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Some Ecological Aspects of Antarctic Krill, *Euphausia superba* in the Antarctic Ocean

Jang-Uk LEE · Jung-No KWON · Tae-Ik KIM and Weon-Suk YANG
National Fisheries Research and Development Agency, Yangsan 626-900, Korea

Spatial distribution patterns of Antarctic krill, *Euphausia superba* in the Atlantic Ocean sector were seasonally divided into three or four regions; South George Island, Laurie/Coronation Islands and Livingston/King George Islands. Antarctic krill were caught from the surface to about 150 *m* in depth. The vertical distribution of catch per hour (CPUE) did not show much differences between the 10 *m* layers, but there were gradually poorer CPUEs as trawl depth increased. It was estimated from relationship between water temperature and CPUE that the Antarctic krill abundance was maximal at water temperatures of 0.8~1.0℃. The length compositions of Antarctic krill showed that female fish were, on an average, significantly larger than males. Relationship between carapace length and body length, and body length-body weight relationship were well fitted. Sex ratio was 60.3% for male and 39.7% for female with significant difference at the 5% level.

Introduction

There has been widespread interest in the Antarctic marine living resources, particularly in Antarctic krill, *Euphausia superba* as new sources of animal protein of marine origin for human.

Fishing for Antarctic krill was started in 1972 initially by Japan, then followed by the Russian Federation (former Soviet Union) in 1973, Chile in 1975 and Poland in 1976. Korea participated in the exploratory fishing for Antarctic krill in December 1978, covering the areas off Wilkes Land and Enderby Land in the Indian Ocean sector.

Total annual production of Antarctic krill from the whole oceans kept showing gradual increase from the 1970s to the early 1980s, reaching a peak of about 530,000 tonnes in the 1981/82 fishing season. From the 1985/86 fishing season onward, it varied between 300,000 and 445,000 tonnes per annum. But its catch in the 1992/93 fishing season amounted to only about 87,500 tonnes, a decrease of 83.4%, 80.4% and 71.1% over the 1981/82, 1985/86 and 1991/92 fishing seasons' figures, respectively (CCAMLR, 1990, 1993).

Scientists who are involving in research on the Antarctic krill resources have been mainly focused on quantitative analyses such as estimations of the stock size and potential yield. Biomass of the Antarctic krill stocks has been estimated by several authors, using different methods (Everson, 1977; Doi and Kawamaki, 1979; Lyubimova *et al.*, 1973; Kalinowski and Witek, 1983; Voronina, 1983). The estimates have varied greatly between 44.5 million tonnes and 5,000 million tonnes. However, most authors still believe that the stocks are not smaller than 100 million tonnes and not greater than 500 million tonnes (Kalinowski and Witek, 1983). It is estimated, on the other hand, that the annual potential yield is in a range from 50 million tonnes to 200 million tonnes (Lyubimova *et al.*, 1973; FAO, 1974; Doi and Kawamaki, 1979; Kalinowski and Witek, 1983).

Horizontal distribution patterns of juvenile and adult krill are reported in detail (Marr, 1962; Voronina, 1968; Nasu, 1983; Amos, 1984; Musica and Asencio, 1985). Vertical distributions and movements of the adults were described by some authors (Marr, 1962; Nast, 1978/79). Nocturnal and diurnal

movements were also reported by Kalinowski and Witek (1980), Witek *et al.* (1981) and Paitkowski (1985), indicating that they move to deeper layers in the day time and upper at night.

The National Fisheries Research and Development Agency (NFRDA), Korea conducted exploratory fishing for Antarctic krill during the 1978/79~1986/87 fishing seasons around the Southern Ocean in the Atlantic and Indian Ocean sectors (NFRDA, 1984, 1986, 1987, 1988), and experimental fishing from the 1987/88 to 1991/92 fishing seasons in the Atlantic Ocean sector.

Despite increased interests in the possible commercial utilization of Antarctic krill resources, very little literature or original analyses dealing with ecological aspects of Antarctic krill are available. The objectives of this study are to provide spatial and temporal distribution patterns, to establish the relationship between water temperature and relative abundance, and to estimate size composition and sex ratio of the Antarctic krill, based on fishery and environmental research data collected from the Korean experimental surveys around the Scotia Sea from 1987 to 1992.

Materials and Methods

From the 1987/88 fishing season, the Korean experimental fishing activities for Antarctic krill were only concentrated in the northern part of the Scotia Sea, known as abundant distribution area of *Euphausia superba*. During the fishing seasons from 1987 to 1992, daily haul by haul krill fishery data on catch and fishing effort statistics and surface water temperature were recorded in the format standardized by the Commission for the Conservation and Antarctic Marine Living Resources (CCAMLR). Fishing depth was also checked at every trawling position. The haul by haul data on catch and fishing hour were compiled according to the statistical sea-block (10′ lat., 30′ long.) and every 10 *m* in depth. Catch per unit of effort (CPUE) were obtained for each statistical sea-block. These data were used to describe horizontal and vertical distribution patterns of Antarctic krill in this region. The estimated CPUEs by sea-block were analyzed together with surface water temperature of the fishing grounds to demonstrate relationships between water temperature and distribution pattern of Antarctic krill. Quarterly distribution maps were made for each statistical sea-block (30′ lat., 30′ long.) so as to analyze spatial and temporal fishing patterns, based on the CCAMLR's database on catch and fishing effort of Antarctic krill (CCAMLR, 1993).

About 700 Antarctic krill were sampled from January 23 to February 6, 1992 using a trawl net with 80 *mm* stretched codend mesh size at depths of 5~20 *m* around the northern part of the Livingston Island of the Atlantic Ocean sector for detailed biological observations in the laboratory (see Fig. 2). The sampled individuals were sexed, then both carapace length and body length were measured to the nearest centimeter under, and body weight to the nearest gram under. Both length and weight compositions were constructed using the measured data. Relationships between carapace length and body length, and body length-body weight relationship were obtained by sex.

Results

Fishing Grounds and Distribution Patterns

Fishing grounds from all fishing nations harvesting Antarctic krill in the Atlantic Ocean sector were seasonally divided into three or four areas according to the distribution in catch level by statistical sea-block during the 1990/91~1991/92 fishing seasons (Fig. 1). Fishing activities were concentrated only in the waters around the South George Island during the first quarter. During the second quarter, fishing grounds were expanded to the waters off the Laurie/Coronation Islands and to the King George Island. Fishing grounds were located in the area from the Laurie/Coronation Islands to the Livingston Island during the third quarter, showing larger concentrations compared with other seasons. Fishing grounds during the fourth quarter were easily classified into three regions with abundant distribution; Livingston/King George

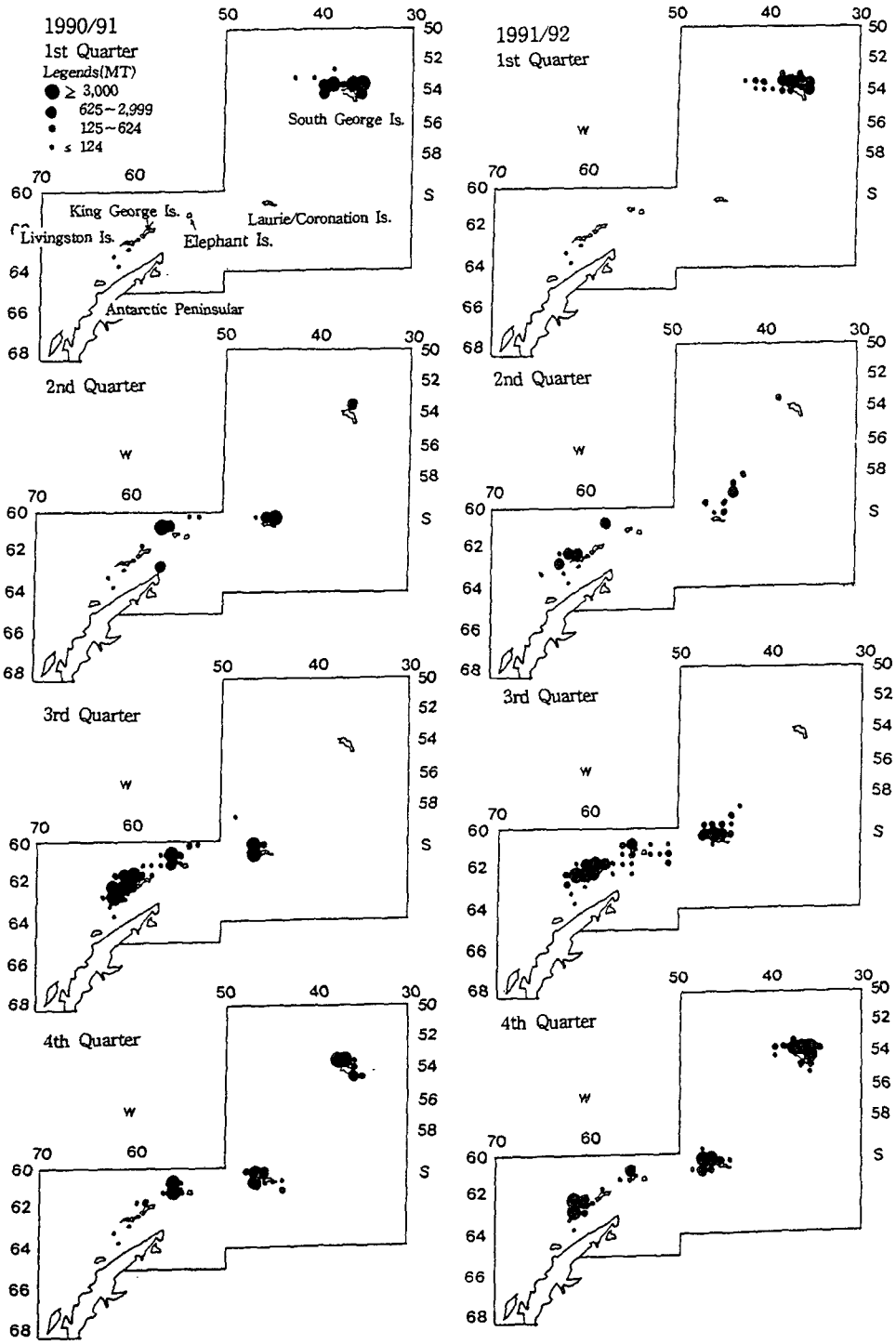

Fig. 1. Quarterly distributions of Antarctic krill in the Atlantic Ocean sector during 1990~1992, based on data from all fishing nations harvesting Antarctic krill.

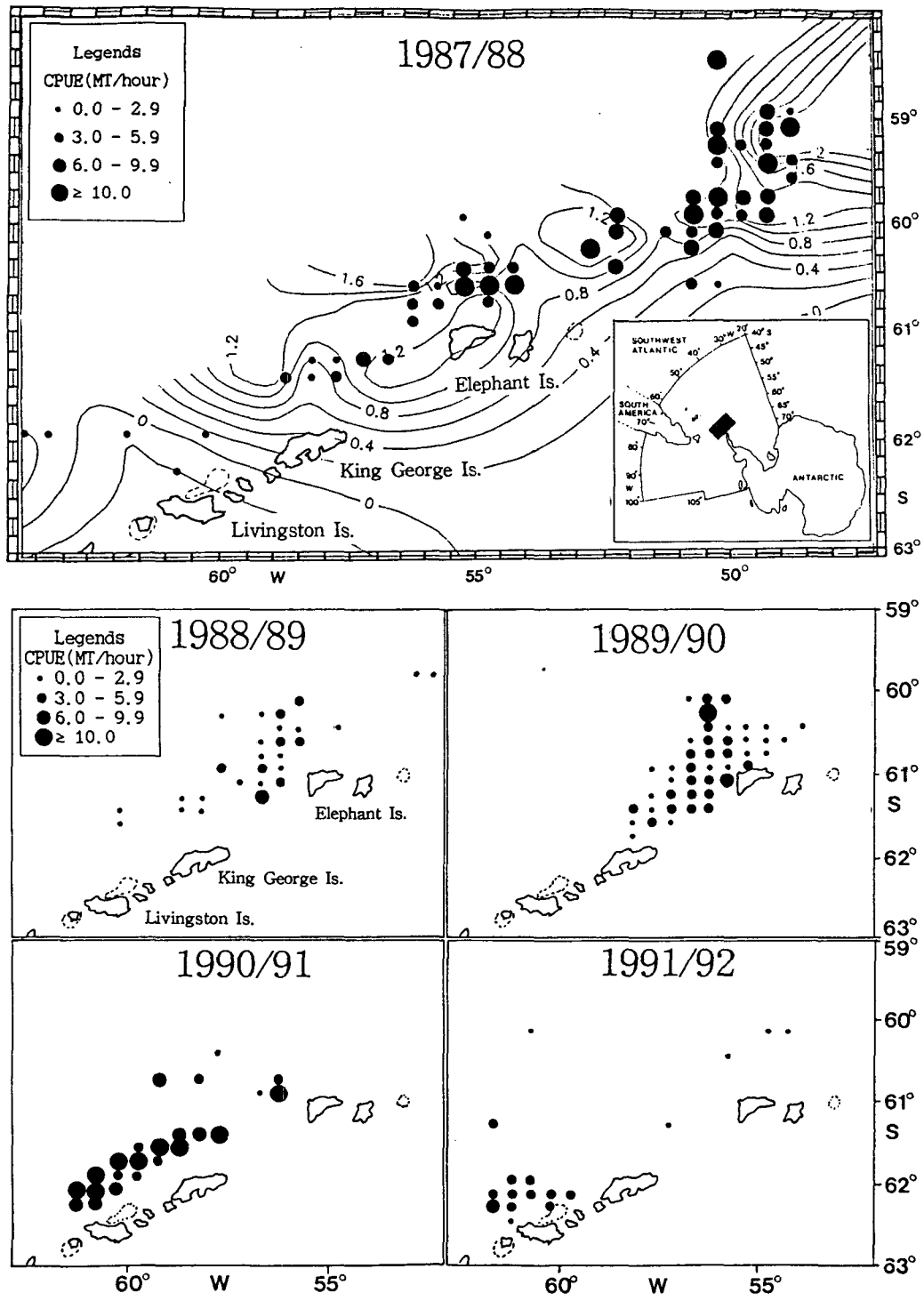

Fig. 2. Korean experimental fishing grounds using trawl vessels for Antarctic krill in the Atlantic Ocean sector during 1987~1992.

Islands, Laurie/Coronation Islands and South George Island (Fig. 1).

Korean trawl fishing for Antarctic krill was concentrated generally in the waters off the edge of the Antarctic peninsular (CCAMLR statistical area 48.1) from the 1987/88 fishing season to the 1991/92 fishing season (Fig. 2). Areas with high CPUEs occurred near the north of Livingstone Island and the north of King George Island during the 1990/91 fishing season. Antarctic krill were caught from the surface to about 150 *m* deep (Fig. 3). The vertical distribution of CPUE did not show large differences between layers at each 10 *m* in depth, but a trend was evident towards gradually poorer abundance as trawling depth increased.

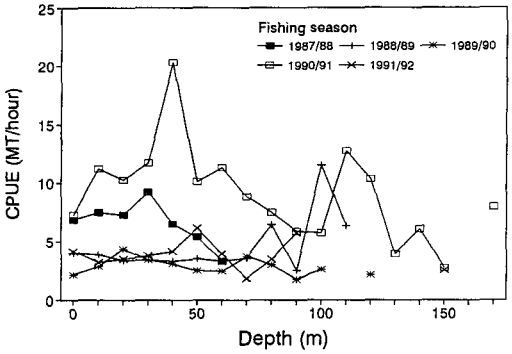

Fig. 3. Vertical distributions of catch per hour of Antarctic krill from Korean trawl fishing in the Atlantic Ocean sector during 1987~1992.

Relationship between Water Temperature and CPUE

Surface water temperature around the fishing grounds of Antarctic krill in the Atlantic Ocean sector ranged from -1 to 5.6℃ (Fig. 4). Antarctic krill were distributed mainly at water temperatures of 0.8~2.0℃ and high CPUEs were recorded at water temperatures of 0.8~1.6℃ (see the distribution pattern of the 1987/88 fishing season's CPUE in Fig. 2). From studying the relationship between averaged CPUE values and mean water temperatures during 1987~1992, the CPUE increased from about 4 tonnes per hour at -1~0℃ to 8 tonnes per hour at 0.8~1.0℃. The CPUE values gradually decreased with increase of water temperature, and they

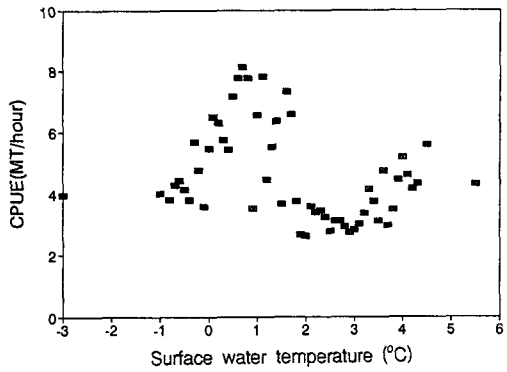

Fig. 4. Relationship between catch per hour of Antarctic krill from Korean trawl fishing and surface water temperature in the Atlantic Ocean sector during 1987~1992.

levelled off at a value of 3 tonnes per hour at water temperatures of 2~3.5℃, even though the values increased slightly to the level of 5 tonnes per hour (Fig. 4). It was estimated from relationship between water temperature and CPUE that the Antarctic krill abundance was maximal at water temperatures of 0.8~1.0℃.

Size Composition, Sex Ratio and Length-Weight Relationship

The length compositions of Antarctic krill showed marked differences between sexes, those of male fish being smaller than females (Fig. 5). Carapace length of male fish ranged from 1.0 to 1.8 *cm* with an average of 1.48 *cm* and females from 1.2 to 1.9 *cm* with an average of 1.54 *cm* (Fig. 5a). Body length of male krill ranged from 2.8 to 4.6 *cm* with an average of 3.67 *cm* and females from 3.1 to 4.8 *cm* with an average of 3.81 *cm* (Fig. 5b). In the percentage length compositions of Antarctic krill, male fish both less than 1.5 *cm* and 3.9 *cm* in carapace and body lengths dominated over females but vice versa in larger sizes. Sex ratio was 60.3% for the male and 39.7% for the female with significant difference at the 5% level. Relationship between carapace length (CL) and body length (BL) was well fitted and can be expressed as $BL = 1.57CL + 1.40$ ($r^2 = 0.67$) for the male fish (Fig. 6a) and $BL = 1.33CL + 1.76$ ($r^2 = 0.69$) for the female fish (Fig. 6b).

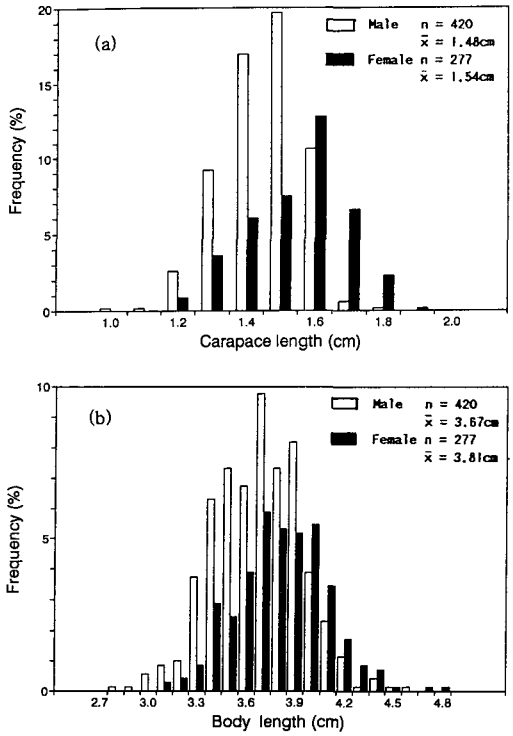

Fig. 5. Carapace length and body length compositions of Antarctic krill by sex from samples of Korean trawl fishing in the Atlantic Ocean sector during the 1990/91 fishing season.

Body weights of males were in the range of 0.2 to 1.4 *g* with an average of 0.56 *g* and females from 0.3 to 1.3 *g*, an average of 0.62 *g* (Fig. 7). Empirical body length (BL)-body weight (BW) relationship was expressed by; $BW=2.05BL^{2.52}\times10^{-2}$ ($r^2=0.63$) for the male (Fig. 8a) and $BW=1.49BL^{2.75}\times10^{-2}$ ($r^2=0.67$) for the female (Fig. 8b).

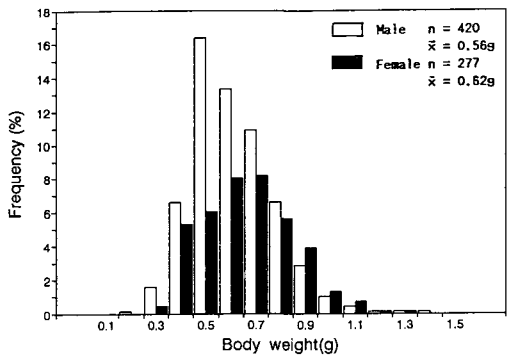

Fig. 7. Body length compositions of Antarctic krill by sex from samples of Korean trawl fishing in the Atlantic Ocean sector during the 1990/91 fishing season.

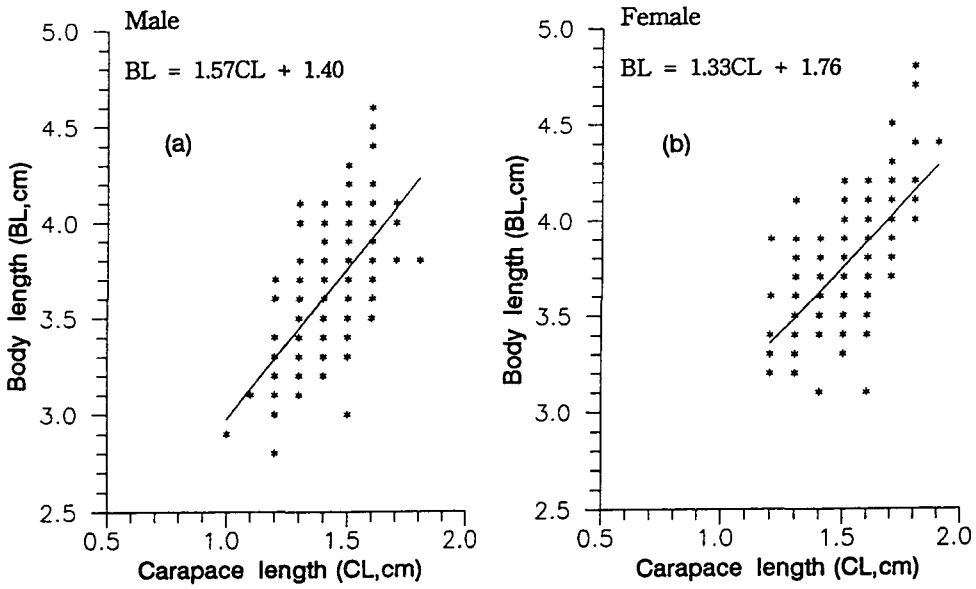

Fig. 6. Relationship between carapace length and body length of Antarctic krill by sex from samples of Korean trawl fishing in the Atlantic Ocean sector during the 1990/91 fishing season.

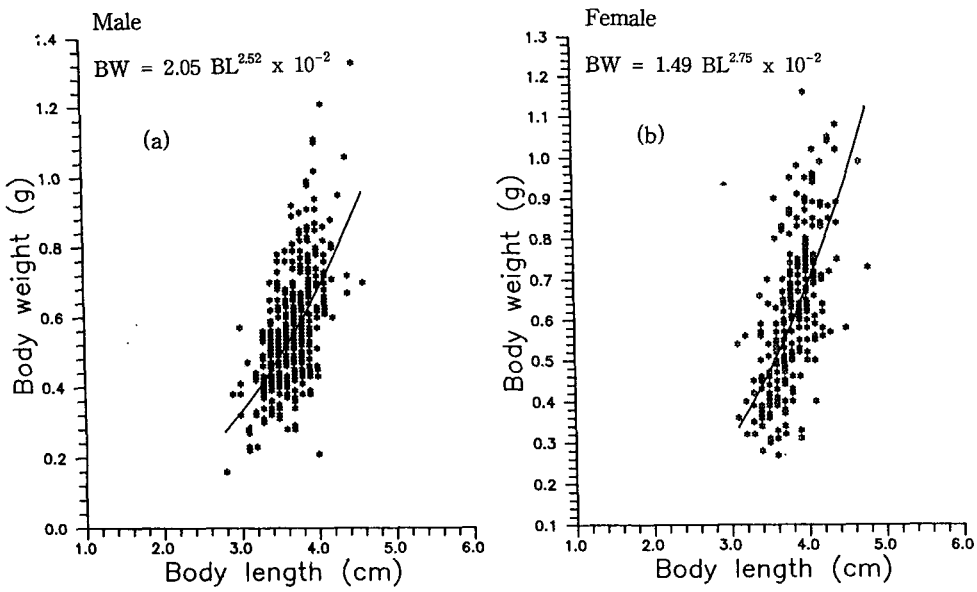

Fig. 8. Relationships between body length and body weight of Antarctic krill by sex from samples of Korean trawl fishing in the Atlantic Ocean sector during the 1990/91 fishing season.

Discussion

The probability that several stocks of Antarctic krill may exist has been indicated by evidence from physical oceanography, such as water mass circulation, in conjunction with the discontinuous nature of the Antarctic krill distribution (CCAMLR, 1984). The possible existence of Antarctic krill around the Antarctic continent are roughly from the Weddell Sea, the Ross Sea, the Prydz Bay and the Lazarev Sea (Lyubimova, 1986a). However, there have been no scientific results obtained from such direct methods of identifying Antarctic krill population into stocks as tagging, markings and recapture, analyses of differences in DNA between areas etc. In the absence of such information on stock identification, the Antarctic krill catch and effort statistics were compiled in this report simply according to the CCAMLR statistical area for analyses of the fluctuations of relative abundances and distribution patterns.

It is reported that dense distribution areas in the Atlantic Ocean sector are the Scotia Sea including the area between the Shetland Islands and the Antarctic peninsular, and the King George Island (Marr, 1962; Voronina, 1968; Nasu, 1983; Amos, 1984; Musica and Asencio, 1985) and the Elephant Island area (Rosenberg and Hewitt, 1991). However, low abundance of Antarctic krill was observed in the Scotia Sea, particularly in the vicinity of the Elephant Island area and the South Georgia area (CCAMLR, 1984). It was noted that this was not the first time such an event had occurred. The reasons for this phenomenon were not established as to whether the observed low abundance might be due to poor recruitment, but it was felt that the cause was a natural variation in water circulation and were not the results of fishing. Accordingly, distribution patterns of Antarctic krill seem to depend largely on physical oceanographic conditions.

Marr (1962) reported that Antarctic krill appear from the surface to 100 *m* in depth and abound in the layers less than 10 *m* deep. According to the theoretical and practical studies aimed at detecting dispersed Antarctic krill using echosounders (Lyubimova, 1986b), individual krill could be detected down to a depth of 50~60 *m*. As a matter of fact, Antarctic krill have been caught at a depth of 0~150 *m* from Korean trawler around the north of the Antarctic peninsular during 1987~1992.

Dense areas of Antarctic krill abundance were observed at water temperatures of 0~1.5℃ at 0~200 *m* (Naganobu and Hirano, 1982). In this report, high CPUEs of Antarctic krill occurred in a range of water temperatures of 0.8~1.0℃ at depths of 0~150 *m*, which coincided with the outcome of Naganobu and Hiranos' study. A growth study based on analyses of size frequency distribution during 1931~1939 indicated that fast growth takes place during summer and zero growth in winter (CCAMLR, 1986). But there was no scientific evidence to back up this finding. In-depth studies on age and growth characteristics of Antarctic krill are needed.

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남빙양 새우의 생태학적 특성

이장욱 · 권정노 · 김태익 · 양원석
국립수산진흥원 원양자원과

대서양 남빙양 새우의 주된 분포역은 South George Island, Laurie/Coronation Islands와 Livingston/King George Islands 지역으로 공간적인 구분을 뚜렷이 하였다. 어획 수심은 표층에서 150 *m*층까지 달했고, 10 *m*층으로 구분한 단위노력당어획량의 수직 분포는 층간에 큰 차이가 없었으나 수심이 깊어 질수록 낮아지는 경향을 보였다. 수온과 단위노력당 어획량의 관계로 부터 남빙양 새우는 주로 0.8~1.0℃ 범위에서 높은 밀도를 나타내었다. 남빙양 새우의 암수별 체장 조성은 큰 차이를 보여 숫컷의 비율은 작은 체장에서, 암컷의 비율은 큰 체장에서 각각 높았다. 두흉갑장과 체장관계, 체장과 체중관계가 암수별로 추정되었다. 암수별 성비조성은 숫컷이 60.3%, 암컷이 39.7%로서 유의한 차이를 나타내었다.