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Study on the distribution, abundance and growth condition of Antarctic Krill (*Euphausia superba*) in the Prydz Bay region, Antarctica during the Austral summer of 1999/2000

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Abstract Antarctic krill (*Euphausia superba*) were collected from the Prydz Bay region during the austral summer of 1999/2000. The sample – collection was made at 15 sites in 3 longitudinal transects. Although krill were encountered at 14 sites, the abundance was comparatively low in general. The main component of the krill population was of post – larval stages. The mean numerical and weight density of krill integrated for all sampling stations in the survey area were 16.17 ind. 1000 m^{-3} and 12.02 g 1000 m^{-3}, respectively. In the survey area, stations with larger krill density are mainly located in the slope zone, except that the largest sample was collected in the open sea zone. No krill occurred in the only station of the shelf zone during our investigation. Krill collected from the slope zone were under better growth condition than those from the open sea zone, but when the survey area is considered as a whole, the growth condition is normal. The results of the comprehensive analysis of the environmental factors show that the three large sample stations seem to be related with the cold water mass at 75 m depth and the confluence area between the high and low Chl *a* centers at the depth of 25 m.

Key words Antarctic krill (*Euphausia superba*), Prydz Bay, Antarctica, growth condition.

1 Introduction

Though Marr (1962) and Mackintosh (1973) suggested that the South Indian Ocean might be another fishing area of Antarctic krill (*Euphausia superba*) other than the South Atlantic Ocean, little work has been done before BIOMASS program in this region (EI – Sayed *et al.* 1979; Hempel 1983). Since the initiation of BIOMASS program, more and more research work (Inagake *et al.* 1985; Lubimova *et al.* 1985; Hosie *et al.* 1988; Higginbottom and Hosie 1989; de la Mare 1994; EI – Sayed 1994; Hosie and Cochran 1994; Hosie *et al.* 2000) and some fishing programs (Dolzhenkov and Timonin 1990; Ichii 1990) concerned with the study of Antarctic krill in this region have been increasingly conducted. In 1994, the international GLOBEC working group recommended some areas of the South Indian Ocean as one of the three principal study areas for SO – GLOBEC field studies. But some later studies (Hosie *et al.* 1988; Pauly *et al.* 2000) carried out in the limited area of the South Indian Ocean show that the krill abundance was very low.

China is engaged in the Antarctic research program in 1980's, and became one of the participants of the SO - GLOBEC program in 1994. In 1985, China commenced the work related to ecology and biology study on Antarctic krill. Except a few sporadic investigations carried out near Antarctic peninsula areas (Wang 1989, 1990; Wang and Chen 1989), where Great Wall station is located, most of the research work was carried out in some areas of the Indian Ocean, especially in the Prydz Bay region (Wang and Zhong 1993; Wang *et al.* 1993a, b; Zhong and Wang 1995; Sun *et al.* 1995; Sun and Wang 1995, 1996). However, the majority of these works were concerned mainly with the biology of Antarctic krill, little work was done on the distribution and abundance of krill. In the austral summer of 1999/2000, net sampling was carried out in the Prydz Bay region. The purpose of this paper is to present the results of the net sampling on the distribution, abundance and growth condition of Antarctic krill, and to provide some more actual information for better understanding of Antarctic krill population variation in the Prydz Bay region.

2 Materials and methods

2.1 *Survey tracks*

The area between 70.5°E and 75.5°E was surveyed from 18 to 27 of January, 2000. Three longitudinal transects (along 70.5°E, 73°E and 75.5°E) and a total of 15 sampling stations were included. The intervals of the two neighboring sampling sites along each transect was one degree off the slope, and half degree near the shelf. The cruise tracks and the details of the sampling stations are shown in Fig. 1.

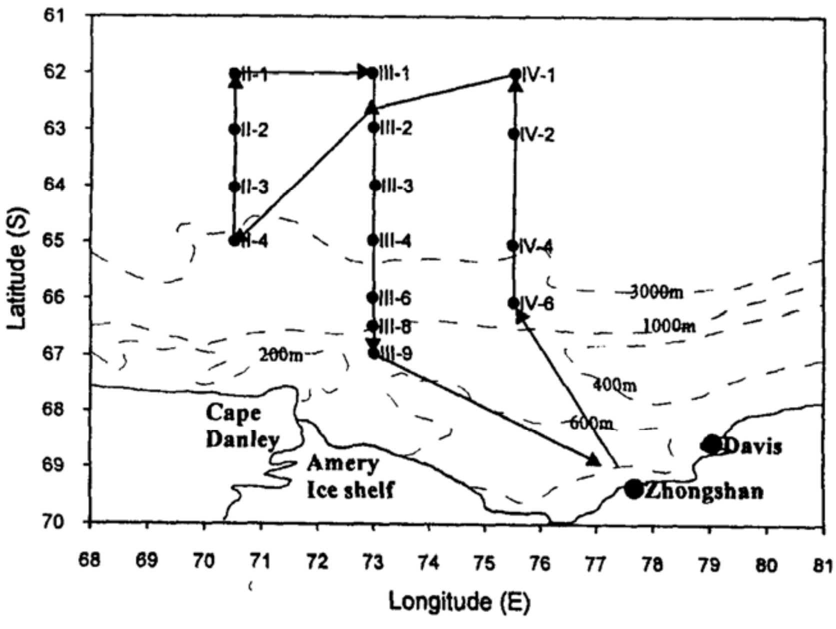

Fig. 1. Transects, stations and survy tracks.

2.2 *Sampling and analysis*

Oblique tows were made to collect krill from around the 200 m depth to the surface by using the IKMT (Isacca – Kidd Midwater Trawl) net, whose mouth area was 2 m^2, mesh size 6 mm, under the speed of 2 – 4 knots. Similar to the RMT8 net (Rectangular Midwater Trawl) (Pommeranz *et al.* 1982; Roe *et al.* 1980), the effectiveness of the IKMT net can also be affected by the trawling speed and the trawling trajectory. In our study, we assumed that 2 m^2 mouth area of the IKMT net remained steady and kept open through each operation, thus the volume of the water filtered each time was determined through multiplying the trawling speed by the trawling time and mouth area.

The sample collected in the field was preserved in 5% formaldehyde seawater solution for later examination. After the voyage, Krill samples were sorted and measured in the land laboratory. Overall wet weight of each whole sample were measured first, then a sub – sample of about 400 krill individuals was randomly selected from each sample for body length measurement (standard 1, Mauchline 1980) (using vernier caliper, measured to mm), eye diameter measurement (using the dissecting microscope with a micrometer, measured to 0.1 mm) and maturity stage analysis (according the standard of Makarov and Denys (1981)); and all individuals were analyzed in the case of small (<400 individual) krill catches.

2.3 *Observation of environmental factors*

Seawater was collected from the depth of 0 m, 25 m, 50 m, 100 m, 150 m, and 200 m at each station for the determination of Chl *a* concentration. During the experiment, 250 ml seawater was filtered through the GF/F (Whatman) filter membrane, and the phytoplankton cells trapped on the membrane was extracted with 90% acetone for 24 h. The Chl *a* concentration of the extracting solution was determined by using the Turner Designs Fluorometer, Model 10.

The temperature and salinity data obtained from the CTD system was provided by the First Institute of Oceanography, SOA.

3 Results

3.1 *Distribution and abundance*

Euphausia superba post – larval stages (adult and juvenile) occurred at most of the stations in the study area, though the densities were very low (fig. 2 a, b). Krill distribution was rather patchy in the survey area, density ranged from 0.1 to 185.81 ind. 1000 m^{-3} in number and 0.12 to 128.64 g1000 m^{-3} in weigh. Krill abundance rarely exceeded 4 ind. 1000 m^{-3} and 3 g1000 m^{-3}, except for stations Ⅱ – 3, Ⅲ – 6 and Ⅳ – 4, the three large sample stations, where krill densities were more than 20 ind. 1000 m^{-3} or 11 g1000 m^{-3}. At Ⅱ – 3 station krill density reaches the highest value, 185.81 ind. 1000 m^{-3} in number and 128.64 g1000 m^{-3} in weight. No krill were found at Ⅲ – 9, the only station that lies south of the 1000 m isobath in the survey area. The mean numerical and weight densities of krill integrated for the whole survey area, calculated from the total number or wet weight of krill divided by the total volume of water filtered, were 16.17 ind. 1000 m^{-3} and 12.02 g1000 m^{-3}. Leaving aside the station Ⅱ -3, krill densities were relatively high and more evenly distributed in the slope zone (between 1000 m and 3000 m isobath) than those in the open sea zone (>3000 m).

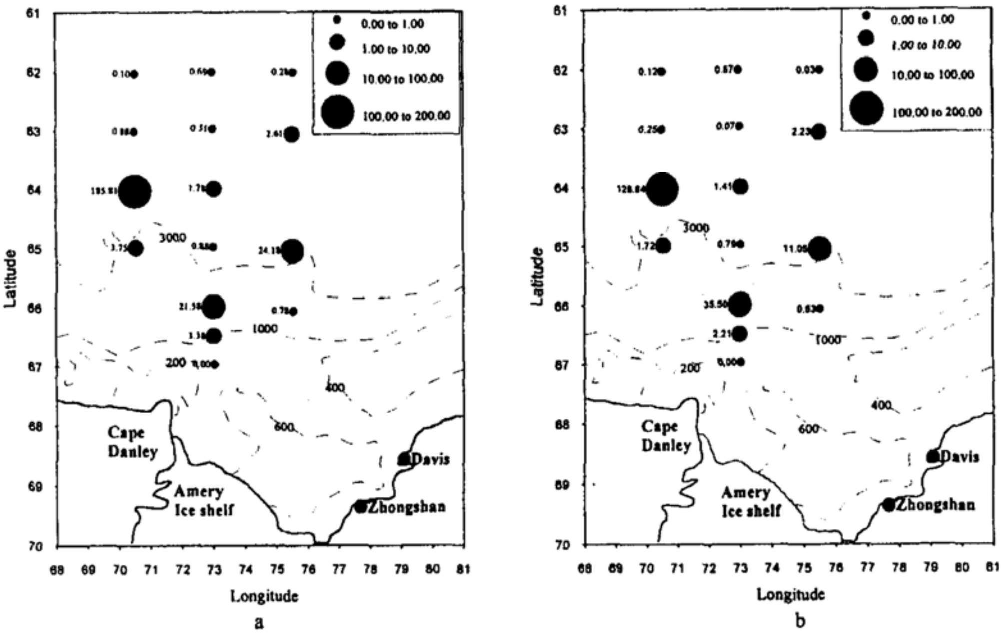

Fig. 2. Distribution and abundance of *Euphausia superba* . a: The numerical density of *Euphausia superba* (ind. 1000 m^{-3}); b: The wet weight density of *Euphausia superba* (g1000 m^{-3})

During the investigation period, 15 net hauls were carried out in the survey area, of these 14 caught krill, but only 7 nets caught more than 15 individuals, the other catches were all very small (1 - 7 individuals). We analyzed the 7 samples whose catches were more than 15, and plotted its frequency distribution of maturity stages in Fig. 3. From the picture we can see that juvenile stage was found only at 2 stations (Ⅱ -3 and Ⅳ -4), and its proportion was very low. The proportion of female was ascending from slope zone to open sea zone along the transect Ⅱ, but there is a reverse trend along the transect Ⅲ or Ⅳ. Gravid females were found at the three large sample stations and station Ⅲ -8, but only at station Ⅱ -3 and Ⅲ -8, the proportion of gravid individual attains a value higher than 30%. The last adult stage of male, 3BM stage, was found at almost all stations analyzed, this indicates that male krill usually matured more quickly than female ones.

3.2 Growth condition

Sun and Wang (1996) studied the relationship between the diameter of the compound eye and the growth of the Antarctic krill, they proposed that the ratio of body length to eye

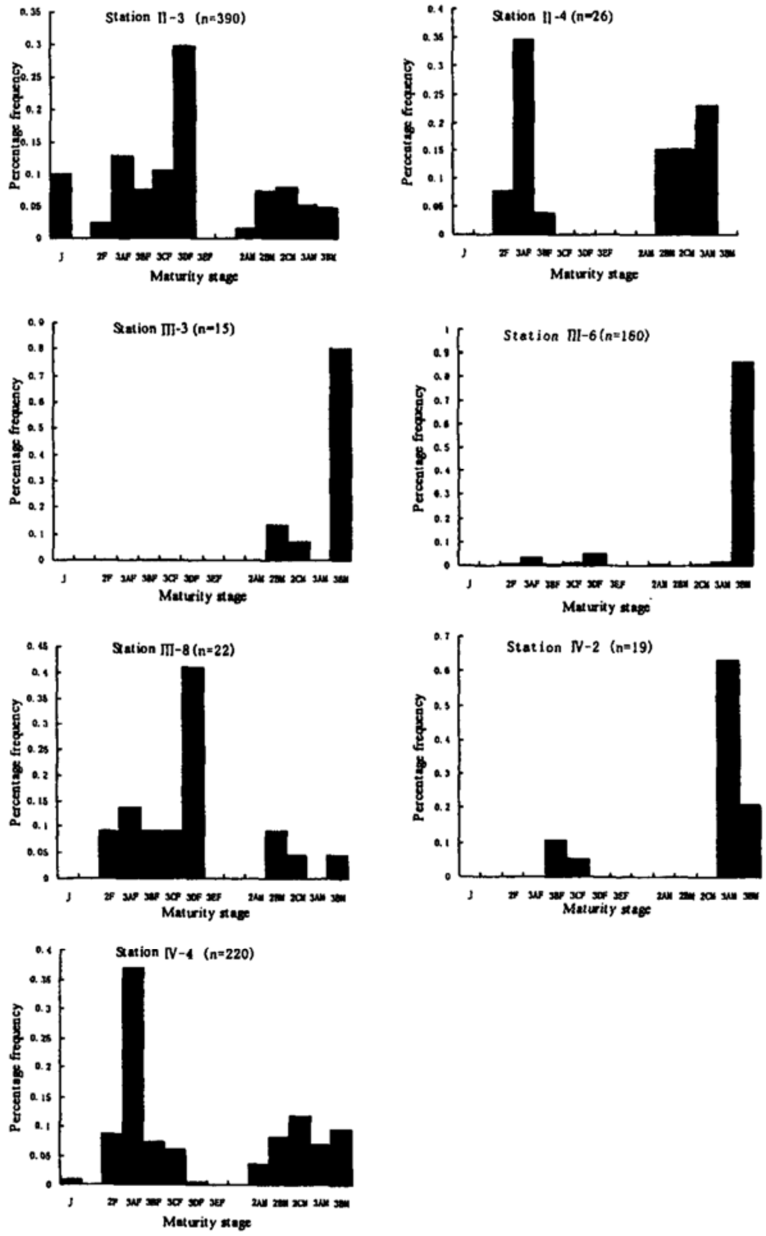

Fig. 3. Percentage - frequency distribution of *Euphausia superba* post - larval maturity stage. J = juvenile; 2F = sub - adult female; 3AF = mature female not mated; 3BF = mated mature female, ovaries small; 3CF = mated mature female, ovaries fill thoracic space; 3DF = spawning female; 3EF = spent female; 2AM - 2CM = sub - adult male with developing petasma; 3AM = mature male, no spermatophore in ampullae; 3BM = mature male with spermatophore, ready to mate.

diameter can be used as an indicator of growth condition for krill. Sun and Wang (1996)'s results indicate that the higher the ratio of the BL/ED (Body Length to Eye Diameter) the better the growth condition of Antarctic krill of the same age. They studied the relationship between the body length and the eye diameter of krill under the normal growth condition, and obtained a set of exponential functions: $ED = 0.574e^{0.0292BL}$ (juvenile + female + male), $ED = 0.5898e^{0.0282BL}$ (juvenile + female) and $ED = 0.544e^{0.0309BL}$ (juvenile +

male). Using these functions as source of the standard curves (r = 1), we plotted dot graph according to the ratio data of body length to eye diameter to see if the krill collected from the survey area were under normal growth condition (fig. 4). Results show that krill at station Ⅱ -3 were growing better than those collected from any other stations, and there was a trend of better growth condition in the slope zone than those in the open sea zone. Considering the survey area as a whole, the krill were under normal growth condition.

3.3 *Environmental factors*

3.3.1 *Temperature*

Surface temperature increased from the shelf zone to the open sea zone, and it increased rather slowly east of 73°E than west of 73°E (fig. 5a). The surface temperature varied from -1.5℃ to 1℃ in the survey area, and > -0.5℃ at the three large sample stations. A relatively warm water mass is located at the north - west corner near the location of station Ⅱ -3 (fig. 5a). When comparing the vertical distribution (0 - 200 m) of temperature of the three large - sample stations, we found that they all have a thermocline at 20 - 30 m and a cold water mass around 75 m (fig. 6a)

3.3.2 *Salinity*

The distribution of surface salinity is shown in fig. 5b. It shows that the salinity was declined from the northwest corner to the southeast corner, and the salinity along the diagonal line was descending rather slowly than that along the two sides. The surface salinity of survey area fell in the range 32.8‰ - 33.7‰ , and >33.3‰ at the three large sample stations. The depth - salinity profile chart (0 - 200 m) of the three large sample stations show that they all have a halocline at 20 - 30 m, and the relatively stable high - salinity water at the depth corresponding to the cold water mass at 75 m (fig. 6b). This indicates that the characteristics of the cold water mass were low temperature and high salinity.

3.3.3 *Chlorophyll a*

Surface distribution of Chl *a* is shown in fig. 5c. Chl *a* density was high in the shelf zone, and lower in the slope zone, being lowest in the ocean zone. Patchy aggregation of Chl *a* was not apparent in the study area, except in the area around station Ⅲ -6 and Ⅲ - 8 as well as near the station Ⅲ -9, where there was a relatively high Chl *a* center. Vertical profile (0 - 200 m) of Chl *a* along each transect is displayed in fig. 7. There are a high Chl *a* center (near shore) and a low Chl *a* center (off shore) located at the depth of 25 m along each transect, and the three large krill sample stations (Ⅱ -4, Ⅲ -6 and Ⅳ -4) were all found near the boundary area between the two centers.

4 Conclusion and discussion

The majority of the studies carried out in the Prydz Bay region turn out relatively low krill abundance (Higginbottom *et al.* 1988; Hosie *et al.* 1988) when compared with that obtained from Southern Atlantic sector. Exception was found in 1989, Higginbottom and

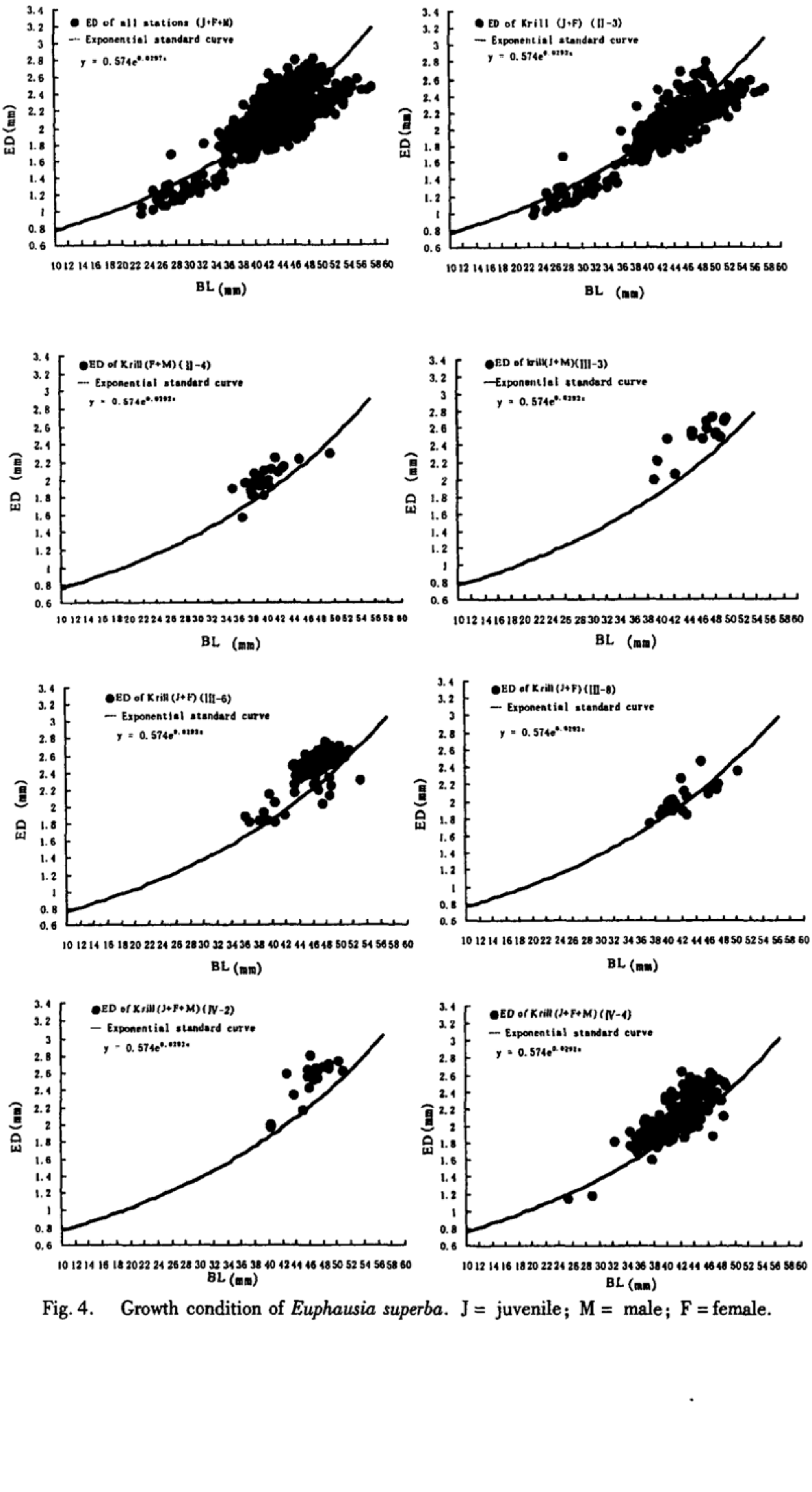

Fig. 4. Growth condition of *Euphausia superba*. J = juvenile; M = male; F = female.

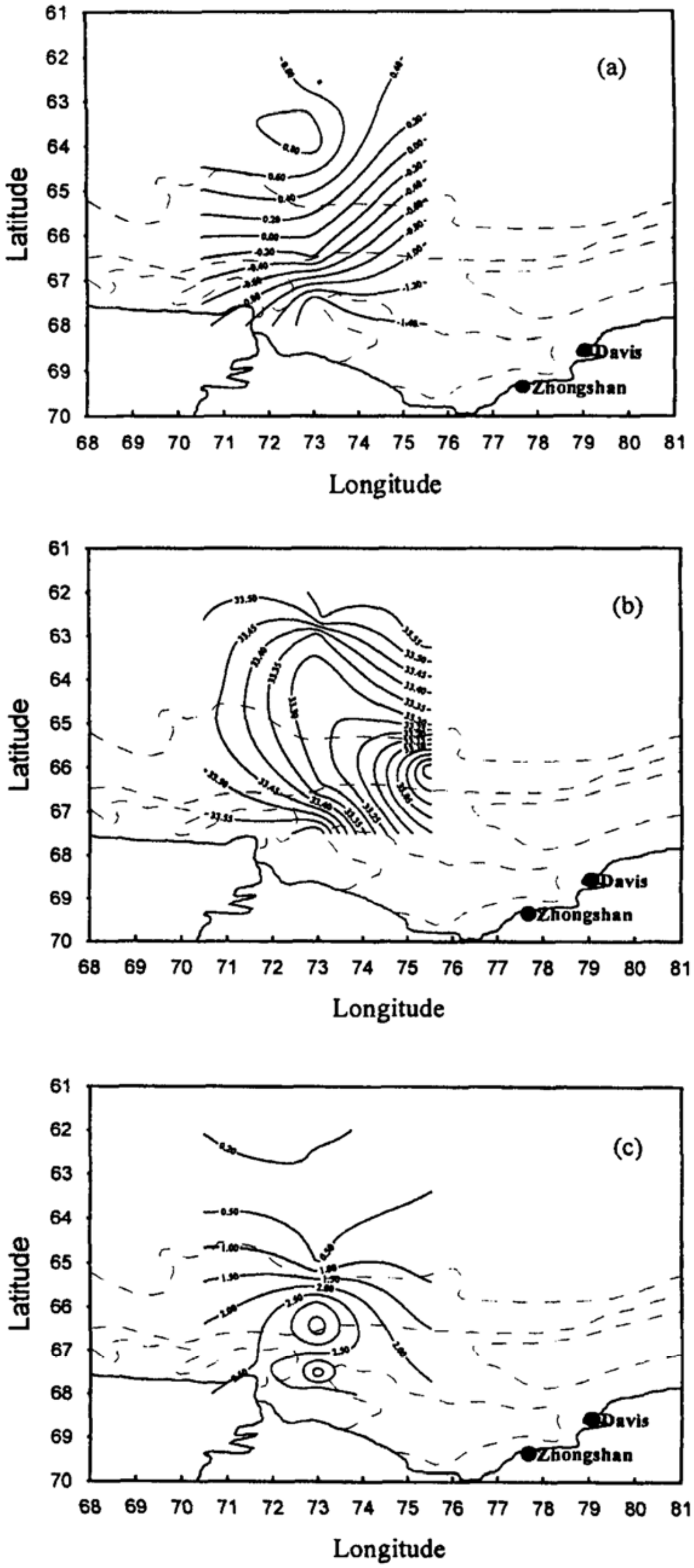

Fig. 5. The distribution of surface temperature, salinity and Chl *a*. a: temperature; b: salinity; c: Chl *a*.

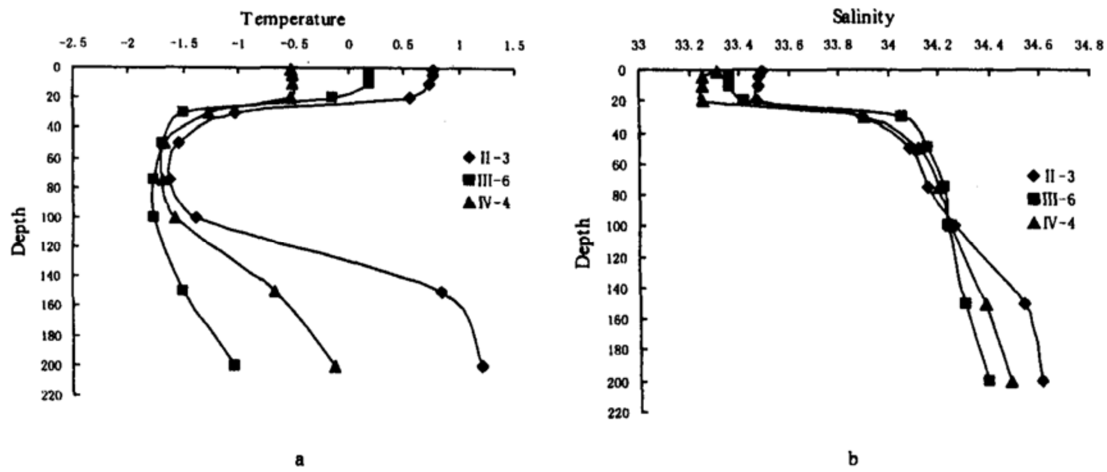

Fig. 6. Vertical distribution of temperature salinity of the three large sample stations. a: Vertical profile of temperature – depth. b: Vertical profile of salinity – depth.

Hosie(1989) reported a large aggregation of krill with the mean density of 101 gm $^{-3}$. The mean krill abundance integrated for the whole survey area in our study falls within the range recorded in the Australian sector (117° – 150°E) by Terazaki and Wada (1986). The pronounced patchy distribution of Antarctic krill in the Prydz Bay region may contribute much to the low estimates of mean densities (Siegel 1985). It was shown clearly in our study that the highest density is 185.81 ind. 1000 m $^{-3}$ in number and 128.64 g 1000 m $^{-3}$ in weight in II –3, but only 16.17 ind. 1000 m $^{-3}$ and 12.02 g 1000 m $^{-3}$ when integrated for the whole study area. Similar to the results of Miller (1986), our results also seem to prove that the waters within the East Wind Drift area are more productive, because the three large sample stations were all located in or near the East Wind Drift Area of Prydz Bay defined by Deacon (1937). The analysis of the vertical distribution of temperature at the three large sample stations shows that there was a cold water mass at the depth of 75 m. According to the literatures, *Euphausia superba* mainly inhabits in the waters above 200 m, and in these waters the vertical distribution of temperature and salinity varied considerably, and many areas have thermocline in the certain layers. There is a similarity in the 0 – 200 m vertical distribution of temperature and salinity of the three large sample stations, i. e. at 20 – 30 m there was a thermocline and a halocline and a cold water mass with the temperature lower than –1.5℃ at the depth of 75 m. Due to the lack of the stratified samples, we dont know the exact depth in which the krill inhabit. According to Wang and Chen (1988), the presence of krill swarm seems to be associated with the low water temperature, so we guess the occurrence of krill at the three high abundance stations may be related with the cold water mass.

The vertical Chl *a* profile along the three transects shows there was a similarity in the position of the three large sample sites at the depth of 25 m (Fig. 7). It is shown that the three large sample stations were all located between the low Chl *a* center and the high Chl *a* center found at the depth of 25 m along each transect. Ichii *et al.* (1998) suggested good feeding conditions could influence the richness of krill, if this is true, the krill of the three

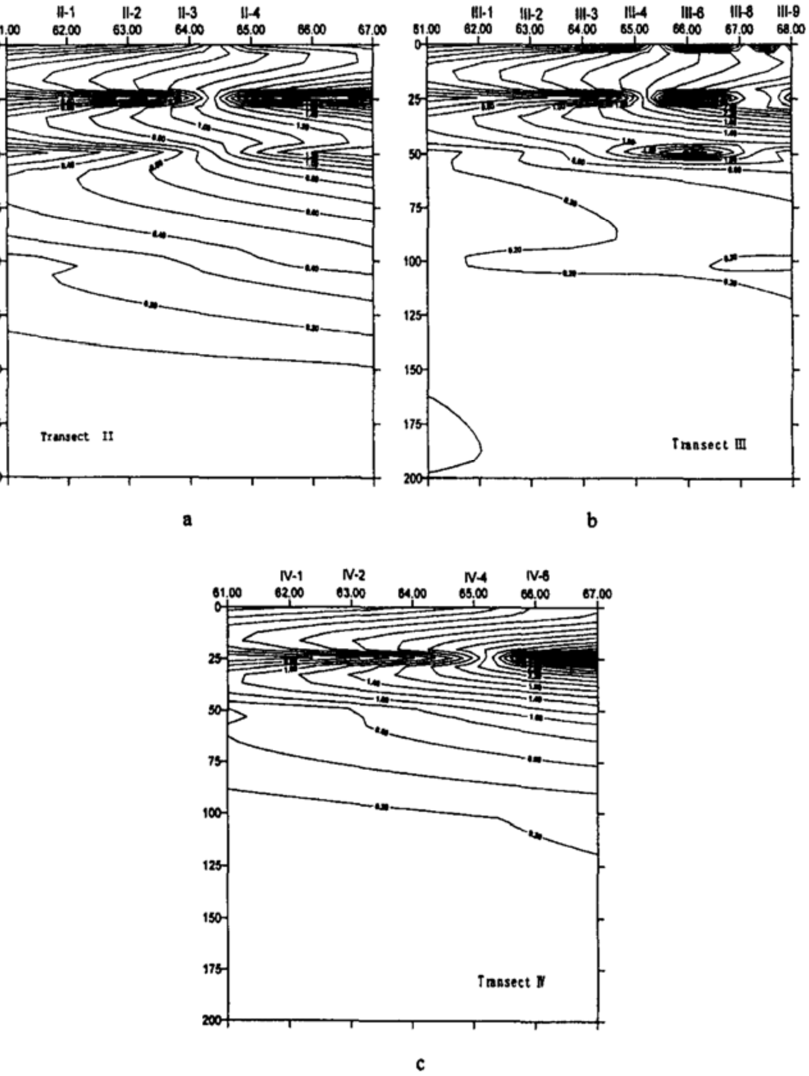

Fig. 7. The Chl *a* vertical profile of the three transects (the above coordinate represents the latitude and the stations, the vertical coordinate represents the depth). a: transect Ⅱ; b: transect Ⅲ; c: transect Ⅳ.

large stations should be found in the high Chl *a* center (before feeding) or in the low Chl *a* center (after feeding). So why the three large samples were found between the two centers, we guess that it may be connected with the spawning behavior.

Krill samples obtained in the study area are mainly composed of post - larval stages, this may be due to the existence of the larval stage in the deeper waters (Marr 1962; Hempel and Hempel 1986) and the large mesh size (6 mm) of the IKMT net. That the high frequency of matured 3BM male occurred in the survey area indicates that male krill reach sexual maturity prior to female ones. Samples obtained at station Ⅱ - 3 are composed of 63.07% female krill, most of which are gravid individuals, so station Ⅱ - 3 may be a favorable spawning field. Marr (1962) and Ichii *et al.* (1998) indicate deep water can provide a protection for newly born eggs. Station Ⅱ - 3 is located in the open sea zone but near the slope zone, it can provide a good food field for the larval stages.

In the present study, we analyzed the growth condition of Antarctic krill in the Prydz

Bay region. Results show that krill were under normal growth condition in the survey area in general, but in individual station, the growth condition varied to some extent due to the small number of krill collected at most stations. Still we can see that krill were under better growth condition in the slope zone than those in the open sea zone.

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References

de la Mare WK(1994): Hydroacoustic survey of Antarctic krill populations in CCAMLR Divion 58.4.1 during 1995/1996 summer season. CCAMLR, Hobart, Australia, 4.

Deacon GRE (1937): The hydrology of the Southern Ocean. Discovery Rep., 15: 1 - 124.

Dolzhenkov VN, Timonin VP (1990): Krill (*Euphausia superba* Dana) resources and distribution in the Wilkes Land area in the seasons 1986 to 1989. selected Scientific Papers, 1990 (SC - CAMLR - SSP/7), CCAMLR, Hobart, Australia.

EI - Sayed SZ (1994): History, organization and accomplishments of the BIOMASS program. In: EI - Sayed SZ, Ed. Southern Ocean Ecology: The BIOMASS perspective, Cambridge: Cambridge University Press, Committee of CCAMLR 1982 - 1984. Part II, 391 - 505.

EI - Sayed SZ, Stockwell DA, Reheim HA, Taguchi S, Meyer MA (1979): On the productivity of the Southwestern Indian Ocean. CNFRA, 44: 83 - 110.

Hempel G (1983): FIBEX - An international survey in the Southern Ocean: review and outlook. Mem. Natl. Inst. Polar Res., Spec. Issue, 27: 1 - 15.

Hempel I, Hempel G (1986): Field observations on the developmental ascent of larval *Euphausia superba* (Crustacea). Polar Biol., 6: 121 - 126.

Higginbottom IR, Hosie GW (1989): Biomass and population structure of a large aggregation of Krill near Prydz Bay, Antarctica. Mar. Ecol. Prog., 58: 197 - 203.

Higginbottom IR, Kerry KR, Wayte SE (1988): The distribution and abundance of krill in the region of Prydz Bay, Antarctica. A report of the hydroacoustic surveys carried out on the research cruises FIBEX, ADBEX - II and SIBEX - II, ANARE Res. Notes, 62: 1 - 46.

Hosie GW, Cochran TG (1994): Mesoscale distribution patterns of macrozooplankton communities in Prydz Bay Antarctic — January to February 1991. Mar. Ecol. Prog., 106: 21 - 39.

Hosie GW, Ikeda T, Stolp M (1988): Distribution, abundance and population structure of the antarctic krill (*Euphausia superba* Dana) in the Prydz Bay region, Antarctica. Polar Biol., 8: 213 - 224.

Hosie GW, Schultz MB, Kitchener JA, Cochran TG, Richards K (2000): Macrozooplankton community structure off East Antarctic (80°- 150°E) during the Austral summer of 1995/1996. Deep - sea Research II, 47: 2437 - 2463.

Ichii T (1990): Distribution of Antarctic krill concentrations explited by Japanese krill trawlers and Minke whales. Proceedings of the National Institue of Polar Research Symposium on Polar Biology, 3: 36 - 56.

Ichii T, Katayama K, Obitsu N, Ishii H, Naganobu M (1998): Occurrence of Antarctic Krill (*Euphausia superba*) concentrations in the vicinity of the South Shetland Islands: relationship to environmental parameters. Deep - Sea Research I, 45:1235 - 1262.

Inagake D, Matsuura N, Kurita Y (1985): Stock and quantitative distribution of the Antarctic krill (*Euphausia superba* Dana) in the Antarctic Ocean South of Australia in January and February 1984. Transactions of the Tokyo University of Fisheries, 6: 139 - 147.

Lubimova TG, Makarov RR, Maslenikov VV, Shevtsow VV, Shust KV (1985): The ecological peculiarities, stocks and role of *E. superba* in the role in the trophic structure of the antarctic ecosystem. Selected Papers Presented to the Scientific Committee of CCAMLR 1982 - 1984, Part II, 391 - 505.

Mackintosh NA (1973): Distribution of post - larval krill in the Antarctic. Discovery Reports, 36: 1 - 94.

Makarov RR, Denys CJ (1981): Stages of sexual maturity of *Euphausia superba* Dana. BIOMASS Handbook Series, 11: 1 - 13.

Marr JWS (1962): The natural history and geography of the Antarctic krill (*Euphausia superba*). Discovery Reports, 32: 33 - 464.

Mauchline J (1980): Measurements of body length of *Euphausia superba* Dana. BIOMASS Handbook Series, 4: 1 - 9.

Miller DGM (1986): Results from biological investigations of krill (*Euphausia superba*) in the Southern Indian Ocean during SIBEX I. Mem. Natl. Inst. Polar Res., Spec., 40: 117 - 139.

Pauly T, Nicol S, Higginbottom Hosie G, Kitchener J (2000): Distribution and abundance of Antarctic krill (*Euphausia superba*) off East Antarctica (80° - 150°E) during the Austral summer of 1995/1996. Deep - Sea Research II, 47: 2465 - 2488.

Pommeranz T, Hermann C, Kühn A (1982): Mouth angles of the Rectangular Midwater Trawl (RMT + 8) during paying out and hauling. Meeresforschung, 29:267 - 274.

Roe HSJ, Baker AdC, Carson RM, Wild R, Shale DM (1980): Behaviour of the Institute of Oceanographic Science's rectangular midwater trawls: theoretical aspects and experimental observations. Mar. Bio., 56: 247 - 259.

Siegel V (1985): The distribution pattern of krill, *Euphausia superba*, west of the Antarctic Peninsula in February 1982. Meeresforschung, 30: 292 - 305.

Sun S, de la Mare W, Nicol S (1995): The compound eye as an indicator of age and shrinkage in Antarctic krill. Antarctic Science, 7(4):387 - 392.

Sun S, Wang R (1995): Study on the relationship between the crystalline cone number and the growth of the Antarctic krill. Antarctic Research, 7(4):1 - 6 (Chinese Edition).

Sun S, Wang R (1996): Study on the relationship between the diameter of the compound eye and the growth of the Antarctic krill. Chinese Journal of Polae Science(name used before: Antarctic Research), 7(2): 87 - 93.

Terazaki M, Wada M (1986): Euphausiids collected from the Australian sector of the Southern Ocean during the BIOMASS SIBEX Cruise (KH - 83 - 4). Mem. Natl. Inst. Polar Res., Special Issue, 40: 97 - 109.

Wang R (1989): Distribution and abundance of eggs and larvae of Antarctic krill (*Euphausia superba* Dana) in Antarctic Peninsula area. Chin. J. Oceanol. Limnol., 7(2): 97 - 104.

Wang R (1990): Population structure of Antarctic krill (*Euphausia superba* Dana) in the waters North and West of Antarctic Peninsula. Chin. J. Oceanol. Limnol., 8(2): 101 - 108.

Wang R, Chen SH (1988): Swarm structure of Antarctic krill (*Euphausia superba* Dana) in waters northeast of King George Island, January 1985. Chinese Journal of Polae Science(name used before: Antarctic Research), 1(2): 15 - 21.

Wang R, Chen SH (1989): Sex ratio, fecundity and some reproduction characteristics of krill (*Euphausia superba* Dana) in the water northwest of Antarctic Peninsula. Antarctic Research (Chinese Edition), 1 (3): 61 - 68.

Wang R, Zhong XF (1993): Distribution and abundance of larvae of Antarctic krill in the Prydz Bay region, Indian Ocean sector of the Southern Ocean. Antarctic Research, 5(4):22 - 31(Chinese Edition).

Wang R, Zhong XF, Sun S, Liu MR, Li HL, Wang K, Ji P (1993a): Population structure of the Antarctic krill in the Prydz Bay region, Indian Ocean sector of the Southern Ocean. Antarctic Research, 5(4): 1 - 11(Chinese Edition).

Wang R, Zhang YB, Zhong XF, Sun S, Liu MR (1993b): Sexual maturity stages and spawning of Antarctic krill in the Prydz Bay region. Antarctic Research, 5(4):12 - 21(Chinese Edition).

Zhong XF, Wang R (1995): Reproductive characteristics of Antarctic krill, *Euphausia superba* Dana, in the Prydz Bay region. , 6(1): 58 - 72.