SOME PROGRESS IN EXAMINATION ON AGE DISTRIBUTION AND SEGREGATION OF THE SOUTHERN MINKE WHALE POPULATION USING DATA FROM THE JAPANESE RESEARCH TAKE

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ABSTRACT

The present study developed some aspects in estimating method for age distribution by the data from the Japanese research take, where as aging error and allocation of animals whose ages were not determined were considered. The developed method gave more smoothed age distribution than the before. Analyses on the data (326 individuals) obtained from the 1989/90 research take revealed decreasing pattern with age with relatively higher proportion of younger animals. Seasonal change in age distribution was also identified through the analyses as: the proportion of younger males (1-3 years of age) increased to the later season. In contrast to this, younger females (1-5 years) was decreased with time. The AIC' analysis for detecting heterogeneity in biological parameters suggests the following nature: (1) mature males are dominant in the earlier season, (2) immature males migrated later than mature males and often in the offshore waters, (3) immature females migrated earlier than the others and are in a singleton. (4) mature females migrated later than the immature and make large schools in ice edge areas.

INTRODUCTION

Following the researches 1987/88 and 1988/89, the Japanese research take of southern minke whales, *Balaenoptera acutorostrata*, was undertaken covering the entire area of Area IV (70°E-130°E, south of 55°S). The most major objectives for the 1989/90 research plan is to estimate the age distribution for the components migrating to research area, and to investigate seasonal and areal factors for changes in biological parameters (Government of Japan, 1989).

The age structure of the migrated population was previously estimated by the data from the past two feasibility studies in

1987/88 and 1988/89 (Kato, Fujise and Kishino, 1991; Kato, Kishino and Fujise, 1990a; Kishino, Kato, Kasamatsu and Fujise, 1991b). However they did not take account of aging errors and the presence of individuals whose ages were not determined.

In the present study, we examine true age structure with taking the above point, using sighting and biological data obtained from the research take in 1989/90. Changes in the pattern of segregation in some biological parameters, respect to month, were examined.

Materials and Methods

Whale sample used and their stratification

As reported by Fujise, Yamamura, Zenitani, Ishikawa, Yamamoto, Kimura and Komaba (1990) for 1989/90, the research area was defined by 100°E for the Western and the Eastern sector which were further stratified by the line corresponding to 45 n.miles from ice edge line for the middle (offshore) and the south (ice edge) stratum. During the cruise in December 6, 1989 to March 12, 1990, the total of 329 minke whales including three diminutive form was randomly sampled from 767 primary sightings (1,978 ind.), and these positions of samples based on that sighted are shown Fig. 1.

The present study excluded three diminutive minke whales from all analyses, therefore, 326 whales were used as the basic set of sample.

The sampling activity in the 1989/90 cruise was ended at the Western Sector in the second half on Feb. 14, 1990. Because of the sample size limitation (300 whales with 10% allowance), then, the present analyses established the following six localities:

First half
- Western Sector (70-100°E)
  - Offshore (middle stratum) - Dec. 9-21, 1989.
  - Ice edge (south stratum) - Dec. 22-29, 1989.
- Eastern Sector (100-130°E)
  - Offshore (middle) - Jan. 11-19, 1990
  - Ice edge (south) - Dec. 31, 1989-Jan. 10, 1990

Second half
- Western Sector (70-100°E)
  - Offshore (middle) - Feb. 8-15, 1990.
  - Ice edge (south) - Jan. 21-Feb. 3, 1990

To estimate the biological parameters, samples in each localities were further stratified by the school size (singleton and >2). Finally, twelve strata were established. Table 1 indicates the data grouping and number of the whale samples used.

Age determination

As reported Kato *et al.* (1990a) and Kato *et al.* (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 growth layer (a pair of dark and pale lamina) assuming annual deposition rate, the counting growth layer was made by Kato using the stereoscopic microscope (10 x 6.4 - 16). By this method, individual ages were obtained from 267 of the total 326 whales captured (male: 150 ind., Female: 117).

Kato and Zenitani (1990) reported that the presence of notch on outer margin of baleen plate and the position of the notch on the baleen plate could be useful for determination of age to juvenile whales (<3 years). Then we introduced their method for the juvenile whose ages were not determined by earplug in the present study. The 15 individuals (male: 11 ind., female: 4) were thus determined by the method.

Finally, age of individual was successfully determined for 282 samples (267 by earplug and 15 by baleen plate).

Estimation of the age of individuals whose ages were not determined by earplugs and baleen plates

As mentioned above, although we tried to determine the age for all of samples, 44 individuals (24 ind. of male and 20 of female) were not determined age by both earplug and baleen plate, due to obscure formation of the growth laminae (33 animals) of the earplug, the lack of parts of the earplug core (6) and others (5). The ages of these individuals for whom the information of the earplugs and baleen plates were not reliable were estimated by the age-length relationship. Figs 2 and 3 shows the relation obtained by the data from Japanese research takes in 1987/88 to 1989/90 (728 ind.). For each of the 20cm length class, the age distribution was fitted by the log-normal distribution. From this information, the distribution of body length were transformed to the age distribution for the above individuals.

Sexual maturity

Females were considered sexually mature if at least one corpus luteum or albicans was present in the ovary, the others were to be sexually immature. Sexual maturation of male was examined by the histological section of testis tissues which were collected from center of right side testis. Males having seminiferous tubule over 100μm of its diameter (average in 20 measurements) based on the criterion by Kato (1986) or sperm in tubule were considered sexually mature, and others as sexually immature (Kato *et al.*, 1990a; Kato *et al.*, 1991).

Estimation of age distribution for the migrated population

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

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

Here, ui is the relative size of abundance of the ith stratum estimated by the sighting data concurrently obtained in the survey (Kishino, Taga, Nishiwaki and Kasamatsu, 1991c, see Table 2). yit is the estimated proportion of individuals at age t in the ith stratum.

Variance of estimated age frequency

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

Kato, Zenitani and Nakamura (1990b) examined the nature of error in earplug reading, and obtained the estimated magnitude of reading error as coefficient of variance (C.V.%) = 6.586%.

To take account of 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. ϵi ($i=1...n$) are independent among others and follow normal distributions with mean zero and variances $(0.06586xi)^2$ ($i=1...n$). For each of hundred resampled data set (1) was calculated.

Heterogeneity for the biological parameters

According to Kishino *et al.* (1991), Kato *et al.* (1990a) and Kato *et al.* (1991), heterogeneities in proportion of male, sexual maturity and mean age among school size, localities and both combined, were tested separately using the method of model selection. Data was constructed twenty models based on different combinations of the 12 strata by school size (singleton and ≥ 2), locality (offshore and ice edge), and season (Western Sectors in the first and second half and Eastern Sector). In the present study, the most probable model were determined by minimum value of AIC (Akaike Information Criterion; Akaike, 1974, 1985).

RESULTS

1. Age Distribution

As mentioned above sections, we estimated age structure for the population using data from the Japanese research take in 1989/90. Fig. 4 indicates the crude age distribution for each sex, with separately by age character. Although its 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. 4 also compares the estimated age distributions to those by commercial whaling operated in Area IV (1971/72-1984/85). The estimate procedure push up frequency in younger age classes which are obviously higher than those in the commercial.

Variances of the estimates were give in Tables 3 and 4 for male and female, respectively. The tables include in both case with amendment of estimated age by age-length key and without those.

2. Segregation of the biological parameters

Using the methods described in the previous section, we examined to heterogeneity of biological parameters by school size, locality, and season. We examined the segregation in proportion of male, sexual maturity and mean age, and the resultants are given Table 5.

Proportion of male

In the first Western Sector, proportion of male is relatively higher throughout all strata (0.591-0.864), especially in school size ≥2 with regardless of locality (offshore and ice edge; 0.857-0.864). In the Eastern Sector, the higher value is obtained in the singleton of offshore (0.875), and lower in ice edge group (0.143-0.372). In the second Western Sector, the proportion was almost even in all strata (0.438-0.556).

The proportion of male in each Sector is estimated from sighting and biological data, and the value in the first Western Sector (0.7592) is higher than in the Eastern and second Western Sectors (0.4911 and 0.4996).

AIC' statistics revealed that the model which is the male proportion is different school size and locality and further it is homogeneous in male proportion between the Eastern and second Western Sectors.

Sexual maturity

The sexual maturity rate for male is relatively higher in all strata of three Sectors (0.667-1.000), with exception of singleton in ice edge in the Eastern and offshore in the second Western Sector (0.000-0.200).

Estimated male sexual maturity rate for each Sector is higher in the first Western and Eastern Sectors (0.8843 and 0.9521) than in the second Western Sector (0.5670).

From the most probable model selected by AIC analysis, the male maturity rate is different school size and locality and further it is homogeneous in the maturity rate between the first Western and Eastern Sectors.

The female sexual maturity rates is lower in singleton in the first Western Sector (0.143-0.167) than in the others (0.333-1.000).

Estimate for each Sector is lower in the first Western Sector (0.3401) than in the Eastern and second Western Sectors (0.6308 and 0.5483).

Most probably model by the model selection indicates that the female maturity rate is different school size, and further it is homogeneous in the rate for female between the Eastern and second Western Sectors.

Mean age

Mean age for males in each stratum varied from 2.00 to 18.71. Estimated mean ages for each Sector are 14.79, 15.80 and 10.12 in the first Western, the Eastern and the second Western Sector, respectively. AIC' analysis revealed that the model which is the age is different locality and further it is homogeneous in the age between the first Western and Eastern Sectors.

The mean age for females is also varied between 2.90 and 15.75. Estimated mean age is 8.45, 12.73 and 19.89 in the first Western, Eastern and second Western Sector, respectively. By the model selection, the most probably model revealed that it is different in all strata.

Age composition

Fig. 6 gives seasonal changes in age distribution between the first and the second half of the Western Sector with indication of that in the Eastern for comparison. The distributions are represented with estimated one taking account corrections of animals which were not determined their ages. Mean sampling interval between the two halves is 43 days.

It can be found between the male distributions that younger males (1-3 years of age) increased dramatically in the later season (17.6% and 43.5% in the first and the second, respectively). While the proportion of middle age classes (5-25 years) apparently decreased with progress of the time, it is not true quantitatively as 62.5% in the first to 45.9% in the second. In contrast, younger females (1-5 years) decreased with time while the middle age class (6-25 years) somewhat increased. The quantitative changes are as follows;

	first half	second half
1-5 years :	75.7%	50.2%
6-25 years :	16.6%	44.6%.

Samples of the Eastern Sector were collected in Dec. 31, 1989 to Jan. 19, 1990, corresponding to intermediate period between the first and the second half of the Western Sector. With respect to this timing, the age distribution for both sexes shows just intermediate pattern between the two periods of the Western Sector. This may suggest that there is few variation between the Sectors.

DISCUSSION

The most remarkable points in the present study are incorporating age error and correlation of animals whose ages were not able to determined. This provided progress in technical points to estimating the true age distribution, which have not been examined by the previous studies. It will be necessary to examine the past data again by this procedures.

However, the estimate method adopted in the present study is based on the assumption that the length of whales migrated to the research is constant regardless of their sex and reproductive status. It should be also examined this point for future study.

The authors point is to investigate seasonal changes in some biological parameters as well as in age distribution. Due to lack of complete seasonal sample set had not been obtained from the eastern sector, this feature was not able to examine fully. However, the comparison has provided new knowledge about seasonality of biological parameters as follows;

(1) In the Western Sector in the first half (Dec., 1989), the older matured male and younger immature female were dominated. The males were distributed all area and make school, but the females were mainly distributed in the offshore.

(2) In the Eastern Sector (Dec., 1989- Jan., 1990), trend for male was similar to that in the above Sector, but for female older and matured animals were migrated in the research area.

(3) In the Western Sector in the second half (Jan.-Feb.,1990), matured and older animals were concentrated in the ice edge, and younger and immature animals (especially male) were distributed in the offshore.

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Table 1. Number of whales used this study.

Stratum	Number of Samples	
	School size	
	1	>=2
First half		
Western Sector		
Offshore	21*	22
Ice edge	37	44
Eastern Sector		
Offshore	8	15
Ice edge	7	65
Second half		
Western Sector		
Offshore	18	7
Ice edge	16	56

*) including 3 whales cauht in the North Sector at the first half.

Table 2. Estimated population size, their proportion to the total estimated population, and proportion of male to the total each stratum (after Kishino *et al.*, 1991).

Stratum	School size	Estimated population size	Proportion
First half			
Western Sector			
Offshore	1	2,373	(0.0620)
	≥2	2,659	(0.0695)
Ice edge	1	748	(0.0195)
	≥2	991	(0.0259)
Eastern 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 half			
Offshore	1	5,073	(0.1326)
	≥2	2,991	(0.0782)
Ice edge	1	1,268	(0.0331)
	≥2	3,402	(0.0889)

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

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	4	10	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

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.

Age class	Crude			Estimated(A)[3]		Estimated(B)[4]	
	E[1]	B[2]	E+B	Est.	S.E.	Est.	S.E.
1	4	1	5	0.0550	0.0333	0.0522	0.0333
2	11	3	14	0.1020	0.0719	0.1040	0.0693
3	12	-	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

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

Table 5. Means and standard errers of biological parameters (Male proportion, maturity and mean age) in each stratum.

	First western		First eastern		Second western	
	Offshore	Ice edge	Offshore	Ice edge	Offshore	Ice edge
Male proportion						
1	0.591	0.676	0.875	0.143	0.556	0.438
	(0.107)	(0.078)	(0.125)	(0.143)	(0.121)	(0.128)
	22[1]	37	8	7	18	16
≥2	0.857	0.864	0.533	0.372	0.500	0.438
	(0.082)	(0.050)	(0.124)	(0.068)	(0.224)	(0.070)
	14	33	15	39	5	32
Sexual maturity						
Male						
1	0.833	0.720	0.857	0.000	0.200	1.000
	(0.112)	(0.092)	(0.142)	(0.000)	(0.133)	(0.000)
	13	25	7	1	10	7
≥2	0.923	0.968	1.000	0.974	0.667	1.000
	(0.077)	(0.032)	(0.000)	(0.026)	(0.333)	(0.000)
	13	31	9	19	3	20
Female						
1	0.143	0.167	1.000	0.500	0.500	0.778
	(0.143)	(0.112)	(0.000)	(0.224)	(0.189)	(0.147)
	9	12	1	6	8	9
≥2	0.667	0.571	0.500	0.759	0.333	0.688
	(0.333)	(0.202)	(0.164)	(0.073)	(0.333)	(0.089)
	3	7	8	29	3	24
Mean age						
Male						
1	16.27	12.68	12.75	2.00	4.80	18.71
	(2.97)	(1.85)	(4.96)	(0.00)	(1.87)	(3.46)
	11	22	4	1	10	7
≥2	13.29	17.43	17.63	15.44	10.83	16.28
	(3.05)	(1.99)	(3.46)	(2.40)	(4.97)	(2.52)
	12	27	8	18	3	18
Female						
1	10.86	2.90	21.00	9.67	11.29	15.75
	(5.98)	(0.53)	(0.00)	(2.84)	(4.03)	(2.81)
	7	10	1	6	7	8
≥2	5.00	12.60	11.14	14.35	3.00	14.78
	(1.15)	(5.71)	(2.56)	(1.69)	(1.15)	(2.07)
	3	5	7	26	3	23

1) : number of schools.

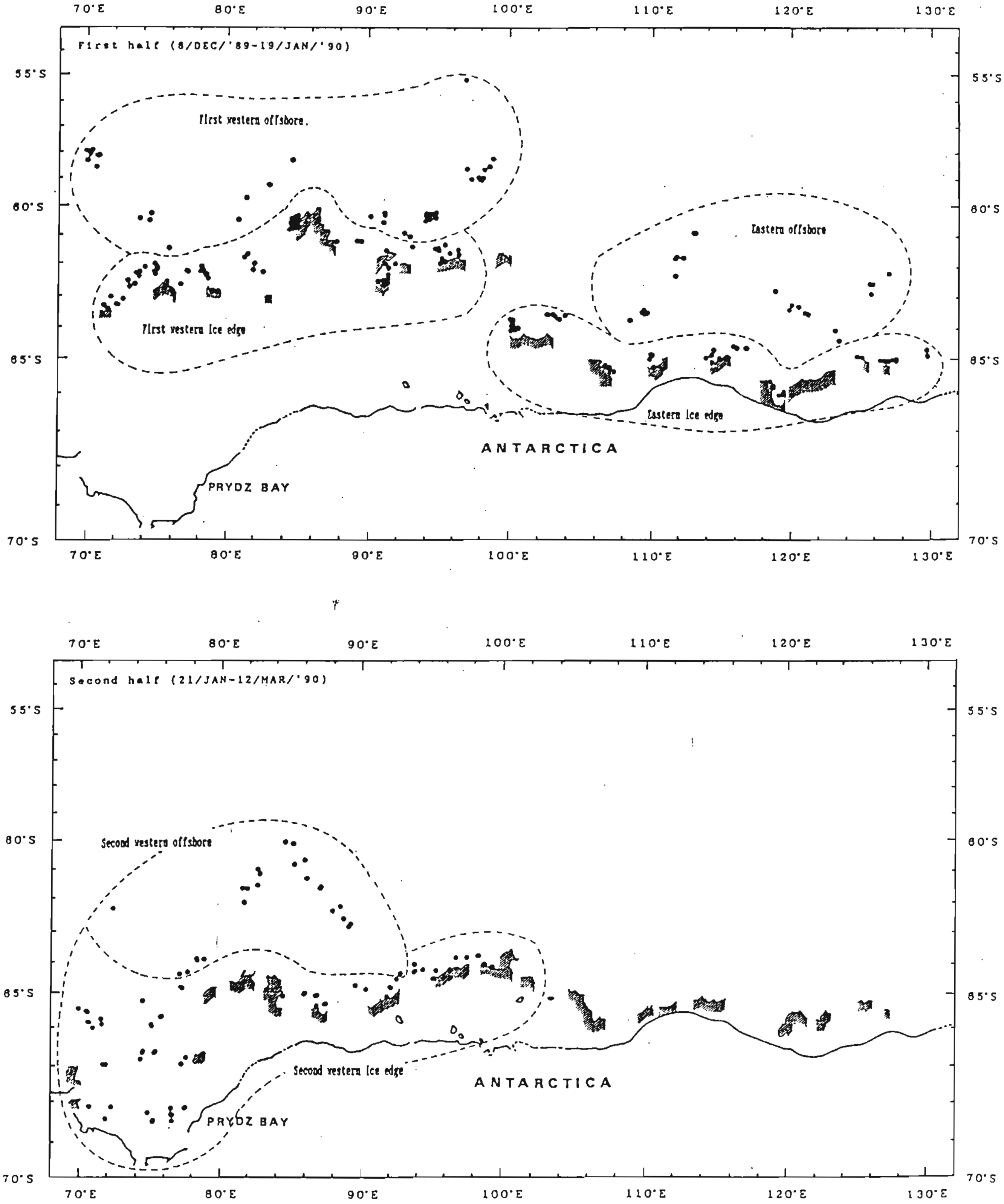

Fig. 1. Grouping of geographical and seasonal strata in Area IV (1989/90)(after Fujise *et al.* 1990).

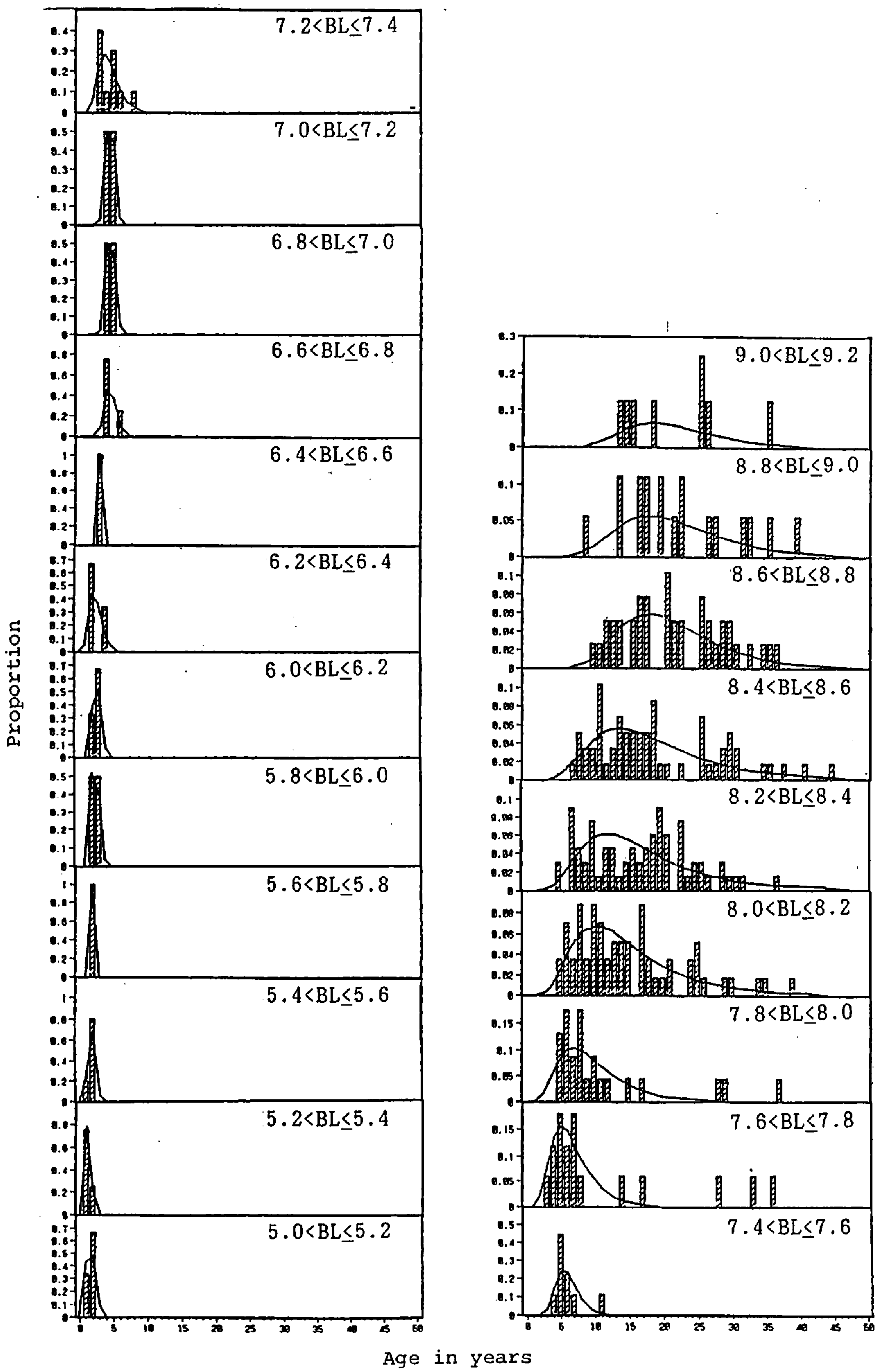

Fig. 2. Age distribution and the fitted log-normal distribution for male in each interval with pooling 20cm of body length.

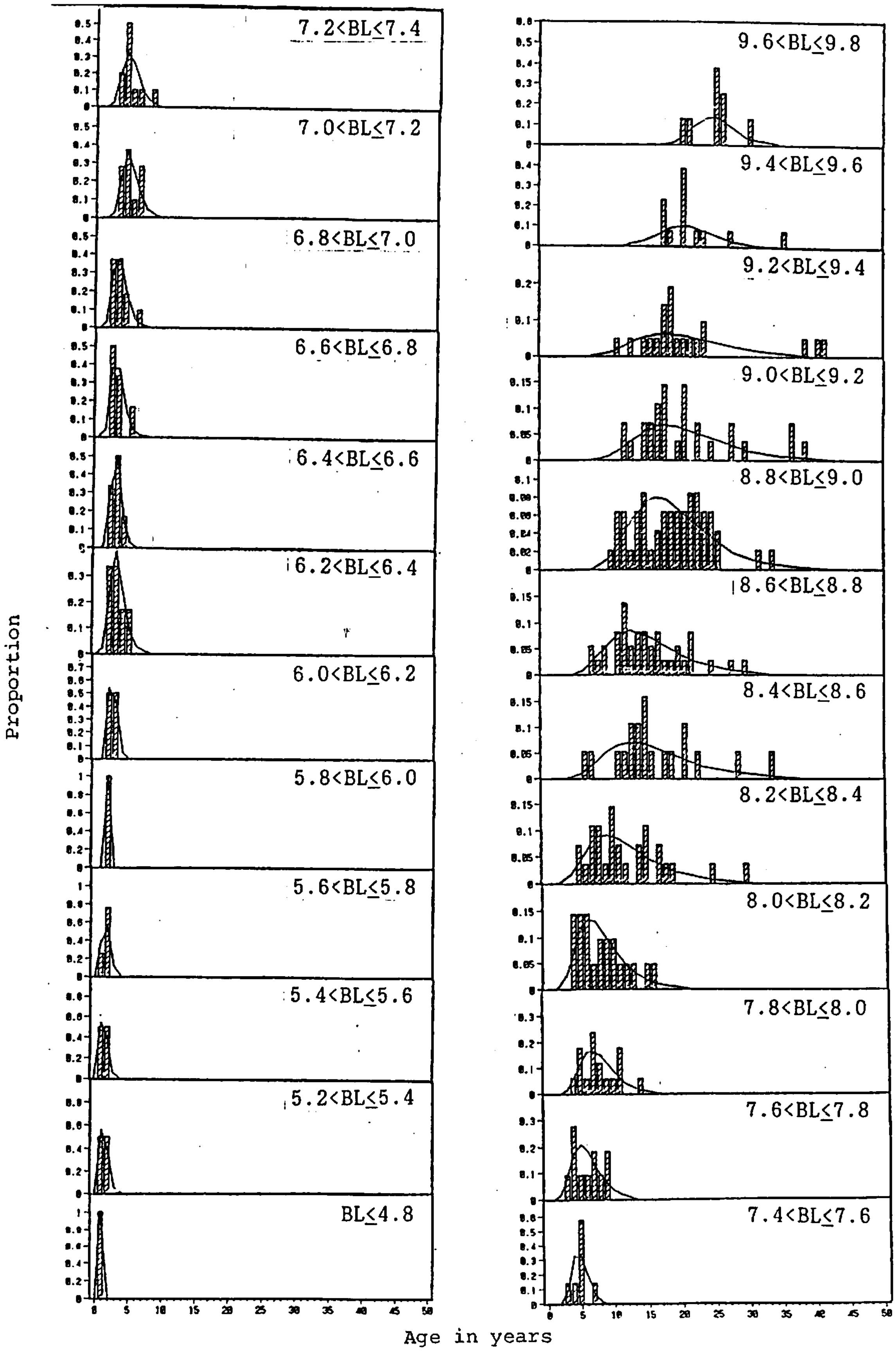

Fig. 3. Age distribution and the fitted log-normal distribution for female in each interval with pooling 20cm of body length.

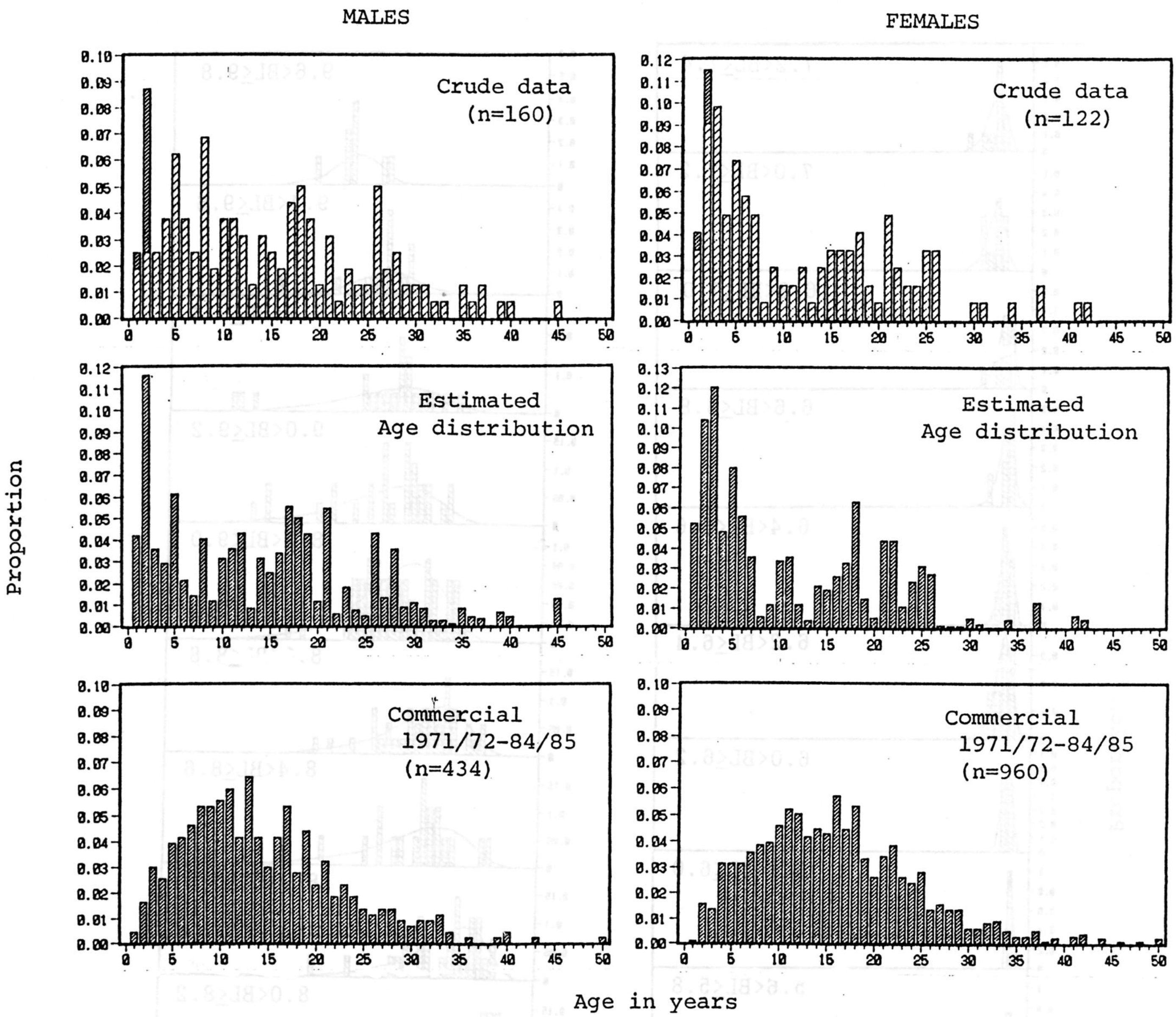

Fig. 4. Comparison of age compositions by crude data (upper), the present correction procedure (middle) and by the Japanese commercial catches based on combined data for 1971/72-84/85 inclusive (bottom). Hatched and solid lines in the upper figure indicate individuals whose ages were determined by earplugs and baleen plates, respectively.

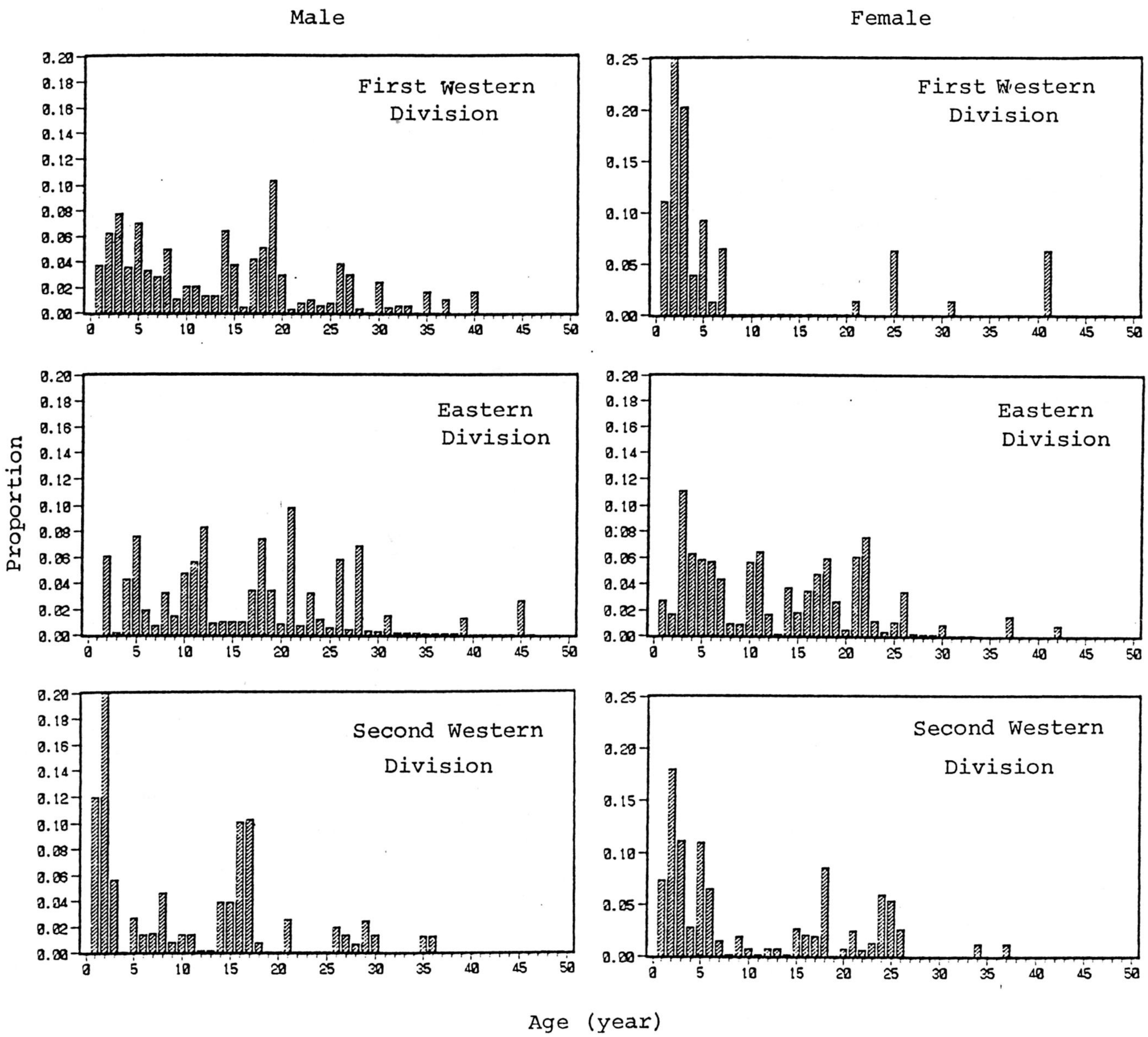

Fig. 5. Comparison of the estimated age distribution in each Sector by sex. Upper: first Western Sector (Dec. 9-29, 1989), middle: Eastern Sector (Dec. 31, 1989- Jan. 19, 1990), bottom: second Western Sector (Jan. 21-Feb. 15, 1990).