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REPRODUCTIVE SEGREGATION OF THE MINKE WHALE POPULATION IN HIGH LATITUDINAL WATERS WITH SOME ESTIMATIONS OF PREGNANCY AND SEXUAL MATURITY RATES, DATA FROM JAPANESE RESEARCH TAKES IN 1987/88 AND 1988/89

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ABSTRACT

Sexual and reproductive segregations in southern minke whale populations were examined by the estimation of relative abundance and biological parameters (sex ratio, sexual maturity rate, and apparent pregnancy rate) using the bootstrap resampling method, based on biological data from 272 individuals in 1987/88 and 236 individuals in 1988/89 Japanese research take as well as primary sighting data. The 1987/88 research in part of Area IV revealed the following nature: (1) both of immature and mature males were tended to be in larger schools in both offshore and ice edge, and those were dominated in the offshore (2,353-3,671 ind.) with few pregnant females; (2) while in the ice edge, matured animals mainly occurred (2,251-3,590 ind.), and most of mature females were pregnant (682-1,229 ind.), and they tended to be in larger schools. From the 1988/89 research in part of Area V: (1) the numbers of animals for males were almost equal to those for females in the offshore (male: 7,236-10,267 ind., female: 7,194-10,006 ind.); (2) in the ice edge, those of females (5,991-10,374 ind.) were higher than those of males (3,395-5,699 ind.); (3) in the Ross Sea, mature females exclusively dominated (2,038-3,030 ind. out of 2,351-3,518 total animals in the area).From the bootstrap resampling method, the representative pregnancy rates were estimated to be 0.906-0.946, the female sexual maturity rates 0.344-0.632, the male maturity rates 0.707-0.815, for the migrating populations.

1. INTRODUCTION

In 1987/88 and 1988/89 austral summers, the Japanese research take of southern minke whales, *Balaenoptera acutorostrata*, had undertaken in the parts of Antarctic Area IV and V by using the

random sampling and systematic sighting survey. Kato, Kishino and Fujise (1990a) and Kato, Fujise and Kishino (1990c) attempted to estimate the true age structure of the migrating population using the method which was originally proposed by Kishino, Kato, Kasamatsu and Fujise (1989) incorporating with the bootstrap methods (Efron, 1979). They made the age compositions in both sexes having peaks at age one or two years for the first research. They also gave those for the second research have a peak at age five years. These compositions were clearly different from the commercial ones. Furthermore, they also examined some aspect of segregations in minke whale by AIC analyses of some factors (sex ratio, sexual maturity, mean age) using samples from the research takes. However they did not discussed to consider the segregation of the whales with abundance of animals.

In the present paper, using sighting and biological data from two the research takes, we have examined the reproductive segregation of migrating population to the research area with estimating real number of animals by the bootstrap resampling method from Japanese research takes in 1987/88 and 1988/89.

2. Materials and Methods

2.1 Whale samples, sighting information and their stratification

In the research cruise in 1987/88 season, as reported by Kato, Hiroyama, Fujise and Ono (1989), the total of 273 minke whales including one diminutive form was randomly sampled from 227 primary sightings (675 individuals) during the cruise in January 17 to March 26 1988. And in 1988/89, total of 241 minke whales including five diminutive and 236 ordinary forms was sampled from 340 primary sightings made during January 12 to March 31 1989, as reported by Kato, Fujise, Yoshida, Nakagawa, Ishida and Tanifuji (1990b). The present study excluded diminutive forms from analyses, therefore, 272 and 236 individuals in 1987/88 and 1988/89, respectively, were used as the basic set of sample. In order to examine the nature of reproductive or sexual segregation with real number of individuals for the population migrating to the research area, it was used the population size which were estimated in each zone by Kasamatsu, Kishino and Hiroyama (1989) and Kasamatsu, Kishino and Taga (1990).

According to the grouping of Kato *et al.* (1990c), whale samples were grouped into strata by two school size groups (solitary and school size ≥ 2) and two geographical locations in 1987/88 and three locations in 1988/89, respectively, (Offshore, Ice edge in 1987/88, Offshore, Ice edge and the Ross Sea in 1988/89). The area of the Ross Sea was tentatively decided as waters in south of 72 30'S. The group of ice edge includes animals caught in waters within 60 n.miles from ice edge line except in the Ross Sea, and the other individuals were pooled as the offshore group. Therefore, the totals of four in 1987/88 and six strata in 1988/89 were used as units of the grouping of data. Table 1 indicates the data grouping and number of the

whale samples used, and their sighted positions were shown Figs 1 and 2.

2.2 Sexual maturity and age determination

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 100 m 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, 1990c).

As reported Kato *et al.* (1990a, 1990c), 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 eye (Kato) under the stereoscopic microscope (10 x 6.4 - 16). Age of individual was determined for 255 of 272 samples in 1987/88 and 191 of 236 in 1988/89, respectively (Kato *et al.*, 1990a, 1990c).

2.3 Statistical procedure to estimation of biological parameters

The biological parameters for the population migrated were estimated by extrapolating those of samples to animal of the primary sightings that were targeted but unsampled and animals present in the research area but unsighted in each stratum. Details of these methodological procedure were reported by Kishino *et al.* (1989) and Kato *et al.* (1990a). In the present study, both of basic set of whale samples and sighting data were resampled by the bootstrap method. Obtaining the values of the parameters from each data set of pooled by resampled days, and the mean of 100 estimated values was determined as the biological parameter of the population.

When the parameter (such as sexual maturity rate) should be separately estimate the data of females and males, u_i^F (or u_i^M), which is the proportions of females (or males) in the ith stratum to all females (or males) combined among strata, should be used. Because it is impossible to discriminate between female and male in the sighting survey, u_i^F are estimated as (the estimated number of animals in the ith stratum) x (the estimated sex ratio obtained from the sample in the ith stratum).

To indicate of number of individuals with reference to sexual or reproductive segregation, we converted real number of individuals from multiplying estimated values of biological parameters and population sizes modified from Kasamatsu, Kishino and Hiroyama (1989) and Kasamatsu, Kishino and Taga (1990). The population sizes in each strata were expressed as mean of 100 estimated values by bootstrap methods for each vessel (1987/88)

and track line (1988/89) which were mentioned by Kasamatsu *et al.*, (1989, 1990).

3. RESULTS

3.1 Comparison of samples between research take and commercial ones by crude data.

Table 2 indicates the reproductive status of samples from the researches with those by commercial catches (1971/72-1986/87) from which the area corresponded to the research area in respective season. The proportions of immature animals of both sexes (male: 17.7-21.1%, Female: 29.1-50.4%) were higher than those by commercial whaling (male: 2.7-9.1%, female: 9.0-16.2%). Sex ratio was differed by Area as being 0.563 (Area IV) to 0.360 (Area V). The value of Area IV considerably higher and that of Area V was slightly lower than commercial ones (0.393 and 0.432).

Because of small sample sizes, we couldn't estimate for average age at sexual maturity. Table 3 and 4 indicates the crude number of sexually immature and mature animals by sex and age class in 1987/88 and 1988/89 researches. Ages of youngest sexually mature male were 2 and 5, and oldest sexually immature were 6 and 4 in 1987/88 and 1988/89, respectively. Then we considered here that most of males attain sexual maturity between 2 and 6 years, and 5 (or 6) and 13 years for female.

3.2 Proportion of number of estimated animals by each school size to the total (u_i^F and u_i^M).

Using the methods described in the previous section, the school size compositions in each stratum were estimated separately by male and female, and these were shown in Table 4. In 1987/88 (Area IV), following trend was detected that the estimated populations of animals taken from the school size ≥ 2 occupied 64.9% (male) and 54.6% (female) in offshore, and 84.2% (male) and 76.3% (female) in ice edge respectively. About half of total males (55.7%) were estimated to be in the offshore while females were often in Ice edge zone (57.2%). On the other hand, in the 1988/89 (Area V), males tend to be in the offshore (63.7%) irrespective of its school size, whereas females tended to make larger schools in both of offshore and ice edge (26.0-36.9%). On the other hand, the estimated population of animals taken in the Ross Sea was considerably lower in both of sexes (male: 3.0%, female 13.4%).

3.3 Estimated sex ratio and sexual maturity rate.

Table 6 indicates the male sex ratios from bootstrap methods in each stratum. The male sex ratio from the offshore (0.60-0.71) was higher than those from Ice edge in 1987/88 (0.42-0.55). Through both researches, the male ratio tend to be lower with higher latitudes irrespective of school sizes excepting one

abnormality from solitary at ice edge in 1988/89.

Table 7 indicates the estimated sexual maturity rates from bootstrap methods by stratum and sex. In most of stratum, the rates for male were higher (66.4-100%). On the other hand, the rates for female were lower in 1987/88 (0.0-18.1%), while those in 1988/89 were higher (57.6-100%) with some exception. The given rates for both sexes tended to be higher with increasing school size and latitude in throughout two researches, especially the female rates showing 0.0-25.1% from solitary in offshore and 61.2-65.4% from solitary in ice edge.

3.4 Estimation of biological parameters for the population migrating to the research area.

In order to estimate representative values of biological parameters, we re-estimated each value from the data combined all strata by adopting the bootstrap sampling again. Those estimates are given in Tables 8 and 9 by the crude data. In addition to biological parameters which examined previous section, we estimate pregnancy rate by the same procedure for the others.

In 1987/88, male sex ratio of the population was 0.596 (s.e. 0.056), and sexual maturity rates were 0.707 (0.056) and 0.344 (0.057) in male and female, respectively. Allover means of pregnancy rates were 0.946 (0.062).

In 1988/89, the sex ratio was 0.414 (s.e. 0.041), and sexual maturity rates were 0.815 (0.050) and 0.632 (0.047) in male and female, respectively. The means of pregnancy rates were 0.906 (0.031).

3.5 Reproductive segregation with particular reference to individuals number

Tables 10 and 11 gives the converted real numbers of individuals by reproductive status from multiplying estimated values of biological parameters which were estimated in 3.2 and 3.3 and population sizes. Fig. 3 schematically shows proportions of animals by sexual and reproductive status with indications of different size of circles representing population size.

From 1987/88 research, a total number of individuals was estimated to be 6,936-10,173 in entire the research area. Those individuals almost equally distributed in offshore and ice edge (offshore: 3,538-5,434 individuals, ice edge: 3,398-4,739 ind.). In the offshore, total numbers of nature animals were to be 2,353-3,671 and 1,185-1,763 individuals for males and females, respectively. While in the ice edge, number of males (1,748-2,563 ind.) were almost equal to those for females (1,650-2,176 ind.), among them mature males exceed mature females (mature male: 1,502-2,319 ind., mature female: 1,650-2,176 ind.). Of mature females, 682-1,229 animals were pregnants.

From the 1988/89 research, total animals was estimated to be 26,167-39,865 individuals comprising 14,430-20,274 individuals in the offshore, 9,386-16,073 individuals in the ice edge, and 2.351-3,518 individuals in the Ross Sea. A total females were to

be 15,223-23,410 individuals, there was no difference in number between offshore (7,194-10,006 ind.) and ice edge (5,991-10,374 ind.) while number of females in Ross Sea (2,038-3,030 ind.; all females were mature) were fewer than an other area. On the other hand, number of mature males in offshore (5,789-8,191 ind.) is more abundant than the other.

4. DISCUSSION

It have been suggested that sexual or reproductive segregation on southern minke whales in high latitudinal waters by analyzing of data from commercial catches (Ohsumi, Masaki and Kawamura, 1970; Ohsumi and Masaki, 1975; Best 1982; Kato, 1983, 1986, 1987), and Japanese research takes (Kato *et al.*, 1990a, 1990c).

The present study has clarified the sexual and reproductive segregation of southern minke whales with indicating real number of animals. This is a first attempt to evaluate the nature of segregation with examining its details using individuals number. The estimated sexual maturities were considerably lower than those of commercial catches in both sexes. This is evidently results from incorporating the random sampling method. However the estimated apparent pregnancy rates from the present study were as high as 90% which is similar to those of commercial ones. Although sexual interpretations can be made on this matter, this nature is expected to be examine by the future data from more wider areas or wider range of month.

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Table 1. Basic set of minke whale samples used in the present study, indicating number of whales by sex, school size and locality.

	School size	Group*		
		Offshore	Ice edge	Ross sea
1987/88 cruise				
Male				
	1	23	8	—
	≥ 2	28	94	—
Female				
	1	12	10	—
	≥ 2	12	85	—
1988/89 cruise				
Male				
	1	13	9	2
	≥ 2	37	21	3
Female				
	1	11	5	14
	≥ 2	48	66	7

*) see text.

Table 2. Comparison of sexual composition of samples from research takes and the corresponding commercial catches.

Research or Commercial	Male				Male sex ratio
	Imm.	Mat.	Unk.	Total	
Research 1987/88 (Area IV)	32 (21.1)	120 (78.9)	1	153	0.563
Commercial (Area IV)	262 (9.0)	2634 (91.0)	11	2907	0.393
Research 1988/89 (Area V)	15 (17.6)	70 (82.4)	0	85	0.360
Commercial (Area V)	11 (2.7)	400 (97.3)	1	412	0.432

Research or Commercial	Female								
	Imm.	Mat.						Unk.	Total
		Preg.	P&L	Ovu.	Rest.	Unk.	Total		
Research 1987/88 (Area IV)	60 (50.4)	57 [98.3]	-	-	1 [1.7]	1	59 (49.6)	-	119
Commercial (Area IV)	716 (16.2)	3410 [92.5]	-	168 [4.6]	109 [3.0]	12	3699 (83.8)	72	4487
Research 1988/89 (Area V)	44 (29.1)	98 [93.3]	1 [1.0]	2 [1.9]	4 [3.8]	2	107 (70.9)	-	151
Commercial (Area V)	47 (9.0)	436 [91.2]	-	5 [1.0]	37 [7.7]	-	478 (91.0)	16	541

(): indicates the proportion of animals to the total animals which were determined for maturaty of animal.

[]: indicates the proportion of animals to the total matured females which were determined for reproductive status.

Table 3. Sexual maturity by sex and age of samples in the 1987/88 cruise.

Age (year)	Male			Female		
	Immature	Mature	Total	Immature	Mature	Total
1	7 (1.00)	0	7	10 (1.00)	0	10
2	7 (0.88)	1	8	6 (1.00)	0	6
3	3 (0.60)	2	5	9 (1.00)	0	9
4	5 (0.63)	3	8	13 (1.00)	0	13
5	4 (0.57)	3	7	2 (1.00)	0	2
6	1 (0.25)	3	4	2 (0.67)	1	3
7	0	7	7	3 (0.43)	4	7
8	0	4	4	3 (0.60)	2	5
9	0	2	2	1 (0.50)	1	2
10	0	6	6	3 (0.75)	1	4
11	0	4	4	1 (0.20)	4	5
12	0	2	2	0	3	3
13	0	6	6	1 (0.50)	1	2
14	0	6	6	0	2	2
15	0	5	5	0	3	3
16	0	5	5	0	1	1
17	0	6	6	0	3	3
18	0	5	5	0	4	4
19	0	3	3	0	4	4
20	0	7	7	0	3	3
>20	0	37	37	0	20	20

Figure in parentheses indicates proportion of immature animals.

Table 4. Sexual maturity by sex and age of samples in the 1988/89 cruise.

Age (year)	Male			Female		
	Immature	Mature	Total	Immature	Mature	Total
1	3 (1.00)	0	3	2 (1.00)	0	2
2	4 (1.00)	0	4	4 (1.00)	0	4
3	2 (1.00)	0	2	3 (1.00)	0	3
4	2 (1.00)	0	2	3 (1.00)	0	3
5	0	4	4	8 (0.89)	1	9
6	0	4	4	4 (1.00)	0	4
7	0	4	4	1 (0.50)	1	2
8	0	2	2	3 (0.60)	2	5
9	0	3	3	2 (0.67)	1	3
10	0	4	4	1 (0.50)	1	2
11	0	4	4	0	7	7
12	0	2	2	1 (0.14)	6	7
13	0	2	2	2 (0.25)	6	8
14	0	3	3	0	6	6
15	0	1	1	0	10	10
16	0	1	1	0	4	4
17	0	4	4	0	4	4
18	0	0	0	0	7	7
19	0	2	2	0	5	5
20	0	1	1	0	3	3
>20	0	15	15	0	26	26

Figure in parentheses indicates proportion of immature animals.

Table 5. Estimated mean school size composition and standard error (parenthesis) for male and female (u_i^F and u_i^M) in each stratum based on the bootstrap resampling method from sighting and sampled data obtained from the 1987/88 and 1988/89 cruises.

	School size	Group*		
		Offshore	Ice edge	Ross Sea
1987/88 cruise				
Male (u_i^M)	1	0.1955 (0.0599)	0.0701 (0.0430)	—
	≥ 2	0.3617 (0.1163)	0.3728 (0.1066)	—
Female (u_i^F)	1	0.1945 (0.0809)	0.1356 (0.0758)	—
	≥ 2	0.2338 (0.1111)	0.4361 (0.0971)	—
1988/89 cruise				
Male (u_i^M)	1	0.3117 (0.0611)	0.1440 (0.0400)	0.0245 (0.0136)
	≥ 2	0.3257 (0.0777)	0.1887 (0.0690)	0.0055) (0.0025)
Female (u_i^F)	1	0.1909 (0.0516)	0.0454 (0.0249)	0.1238 (0.0278)
	≥ 2	0.2600 (0.0738)	0.3693 (0.0882)	0.0105 (0.0052)

*) see text.

Table 6. Estimated mean sex ratio (ratio of male to the total) and standard error (parenthesis) in each stratum based on the bootstrap resampling method from sighting and sampled data obtained from the 1987/88 and 1988/89 cruises.

Area	School size	Research cruise	
		1987/88	*1988/89*
Offshore			
	1	0.6016 (0.1281)	0.5399 (0.0833)
	≥ 2	0.7099 (0.0834)	0.4738 (0.0700)
Ice edge			
	1	0.4241 (0.1191)	0.6979 (0.1407)
	≥ 2	0.5541 (0.0468)	0.2603 (0.0507)
Ross sea			
	1	—	0.1209 (0.0581)
	≥ 2	—	0.2815 (0.0994)

Table 7. Estimated mean maturity rate and standard error (parenthesis) for male and female in each stratum based on the bootstrap resampling method from sighting and sampled data obtained from the 1987/88 and 1988/89 cruises.

Area	School size	Research cruise	
		1987/88	*1988/89*
Male			
Offshore			
	1	0.3364 (0.0968)	0.7834 (0.1273)
	≥ 2	0.6836 (0.1109)	0.8135 (0.0603)
Ice edge			
	1	0.6644 (0.2803)	0.7895 (0.0843)
	≥ 2	0.9251 (0.0279)	0.8540 (0.0799)
Ross sea			
	1	—	1.0000 (0.0000)
	≥ 2	—	1.0000 (0.0000)
Female			
Offshore			
	1	0.0000 (0.0000)	0.2514 (0.1347)
	≥ 2	0.1811 (0.1048)	0.7617 (0.0635)
Ice edge			
	1	0.1004 (0.1018)	0.5762 (0.2703)
	≥ 2	0.6543 (0.0475)	0.6122 (0.0625)
Ross sea			
	1	—	1.0000 (0.0000)
	≥ 2	—	1.0000 (0.0000)

Table 8. Corrected biological parameters (sex ratio, sexual maturity, age at sexual maturity and apparent pregnancy rate) and their standard errors (in parentheses) by the bootstrap method with crude data of samples obtained from the research cruise in 1987/88.

1987/88

Parameter	Crude data		Corrected	
	calc.	n	calc.	(s.e.)
Sex ratio				
Male	0.5625	272	0.5959	(0.0559)
Female	0.4375	272	0.4041	(0.0559)
Sexual maturity rate				
Male	0.7908	153	0.7069	(0.0561)
Female	0.4958	119	0.3439	(0.0572)
Apparent pregnancy rate	0.9661	59	0.9463	(0.0620)

Table 9. Corrected biological parameters (sex ratio, sexual maturity, age at sexual maturity and apparent pregnancy rate) and their standard errors (in parentheses) by the bootstrap resampling method with crude data of samples obtained from the research cruise in 1988/89.

Parameter	Crude data		Corrected	
	calc.	n	calc.	(s.e.)
Sex ratio				
Male	0.3602	236	0.4144	(0.0409)
Female	0.6398	236	0.5856	(0.0409)
Sexual maturity rate				
Male	0.8235	85	0.8153	(0.0500)
Female	0.7086	151	0.6319	(0.0469)
Apparent pregnancy rate	0.9252	107	0.9057	(0.0312)

Table 10. The estimated numbers of minke whales in the population migrating to the research area in 1987/88 by sexual status.

Area	School size	Male			Female				Total
		Imm.	Mat.	Total	Imm.	Preg.	Mat. Others	Total	
		A* – B*	A – B	A – B	A – B	A – B	A – B	A – B	A – B
Off shore	1	582 - 686	295 - 348	876 –1,033	581 - 685	0 - 0	0 - 0	0 - 0	581 - 685	1,457 - 1,718
	≥ 2	467 - 835	1,010 –1,803	1,477 –2,638	494 - 883	109 - 195	0 - 0	109 - 195	604 –1,078	2,081 - 3,716
Ice edge	1	147 - 68	291 - 135	439 - 203	536 - 248	0 - 0	60 - 28	60 - 28	596 - 276	1,035 - 479
	≥ 2	98 - 177	1,211 –2,184	1,309 –2,360	364 - 657	682 –1,229	8 - 14	689 –1,243	1,054 –1,900	2,363 - 4,260
Total		1,294 –1,766	2,807 –4,470	4,101 –6,234	1,975 –2,473	791 –1,424	68 –42	858 –1,466	2,835 –3,939	6,936 –10,173

* The numbers of individuals in each status were estimated by multiplying estimated values of biological parameters and population sizes based on the data by *Kyomaru No.1* (A) and *Toshimaru No.25* (B) which were modified from Kasamatsu *et al.* (1989).

Table 11. The estimated numbers of minke whales in the population migrating to the research area in 1988/89 by sexual status.

Area	School size	Male			Female				Total	
		Imm.	Mat.	Total	Imm.	Mat.		Total		
						Preg.	Others			
		S* – D*	S – D	S – D	S – D	S – D	S – D	S – D	S – D	S – D
Off shore	1	707 –1,171	2,559 –4,238	3,266 –5,408	2,084 –3,450	460 – 762	240 – 397	700 –1,159	2,784 –4,609	6,050 –10,018
	≥ 2	741 – 906	3,230 –3,953	3,970 –4,859	1,051 –1,286	3,233 –3,957	126 – 154	3,359 –4,111	4,410 –5,397	8,380 –10,256
Ice edge	1	320 – 509	1,198 –1,907	1,518 –2,416	279 – 443	379 – 603	0 – 0	379 – 603	657 –1,046	2,175 – 3,462
	≥ 2	274 – 479	1,603 –2,804	1,877 –3,283	2,068 –3,617	3,025 –5,290	240 – 420	3,265 –5,711	5,334 –9,328	7,211 –12,611
Ross Sea	1	0 – 0	263 – 379	263 – 379	0 – 0	1,589 –2,290	320 – 462	1,909 –2,751	1,909 –2,751	2,172 – 3,130
	≥ 2	0 – 0	50 – 109	50 – 109	0 – 0	129 – 279	0 – 0	129 – 279	129 – 279	179 – 388
Total		2,042 –3,065	8,903 –13,390	10,944 –16,454	5,482 –8,796	8,815–13,181	926 –1,433	9,741–14,614	15,223–23,410	26,167 –39,865

* The numbers of individuals in each status were estimated by multiplying estimated values of biological parameters and population sizes based on the data of single (S) and double (D) track lines which were modified from Kasamatsu *et al.* (1990).

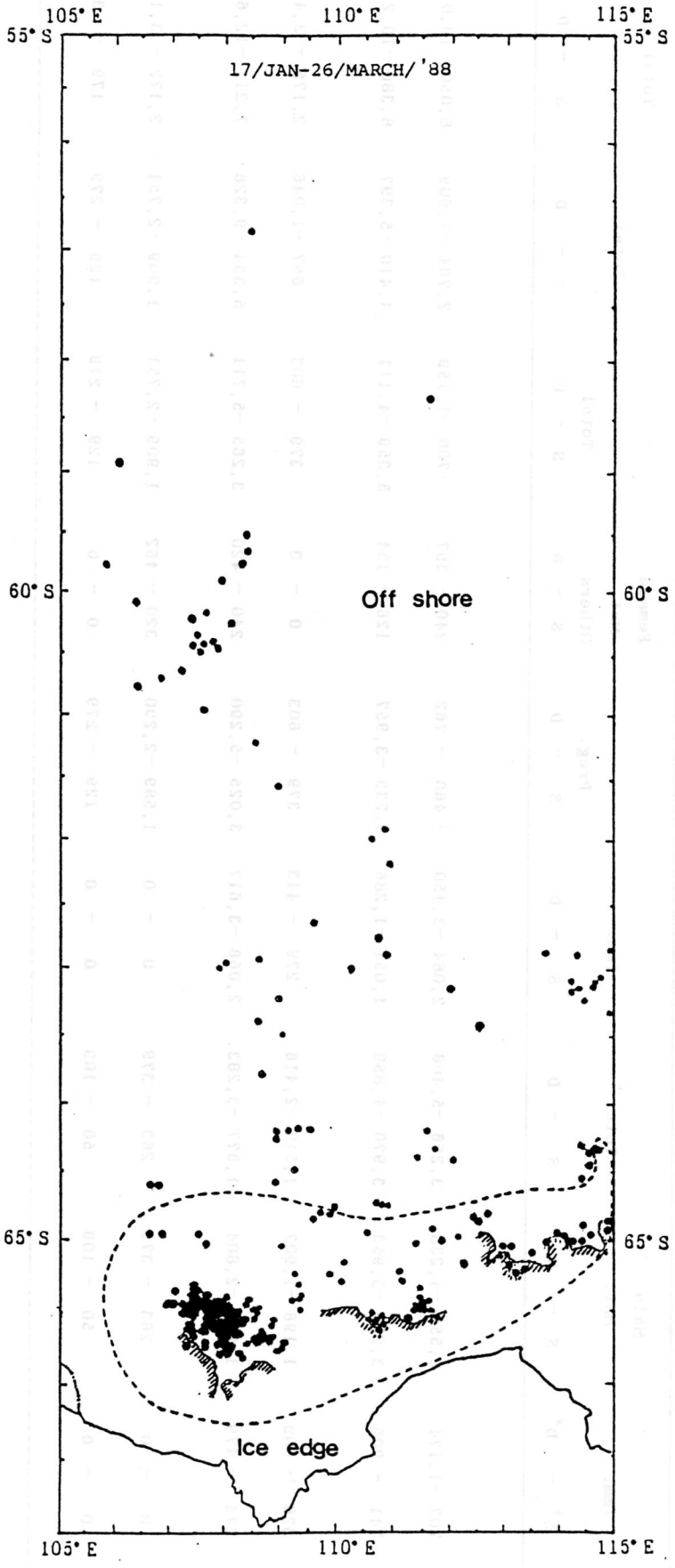

Fig. 1. Grouping of geographical strata in Area IV (1987/88). "Ice edge" stratum indcludes animals taken from in waters with in 60.n.miles from ice edge line (inside of broken lines). Offshore" stratum indicates all animals taken from outsides waters of "Ice edge".

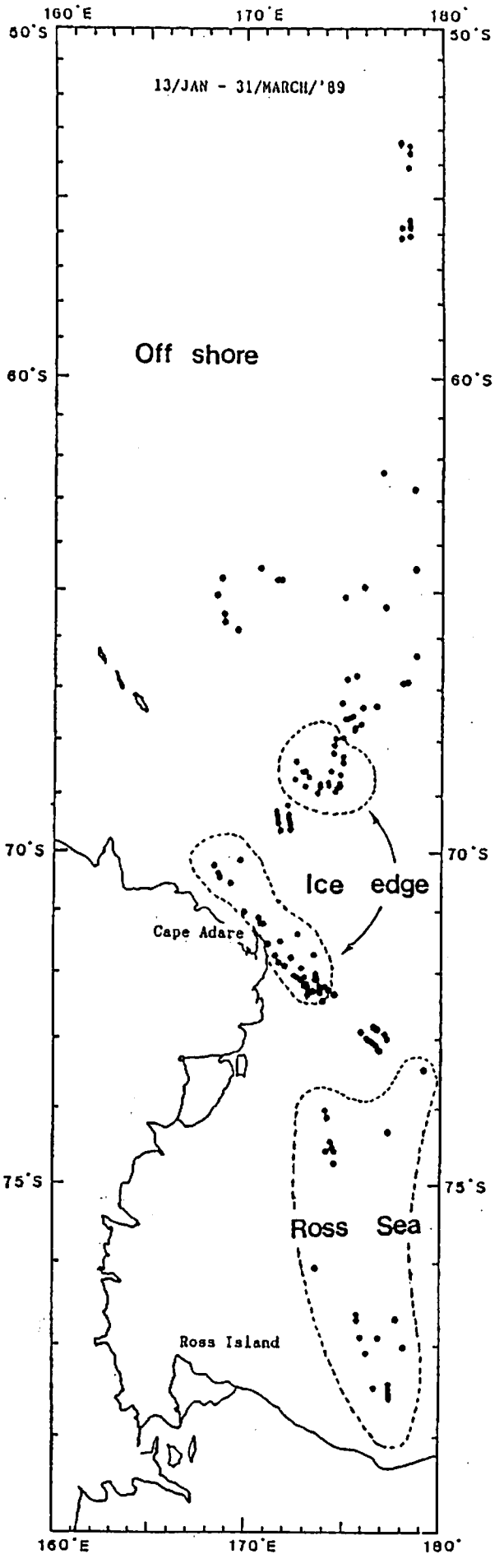

Fig. 2. Grouping of geographical strata in Area V (1988/89 reserch). "Ice edge" stratum indcludes animals taken from in waters with in 60.n.miles from ice edge line in the north of 72 30'S (inside of broken lines), Offshore" stratum indicates all animals taken from outsides waters of "Ice edge", and "Ross Sea" strata (After Kato *et al.*, 1990c).

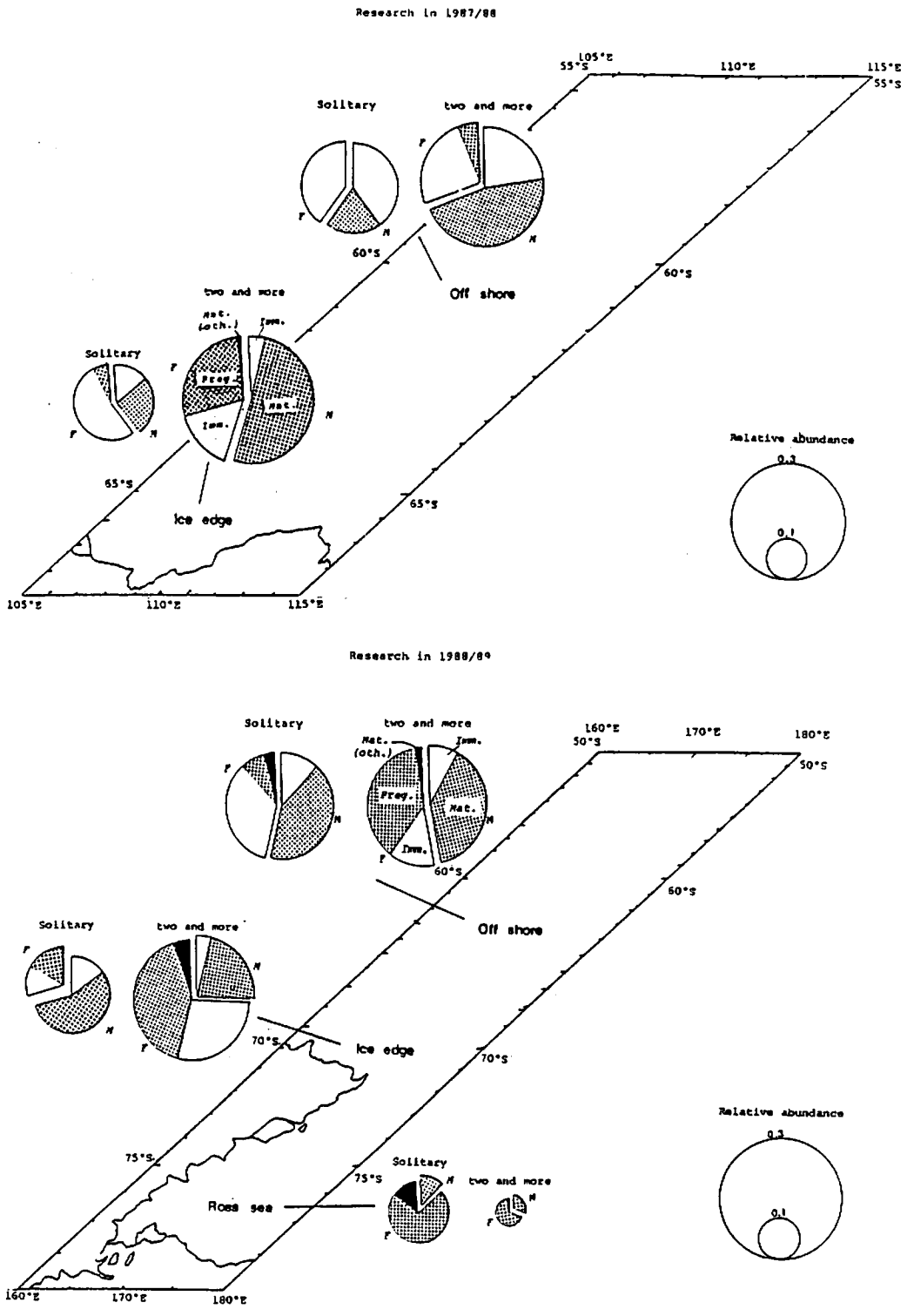

Fig. 3. Proportions of animals by sexual and reproductive status in each stratum with indications of different size of circles representing population size in 1987/88 (Upper) and 1988/89 researches (bottom).