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Taxonomic Composition and Grazing Impact of Calanoid Copepods in Coastal Waters near Nuclear Power Plants in Northern Taiwan

Chong-Kim Wong[1], Jiang-Shiou Hwang[2,*] and Qing-Chao Chen[3]

[1]*Department of Biology, The Chinese University of Hong Kong, Shatin, Hong Kong, China*
[2]*Institute of Marine Biology, National Taiwan Ocean University, Keelung, Taiwan 202, R.O.C.*
[3]*South China Sea Institute of Oceanology, Academia Sinica, Guangzhou, China*

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Chong-Kim Wong, Jiang-Shiou Hwang and Qing-Chao Chen (1998) Taxonomic composition and grazing impact of calanoid copepods in coastal waters near nuclear power plants in northern Taiwan. *Zoological Studies* **37**(4): 330-339. This study was carried out in August 1996 to study the taxonomic composition and grazing impact of calanoid copepods in coastal waters at 8 sampling stations outside Nuclear Power Plants 1 and 2 on the northern tip of Taiwan. Thermal pollution was observed at station 3 outside Nuclear Power Plant 2 where surface water temperature reached 30.0 °C. At each sampling station, the abundance and species composition of calanoid copepods were analyzed; the gut fluorescence method was used to estimate in situ ingestion rates and clearance rates. Thirty-seven species of calanoid copepods were identified. The abundance and species composition of calanoid copepods varied among sampling stations. *Acrocalanus gracilis*, comprising 30%-90% of the numerical abundance, strongly dominated the calanoid copepod community in the area during the study period. Variability of ingestion rates and clearance rates for a single species was high among the sampling stations. Despite its relatively small size and low clearance rate, *A. gracilis* was the most important grazer because of its numerical abundance. Grazing impact, estimated as the fraction of chlorophyll removed from 1 m^3 of water by the calanoid copepod assemblage ranged from 0.05% to 11%, suggesting that the grazing pressure of calanoid copepods on phytoplankton in the near shore waters outside Nuclear Power Plants 1 and 2 was minor. There was no evidence to suggest that the slightly elevated surface water temperature had affected the community structure or grazing impact of calanoid copepods at station 3.

Key words: Calanoid copepods, Taxonomic composition, Grazing impact.

Discharge of heated water from power plants into shallow coastal waters can have harmful effects on aquatic organisms (Roessler and Zieman 1969, Jones and Randall 1973, Jokiel and Coles 1974, Johannes 1975). There are 3 nuclear power plants in Taiwan. In southern Taiwan, thermal pollution is believed to be the cause of coral bleaching near the outlet of Nuclear Power Plant 3 during the summer (Fang 1989). To the north, input of excess heat to the coastal environment has been implicated in the presence of deformed fish near the outlet of Nuclear Power Plant 2. Warm water from power plants can increase algal growth, speed up the process of eutrophication, and cause changes in species composition. At the same time, warmer temperatures may affect the feeding rates of herbivorous zooplankton (Deason 1980) and change the efficiency with which phytoplankton is harvested. Nuclear Power Plants 1 and 2 are located on the northern coast of Taiwan. The water mass outside the nuclear power plants represents a region where water along the edge of the Kuroshio Current mixes with water from the Taiwan Strait and the East China Sea. The Kuroshio Edge Exchange Processes (KEEP) project, launched in 1989 to study the oceanography of northern and eastern Taiwan, has produced important information on phytoplankton distribution and production (Chen 1995, Gong et al. 1996), but data on zooplankton grazing, which are essential to investigations of trophic interactions and secondary production, are still lacking. Input of warm water from the

*To whom correspondence and reprint requests should be addressed.

nuclear power plants may be an important factor affecting the local community structure and trophic interactions. The present research represents a preliminary attempt to study the taxonomic composition and grazing impact of calanoid copepods in nearshore waters outside Nuclear Power Plants 1 and 2. The gut fluorescence method, developed by Mackas and Bohrer (1976), was used to estimate calanoid copepod ingestion of phytoplankton. Assumptions and methodological artifacts of the gut fluorescence method have been extensively reviewed (e.g., Dam and Peterson 1988, Morales and Harris 1990, Peterson et al. 1990). We used the gut fluorescence method mostly because it permits easy collection of data needed to estimate the in situ grazing rate of herbivorous zooplankton.

MATERIALS AND METHODS

The study was conducted on board *Ocean Research Vessel* II during cruises 252 and 253 from 27 to 31 Aug. 1996. Data were collected from 8 sampling stations in shallow coastal waters outside Nuclear Power Plants 1 and 2 in northern Taiwan. Locations of the stations are shown in Fig. 1. Water depths at the stations ranged from 22 to 94 m (Table 1). At each sampling station, temperature and salinity at the surface (2-5 m) and near the bottom were measured with a Seabird CTD. A rosette sampler with Niskin bottles was used to collect seawater samples from 2 to 5 m below the surface. Chlorophyll concentrations in the seawater samples were measured fluorometrically using the method described in Parsons et al. (1984).

Calanoid copepods were collected within the upper 5 m of each station by horizontal tows using a 4.5-m-long conical net with a 1-m mouth diameter and 0.33-mm mesh. All collections were made between 1100 and 2130 h. Animals collected from the 1st net tow were preserved in 5% formaldehyde. In the laboratory, calanoid copepods were enumerated by species under a stereomicroscope. Animals captured in the 2nd net tow were frozen immediately with liquid nitrogen and stored in a freezer at -20 °C for later measurement of gut pigment content. On returning to the laboratory, 5th stage copepodites and adult females of individual species were sorted rapidly under dim light. Sorted animals were rinsed in filtered seawater to remove adhering debris. Gut pigment contents of some small and rare species were not measured. Depending on abundance and body size, 5 to 30 individual animals were placed in small glass tubes containing 6 ml of 90% analytical acetone and extracted overnight in a dark refrigerator. Samples were not homogenized because preliminary experi-

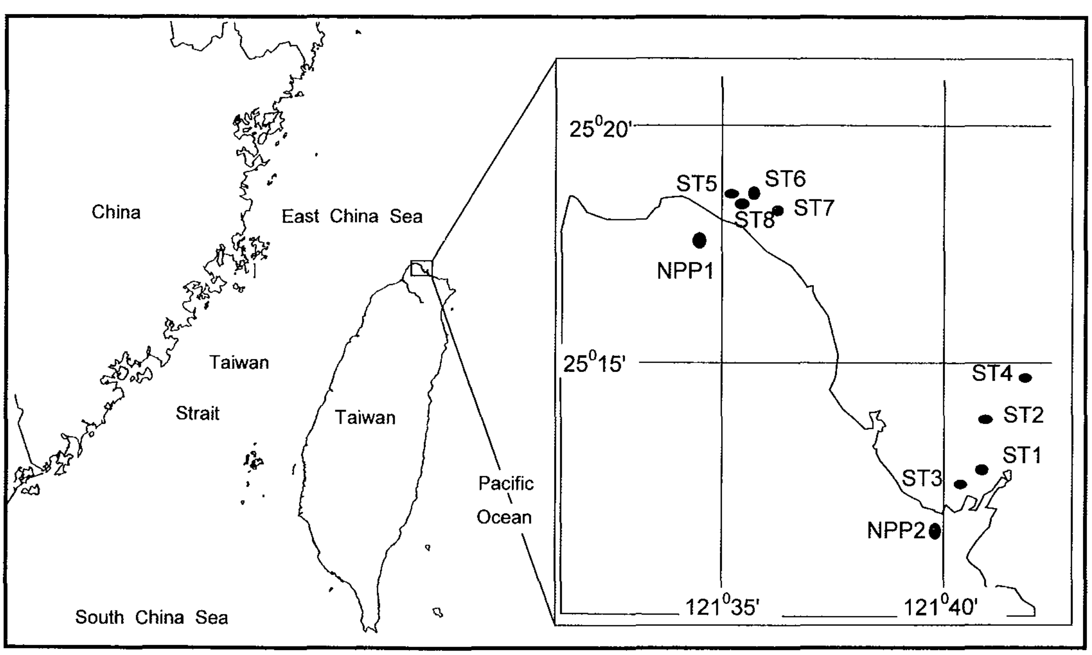

Fig. 1. Map of the South China Sea and East China Sea showing location of nuclear power plants (NPP1 and NPP2) and sampling stations on the northern tip of Taiwan.

ments showed no difference in gut pigment fluorescence between samples ground with a glass rod and unground samples, even for some of the larger species. Because individual variability in gut pigment fluorescence was great, 3 replicate samples were processed for each species when animal abundance in the net sample was sufficient. Fluorescence of acetone extracts before and after acidification with 1 drop of 10% HCl was measured with a Turner Model 112 fluorometer. The equations of Dagg and Wyman (1983) were used to calculate the amount of chlorophyll *a* and chlorophyll *a* equivalent weight of phaeopigment in the guts. No correction for background fluorescence was applied because fluorescence was nearly undetectable in some samples. Phaeopigment values were corrected for pigment destruction during gut passage using an estimated average loss of 33% (Dam and Peterson 1988). Final gut pigment content (G) was expressed as nanograms chlorophyll *a* equivalent per copepod (ng Chl *a* copepod^{-1})

Measurements of gut evacuation rate were performed on females and 5th stage copepodites of *Calanus sinicus* and *Eucalanus subcrassus* collected from Tolo Harbour (22°27'N, 114°17'E), Hong Kong. Gut evacuation experiments carried out in northern Taiwan were not successful because the abundance of copepods of any single taxon in any single net tow was too low for repeated sub-sampling. Copepods were collected near the surface at night and transferred to 0.45-μm-filtered seawater at 24-26 °C. Subsamples of copepods were taken at 1-10 min intervals for 40 min. Decline in gut pigment content (ng Chl *a* copepod^{-1}) over time was assumed to be exponential and described by the equation:

$$G_t = G_0e^{-kt};$$

where G_t is the gut pigment content at time t, G_0 is the initial gut pigment content, and k is the gut evacuation rate constant in min^{-1}. Assumptions related to the measurement of gut evacuation rates have been reviewed by Morales and Harris (1990). Ingestion rates were estimated as:

$$I = kG;$$

where I is the ingestion rate in ng Chl *a* copepod^{-1} min^{-1} and G is gut pigment content in ng Chl *a* copepod^{-1}. Clearance rates, defined as the volume of water swept clear of food particles per unit time, were calculated from:

$$F = I / C;$$

where F is the clearance rate in ml copepod^{-1} min^{-1} and C is the chlorophyll *a* concentration in the upper 2-5 m of the water column in ng Chl *a* ml^{-1}. Daily clearance rates, expressed in ml copepod^{-1} day^{-1}, can be estimated by extrapolating F over 24 h. The estimates are considered conservative because the extrapolation does not take into account diel differences in grazing rates. Grazing impact by a copepod species (T), was calculated from the relationship:

$$T = A F;$$

where A is the abundance (copepod m^{-3}) and T, in units of ml m^{-3} day^{-1}, is the volume of water swept clear of food per cubic meter per day by copepods.

Table 1. Location and water depth of sampling stations; dates and times in 1996 when copepods were collected; and surface temperature, salinity, and chlorophyll *a* concentration at the stations during sampling

Station	Location		Date	Time	Depth	Temperature	Salinity	Chl*a*
	Longitude (E)	Latitude (N)			(m)	(°C)	(ppt)	(mg m^{-3})
Nuclear Power Plant 2								
1	121° 40.9	25°13.2	31 Aug	2045 - 2115	22	27.5	33.6	0.53
2	121° 41.1	25°13.9	27 Aug	1200 - 1415	32	27.6	33.6	1.18
3	121° 40.7	25°12.9	30 Aug	1250 - 1310	31	30.1	33.2	0.74
4	121° 41.7	25°14.7	27 Aug	1350 - 1445	94	27.8	33.5	1.33
Nuclear Power Plant 1								
5	121° 35.0	25°18.1	29 Aug	1030 - 1050	34	27.6	33.6	0.42
6	121° 35.2	25°18.1	29 Aug	1445 - 1550	46	27.3	33.5	0.88
7	121° 35.8	25°17.9	30 Aug	1445 - 1515	36	27.3	33.4	0.35
8	121° 35.1	25°18.1	31 Aug	1910 - 1930	31	26.8	33.5	0.53

RESULTS AND DISCUSSION

Vertical profiles of water temperature and salinity at 8 sampling stations are presented in Figs. 2 and 3, respectively. Table 1 shows the surface temperature and salinity at 8 stations. Thermal pollution was observed outside Nuclear Power Plant 2 at station 3 where the surface temperature reached 30.0 °C. Surface temperatures at the other stations ranged from 26.8 °C at station 8

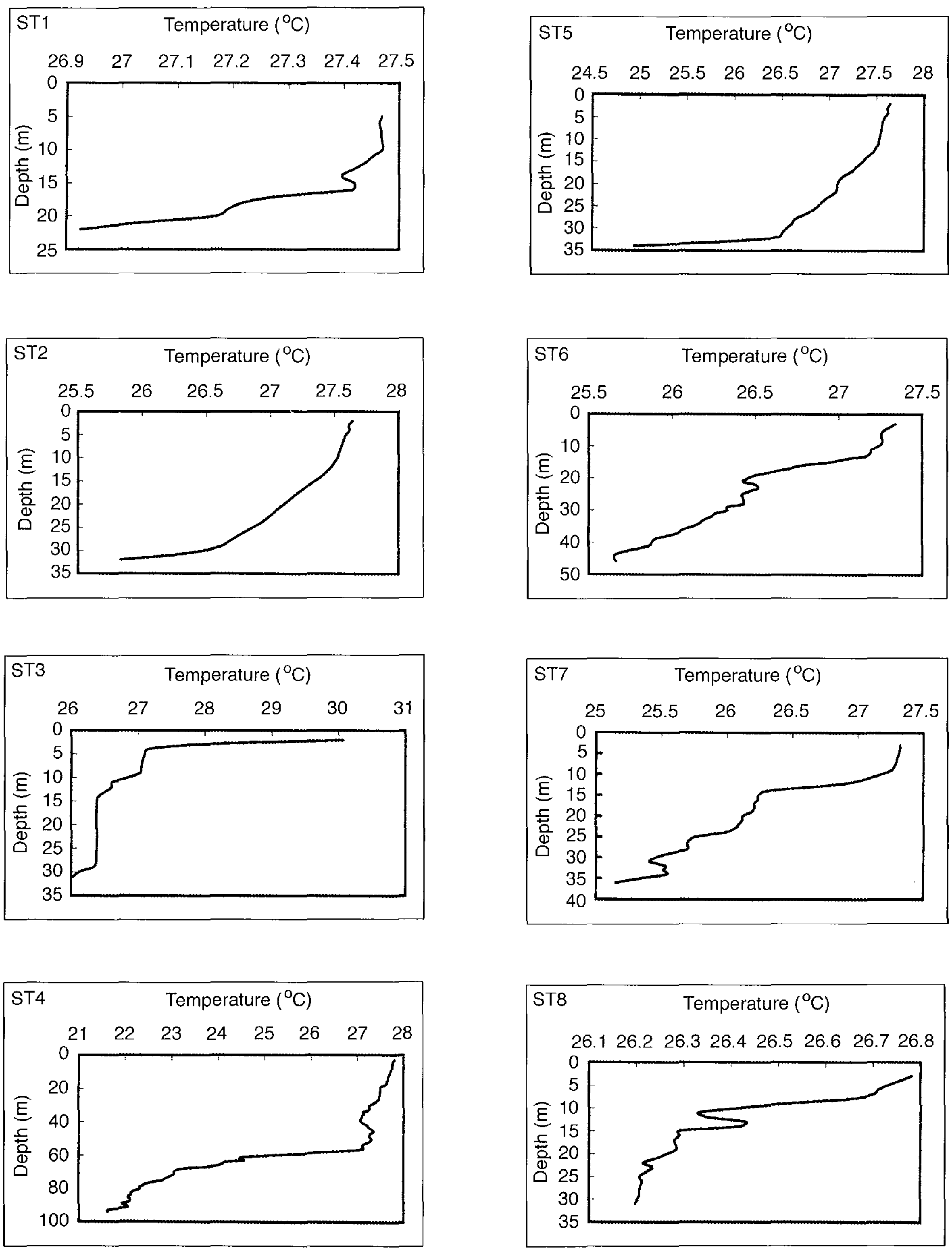

Fig. 2. Vertical profile of water temperature at 8 sampling stations on the northern tip of Taiwan.

to 27.8 °C at station 4. Salinity at the surface showed little variation among the sampling stations. Chlorophyll *a* concentrations were low, but the average value of 0.75 mg m^{-3} was within the range of values previously reported in the same area by Hwang et al. (1998). Average concentrations appeared to be higher outside Nuclear Power Plant 2 (0.95 mg m^{-3}) than outside Nuclear Power Plant 1 (0.55 mg m^{-3}), but the difference was not statistically significant (*t*-test, $p > 0.05$).

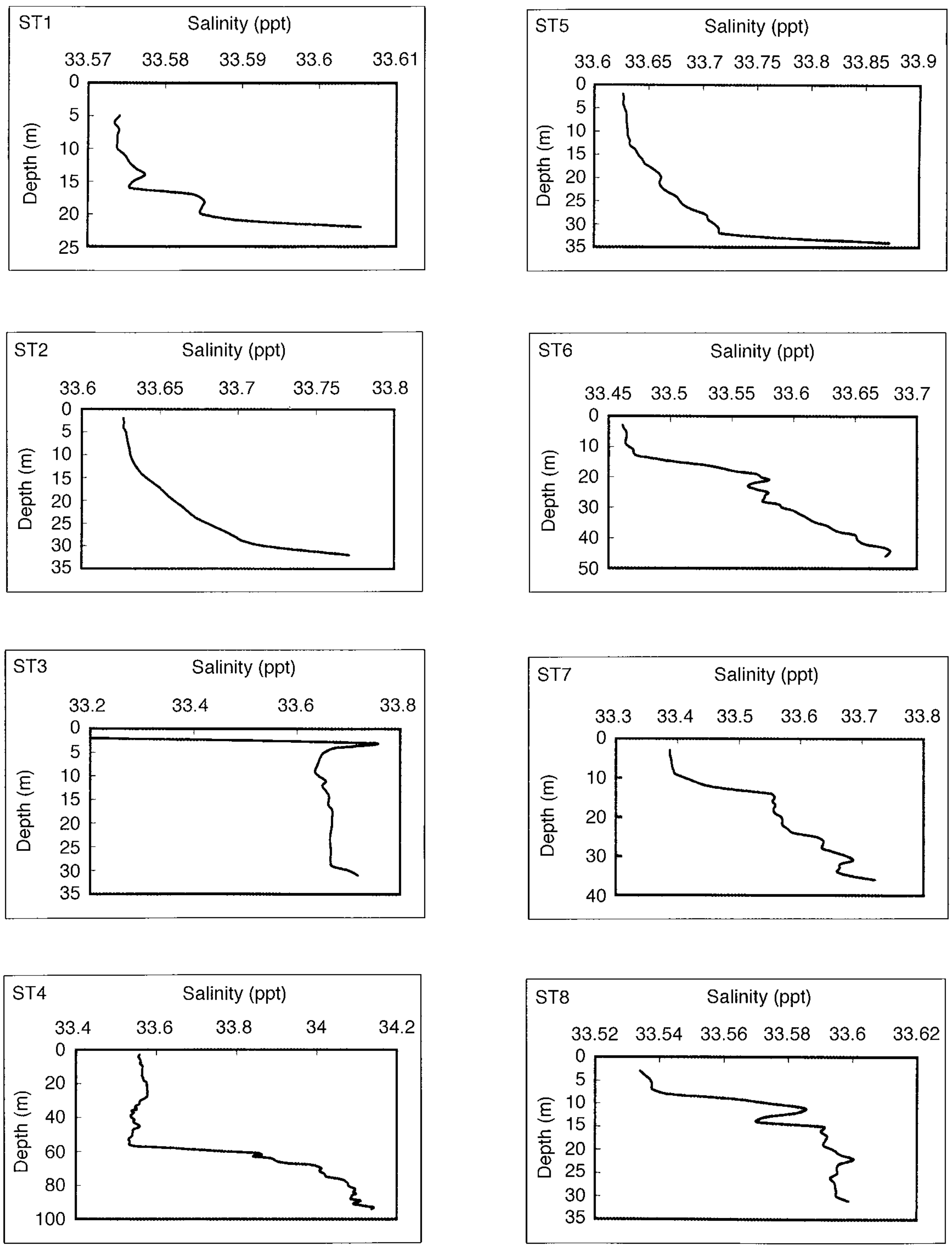

Fig. 3. Vertical profile of salinity at 8 sampling stations on the northern tip of Taiwan.

Calanoid copepods were the most dominant component of the crustacean zooplankton in the study area in terms of species diversity and numerical abundance. The distribution of calanoid copepods was extremely patchy. Total density varied widely among stations, ranging from 14 copepods m^{-3} at station 7 to 3287 copepods m^{-3} at station 2. Thirty-seven species, distributed among 20 genera, were identified (Table 2). Species composition also varied among sampling stations. Species richness at sampling stations ranged from 11 at station 6 to 24 at station 3. Six species, *Acrocalanus gracilis*, *Centropages orsini*, *Eucalanus subcrassus*, *Nannocalanus minor*, *Temora turbinata*, and *Undinula vulgaris*, were found at all 8 sampling stations. *A. gracilis*, was the most dominant species in the area during the study period, comprising 31% to 91% of the calanoid copepods present. *Acrocalanus gibber*, *N. minor*, *T. turbinata*, and *U. vulgaris* each made up more than 10% of the calanoid copepod community at station 2. While *T. turbinata* was also

Table 2. Density and species composition of calanoid copepods at 8 stations outside 2 nuclear power plants in northern Taiwan

Species	Density (copepods m^{-3})							
	Station							
	1	2	3	4	5	6	7	8
Acartia erythraea		9.9	5.5				< 0.1	2.2
Acartia negligens		9.9		0.7	2.0		0.2	
Acrocalanus gibber	53.9	370.1	13.4		99.9		0.3	1.5
Acrocalanus gracilis	883.9	1431.0	288.0	24.9	2304.5	105.1	11.5	150.3
Acrocalanus monachus				0.3	5.0	0.3		
Calanopia elliptica	94.3	4.9	0.8	0.2	13.0		0.6	63.2
Calanopia minor	24.3		1.6					
Calanus sinicus			3.2		28.0			
Calocalanus pavo		4.9		0.2	6.0			
Candacia bradyi			2.4					
Candacia catula	2.7	9.9		< 0.1	1.0			0.7
Candacia truncata				< 0.1				
Canthocalanus pauper	24.3	138.2	14.2	1.4	16.0	0.7	0.1	
Centropages calaninus			0.8					
Centropages furcatus	24.3		15.0	0.8	15.0		< 0.1	7.4
Centropages orsini	16.2	4.9	17.4	1.3	91.9	0.7	0.1	27.5
Cosmocalanus darwini	8.1	9.9		< 0.1	3.0			
Eucalanus crassus			1.6		2.0			
Eucalanus pseudattenuatus	2.7		0.8					
Eucalanus subcrassus	67.4	143.1	1.6	1.7	60.9	1.6	0.3	8.9
Eucalanus subtenuis				< 0.1				
Euchaeta wolfendeni			0.8		1.0			
Labidocera acuta	5.4	19.7	0.8		24.0			2.2
Labidocera bipinnata								0.7
Labidocera detruncata				< 0.1				
Labidocera euchaeta							< 0.1	
Labidocera minuta			0.8	0.2	1.0	0.7	< 0.1	
Nannocalanus minor	45.8	404.6	40.3	4.1	64.9	0.3	0.2	7.4
Paracalanus aculeatus	5.4	19.7	1.6	0.7	5.0	2.3	< 0.1	
Pontellopsis regalis		4.9						0.7
Pseudodiaptomus sp.							< 0.1	
Rhincalanus cornutus		9.9	0.8					
Scolecithrix danae		4.9		< 0.1	2.0			
Temora discaudata	13.5		10.3	0.1	8.0		0.1	3.0
Temora turbinata	503.9	330.6	26.1	4.4	39.9	2.8	0.6	46.1
Tortanus gracilis						0.3	< 0.1	0.7
Undinula vulgaris	99.7	350.4	19.0	0.3	51.9	0.7	< 0.1	14.9
Total	1878.2	3286.5	469.1	41.4	2845.9	115.4	14.2	337.7

common at station 1, the other 3 species were rare at the other sampling stations. Seven species were each recorded from only 1 sampling station.

A survey of the taxonomic composition of calanoid copepods in coastal waters in the northern tip of Taiwan conducted in May 1996 recorded 25 species (Hwang et al. 1998). *A. gracilis* was also the most dominant calanoid copepod in that survey. In contrast, *N. minor* which occurred at all 8 sampling stations in this study was not found in the May 1996 survey. The differences in species composition and species richness may represent sea-

Table 3. Density, gut pigment content (G), ingestion rate (I), clearance rate (F), and feeding impact (T) of calanoid copepods at 8 stations outside 2 nuclear power plants in northern Taiwan

Station	Species	Density (copepods m^{-3})	G (ng $copepod^{-1}$)	I (ng $copepod^{-1}h^{-1}$)	F (ml $copepod^{-1}h^{-1}$)	T (ml $m^{-3}day^{-1}$)
1	*Acrocalanus gracilis*	883.9	0.55	1.00	1.90	40255
	Calanopia elliptica	94.3	0.27	0.48	0.91	2066
	Canthocalanus pauper	24.3	0.66	1.19	2.26	1317
	Labidocera acuta	5.4	0.77	1.39	2.64	341
	Temora discaudata	13.5	0.31	0.55	1.05	338
	Temora turbinata	503.9	0.10	0.18	0.34	4063
	Undinula vulgaris	99.7	1.88	3.39	6.46	15462
2	*Acrocalanus gracilis*	1431.0	0.38	0.68	0.58	19908
	Canthocalanus pauper	138.2	0.20	0.36	0.30	1009
	Centropages orsini	4.9	0.19	0.34	0.28	33
	Cosmocalanus darwini	9.9	0.42	0.75	0.63	150
	Eucalanus subcrassus	143.1	0.45	0.80	0.68	2342
	Temora turbinata	330.6	0.18	0.33	0.28	2202
3	*Acrocalanus gracilis*	288.0	0.20	0.35	0.48	3289
	Canthocalanus pauper	14.2	0.51	0.93	1.25	425
	Eucalanus subcrassus	1.6	1.03	1.85	2.48	94
	Temora discaudata	10.3	0.95	1.72	2.31	569
	Temora turbinata	26.1	0.15	0.26	0.35	221
	Undinula vulgaris	19.0	1.76	3.17	4.26	1940
4	*Acrocalanus gracilis*	24.9	0.15	0.26	0.20	117
	Eucalanus subcrassus	1.7	0.26	0.47	0.35	14
	Temora turbinata	4.4	0.26	0.48	0.36	37
5	*Acrocalanus gracilis*	2304.5	0.22	0.40	0.94	52174
	Calanopia elliptica	13.0	0.20	0.36	0.86	266
	Canthocalanus pauper	16.0	0.12	0.21	0.51	194
	Centropages furcatus	15.0	0.06	0.10	0.25	88
	Eucalanus subcrassus	60.9	0.33	0.59	1.40	2044
	Labidocera acuta	24.0	0.25	0.44	1.05	605
	Temora discaudata	8.0	0.21	0.38	0.91	174
	Temora turbinata	39.9	0.14	0.26	0.62	592
	Undinula vulgaris	51.9	0.88	1.58	3.74	4658
6	*Acrocalanus gracilis*	105.1	0.11	0.20	0.22	561
	Eucalanus subcrassus	1.6	0.38	0.68	0.77	30
	Temora turbinata	2.8	0.66	1.19	1.35	90
7	*Acrocalanus gracilis*	11.5	0.12	0.21	0.59	164
	Centropages furcatus	< 0.1	0.07	0.12	0.35	< 1
	Centropages orsini	0.1	0.04	0.07	0.20	< 1
	Temora discaudata	0.1	1.03	1.85	5.22	8
	Temora turbinata	0.6	0.40	0.73	2.05	30
8	*Acrocalanus gracilis*	150.3	0.14	0.25	0.44	1603
	Calanopia elliptica	63.2	0.32	0.58	1.04	1578
	Eucalanus subcrassus	8.9	1.15	2.07	3.72	796
	Labidocera acuta	2.2	2.37	4.27	7.70	412
	Temora turbinata	46.1	0.32	0.57	1.03	1139
	Undinula vulgaris	14.9	9.15	16.47	29.66	10589

sonal variation.

The gut pigment level, ingestion rate, and clearance rate of 11 species were measured. Not all identified species were studied due to relatively low abundance of some. Variability of gut pigment content for a single species among sampling stations was great, suggesting that the grazing activity of calanoid copepods varied with time of day and ambient food concentration. Gut pigment levels of *A. gracilis* and *T. turbinata* were measured at all 8 sampling stations. The values for *A. gracilis* averaged 0.23 ng copepod^{-1} and ranged from 0.12 ng copepod^{-1} at station 6 to 0.55 ng copepod^{-1} at station 1. In comparison, the values for *T. turbinata* averaged 0.28 ng animal^{-1} and ranged from 0.10 ng animal^{-1} at station 1 to 0.66 ng animal^{-1} at station 6. The highest gut pigment level was recorded in *U. vulgaris* at station 8. In general, the values obtained for most species measured in this study were lower than, but within the range of, those reported for specimens collected from the same area in May 1996 (Hwang et al. 1998).

Gut evacuation rates were measured for *Calanus sinicus* and *Eucalanus subcrassus* collected in coastal waters of Hong Kong. Values of k ranged from 0.025 min^{-1} for *C. sinicus* to 0.034 min^{-1} for *E. subcrassus*. The values are within the range of the extremely variable data in the literature, as reviewed by Morales et al. (1990). Dam and Peterson (1988) suggested that gut evacuation rates of copepods was strongly dependent on temperature. Because the gut evacuation rates for *C. sinicus* and *E. subcrassus* were obtained in water temperatures (24-26 °C) close to those encountered in this study and data in the literature show no consistent trend in relation to taxa and body size, an average value of 0.030 min^{-1} was used for estimating ingestion rates.

The highest ingestion rate and clearance rate were found in *U. vulgaris*. Ingestion rates and clearance rates recorded in this study were lower than, but within the range of, ingestion and clearance rates measured in animals collected from the same area in May (Hwang et al. 1998). For example, the average ingestion rate recorded for *A. gracilis* was 1.05 ng copepod^{-1} h^{-1} in May and 0.42 ng copepod^{-1} h^{-1} in the present study. Similarly, clearance rate, which has taken into account differences in food concentration, averaged 1.29 ml copepod^{-1} h^{-1} in May and only 0.67 ml copepod^{-1} h^{-1} in the present study. In general, the ingestion and clearance rates for *T. turbinata*, *Canthocalanus pauper*, and *U. vulgaris* were lower in this study than in the previous study.

Despite its small size and low ingestion rate, *A. gracilis* was the most important grazer at all sampling stations except station 8 where *U. vulgaris* was the major grazer. Grazing impact, estimated as the volume of water swept clear of food per cubic meter per day by *A. gracilis*, ranged from 117 ml at station 4 to 52 174 ml at station 5. In terms of the fraction of chlorophyll removed from 1 m^3 of water by *A. gracilis*, these values corresponded to about 0.01% and 5%, respectively. The average clearance rate for all species was 1.48 ml copepod^{-1} h^{-1} if the unusually high value for *U. vulgaris* at station 8 was not included in the calculation. Using this averaged value, grazing impact by all calanoid copepods ranged from 504 ml m^{-3} day^{-1} at station 7 to 116 718 ml m^{-3} day^{-1} at station 2. These values correspond to feeding impacts of 0.05% and 12%, respectively. Significantly, these estimates suggest that the fraction of phytoplankton consumed by the calanoid copepod assemblages in the nearshore waters outsider Nuclear Power Plants 1 and 2 was low.

Feeding by herbivorous calanoid copepods is one of the most important trophodynamic processes in the ocean. Results presented in this paper show that the grazing impact of calanoid copepods in coastal waters outside nuclear power plants in northern Taiwan was low. The low values recorded here are, however, within the range of very variable values reported in the literature (Baars and Fransz 1984, Peterson et al. 1990, Morales et al. 1991).

It must be pointed out that the grazing impact we present in this paper may have been underestimated because of several sources of error. Many investigators (Peterson et al. 1990, Morales et al. 1991) have reviewed the errors associated with the measurement of gut evacuation rate and the calculation of both ingestion and clearance rates. Specifically, feeding impacts calculated in this preliminary study have not taken into account diel differences in grazing rates. Diel variations in the gut pigment contents of calanoid copepods have been reported by many investigators (Mackas and Bohrer 1976, Peterson et al. 1990, Tang et al. 1994). Species which perform diel vertical migrations show a significant increase in gut pigment contents at night. Copepods collected during the evening from stations 1 and 8 contained no more gut pigments than did copepods collected during daytime from other stations. This observation suggests that all samplings in this study were made before the commencement of nocturnal feeding. Daily ingestion rates which take into account diel differences in gut pigment contents would double or triple our estimates of grazing impact. Another possible source for underestimating the grazing impact of the calanoid copepod community is that grazing by juveniles was not measured. Also, zooplankton abundance can have large variations over horizontal distances of 1 to 10 km (Mackas et al. 1985). Despite these various sources of error, however, we estimate that the true feeding impact of calanoid copepods in the coastal waters was probably no more than 20% to 30% of the phytoplankton standing crop. There was no evidence to suggest that the slightly elevated surface water temperature at station 3 had affected the community structure or grazing impact of calanoid copepods.

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臺灣北部核電廠近岸海域哲水蚤橈足類之種組成與攝食衝擊

黃創儉[1] 黃將修[2] 陳清潮[3]

1996年8月在臺灣北部核一與核二廠附近海域八個測站研究Calanoid橈足類攝食浮游植物之情形。本研究分析每個測站之Calanoid橈足類之含量、種組成與攝食速率；並採用消化道螢光色素分析法估算Calanoid橈足類在每個測站之攝食率與濾食率。本次研究發現共有38種Calanoid橈足類存在，而每個測站Calanoid橈足類的豐度、種組成均有不同，其中*Acrocalanus gracilis*為在採樣期間之Calanoid橈足類中的優勢種，且其占所有Calanoid橈足類含量之30%-90%之多。各種Calanoid橈足類其攝食率及濾食率在每個採樣站之間的變化很大。雖然*A. gracilis*的體型相對的較小及其較低的濾食率，但因為其具有最多的生物豐度所以牠是本研究海域採樣期間最重要的草食者。對核一與核二廠附近海域分析Calanoid橈足類攝食浮游植物之情形，顯示出在每立方公尺海水中有0.05%-11%的葉綠素是被Calanoid橈足類所攝食。同時本次研究沒有證據顯示第三採樣站海水表面溫度雖達攝氏三十度，對Calanoid橈足類之群聚結構或攝食情形產生顯著之影響。

關鍵詞：哲水蚤橈足類，種組成，攝食衝擊。

[1]香港中文大學生物系
[2]國立臺灣海洋大學，海洋生物研究所
[3]中國科學院南海海洋研究所，廣州