0	0	0	0.14	0	0	0	0
<i>Oithona plumifera</i> Baird, 1843	0.56	0	0.30	0	0.63	0	0	0
* <i>Oithona setiger</i> (Dana, 1849)	0	0	0.15	0	11.01	2.40	6.48	4.40
* <i>Oithona similis</i> Claus, 1866	0	1.46	3.58	0	0	0	0	0
<i>Oithona tenuis</i> Rosendorn, 1913	0	0	0	0	0	0	0	0.33
HARPACTICOIDA								
CLYTEMNESTRIDAE								
<i>Clytemnestra scutellata</i> Dana, 1847	0	0	0	0.14	0	0	0	0
POECILOSTOMATOIDA								
CORYCAEDAE								
* <i>Corycaeus (Aetus) flaccus</i> Giesbrecht, 1891	0	0.24	0.15	0	5.03	1.56	2.73	3.10
<i>Corycaeus (Aetus) limbatus</i> Brady, 1883	0.56	0	0	0	0	0	0	2.12
<i>Corycaeus (Aetus) typicus</i> (Kroyer, 1849)✓	0	0	0	0	0	0	1.02	0
* <i>Corycaeus (Corycaeus) crassiusculus</i> Dana, 1849	0	3.64	0.89	0.43	0	0	0.34	1.47
<i>Corycaeus (Corycaeus) speciosus</i> Dana, 1849	1.12	0.97	0	0.87	1.57	0.83	0.34	0.49
<i>Corycaeus (Corycaeus) viretus</i> Dana, 1849	0	0	0	0.14	0	0.10	0.34	0.16
<i>Corycaeus (Ditrichocorycaeus) asiaticus</i> Dahl, 1894	0	1.21	0	0	0	0	0	0.16
<i>Corycaeus (Ditrichocorycaeus) dahl</i> Tanaka, 1957	0	0	0	0.87	0	0.73	0	0
<i>Corycaeus (Ditrichocorycaeus) erythraeus</i> Cleve, 1901✓	0	0	0	0.14	0	0	0	0.16
<i>Corycaeus (Ditrichocorycaeus) lubbockii</i> Giesbrecht, 1891	0	0.73	0	0	0	0	0	0.16
<i>Corycaeus (Onychocorycaeus) agilis</i> Dana, 1849	0	0	0.60	0	0	0.10	0	0
<i>Corycaeus (Onychocorycaeus) catus</i> Dahl, 1894	0	0	0	1.01	0.63	0.10	0	0.49
<i>Corycaeus (Onychocorycaeus) giesbrechti</i> Dahl, 1894	0	0	0	0	0	0.52	0.34	0
<i>Corycaeus (Onychocorycaeus) pacificus</i> Dahl, 1912✓	0.56	0	0.89	1.15	0.31	0.94	0.68	0.16
<i>Corycaeus (Urocorycaeus) furcifer</i> Claus, 1863	0	0	0	0	0.31	0.10	0	0
<i>Corycaeus (Urocorycaeus) lautus</i> Dana, 1849	0	0	0	0	0.31	0	0.34	0
<i>Corycaeus (Urocorycaeus) longistylis</i> Dana, 1849✓	0	0	0	0	0	0	0	0.49
<i>Farranula carinatus</i> (Giesbrecht, 1891)✓	0	0	0	0	0.31	0	0	0
<i>Farranula gibbulus</i> (Giesbrecht, 1891)✓	0	0	0	0.14	0	0.31	0	0.98

Table 1 (continued)

Station:	416-01	416-03	416-07	416-10	416-11	416-12	416-15	416-20
ONCAEIDAE								
<i>Lubbockia squillimana</i> Giesbrecht, 1891	0	0	0.15	0	0	0	0	0.16
<i>Oncaea confifera</i> Giesbrecht, 1891	0	0	0	0	0	0	0.34	0
* <i>Oncaea mediterranea</i> Claus, 1863	1.12	2.91	1.79	0	4.09	1.46	0.34	2.77
* <i>Oncaea venusta</i> Philippi, 1843	6.74	8.98	3.73	11.40	4.72	2.09	5.80	8.65
SAPPHRINIDAE								
<i>Copilia mirabilis</i> Dana, 1849	0	0	0.15	0	0	0.21	0	0
<i>Sapphirina gemma</i> Dana, 1849	0	0	0	0	0.31	0	0	0.49
<i>Sapphirina metallina</i> Dana, 1849	0	0	0	0	0	0	0	0.16
<i>Sapphirina nigromaculata</i> Claus, 1863	0	0	0	0	0	0	0	0.16
<i>Sapphirina opalina</i> Dana, 1849	0	0	0	0.14	0	0	0	0
Total number of species	21	37	46	44	49	56	41	64
Number of selected species	16	26	27	27	32	31	27	36
Shannon diversity index	1.3904	2.7661	2.8863	2.1191	2.9894	2.4354	2.9523	3.1315
Simpson's evenness	0.5015	0.8490	0.8757	0.6430	0.8626	0.7092	0.8860	0.8808

Species in boldface: the selected species, i.e., species with 1% or more of the total number of specimens in one or more stations.

Species with asterisk: one of the twenty most abundant species in the whole collection.

Species followed by a tick (✓): new records for the study area.

fish eggs, larval fishes, and zooplankton was higher in the midshelf stations (ECS) than in the upwelling (MIX) or oceanic stations (KUR). Shiah et al. (1995) observed that the normalized productivity measured by the ^{14}C assimilation method was higher in the

MIX than in the COAST and KUR. Similarly Chen (1995) recorded high primary productivity in the MIX and low primary productivity in the KUR. Chen and Chen (1992) reported that zooplankton biomass was positively correlated with upwelling

Fig. 3. Dendrogram of the twenty most abundant species measured by Euclidean distances showing the degree of relative dissimilarity of distribution between species in the water masses of the KEEP-II study area.

Fig. 4. Dendrogram of station associations calculated from Spearman's rank correlation coefficients showing the degree of similarity in copepod faunas between stations.

indicators such as low temperature and high $\text{NO}_3\text{-N}$ and chlorophyll *a*. In our collection, the copepod density (number of individuals/ m^3) in the four water masses showed a decreasing order from ECS to MIX, COAST and KUR. The present study thus confirms that the biotic abundance is generally higher in the ECS and MIX and lower in the COAST and KUR.

The present work has expanded our knowledge on the copepods of the KEEP-II study area. Some species reported by Tan (1967), for instance, *Calanus finmarchicus* and *C. helgolandicus* (North Atlantic species, see Shih, 1979), and *Pseudocalanus gracilis* and *P. minutus* (boreal or temperate species, see Frost, 1989), are erroneous records. The two *Calanus* species probably are misidentifications of *C. sinicus*, and the *Pseudocalanus* species may belong to some species of the genus *Clausocalanus*. *Candacia pacifica* and *C. pectinata* in Tseng (1972) are respectively synonyms of *C. columbiae* and *C. armata* (see Grice, 1963). Fifteen species in our collection, mostly from the KUR and MIX, are new to the study area (marked with a tick in Table 1).

Calanus sinicus is limited to the western marginal seas of the North Pacific, and dominant in the Yellow and East China seas. Its southern distribution limit extends to the South China Sea, especially in winter when the northeast monsoon prevails (Chen, 1992). *C. sinicus* is the most dominant copepod in our collection except in stations 15 and 20. In con-

trast to the large number of adult females and males and numerous younger copepodids present in the COAST, ECS and MIX stations, there were only small numbers of adult females and no (station 20) or very few (station 15) young copepodids found in the KUR stations. The occurrence of this species in the Kuroshio is probably expatriate. *C. sinicus* usually inhabits the water over the continental shelf but enters the coastal water from April to June (Chen, 1992). Its great abundance in our station 1 confirms Chen's observation.

Euchaeta marina is widely distributed including a number of records from the western North Pacific (Mori, 1937; Chen and Zhang, 1965). Bradford (1974) established and described *Euchaeta rimana*. She included many previous Pacific records of *E. marina* (including Mori's) under this name. She suggested that *E. marina* is limited to the Atlantic Ocean and Mediterranean Sea. Our specimens conform with *E. rimana* in morphology.

We compared the abundance and diversity of the copepods in our study with those reported by He and Yang (1990) from the Kuroshio (just downstream of our section) and adjacent waters. The numbers of copepod species found in each station range from 8 to 94 (mean 51) in He and Yang (1990) and from 21 to 64 (mean 45) in our study. The Shannon species diversity index and Simpson's evenness in our study, respectively varying from 1.3904 to 3.1315 (mean 2.5838) and 0.5015 to 0.8860 (mean 0.7759), are

also smaller than those of He and Yang (1990): from 0.8898 to 5.6524 (mean 3.9529) and 0.2966 to 0.8780 (mean 0.7205). It should be cautioned, however, that He and Yang included all species in their calculation, while the present study only considered the selected species

The dendrogram of the species association depicts some relationships among the twenty most abundant species in our collection (Fig. 3). It links the widely distributed species (in the upper part of the dendrogram) and the species that at most rarely occur in the coastal water (the lower part of the dendrogram) to close clusters. The species (from *Clausocalanus arcuicornis* to *Scolecithrix danae*) that form the middle clusters of the dendrogram are, however, lacking of traits in the distribution pattern, except that they are mostly widely distributed in subtropical and tropical waters around the world.

The temperature–salinity curves for stations 1 and 3 are nearly straight, showing a linear T–S relationship in the shallow coastal area. The low salinity and low temperature are due to freshwater runoff and cold coastal currents from the north. The higher temperature and salinity in the lower water of station 3 indicate a strong influence of the ECS. This influence is reflected in the dendrogram of station association where station 3 joins with station 7 in a cluster (Fig. 4). Station 20 is near the most westward part of the Kuroshio. The characteristic T–S curve of the KUR at station 20 confirms previous report of the westward location of the Kuroshio intrusion (Hwang and Tang, 1993). The upper part of the T–S curve in station 20, however, leans toward that of stations 11 and 12, an indication of strong influence from the MIX. This influence is also demonstrated in the dendrogram of station association where stations 20 is linked with stations 11 and 12 (not 15) to form a cluster. This close similarity in T–S curves between stations also illustrates the species composition. For instance, the composition of the species is highly similar in stations 3 and 7. There are more deepwater species belonging to the Scolecithricidae in station 20 than in other stations, probably brought up to the upper layer by the upwelled Kuroshio subsurface water. Most of these scolecithricids are known from the Kuroshio (Chen and Zhang, 1965). A similar distribution pattern is also found in ichthyoplankton in the intermediate waters of KUR–MIX (Chiu and

Lee, 1991) and some mesopelagic gonostomatid species become abundant in the vicinity of station 20 (Chen and Chiu, 1992).

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