Seasonal and Areal Changes in Age Distribution and Segregation of the Southern Minke Whales in Antarctic Areas IV and V Using Data from the Japanese Researches

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ABSTRACT

Seasonal and areal variations (within feeding ground) of the age structure were examined using data from the Japanese research catches in 1989/90 (Area IV) and 1990/91 (Area V). Although the estimated age distribution in Area IV indicated the decreased with age having a peak at 2-3 year of age, those in Area V had different pattern had a peak at 15-20 years. The age distribution in Area V might be effected by the following reasons: (1) younger animals, especially males, segregated from the research area or mature animals in the Ross Sea contributed to much for producing age structure, (2) the 1990/91 samples (Area V) was biased to older animals because of different sampling efficiency by whale body length, and (3) the timing of migration of whale to the feeding ground was differed by sex and sexual status. Possible factors (school size, localities and season) caused to the analyses of biological parameters such as proportion of males, sexual maturity and mean age, were examined by the AIC' analyses. Pro-

portion of males was principally varied by school size, localities and season. Sexual maturities for both sexes differed by school size and season. Mean ages of both sexes were varied by all these factors.

INTRODUCTION

Since 1987/88, Japanese Government has issued to conduct the Japanese researches to take Southern Hemisphere minke whales, *Balaenoptera acutorostrata*, in the Antarctic. The principal objectives of the researches are to estimate the age distribution for the components migrating to research area, and to investigate seasonal and areal factors on changes in biological parameters (Anon, 1989, 1990).

The previous authors (Kato, Kishino and Fujise, 1990; Kato, Fujise and Kishino, 1991; Kishino *et al.*, 1991a) estimated age structure of the minke whales migrating to the research areas using data obtained from those cruises. However, they did not examine seasonal (monthly) and local variations within Area on the age structure and biological parameters. Fujise, Kato and Kishino (1991) preliminary examined those features using the data obtained from the 1989/90 Japanese research. Following their study we examined to obtain true age structure using sighting and biological data obtained from the Japanese research in 1990/91 (Area V).

Materials and Methods

Whale sample used and their stratification

As it was reported by Fujise *et al.* (1990), the research area (Area IV) of the Japanese research in 1989/90 was divided in two sectors, West and East at 100°E. Each sector was further divided into two strata by the contouring line corresponding to 45 n.miles from ice edge line: Middle and South which will be called as 'offshore' and 'ice edge' zones, respectively.

During the cruise from 6 December 1989 to 12 March 1990, a total of 329 minke whales including three diminutive forms was randomly sampled from 767 primary sightings (Fig.1). The present study excluded three diminutive minke whales for all of analyses, therefore, 326 whales were used as the basic set of sample. The reason why we were not able to establish strata incorporating seasonal and areal changes were that sampling was cut off on the way of the operation. By this reason, the sample size was limited the present analyses established following the six localities for examining the seasonal and local variations within Area on the age structure and biological parameters:

First period
  West Sector (70°E-100°E)
    Offshore zone (=Middle stratum) - 9-21 Dec. 1989.
    Ice edge zone (=South stratum) - 22-29 Dec. 1989.

  East Sector (100°E-130°E)
    Offshore zone (=Middle) - 11-19 Jan. 1990
    Ice edge zone (South) - 31 Dec. 1989-10 Jan. 1990

Second period
  West Sector (70°E-100°E)
    Offshore zone (=Middle) - 8-15 Feb. 1990
    Ice edge zone (=South) - 21 Jan.-6 Feb. 1990

In the 1990/91 Japanese research (Kasamatsu *et al.*, 1991), the research area (Area V) was divided into two major sectors, West and East at 168°E. The West and East Sectors were further stratified by the same manner indicated above, excepting for the East Sector in the Second period. In the East Sector in the Second period, the northern boundary of the South stratum was defined by 69°S instead of the 45 n.miles line. During the cruise, conducted from 19 December 1990 to 22 March 1991, a total of 327 minke whales including four diminutive forms was randomly sampled from 750 primary sightings (1,725 individuals). Geographical distribution for those samples is shown in Fig. 2.

The present study also excluded four diminutive minke whales from all analyses, therefore, 323 whales were used as the basic set of sample. The present analyses established the following eight localities:

First period
  West Sector (130°E-165°E)
    Offshore zone (=Middle stratum) - 21-31 Jan. 1991
    Ice edge zone (=South stratum) - 11-20 Jan. 1991
  East Sector (165°E-170°W)
    Offshore zone (=Middle) - 1-9 Jan. 1991
    Ice edge zone (=South) - 22-31 Dec. 1990

Second period
West Sector (130°E-165°E)
Offshore zone (=Middle) - 10-20 Mar. 1991
Ice edge zone (=South) - 27 Feb.-9 Mar. 1991
East Sector (165°E-170°W)
Offshore zone (Middle) - 16-26 Feb. 1991
Ice edge zone (=South, the Ross Sea) - 2-14 Feb. 1991

To estimate the biological parameters, samples in each locality were further grouped by two school sizes (singleton and ≥ 2 individuals). Finally, twelve and sixteen strata were established in 1989/90 and 1990/91 samples, respectively. Table 1 indicates the number of samples used by each group.

Age determination

As reported by Kato (1986), Kato, Kishino and Fujise (1990) and Kato, Fujise and Kishino (1991), individual age was determined by counting dark laminae appeared on the bisected surface of the earplug core. We determined animal ages by the counting of growth layer (a pair of dark and pale lamina) assuming annual deposition rate, the counting of growth layers was made by Kato (all of 1989/90 and some portion of 1990/91 samples) and Zenitani (1990/91 samples) using the stereoscopic microscope (10 x 6.4 - 16). Using the 1989/90 samples, no bias in age readings was observed between these two readers by use of the method of Kato, Zenitani and Nakamura (1991). By this manner, individual ages were obtained from 267 of the total 326 whales captured in the 1989/90 research (150 males and 117 females), and 298 of the total 323 whales captured (153 males and 145 females) in the 1990/91 research.

Kato and Zenitani (1990) reported that the presence of notch on outer margin of baleen plate, and these authors believed it was formed at birth, and the position of the notch on the baleen plate could be useful for determination of age of juvenile whales (<3 years). Then, we introduced their method for the juveniles whose ages were not determined by earplug in the present study. The 15 individuals (10 males and 5 females) were thus newly determined by use of this method on the materials in 1989/90 season, and age data for three females were corrected from determination by baleen plate. In the 1990/91 samples, no whales were newly determined for age by baleen plate.

Thus, ages of whales were determined on 282 (267 by earplugs and 15 by baleen plates) and 298 samples (298 and 0) in the

1989/90 and 1990/91 researches, respectively.

Estimation of the age of individuals whose ages were not determined directly

A total of 69 individuals were not aged, due to obscure formation of the growth laminae of the earplug (30 in 1989/90 and 15 in 1990/91), the lack of parts of the earplug core (12 and 10) and others (2 and 0). In the following analyses, we took account those animals having no age information and corrected the age distribution using age-length key and body length. Figs. 3 and 4 show the age-length keys used for the present analyses, which were obtained by the data from the Japanese researches from 1987/88 to 1989/90 (728 individuals). After fitting log-normal distribution of the keys, we used the function for extrapolating those animals to the age distribution.

Sexual maturity

Females were considered sexually mature if at least one corpus luteum or c. albicans was present in either side of ovaries, others were regarded to be sexually immature. Sexual maturation of males was examined by the histological section of testis tissues which were collected from the center of the right sided testis. Males having seminiferous tubules over 100um of its diameter (average in 20 measurements) based on the criterion by Kato (1986) or sperm in tubule were considered as sexually mature, and others as sexually immature (Kato, Kishino and Fujise, 1990; Kato, Fujise and Kishino, 1991).

Estimation of age distribution for the migrated population

To estimate age distribution of a migrated population, we follow the method by Kishino *et al.* (1991a). Estimating the age distribution in each stratum, the age distribution of the weighted average of these estimates was used. Specifically, the estimated proportion of the individuals at age t (yt) was obtained by

$$yt = \Sigma\ ui \cdot yit \qquad (1).$$

where, ui is the relative size of abundance of the i-th stratum estimated by the sighting data concurrently obtained in the survey (Kishino *et al.*, 1991b, Nishiwaki *et al.*, 1992, see Table

2), and *yit* is the estimated proportion of individuals at age *t* in the *i*-th stratum.

Variance of estimated age frequency

To estimate variances of the estimated age distribution, we applied the bootstrap method (Efron, 1979) by resampling the legs of the trackline with replacement.

According to Kato, Zenitani and Nakamura (1991), we introduced the error in earplug reading for the examination, and obtained the estimate of reading error as coefficient of variance (C.V.%), 6.586% (1989/90) and 17.44% (1990/91).

To take into account this error in age reading, the age data of the resampled individuals were further modified as $xi'=xi+\epsilon i$, where xi (i= 1...n) is the observed age. Value of ϵi (i=1...n) is a estimate of deviation from the observed age. Value of ϵ are independent from each other and followed a normal distribution with mean zero and variances $(0.06586xi)^2$ in 1989/90 and $(0.1744xi)^2$ in 1990/91 samples (i=1...n). For each of hundred resampled data set was calculated by use of Equation (1).

Heterogeneity for the biological parameters

According to Kishino *et al.* (1991a), Kato, Kishino and Fujise (1990) and Kato, Fujise and Kishino (1991), heterogeneities in proportion of male and sexual maturity among school size, localities and both combined, were tested separately using the method of model selection as follows.

Examination of heterogeneity was applied in each research. Data was constructed by 16 models based on different combinations of the 12 (1989/90) and 16 (1990/91) strata by school sizes (singleton and ≥ 2), zone (offshore and ice edge), and sectors (West and East Sectors) and research periods (First and Second periods). In the present study, the most probable model was determined by the minimum value of AIC' (Akaike Information Criterion; Akaike, 1974, 1985).

RESULTS

Age distribution

As mentioned above sections, we estimated age structure for the population using data taken by the Japanese researches in 1989/90 and 1990/91. Fig. 5 indicates the crude age distribution for each sex, separately by age character in 1989/90. Although it indicates generally decreasing pattern with age, relatively higher proportion of younger animals (1-5 years) were noted in both sexes. This is attributable of increased frequencies by age determination using baleen plate. Fig. 5 also compares the estimated age distributions to those from past commercial whaling operations in Area IV (1971/72-1984/85). The estimating procedure pushes up frequency in younger age classes which are obviously higher than those in the commercial whaling.

The crude and estimated age distributions in 1990/91 (Fig. 6) indicate a different pattern from those of the 1989/90 research, in both sexes. This indicates a peak exists around 15-20 year of ages.

Variances of the estimates for males and females were also given in Tables 3 and 4 for 1989/90, and Tables 5 and 6 for 1990/91, respectively.

Segregation in the biological parameters

Using the methods described in the previous section, we examined the heterogeneity of biological parameters by school sizes, localities (zone and sectors) and season. We examined here the segregations of the proportion of males, sexual maturity and mean age.

Proportion of male

For the 1989/90 research (Table 7), in the West Sector in the First period, the corrected proportion of males was generally higher over all the strata (0.5909-0.8636), especially in school size of $\geq$2 individuals, regardless of zone. In the East Sector, the highest value was obtained from the singletons in the offshore zone (0.8750), while lower values were obtained in the ice edge groups (0.1429-0.3718). In the West Sector in the Second period, the proportion was almost even in all the strata (0.4375-0.5556). This proportion in the West Sector in the First period (0.7592) was higher than those in the East Sector in the same period (0.4911) and in the West Sector in the Second period (0.4996).

For the 1990/91 samples (Table 8), in the West Sector, the corrected proportion of males was higher in the offshore zones (0.6667-0.9231) than in the ice edge zones (0.3846-0.7500) with regardless of the school size throughout the research period. In the East Sector, the proportion was high (0.7000-1.0000), excluding those data from the Ross Sea (Ice edge) as being 0.0769-0.1129. The proportion in each stratum was higher in both Sectors in the First period (West: 0.7137, East: 0.7725) than in those in the Second period (West: 0.5978, East: 0.3617).

The male proportion differed by localities (zone and sector) and research period. Those in the 1989/90 samples further differed by school size.

Sexual maturity of male

The corrected sexual maturity rate of male in 1989/90 (Table 7) was relatively higher throughout all the strata (0.6667-1.0000), except for singleton in the East ice edge in the First period and the West offshore in the Second period (0.0000-0.2000). Estimated male sexual maturity rate was higher in the West and East Sectors (0.8843 and 0.9521) in the First period than in the West Sector (0.5670) in the Second period.

The samples of the 1990/91 research also show high values throughout all the strata (0.6000-1.0000). Estimated male sexual maturity rate for each Sector was also high in all the strata. In the First period values of 0.8839 and 0.9485 were estimated for the West and East Sectors, respectively. In the Second period these values were 0.9281 and 0.9219 for the West and East Sectors, respectively.

From the most probable model selected by AIC' analysis (Table 9), it was suggested that the male maturity rate was different between zones, and differed further between school size and research period for the 1989/90 samples.

Sexual maturity of female

The sexual maturity rate of female for the 1989/90 samples (Table 7) was lower in the singleton of the West Sector (0.1667-0.2222) in the First period than in others (0.3333-1.0000). Estimates tended to be lower in the West Sector (0.3401) in the First period than in the East Sector in the First period and the West Sector in the Second period (0.6308 and 0.5483).

In the 1990/91 samples (Table 8), the rate was lower in the singleton of the First period (0.3333-0.6000). The values in the Second period were higher in all the strata (0.6471-1.0000). The estimate maturity rate was higher in the East in the Second period (0.9299) than in the other Sectors (West: 0.7030, and East: 0.5239 in the First period; West: 0.6634 in the Second period).

Most probable model selected by the AIC' analyses indicates that the female maturity rate was different by school size and research period regardless of localities (Table 9).

Mean age

Mean age of males varied over the strata in both the Japanese researches. These values varied from 2.00 to 18.71 and from 12.20 to 26.67 in the 1989/90 and 1990/91 researches, respectively (Tables 7 and 8). Estimated mean ages in 1989/90 were 14.79 and 15.80 in the West and East Sectors in the First period, respectively, and 10.12 in the West Sector in the Second period. Those values in the 1990/91 research were 16.91 and 17.49 in the West and East Sectors in the First period, respectively, and 16.49 and 18.60 in the West and East Sectors in the Second period, respectively.

AIC' analysis (Table 9) revealed that the model where the age was differed by zones and research period for 1989/90 samples and by school size and sectors for 1990/91 samples, was the most probable one.

The mean age for females (Tables 7 and 8) also varied between the strata in both researches. These values varied from 2.90 to 21.00 in 1989/90 and from 4.0 to 21.50 in 1990/91. Estimated mean age in 1989/90 was 8.45 and 12.73 in the West and East Sectors in the First period, respectively, and 19.89 in the West Sector in the Second period. Those values in the 1990/91 research were 18.46 and 9.75 in the West and East Sectors in the First period, respectively, and 13.48 and 19.03 in the West and East Sectors in the Second period, respectively.

By the model selection (Table 9), the most probably model was that of the mean age differing between localities (zone and sector) and research period in both researches. Furthermore, the model in 1989/90 research also differed by school size.

Age composition

Fig. 7 gives seasonal changes in age distributions with pooling of every five age class, between the First and Second periods of the West Sector, using data from 1989/90 research. Fig.7 also shows the data from in the East Sector for comparison. The distributions incorporated corrections of animals which were not determined their ages. The two age distributions are apart for 43 days each other.

It can be found between the male distributions that the occurrence of younger males (1-5 years of age) increased dramatically in the later season (28.21% and 46.33% in the First and Second periods, respectively). In contrast, the proportion of the middle age classes (6-25 years) apparently decreased with the time from 62.5% in the First period to 45.9% in the Second period. The seasonal changes of age distribution in females were different from those in the males. The occurrence of younger females (1-5 years) decreased with the time, while the middle age class (6-25 years) somewhat increased. The quantitative changes are as follows;

		First period	Second period
1-5 years	:	75.7%	50.2%
6-25 years	:	16.6%	44.6%.

Samples from the East Sector were collected from 31 December 1989 to 19 January 1990. The day deposed between the First and Second periods of the West Sector. With respect to this timing, the age distribution for both sexes shows just a intermediate pattern between both periods of the West Sector. This may suggest that there are few variations between the Sectors.

Fig. 8 gives seasonal changes in age distribution by pooling of every five age class in each Sector of the 1990/91 research. The distributions were produced with taking account of the pattern in seasonal change difference. Pattern of seasonal change of distribution was different by sector as follows: In the East Sector, the distribution of age had a peak at 16-20 year class, and the proportion of older animals (about 21 and more years old) increased from 21.7% in the First period to 39.0% in the Second periods. On the other hand, those values in the West Sector showed a decreasing pattern with the age having a peak at 11-15 year class, and the proportion of older animals (over 10 years) decreased from 72.1% in the First period to 51.5% in the Second periods.

The female age distribution shows a decreasing pattern with age. The proportion of older females (21 and more years old) in the East Sector relatively increased in later season (14.3% and 38.7% in the First and Second periods, respectively). On the other hand, no change was indicated on those in the West Sector.

DISCUSSION

As mentioned above section, the estimated age distributions for the population differed between Areas IV and V. The estimated age distribution in the Area IV showed that the proportion decreased with the age having a peak of 2-3 year of age, and was considered to be close to the expected pattern of age distribution for the population. However, the estimates on Area V had different pattern. We discussed here this aspect by following possible three factors: (1) coverage of the research area, (2) sampling efficiency, and (3) timing of migration of minke whale to and from the research area.

Coverage of the research area

Judging from Kasamatsu *et al.* (1991) which outlined the Japanese research in Area V in 1990/91, minke whales were highly concentrated in the Ross Sea. It occupied 32.24% of the total cumulative abundance in the whole research period (Table 2).

Most of the animals in the Ross Sea were mature, especially pregnant females, and they were relatively older (Tables 7 and 8). Mean age in the Ross Sea was also high as 18.93 and 20.08 for males and females, respectively. The present estimated age distribution in Area V was effected by such segregation.

Here, we tried to examine the estimated age distribution in this Area using the *ui* data from the previous cruise reported by Kato, Fujise and Kishino (1991). Fig. 9 shows the estimates in Area V by this trial. Compared with those in Fig. 6, this trial pushed up frequency in younger age classes which are obviously higher than those in Fig. 6, especially for females. This may suggest that younger animals of the population did not migrated to the area or moved out from the area.

Sampling efficiencies

As reported by Fujise *et al.* (1990) and Kasamatsu *et al.* (1991), there were whales which were targeted but not sampled. We examined the sampling efficiency with respect to the body length in this section.

The body lengths estimated before catching (EBL) and measured after catching (BL) are compared, Fig. 10 indicates the correlation between both lengths. Both two kind of body lengths agreed among length class smaller than 7.5m of EBL ($r=0.669$, $n=80$). Whereas, those for >7.5m of EBL are not significantly corelated ($r=0.228$, $n=569$).

In order to examine biases in the samples, we subsequently examined the sampling efficiency (no. of whales sampled/no. of whales targeted) in each EBL class between years by the length class mentioned above. The efficiencies in those EBL classes are as follows;

	$\leq$7.5m EBL	>7.5m EBL
1989/90 (Area IV):	0.800	0.739
1990/91 (Area V) :	0.405	0.691

It appears that the efficiency is considerably lower for whales among $\leq$7.5m of EBL than those among >7.5m of EBL in the 1990/91 research (Area V). Most of the whales $\leq$7.5m of EBL were younger as $\leq$5 years (Figs 3 and 4). Probably major reason is that the estimated age distributions in Area V was biased to older ages.

Timing of migration of minke whale to the research area

As shown in Fig. 9, the estimation of age distribution in Area V was corrected for the proportion of younger animals. However, it was insufficient for producing age distribution of male, because younger males occupied considerable small portion than the expected in the research area. This may be caused by different timing of younger male minke whales migration and operation of the research, or these whales segregated from the research area. It was suggested that the timing of migration of whales to the feeding grounds may be different by sex and sexual status. In this relation, Kato and Miyashita (1991) reported that the female minke whales that conceived in the earlier part of the mating season tended to arrive earlier in the Antarctic than those conceived later. Therefore, certain migration strategies are also expected for males, and this may be probably one of the reason why biased distribution were produced. But, this feature should be examined further in the future study.

Smaller males tended to be in the northern part of the research area in later season than mature males (Fujise *et al.*, 1990, 1992). In the present study, younger males occurred in the offshore zone in the Second period in Area IV.

If the timing of migration of younger males to the research area is not different between both Areas, lack of younger males must be caused by sampling efficiency in the 1990/91 research. The research activities ceased to be ended earlier than the schedule. Subsequently it lead to shortage of younger samples in the offshore zone in the Second period where it is known that younger males do not dominate. However further study should be needed for the timing of migration of male whales to the feeding ground by sex and sexual status.

SUMMARY

1) The proportion of males differed by school size, zone, and season, and was higher in singleton in earlier offshore zone. The proportion also changed by sector. However, the proportion in Area V remained constant among different school sizes.
2) Male maturity was different between school sizes, zones, and research periods, and was high in singleton in earlier ice edge zone. However, the maturity in Area V changed only by zone, due to poor sample size of immature whales which tended to be more in singleton.
3) Female maturity changed by school size and research period over Areas, and was high in large schools in the Second period.
4) Mean age of males differed between Areas. The mean age was different between zones and seasons in Area IV and between school sizes and sectors in Area V.
5) Mean age of females changed depending on all of the four factors. This may be reflected for those in the Ross Sea in which older females were concentrated regardless of school size.
6) Estimated age distributions indicated a decreasing pattern with a peak at 1-3 year of age in Area IV. Those in Area V indicated a different pattern with a peak existing around 15-20 year of age. The age distribution in Area V might be affected by the following reasons: (1) younger animals, especially males, segregated from the research area or mature animals in the Ross Sea contributed to much for producing age structure, (2) the 1990/91 samples (Area V) was biased to older animals because of different sampling efficiency by whale body length, and (3) the timing of migration of whale to the feeding ground was different by sex and sexual status.

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Table 1. Number of whale samples used in this study.

Stratum	Number of samples: School size 1	Number of samples: School size >=2
1989/90 season (Area IV)		
First period		
West Sector		
Offshore zone	21*	22
Ice edge zone	37	44
East Sector		
Offshore zone	8	15
Ice edge zone	7	65
Second period		
West Sector		
Offshore zone	18	7
Ice edge zone	16	56
Total	107	209
1990/91 season (Area V)		
First period		
West Sector		
Offshore zone	26	18
Ice edge zone	13	63
East Sector		
Offshore zone	10**	7
Ice edge zone	2	2
Second period		
West Sector		
Offshore zone	3	21
Ice edge zone	4	39
East Sector		
Offshore zone	4	30
Ice edge zone	26	54
Total	88	234

*: including 3 whales caught in the North Sector in the First period.
**: including one whale caught in the North Sector in the First period.

Table 2. Estimated population size in each stratum and their proportion to the total.

Stratum	School size	Estimated population size	Proportion (ui)
1989/90 season (Area IV)*			
First period			
West Sector			
Offshore	1	2,373	(0.0620)
	≥2	2,659	(0.0695)
Ice edge	1	748	(0.0195)
	≥2	991	(0.0259)
East Sector			
Offshore	1	2,098	(0.0548)
	≥2	8,780	(0.2294)
Ice edge	1	1,017	(0.0266)
	≥2	6,872	(0.1796)
Second period			
Offshore	1	5,073	(0.1326)
	≥2	2,991	(0.0782)
Ice edge	1	1,268	(0.0331)
	≥2	3,402	(0.0889)
Total		38,272	(1.0000)
1990/91 season (Area V)**			
First period			
West Sector			
Offshore	1	11,250	(0.0972)
	≥2	19,230	(0.1555)
Ice edge	1	1,820	(0.0153)
	≥2	3,917	(0.0336)
East Sector			
Offshore	1	2,941	(0.0262)
	≥2	1,666	(0.0149)
Ice edge	1	473	(0.0041)
	≥2	339	(0.0029)
Second period			
West Sector			
Offshore	1	1,228	(0.0102)
	≥2	3,578	(0.0314)
Ice edge	1	1,508	(0.0132)
	≥2	9,689	(0.0844)
East Sector			
Offshore	1	8,346	(0.0738)
	≥2	12,861	(0.1148)
Ice edge	1	14,195	(0.1192)
	≥2	23,795	(0.2032)
Total		116,836	(1.0000)

*: After Kishino *et al.* (1991b).
**: After Nishiwaki *et al.* (1992).

Table 3. Crude and estimated age compositions of male southern minke whales taken in 1989/90 research (Area IV).

Age class	Crude			Estimated(A)[3]		Estimated(B)[4]	
	E[1]	B[2]	E+B	Est.	S.E.	Est.	S.E.
1	3	1	4	0.0479	0.0299	0.0421	0.0298
2	5	9	14	0.1310	0.0413	0.1160	0.0354
3	4	-	4	0.0314	0.0173	0.0358	0.0239
4	6	-	6	0.0435	0.0252	0.0294	0.0152
5	10	-	10	0.0679	0.0261	0.0611	0.0218
6	6	-	6	0.0187	0.0115	0.0211	0.0117
7	4	-	4	0.0105	0.0093	0.0143	0.0094
8	11	-	11	0.0405	0.0104	0.0404	0.0103
9	3	-	3	0.0090	0.0100	0.0119	0.0096
10	6	-	6	0.0291	0.0189	0.0315	0.0137
11	6	-	6	0.0337	0.0238	0.0357	0.0213
12	5	-	5	0.0453	0.0352	0.0430	0.0187
13	2	-	2	0.0022	0.0188	0.0083	0.0162
14	5	-	5	0.0285	0.0178	0.0314	0.0163
15	4	-	4	0.0212	0.0221	0.0249	0.0188
16	3	-	3	0.0312	0.0256	0.0335	0.0215
17	7	-	7	0.0563	0.0273	0.0553	0.0278
18	8	-	8	0.0504	0.0254	0.0499	0.0204
19	6	-	6	0.0421	0.0236	0.0423	0.0184
20	2	-	2	0.0074	0.0206	0.0115	0.0204
21	5	-	5	0.0569	0.0197	0.0546	0.0202
22	1	-	1	0.0015	0.0193	0.0057	0.0196
23	3	-	3	0.0163	0.0145	0.0183	0.0150
24	2	-	2	0.0045	0.0146	0.0076	0.0111
25	2	-	2	0.0026	0.0113	0.0049	0.0105
26	8	-	8	0.0454	0.0187	0.0428	0.0129
27	3	-	3	0.0121	0.0175	0.0132	0.0139
28	4	-	4	0.0379	0.0191	0.0355	0.0138
29	2	-	2	0.0077	0.0176	0.0088	0.0126
30	2	-	2	0.0106	0.0151	0.0111	0.0135
31	2	-	2	0.0080	0.0113	0.0086	0.0092
32	1	-	1	0.0015	0.0090	0.0028	0.0083
33	1	-	1	0.0015	0.0084	0.0026	0.0041
34	0	-	0	0.0000	0.0040	0.0011	0.0031
35	2	-	2	0.0132	0.0067	0.0085	0.0047
36	1	-	1	0.0040	0.0048	0.0044	0.0026
37	2	-	2	0.0031	0.0058	0.0034	0.0032
38	0	-	0	0.0000	0.0033	0.0007	0.0022
39	1	-	1	0.0069	0.0067	0.0066	0.0027
40	1	-	1	0.0046	0.0028	0.0045	0.0029
41	0	-	0	0.0000	0.0042	0.0004	0.0030
42	0	-	0	0.0000	0.0061	0.0004	0.0037
43	0	-	0	0.0000	0.0042	0.0003	0.0050
44	0	-	0	0.0000	0.0047	0.0003	0.0049
45	1	-	1	0.0141	0.0051	0.0126	0.0062
46	0	-	0	0.0000	0.0054	0.0002	0.0058
47	0	-	0	0.0000	0.0049	0.0002	0.0057
48	0	-	0	0.0000	0.0050	0.0002	0.0043
49	0	-	0	0.0000	0.0031	0.0002	0.0020
50	0	-	0	0.0000	0.0051	0.0000	0.0023
Total	150	10	160	1.0000		1.0000	

1): determined by earplug, 2): determined by baleen plate, 3): considered with aging error, 4): considered with aging error and age undetermined samples.

Table 4. Crude and estimated age compositions of female southern minke whales taken in 1989/90 research (Area IV).

Age class	Crude			Estimated(A)[4]		Estimated(B)[5]	
	E[1]	B[2]	E+B[3]	Est.	S.E.	Est.	S.E.
1	4	2	5	0.0550	0.0333	0.0522	0.0333
2	9	6	14	0.1020	0.0719	0.1040	0.0693
3	13	-	12	0.1210	0.0480	0.1200	0.0403
4	6	-	6	0.0289	0.0143	0.0479	0.0114
5	9	-	9	0.0885	0.0345	0.0799	0.0239
6	7	-	7	0.0520	0.0261	0.0556	0.0187
7	6	-	6	0.0356	0.0139	0.0356	0.0142
8	1	-	1	0.0095	0.0086	0.0059	0.0064
9	3	-	3	0.0118	0.0188	0.0118	0.0177
10	2	-	2	0.0381	0.0285	0.0334	0.0265
11	2	-	2	0.0381	0.0305	0.0357	0.0267
12	3	-	3	0.0118	0.0194	0.0121	0.0167
13	1	-	1	0.0024	0.0098	0.0038	0.0069
14	3	-	3	0.0213	0.0119	0.0210	0.0089
15	4	-	4	0.0193	0.0111	0.0194	0.0113
16	4	-	4	0.0264	0.0169	0.0261	0.0158
17	4	-	4	0.0332	0.0274	0.0326	0.0193
18	5	-	5	0.0666	0.0266	0.0629	0.0235
19	2	-	2	0.0130	0.0247	0.0148	0.0251
20	1	-	1	0.0024	0.0254	0.0052	0.0210
21	6	-	6	0.0449	0.0245	0.0435	0.0222
22	3	-	3	0.0452	0.0236	0.0436	0.0205
23	2	-	2	0.0095	0.0269	0.0111	0.0235
24	2	-	2	0.0234	0.0211	0.0234	0.0185
25	4	-	4	0.0349	0.0197	0.0312	0.0157
26	4	-	4	0.0287	0.0169	0.0275	0.0111
27	0	-	0	0.0000	0.0119	0.0013	0.0103
28	0	-	0	0.0000	0.0097	0.0010	0.0046
29	0	-	0	0.0000	0.0043	0.0008	0.0035
30	1	-	1	0.0047	0.0023	0.0049	0.0024
31	1	-	1	0.0015	0.0024	0.0019	0.0022
32	0	-	0	0.0000	0.0028	0.0004	0.0018
33	0	-	0	0.0000	0.0028	0.0003	0.0039
34	1	-	1	0.0047	0.0050	0.0045	0.0030
35	0	-	0	0.0000	0.0038	0.0002	0.0032
36	0	-	0	0.0000	0.0036	0.0001	0.0044
37	2	-	2	0.0142	0.0030	0.0129	0.0029
38	0	-	0	0.0000	0.0025	0.0001	0.0032
39	0	-	0	0.0000	0.0024	0.0001	0.0024
40	0	-	0	0.0000	0.0022	0.0001	0.0026
41	1	-	1	0.0071	0.0014	0.0065	0.0009
42	1	-	1	0.0047	0.0012	0.0043	0.0007
43	0	-	0	0.0000	0.0009	0.0000	0.0004
44	0	-	0	0.0000	0.0004	0.0000	0.0002
45	0	-	0	0.0000	0.0003	0.0000	0.0002
46	0	-	0	0.0000	0.0001	0.0000	0.0004
47	0	-	0	0.0000	0.0003	0.0000	0.0002
48	0	-	0	0.0000	0.0000	0.0000	0.0000
49	0	-	0	0.0000	0.0001	0.0000	0.0000
50	0	-	0	0.0000	0.0000	0.0000	0.0000
Total	117	8	122	1.0000		1.0000	

1): determined by earplug, 2): determined by baleen plate, 3): ages of three whales determined by earplug were corrected by determination by baleen plate, 4): considered with aging error, 5): considered with aging error and age undetermined samples.

Table 5. Crude and estimated age compositions of male southern minke whales taken in 1990/91 research (Area V).

Age class	Crude			Estimated(A)[3]		Estimated(B)[4]	
	E[1]	B[2]	E+B	Est.	S.E.	Est.	S.E.
1	0	-	0	0.0000	?	0.0000	?
2	1	-	1	0.0072	?	0.0073	?
3	3	-	3	0.0035	?	0.0039	?
4	5	-	5	0.0182	?	0.0258	?
5	10	-	10	0.0582	?	0.0613	?
6	9	-	9	0.0784	?	0.0663	?
7	5	-	5	0.0250	?	0.0262	?
8	3	-	3	0.0058	?	0.0079	?
9	5	-	5	0.0338	?	0.0333	?
10	11	-	11	0.0512	?	0.0506	?
11	2	-	2	0.0169	?	0.0196	?
12	5	-	5	0.0262	?	0.0263	?
13	4	-	4	0.0375	?	0.0359	?
14	6	-	6	0.0270	?	0.0290	?
15	3	-	3	0.0513	?	0.0455	?
16	8	-	8	0.0496	?	0.0498	?
17	4	-	4	0.0286	?	0.0287	?
18	6	-	6	0.0614	?	0.0639	?
19	6	-	6	0.0571	?	0.0531	?
20	3	-	3	0.0136	?	0.0157	?
21	5	-	5	0.0289	?	0.0297	?
22	5	-	5	0.0423	?	0.0372	?
23	5	-	5	0.0269	?	0.0284	?
24	4	-	4	0.0154	?	0.0173	?
25	3	-	3	0.0139	?	0.0146	?
26	4	-	4	0.0409	?	0.0424	?
27	5	-	5	0.0372	?	0.0360	?
28	4	-	4	0.0489	?	0.0492	?
29	3	-	3	0.0112	?	0.0122	?
30	1	-	1	0.0030	?	0.0035	?
31	1	-	1	0.0064	?	0.0072	?
32	3	-	3	0.0124	?	0.0106	?
33	0	-	0	0.0000	?	0.0006	?
34	1	-	1	0.0023	?	0.0029	?
35	1	-	1	0.0096	?	0.0097	?
36	1	-	1	0.0012	?	0.0016	?
37	2	-	2	0.0262	?	0.0220	?
38	1	-	1	0.0051	?	0.0054	?
39	1	-	1	0.0006	?	0.0009	?
40	0	-	0	0.0000	?	0.0002	?
41	1	-	1	0.0023	?	0.0025	?
42	1	-	1	0.0064	?	0.0066	?
43	1	-	1	0.0072	?	0.0074	?
44	0	-	0	0.0000	?	0.0001	?
45	0	-	0	0.0000	?	0.0001	?
46	0	-	0	0.0000	?	0.0001	?
47	1	-	1	0.0012	?	0.0013	?
48	0	-	0	0.0000	?	0.0001	?
49	0	-	0	0.0000	?	0.0001	?
≥50	0	-	0	0.0000	?	0.0000	?
Total	153	0	153	1.0000		1.0000	

1): determined by earplug, 2): determined by baleen plate, 3): considered with aging error, 4): considered with aging error and age undetermined samples.

Table 6. Crude and estimated age compositions of female southern minke whales taken in 1990/91 research (Area V).

Age class	Crude			Estimated(A)[4]		Estimated(B)[5]	
	E[1]	B[2]	E+B[3]	Est.	S.E.	Est.	S.E.
1	1	-	1	0.0055	?	0.0055	?
2	1	-	1	0.0033	?	0.0044	?
3	3	-	3	0.0203	?	0.0264	?
4	5	-	5	0.0241	?	0.0310	?
5	3	-	3	0.0101	?	0.0151	?
6	4	-	4	0.0239	?	0.0262	?
7	4	-	4	0.0230	?	0.0239	?
8	4	-	4	0.0319	?	0.0327	?
9	4	-	4	0.0564	?	0.0565	?
10	3	-	3	0.0092	?	0.0100	?
11	5	-	5	0.0316	?	0.0316	?
12	5	-	5	0.0301	?	0.0313	?
13	8	-	8	0.0395	?	0.0399	?
14	6	-	6	0.0424	?	0.0440	?
15	6	-	6	0.0574	?	0.0524	?
16	4	-	4	0.0322	?	0.0325	?
17	7	-	7	0.0573	?	0.0558	?
18	6	-	6	0.0371	?	0.0378	?
19	8	-	8	0.0739	?	0.0673	?
20	4	-	4	0.0292	?	0.0273	?
21	10	-	10	0.0770	?	0.0723	?
22	4	-	4	0.0301	?	0.0318	?
23	4	-	4	0.0233	?	0.0247	?
24	5	-	5	0.0204	?	0.0211	?
25	4	-	4	0.0329	?	0.0338	?
26	3	-	3	0.0294	?	0.0233	?
27	2	-	2	0.0129	?	0.0137	?
28	2	-	2	0.0104	?	0.0110	?
29	2	-	2	0.0137	?	0.0080	?
30	1	-	1	0.0121	?	0.0126	?
31	2	-	2	0.0155	?	0.0158	?
32	3	-	3	0.0144	?	0.0130	?
33	0	-	0	0.0000	?	0.0003	?
34	4	-	4	0.0214	?	0.0210	?
35	1	-	1	0.0070	?	0.0059	?
36	0	-	0	0.0000	?	0.0002	?
37	2	-	2	0.0166	?	0.0153	?
38	0	-	0	0.0000	?	0.0001	?
39	1	-	1	0.0016	?	0.0014	?
40	1	-	1	0.0061	?	0.0061	?
41	0	-	0	0.0000	?	0.0000	?
42	0	-	0	0.0000	?	0.0000	?
43	0	-	0	0.0000	?	0.0000	?
44	1	-	1	0.0016	?	0.0014	?
45	1	-	1	0.0061	?	0.0060	?
46	0	-	0	0.0000	?	0.0000	?
47	0	-	0	0.0000	?	0.0000	?
48	0	-	0	0.0000	?	0.0000	?
49	0	-	0	0.0000	?	0.0001	?
≥50	1	-	1	0.0096	?	0.0095	?
Total	145	0	145	1.0000		1.0000	

1): determined by earplug, 2): determined by baleen plate, 3): ages of three whales determined by earplug were corrected by determination by baleen plate, 4): considered with aging error, 5): considered with aging error and age undetermined samples.

Table 7. Means and standard errors (in parenthesis) of biological parameters (male proportion, sexual maturities and mean ages) in each stratum in Area IV (1989/90 research).

	West Sector		East Sector	
	Offshore	Ice edge	Offshore	Ice edge
Male proportion				
First period				
1	0.5909	0.6756	0.8750	0.1429
	(0.1073)	(0.0780)	(0.1250)	(0.1429)
	22[1)]	37	8	7
≥2	0.8571	0.8636	0.5333	0.3718
	(0.0817)	(0.0499)	(0.1240)	(0.0680)
	14	33	15	39
Second period				
1	0.5556	0.4375	—	—
	(0.1205)	(0.1281)	(—)	(—)
	18	16		
≥2	0.5000	0.4375	—	—
	(0.2236)	(0.0701)	(—)	(—)
	5	32		
Sexual maturity				
Male				
First period				
1	0.7692	0.7200	0.8571	0.0000
	(0.1216)	(0.0917)	(0.1429)	(0.0000)
	13	25	7	1
≥2	0.9231	0.9677	1.0000	0.9736
	(0.0769)	(0.0323)	(0.0000)	(0.0263)
	13	31	9	19
Second period				
1	0.2000	1.0000	—	—
	(0.1333)	(0.0000)	(—)	(—)
	10	7		
≥2	0.6667	1.0000	—	—
	(0.3333)	(0.0000)	(—)	(—)
	3	20		
Female				
First period				
1	0.2222	0.1667	1.0000	0.5000
	(0.1470)	(0.1123)	(0.0000)	(0.2236)
	9	12	1	6
≥2	0.6667	0.5714	0.5000	0.7586
	(0.3333)	(0.2020)	(0.1637)	(0.0729)
	3	7	8	29
Second period				
1	0.5000	0.7778	—	—
	(0.1890)	(0.1470)	(—)	(—)
	8	9		
≥2	0.3333	0.6875	—	—
	(0.3333)	(0.0893)	(—)	(—)
	3	24		

* : number of schools examined.

(continued)

Table 7. (continued).

	West Sector		East Sector	
	Offshore	Ice edge	Offshore	Ice edge
Mean age				
Male				
First period				
1	16.27 (2.97) 11	12.68 (1.85) 22	12.75 (4.96) 4	2.00 (0.00) 1
≥2	13.29 (3.05) 12	17.43 (1.99) 27	17.63 (3.46) 8	15.44 (2.40) 18
Second period				
1	4.80 (1.87) 10	18.71 (3.46) 7	— (—)	— (—)
≥2	10.83 (4.97) 3	16.28 (2.52) 18	— (—)	— (—)
Female				
First period				
1	10.86 (5.98) 7	2.90 (0.53) 10	21.00 (0.00) 1	9.67 (2.84) 6
≥2	5.00 (1.15) 3	12.60 (5.71) 5	11.14 (2.56) 7	14.35 (1.69) 26
Second period				
1	11.29 (4.03) 7	15.75 (2.81) 8	— (—)	— (—)
≥2	3.00 (1.15) 3	14.78 (2.07) 23	— (—)	— (—)

Table 8. Means and standard errors (in parenthesis) of biological parameters (Male proportion, sexual maturities and mean age) in each stratum in Area V (1990/91 research).

	West Sector		East Sector	
	Offshore	Ice edge	Offshore	Ice edge
Male proportion				
First period				
1	0.8077 (0.0788) 26*	0.3846 (0.1404) 13	0.7000 (0.1528) 10	1.0000 (0.0000) 2
≥2	0.7500 (0.1142) 14	0.4186 (0.0664) 43	0.7857 (0.1487) 7	1.0000 (0.0000) 2
Second period				
1	0.6667 (0.3333) 3	0.7500 (0.2500) 4	0.7500 (0.2500) 4	0.0769 (0.0533) 26
≥2	0.9231 (0.0769) 13	0.4444 (0.0898) 27	0.8261 (0.0744) 23	0.1129 (0.0382) 31
Sexual maturity				
Male				
First period				
1	0.8571 (0.0782) 21	0.6000 (0.2449) 5	1.0000 (0.0000) 7	1.0000 (0.0000) 2
≥2	0.9091 (0.0610) 11	0.9783 (0.0217) 23	0.8333 (0.1667) 6	1.0000 (0.0000) 2
Second period				
1	1.0000 (0.0000) 2	1.0000 (0.0000) 3	1.0000 (0.0000) 3	1.0000 (0.0000) 2
≥2	0.7917 (0.1145) 12	1.0000 (0.0000) 14	0.8500 (0.0734) 20	1.0000 (0.0000) 7
Female				
First period				
1	0.6000 (0.2449) 5	0.3750 (0.1830) 8	0.3333 (0.3333) 3	—— (——) 0
≥2	0.7500 (0.2500) 4	0.8833 (0.0572) 30	1.0000 (0.0000) 2	—— (——) 0
Second period				
1	1.0000 (0.0000) 1	1.0000 (0.0000) 1	1.0000 (0.0000) 1	0.9583 (0.0417) 24
≥2	0.0000 (0.0000) 1	0.6471 (0.1115) 17	0.8000 (0.2000) 5	0.9194 (0.0408) 31

* : number of schools examined.

(continued)

Table 8. (continued).

	West Sector		East Sector	
	Offshore	Ice edge	Offshore	Ice edge
Mean age				
Male				
First period				
1	16.42 (2.15) 21	12.20 (3.21) 5	17.85 (3.51) 7	19.50 (0.50) 2
≥2	17.28 (2.88) 9	18.33 (2.51) 23	15.67 (3.88) 6	19.50 (9.50) 2
Second period				
1	16.00 (7.00) 2	26.67 (10.33) 3	24.00 (3.06) 3	22.50 (4.50) 2
≥2	18.17 (2.79) 12	12.63 (2.36) 12	15.37 (1.91) 19	17.20 (3.97) 5
Female				
First period				
1	15.00 (5.14) 5	14.83 (5.63) 6	5.00 (3.05) 3	— (—) 0
≥2	19.83 (3.24) 3	20.65 (2.00) 26	21.50 (9.50) 2	— (—) 0
Second period				
1	— (—) 0	21.00 (0.00) 1	9.00 (0.00) 1	19.67 (1.99) 24
≥2	4.00 (0.00) 1	14.46 (2.88) 14	12.20 (3.12) 5	20.34 (1.30) 31

Table 9. The Models and the AIC's value by models of heterogeneiety of biological parameters (proportion of males, sexual maturities and mean ages) among different grouping of strata by each factors, in 1989/90 (left column) and 1990/91 researches (right). Mark "y" in the table means yes as factor to change the parameter among strata.

a. Proportion of males

Area IV (1989/90)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
16	y	y	y	y	24.19
14		y	y	y	26.10
15	y		y	y	29.30
11			y	y	33.35
12	y	y	y		45.51
07		y	y		49.98
09	y		y		55.01
04			y		58.10
05				y	62.37
08		y		y	63.85
10	y			y	64.05
13	y	y		y	68.58
02		y			72.17
01					73.25
06	y	y			73.45
03	y				73.84

Area V (1990/91)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
14		y	y	y	22.31
07		y	y		26.39
12	y	y	y		33.10
16	y	y	y	y	35.66
08		y		y	36.94
13	y	y		y	43.51
02		y			54.01
06	y	y			55.77
15	y		y	y	129.60
11			y	y	133.15
09	y		y		160.62
04			y		161.83
10	y			y	180.83
05				y	196.75
01					234.00
03	y				235.04

b. Sexual maturity rate of males

Area IV (1989/90)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
13	y	y		y	18.43
08		y		y	21.25
14		y	y	y	24.30
16	y	y	y	y	25.34
03	y				26.89
10	y			y	27.54
06	y	y			27.85
09	y		y		29.66
12	y	y	y		30.54
15	y		y	y	31.02
02		y			39.97
07		y	y		40.56
04			y		47.52
01					47.75
05				y	48.06
11			y	y	48.85

Area V (1990/91)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
02		y			16.36
06	y	y			19.05
08		y		y	19.69
07		y	y		20.34
01					20.54
03	y				21.05
04			y		21.35
05				y	21.63
09	y		y		21.84
10	y			y	23.35
11			y	y	25.13
13	y	y		y	25.43
12	y	y	y		25.74
14		y	y	y	27.43
15	y		y	y	29.30
16	y	y	y	y	39.97

(continued)

Table 9. (continued).

c. Sexual maturity rate of female

Area IV (1989/90)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
10	y			y	22.40
11			y	y	22.58
15	y		y	y	23.56
14		y	y	y	25.18
13	y	y		y	26.39
03	y				27.74
06	y	y			29.28
16	y	y	y	y	30.46
09	y		y		30.70
04			y		34.56
07		y	y		34.84
12	y	y	y		35.49
02		y			35.94
08		y		y	37.80
05				y	38.26
01					38.71

Area V (1990/91)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
10	y			y	26.22
09	y		y		28.42
15	y		y	y	28.48
11			y	y	29.84
04			y		29.96
07		y	y		31.51
12	y	y	y		32.30
02		y			33.33
05				y	33.36
13	y	y		y	33.45
01					34.47
14		y	y	y	34.55
08		y		y	35.18
06	y	y			35.70
03	y				36.08
16	y	y	y	y	38.81

d. Mean age of male

Area IV (1989/90)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
08		y		y	52.31
13	y	y		y	55.17
14		y	y	y	56.16
16	y	y	y	y	59.92
06	y	y			61.76
10	y			y	61.96
03	y				63.82
07		y	y		64.32
02		y			65.11
15	y		y	y	65.27
12	y	y	y		65.29
05				y	66.92
09	y		y		67.74
11			y	y	68.91
01					72.26
04			y		73.20

Area V (1990/91)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
09	y		y		65.57
03	y				67.03
04			y		67.23
10	y			y	67.50
07		y	y		68.26
15	y		y	y	69.31
11			y	y	70.30
06	y	y			70.68
12	y	y	y		71.22
05				y	72.57
13	y	y		y	72.59
08		y		y	72.91
02		y			72.96
01					73.45
14		y	y	y	75.26
16	y	y	y	y	80.41

(continued)

Table 9. (continued).

e. Mean age of female

Area IV (1989/90)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
16	y	y	y	y	56.43
13	y	y		y	61.29
14		y	y	y	62.12
12	y	y	y		70.30
06	y	y			79.94
15	y		y	y	83.85
11			y	y	94.35
09	y		y		102.96
04			y		105.66
07		y	y		107.47
08		y		y	130.06
10	y			y	148.75
03	y				167.86
05				y	175.69
02		y			177.17
01					177.87

Area V (1990/91)

Model No.	Factor				AIC' value
	School size	Zone	Sector	Seasonal	
14		y	y	y	60.80
07		y	y		61.28
06	y	y			62.21
02		y			63.70
11			y	y	63.79
13	y	y		y	64.86
12	y	y	y		65.43
10	y			y	66.53
15	y		y	y	66.54
08		y		y	67.32
16	y	y	y	y	67.72
03	y				75.28
01					77.69
05				y	78.50
09	y		y		79.07
04			y		79.65

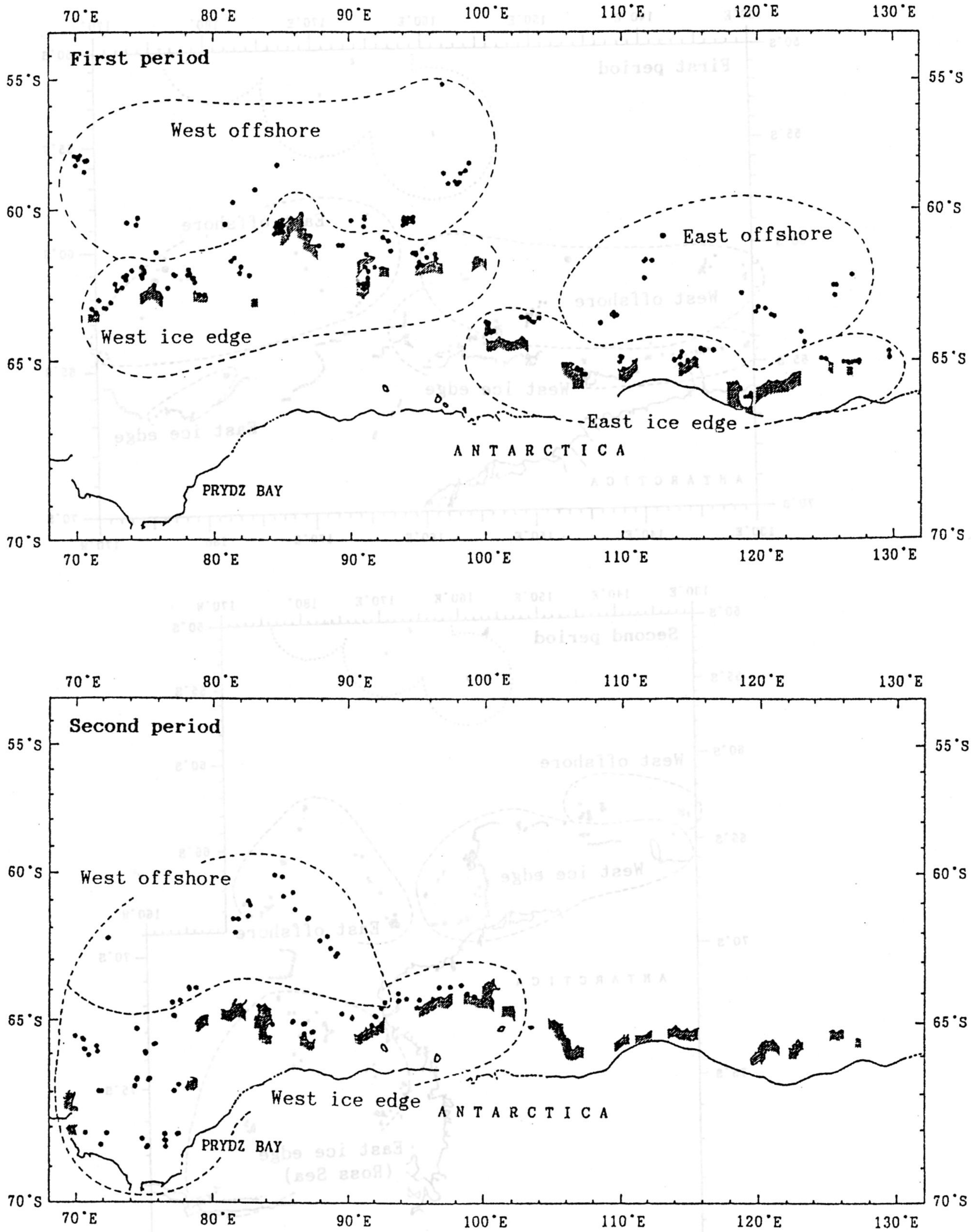

Fig. 1. Grouping of geographical and seasonal strata in Area IV (1989/90) (after Fujise *et al.* 1990). Closed circles represent the minke whale samples taken based on their sighted position. Broken line indicates the grouping of samples used for this analyses.

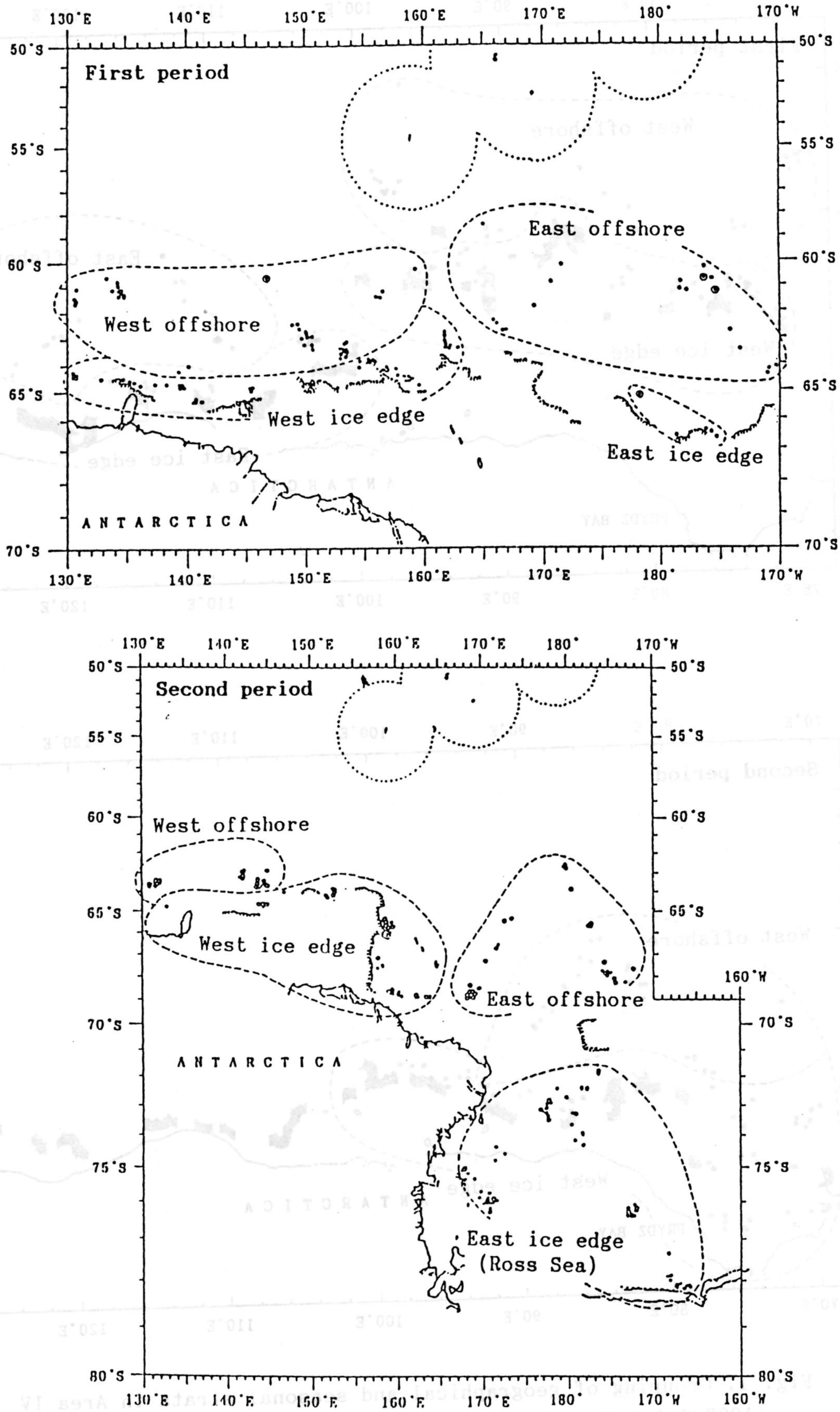

Fig. 2. Grouping of geographical and seasonal strata in Area V (1990/91) (after Kasamatsu *et al.* 1991). Closed circles represent the minke whale samples taken based on their sighted position. Broken line indicates the grouping of samples used for this analyses.

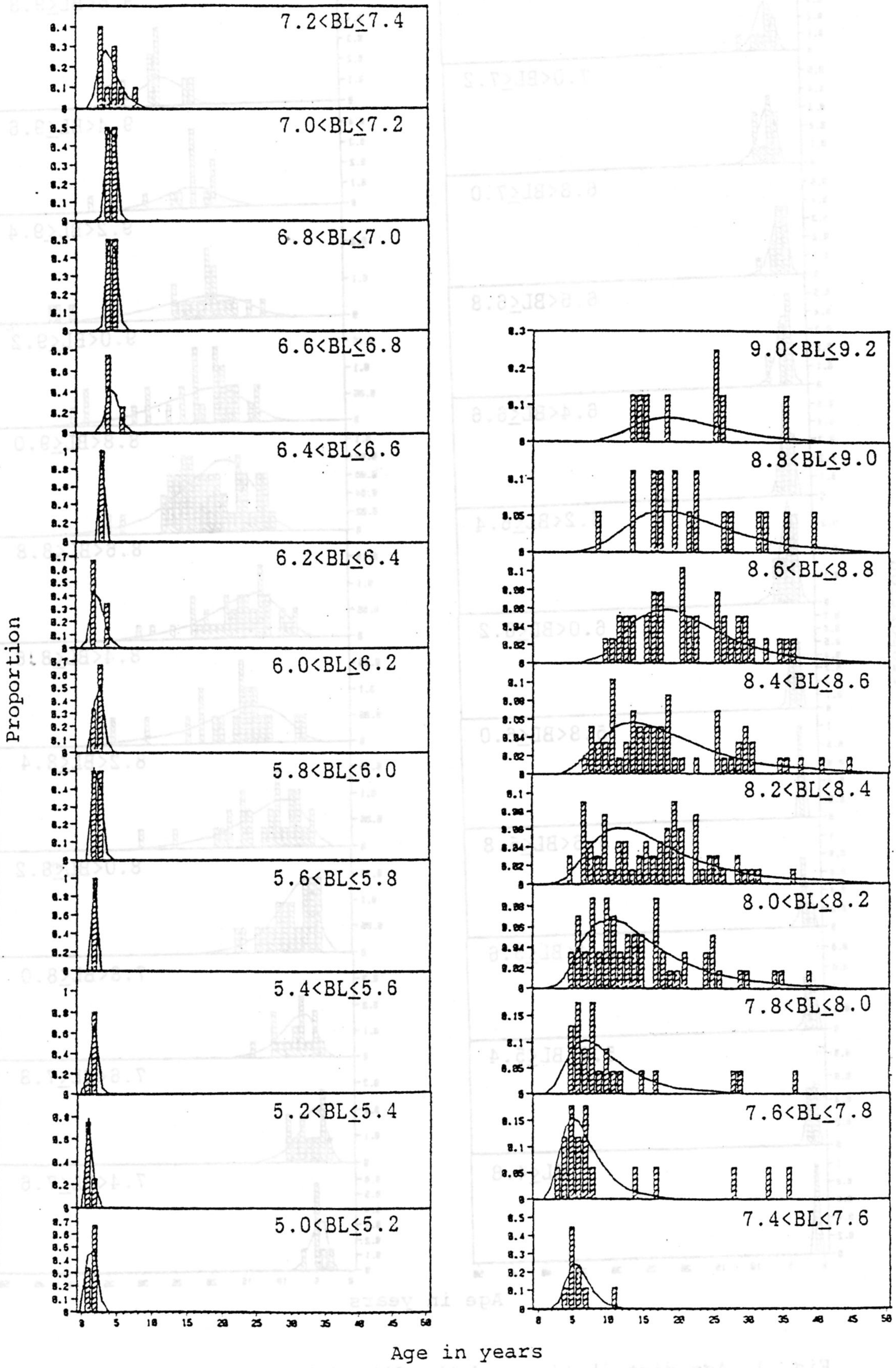

Fig. 3. Age distribution and the fitted log-normal distribution for males by the body length interval. BL means the body length (m).

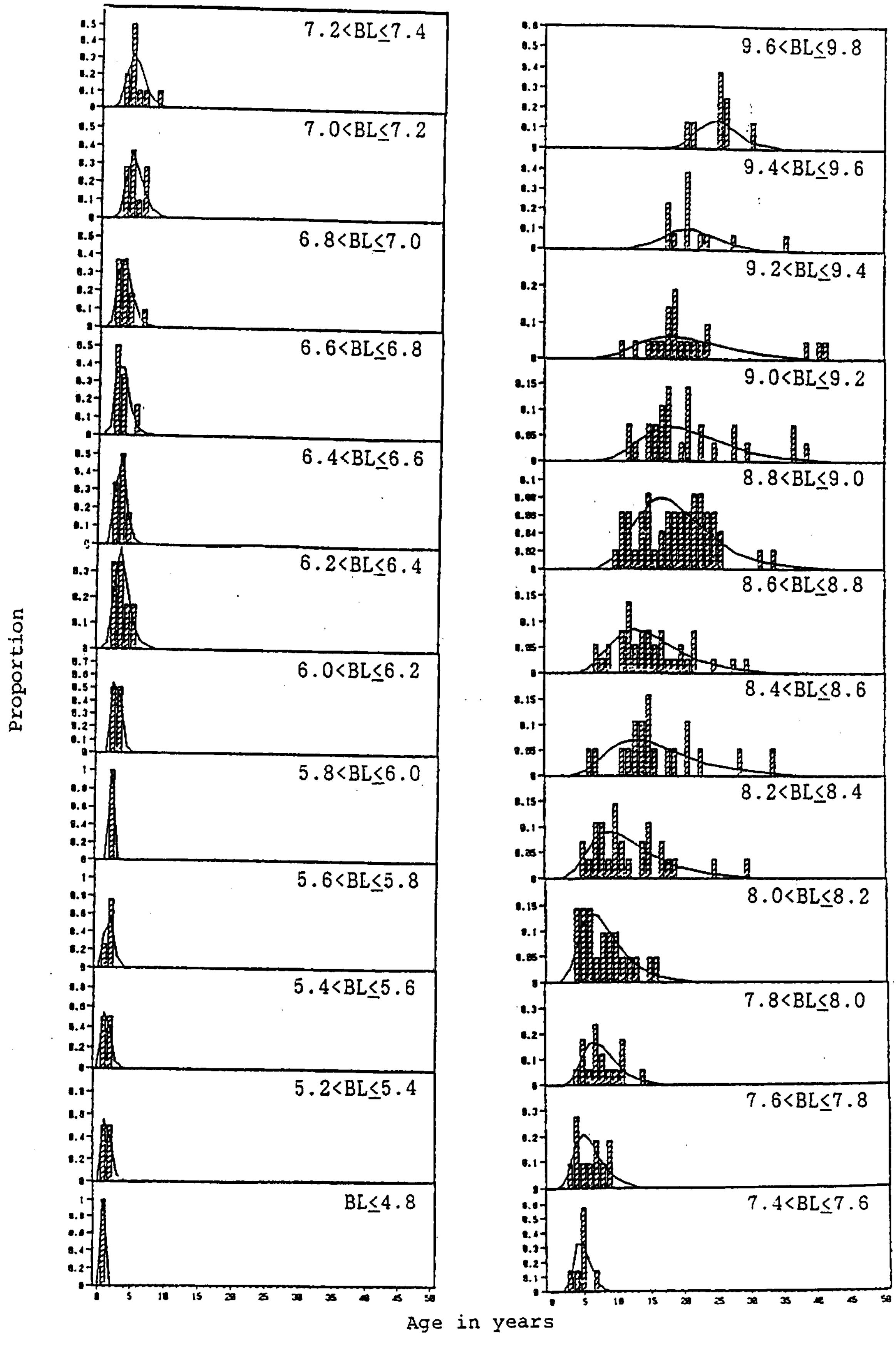

Fig. 4. Age distribution and the fitted log-normal distribution for females by the body length interval. BL means the body length (m).

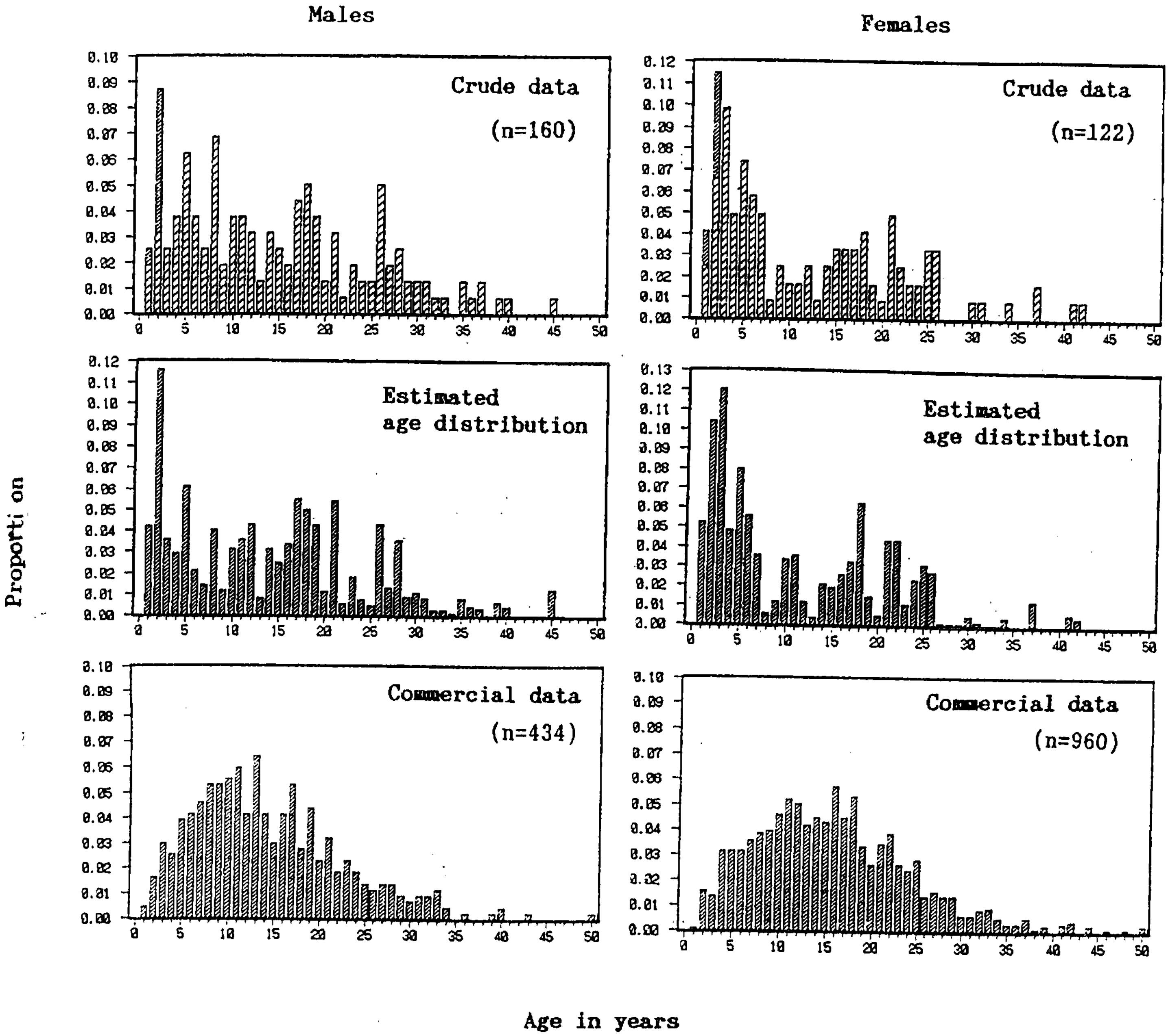

Fig. 5. Comparison of age compositions by crude data in the Japanese research in 1989/90 (upper), the present correction procedure (middle) and by the Japanese commercial catches based on combined data for 1971/72-84/85 inclusive (bottom). Hatched and solid lines in the upper figure indicate individuals whose ages were determined by earplugs and baleen plates, respectively.

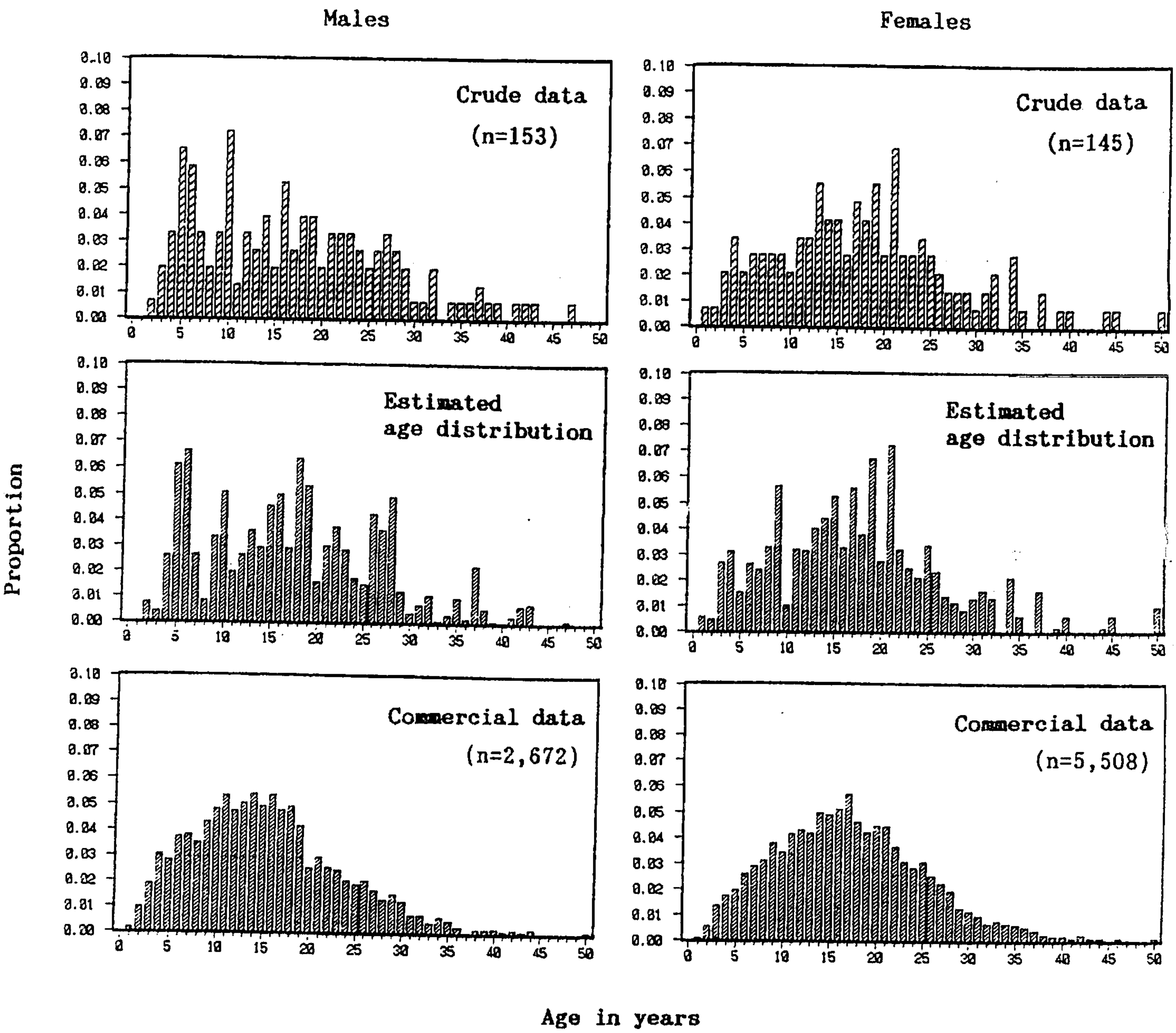

Fig. 6. Comparison of age compositions by crude data in the Japanese research in 1990/91 (upper), the present correction procedure (middle) and by the Japanese commercial catches based on combined data for 1974/75-86/87 inclusive (bottom). Solid line in the upper figure indicate individuals whose ages were determined by earplugs.

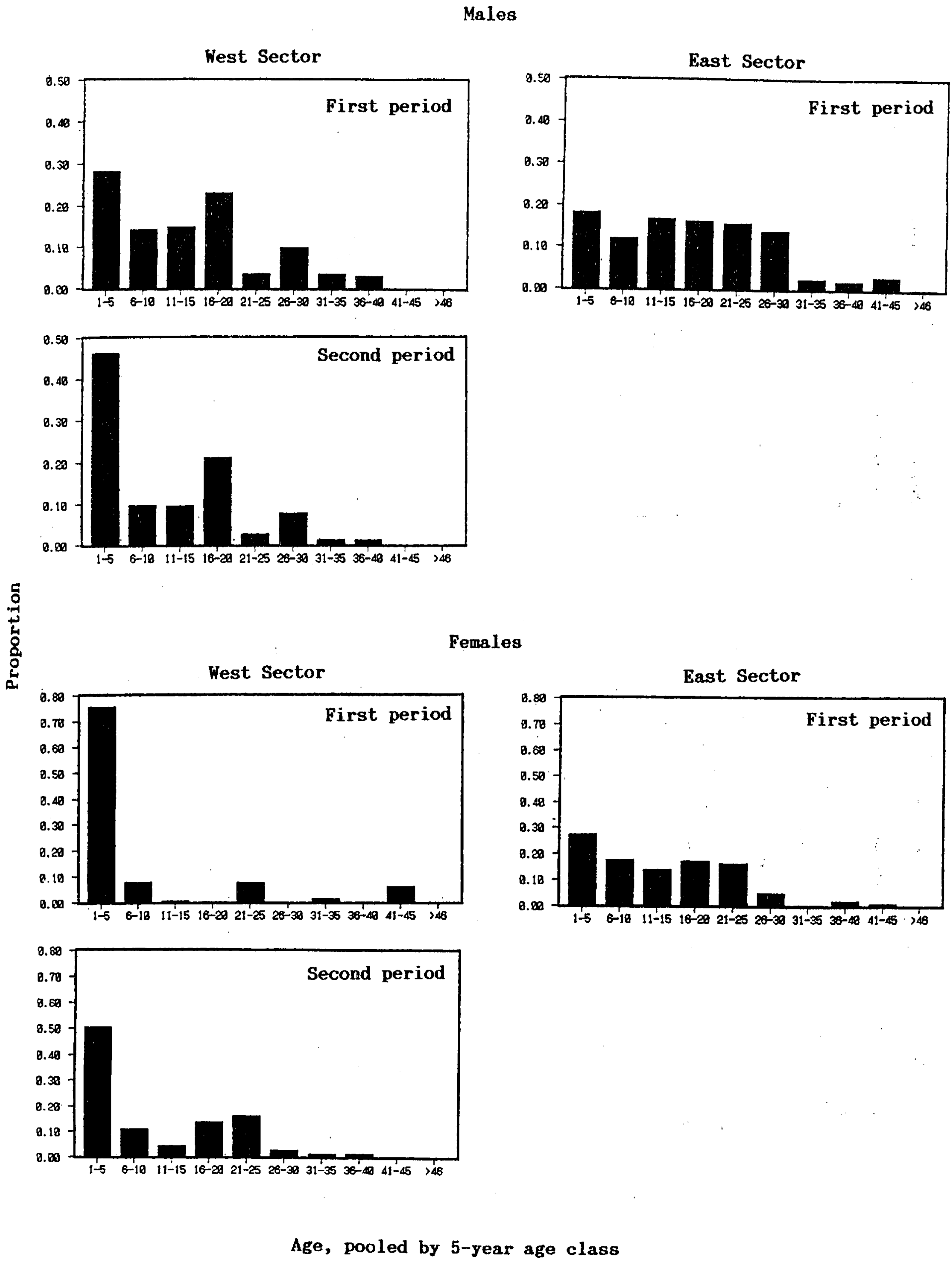

Fig. 7. Comparison of the estimated age distribution in each Sector by sex in the Japanese research in 1989/90.

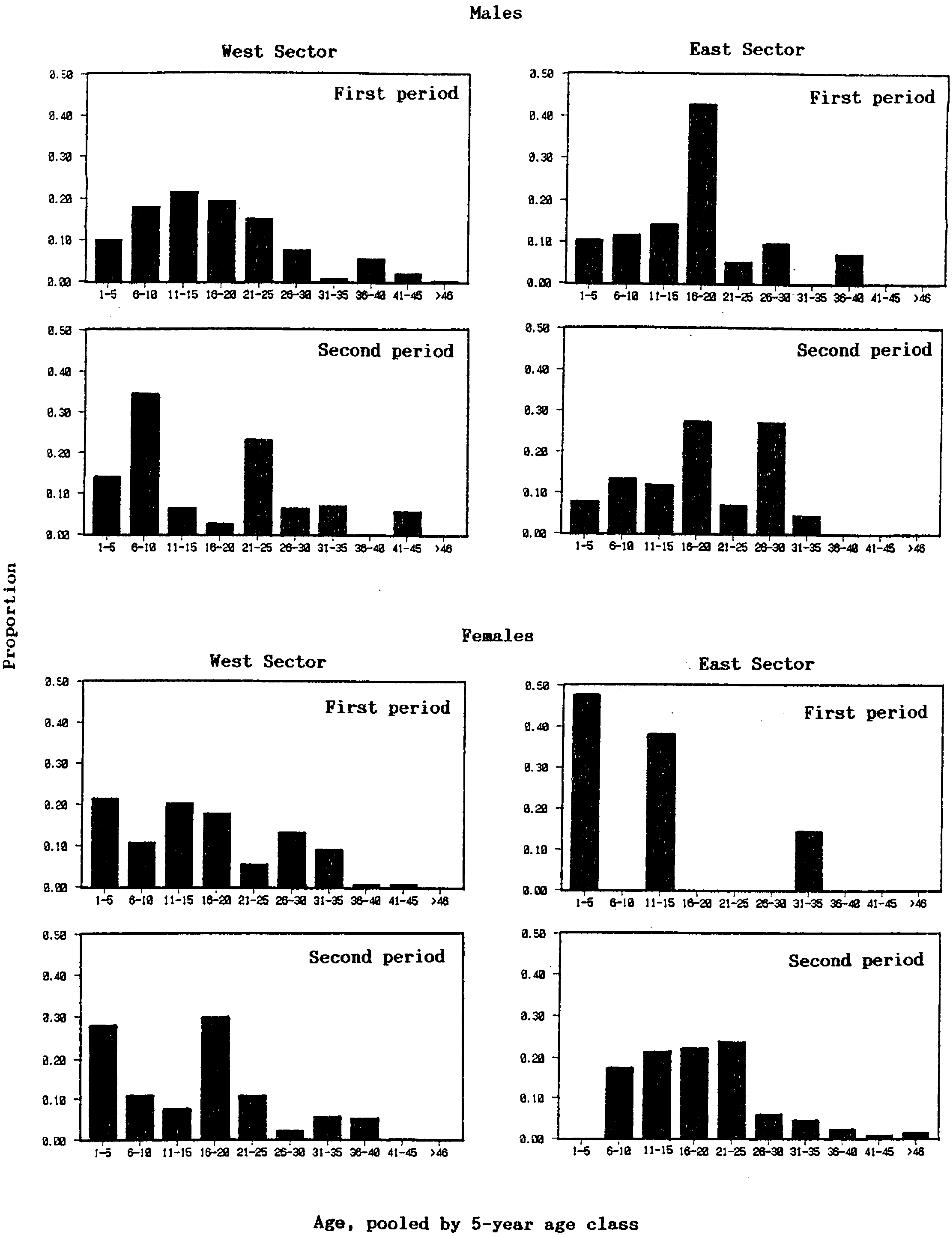

Fig. 8. Comparison of the estimated age distribution in each Sector by sex in the Japanese research in 1990/91.

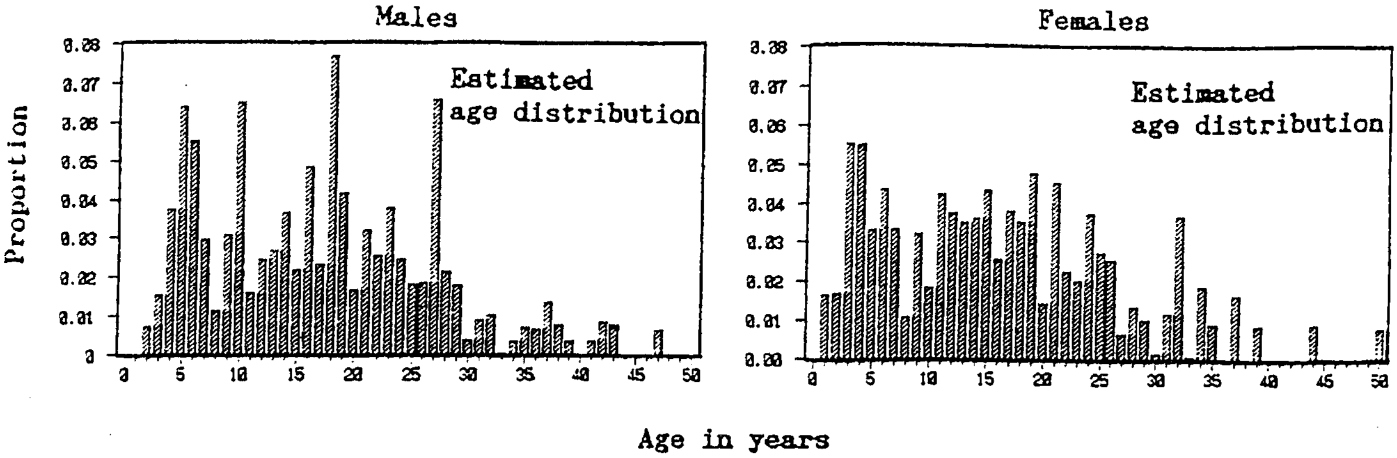

Fig. 9. The results of the trial for estimating for age distribution in Area V using the *ui* data in the Japanese research in 1988/89 from Kato, Fujise and Kishino (1991).

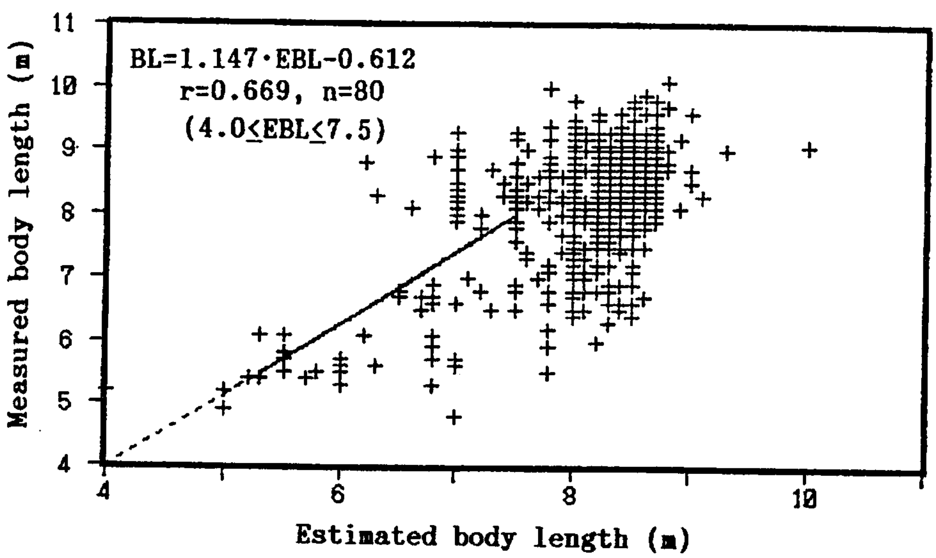

Fig. 10. Relationship between the body lengths estimated before catch (EBL) and measured after catch (BL).