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Migration of northern fur seals along the coast of Sanriku

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Kazuo Wada

Sanriku-oki no ottosei no kaiyu ni tsuite (Migration of northern fur seals along the coast of Sanriku)

Tokai-ku Suisan Kenkyusho Kenkyu Hokoku, Dai gojuhachi go, Showa yonjuyo nen go gatsu (Bulletin of the Tokai Regional Fisheries Research Laboratory, No. 58, May 1969).

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Abstract: Several observations on the migratory habits of northern fur seals were made along the coast of northern Honshū (the main island of Japan) in 1965–1967. The results obtained are summarized as follows:

I) The mode of migration is peculiar to the developmental stage of the animal: a) *Yearlings:* they are few in number and found sporadically in the investigated area. They come south to there a little later than the older animals, and leave there after the latter. Sexual segregation is rarely observed in this group. b) *Animals of 2–3 years:* the time of arrival and the duration of staying in the area are similar to those of the first age group. They are more numerous, and sexual segregation is more conspicuous than among the yearlings. c) *Females of 4–5 years:* reach the area earlier than the younger individuals, and leave there earlier. d) *Females of 6–10 years:* these form the advance group of the southward migrating herd, and are found around the southernmost limit of migration of fur seals, while they leave there earlier than the younger females. e) *Females of 11 years and over:* their mode of migration is similar to that of the 6–10-years females,

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although they leave for the north a little earlier. f) *Males of 4–5 years:* arrive rather later than the animals of the above-described developmental stages, and leave earlier than the latter. The duration of their stay in the area is therefore shorter, and their migrating area is limited to the northern half of the coast of Sanriku. g) *Males of 6–8 years:* reach the area even later than the 4–5-year-old males, and leave earlier, staying there a still shorter time. h) *Males of 9 years and over:* few individuals arrive in the area. i) Sexual segregation of fur seals in time and space become conspicuous with the advance in developmental stage.

II) The present observations on fur seals reveal the following tendencies in the relation between developmental stage and density of distribution: a) During the first half of the migration period, females of 4 years and over are concentrated around the southern limit of the migration route, showing the highest percentage in number of individuals among the daily total catch. These tendencies were most prominently observed in the group of females of 6 years of age and over, which are inclined to accumulate in greater numbers in the higher density areas (especially Indices VII and VIII). On the other hand, the male yearling and 2–3–year–olds are found in the areas of lower density. b) In the second half of the migration period, the females of 4 years and over start to move to the north, maintaining their tendency to concentrate, with the result that as the females of 4 years and over leave the coast of Sanriku, the population of fur seals disappears from this area. c) Female yearlings and 2–3–year–olds, and males of 4 years and over, are mainly distributed in the areas of low density which correspond to Indices II and III. d) The total data of three years' observations show tendencies for both sexes of yearlings and males of 2 years to be concentrated in the lower degree of density (mainly II), females of 6–10 years in higher degrees of density (IV-VIII), and females of 11 years and over in the highest density (VI–VIII). The individuals of the other developmental stages do not show these tendencies. e) The mode of the isograms of density distribution can be considered as basically concentric circles that indicate a decreasing incline of density from center to periphery. The changes of breadth between the density isograms correspond to changes in oceanographic conditions or the prey of the fur seals.

III) The yearly cycle of life on the sea of adult fur seal females is characterized by the mode of their migration and density distribution: i) *Period of southward migration:* Its character is indicated by the duration of the southward migration from the breeding islands to the coast of Sanriku. ii) *Period of stay I:* Is the length of time during which adult females are stably staying with high degree of density near the southern limit of dis-

tribution of fur seals. iii) *Period of stay II:* Is the period during which the adult females slowly move northward along the coast of Sanriku with high degrees of density. iv) *Period of northward migration:* Is the time that concentrations of adult females disappear from the coast of Kushiro.

IV) The size and the composition of pods depend on the density of distribution and the developmental stages: a) The sizes of pods become smaller and the number of solitaries increases in the low degree of density, whereas the sizes of pods become larger and the number of solitaries decreases with increases in density. b) Females of 4 years and over frequently show a tendency to make large pods, and to make larger pods than the individuals of other developmental stages compared with the same degree of density. c) The pods tend to be composed of individuals of the same developmental stages that are predominant in time and in space, while when the indivduals of other developmental stages enter an area where individuals of a certain developmental stage are predominant, the composition of the pod becomes complicated. Therefore, it seems probable that the components of a pod are not fixed, and the relations between individuals in a pod are socio-ecologically loose and changeable.

V) Examining the relations between the mode of migration and the temperature of the surface water, the following tendencies were revealed: a) It seems credible that a temperature just below 15°C is suitable for the migration of fur seals, and that water temperature of 15°C and atmospheric temperature of 12°C on the islands represent the upper limits at which fur seals can maintain the regulation of their body temperature, and carry on their normal activities. b) In the period of stay I in 1967, very few fur seals were observed in water of more than 12°C, but in the period of stay II, a large number of them were observed in water of 12°–15°C on the coast of Kurosaki. c) Regions of the dense distribution of fur seals of 4 years and over are located in the cold water masses, especially adjacent to the boundary between cold and warm water masses, and the isogram of the density distribution shows a steep gradient around such boundaries. d) The numbers of male yearlings and 2–3–year–olds as well as males of 4 years and over tend to increase or decrease in accordance with the expansion or diminution of the water of Oyashio (name of a cold current). e) The male predominancy of yearlings and 2–3–year–olds disappears with the northward migration of females of 4 years and over in the period of stay II, but the numbers of male individuals increase. f) Dense populations of fur seals are not always in contact with the boundary between different water masses during stay II, although they are located in the cold water mass in the period of stay I. The explanation of this may be that in the

earlier period the water temperature is roughly the same at the surface and in the 100 m layer, while in the later period the water temperature differs greatly in these two layers. g) The remarkable diminution in the population of the 1965 year class, observed along the coast of Honshū in 1966 and 1967, could be attributed to the extraordinarily high mortality of pups at Robben Island, their place of birth, in 1965.

VI) The mode of migration of fur seals is related to their food habits: a) Several kinds of food commonly found in their stomachs were as follows; *Watasenia scintillans, Todarodes pacificus, Notoscopelus japonicus, Diaphus* sp., *Laemonema longipes, Scomber japonicus, Engraulis japonica* and *Theragra chalcogramma.* b) Among these species listed above, *W. scintillans* and squids (mainly *T. pacificus*) were abundant in general, although some seasonal and geographical prevalencies were noted in their frequency. *W. scintillans* was predominant between January and March, especially in the southern part of fur seal range. On the other hand, the squids and *E. japonica* appear in abundance later, and farther north than *W. scintillans.* Squids were usually more numerous than *N. japonicus.* c) The total catch of commercially useful fishes, excepting these fishes too large in size to be food for fur seals, and bottom fishes (from data of monthly fisheries statistics of Japan in 1962), is smaller during the winter and spring than in other seasons in the region between Aomori and Fukushima, suggesting that they are less numerous then. d) Changes in the kinds of prey and their predominancy in the stomachs of fur seals with time and place correspond with those of oceanographic conditions: *Watasenia scintillans*——appears in the mixing water area between Oyashio and Kuroshio (warm current) in January to April. *Squids*——their predominancy to the north of the coast of Kesennuma in and after April coincides with the period of the seal migration to the coast of Sanriku. *Diaphus* sp.——its appearance in the area corresponds with that of water of 2°C. *Notoscopelus japonicus*——is observed a long time and wide area, while it does not appear in water of 2°C or around warm water masses. *Scomber japonicus*——its appearance coincides with the period when the sub-adult seals are staying on the coast of Sanriku and Joban, although they do not predominantly occupy the stomachs of fur seals as do the four species listed above. *Theragra chalcogramma*——appears in the stomachs of fur seals although not very predominantly, during the season which corresponds to its spawning period in which the fish approach the coast. *Laemonema longipes*——is found in the degrees of digestion I–IV betweee January and March on the coast of Sanriku within the external fringe of the water mass of 200 m isogram of depth. e) The region where both sexes of yearlings and 2–3-year-olds and males of 4 years and over

exist in low density coincides with the areas of thin distribution of their prey, while the regions showing a predominancy of females of 4 years and over correspond with those areas rich in food. Therefore, the difference in relation to prey between the two modes of seal distributions tends to be connected with the intake of food. f) The variation in food species described above seems to be connected with the quantity and the density of the prey; in other words, fur seals tend to take non-selectively those fishes or squids which are numerous and easily available. g) *L. longipes* and *T. chalcogramma* were never found in the stomachs of yearlings. This fact would be attributed to the size and activity of these fishes, which the yearlings are not able to catch. Among a group of fur seals consisting of animals of various ages, with the exception of yearlings, there is no significant difference in the quality of their food, if the survey is carried out with samples obtained simultaneously.

Introduction

Since the eighteenth century fur seals have been the objects for a commercial hunting. Therefore research concerning fur seals also has a long history. Research reports have been published since the latter half of the nineteenth century. In recent years researches have been carried out chiefly from the point of view of conservation of fur seals. The variable movement of pods, their distribution, the rate of mixing at sea among the groups classified by the breeding islands and the previously assumed death rates have been systematically studied using pups* bearing tags in the following islands: Pribilof Islands (U.S.A.) since 1941, Robben Island (U.S.S.R.) since

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* A pup is defined as an individual from the date of its birth to December 31st of the year of its birth.

1958. These studies were derived from the idea that it is necessary to know the variation of resources in order to conserve fur seals through international agreements.

Robben Island was in the possession of Japan before the Second World War. Hunting of fur seals was done both on land and at sea. However, a systematic study on fur seals had not been carried out before 1952. The investigations around Japan which took place recently are the investigation by Wilke of America on the coast of Sanriku in 1950 (Wilke, 1951), the joint investigation by Japan, U.S.A. and Canada from the coast of Kushiro in Hokkaidó to the coast of Sanriku in 1952 (Taylor, Fujinaga and Wilke, 1954) and Japanese investigations in 1953 and in 1954 in areas of the Japan Sea, the North Pacific Ocean and the Bering Sea (Fisheries Agency of Japan, 1953 and 1954).

In 1957 the treaty "Fur seals, North Pacific Ocean: interim convention on conservation of North Pacific fur seals" was signed by Japan, U.S.A., Canada and U.S.S.R. In Japan, Tokai Regional Fisheries Research Laboratory holds responsibility for the studies of fur seals based on this convention. Systematic studies were begun. The object of this convention is to enable "the maximum and sustainable productivity of the fur seal resources". The description of studies to be carried on are given in the

items of the convention. Studies are intended mainly to reveal the variable movements of fur seals. In Japan since 1957 reseach on fur seals which move northward around the coast of Sanriku has been carried out according to the purpose set down in the convention. U.S.S.R. did independent studies in 1959, 1960, 1963 and 1964 on the coast of Sanriku (U.S.S.R., 1959, 1960, 1963 and 1964).

The reports of these investigations mentioned above are given only as data in a form prescibed in the items. Therefore there have not been done sufficiently comprehensive ecological studies on the relationships within species, between species and between fur seals and the inorganic environment.

In this paper the author made some ecological studies and analyses based on the investigation of the 24 migration of fur seals carried out along the coast of Sanriku in the following years; March 1 - July 31 in 1965, March 1 - June 30 in 1966 and January 8 - May 31 in 1967 (Fisheries Agency of Japan, 1965, 1966 and 1968).

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§1. General description of fur seals

The origin of fur seals---Callorhinus ursinus (Linneus, 1758)---is not known for certain. The difficulty is due to the scarcity of fossile material and of similar species. The ancestral land type is not well known. Neither is the direction of its evolution exactly known except that the time of its adaptive dispersion might be in the Miocene Epoch (Mitchell, 1968). In the geneological classification the fur seal belongs to Otariidae,

Pinnipedia. However, there are many genealogical questions to be answered.

The fur seal has the widest area of migration among Pinnipedia. Compared with those of other animals such as the common seal, the sea lion and the walrus, its structure contains various aspects which facilitate swimming. The breeding grounds of North Pacific fur seals are limited to Robben Island, the central part of the Kurile Islands, the Commander Islands and the Pribilof Islands in the sub-frigid zone. Most of the individuals come back to their birth places. In the middle of May bulls begin to land. Then each bull forms his own territory in order to form a harem of pregnant cows who come to land somewhat later. The pregnant cows give birth to pups within a few days. Within a week cows become estrus and copulate. Cows start suckling pups as soon as the pups are born. In early August the harems break down as cows who become estrus leave the ground. Animals of three to four years land somewhat later. Males form howling grounds (the place where males who cannot participate in copulation gather) around the harems. Sometimes these individuals usurp the place of harem bulls. Pups begin to practice swimming two weeks after their births and prepare to leave the island. Bulls begin to go out to the sea after the harems break down. Most of the Pribilof

groups migrate southward along the west coast of U.S.A. to the coast of California. The Robben group migrates to the Japan Sea, Hokkaido and the east coast of Honshu (the main island of Japan). These fur seals appear in the middle of December on the east coast of Hokkaido. When the Oyashio (the Kurile current) is strong they go southward to Oshima. They eat mainly several kinds of Myctophidae, Watasenia scintillans and other squids found along the coast of Sanriku. They disappear from the coast of Sanriku usually at the end of June and move towards their breeding ground. Yearlings and bulls seldom appear on the coast of Sanriku and their migration is not known.

2. Details of investigations of fur seals in Japan

The investigations of fur seals described here were carried out during 1965 and 1967. Ozuchi-machi in Iwate Prefecture became the base of the investigations. In 1965 three fishing boats of about thirty-five tons and in 1966 and 1967 two boats were hired. Three investigators were hired throughout the three years. The main areas of investigations were the coasts of Sanriku and Joban. In 1965 and 1967 the coast of Kushiro was visited several times (Table 1). The investigations at sea were limited usually to the west of 143° E because of the weather and the conditions of the operation of the boats. However,

from May to July when the weather was settled, the investigations were extended several times to 144° E and to 146° E.

Table 1. Total numbers of fur seals observed and collected in 1965-1967.

	Region of survey	March A	March B	March C	April A	April B	April C	May A	May B	May C	June A	June B	June C	July A	July B	July C
1965	Kushiro coast	Grand Total A 108	B 2007	C 1150							4	12	5	1	1	1
	Erimo-misaki c.										4	61	20	2	4	2
	Kurosaki c.										2	67	20	3	20	5
	Ōzuchi c.	12	80	43	8	74	53	14	409	270	20	476	316	2	1	1
	Kesennuma c.	6	40	20	5	7	6	3	134	70	Number of research vessels					
	Kinkasan c.	2	46	16	8	136	82	4	206	120	March-June		3			
	Onahama c.	8	233	100							July		1			
	Total	28	399	179	21	217	141	21	749	460	30	616	361	8	26	9
1966	Kurosaki c.							4	246	79	1	4	2	Number of resarch vessels 2		
	Ōzuchi c.	2	34	22	10	249	109	11	1411	136	8	165	66	Grand Total		
	Kesennuma c.	3	35	20	6	164	94	4	223	67	6	40	16	A 69	B 2758	C 715
	Kinkasan c.	11	252	102	1	1	1	2	3	1						
	Total	16	252	144	17	414	204	21	1883	283	15	209	84			
1967		January			February			March			April			May		
	Kushiro c.	Grand Total A 121	B 3445	C 910										3	3	1
	Erimo-misaki c.													5	140	31
	Kurosaki c.				2	10	4				4	414	38	9	786	163
	Ōzuchi c.	15	55	32	13	88	44	8	44	29	13	498	185	2	0	0
	Kesennuma c.	4	75	48	10	1093	197	11	226	131	3	3	1	Number of research vessels 2		
	Kinkasan c.	2	2	2	4	1	0	4	6	3	3	0	0			
	Onahama c.	4	0	0				2	1	1						
	Total	25	132	82	29	1192	245	25	277	164	23	915	224	19	929	195

A : Number of boat-hunting days
B : Total numbers of seals observed
C : Total numbers of seals collected

The temperature of the surface water was entered on a chart. When fur seals were observed, the time, place, the number of fur seals and the temperature of the surface water at that time were entered on a chart. When fur seals were captured the numbers were also noted. When fur seals were captured, the time, the sex, weight and length

were noted. In the case of a pregnant fur seal, sex, 25
weight and length of fetus were noted. The fur was removed and preserved in salt. Necessary specimens such as stomach, small intestines, colon, ovary, testicles, penis, cystic, canine tooth, cerebrum and frame were collected. They were studied on land. Variety and quantity of the contents of the stomach, the small intestines and the colon were noted and parasites were collected. The size of the ovary, the size and shape of follicles, the corpora lutea, the shape and size of the uterus, the weight and size of testicles and the growth condition of spermary were checked. These characteristics were used to clarify the breeding process. The canine tooth was cut lengthwise and age was determined by counting the transparent lines of the dentine.

§3. Mode of migration of fur seals

The mode of distribution must be studied in order to clarify the mode of migration. For this purpose the variation of structure of fur seals in time and in space according to age and sex was studied. The material on this matter is scarce. Our investigations were not carried out for a fixed area. Therefore they were rather fragmentary in time and in area. In fact the investigated area was within eighty miles from shore due to bad weather and the sailing capability of the boats. This

may be the weakest point in our discussion of distribution. However, the author considers that it is meaningful to raise a few questions and to draw certain conclusions at this stage with the hope that this may be a starting point for future studies.

Variations according to time and space were observed in the mode of distribution and in the eating habits of fur seals on the coast of Sanriku. Firstly, the age and sex composition in time and in space was studied (the distance from shore is not considered in space). The area was divided as in Fig. 1 from north to south: the coasts of Kushiro, Erimo-misaki, Kurosaki, Ozuchi, Kesennuma, Kinkasan and Onahama.

1) Distribution of fur seals on the coast of Sanriku

The southern limit of distribution and the disappearance from the surveyed area of fur seals between 1965 and 1967 are explained below in order to have a clear view of the distribution of fur seals.

The southern limit of distribution of fur seals became most southerly in 1965 during the three years of investigations. The limit reached was the coast of Choshi (Chiba Prefecture) between March and April. In 1965 fur seals largely disappeared in early July from the coast of Sanriku to the coast of Kushiro. In 1966 the southern

limit was the coast of Kinkasan. Fur seals disappeared from the coast of Sanriku in the end of June. The distribution in 1967 was most northerly. Its southern limit was the coast of Kesennuma. Fur seals were not found on the coast of Ozuchi in May. They disappeared earliest in 1967.

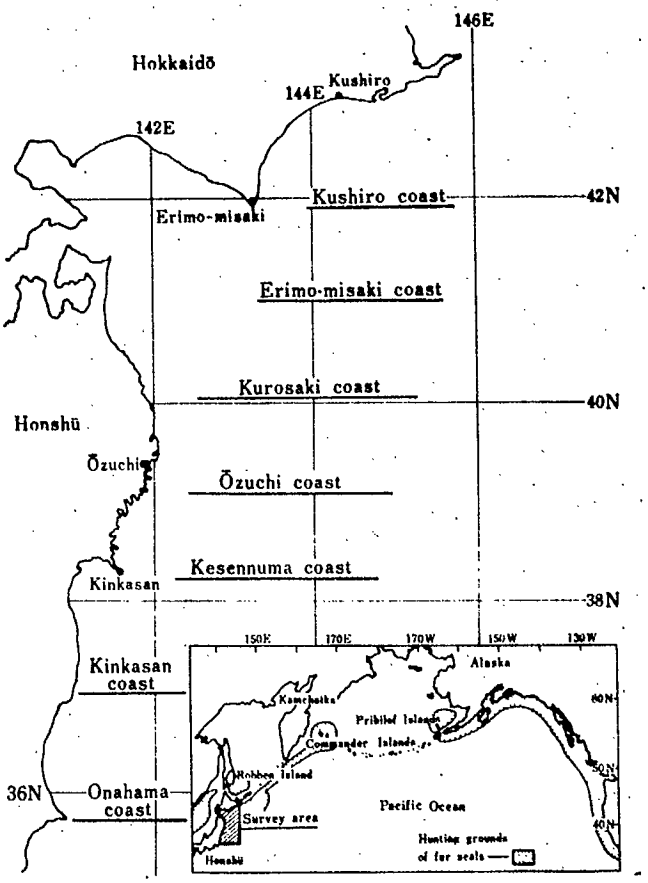


Fig. 1. Divisions of surveyed area.

However, in the area from the coast of Kurosaki to the coast of Kushiro, many fur seals were still present even in the end of May. The time of disappearance from these areas is not known for sure.

The variations of the age and sex composition in the changes in the distribution of fur seals are explained in the following.

Yearlings: the individual number of yearlings should be many compared with the numbers at present. Both males and females, however, appear on the coast of Sanriku much less in number than those of two to three years. The ratio of catch of yearlings in the total catch was 3.3 % average in the three years. There are some peculiarities in the appearance and disappearance of yearlings on the coast of Sanriku. In 1967 they were not found on the coasts of Onahama and Kinkasan. They were caught for the first time that year at the end of February on the coasts of Kesennuma and Ozuchi. They were assumed to have appeared a little later than other fur seals in the south of the coast of Ozuchi. Between June and July in 1965 a total of three yearlings were caught on the coasts of Ozuchi and Kurosaki. It is assumed that they stay along the coast of Sanriku until the time of migration to the north(Figs. 2a, b and c). 27

There is no distinctive pattern in time and space distribution. The distribution seems very small in number but very wide in time and space. In other words, it is a dispersed distribution.

The sex ratio between males and females in the

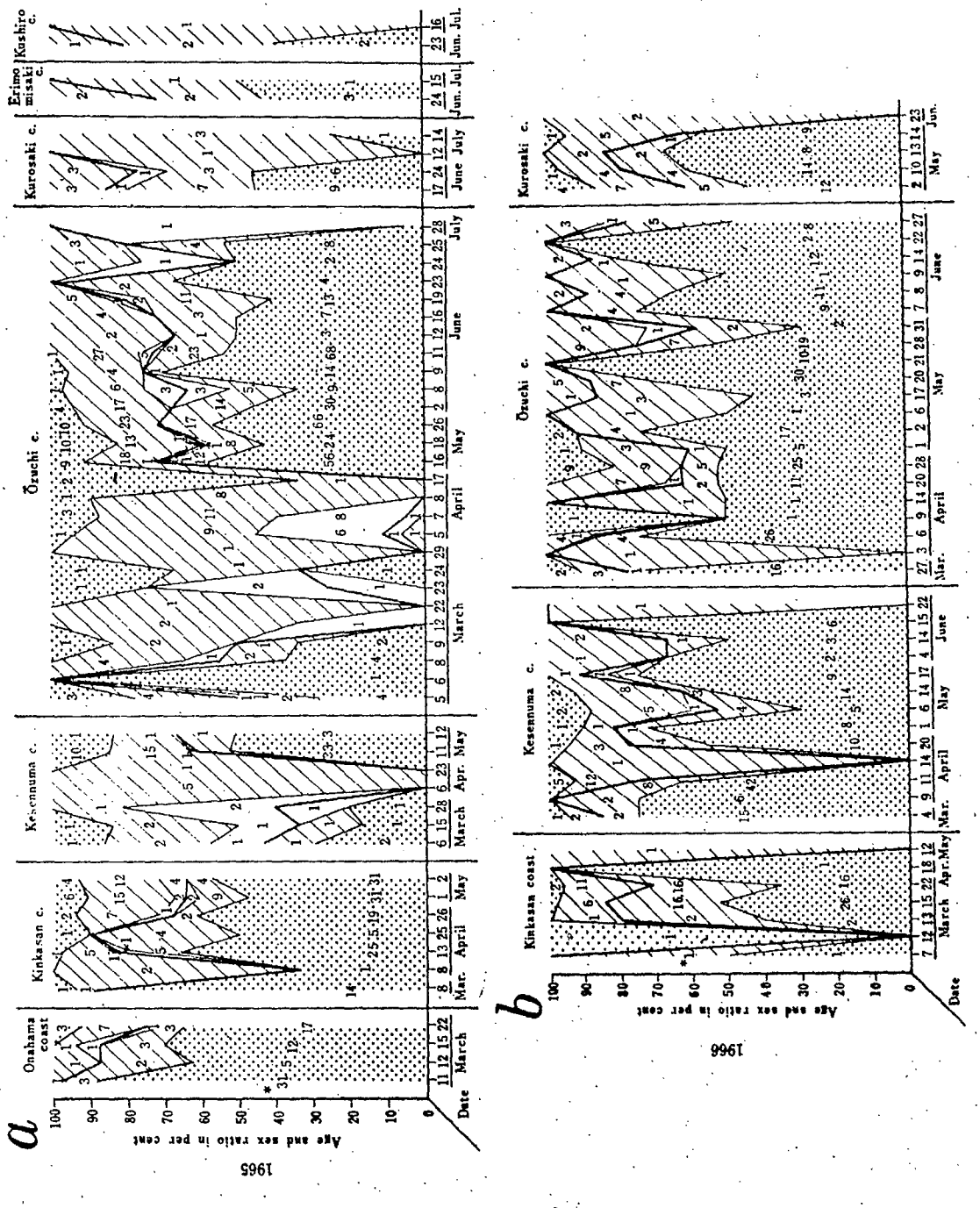
three years shows that the ratio of males is always more than 66 % and mean value in the three years was 72.4 % (Table 2). Especially from early March to early April in 1965 along the coast of Ozuchi males were apparently more prevalent than at other time and in other space. In 1966 mostly males were found along the coast of Ozuchi. In general, however, there is no distinction in the sexual segregation.

Table 2. Age and sex ratio of fur seals taken on the coast of Honshū in 1965–1967.

Age	Sex	1965 No.	1965 Age ratio (%)	1965 sex ratio of each age (%)	1966 No.	1966 Age ratio (%)	1966 sex ratio of each age (%)	1967 No.	1967 Age ratio (%)	1967 sex ratio of each age (%)
1	♂	43	5.7	66.2	5	0.8	83.3	21	3.4	67.7
	♀	22		33.8	1		16.7	10		32.3
2-3	♂	255	36.9	60.1	125	35.4	49.4	105	24.2	47.7
	♀	169		39.9	128		50.6	115		52.3
4-5	♂	62	24.4	22.1	30	29.5	14.2	33	22.1	16.4
	♀	218		77.9	181		85.8	168		83.6
6-10	♂	18	26.6	5.9	6	26.2	3.2	5	32.3	1.7
	♀	288		94.1	181		96.8	289		98.3
11+	♂	1	6.4	1.4	1	8.1	1.7	0	18.0	0
	♀	73		98.6	57		98.3	164		100.0
Total		1149	100.0		715	100.0		910	100.0	

Animals of two to three years: the ratio in total catch is higher than that of yearlings. The mean value in the three years was 32.2 %. The catch increases as age increases. The appearance of animals of two to three

Fig. 2. Age and sex ratio of fur seals (based on the daily catch at various stations in 1965-1967).



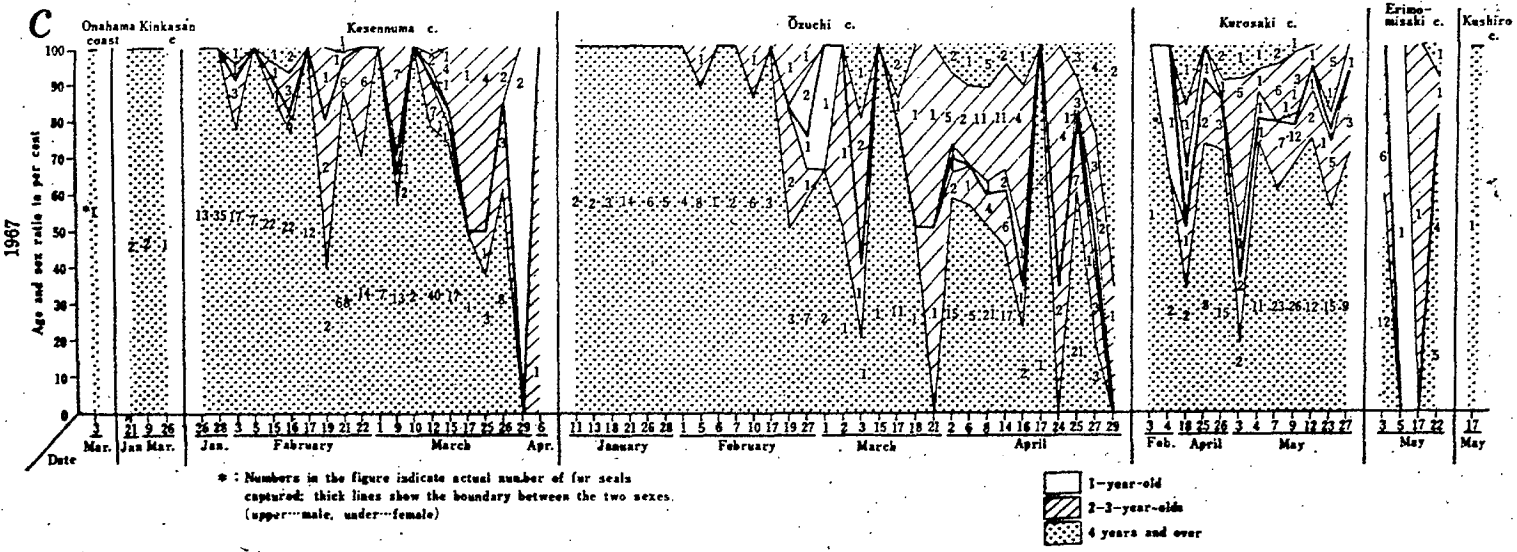
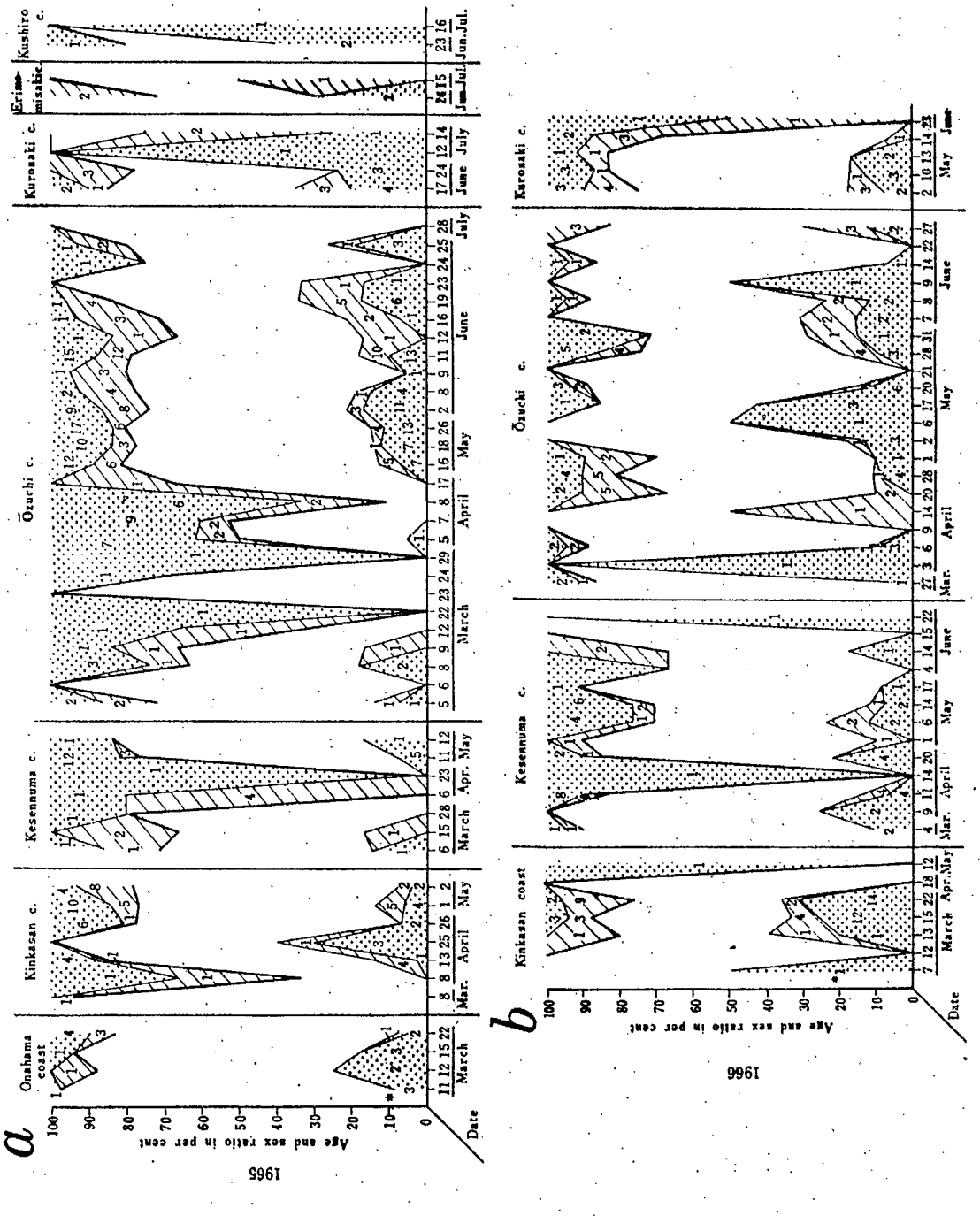


Fig. 2. Age and sex ratio of fur seals (based on the daily catch at various stations in 1965—1967).

Fig. 3. Age and sex ratio of fur seals (based on the daily catch at various stations in 1965-1967).



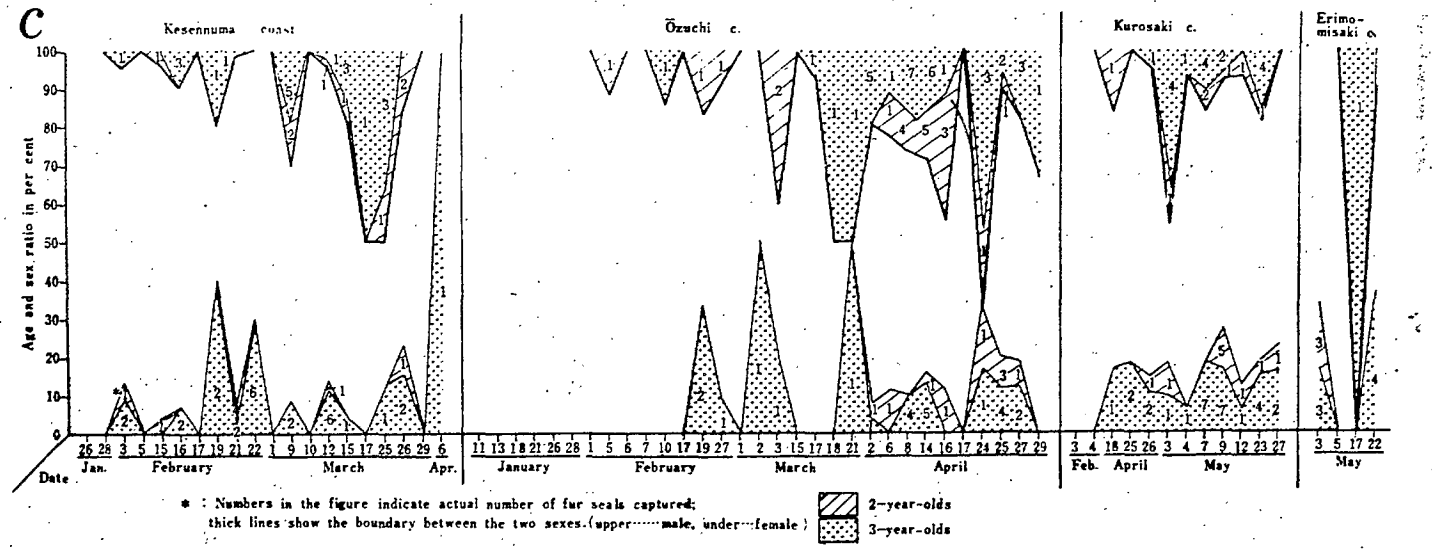
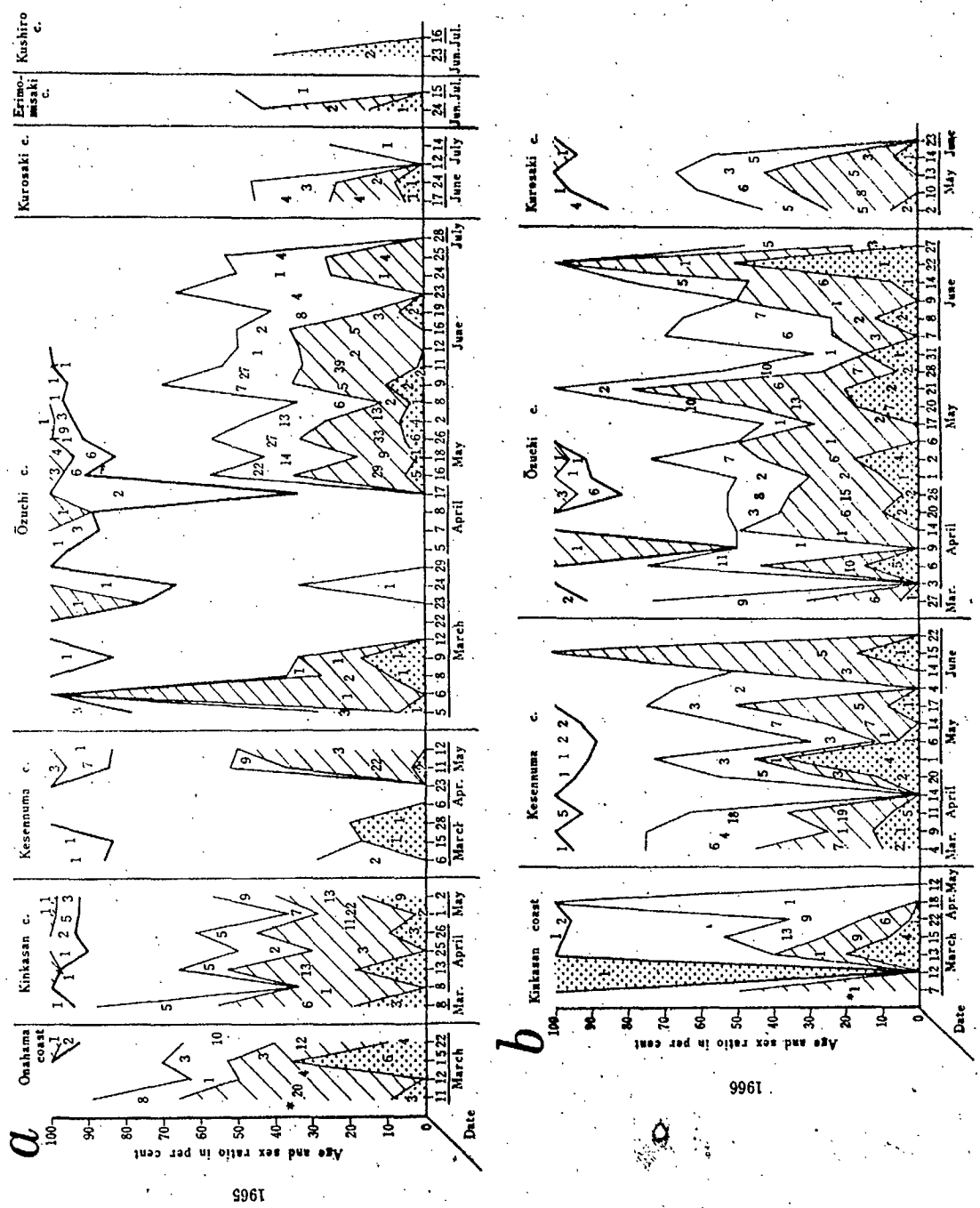


Fig. 3. Age and sex ratio of fur seals (based on the daily catch at various stations in 1965—1967).

Fig. 4. Age and sex ratio of fur seals (based on the daily catch at various stations in 1965-1967). 32



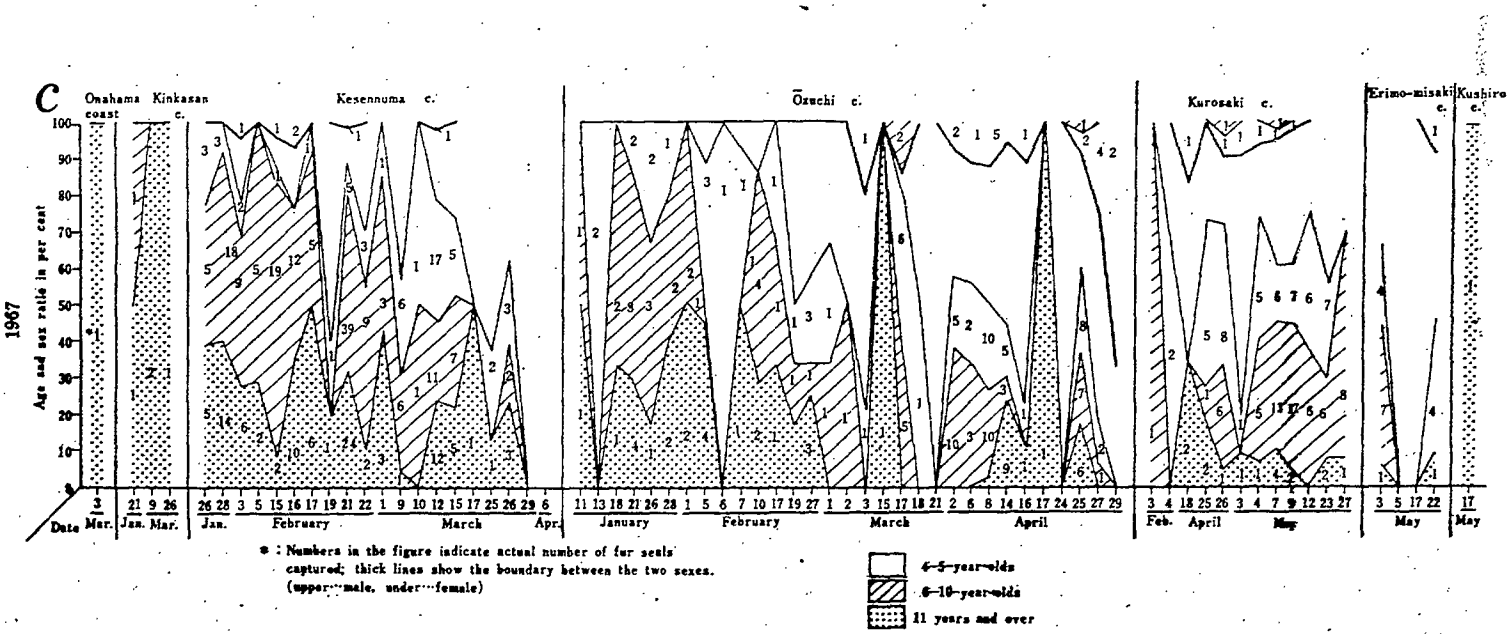


Fig. 4. Age and sex ratio of fur seals (based on the daily catch at various sations in 1965—1967).

years along the coast of Sanriku is a little later than other fur seals. There was no catch in January, 1967. They were caught from February along the coasts of Kesennuma and Ozuchi. During their stay along the coast of Sanriku, animals of two to three years are distributed continuously in time and space. In July, 1965 when the northward migrating fur seals were pursued to the last, the total numbers observed were very small in the area from the coast of Kurosaki to the coast of Kushiro. The ratio of animals of two to three years in the total catch was 81 % (Fig. 3a,b and c). Thus they were thought to form the last group of the northward migrating herd.

The sex ratio varies according to age. However, the ratio of males to females was closest to unity in comparison with the animals of other ages (Table 2). 34 The sex ratio somewhat varied in time and space. Especially, in 1965, the ratio of males to total population reached 100 % along the coasts of Kinkasan(April 8), Kesennuma (April 6 and 23) and Ozuchi (March 12, 22, and 29; April 5, 7 and 8).

In order to explain the behaviour of fur seals of four years of age and over (written as four^{+} years henceforward), it is necessary to note the result of the commercial hunting of fur seals in each breeding island. Mainly three to four year-old males were caught in Robben

Island, the Commander Islands and the Pribilof Islands. In the Pribilof Islands many females of two to five years were caught during 1956 and 1965 (Table 3). Therefore it is quite clear that a certain amount of unnatural distortion is added to distribution of the animals from two to five years old. Considering the increase according to age of fur seals from the Pribilof Islands to the coast of Sanriku, the distortion is considered to be greater for males than for females. At this stage the author would like to note that when discussing distributions it is necessary to remember that there is this unnatural distortion which is pronounced for animals of four^{+} years, and especially so for males.

Females of four^{+} years: the percentage of animals captured at a given age to the total number of captured animals is shown in order to give a rough idea of age composition (Fig. 4a, b and c).

The appearance and disappearance of females of four^{+} years: they form an advance group of the southward migrating herd. They appeared the earliest along the coast of Sanriku. They distributed widely in time and space except for a certain period in 1965 along the coasts of Kesennuma and Ozuchi. The time of disappearance was a little earlier than that of animals of two to three years. This was indicated by the fact that they were very

few along the coasts of Sanriku and Kushiro in July, 1965.

Table 8. Commercial kill in breeding islands.

year	Robben Island	Commander Is.	Pribilof Is.	
	♂	♂	♂	♀
1948	6,648	4,514	69,893	249
49	5,864	5,194	70,553	337
50	6,529	5,836	59,925	279
51	3,065	5,146	60,503	186
52	3,973	2,784	63,670	252
53	3,705	2,876	65,824	845
54	5,175	3,629	63,224	658
55	4,058	3,300	64,727	726
56	2,000	4,256	96,066	27,599
57	3,651	3,065	46,198	47,413
58	3,127	3,021	47,872	31,102
59	4,860	2,261	30,195	28,064
60	6,210	40,79	36,320	4,315
61	6,947	5,023	82,197	43,849
62	7,123	6,427	53,680	43,860
63	7,339	7,381	42,386	43,860
64	8,317	10,556	48,980	16,452
65	8,586	11,424	40,367	10,465
66	9,380	9,095	52,472	0
Total number of population	150,000	200,000	>1,500,000	

From "Fur seals of USSR far east 1964" and "North pacific fur seal commission report on investigations from 1958 to 1961," with some modifications by the author.

Females of eleven years of age and over (written as eleven^{+} years henceforward) formed only 13.8 % of the entire female population (the mean value of the three years investigation). However, they were distributed continuously and widely in time and space. They were observed to be more numerous than for any other time and space in January and February in 1967 along the coasts of Kesennuma and Ozuchi. 35

That the advance group of the southward herd consisted mostly of females of four^{+} years was indicated by

the data from the coast of Kesennuma, January to March, 1967 and from the coast of Ozuchi, January to February, 1967. In both areas the percentage of females of four^{+} years was 100 % in January. It was 80 % along the coast of Kesennuma from early February to mid March. The percentage was 96 % along the coast of Ozuchi from early to mid February. It decreased to about 40 % in both areas after the times stated above (Fig. 4c).

Table 4. Age ratio of females (4^{+} and 11^{+}) in 1967.

Age	Kesennuma coast		Age	Kesennuma c.	
4^{+} January 100.0*%	3,Feb. ~15, March 80.9%	17,March ~6, April 31.3%	11^{+} January 39.2%	3, Feb. ~1, March 28.1%	9, March ~6, April 15.0%
	Ōzuchi c.			Ōzuchi c.	
4^{+} January 100.0%	1, Feb. ~17, Feb. 95.6%	19, Feb. ~29, April 46.4%	11^{+} 11, Jan.~27, Feb. 29.8%		1, March~29, April 14.4%

* Percentages were calculated against the total number of fur seels taken in a definite period.
4^{+}...4 years of age and over
11^{+}...11 years of age and over

The seasonal change in the percentage of females of eleven^{+} years differs somewhat from that of females of four^{+} years. Females of eleven^{+}years were found numerously along the coast of Kesennuma in January, 1967. They reached 39 % of the total catch. The proportion was less in Feoruary than in January. In March they formed 15 % of the total catch. They formed about 30 % of the catch along the coast of Ozuchi from January to February. This decreased to about 14 % from March to April (Table 4). Therefore the difference along the coast of Kesennuma

between females of four to ten years and eleven+ years is that the latter decrease in percentage after February and earlier in time than the former.

Table 5. Age ratio of females (4-10-year-olds) in 1967.

Age	Kesennuma coast		Ōzuchi c.		Kurosaki c.		
	22, Jan. ~1, March	9, March ~6.Apr.	11, Jan. ~27, Feb.	1, March ~29,Apr.	February (%)	April (%)	May (%)
4	8.3(%)	21.0(%)	16.3(%)	21.0(%)	33.3	35.0	16.1
5	5.6	33.9	23.3	29.6	33.3	30.0	20.7
6	18.1	19.3	11.6	13.6		10.0	13.8
7	22.2	4.8	11.6	14.8		5.0	17.2
8	21.5	6.5	16.3	4.9	33.4	20.0	18.4
9	12.5	9.7	11.6	9.9			12.6
10	11.8	4.8	9.3	6.2			1.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The tendency stated above is apparent in the change of the age composition as a whole among females of four to five years and six to ten years (Table 5). There was an obvious difference between the period from January to February and the period from March and April. The ratio of animals of four to five years in January and February did not reach half their ratio for March and April. The reverse holds for animals of six years of age and over. The percentage of animals from seven to ten years in January and February became greater than their percentage in March and April. Except nine year-old animals, they were more than twice as numerous in the earlier period. A similar tendency was observed along the coast of Ozuchi, however, it was not so pronounced as along the coast of

Kesennuma. Along the coast of Kurosaki data for January and February are lacking. Therefore the tendency indicated cannot be confirmed. However, in the author's opinion such a tendency would not have been observed for this area. More females of eleven^{+} years were observed during January and February than during March and April along the coasts of Kesennuma and Ozuchi. Females from six to ten years were the most numerous among females of four^{+} years. When the ratio of pregnant to non-pregnant cows was calculated, proportionately ~~less~~ fewer pregnant cows were observed in March and April than in January and February when the animals of advanced age were prevalent. 36

Table 6. Age ratio of females (4^{+}) in 1965.

Ozuchi coast			Kurosaki c.	Erimo-misaki c.	Kushiro c.
5, March ~9, March	12, March ~17, April	16, May 28, July	17, June ~14. July	24, June ~15, July	23, June ~16, Juuly
49.6%*	3.7%	51.6%	29.1%	46.5%	40.0%
Onahama c.	Kinkasan c.		Kesennuma c.		
11, March ~22, March	8, March	8, April ~, May	6, March ~28, March	6, April 23, April	11, May 12, May
71.7%	87.6%	52.4%	21.7%	0%	50.8%

*: Percentages were calculated against the total number of fur seals taken in a definite period.
4^{+}: 4 years of age and over

On the whole, females of four^{+} years were distributed widely in time and space. However, in 1965, the density became almost zero in April along the coast of Kesennuma and from mid March to mid April along the coast of Ozuchi. In both areas the density began decreasing

from early March. However, the percentage of females of four^{+} years was more than 50 % of the total catch along the coasts of Onahama and Kinkasan in March, and the coast of Kinkasan in April (Table 6).

Table 7. Rates of pregnant and non-pregnant females (4^{+}) in 1965.

	Kurosaki coast		Erimo-misaki c.		Kushiro c.
	17, June~14, July		24, June, 15, July		16, July
non-pregnant	11.9%*		50.0%		0.0%
pregnant	17.1%		42.9%		40.0%
	Ōzuchi c.				
	5, March ~17, April	16, May 26, May	2, June 9, June	11, June 19, June	23, June 25, June
non-pregnant	1.9%	14.8%	23.2%	22.9%	47.8%
pregnant	15.9%	37.5%	26.6%	25.7%	8.9%
	Onahama c.		Kinkasan c.		Kesennuma c.
	11, March~22, March		8, March~2, May		6, March~12, May
non-pregnant	14.2%		10.8%		5.2%
pregnant	57.5%		46.7%		18.6%

In 1965 when the northward migration of fur seals was investigated to the last, the number of pregnant cows of four^{+} years began to decrease in June along the coast of Ozuchi (Table 7), thus increasing the age ratio for the younger females of four^{+} years. On the other hand the number of non-pregnant females of four^{+} years doubled in the end of June. This indicates that pregnant cows leave for the north ealier. In 1965 and in 1966 the variation in age composition somewhat differed. In 1965 towards the end of June, females of four to five years constituted 64 % of females of four^{+} years. In June, 1966, they

increased in number over previous months, however, attained only a 61 % level(Table 8). In both years the percentage of young females of four to five years increased in June. When the number of young females increases the number of non-pregnant animals also increases. It can be said that the percentage of non-pregnant animals increases in the latter part of the migration even among the animals of same age.

Table 8. Age ratio of females (4-5 and 6-10-year-olds) in 1965-1966.

	Age	Onahama coast	Kinka-san c.	Kesen-numa c.	Ōzuchi c.					Kurosaki c.	Erimo-misaki c.	Kushiro c.
1965		March (%)	March ~May (%)	March ~May (%)	5, March ~17, April (%)	16 ~26, May (%)	2~9, June (%)	11~19, June (%)	23~25, June (%)	June ~Jnly (%)	June ~July (%)	June ~July (%)
	4~5	35.5	32.4	30.6	55.6	47.0	56.6	43.7	64.3	57.2	33.3	0
	6~10	64.5	67.6	69.4	44.4	53.0	43.4	56.3	35.7	42.8	66.7	0
			March ~April (%)	March ~June (%)	27, March ~31, May (%)		7~ 9, June (%)	14~ 27, June (%)		May ~June (%)		
1966	4~5		57.5	47.5	46.3		68.3	52.6		47.5		
	6~10		42.5	52.5	53.7		31.7	47.4		52.5		

Males of four$^+$ years: the percentage of males of four$^+$ years of the total catch in the three years was 4-6 % , a very small percentage. Males of four$^+$ years constituted 20 % of all males caught. Of males of four$^+$ years, four year-olds were 65 % of the total, five year-olds were 15 % and six to eight year-olds were 17 %. Males of nine years of age and over (henceforward written as nine$^+$ years) seldom appeared (Fig. 4a, b and c). 37

Some peculiarities were observed in the distribution

of males of four^{+} years in time and spce. In 1967 there 38
was no catch along the coasts of Onahama and Kinkasan during the entire season, nor along the coast of Kesennuma in January nor along the coast of Ozuchi from January to February. In 1965 there was no catch along the coasts from Kurosaki to Kushiro in the entire season nor along the coast of Ozuchi after mid June. These data indicated that males of four^{+} years (mostly males of four years) appear late in the area of investigation and disappear early. The highest percentage in appearance of males of four^{+} years in the three years was 12.1 % from early March to mid April in 1965 along the coast of Ozuchi. This period coincided with a time when males of one to three years predominated. The appearance of males of six years of age and over (henceforward written as six^{+} years) was very rare. None were observed in the areas from the coasts of Onahama to Kesennuma in 1967. None were observed in the area north of the coast of Kurosaki in 1965 and after early June along the coast of Ozuchi. These data indicate that males of six^{+} years appear much later than those of four to five year and disappear much earlier. Therefore it may be concluded that they stay along the coast of Sanriku for a very short period (Table 9).

Table 9. Age ratio of males in 1965—1967.

	Age	Onahama coast	Kinkasan c.	Kesennuma c.	Ōzuchi c.			Kurosaki c.	Erimomisaki c.	Kushiro c.
		March (%)	March ~May (%)	March ~May (%)	5, March ~17, April (%)	16, May ~11, June (%)	12, June ~28, July (%)	June ~July (%)	June ~July (%)	June ~July (%)
1965	1	1.0*	3.4	5.3	18.6	1.8	2.6	0	0	0
	2~3	10.0	17.6	28.7	45.4	21.2	19.2	15.8	22.2	16.7
	4~5	1.3	5.1	8.3	11.3	5.5	0	0	0	0
	6+	0.6	0.8	0.7	2.1	1.8	0	0	0	0

	Age	March ~May (%)	March ~June (%)	27, March ~2, May (%)	6, May ~27, June (%)	May ~June (%)
1966	1	0	0.5	1.2	1.2	0
	2~3	18.3	18.3	15.9	14.2	24.7
	4~5	0.9	3.6	6.1	0	3.7
	6+	14.3	0	3.1	0	1.3

	Age	Onahama coast	Kinkasan c.	Kesennuma c.	Ozuchi c.			Kurosaki c.	Erimomisaki c.	Kushiro c.
		January ~March (%)	January ~April (%)	January ~April (%)	February (%)	1, Feb.~ 15, Mar. (%)	17, Mar.~ 29, April (%)	February ~May (%)	May (%)	May (%)
1967	1	0	0	0.8	0	3.6	3.9	3.4	3.2	0
	2~3	0	0	7.2	0	10.9	23.2	11.2	6.5	0
	~5	0	0	0.9	0	1.8	9.4	3.5	2.3	0
	6	0	0	0	0	0	1.5	0.6	0	0

* Percentages were calculated against the total number of fur seals taken in a definite period.

2) Migration of fur seals along the coast of Sanriku

In the previous section were stated the peculiarities in the changes of the composition by the age and the sex of fur seals. In this section the author would like to add the results of investigations of ecological peculiarities of fur seals migrating between their breeding islands and the coast of Sanriku. In order to avoid confusion "distribution" and "migration" are treated distinctively in the following analysis.

The direct proofs of migration of fur seals are

firstly, by tags attached to fur seals on a breeding island are recovered from fur seals caught along the coast of Sanriku and secondly, by observation of the tagged animals later on the breeding island. However, the tagged animals caught along the coast of Sanriku were less than 10 % of the total catch. The tagged animals do not indicate anything about the migration after they appear along the coast of Sanriku. Therefore the author would like to analyze the migration along the coast of Sanriku using data for the distribution given in the previous section.

Yearlings: they appear along the coast of Sanriku somewhat later than the advance herd migrating southward. They spread afterwards in time and space. Yearlings are few in number and are found sporadically. They stay along the coast of Sanriku to the last until migrating northward. Sexual segregation in time and space is rarely observed.

Animals of two to three years: the time of arrival and the duration of stay in the investigated areas are similar to those of the first age group. They are more numerous, spread widely in time and space and stay along the coast of Sanriku continuously. Sexual segregation is more conspicuous than among the yearlings. It is apparent from the data of the coasts of Kesennuma and Ozuchi in

1965 that many males of two to three years appeared in March and April. This did not occur in the other two years. The reason is thought to be that many males stayed north of the coast of Sanriku.

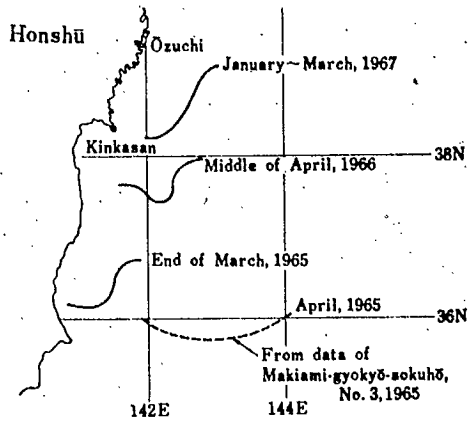


Fig. 5. Southern boundary of fur seal distribution by season in 1965—1967.

Animals of four^{+} years: almost all of the advance group of the southward migrating herd are females of four^{+} years. Females of six to ten years and eleven^{+} years are 41
foremost in the southward migration. They stay at the southernmost boundary of the migration. The large concentration of females of six^{+} years lessens as females of two to three years and four to five years migrate southward in increasing numbers. These latter groups eventually constitute the majority at the southern half of the migration. The northward migration begins gradually. Among the females of four^{+} years pregnant animals and females of six^{+} years disappear early. The rest of this

group (mostly females of four to five years and non-pregnant females) leave for the north earlier than females of two to three years. Therefore females of two to three years form the last group of the northward migrating herd. On the other hand, males of four+ years appear later than the other fur seals and disappear earlier. Therefore they stay along the coast of Sanriku the shortest time. This tendency is prominant among males of six to eight years. Males of nine years of age and over (henceforward written as nine+ years) seldom appear. Sexual segregation in time and space is most conspicuous. Females tend to be in the south of the migration and males in the north.

The above is an outline of the characteristics of the migration according to age and sex. In order to examine the cause of the change in age and sex compostion which occurs along the coast of Sanriku, the author views in the following migration in a more abstract manner and also reviews the developmental stages of the animal. It is thought to be appropriate that the following age groups form the developmental stages which have their own peculiar modes of life: yearlings, males and females of two to three years, males of four to five years, females of four to five years, males of six to eight years, females of six to ten years, males of nine+ years and females of eleven+ years. The names for each developmental stage

should be decided in future after a sufficient study on the modes of life is made.

Ito (1969) has divided the developmental stages by morphological formation and sexual maturity. In the case of males they are fetus, infants (yearling and young animals of two to three years), full grown animals I (five to seven years), full grown animals II (over eight years). In the case of females they are fetus, infants yearlings and young animals of two to three years) and full grown animals (over four years).

The division of developmental stages made by Ito and that by the author somewhat differ. Ito treated females of four^{+} years as one group. The author divided them into three divisions, four to five years, six to ten years and eleven^{+} years in accordance with the characteristics observed in the migration along the coast of Sanriku. Ito divided males of over two years into three groups, two to four years, five to seven years and eight years of age and over. The author divided them into four, two to three years, four to five years, six to eight years and nine^{+} years for the same reason as for females of four^{+} years. However, so far as the developmental stages are concerned we agree in dividing the animals into groups of infants, young animals and adult animals. Thus the differences in age in both male and

female divisions are due to a difference in emphasis in the analysis whether it be from a morphological or ecological point-of-view.

In this paper the following are explained: the density distribution, peculiarities of pods, the characteristics of relationships between the mode of migration, the oceanographic conditions and food habits for almost each developmental stage. (A lack of data prevented the author from dealing with all the developmental stages.)

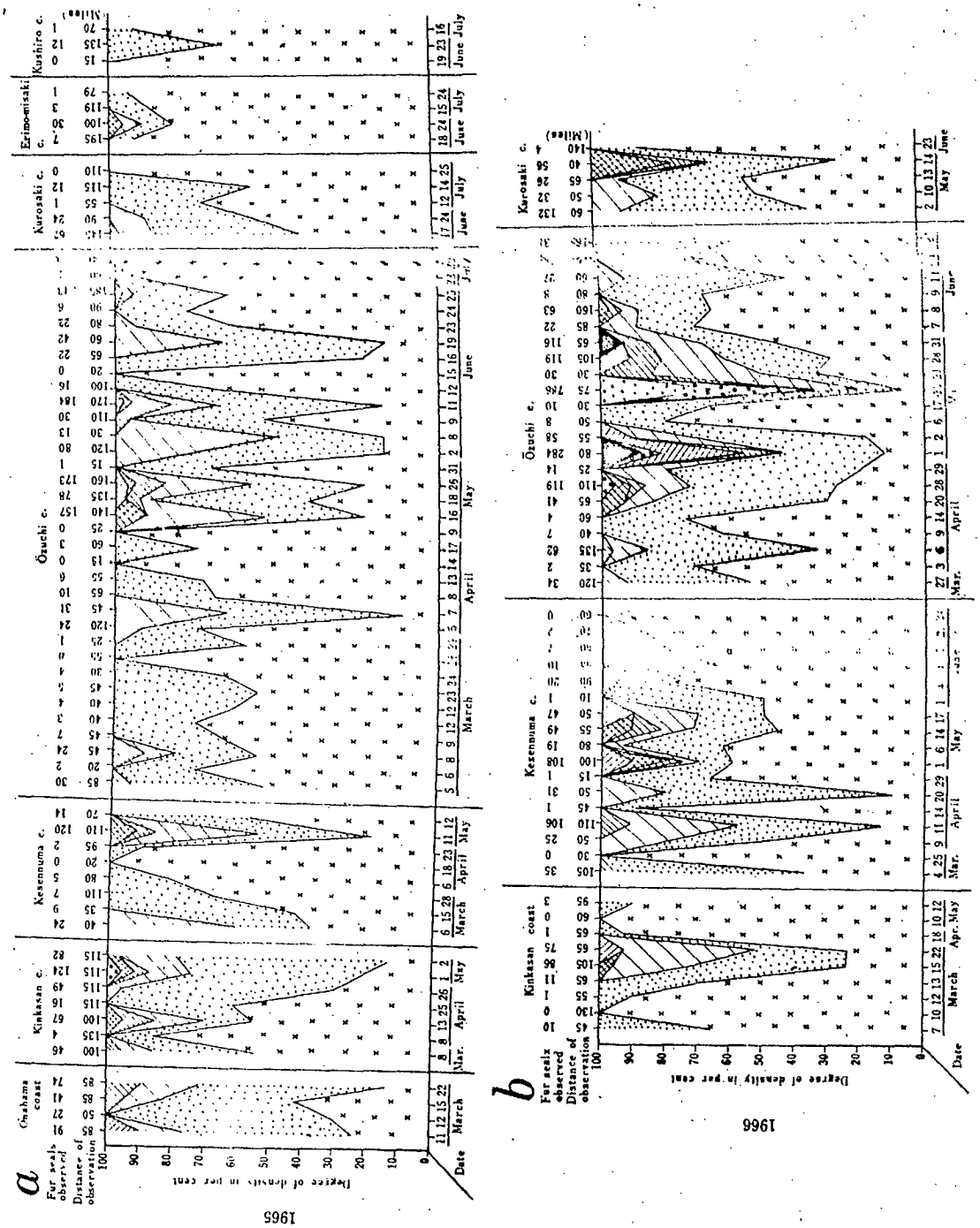
The basic mode of migration does not change yearly. However, the changes in age and sex compositions observed each year vary in time and space according to the location of the investigation in the migration area. In 1965 the southern boundary of fur seals reached the southern half of the coast of Onahama (Fig. 5). Thus the portion in which females of six^{+} years predominated moved beyond the area of the investigation. However, the investigation was carried out in the area in which females of four^{+} years predominated which was just north of the group of females of six^{+} years, in the area in which males of two to three years predominated and on females of two to three years which were the last group of northward migration. In 1967 the southern boundary was the coast of Kesennuma. Therefore the area of investigation held a concentration of females of six^{+} years. Thus the group was fully

investigated. However, males of two to three years who were thought to be north of the females of six^{+} years, the prevalent area for males of four^{+} years and the latter half of the northward migration could not be investigated. In 1966 the southern boundary was not as apparent as in other years. Since no large groups of females of six^{+} years and males of two to three years appeared, it was thought to be midway between the boundaries for 1965 and 1967. Therefore the part of the migration in which the annual investigation took place can be determined through analyses of age and sex compositions in time and space.

§4. Relationship between the density distribution and the mode of migration of fur seals

It has been explained in the former chapters that fur seals migrate according to their developmental stages. In this chapter how the density of fur seals varies in time and space is studied. Taylor et al. (1954) used the equation below to estimate the density supposing fur seals are observed within 100 yards of both sides of a fishing boat. Density (per square mile) = total number discovered/ sailing distance x 200 yards. In Canada, on the other hand, the following equation is used: density (per square mile) = total number discovered/ sailing distance x the visibility factor (1 when a fur seal is sighted $\frac{1}{2}$ mile from a boat, 2 when $\frac{1}{4}$ mile, 8 when 1/16) (Fisheries 46

Fig. 6. Density of distribution of fur seals in 1965-1967.



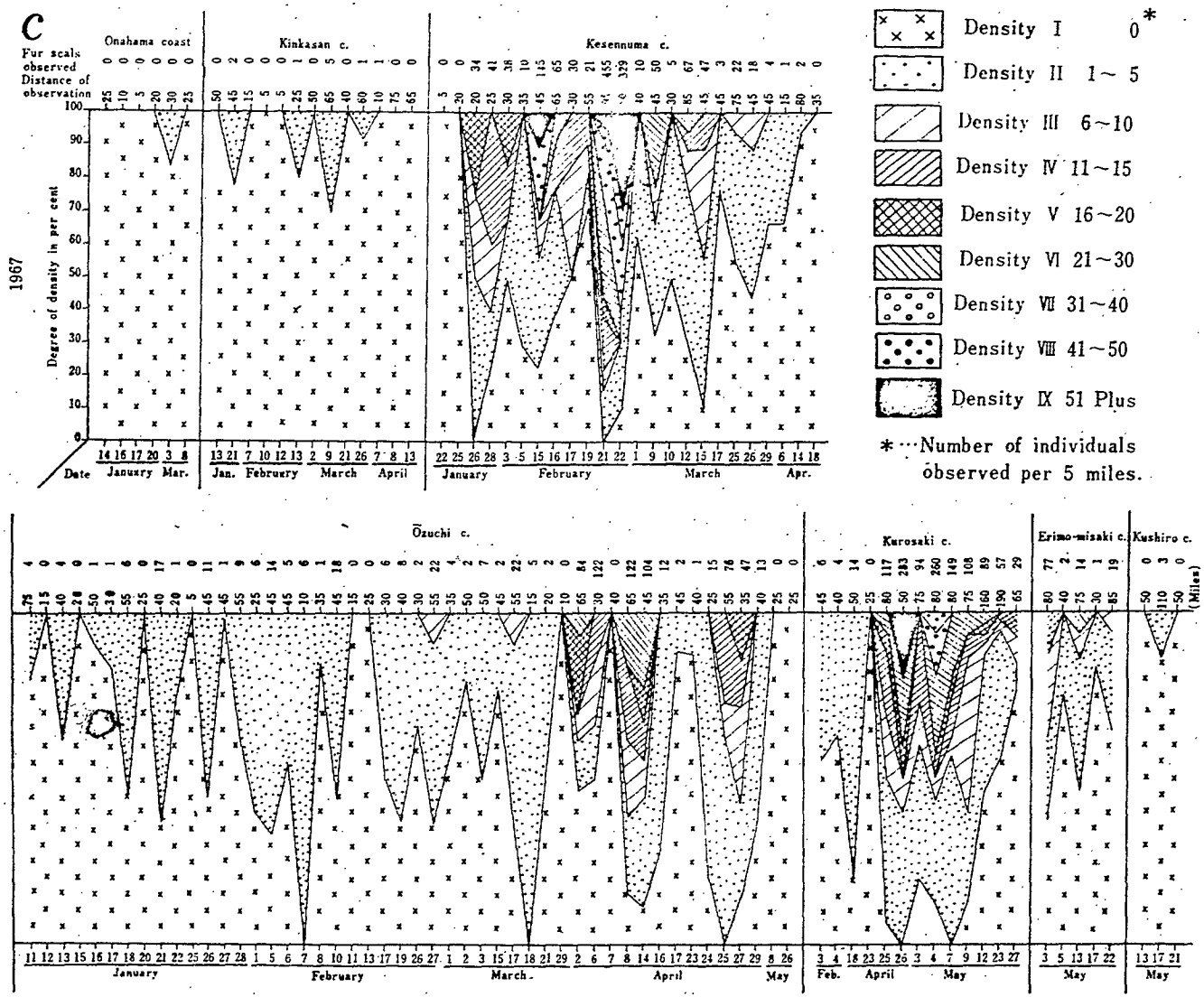


Fig. 6. Density of distribution of fur seals in 1965—1967.

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Table 10. Relation between the developmental stages and

Region	Date	Density	Age 1 ♂ No.	Age 1 ♂	Age 1 ♀ No.	Age 1 ♀	Age 2 ♂ No.	Age 2 ♂	Age 2 ♀ No.	Age 2 ♀	Age 3 ♂ No.	Age 3 ♂	Age 3 ♀ No.	Age 3 ♀
Onahama coast 3, Mar.		II												
Kinka-13, Jan.~9, Mar.		II												
san c. 21, Mar.~8, Apr.		II												
Kesennuma c.	22, Jan. ~15, March	II	1	5.9	1	2.0	3	3.5	1	0.8	3	1.2	2	0.5
		III		*							3	1.5	7	2.3
		IV			1	1.5			3	1.9	2	0.6	4	0.8
		V			1	3.4	1	2.1			5	0.3		
		VI							2	1.4	2	0.6	6	1.3
		VII					1	1.5	1	1.0			3	1.0
		VIII											1	1.5
	17, March ~8, April	II	2	1.4			2	0.9	1	1.4	3	1.0	4	1.4
		III					1	1.2			1	0.9		
Ōzuchi c.	Ōz. 11, Jan.~17, Feb., Kuro. 3-4, Feb.	II			1	1.0	1	1.0			1	1.0		
	Ōz. 19, Feb. ~8, April	II	1	2.2	2	1.7	4	1.1	1	1.2	6	0.9	7	1.6
		III	2	2.6	1	1.7	4	2.3	1	2.6	1	0.3	2	0.9
		IV					1	0.7			4	1.6	1	0.6
		V									2	1.0	1	0.7
		VI									3	0.6		
	Ōz. 14, April ~17, April	II	2	2.7			3	1.5	1	2.0	1	0.6		
		III					1	1.2			2	2.7		
		IV												
		V							1	6.0			1	2.4
		VI	1	0.7			4	1.0			4	1.2	4	1.7
	Ōz. 23, April ~8, May	II	1	0.9			2	2.7	1	0.5	6	1.8	2	0.8
		III	2	1.9							1	1.0	3	3.7
		IV	1	0.8	1	2.3			4	1.8			2	0.7
		V									2	2.7		
	Ōz. 26, May Kuro. 12-27, May	II	1	0.8	2	1.6	2	1.6	2	1.1	3	1.2	5	1.2
		III												
		IV									1	3.5		
		V	1	2.5					1	1.7			2	1.5
Kurosaki c.	Kuro. 18, April	II	1	1.0			1	1.0					1	1.0
	Kuro. 25, April ~9, May Erimo. & Kushi. 3-5, May	II	4	2.1			2	3.9			4	1.3	10	0.7
		III	1	0.8					4	1.5	2	0.6	4	0.7
		IV					1	1.5	2	1.2	3	1.5	2	0.5
		V							2	2.9				
		VI							2	0.8	3	1.0	7	1.3
Erimo-misaki 13-22, & Kushiro c. May		II									1	2.2	1	0.5
		III					1	1.9					3	1.4

$$* = \frac{X_{ij} \cdot N}{\sum_j X_{ij} \cdot \sum_i X_{ij}}$$

X_{ij}……Number of individuals

i ……Class by density degree

j ……Class by age and sex

N ……Total number of individuals,

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the degree of concentration of fur seals in 1967.

4 ♂ No.		4 ♀ No.		5 ♂ No.		5 ♀ No.		6～10 ♂ No.		6～10 ♀ No.		11+ ♀ No.	
												1	1.0
										1	1.0	3	1.0
												1	1.0
1	1.5	4	1.1			4	0.9			24	0.9	16	1.0
		2	0.7			5	1.4			11	0.6	18	1.5
1	1.1	5	1.0	1	2.2	4	0.7			35	1.0	24	1.1
1	2.6	2	0.9			6	2.3			12	0.8	6	0.7
1	1.2	4	0.0			7	1.2			32	1.0	19	1.0
		4	1.3	1	3.7	1	0.3			29	1.4	8	0.6
		1	1.6							6	1.4	2	0.8
		3	1.4			1	0.7					3	0.8
						1	1.9			2	3.7	2	1.5
		6	1.0			9	1.0			25	1.0	19	1.0
1	0.4	6	1.0			5	0.8	1	1.2	10	0.8	5	2.1
1	0.7	5	1.7	1	2.6	3	1.0	1	2.6	2	0.3		
4	3.7	1	0.4			1	0.4			7	1.4		
1	1.1	1	0.5	1	3.9	4	2.1			6	1.5		
		2	1.1			2	1.1			7	1.8	1	1.4
1	2.0					1	0.8					3	1.1
				1	9.6							1	0.9
						3	7.2					1	1.1
1	6.0	1	2.1									1	1.1
						1	4.4			3	2.1	5	0.9
3	1.4					2	0.9			3	1.0	2	0.9
		2	4.3										
1	0.4	2	1.5	1	1.2	4	1.5	1	2.3	5	1.4	4	1.5
2	4.0			1	6.0								
		5	1.4			4	0.9			8	0.7	2	1.1
										6	2.4	1	2.7
						2	4.0			1	0.7		
		1	0.8			1	0.7			5	1.3		
				1	1.0							2	1.0
2	1.5	3	0.8			3	0.6	1	1.9	8	0.6	3	1.0
1	0.8	2	0.5			10	1.8			15	1.2	3	0.9
1	1.2	2	0.8			4	1.2			10	1.2	1	0.5
1	2.9	2	1.9			2	1.4	1	7.2	3	0.9		
		6	1.7			2	0.4			13	1.1	5	1.7
1	2.2	1	2.2			1	0.7					1	1.1
						2	1.2					1	0.9

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Table 11. Relation between the developmental stages and

Region	Date	Density	Age 1 ♂ No.	1 ♂	1 ♀ No.	1 ♀	Age 2 ♂ No.	2 ♂	2 ♀ No.	2 ♀	Age 3 ♂ No.	3 ♂	3 ♀ No.	3 ♀
	Onahama 11–22,	II	1	2.0	1	2.0	3	1.5	1	2.0	1	0.3	7	1.4
	Coast March	III		*			1	1.0			2	1.4		
		IV									2	2.2	1	1.3
		VI									1	0.9	2	1.1
	8, April	II												
		III					1	1.8						
		IV												
Kesennuma c.	8, April	II	5	1.4	3	2.2	7	1.0	5	0.9	12	1.1	5	0.9
		III	2	1.0			5	1.2	3	1.0	7	1.1	5	1.7
		V					1	1.1			1	0.	1	1.
		VII							1	0.8	3	1.2	1	0.8
	6–28, March	II	4	1.3	1	1.3	2	0.9	1	1.3	2	1.3		
		III					1	1.5					1	4.5
	6–23, April	II					4	0.7			2	0.3		
	11–12, May	II									5	1.4	1	0.6
		III					2	1.9			4	0.9	1	0.5
		IV											1	0.2
		V	1	3.3			1	1.1			4	1.0	3	1.7
	5–9, March	II			1	1.6	3	1.2	2	1.6	3	0.8	1	0.5
		III					1	1.1			2	1.5	1	1.5
		IV	1	6.4							1	1.1	1	2.1
	12, March～	II	9	1.0	2	1.2	5	1.1			13	0.9	1	1.8
	17, April	III	7	1.0	1	0.8	3	0.9			13	1.2		
		IV	1	1.9										
Ōzuchi c.	9, May～	II	2	0.7	2	1.0	14	1.2	9	1.4	19	1.0	18	1.2
	12, June	III	5	1.3	4	1.5	18	1.1	7	0.8	17	0.7	24	1.2
		IV	2	1.4	1	1.1	6	1.0	3	0.9	9	1.0	9	1.1
		V	1	0.8			1	0.2	3	1.0	13	1.6	4	0.6
		VI					3	1.2	1	0.7	7	1.8		
		VII					1	0.9	1	1.5	2	1.1	1	0.7
	15, June～	II	1	1.0	1	0.7	7	1.6	2	0.4	3	0.7	2	0.4
	29, July	III	1	1.0	2	1.3	2	0.4	7	1.6	1	0.5	9	1.6
	Kurosaki 17, June	II			2	1.4	4	1.2	4	1.1	1	0.7	8	1.2
	c. ～14, July	III							1	0.8	1	1.9	1	0.4
	Erimo-misaki 24, June	II							1	4.5				
	c. 15, July	III					2	3.0					2	2.3
		V												
	Kushiro 23, June	II									1	1.0	3	1.
	c. 16, July													

$$*=\frac{X_{ij}\cdot N}{\sum_j X_{ij}\cdot\sum_i X_{ij}}$$

X_{ij}……Number of individuals

i……Class by density degree

j……Class by age and sex

N……Total number of individuals

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the degree of concentration of fur seals in 1965.

4				5				6–10				11+	
♂ No.		♀ No.		♂ No.		♀ No.		♂ No.		♀ No.		♀ No.	
		5	0.6	1	2.0	3	1.0	1	2.0	18	0.9	7	1.1
1	4.2	7	1.8							7	0.7	6	1.9
		1	0.8			1	2.1			3	1.0		
		3	1.0			2	1.8			11	1.5		
				1	4.0					1	0.7	2	2.7
		2	1.8			2	1.2			3	0.9	1	0.6
						1	1.8			2	1.8		
5	1.4	5	0.9	2	1.5	7	1.0	1	0.7	25	0.9	8	0.9
		1	0.3	1	1.3	5	1.2	1	1.3	13	0.3	8	1.5
2	1.4	2	1.2			2	0.9			12	1.3	2	0.7
		2	2.8			1	1.1			5	1.3	1	0.8
1	1.3	2	1.7			1	0.6			8	1.3	2	1.0
2	1.3											2	1.3
		2	4.5										
3	1.6									10	1.5		
2	0.8	3	2.1			3	1.7	2	1.9	6	0.7	2	2.8
										4	2.2		
2	1.0	1	0.8	1	3.3	2	1.3	1	1.1	5	0.7		
3	1.6	2	1.1	1	1.6					2	0.8	2	1.1
		1	1.5			1	4.6					1	1.5
										2	3.2		
4	1.0	1	1.8					1	0.9				
3	1.0												
								11	6.3				
7	1.2	20	1.1	1	0.6	12	0.9	2	0.8	31	0.8	5	0.9
9	1.2	21	0.8	3	1.3	21	1.1	5	1.5	48	1.0	10	1.3
		12	1.3	1	1.2	5	0.7	2	1.6	19	1.0	3	1.0
3	1.1	10	1.2			7	1.1			20	1.2	2	0.8
2	1.7	3	0.8	1	2.9	3	1.1			8	1.1	1	0.8
		1	0.5			2	1.5			6	1.7		
		6	1.0			4	1.1			10	1.5		
		6	1.0			3	0.9			3	0.5	2	2.0
		4	0.9			1	0.7			3	0.7	1	0.7
		2	1.3			1	1.9			3	1.9	1	1.9
		1	4.5										
										1	1.5		
										1	1.1	1	2.3
												2	1.0

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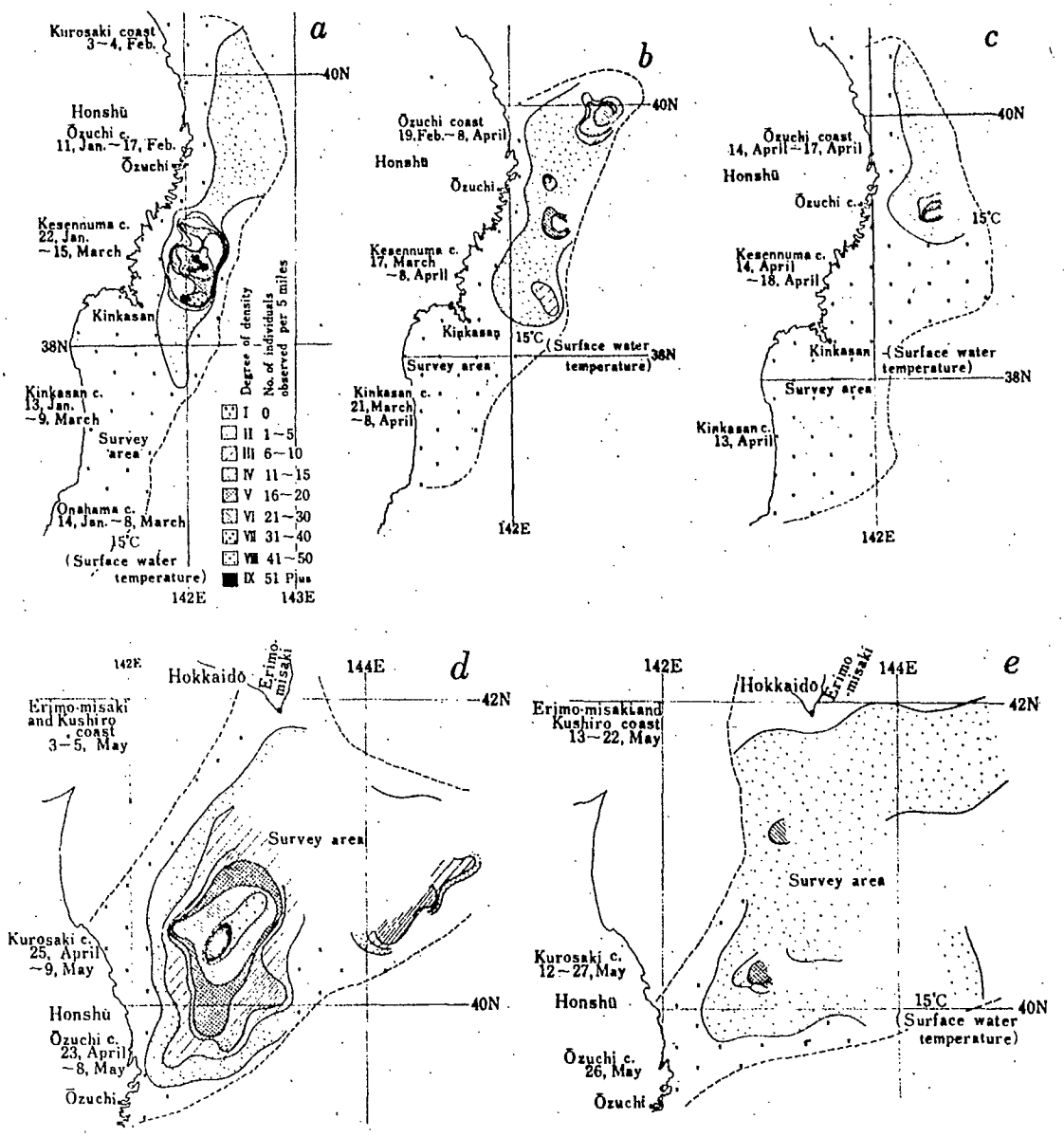

Fig. 7. Population density of fur seals in 1967.

47

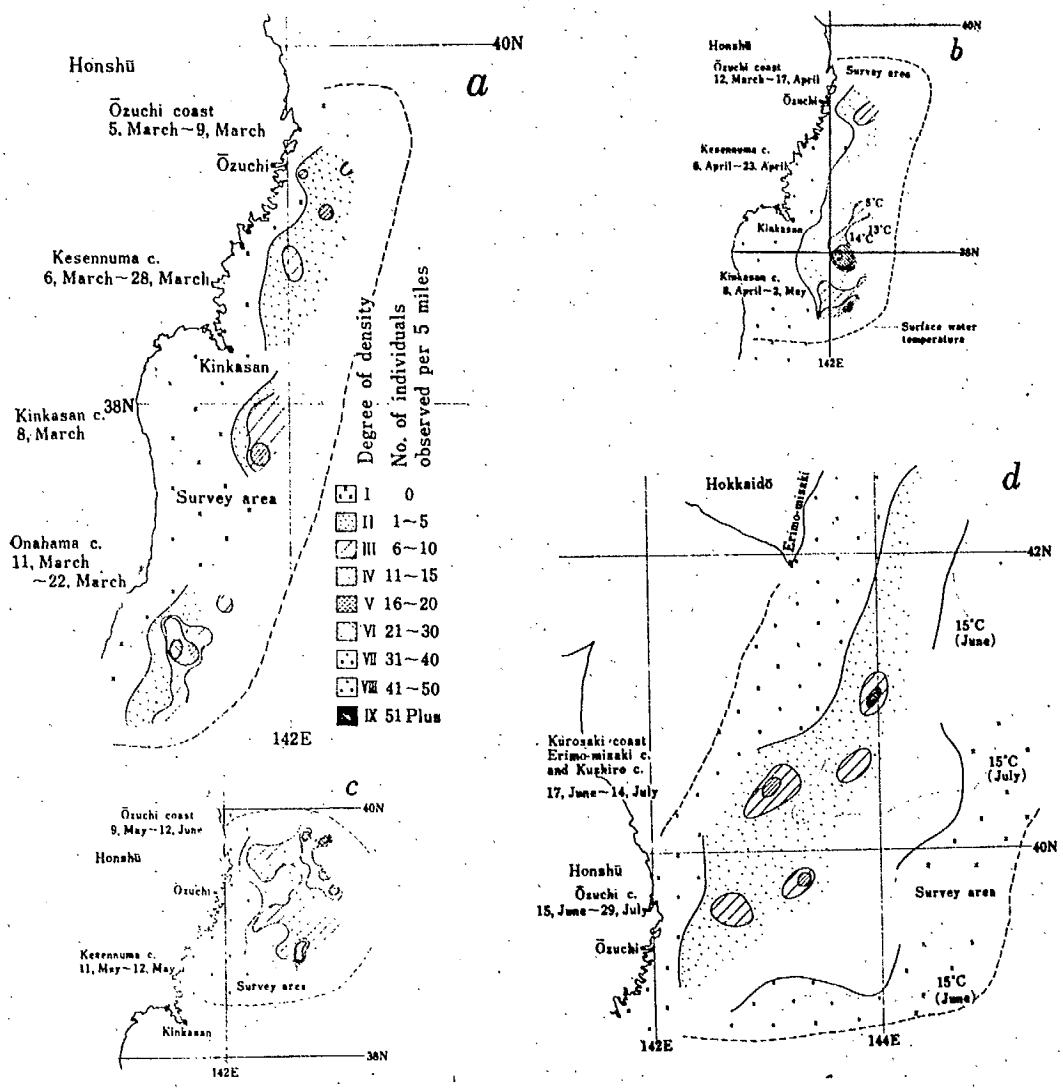

Fig. 8. Population density of fur seals in 1965.

48

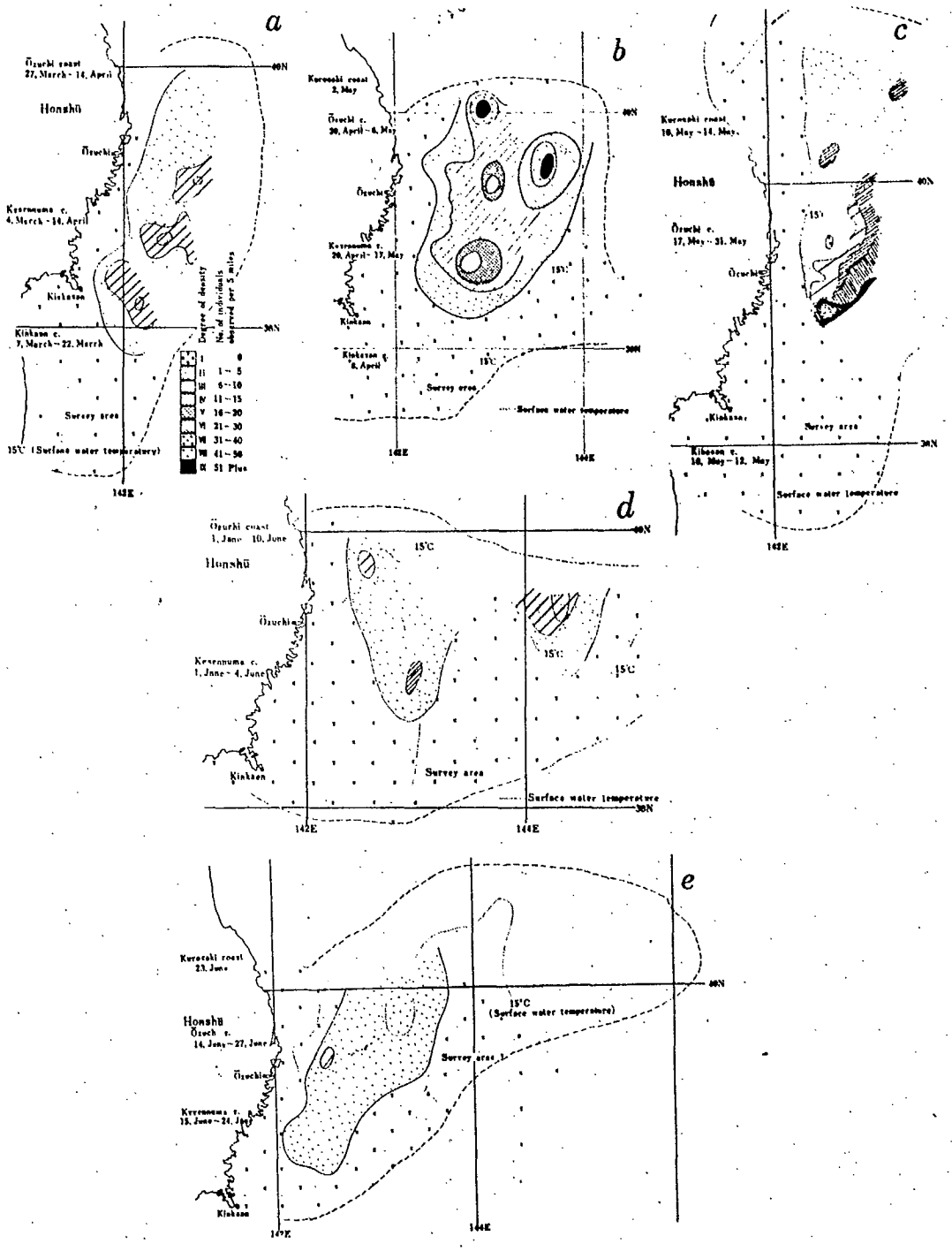

Fig. 9. Population density of fur seals in 1966

Research Board of Canada, 1958).

The author regarded the number of individuals observed per five miles of sailing as an index of the density in the area. This is because there are many factors which influence the density such as alterations in the percentage of fur seals observed due to oceanographic conditions, the difference in boat speed, the probability of recounting an individual already counted, changes in the percentage of fur seals observed due to possible confused movement of fur seals during catching and the difference in the ability of observers. The factor of 200 yards given by Taylor et al. and the visibility factor used 47
in Canada seem to be within the limit of errors caused by the factors stated above. Therefore the author decided not to apply the aforementioned equations. These relationships should be studied further. The author used his own method in this paper. The density is divided into nine (I-IX) degrees of concentration.

1) Relationship between density distribution and mode of migration

In order to obtain a general view of the density variation in time and space, the degree of density in per cent was studied. It was based on charts taken in the same investigation area at the same time (Fig. 6a, b and c).

The best observations of fur seals migrating southward were obtained in 1967. In 1967, the density was almost zero along the coasts of Onahama and Kinkasan. Thus it is apparent that the migration of fur seals stopped along the coast of Kesennuma. From January to mid March along the coast of Kesennuma and from January to mid February along the coast of Ozuchi females of four^{+} years constituted over 80 % of the population. The density along the coast of Kesennuma was over degree III only from January to mid March. The density along the coast 49
of Ozuchi from January to March was seldom over degree III (Fig. 7a-e). Therefore the center of concentration for females of four^{+} years in both the areas from January to mid March was about ten to forty miles from the shore of the coast of Kesennuma (Fig. 7a). In the same area females of six to ten years were observed in areas of high concentration (degrees VII and VIII) rather than in sparsely populated areas. Males of one to three years were observed in the areas of low density (degrees II and III). There was no apparent tendency observed in any other developmental stages (Table 10*).

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* Values given in Table 10, 11 and 12 are calculated using the equation:

$$y = \frac{X_{ij} \cdot N}{\sum_j X_{ij} \cdot \sum_i X_{ij}}$$

X_{ij} ..... Number of individuals
i ..... Class by density degree
j ..... Class by age and sex
N ..... Total number of individuals

Table 12. Relation between the developmental stages and the degree of concentration of fur seals in 1965—1967.

Density / Age	1		2		3		4		5		6–10	11+	Total
	♂ No.	♀ No.	♂ No.	♀ No.	♂ No.	♀ No.	♂ No.	♀ No.	♂ No.	♀ No.	♀ No.	♀ No.	
II	40 1.5*	19 1.6	98 1.3	47 1.0	117 1.1	114 1.1	39 1.0	106 1.0	7 0.8	88 0.8	244 0.9	107 0.9	1035
III	20 1.1	8 1.0	54 1.0	35 1.1	69 0.9	85 1.1	24 0.9	81 1.1	9 1.4	87 1.2	171 0.9	69 0.9	724
IV	6 0.6	3 0.7	20 0.7	16 0.9	36 0.9	27 0.7	13 0.9	35 0.9	3 0.9	44 1.2	132 1.3	41 1.0	380
V	3 0.5	1 0.4	6 0.4	11 1.1	31 1.3	16 0.7	12 1.5	25 1.1	3 1.6	28 1.3	66 1.1	19 0.8	223
VI	1 0.2	1 0.3	11 0.6	7 0.6	24 0.9	34 1.3	5 0.5	30 1.1	1 0.4	22 0.8	89 1.2	38 1.4	263
VII			4 0.5	4 0.8	8 0.7	8 0.7	4 1.0	10 0.9	1 1.1	5 0.5	48 1.6	13 1.2	107
VIII				2 2.3	2 1.0	1 0.5		1 0.5			9 1.6	5 2.4	20
IX			4 3.1	1 1.3	2 1.1	1.	4 6.1	1 0.5		3 1.7			18
Total	70	32	197	123	289	286	101	289	24	277	759	292	2770

$$*=\frac{X_{ij}\cdot N}{\sum_j X_{ij}\cdot\sum_i X_{ij}}$$

X_{ij}……Number of individuals
i……Class by density degree
j……Class by age and sex
N……Total number of individuals

From the end of March on there occurred an increase in the numbers of animals of one to three years and males of four$^+$ years while correspondingly the concentration of females of four$^+$ years disappeared from the coast of Kesennuma. High density areas of dgrees III-VI were found along the coast of Sanriku (Fig. 7b and e). However, there was no change in the constituents of the high density area in that they were females of four$^+$ years and especially females of six$^+$ years. From these findings it is possible to conclude that the high density areas along the coast of Kesennuma begin moving northward somewhat ahead of the migrating herd at the southern boundary. Therefore the high density areas which scatter along the coast

of Sanriku are regarded as groups in the process of northward migration. The changes in the density distribution according to the developmental stages indicated previously for this time and place can be observed partially in the results given in Table 10*.

From March to April of 1965 high density areas were observed at the southernmost areas. There was a high concentration of females of four+ years and females six to ten years populating the high density areas. This agrees with the observations of 1967 (Fig. 8a and Table 11). At the same time an area which consisted almost entirely of males (especially males of two to three years) appeared towards the north of the area with a concentration of females of four+ years. However, the density for males was low (degre II or III) and there was no tendency towards a special density distribution such as for females of six to ten years. After mid June when the percentage of females of four+ years against the total catch began to decline, densities degrees IV and V occurred in some locations. The high density areas disappear from the coast of Sanriku as females of four+ years move northward (Fig. 6a and Fig. 8c and d).

In 1966 the catch was small compared with number of individuals observed. Therefore it was not suitable for a study of the relationship between the density

distribution and the distribution of individuals according to the developmental stages. Thus only the changes in density distribution in time and space are given in figures (Fig. 9a-e). 50

When the deviation of the density distribution in each developmental stage is compared in each time and place, the number of fur seals observed becomes less and the relationship becomes less apparent. However, when the data obtained over the three years are studied the relationships become clearer (Table 12). The tendency towards low density areas (degree II) was observed clearly for yearling and males of two years. The tendency towards high density areas was observed for females of six to ten years (degrees IV-VII) and females of eleven^{+} years (degrees VI-VIII). No apparent tendency was observed for animals of other developmental stages. One of the reasons is that the observations were weighted towards a specific time, space and density distribution.

The following is a summary of the relationship between density distribution and the mode of migration of fur seals: a) during the first half of the migration period, females of four^{+} years are concentrated around the southern limit of the distribution. Especially females of six to ten years tend to gather in greater numbers in the high density areas (degrees VII and VIII). Sometimes

males of one to three years are found in the areas of lower density. b) In the second half of the migration period, the females of four^{+} years start to move to the north, maintaining their tendency to concentrate in the high density areas. As the females of four^{+} years move northward, the high density areas disappear from the coast of Sanriku. c) The percentage of yearlings, animals of two to three years and males of four^{+} years against the total catch (per day) sometimes rises in the low density areas (degrees II and III). d) The data obtained in the three years of investigation indicated the tendencies that yearlings add males of two years concentrate in low density areas (mainly degree II), females of six to ten years and females of eleven^{+} years in high density areas (degrees IV-VIII) and (degrees VI-VIII) respectively. Animals of other developmental stages do not show similar tendencies.

2) The yearly cycle of life for the adult female fur seals

The yearly cycle of life for adult females is considered to be divided into two parts: fistly, the breeding season occupied mainly by delivery, nursing and reproduction; secondly, feeding and migrating season. The yearly cycle of life of adult females studied here is limited to that of the feeding and migrating season along the east coast of Hokkaido and along the coast of Sanriku.

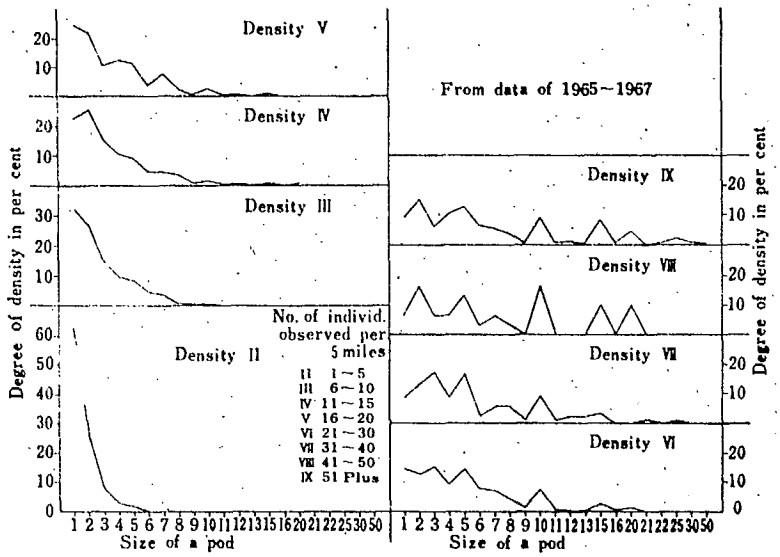
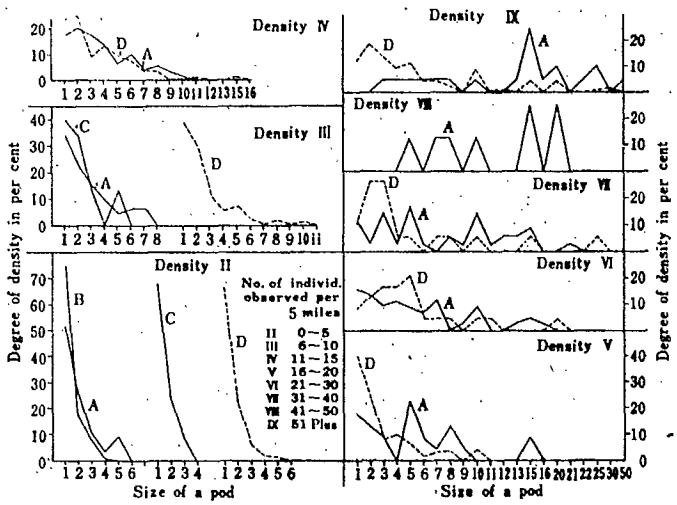


Fig. 10. Relation between density of fur seal populations and size of pods.



A···1965, Onahama coast II, March~22, March
Kinkasan c. 8, March
1967, Kesennuma c. 26, Jan.~15, March
B···1967, Ōzuchi c. 11, Jan.~27, Feb.
C···1965, Kesennuma c. 6, April~23, April
Ōzuchi c. 12, March~17, April
D···1965, Ōzuchi c.~Kushiro c. 16, May~28, July
1966, 1966, Ōzuchi c.~Kurosaki c. 6, May~27, June

Fig. 11. Relation between density of fur seal populations and size of pods.

The yearly cycle of life can be divided into the following periods: i) period of southward migration; ii) periods-of-stay I and II; and iii) period of northward migration.

i) Period of southward migration: this period is not yet understood fully. In 1967, this period corresponds to a time before January. The adult females migrate southward from the breeding islands or their vicinity.

ii) Periods-of-stay I and II: period-of-stay I is the time in which the adult females stay in the comparatively stable and high density areas near the southern limit of the distribution. This time corresponds to the period from before March to the end of April in 1965 at the southern half of the coast of Onahama and the period from January to mid March in 1967 along the coast of Kesennuma. Period-of-stay II is the period during which the adult females move northward slowly along the coast of Sanriku in areas of a high degree of density. This time corresponds to the period from the end of April in 1965 and from April to early and/or mid June in 1967.

iii) Period of northward migration: this is the period during which the high concentration of adult females disappears from the eastern coast of Hokkaido. It occurs in early June or after mid June.

Since the migration of adult males was not observed

to any appreciable extent in this investigation, it is not possible to draw any conclusion on the yearly cycle of life of adult males.

3) The structure of density distribution

In the previous chapter the structure of the density distribution was seen to be roughly in the form of concentric circles. However, the density distribution changes rather suddenly in time and space. Therefore in order to obtain a better structure for the density distribution, it is necessary to study the matter in detail.

When the spacings of concentric circular isograms differ, the narrower spacing occurs near the center which is offshore. This mode of density distribution appears near the boundary of the distribution of fur seals (Fig. 16 and Fig. 19b).

The mode of density distribution in which the spacings between concentric circular isograms are nearly eaual appears somewhat away from the distribution boundary (Fig. 17a, b and c, Fig. 18a and b, and Fig. 19a).

In both cases stated above, the density decreased away from the center. However, in the case of Kesennuma in 1967, the density became somewhat higher at the edge 51 of the pattern (Fig. 16).

The structure of the density distribution is basically a concentric circle. However, whether the mode

becomes nearly a complete circle or a highly eccentric ellipse depends on not the peculiarities in nature of fur seals but the relationships between fur seals, their food habits and oceanographic conditions.

Table 13. Composition of pods and frequency of appearance in 1965—1967.

Frequency of appearance	Component of pod	
very often	4⁺♀	
frequent	4⁺♀, 2~3♀	2~3♀
	4⁺♀, 2~3♂	2~3♂
seldom	4⁺♀, 4⁺♂	4⁺♀, 2~3♀, 2~3♂
	4⁺♂	2~3♀, 2~3♂
	2~3♀	
rare	4⁺♀, 4⁺♂, 2~3♀	4⁺♀, 1♂
	4⁺♀, 2~3♀	2~3♀, 2~3♂, 1♀
	4⁺♀, 2~3♀, 1♀	2~3♀, 1♂
	4⁺♀, 4⁺♂, 2~3♂	2~3♂, 1♂
	4⁺♂, 2~3♂	1♂
	4⁺♀, 2~3♂, 1♂	

1♂…1-year-old males
1♀…1-year-old females
2~3♂…2-3-year-old males
2~3♀…2-3-year-old females
4⁺♂…Males of 4 years and over
4⁺♀…Females of 4 years and over

§5. Relationship between pods and the mode of migration of fur seals 52

Fur seals at sea distribute in groups of fairly large numbers. The sizes of pods differ. Fur seals stay close to one another in sleep or in swimming. They tend to flee from a pursuing boat in groups all moving in the same direction. A study has not been done on whether these pods have any social and ecological structure and functions. However, since the pods have a certain relationship with the mode of migration, the nature of pods

can be revealed by studying this relationship.

The recognition of pods are influenced by the weather condition and the ability of the observers. The weather conditions necessary for such an investigation are clear visibility and a sea state less than 3.

1) Relationship between the sizes of pods and the degree of density

The observations on pods were classified according to the degree of density and the sizes of the pods. The results indicated that in a low density area, pods were small and that the higher the density, the bigger the pods. In an area of density degree II the individuals made up over 60 % of the population and the pods consisted of two to three animals. For higher degrees of density the proportion of individuals decreased to less than 10 % and pods increased in size. The largest pod which included thirty to fifty animals was found in an area of density degree IX (Fig. 10).

2) Relationship between the sizes of pods and the developmental stages

As stated above, there is a fixed relationship between the sizes of pods and the degree of density. Moreover, there are differences in the relationship according to the developmental stages (Fig. 11).

There are some different tendencies in the following

areas: the coasts of Onahama and Kinkasan in March, 1965 and the coast of Kesennuma from January to March, 1967 which had a prevalence of females of four^{+} years who were at the tip of the southward migrating herd and females of eleven^{+} years; the coast of Ozuchi in April, 1967 which had a prevalence of yearlings and males of two to three years; north of the coast of Ozuchi in May, 1965 and 1966 for which there was to be observed a decrease in females 53 of four^{+} years and a prevalence of females of two to three years in the second half of the migration.

The tendency of gathering together is most strong where females of four^{+} years are prevalent, that is, large sizes of pods are observed often in such an area. When the degree of density is II, the individuals made up at least 50 % of the population. The maximum percentage for individuals was 75 % and found in the females of four^{+} years along the coast of Ozuchi from January to February in 1967. The degree of density was II. In the area where male yearlings and males of two to three years are prevalent fur seals do not form large sized pods than those of females of four^{+} years when the degree of density is II to III. Since the structures are more complicated than those two cases above at the period-of-stay II and during the period of northward migration, the nature of a special developmental stage cannot be explained easily. However,

it is apparent that the increase in June in the numbers of non-pregnant females and females of two to three years should be considered to be influencial. In the period-of-stay II and the period of northward migration, it is clear that the pods tend to be smaller in all degrees of density than in the areas in which females of four^{+} years are prevalent and also smaller than the mean size for the three years of investigation.

3) Components of pods 54

The composition of pods and their variations are two of the more important means of revealing the function of pods. The cases in which every member of a pod was captured were noted and analyzed. The pod in most cases consisted of two to five animals. There were not enough larger pods to enable analysis.

Firstly, the combination of components of pods and the approximate frequency of appearance were studied. Animals were divided into six groups: males and females of one year old, males and females of two to three years, 57 males and females of four^{+} years. If males and females of four^{+} years were divided further, there would not be enough examples. The frequency of appearance of pods in the three years was graded into 1) very often, 2) frequent, 3) seldom and 4) rare. The components of 1) and 2) were females of four^{+} years and males and females of

two to three years. They appeared most frequently in the total catch forming the majority. Their combinations were females of four^{+} years only, females of two to three years only, females of four^{+} years and males and females of two to three years. The components of 3) and 4) were highly variable. The frequency of appearance was low. Almost every combination was observed (Table 13).

The appearance of these combinations indicate some peculiarities in the relationships between fur seals during migration. From January to March in 1967 along the coast of Kesennuma and from January to February along the coast of Ozuchi, the most females of four^{+} years remained in the area. The components of pods were mostly females of four^{+} years. Most of the combinations were also made of females of four^{+} years only. There were only a few examples of the combination of females of four^{+} years and males and females of two to three years (Table 14a, b and c).

From March to April in 1965 along the coast of Ozuchi, there was a time during which females of four^{+} years did not appear. The components of pods were males of four^{+} years, males of two to three years and male of yearlings. Most of the combinations were made of males of two to three years only. There were no apparent characteristics such as mentioned above for other times and

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Table 14 a. Regional and seasonal prevalencies of fur seals based on the combination of components of each pod observed in 1965.

Region	Date		F*	FE	E	FED	FD	ED	D	FDB	FEC	FDC	FC	EC	DC	C	FCA	FA	DCB	DA	CA	A
Onahama coast	Mar.,	15	1																			
		22	2				2						1									
Kinkasan c.	Apr.,	13	1	1												1						
		25					1															
		26	2	1			1															
	May,	1	2	1											1					1		
		2	2								1		1									
Kesennuma c.	Apr.,	6														1						
	May,	11	4	1			1				1											
		12					1															
Ozuchi c.	Mar.,	5											1									
		9													1							
		12														1						
	Apr.,	5														1						
		7												2		3						1
		8														3						
	May,	16	4		1	1	2						2									
		18	3	1	1			1	1					1		1						
		26	5	2	1				1			2	3									
	June,	2	2	2								1	2		2							
		8	3						1				1			1				1		
		9	1																			
		11	4				3		1			1	3				1				1	
		19	1				1		3	1		1	1					1				
Kurosaki c.	June,	17	1				2												1			
		24																				
	July,	14											1									

* : Combination of components of each pod

A : 1-year-old males C : 2-3-year-old males E : Males of 4 years and over

B : 1-year-old females D : 2-3-year-old females F : Females of 4 years and over

places. Many combinations were made of females of four^{+} years only, females of four^{+} years and females of two to three years, females of four^{+} years and males of two to three years and males of two to three years only. 57

The characteristics stated above concerning the components and combinations of pods do not indicate any

Table 14 b. Regional and seasonal prevalencies of fur seals based on the combination of components of each pod observed in 1966.

Region	Date	F*	FE	E	FED	FD	D	FEDC	FDC	FC	EC	DC	C
Kinkasan coast	Mar., 13											1	
	15	1				1	1			1			
	22					1			1	1		1	1
Kesennuma c.	Mar., 4	1	1										
	Ap.r, 11	2	1			1		1		1		1	
	20										1		
	May, 6	1					1				1	2	
	14	1				1				1			1
	17	1				1							
	June, 14											1	
	15	1											
Ōzuchi c.	Mar., 27	1			1								
	Apr., 6					1							
	20	1											
	28	1		1		1				1			
	May, 2					1							
	17								1				
	20					1	1			1			
	21	1											
	28	1								1			
	June, 8					1	2			1			
	14	1								1			
	27									2		1	
Kurosaki c.	May, 10					1	1			2			
	13					1							
	14										1		

* : Combination of components of each pod

A : 1-year-old males C : 2-3-yeay-old males E : Males of 4 years and over

B : 1-year-old females D : 2-3-year-old females F : Females of 4 years and over

special and apparent difference according to the size of pods. 57

The facts stated above indicate that when females of four+ years or males of two to three years are prevalent they tend to form pods by themselves. If other animals different from those above enter the areas they

Table 14 c. Regional and seasonal prevalencies of fur seals based on the combination of components of each pod observed in 1967.

Region	Date		F*	F E	E D	D	F D C	F C	E C	D C	C	D A	C A
Kesennuma coast	Jan.,	26	1										
		28	8										
	Feb.,	3			1								
		5	1										
		15	2										
		16		1				1					
		17	1										
		21	1										
	Mar.,	1	1										
		9						1					
		12	4	1	3								
		15	1					2					
		25						1					
		26	2		2								
Ōzuchi c.	Jan.,	21	2										
	Feb.,	1	1										
		5	1										
		7	1										
		19	1										
	Apr.,	2			1				1	1			
		8	1		1			1		1			1
		14	1								1		
		16			1						1		
		24								1			
		25	2	1		1							
		27					1						
Kurosaki c.	Apr.,	25										1	
		26	1							1			
	May,	3									1	1	
		4	1										
		7	2		1								
		9	1		1			1		1		1	
		12	1		1								
		23	2		1								
Erimo misaki c.	May,	3	1		1								
		22					1						

* : Combination of components of each pod

A : 1-year-old males C : 2-3-year-old males E : Males of 4 years and over

B : 1-year-old females D : 2-3-year-old females F : Females of 4 years and over

form pods of various combinations. These facts are apparent when the variations of combinations in time and space and the variation of the developmental stages in time and space are compared. Therefore there are no data that indicate the existence of the social and ecological relationships which continue (the relationships such as between parents and children, males and females, individuals of different developmental stages). Fur seals have a strong tendency that individuals form a pod when in a developmental stage which has a peculiar mode of migration. From the examples taken from the catch, the more complex the components are the more diversified are the combinations. Therefore it is considered that the relationships between individuals in a pod are comparatively loose and temporary. Thus it is considered that the pods are changeable.

6. Relationship between the temperature of the surface water and the mode of migration of fur seals

Migrating fur seals are influenced directly by the oceanographic conditions and indirectly by the mode of life of their prey. Several factors can be considered in the weather and the oceanographic conditions which influence the fur seals. The most apparent factor is the water temperature.

Table 15. Oceanographic records of Sanriku and Jōban coast in 1965—1967.

	Date	The Kuroshio current		Transition area	The Oyashio current	
					1st branch of the Oyashio Sanriku coast	2nd branch of the Oyashio 39°N, 146°E
1956	March	Northern limit	33.3°N 145.0°E	Water temperature 7°—10°C		
	Aplil	〃	35.0°N 141.3°E	Large cold eddy off Joban, warm eddy out of cold eddy stretching Sanriku coast	Sanriku and Jōban coast	———
	May	〃	35.5°N 142.0°E	Large warm eddy stretching 41.5°N along 143°E —145°E	38.5°N, 142.8°E	39°N, 146°E
	June	〃	35.7°N 141.5°E	Going north of secondary Kuroshio current (to 37.5°N, 143.5°E)	40°N, 142.5°E	39°N, 147°E
	July	〃	35.5°E	Going north of secondary Kuroshio current (to 40°N, 145°E)	Sanriku coast	———
1966	March	〃	37.0°N 143.5°E	Remarkable boundary between water masses off Shioyasaki and Kinkasan coast	Sanriku coast	Stretch south, and contact with the Kuroshio
	April	〃	35°-50′N 141°-30′E	Warm eddy off Shioyasaki and Kinkasan, Secondary Kuroshio current make remarkable boundary with the Oyashio current at 41°N, 144°E—146°E	Sanriku coast, contacts with the Kuro. out of warm eddy of transition area	
	May	〃	35.0°N 142.5°E	Remarkable boundary between water masses off Jōban and Sanriku coast	Sanriku coast	Join with 1st branch off Kinkasan
	June	〃	35.0°N	Secondary Kuroshio current go up north to Sanriku coast	Middle of Sanriku coast	39°N, 145°E
1967	January	〃	Inubōsaki SE 30 M	Kinkasan coast 11°—14°C, none cold eddy between middle of Sanriku coast and Inubōsaki c.	———	———
	February ~March	〃	36°N 143°E	Small cold eddy on Sanriku coast	Middle of Sanriku coast	39°N, 145°E
	May	〃	35°N 142°E	Large warm eddy between middle of Sanriku coast and Kinkasan c., its northern edge is 39°N	〃	40°N, 146°E

From the data of *Tōhokukaiku Gyojō Kaikyō Gaiho*, 1965—1967 and *Jour. Oceanogr. Soc. Japan*, 23(2) : 36—38, 1967, with some additions and rearrangement by the author.

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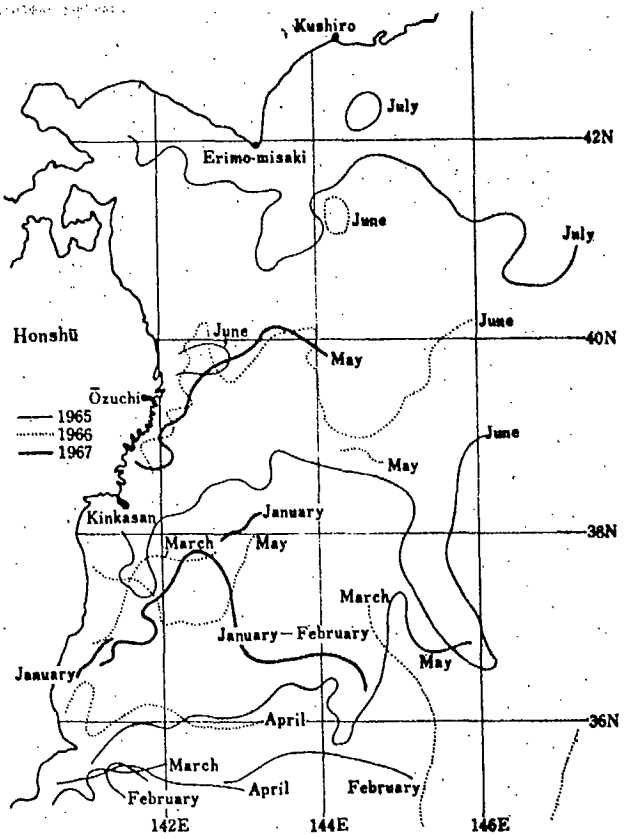

Fig. 12. Monthly variation of 15°C-isotherm (To) in 1965—1967 (from the data of Tōhokukaiku-Gyojō-kaikyō-Gaihō, 1965—1967).

Along the coasts of Sanriku and Joban to where 57
fur seals migrate, Oyashio (the Kurile current) and Kuroshio (the Black current) oppose each other. Therefore these areas have more complicated and active oceanographic conditions than those of the Japan Sea and the eastern Pacific Ocean also to where fur seals migrate.

Fur seals in the sea usually have their rest and sleep afloat from immediately after the sunrise and just before the sunset. At night they eat fishes and squids near the surface of water. Therefore it is considered

that they are influenced most strongly by the temperature of the surface water. When past observations and catches of fur seals are studied, it is found that they were not observed at water temperatures above 15°C. Therefore the occurrence of the 15°C-isotherm at the surface should be noted.

The strength of Oyashio (the Kurile current) and Kuroshio (the Black current) changes remarkably from year to year along the coasts of Sanriku and Joban. Here the changes in the oceanographic conditions from 1965 to 1967 are explained with special attention given to the isothermal line at 15°C (Table 15).

The 15°C-isotherm near the coasts of Sanriku and Joban in 1965 stayed in the area of 35°30'N from early February to the end of April. In May it began moving northward and at the end of May it reached the area 38°20'N. At the end of June the area to Shioyasaki had a 13°-15°C surface water temperature. In July the water temperature of the whole area of investigation rose above 15°C (Fig. 12)

In 1966 the rise in temperature of the investigated areas began somewhat earlier than the previous year. The 15°C-isotherm in April was at 36°20'N, in mid May it reached 39°N, 144°E and in early June it stretched out to 40°N along 142°50'E. By the end of June the surface water

temperature along the coast of Ozuchi was already above 58
15°C. From these facts the northward movement of the 15°C-isotherm after May in 1966 is considered to be about half a month earlier than the previous year.

In 1967 the 15°C-isotherm was most northerly of the three years and also it began its move to the north earliest. From January to March the 15°C-isotherm was around 37°N to 38°N. However, in May it was already at 40°N, 144°E.

1) Relationship between the distribution boundary of fur seals and the 15°C-isotherm

It is the author's opinion that there is a close relationship between the distribution boundary of fur seals and the 15°C-isotherm. The movement of the distribution boundary at the period of northward migration in 1965 and the period-of-stay I and II in 1966 and 1967 corresponds with the movement of the 15°C-isotherm. This indicates that fur seals seldom migrate to an area where the water temperature is above 15°C. However, each year fur seals were observed and caught in an area of water temperature greater than 15°C. They were very few in number compared with those in waters below 15°C (cf. Figs. 13, 14 and 15).

The distribution of fur seals in the waters above 15°C differed each year. The following is a detailed

explanation (Table 16*). The number of fur seals observed or caught in water above 15°C are the following. In 1965 the number of fur seals observed were 13 and of those caught 4. In 1966, the numbers were 68 and 27, respectively. In 1967, 56 and 12, respectively. In 1965, ten investigations were carried out in waters of 15°C and above from June to July in the area from the coast of Ozuchi to the coast of Kushiro (Fig. 13a-f). As shown in the figure, the 15°C-isotherm at the end of June stretched from 142°E to 145°E along latitude 39°N. The observations and catches on the 23rd and 24th of June were in waters below 15°C (Type B). A belt of density degrees III and IV was discovered, for example, along the coast of Ozuchi at the end of June to the north of the 15°C-isotherm around 39 N. Under these oceanographic conditions no fur seals were observed or caught in waters above 15°C. From mid July to the end of July most areas had temperatures above 15°C, however, a narrow belt of 13°-14°C stretched to the coast of Kushiro. Nine fur seals were caught in July. In water above 15°C four fur seals (females of one to four years respectively) were caught. In water below

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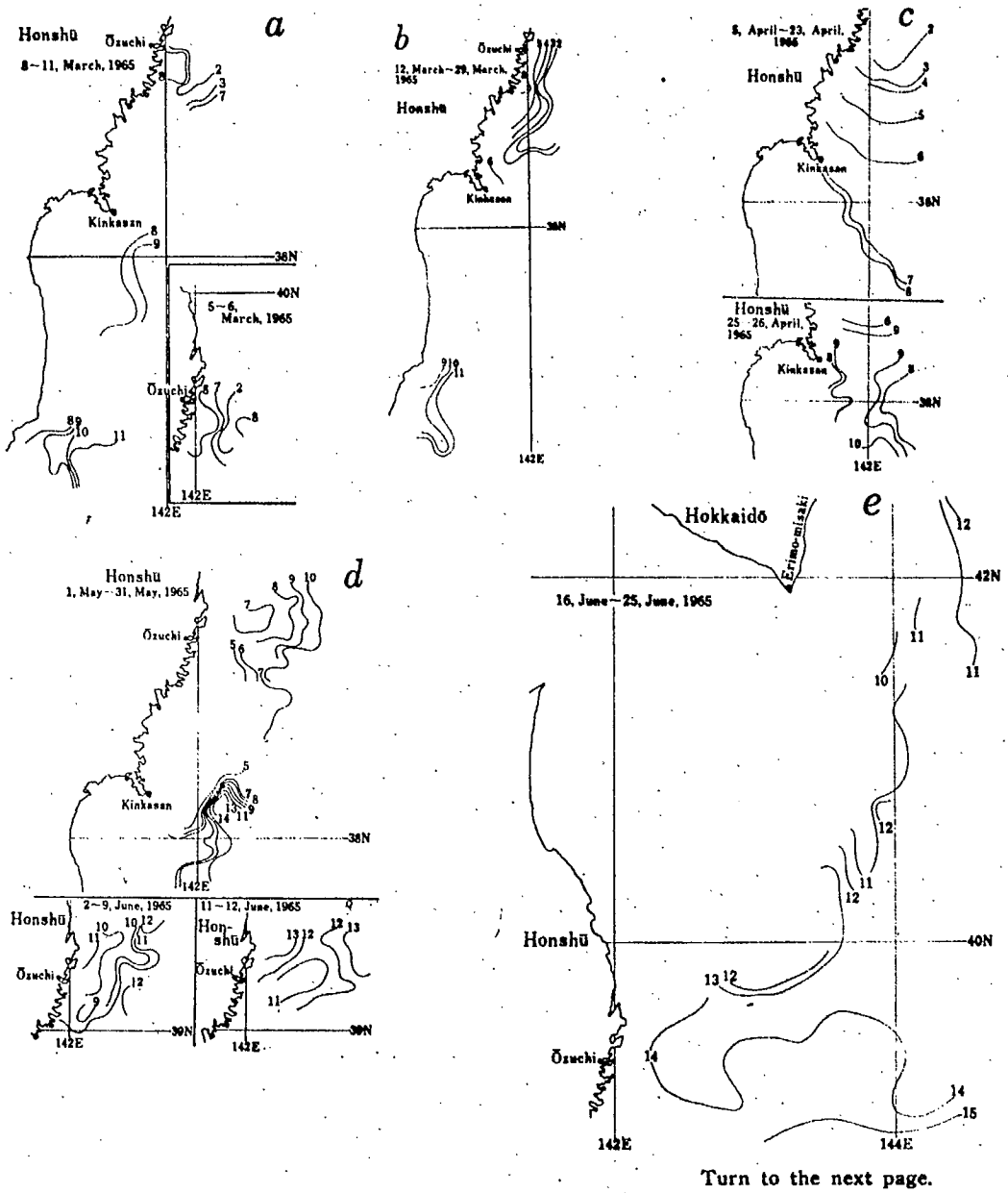
* The observations of fur seals made both in areas at temperatures above 15°C and below 15°C were divided into four types. A ... No fur seals were observed in either area. B and B' ... Fur seals were observed in water below 15°C. C ... Fur seals were observed in both areas. D ... Fur seals were observed in water above 15°C.

Table 16. Fur seal distribution in the two categories of water-areas with respective temperatures of >15°C, and <15°C.

	Date		Water of <15°C			Water of >15°C			Region surveyed	Type of appearance
			Distance surveyed	Fur seals observed	Fur seals collected	Distance observed	Fur seals observed	Fur seals collected		
1965	June,	23	55	22	6	25	0	0	Ōzuchi coast	B
		24	66	6	4	25	0	0	〃	B
	July,	13	55	0	0	0	0	0	Kurosaki c.	A
		14	30	3	3	80	9	1	〃	C
		15	10	0	0	109	3	2	Erimo-misaki c.	D
		16	37	1	1	35	0	0	Kushiro c.	B
		24	75	1	0	5	0	0	Erimo-misaki c.	B
		25	50	0	0	61	0	0	Kurosaki c.	A
		28	0	0	0	62	1	1	Ōzuchi c.	D
		29	0	0	0	60	0	0	〃	A
1966	March,	10	25	0	0	107	0	0	Kinkasan c.	A
		12	52	0	0	5	0	0	〃	A
	May,	1	51	105	9	55	3	2	Kesennuma c.	C…B′
		12	70	3	1	25	0	0	Kinkasan c.	B
		20	30	83	30	20	23	5	Ōzuchi c.	C…B′
	June,	4	34	19	3	60	1	0	Kesennuma c.	C…B′
		8	35	47	8	51	6	2	Ōzuchi c.	C…B′
		9	40	7	2	39	1	0	〃	C…B′
		14	55	27	15	7	0	0	〃	B
		14	40	9	6	19	1	0	Kesennuma c.	C
		15	15	2	1	37	5	5	〃	C
		22	71	7	2	55	7	0	Ōzuchi c.	C
		22	0	0	0	72	2	1	Kesennuma d.	D
		23	140	4	2	5	0	0	Kurosaki c.	B
		24	0	0	0	61	0	0	Kesennuma c.	A
		27	55	12	5	115	19	12	Ōzuchi c.	C
1967	January,	14	15	0	0	10	0	0	Onahama c.	A
		16	12	0	0	5	0	0	〃	A
	March,	2	45	0	0	8	0	0	Kinkasan c.	A
		3	7	1	0	25	0	0	Onahama c.	B
		8	10	0	0	15	0	0	〃	A
		9	61	5	0	5	0	0	Kinkasan c.	B
		12	44	31	26	5	0	0	Kesennuma c.	B
		21	39	0	0	5	0	0	Kinkasan	A
	April,	8	66	0	0	10	0	0	〃	A
		13	31	0	0	35	0	0	〃	A
		14	23	0	0	55	0	0	Kesennuma c.	A
	May,	12	35	17	8	40	33	5	Kurosaki c.	C
		23	170	38	23	27	17	4	〃	C
		26	0	0	0	26	0	0	Ōzuchi c.	A
		27	29	23	10	40	6	3	Kurosaki c.	C

A : Fur seals are not observed in water-areas of >15°C and <15°C.
B, B′ : Fur seals are observd in water-areas of <15°C.
C : Fur seals are observed in water-areas of >15°C and <15°C.
D : Fur seals are observed in water-areas of >15°C.

Fig. 13. Distribution of surface water temperature (°C) in 1965.



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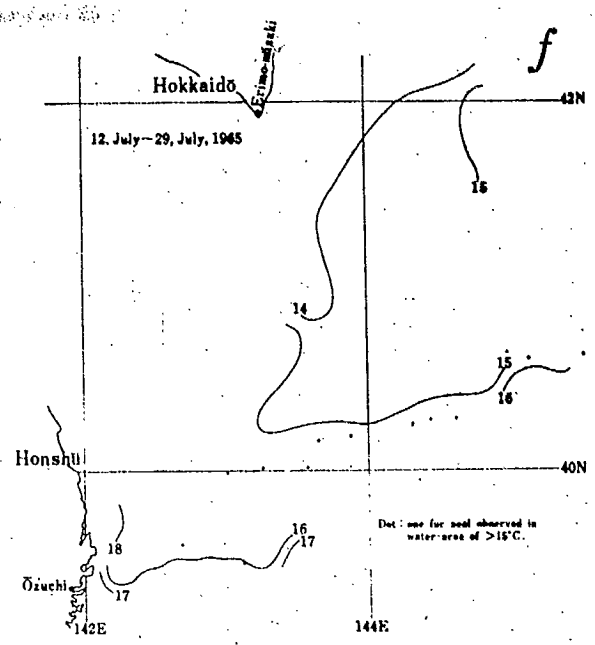

Fig. 13. Distribution of surface water temperature (°C) in 1965.

15° C five were caught (four females of two to three years and one female of four years). No differences were observed in the composition of fur seals at the boundary of the 15° C-isotherm. The density distribution in these areas was very low (degree II). No apparent differences were observed in the observations and catches per distance of sailing in the areas above and below 15° C. In July the temperature rose in almost all areas from the coast of Ozuchi to the coast of Kushiro and the density distribution decreased to degree II. Under these oceanographic and migratory conditions the fur seals distributed themselves in areas above 15° C where they did not gather when there were wide areas below 15° C.

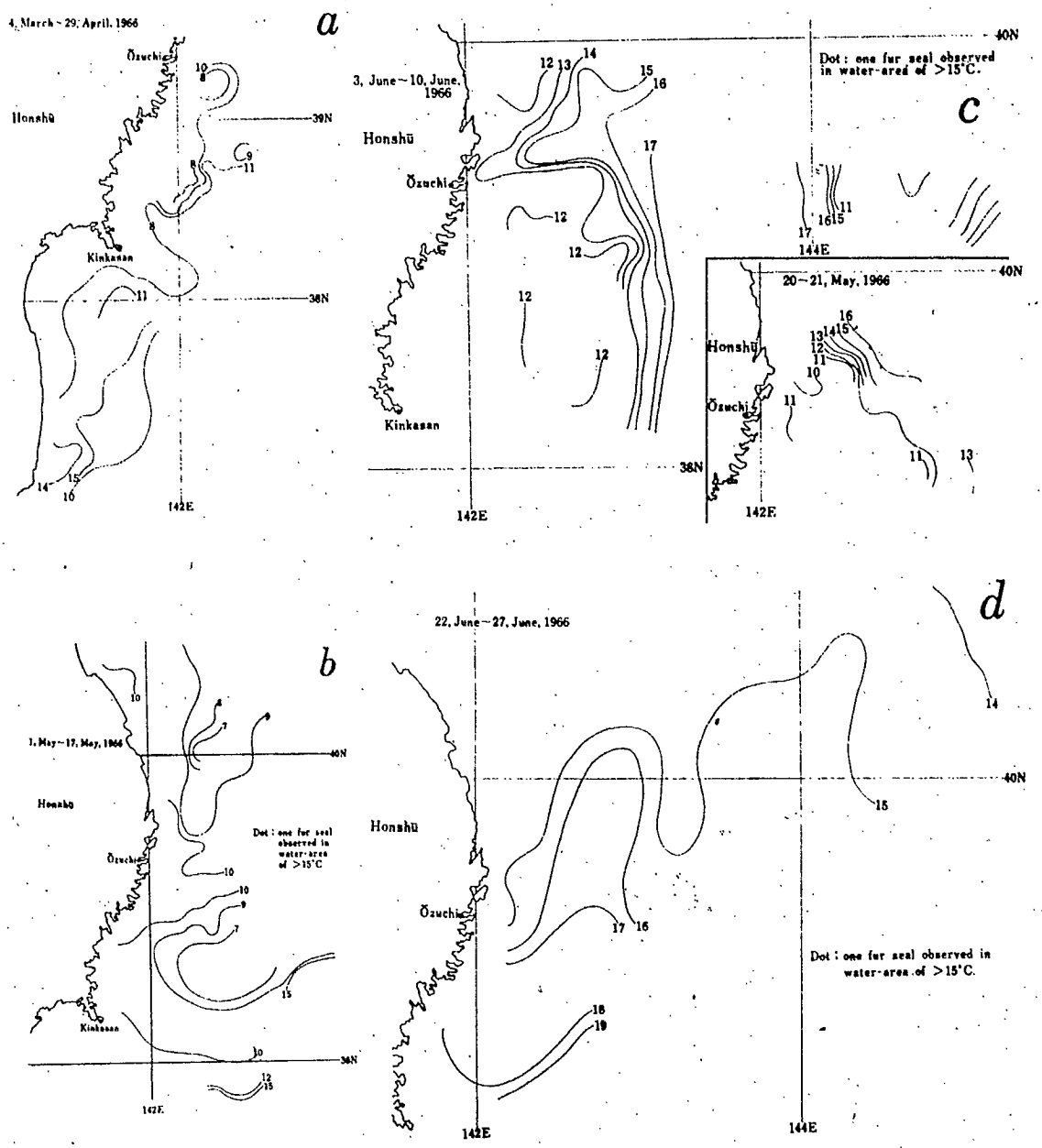

Fig. 14. Distribution of surface water temperature (°C) in 1966.

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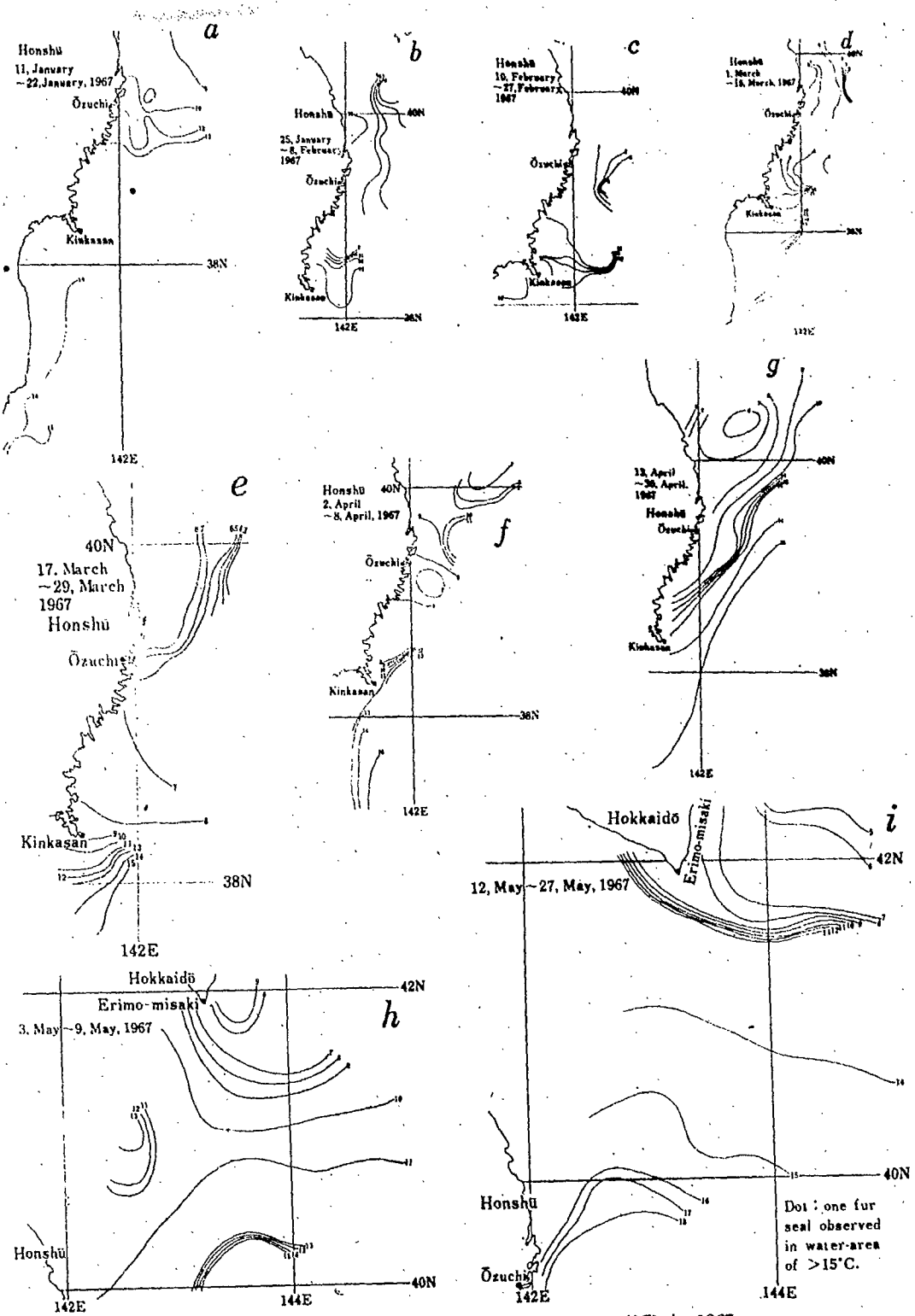

Fig. 15. Distribution of surface temperature (°C) in 1967.

In 1966 from March to June seventeen investi- 61
gations were carried out in the area above 15°C. The temperature of the area (Type A) in March was 12°-15°C. This is a high temperature for the time of year (Fig. 14a-d). In the Type C area from May to early June, all the observations in the area above 15°C were made near the boundary between the cold and the warm water masses. This was considered to be a similar type to Type B. Thus it was denoted as Type B'. Therefore there is no possibility of observing fur seals in waters above 15°C during March to early June. However, the 15°C-isotherm moved north of 40°40'N at 144°E from mid June and the density distribution lowered to degrees II and III. In this period, however, a few fur seals were observed even in waters above 15°C (Type C). Most of the fur seals observed were in the area of surface water temperature 15°-16°C (32 were observed and 27 were caught: one male yearling, five males of two to three years, seven females of two 62
to three years, six females of four to five years, seven females of six to ten years and one female of eleven+ years). For the waters above 15°-16°C, one animal was observed in water of 17.8°C and one in water of 19.0°C. Through the entire period most of the fur seals were observed in waters below 15°C and only a few were observed in waters between 15°C and 16°C.

In 1967, fifteen investigations were made in the all areas during the period from January to May. No fur seals were observed in waters above 15°C from January to April. Only few fur seals were observed in waters above 12°-14°C (Fig. 15a-i). Observations and catches in waters above 15°C were made only along the coast of Kurosaki in mid May and at the end of May. Of the twelve fur seals caught four were females of four to five years, seven were females of six to ten years and one was a female of eleven^{+} years. In this period the water temperature along the coasts of Kurosaki and Erimo rose to 13°-16°C. The density distribution was generally low and degree II with a few patches of degrees III to V. The fur seals listed above consisted of six animals in the 15°C-area and six in the 16°C-area.

A few characteristics were revealed during the three years of investigation: a) in the period-of-stay I and in the first half of the period-of-stay II, no fur seals were observed in waters above 15°C. Only a few fur seals were observed even in the warm water masses of 12°-14°C. b) When fur seals were observed in waters above 15°C, it was in the second half of the period-of-stay II and in the period of northward migration. In this period the water temperature rose to above 12°C and the density began to decrease. Most of the fur seals had begun to move

northward. c) In waters above 15°C most of the observations were made in waters between 15°C and 16°C. Only a few fur seals were observed in waters of 17°-19°C. d) The fur seals caught in waters above 15°C were all females. In 1965 and 1966 they were females of one to four years who stayed behind in the period of northward migration. In 1967 they were females of four+ years in the period-of-stay II.

From the facts stated above it is concluded that waters below 15°C are suitable for migration of fur seals. It is also concluded that under certain circumstances waters above 15°C are suitable for the migration of female fur seals. Therefore the temperature of 15°C is a critical temperature for fur seals in the adjustment of their body temperature.

2) Relationship between the water temperature 15°C as a critical temperature for the normal activities of fur seals, the water temperature around the breeding islands and the atmospheric conditions on the breeding islands

The explanation given in the previous section indicates that the water temperature 15°C is the limit at which fur seals can maintain their normal activities. This fact has also an importance in relation to the waters around the breeding islands where fur seals stay from

summer to autumn and also in relation to the atmospheric temperature on the breeding islands.

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Table 17. Monthly mean temperature(°C) of Commander Islands and Robben Island.

	Commander Islands			Robben Islsand	
Jan.	−3.5	July	8.7	July	14.0
Feb.	−3.9	Aug.	10.0	Aug.	14.7
March	−3.2	Sept.	9.1	Sept.	13.5
April	−1.0	Oct.	4.6		
May	2.0	Nov.	0.3		
June	5.1	Dec.	−2.4		

Commander Islands……1931-1960 mean temperature (WMO, 1967)
Robbeh Island……from data "The fur seal islands of the North Pacific Ocean" by D.S. JORDAN, 1898

Table 18. Monthly mean temperature(°C) of St. Paul (Pribilof islands).

	January	February	March	April	May	June	July	August	September	October	November	December
1957	−0.8	−6.6	−4.8	0.2	2.7	6.4	8.7	9.9	7.5	4.6	1.2	−3.3
1958	−7.3	−5.7	−0.8	0.3	2.0	5.8	7.8	8.7	7.1	3.8	1.1	−1.1
1959	−1.3	−0.4	−7.4	−2.1	1.7	4.6	7.1	9.3	7.2	4.3	2.1	−3.4
1960	−2.4	−3.1	−4.0	−7.9	1.0	4.3	8.0	8.4	6.5	3.0	−0.6	−1.1
1961	−2.6	−7.9	−7.4	−2.0	2.9	5.3	7.2	8.2	7.3	3.2	1.0	−5.5
1962	−6.7	−1.7	−3.2	−0.2	1.0	4.8	8.2	8.6	5.7	2.3	0	−2.7
1963	−1.0	−6.0	−1.6	−1.5	2.3	4.6	7.4	8.0	6.7	2.2	−1.3	−1.2
1964	−3.1	−9.2	−5.1	−1.5	1.3	5.5	7.2	8.2	6.2	2.9	−0.4	−1.3
1965	−5.3	−8.6	−4.3	−1.3	0.4	4.3	7.1	8.1	6.7	2.0	1.3	−2.5
1966	0.3	−0.9	−5.7	−2.4	0.9	4.9	7.6	8.3	6.8	0.2	1.6	−2.4

From local climatological data, 1966, U.S. Department of Commerce

The surface water temperature is 8°-12°C during July-September around Robben Island and the Commander Islands (Зенкевич, 1963). The atmospheric temperature on these islands is low. The highest temperatures (monthly mean) occur in August on Bering Island among the Commander Islands (10.6°C) and on Robben Island (14.7°C) (cf. Table

17). The highest temperature (monthly mean) on St. Paul Island among the Pribilof Islands is also in August. However, it does not exceed 10°C (Table 18). It is foggy on the breeding islands of fur seals from spring to summer and atmospheric temperature stays low. The water temperature around the breeding islands is below 12°C during the summer and autumn. The highest temperature in the monthly mean is below 15°C in each breeding island. Front and hind flippers of fur seals have well developed sweat-glands and blood-vessels. They are considered to play an important role in the diffusion of heat when fur seals are on the breeding island (Bartholomew and Wilke, 1956). From the observations made by the author in 1965 on Mednui Island (the Commander Islands), when the sun began to shine all the fur seals began to move their hind flippers. Some of them went into the sea. According to Bartholomew (1956) when the atmospheric temperature rises above 12°C some females start to enter the sea.

Below 15°C in the sea and below 12°C on land are considered to be the most suitable temperatures for the fur seals. When both the water and atmospheric temperatures go higher than those stated above, it is difficult for fur seals who are covered with dense fur to make a normal adjustment of their body temperature. It is considered that the Commander Islands and the Pribilof

Islands are located within the boundaries of best suited water and atmospheric temperatures, and Robben Island very close to the boundary.

3) Relationship between the migration of fur seals in the period-of-stay I and II in 1967 and the surface water temperature 65

The changes in the oceanographic condtions were divided into five parts according to the surface water temperature measured from the investigating boat. The relationship between the temperature and the migration of fur seals is discussed below.

January 11-22: at the south of the coast of Kesennuma the surface water was above 13°C and very few fur seals were observed. Along the coast of Ozuchi the surface water was between 9°-10°C (Fig. 15a). A low density (II) of females of four+ years was found in the area (Fig. 7a).

January 25-March 15: the surface water temperature lowered to 9°C along the coast of Kesennuma at the end of January. The transition area of water 9°-12°C was observed. The temperature decreased to 8°C along the coast of Ozuchi from mid February and to 6°C in March. A stretch of water of 6°C was observed also along the coast of Kesennuma in March. The temperature was lowest in 1967 in this period (Fig. 15b, c and d). The temperature changed gradually along the coasts of Kesennuma and Ozuchi. A change

in the migration of fur seals was observed corresponding with the changes stated above. In this period a high density of females of four+ years was observed along the coast of Kesennuma. Females of six+ years were observed close in a high density area. However, along the coast of Ozuchi they were observed only in a low density area. 66 This indicates that fur seals concentrate in the transition area where a steep gradient of water temperature exists.

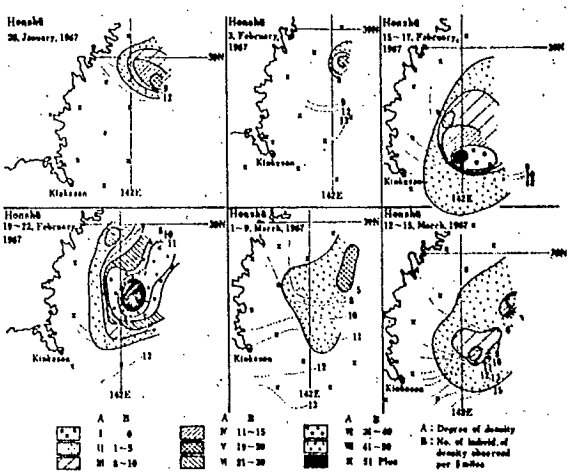

Fig. 16. Relation between surface water temperature(℃) and density of fur seal population.

The locations of the high density areas were concentrated on the coast of Kesennuma. They changed in accordance with the change in the oceanographic conditions of this area (Fig. 16). As the transition area of water of 9°-12°C moved from the south to the north of the coast of Kesennuma, the high density areas of fur seals also

moved always with the water areas below 9° C. This transition area reached the south of the coast of Kesennuma in mid February and stayed there till mid March. This yielded a favourable condition for females of four+ years to stay, that is, the period-of-stay I. In this area the lowest temperature of the investigation between 4°-5° C was observed. It was stated previously that the spacings of the isograms of the density distribution narrow off shore. It is apparent that this is the evidence of the transition area.

Several characteristics are revealed when the relationships between fur seals at each developmental stage and the surface water temperature are studied. Females of four+ years were comparatively numerous. Females of six+ years concentrated in high density areas and were found mostly in water between 8°-12° C. The distribution of water temperature along the coasts of Kesennuma and Ozuchi did not indicate any tendencies dependent on a developmental stage or a sex distinction. However, the appearance of water of 5°-6° C in both areas almost coincided with the appearance of yearlings, males and females of two to three years and males of four+ years. Only females of four+ years were observed in January and the water temperature was not between 5°-6° C. In early February, when the water temperature became 6° C along the

coast of Ozuchi, males and females of two to three years and some males of four^{+} years appeared in both areas (11.4 % of the total catch per day along the coast of Kesennuma, 12.7 % along the coast of Ozuchi). In mid February and at the end of February a water of temperature 5°C was observed close to the shore at 39° N. The percentages given above changed to 22.9 % along the coast of Kesennuma and along the coast of Ozuchi to 30.5 %. In early and mid March when the area of water betwee 5°-6°C became more than half of both areas the figures changed to 22.7 % and 39.2 % respectively (Fig. 2c). From these facts it can be said that the appearance and expansion of areas of 5°C water and the appearance and increase in numbers of yearlings, males and females of two to three years and males of four^{+} years almost coincide. There are some characteristics to be observed in the composition of the herds. In February and March 84.2 % (mean) of animals were two to three years old. Females were predominant (67.0 %) in February and males were predominant (70.1 %) in March. The same phenomenon was observed among yearlings. Females were 65.1 % in February and males were 94.8 % in March. The trend in the sex ratio was observed to be related to the predominance of 5°C water in both areas.

March 17-May 27: the transition area of water

between 9°-12°C stayed at the south along the coast of Kesennuma for about a month and a half from early February. This yielded partially a condition favourable for females of four+ years. However, the 15°C-isotherm began moving northward from mid March (Fig. 15e-i) and the density distribution of fur seals began to change accordingly. This indicates that fur seals entered the period-of-stay II.

The high density areas which appeared along the coast of Kesennuma in February and March were also observed along the coast of Kurosaki from the end of April to early May. In the process of the movement of fur seals (Fig. 7b and c) which was effected by the rise in temperature along the coasts of Kesennuma and Ozuchi, high density areas (IV-VI) appeared (April 2, 6, 8 and 14 along the coast of Ozuchi) continuously in the narrow area close to the coast. These high density areas were in the cold 67
water masses which were within the limits of the transition area of water between 8°-12°C. The relationship between the high density areas of females of four+ years and the water temperature is considered to be basically the same as for females four+ years as described above for the period-of-stay I. The high density areas at the period-of-stay II are not stationary with respect to one definite water. This indicates that oceanographic condtions have changed drastically compared with the coast of Kesennuma

from early February to mid March.

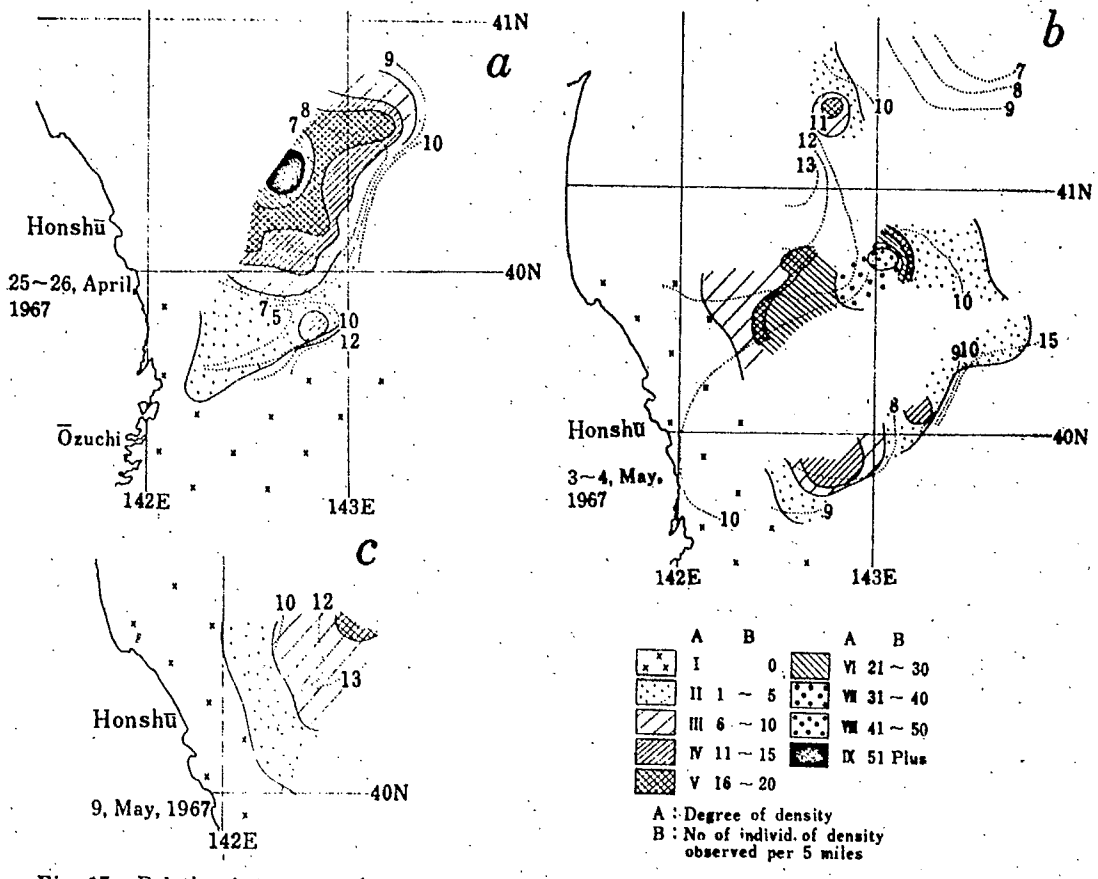

Fig. 17. Relation between surface water temperature (°C) and density of fur seal population.

Yearlings, males and females of two to three years and males of four+ years reached 53.9 % of the total catch per day, a large increase when compared with the percentage in the period from January to mid March. The percentage of animals of two to three years decreased in number and that of yearlings and males of four+ years increased. Males were predominant among yearlings (84.9 %) and among animals of two to three years (71.9 %). Males of two to three years and four+ years (9.4 %) increased in this

period.

The oceanographic conditions were nearly stable along the coast of Kurosaki from the end of April to early May. The high density areas of fur seals along the coast of Kurosaki were more widespread and more stable than those along the coast of Kesennuma (Fig. 17). High density areas which went up to degree IX were located between the southerly transition area of water between 10°-15°C-and the 12°- and 13°C-isotherms running from the Straits of Tsugaru. Females of four+ years constituted 67.9 % of the total catch per day. This indicated an increase in numbers over those found along the coast of Ozuchi in early and mid March. At the north along the coast of Ozuchi from the end of April yearlings, males and females of two to three years and males of four+ years were 37.6 % of the total (mean). In these animals, yearlings and animals of two to three years constituted 75.0 %. Females were predominant in both cases (80.8 % in yearlings and 60.0 % in animals of two to three years). Thus the percentages returned to those observed in January and February. This corresponded to a rise of the surface water temperature from 5°-6°C to 8°-12°C.

The relationship between the migration of fur seals in 1967 and the water temperature was explained roughly above. Several characteristics were revealed: a) in the

period-of-stay I fur seals were not observed in water of 12°C and above. In early May along the coast of Kurosaki 68 many fur seals were observed in waters between 12°-15°C. b) The high density areas (females of four+ years are predominant) appear in the transition area between cold and warm water masses. The high density areas lie nearer the cold water masses. Therefore from January to the end of March along the coast of Kesennuma when the transition area approached the shore the high density areas also approached the shore. This was in fact the closest approach of the whole investigation. c) The area where the density gradient of the high density areas is greatest coincides with that of the transition area. d) The stationary nature of the high density areas in a definite water corresponds to the changes in the oceanographic conditions. When the oceanographic conditions are comparatively stationary the high density areas also are stationary. e) The increase and decrease of the number of yearlings, males and females of two to three years and males of four+ years are in accordance with the appearance, expansion and disappearance of waters of 5°-6°C. The water temperature in this case does not influence the distribution of fur seals directly. Females of four+ years are always found in water of this temperature. f) When the area of water of 5°-6°C expands the number of male yearlings and males of

two to three years and four+ years increase. The period is from early March to mid April along the coast of Sanriku. Before and after this period females are predominant in each case.

4) Relationship between the migration of fur seals in 1965 in the periods-of-stay I and II and the period of northward migration

In 1965 a branch of Oyashio (the Kurile current) approached the coast of Sanriku most closely for the three years of investigation. Huge cold water masses were found off the coast of Joban in April. Therefore fur seals moved more southward and reached the coast of Choshi. The period was divided into two parts in accordance with the oceanographic conditions.

March 3-April 26: a branch of Oyashio (the Kurile current) approached the coast of Sanriku very closely in March and stretched to the coast of Joban in April. The water temperature became 2°-6°C (Tohoku kaiku gyoba kaikyo gaiho (The oceanographic report on the fishing grounds in the Tohoku sea region) March-April, 1965). According to the material the author obtained in the investigation, the area of low temperature reached its greatest extent along the coast of Sanriku in early April (Fig. 13c).

In mid and at the end of March the area of water of 8°-11°C covered the coasts of Onahama and Kinkasan

(Fig. 13a and b). Densities of degree III-VI appeared (Fig. 8a). In both areas the transition area of water between 9°-12°C appeared along the coast of Kesennuma in 1967 was not found. This could be the reason why the comparatively low densities prevailed.

However, in the period-of-stay I in 1965, it was supposed that the high density areas in which females of four^{+} years are predominant such as the ones appeared along the coast of Kesennuma in 1967 appeared in the south of the coast of Onahama. In the middle and the end of April the transition area of water between 10°-15°C appeared not near the coast but near Inubo-zaki. This yielded almost the same oceanographic condition as that along the coast of Kesennuma in 1967. Moreover at the end of April there was a report, "fur seals were sighted in many places", in water of 8°-10°C for about 70 miles from 60 to 130 miles east of Inubo-zaki (Makiami gyokyo sokuho (Current report on seine fishing), 3, 1965). Along the coast of Onahama in March females of four^{+} years were predominant (71.7 % of the total daily catch). Therefore the appearance of transition areas of 9°-12°C water or 10°-15°C water in the period of southward migration and in the periods-of-stay I and II has a correlation with the appearance of high density areas of females of four^{+} years. It is thus considered that the investigated area along the coast of

Onahama in March, 1965 was north of the high density areas of females of four^{+} years.

In early and mid March a transition area of water between 2°-8°C was observed along the coast of Ozuchi (Fig. 13a and b). The density distribution along the coasts of Kesennuma and Ozuchi from March to April was generally low (degree I or II).

In both areas from March to April only male fur seals remained. The male predominancy corresponded closely with the decrease of the temperature and the expansion of water of low temperature. In early March the water along the coast of Sanriku was 8°C. Females of four^{+} years were 28.6 % (the coast of Kesennuma) and 49.6 % (the coast of Ozuchi). Yearlings and males of four^{+} years constituted 14.3 % each along the coast of Kesennuma. Along the coast of Ozuchi yearlings and males of four^{+} years were 4.1 % and 9.5 % each. In both areas yearlings and animals of two to three years constituted about half of the total catch per day. Males made up about 67 % of animals of two to three years (Fig. 2a).

From mid March the area of water of 2°C began to expand along the coast of Sanriku. In early April it expanded further and covered the coasts of Kesennuma and Ozuchi. This condition continued on to mid April. With the decrease in the water temperature females of four^{+}

years decreased to less than 10 % of the total and yearlings and animals of two to three years increased to more than 80 %. The sex ratio changed from early March. Males increased to more than 80 % of both yearlings and animals of two to three years and in some areas reached almost 100 %.

The predominancy of males in yearlings and animals of two to three years from March to April along the 69
coasts of Kesennuma and Ozuchi should not be considered as an increase in numbers. The males have remained in low density areas along both coasts during the southern migration of females of four^{+} years and also as individuals who followed the southern migration of females of four^{+} years.

From these facts it is apparent that males and females are separated into groups to the north and to the south of the coast of Kinkasan. This phenomenon has a close relationship with the oceanographic condition. The segregation of sexes in the distribution is not clear in the early developmental stages. The segregation of sexes becomes more apparent with advancing developmental stages. Yearlings had been already caught in March along the coast of Onahama. However, the segregation of sexes appeared from mid March to mid April along the coast of Ozuchi where males reached 81.2 %. Animals of two to three years were about 29 % (mean) of the total catch from March to

April along the coasts of Onahama and Kinkasan. Along the coast of Onahama females made up about 56 % (mean) of the total catch. From mid March to mid April along the coasts of Kesennuma and Ozuchi animals of two to three years were about 60 % of the total catch and males were over 90 % of these. Females of four^{+} years were predominant as already stated above. However, very few males of four^{+} years were observed along the coast of Sanriku. Thus the segregation of sexes is obscure among yearlings, apparent among animals of two to three years and becomes typical among animals of four^{+} years.

Males move to the south and females to the north. Their relationship with the water temperature is not apparent. It is not clear that males in the south are in an area of low temperature and females in the north in an area of high temperature. This phenomenon also occurred in the process of the decrease in the prevalency of females of four^{+} years in 1967 along the coast of Kesennuma. 70 It is considered that the segregation of developmental stages or of sexes is related more to the movement of water masses as a whole than to the water temperature in a small area.

May 1-July 29: the oceanographic condition began changing rapidly in May. The branch of Oyashio (the Kurile current) which was close to the shore moved southward to

38.5°N, 142.8°E. The warm water masses stretched to 41.5°N along 143°-145°N. Thus the water temperature rose generally along the coasts of Sanriku and Joban. Especially the coast of Joban was enclosed with a warm water mass above 15°C. In mid June the water along the coasts of Ozuchi and Kurosaki rose to 12°C and in July to 15°C (Fig. 13d, e and f).

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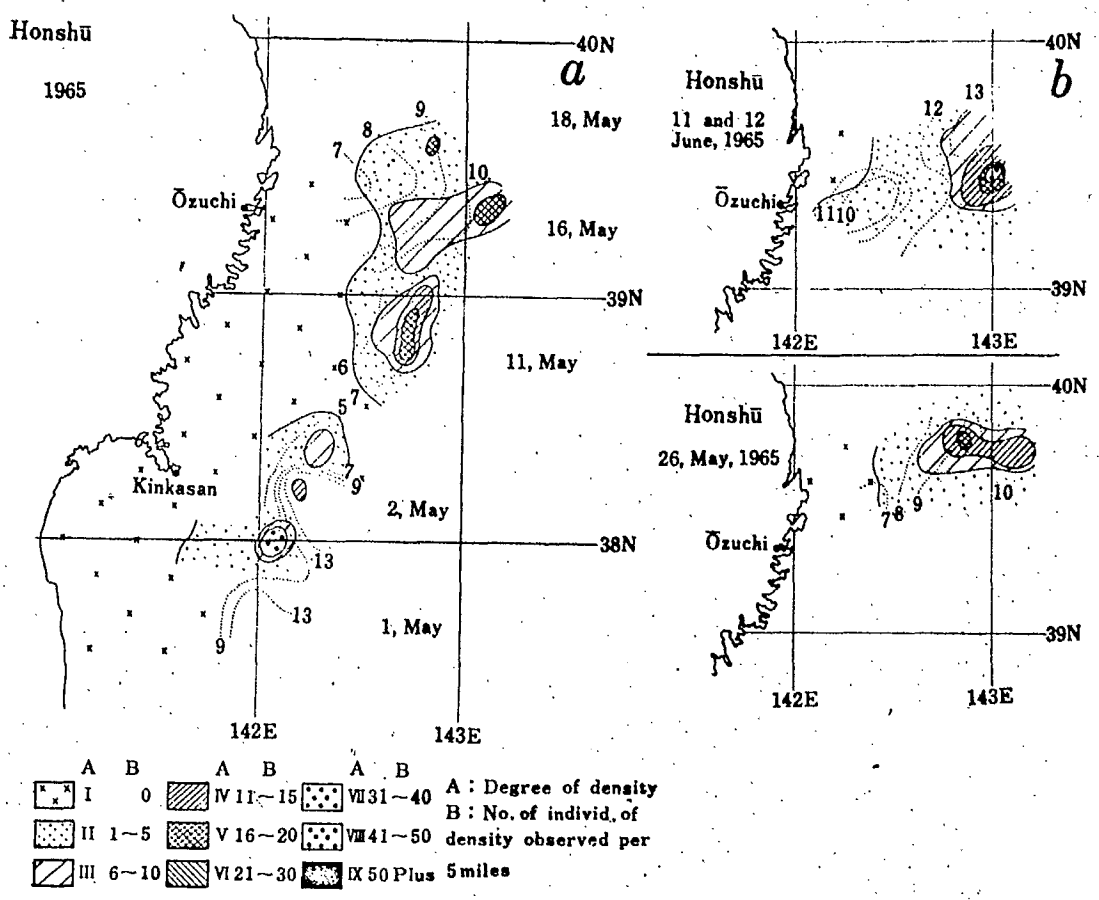

Fig. 18. Relation between surface water temperature (°C) and density of fur seal population.

Corresponding to the changes in the oceanographic condition the migration of fur seals entered the 70

period-of-stay II. The high density areas of degrees III-VII appeared along the coasts of Kesennuma and Ozuchi which were the low density areas in March and April (Fig. 18a and b). The high density areas appeared in May and June in both areas around 143° E, that is, the boundary between the warm water masses and Oyashio (the Kurile current). The high density areas appeared on the side of Oyashio (the Kurile current) in each case. As it was indicated in the migration of fur seals in 1967, females of four^{+} years especially concentrated in these high density areas. Moreover, the tendency was revealed that male yearlings, males of two to three years, four to five years and six to ten years also distributed in areas of density of degree greater than III (Table 11). This has a relationship with the oceanographic condition in that the water of temperature suitable for fur seals was confined to the coastal area by the warm water masses moving northward along 143° E. However, the high density distribution of females of four^{+} years was stationary. Thus it is considered that females of four^{+} years migrate northward in masses through the areas with a low density of males and females of yearlings and two to three years and males of four^{+} years.

Male and female yearlings and males and females of two to three years and males of four^{+} years decreased

in percentage with the increase of females of four^{+} years. On the other hand the numbers of male and female yearlings, males and females of two to three years, males of four^{+} years and the total catch increased when the high density areas were present. The prevalency of these fur seals in March and April was in accordance with the appearance and expansion of the water of 2°C. However, it appears that their decrease in percentage from May does not have any relationship with the disappearance of the water of 2°C. The sudden decrease in numbers and the disappearance of males of four^{+} years indicated their close relationship with the disappearance of the water of 7°-10°C. After the high density areas of degrees III-VII appeared in waters of 10°C along the coast of Ozuchi on June 11 and 12, the high density areas were not observed to the north of the coast of Ozuchi where the water temperature rose to 13°-15°C.

The percentage of animals of two to three years from mid September was increased by the northward migration of males and females of four^{+} years. They were in the areas of low density, remained in waters of 15°-16°C and became the last herd of migration.

The migration of fur seals in 1966 was basically the same as that of 1965. Therefore it is not explained here in detail.

Several characteristics were revealed from the observation of migration of fur seals in 1965: a) the prevalency of females of four^{+} years which occurred in 1967 along the coast of Kesennuma is cosidered to have occurred along the coast of Choshi in 1965. b) To the north of the boundary of the high density areas of females of four^{+} years, the prevalency of male yearlings and males of two to three years in low density areas becomes remarkable. This coincides with the appearance and expansion of water area at 2°C. c) The segregation of sexes in the distribution has a close relationship with the movement of water masses as a whole rather than with the water temperature in a particular area. d) The prevalency of male yearlings and males of two to three years disappears with the northward migration of females of four^{+} years. However, they increase in number. e) The decrease in numbers of male yearlings and males of two to three years and disappearance of males of four^{+} years have a close relationship with the disappearance of water of 7°-10°C.

5) Relationship between the oceanographic condition and the high density areas

The relationship between the high density areas of fur seals and the boundary between the cold and warm water masses is discussed in the following. The typical

high density areas whose main components were females of four+ years appeared in the following locations and time: along the coast of Ozuchi on May 1, 2, 20 and 21 in 1966 (Fig. 19a and b), along the coast of Kesennuma on February 21 and 22 in 1967 and along the coast of Kurosaki on April 26 and May 4 in 1967.

In February 1967 along the coast of Kesennuma the high density areas were adjacent to the cold water masses of the transition area between the cold and warm water masses. In 1965 to the south of the coast of Onahama the high density areas were considered to be adjacent to the north side of the transition area between the cold and warm water masses. However, when fur seals enter the period-of-stay II, the high density areas in the transition zone are on the cold water side but remain apart from the cold water mass.

Along the coast of Sanriku from January to April there was only a small difference in the water temperature at the surface and at a depth of 100 m. However, from May the water temperature at the surface rose considerably relative to at 100 m. This change is considered to affect the density distribution. In the 71
period-of-stay I, the difference in the water temperature at the surface and at a depth of 100 m was small. The high density areas at this time were closely

adjacent to the transition zone between the cold and warm water masses. However, in the period-of-stay II, the high density areas did not coincide with those of period-of-stay I probably because of the large difference in the water temperatures at the surface and at 100 m.

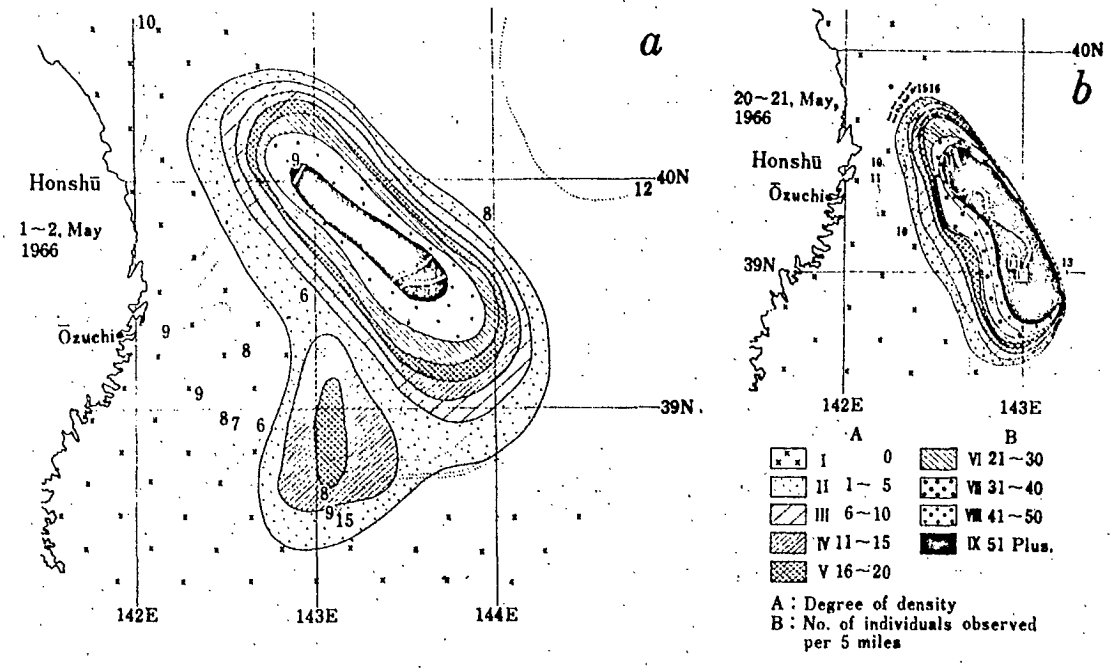

Fig. 19. Relation between surface water temperature (°C) and density of fur seal populaton.

6) Influence of the oceanographic conditions around the breeding islands on fur seals migrating to the coast of Sanriku

When the yearly changes in the numbers of fur seals are studied, it may be noted that sometimes a particular year class has a distinctive characteristic. This is considered to be caused by the change in the mode

of migration which is affected by an abnormal mortality of pups on the breeding islands.

The catch of yearlings in 1966 and animals of two years in 1967 were much less than usual. This is considered to be caused by the high mortality of pups in 1965. Most of yearlings and animals of two years migrating to the coast of Sanriku are Asiatic and more than half of them are from Robben Island (cf. Table 42 and 43, p. 53, Kita-taiheiyo ottosei iinkai chosa hokoku (North pacific fur seals committee research report 1958-1961). Therefore the change in the 1965 year class along the coast of Sanriku was affected chiefly by the mortality of pups on Robben Island.

According to the annual report issued by U.S.S.R. (1965), the drift ice around Robben Island stayed till early June in 1965. Some of the pups were born on the ice or in the sea and died. In mid June a part of the rookery was washed by high waves and many pups died. The number of dead fur seals reached 20,286. The mortality was 41.9 % of the total. This was the highest mortality since 1957 (10.0-17.8 % during 1957 and 1964). On the Commander Islands the rookery was washed by high waves. The mortality was somewhat higher (14.2 %) than in an average year (12-13 %).

The number of yearlings and animals of two years decreased because of this abnormally high mortality. Thus it was considered that the fur seals migrating to the coast of Sanriku also decreased. Yearlings and animals of two years distribute themselves dispersively. Therefore it is not possible to consider that there is an area of concentration other than the investigated areas. Thus it is assumed that the high mortality of pups on the breeding islands affects the number of fur seals migrating to the coast of Sanriku.

7. Relationship between the food habits and the mode of migration of fur seals 72

From the previous chapter it is apparent that the migration of fur seals has a close relationship with the water temperature. The water temperature has also a certain relationship with the distribution of fishes and sqids which are food for fur seals. In this chapter the relationship between the mode of migration of fur seals and the ecology of prey is discussed through the analysis of stomach contents of fur seals.

The following are the methods taken for the analysis of food habits. The collection of stomach contents: firstly, after a fur seal is caught at sea, the cardiac orifice and the pylorus of a stomach are tied by strings and put into 10 % solution of formalin; secondly,

the stomach is opened on land and its contents are separated according to the kind of prey and measured by a mess cylinder; thirdly, the degree of digestion is written down. In the stomach there are beaks and cartilages of squids, bones and otoliths of fishes. Therefore it is possible to determine the species of prey from the contents of the stomach. When the degree of digestion is not advanced, sometimes the number of individuals can be determined.

Thirteen kinds of prey were collected in the three years. The prey which are eaten in great quantity or eaten occasionally (8 kinds) are common every year. The most common squids are Watasenia scintillans and Todarodes pacificus. The most common fishes are Notoscopelus japonicus and Diaphus sp. of Myctophidae, Laemonema longipes, Scomber japonicus, Engraulis japonica and Theragra chalcogramma (Table 19). 73

1) General view of variations in food habits from 1965 to 1967

Several characteristics in food habits of fur seals in the three years of investigation are indicated below.

Food habits in 1965 (Fig. 20*): a) Watasenia

* Beaks and cartilages of squids and bones and otoliths of fishes in one stomach were counted as one appearance of the species. The total appearances of prey according to

scintillans was abundant in March along the coast of Onahama. It constituted 30-55 % of the stomach contents of fur seals caught on one day. It was found in smaller quantity during March to early June in the area north of the coast of Kinkasan to the coast of Ozuchi. It was not found to the north of the coast of Kurosaki. b) Squids were found all the time regardless of time and space. Moroteuthis sp., Gonatopsis borealis and Todarodes pacificus are considered to be most common squids. Only a few squids were found along the coasts of Kesennuma and Ozuchi in March and April. However, they occurred at a rate of 33-100 % along the coast of Ozuchi from mid May and in the area from the coast of Kurosaki to the coast of Kushiro in June and July. They were the most abundant of the prey. c) Diaphus sp. were found regardless of time and space. They occurred at a rate of 50-100 % along the coasts of Kesennuma and Ozuchi from mid March to mid April. d) Notoscopelus japonicus was found in all the areas of investigation. They occurred at a rate of 42-84 % along the coast of Kinkasan from mid March to early May. The rate was almost zero along the coast of Kesennuma and along the coast of Ozuchi in March and April. The rate was 13-63 % along the coast of Ozuchi from mid

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species per day is given in percentage.

May to the end of June. This indicates that the lower the percentage of Diaphus sp. the higher the percentage of Notoscopelus japonicus. e) Scomber japonicus was often found along the coast of Ozuchi and occasionally along the coast of Onahama in March and along the coast of Kesennuma. The fish were young and about 20 cm long in each case. f) Theraga chalcogramma was occasionally found in the area from the north of the coast of Onahama to the coast of Ozuchi in March and April.

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Table 19. List of stomach contents of fur seals, 1965—1967.

◎ *Diaphus* sp. (Myctophidae)	◎ *Watasenia scintillans*
◎ *Notoscopelus japonicus*	◎ *Todarodes pacificus*
◎ *Scomber japonicus*	• *Gonatopsis borealis*
● *Engraulis japonica*	● *Moroteuthis* sp.
● *Cololabis saira*	
• *Hemiramphus sajori*	
• Salmonidae	◎ : very often
● *Theragra chalcogramma*	● : frequently
◎ *Laemonema longipes*	• : rarely

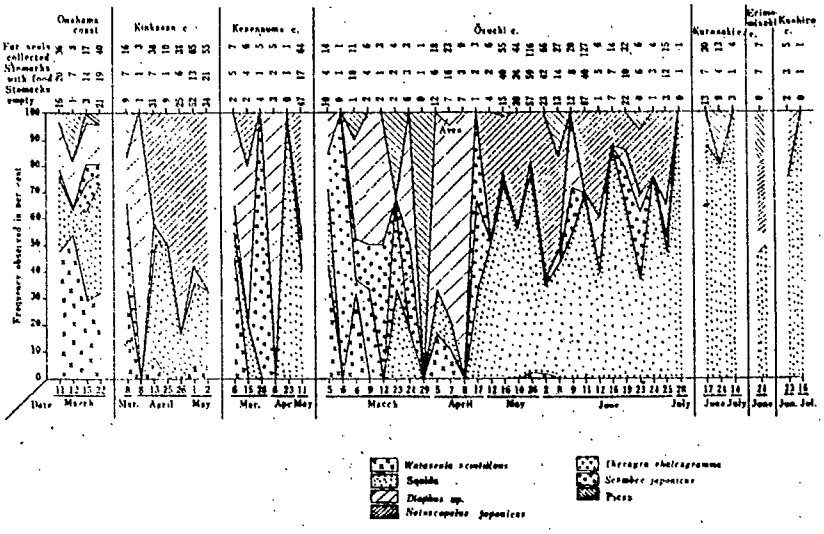

Fig. 20. Stomach contents of fur seals in 1965. (frequency observed of foods of total stomachs per day).

Food habits in 1966 (Fig. 21): a) a predomi- 73
nancy (30-50 %) of Watasenia scintillans was observed along the coast of Kinkasan in March. b) Squids were predominant always everywhere. c) No predominance occurred in Diaphus sp. It was scarce. d) Notoscopelus japonicus was found continuously (20-60 %). e) The appearances of Theragra chalcogramma, Laemonema longipes and Scomber japonicus were few.

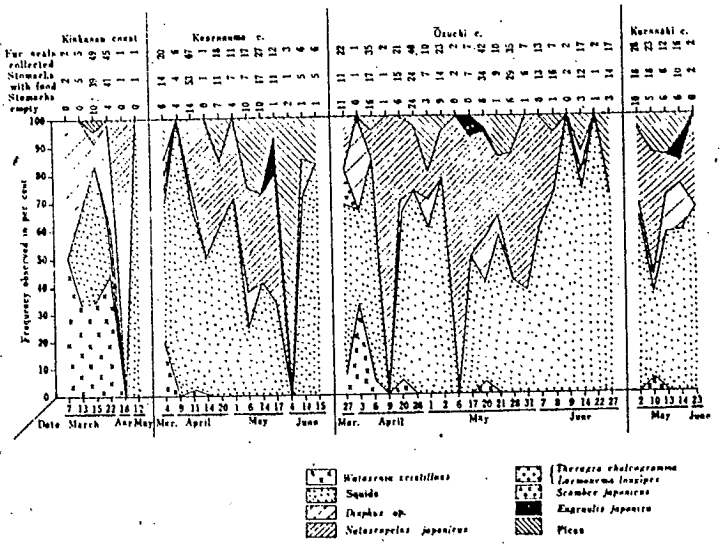

Fig. 21. Stomach contets of fur seals in 1966 (frequency observed of foods of total stomachs per day).

Food habits in 1967 (Fig. 22): a) Watasenia 74
scintillans was found in the area from the coast of Kinkasan to the coast of Kurosaki from January to April continuously. It sometimes occurred at a rate of about 50 %. b) Squids were found always everywhere. They were predominant in May along the coast of Kurosaki. c) The

frequency of appearance and the quantity of Diaphus sp. were the least of the three years of investigation.

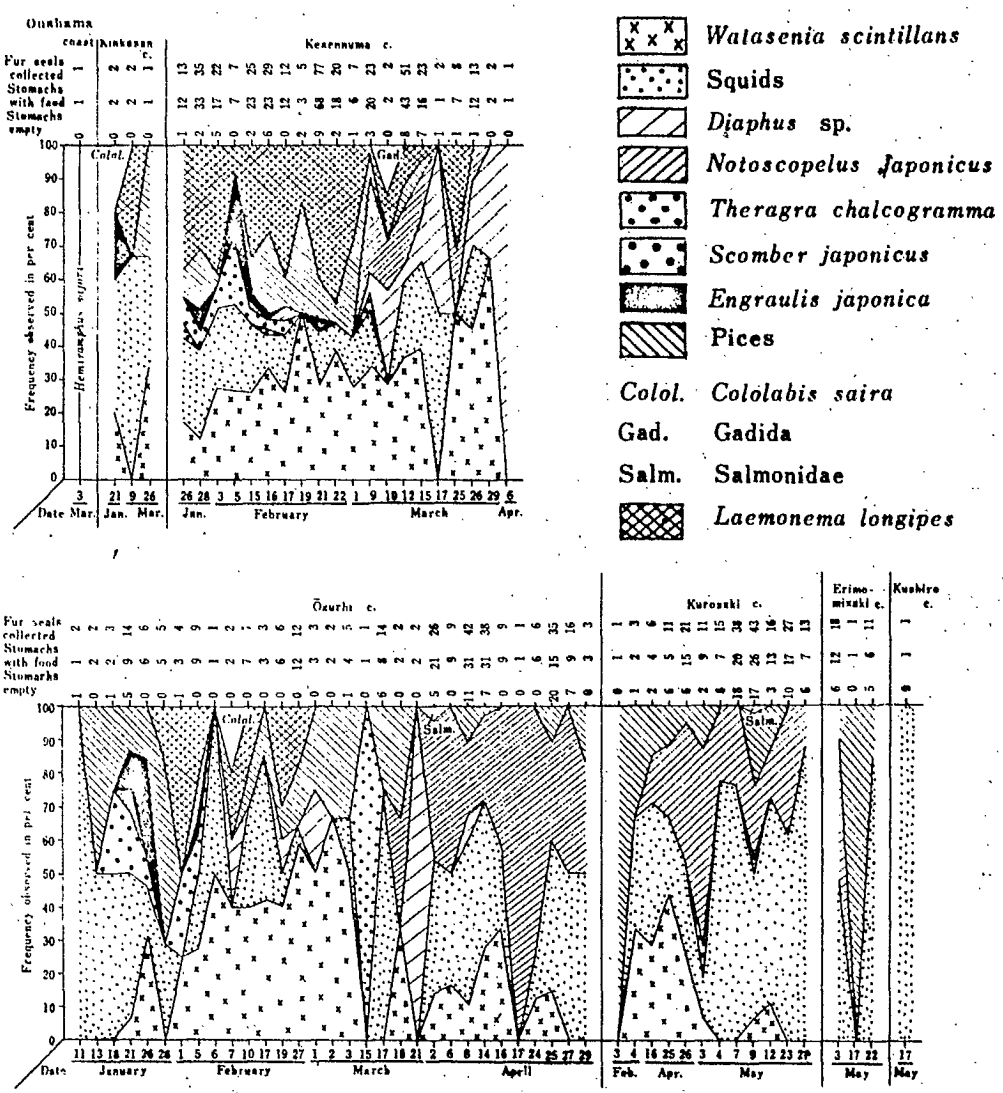

Fig. 22. Stomach contents of fur seals in 1967 (frequency observed of foods of total stomachs per day),

d) Notoscopelus japonicus was found continuously from April along the coasts of Ozuchi and Kurosaki. e) Very few Theragra chalcogramma, Scomber japonicus and Engraulis

japonica were found. They were found only along the coasts of Kesennuma and Ozuchi from January to February. f) Laemonema longipes were especially abundant in 1967. It was found continuously along the coast of Kesennuma from January to March. It was also found along the coasts of Kinkasan and Ozuchi. g) Only a few Cololabis saira, Hemirhamphus sajori and Salmonidae were found.

Several common characteristics were found from the observation of food habits in the three years: a) species which were remarkably predominant were Watasenia scintillans, other squids and Notoscopelus japonicus. 75 b) A predominancy of Watasenia scintillans was found from January to March and for the southern half of the migration. c) In northern areas a predominancy of squids and Notoscopelus japonicus was found for times later than that of Watasenia scintillans. d) A predominancy of squids is more pronounced than that of Notoscopelus japonicus.

2) Simple discription of the ecology of prey

All prey have long and tapered bodies. The size varies within the range of 3 cm for Watasenia scintillans to 50 cm for Laemonema longipes. These prey are mainly inshore fishes such as squids, surface fishes and Myctophidae. Some bottom fishes were also included in the prey. These fishes are generally well known along

the coast of Sanriku and have a high density distribution. There follows a simple discription of their ecology.

Watasenia scintillans: in the Pacific Ocean the young distribute in water of 10°C and above (Okutani, 1966) and are numerous in the mixing area between Oyashio (the Kurile current) and Kuroshio (the Black current) (Okutani, 1968). Not much study on the adult has been done.

Todarodes pacificus: their appearance along the coast of Sanriku is from June (Soeta, 1956). In 1966 along the coast of Sanriku small types of Todarodes pacificus were fished. From the observations made by the author, Todarodes pacificus of pallium about 10 cm began being caught in the fixed net at the mouth of Ozuchi Bay from early May in 1967. "The major factor of restriction for the northward migration of Todarodes pacificus is their prey. The suitable water temperature at the time of migration is 10°C and below. They migrate at about a depth of 100 m. A high density population is found in the transition area between the Tsushima warm current and Oyashio (the Kurile current) (Suzuki, 1963)". From this explanation it is possible that Todarodes pacificus may gather densely in the boundary between Kuroshio (the Black current) or its north branch and Oyashio (the Kurile current).

Myctophidae: the ecological study on Notoscopelus japonicus and Diaphus sp. has rarely been done. Ogawa (1961), Ogawa and Odachi (1961) and Odachi (1966) have studied Myctophidae in the Tohoku sea region. It has been revealed that Arahadaka and Myctophum affine gather densely around the Kuroshio (the Black current) front. These species are also important as the prey for other fishes and animals. Myctophidae are the most important food for bottom fishes such as Atheresthes evermanni, Reinhardtius evermanni, Theragra chalcogramma, and Gadus macrocephalus (Tohoku Suiken Hachinohe Shisho (Tohoku Fisheries Research Laboratory, Hachinohe Branch), 1956 and 1958; Gyogyo Shigen Kenkyu Kaigiho (Fisheries Research Council Report), 1965). Reinhardtius evermanni has been found to take Notoscopelus japonicus and Diaphus theta. Along the coast of Izu Todarodes pacificus take a great amount of Myctophidae (Okutani, 1962) and also Oncorhynchus keta, Oncorhynchus masou, Katsuwonus pelamis and Thunnus thynnus (Ogawa, 1961).

Scomber japonicus: all the Scomber japonicus found in stomachs were young. According to the study by Kawasaki (1966), they stay along the coasts of Sanriku and Joban from December to May. Most of them swim in the surface layer. In order for them to pass the winter in those areas it is necessary that the coldest temperature

should not be below 6°C.

Theragra chalcogramma: they are found in Oyashio (the Kurile current). They live in water of 1°-3°C in the feeding period. The spawning period in the Tohoku sea region is from December to May. Spawning fish gather densely especially from February to March (Tohoku Suiken Hachinohe Shisho (Tohoku Fisheries Research Laboratory, Hachinohe Branch), 1956). The fish approach the shore at depths to 100 m in the spawning period (Gyogyo Shigen Kenkyu Kaigiho (Fisheries Resources Research Council Report), No. 3, 1965).

Laemonema longipes: are sometimes caught in great quantity by trawling from a motor boat in the deep sea at the north of Suruga Bay (Toda).

3) Fishes along the coast of Sanriku in the period of migration of fur seals

The following are important when food and the food chain are considered to be the regulating factors in the migration of fur seals: a) the kinds of squids, fishes and other animals found along the coast of Sanriku; b) their density distribution; c) their quantity; d) their mode of life. There are many kinds of animals living along the coast of Sanriku. In this section, however, only the animals that fur seals can use are discussed. Suisan Tokei Geppo (Monthly Records of the Fisheries Statistics)

Table 20. Monthly records of catch from the fishery statistics in 1962.

Kind of fishs / Date	*Clupea pallasi*	*Sardinops melanostica*	*Etrumeus micropus*	*Engraulis japonica*	Young of some kinds of fishes	*Trachurus japonicus*	*Decapterus muroadsi*	*Scomber japonicus*	*Cololabis saira*	*Gadus macrocephalus*	*Theragra chalcogramma*	*Sebastodes* spp.	*Sebastolobus macrochir*	*Arctoscopus japonicus*	*Argentina semifasciata*	*Todarodes pacificus*	*Sepia (Platysepia) esculenta*	*Pleuronectes azonus*	
	—	0	0	20	—	35	—	1	—	547	776	6	187	—	—	637	—	0	Aomori pref.
	0	1024	—	499	—	0	—	4	—	119	17	124	122	0	0	1047	—	1	Iwate "
January	—	9373	—	82	—	0	—	7	—	385	450	37	399	—	—	131	—	0	Miyagi "
	—	8625	—	249	—	18	—	107	—	181	—	0	84	—	36	25	—	—	Fukushima "
	0	4820	—	3958	—	45	—	3396	—	0	—	0	0	—	—	6	3	—	Ibaragi "
	—	0	—	8	—	—	—	—	—	437	610	84	184	—	—	3	—	0	Aomori "
	—	—	—	71	—	—	—	137	—	72	15	6	111	—	0	—	—	0	Iwate "
February	—	495	—	321	—	268	—	3616	—	3245	483	87	295	—	—	2	—	0	Miyagi "
	—	2278	—	194	—	61	—	3863	—	246	—	13	316	—	29	2	—	—	Fukushima "
	—	1197	—	2672	—	90	—	9800	—	—	—	0	0	—	—	0	2	—	Ibaragi "
	0	—	—	—	—	—	—	—	—	412	2963	130	228	—	—	—	—	0	Aomori "
	—	—	—	0	—	—	—	25	—	85	19	6	189	—	0	—	—	0	Iwate "
March	—	2	—	39	—	—	—	32	—	2332	2010	72	344	—	—	1	—	0	Miyagi "
	—	63	—	23	—	—	—	83	—	339	—	6	139	—	40	—	—	—	Fukushima "
	0	199	—	1704	8	17	—	1724	—	0	—	1	0	—	—	0	3	—	Ibaragi "
	1	—	0	0	—	—	—	—	—	250	1073	625	303	—	—	0	—	7	Aomori "
	—	—	—	8	—	0	—	4	—	109	14	35	175	—	—	3	—	0	Iwate "
April	0	0	—	0	—	0	—	0	—	1525	963	186	492	—	—	0	—	0	Miyagi "
	—	0	—	1	—	0	—	383	—	114	6	18	260	—	22	—	—	—	Fukushima "
	0	217	—	227	481	47	—	2645	—	0	—	0	0	—	—	1	1	—	Ibaragi "
	—	3	—	45	—	0	—	2	—	154	201	1373	297	—	—	117	—	17	Aomori "
	—	0	—	86	—	0	—	438	—	49	17	31	138	—	—	210	—	0	Iwate "
May	0	348	0	36	—	0	—	1284	—	503	436	249	653	—	—	6	—	0	Miyagi "
	—	663	—	1	—	111	—	1378	—	18	—	2	258	—	5	—	—	—	Fukushima "
	0	1498	0	12	1218	380	—	1577	—	—	—	—	0	—	—	1	1	—	Ibaragi "
	—	37	—	235	—	5	—	435	21	207	45	1205	377	—	—	13602	—	3	Aomori "
	—	11	0	101	—	0	—	1834	0	67	16	44	160	0	—	394	—	0	Iwate "
June	0	82	0	35	—	4	—	266	—	238	207	245	742	—	—	26	—	0	Miyagi "
		0	—	—	—	7	—	180	—	10	—	3	249	—	5	—	—	—	Fukushima "
	—	110	0	677	568	537	—	539	—	0	—	0	0	—	—	1	6	—	Ibaragi "
	—	1	0	362	—	8	—	257	—	77	16	1383	246	—	—	19635	—	0	Aomori "
	—	15	—	207	—	2	—	1371	3	0	0	18	0	—	—	3835	—	—	Iwate "
July	0	15	48	109	—	37	—	362	1	62	19	237	109	—	—	251	—	—	Miyagi "
	—	—	—	—	—	48	—	35	—	0	—	0	9	—	4	—	—	—	Fukushima "
	—	0	—	864	72	762	—	47	—	0	0	2	0	—	—	0	0	—	Ibaragi "

From data of Suisan Tōkei Geppō, May, 1962—February, 1963, Ministry of Agriculture.

is worth consulting with regard to the subject. From 75
the 1962 records of catches classified according to
prefecture, we note the comparatively small sized fishes
which may be eaten by fur seals (Table 20). Fishes such
as Thunnus thynnus, Katsuwonus pelamis, Seliola quin-
queradiata and Selachii and bottom fishes such as Para-
lichtys olivaceus, Sebastes matsubarai, Sebastolobus
macrochir and Argentina semifasciata are excluded from 77
this study, since these fishes are too large in size
for fur seals and also because their mode of life is not
suitable in this regard. Sardinops melanosticta has not
been caught recently. According to the study done by
Kawasaki (1966), mainly young Scomber japonicus are pre-
sent from January to April along the coast of Sanriku.
Adults predominate from May. The abundance of Gadus
macrocephalus and Theragra chalcogramma near the coast of
Joban is not reflected correctly in the records of catches
since the records include catches in the north sea.
Sebastes matsubarai, Sebastolobus macrochir and Argentina
semifasciata live in the bottom of the sea and never are
found in the stomach of fur seals. Considering the con-
dition of the kinds of fishes stated above, the present
amount of these useful fishes in various areas should be
reflected in the amount of the catch. The amount of the
catch of useful fishes except bottom fishes is small from

winter to spring. This means that their density distribution is low, especially in areas from Aomori to Fukushima in comparison with the vicinity of Ibaraki.

4) Relationship between the prey and the non-biological environment

Kinds of prey and the changes in their prevalency in the stomaches of fur seals correspond well in time and space to the changes of the oceanographic conditions. The kinds of prey and their prevalency are discussed below in relation to the oceanographic conditions.

Hotaruika (Watasenia scintillans): were prevalent as follows; along the coast of Onahama in March, 1965; along the coast of Kinkasan in March, 1966; along the coast of Kesennuma in February to March, 1967; along the coast of Ozuchi in February to April, 1967; along the coast of Kurosaki in April, 1967. A common factor was the temperature of the surface water which was in the range 9°-12°C. Their prevalency occurred only in the west of 142°E along the coast of Joban and only in the west of 143°E along the coast of Sanriku. This indicates their prevalency occurs in the warm water masses along the coast from January to April. This reflects the mode of life of the species.

Ika rui (Squids): Surume ika (Todarodes pacificus), Nyudo ika zoku (Moroteuthis sp.) and Tako ika (Gonatopsis

borealis) are found. It is difficult to identify the kind when only a beak remains in a seal's stomch. However, Todarodes pacificus is considered to be the kind which occurs frequently with a high density distribution. Therefore of the squids the prevalency of Todarodes pacificus is assumed.

The prevalency of squids occurred as follows: the area to the north of the coast of Ozuchi from May, 1965; the area to the north of the coast of Kesennuma from April, 1966; the area to the north of the coast of Ozuchi from April, 1967; also to the north of the coast of Kesennuma from April in each year. This almost coincides with the period of migration of Todarodes pacificus along the coast of Sanriku. The water temperature at a depth of 100 m is below 10°C and suitable for their northward migration as stated by Suzuki (1963). In each case the prevalency becomes remarkable as time progresses in the period of migration.

Diaphus sp.: prevalency occurred along the coasts of Kesennuma and Ozuchi from mid March to mid April in 1965. This coincides with the period when water of 2°C covered the area.

Okuchi iwashi (Notoscopelus japonicus): appeared for a comparatively long time and in a wide area. However, this species was seldom found in water of 2°C from

mid March to mid April in 1965 and in the area to the south of the coast of Kurosaki from January to March in 1967.

Masaba (Scomber japonicus): a few appeared in the area from the coast of Onahama to the coast of Ozuchi from January to June. This corresponds to the period of stay of the young along the coast of Sanriku and the coast of Joban.

Suketodara (Theragra chalcogramma): only few were found in the area from the coast of Onahama to the coast of Ozuchi from January to April. This corresponds to the spawning period when the fish approach the shore.

Itohikidara (Laemonema longipes): this species was found in the digestive state of degree 1 to 4 in an area close to the shore from January to March and largely within the 200 m isogram (Table 21).

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Table 21. Relation between the degree of digestion of *Laemonema longipes* in the stomachs and the position of fur seals collected in 1967.

Region	Position from coast \ Degree of digestion	1	2	3	4	5	otolith only	
Kesennuma coast	141°30′E—142°00′E		1	5	42	24	36	Continental shelf
								200 m
	142°00′E—142°10′E				9	17	16	deeper
Ozuchi c.	142°00′E—142°10′E	1			2	1	1	Continental shelf
								200 m
	142°10′E—142°30′E				1	3	7	deeper

5) Relationship between the mode of migration of fur seals and their prey 77

i) Females of four+ years: the prevalency of females of four+ years which appeared typically along the coast of Kesennuma from January to March in 1967 and the tendency towards high density areas of distribution of females of six to ten years were observed around the southern limit of migration. Fur seals in this area took Watasenia scintillans, squids and in 1967 Laemonema longipes as food. These constituted two thirds of the prey. Fur seals densely populating the transition area between the warm water mass and Oyashio (the Kurile current) are considered to be regulated by the prey which also gather in the same area.

Several characteristics of the prey were revealed for 1967 which should be noted. Laemonema longipes occurred both in 1966 and 1967. Especially their 78 occurrence was remarkable along the coast of Kesennuma from January to early March in 1967. This peculiarity coincided with the occurrence of high density areas of fur seals. These occurred near the 200 m isogram in the area between 141°50' E and 142°10' E. The central portion moved away from the coast in the middle and at the end of February. Thus the high density areas were near the 200 m isogram. This is considered to have been

caused by the concentration of Laemonema longipes in that area.

ii) Comparison between females of four^{+} years and fur seals of other developmental stages:

Male yearlings and males of two to three years were prevalent along the coasts of Kesennuma and Ozuchi from March to April in 1965. Females of four^{+} years were prevalent in the southern limit of the migration. Males of two to three years appeared in densities of degree II-III and females of six to ten years were concentrated in the high density areas at the southern limit of migration. Female yearlings and females of two to three years were observed to the south of the coast of Kinkasan. However, high density areas were not apparent. These characteristics are common to the three years of observation. The tendency towards low density areas by male and female yearlings and males of two to three years and the apparent high concentration of females of four to five years and six to ten years are related to the density distribution of the prey. The difference in the density distribution is sometimes related directly to the amount of prey taken by fur seals. It is sometimes influenced by social and ecological relationships. Females of two to three years and males of four^{+} years do not show a definite tendency one way or the other in their density distribution.

Their distribution is not related to the distribution of prey. This is considered to be caused by the following factors: females of two to three years are in the process of transition from yearlings to adults of four to five years, and males of four+ years are greatly affected by the oceanographic conditions or conditions on the breeding islands. These factors require further study.

As stated above it is considered that the density distribution from winter to spring of fishes which can be the prey for fur seals is low in the area from Aomori to Fukushima where a branch of Oyashio (the Kurile current) widens. On the other hand the transition zone between the warm water mass and Oyashio (the Kurile current) may contain a concentration of many kinds of fish. The relationships between the transition zone and the prey are not yet fully known. However, there are some grounds in the data given above for the assumption that the prey of fur seals concentrate in the transition zone.

As along the coasts of Onahama and Ozuchi from March to April in 1965 sometimes changes in the density distribution of various kinds of prey are clearly indicated. The chages in food habits of fur seals are considered to be regulated by the amount of fish in the area. Therefore it is possible that fur seals indiscriminately eat squids and fishes which are available in the area.

For example, the prevalency of Todarodes pacificus in the stomach contents of fur seals occurred from April to May when this species migrated to the coast of Sanriku. Scomber japonicus was found from December to May when this species stays along the coast of Sanriku. The few occurrences of Theragra chalcogramma were from December to May when this species approaches the shore for spawning. According to Suisan Tokei Geppo (the Monthly Records of Fisheries Statistics), the catch of useful fishes excluding bottom fishes is small from winter to spring in the area from Aomori to Fukushima. Engraulis japonica, Scomber japonicus and Todarodes pacificus among the useful fishes are not eaten in great amount by fur seals caught in the same time and locations stated above. Therefore the small amount or the low density distribution of the prey coincides with the low frequency of appearance of the prey in the stomach of fur seals. 79

Table 22. Relation between the kinds of food and the developmental stages of fur seals.

Age	Kesennuma coast (%)				Jan.~Apr., 1967		Ōzuchi coast (%)				Jan.~Apr.,1967	
	Laemonema longipes*		Other kinds of food		Stomachs with food		*Laemonema* longipes*		Other kinds of food		Stomachs with food	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	0	0	44.4	55.6	3	3	0	0	66.7	3.3	9	4
1~3	5.0	6.2	38.8	50.0	23	26	0	1.1	65.9	33.0	44	25
4~5	3.1	11.5	10.4	75.0	6	47	0	4.3	25.5	70.2	16	44
6~10	—	35.0	—	65.0	—	129	0	7.2	1.5	91.3	1	45
11+	—	35.3	—	64.7	—	87	—	16.3	—	83.7	—	36

* : Includes few salmonidae and *Theragra chalcogramma*.

The low density areas for male and female yearlings and males and females of two to three years and males of four^{+} years correspond for the most part to the low density areas for the prey. The distribution of fur seals is independent of the species of the prey. This somtimes happens for the areas where females of four^{+} years are prevalent. A high density of females of four^{+} years coincides usually with a high density of prey. The relationship between the density distribution of the prey and the developmental stages of fur seals should be studied further from the viewpoint of the quality and quantity of nutriment necessary for fur seals.

iii) Relationship between the developmental stages of fur seals and the kinds of prey: Theragra chalcogramma and Laemonema longipes are not found in the stomaches of yearlings. Along the coasts of Kesennuma and Ozuchi from January to April in 1967 Laemonema longipes was taken in great amount as food. However, not one was found in the stomaches of yearlings (Table 22). This is considered to be caused by the mobility and the size of the prey and not by the distribution of fur seals. Fur seals in other developmental stages always take whatever suitable prey is available.

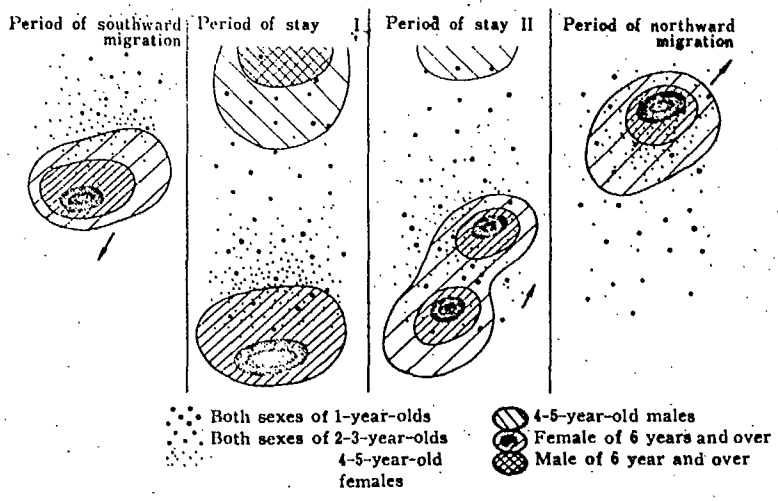

Fig. 23. A model of fur seal migration on the coast of northern Honshū.

§8. Model drawings of the mode of migration of fur seals 80

In this paper the mode of migration of fur seals along the coast of Sanriku has been discussed from several aspects. Model drawings have been made from the results of this study (Fig. 23). This figure should be improved after further studies. The density of distinctive markings for each developmental stage and the shading indicate the degree of density of fur seals and the sizes and components of pods.

Summary

Summary is equivalent to the English abstract given at the beginning of this paper (Translator's note).

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