CONSIDERATION OF DISTRIBUTION AND MIGRATION OF TOOTHED WHALES OFF THE PACIFIC COAST OF JAPAN BASED UPON AERIAL SIGHTING RECORD

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ABSTRACT

The seasonal and annual fluctuation of the sperm whale, Baird's beaked whale, killer whale, the globicephalids, and the dolphins and porpoises in the past 11 years are discussed. The sperm whale is abudant in the northern areas, in summer and autumn seasons. Its density fluctuates with a period of 4 years. The Baird's beaked whale is found only in the northern areas in the season from spring to autumn. The killer whales is relatively abundant in the northern areas.

The globicephalids and the delphinids from the warmer waters migrate into the northern areas in summer season.

INTRODUCTION

In this report the distribution, seasonal movement and annual fluctuation of several toothed whales off the Pacific coast of Japan was discussed basing on the sighting records from airplane. About the larger cetacea caught by commercial whaling, much informations on the distribution and abundance are available from the whaling result, however it is necessary to compare them with the data free from the bias caused by whaling operation or whaling regulation. About the most of the delphinid species the identification of the species was not acomplished, and, in this report, only the seasonal fluctuation of the density or seasonal movement is studied. But this can afford rough information on the seasonal fluctuation of the population of the delphinid species, and can be a first step of the population study of them as one of the members of the marine ecosystem.

MATERIALS AND METHOD OF ANALYSIS

The materials used in this study are the aerial sighting record made in the 11 years from April 1959 to March 1970. It was conducted by The Suisan Koku Co., Ltd. (Fisheries Aviation Co., Ltd.), which has been mostly operating the survey of fishing ground or other oceanographic observation in the adjacent waters of Japan. The aerial sighting of the cetacea was conducted, during the flight for these oceanographic survey, as one of the routine works by Messrs. S. Takashima, Y. Ogawa or S. Tano. The types of used aircrafts were Cessna 175 from 1959 to 1965, and

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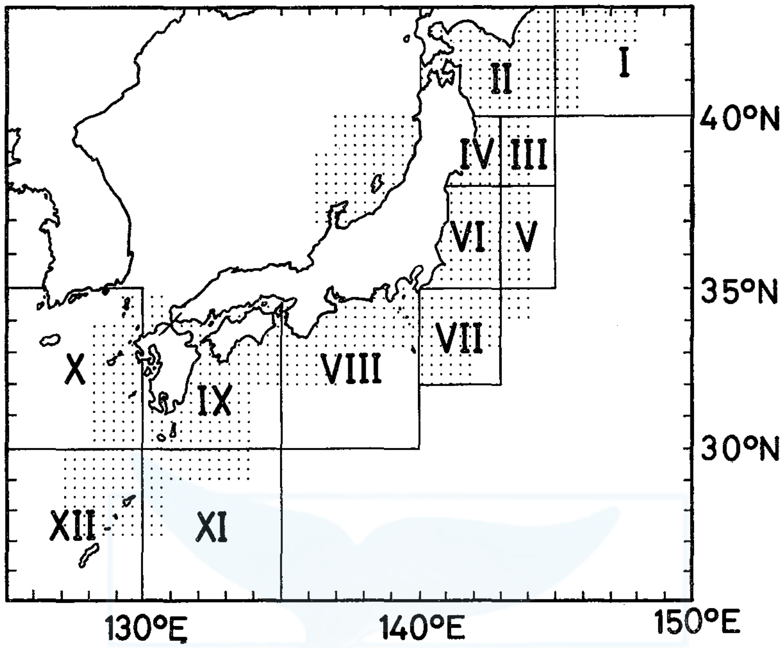

Fig. 1. Section of areas used in this report. Dotted area indicates the approximate range covered by the flight.

TABLE 1. SIGHTING EFFORT SHOWN BY NAUTICAL MILES OF THE DISTANCE FLOWN, FROM APRIL 1959 TO MARCH 1970.

Area	Month: Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
I	0	0	0	106	55	0	0	0	1,802	350	0	0	2,313
II	0	0	0	0	756	63	212	2,928	13,984	7,085	552	0	25,580
III	50	0	0	0	455	629	830	913	1,287	1,365	1,315	85	6,929
IV	471	350	19	217	1,513	2,705	3,970	3,686	5,013	6,933	8,533	1,199	34,609
V	55	0	0	36	160	202	71	115	155	123	74	132	1,123
VI	2,585	1,265	1,019	1,165	6,254	6,076	4,344	2,894	3,671	5,123	11,766	6,474	52,636
VII	1,623	572	601	662	1,558	0	326	808	399	486	1,523	1,169	9,727
VIII	1,269	802	1,146	721	1,633	0	488	2,560	371	2,543	2,179	1,186	14,898
IX	845	924	2,061	0	3,197	0	0	1,305	0	0	1,441	1,415	11,188
X	1,237	916	56	0	3,499	0	372	39	0	0	0	0	6,209
XI	808	585	985	0	0	0	0	145	0	0	384	130	3,037
XII	269	669	1,483	0	140	0	48	951	0	0	0	0	3,560
Total	9,302	6,083	7,370	2,907	19,220	9,675	10,661	16,344	26,682	24,008	27,767	11,790	171,809

Cessna 182 from 1965 to 1970. The cruising speed was 100 knot and the height was 500 m, but in case of precise observation it was lowered to 50 m. The flight was operated only on the day with good visibility and the wind less than 7 m/sec. The flown area covered the waters within 90 to 130 miles from the coast (Fig. 1). It is told that efficient observation was made within the range of 15 nautical miles on each sides of the airplane.

In this report, the Japanese coastal waters is divided into 12 areas, and the seasonal and annual fluctuation of the densitly of the whales or schools are discussed in each areas. The density index of the whales are expressed by the number of the whales sighted per 1,000 miles flown, and that of schools by the number of schools encountered per 1,000 miles flown. The speceies of the cetacea are classified, after the flight records, into following 5 categories or sperm whale, Baird's beaked whale, killer whale, Globicephalids whales, and dophins and porpoises.

SPERM WHALE

Distribution

In the Pacific coast of Japan 759 sperm whales, *Physeter catodon*, in 188 schools were sighted during the 11 years. The number of the schools sighted in each 1° squares is shown in Fig. 2. As seen in this figure, the schools sighted distribute from

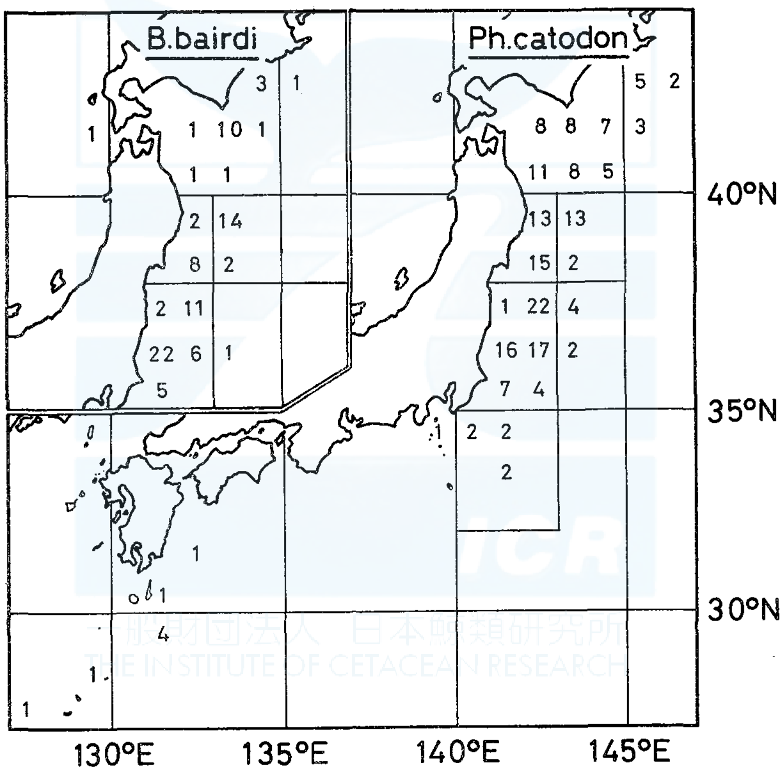

Fig. 2. Number of schools of the Baird's beaked whale and the sperm whale sighted in the 11 years. The number is shown in each 1° squares.

off Ryukyu Islands in the southern waters to the coastal waters of Hokkaido I. in the north. But most of the schools were found at the waters east of 140°E, and the sightings in the south west waters are only 9 occasions which occurred in the coastal area of Ryukyu Islands.

TABLE 2. NUMBER OF SCHOOLS SIGHTED IN RELATION TO THE DISTANCE FROM THE COAST, AREAS I-VI.

1 degree squares	*Ph. catodon*		*B. bairdi*		*O. orca*		Globicephalids		Delphinids	
	no.	%	no.	%	no.	%	no.	%	no.	%
Coastal	27	15.3	18	19.8	4	15.4	87	21.6	263	41.5
Intermediate	117	65.6	64	70.3	17	65.4	260	64.5	327	51.7
Off shore	34	19.1	9	9.9	5	19.2	56	13.9	43	6.8
Total	173	100.0	91	100.0	26	100.0	403	100.0	633	100.0

In the waters off the west coast of Kyushu I. (area X), inspite of sighting effort, there was no sighting. It will indicate that only few sperm whale migrates into this shallow waters.

Table 2 shows the number of schools sighted in relation to the distance from the coast in the areas I-VI. In this table " coastal square " indicates the one degree squares which contain the coast in it, the " intermediate " does those which are bordered by the former square, and the " off shore " does those which don't border on the first or those which do only at the corner. As seen in this table, the number of schools sighted in coastal squares is only 15.7% of the total, and that in off shore squares is 19.3%. This ratio is nearly same with that of killer whale, indicating that the sperm whale distributes in off shore waters compared with the Baird's beaked whale, the Globicephalids, and the dolphins and porpoises. Same phenomenon is seen also in Fig. 3, the density of this species is rather low in the coastal areas IV, VI and VII, and higher in the off shore areas of I, II, III and V.

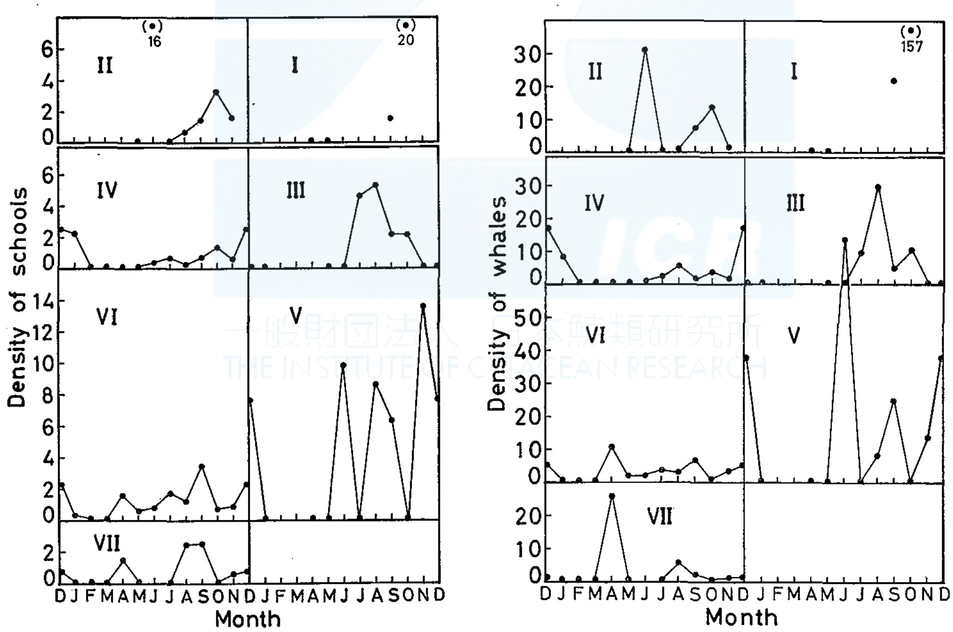

Fig. 3. Monthly fluctuation of the density of the sperm whale (right) and of the schools (left) in areas I–VII.

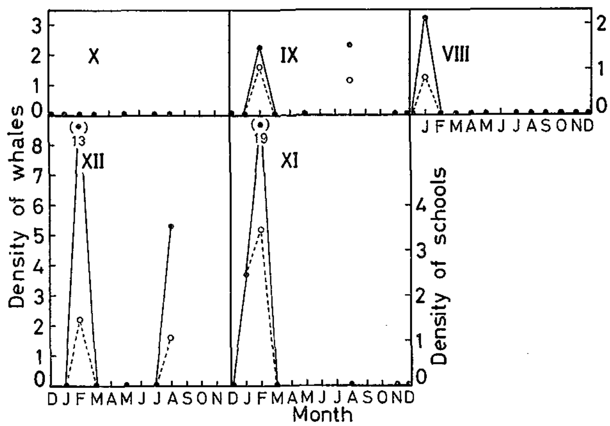

Fig. 4. Monthly fluctuation of the density of the sperm whale (closed circle and solid line) and of the schools (open circle and dotted line) in areas VIII–XII.

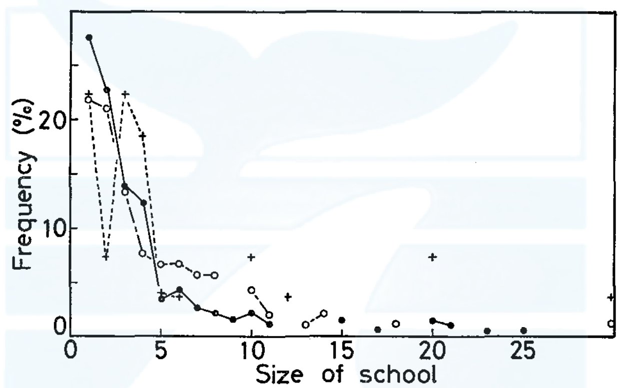

Fig. 5. Frequency distribution of the number of individuals in a school (school size). Closed circle and solid line indicate the sperm whale, open circle and dotted chain the Baird's beaked whale, and cross mark and dotted line the killer whale.

TABLE 3. MONTHLY FLUCTUATION OF THE DENSITY OF SPERM WHALE

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Areas I–II												
no. of schools	—	—	—	0	0	1	0	2	23	30	1	—
no. of whales	—	—	—	0	0	2	0	2	144	156	1	—
density of schools	—	—	—	0	0	(15.9)	0	0.68	1.46	4.03	1.81	—
density of whales	—	—	—	0	0	(31.7)	0	0.68	9.12	21.0	1.81	—
Areas III–VI												
no. of schools	2	0	0	2	4	8	15	11	21	17	17	19
no. of whales	5	0	0	13	15	34	37	60	54	47	65	60
density of schools	0.63	0	0	1.41	0.48	0.83	1.63	1.45	2.07	1.23	0.78	2.41
density of whales	1.58	0	0	9.17	1.79	3.54	4.02	7.89	5.33	3.47	3.00	7.61
Areas VII–XII												
no. of schools	3	4	0	1	0	—	0	4	1	0	1	1
no. of whales	7	22	0	17	0	—	0	13	1	0	2	2
density of schools	1.14	0.90	0	0.64	0	—	0	0.69	1.30	0	0.18	0.26
density of whales	0.49	4.92	0	0.84	0	—	0	2.24	1.30	0	0.35	0.51

Seasonal movement

In the areas VII to XII, though the sighting record is scarce and the seasonal fluctuation of the density is not clear, it can be said that both densities of schools and whales are slightly higher in winter season and lower in summer (Fig. 4 and Table 3). But the winter density is not so high and nearly same with that of the corresponding season in the north eastern warters.

The seasonal fluctuation of the density of this species in the areas I-VI is shown in Fig. 3 and Table 3. In these areas the density is highest in summer season and lowest probably in February and March. The pattern of the seasonal fluctuation of the density is similar with the monthly catch shown by Omura (1950). The high density in June in area II is due to only one sighting, and the sighting data in area V is also very scarce, so they will not correctly indicate the real seasonal fluctuation. If these points are took into consideration, it is possible to say that in areas I and II the density fluctuation has only one peak in October. On the other hand, in areas III–VI, it has two peakes in August and December. The former may correspond to the north bound whales going up to areas I and II, and the latter may do the south bound whales probably comming from areas I and II or more north. The second peak seems to continue till January. The whales sighted in areas IV and VI in April to June may containe the male whales on the way to the north.

School size

The frequency distribution of the school size, or the number of individuals in a school, of the sperm whale is shown in Fig. 4, which is based on 188 schools sighted in areas I-XII. The number of individuals in a school is usually lower estimate of the real number, because some member may be diving. The largest number of the whales in a school is 25, and the mininum is 1. There is a discrepancy of the frequency between the schools with 5 or more members and those with 4 or less. Most of the schools, 77.2% of total number of the schools, are smaller schools and composed of 4 or less individuals, and the number of whales composing these schools is 41.7% of the total number of the whales sighted. The larger schools may be mostly so-called harem schools. As seen in Table 4 the percentage of the small schools, with 4 or less individuals, decreases from July to October and again increases from November to December.

Fig. 6 shows the monthly fluctuation of the mean school size in the areas I-VI. It indicates that the mean school size is high in August and September, and decreases after the summer. This is related with the increase of the percentage of small schools which will be the non-harem schools arriving from the north.

The mean school size in areas VII-XII is 4.3, and no significant difference between the northern areas was found.

Annual fluctuation

Fig. 7 shows the annual fluctuation of the density of this species migrating in areas I to VI. This annual density was calculated combining the above six areas

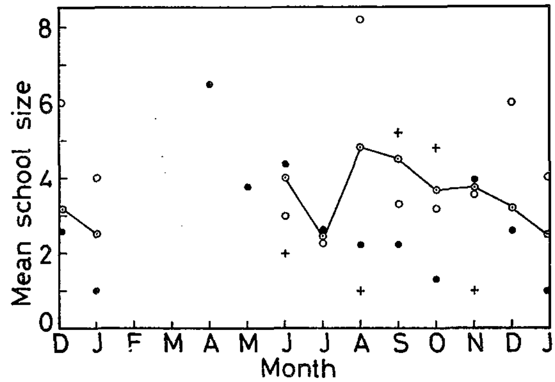

Fig. 6. Monthly fluctuation of the mean school size of the sperm whale. Double circle and solid line indicate the mean school size calculated combining the areas I–VI, cross mark areas I and II, open circle areas III and IV, closed circle areas V and VI.

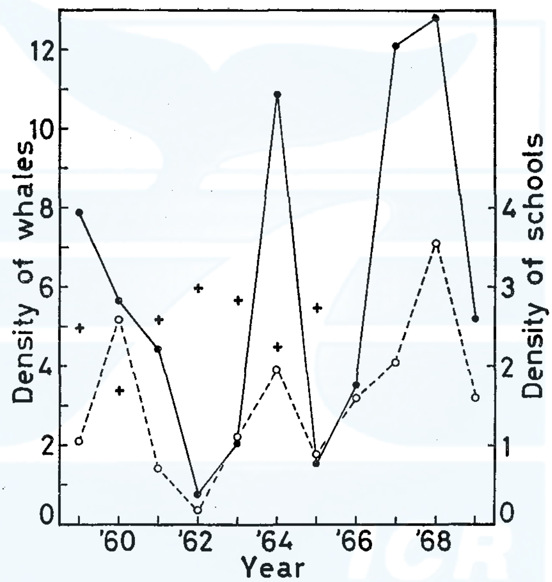

Fig. 7. Annual fluctuation of the density of the sperm whale (closed circle and solid line) and of the school (open circle and dotted line). Areas I–VI and seasons June to October are combined. For the cross mark read the left scale and see the text.

TABLE 4. MONTHLY FLUCTUATION OF THE RATIO OF SMALL SCHOOLS OF SPERM WHALE. "SMALL SCHOOL" INDICATES THE SCHOOL WITH 4 OR LESS INDIVIDUALS.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Area I–VI												
no. of total school	2	0	0	2	4	9	15	13	44	47	18	19
% of small school	100	—	—	50.0	75.0	77.8	93.3	84.6	77.3	63.8	83.4	84.3
Area VII–XII												
no. of total school	3	4	0	1	0	0	0	4	1	0	1	1
% of small school	100	50.0	—	0	—	—	—	75.0	100	—	100	100

and the season from June to October which is considered to be the flourishing migratory season. The annual density fluctuates with the interval of 4 years. Though Omura (1950, Fig 70) did not mention, same periodical fluctuation is seen in the catch of prewar period, but in this case the cycle is 4 or 3 years.

I consider that this fluctuation is resulted by the condensation of the whale in the coastal waters, due to some oceanographic condition. The cross marks in Fig. 7 indicate the distance, measured along 145°E meridian and shown by degree of latitude, between the isothermal lines of 24°C and 18°C surface water temperature in September (Japan Meteorological Agency, 1962–1970). They show the reverse correlation with the annual fluctuation, but further study will be necessary to have a conclusion on this relation.

Another stable trend of the increase of the annual density is observed in Fig. 7, but no explanation was obtained in the present data.

BAIRD'S BEAKED WHALE

Distribution

The distribution of this species, *Berardius bairdi*, off the Pacific coast of Japan is already studied by Omura (1955), and Nishiwaki and Oguro (1971). According to these reports the position of the catch in the Pacific coast is mostly restricted in the east of 139°E or east of the Sagami bay in the north east part of the area VIII, and southern most catch is approximately at 34°N.

In the present data, 414 whales in 91 schools were sighted in areas I-VI, and

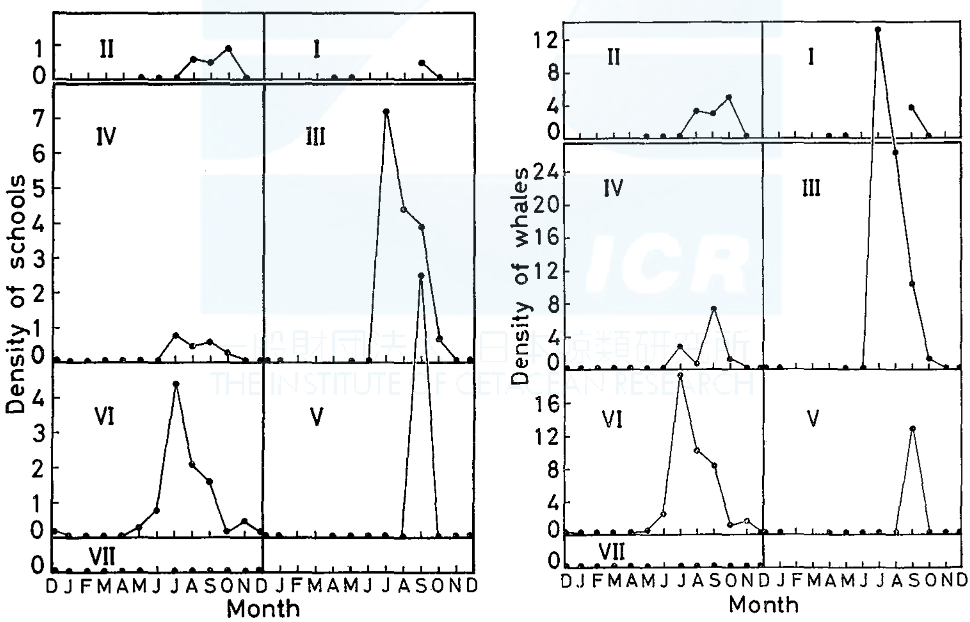

Fig. 8. Monthly fluctuation of the density of the Baird's beaked whale (right) and its schools (left) in areas I–VII.

TABLE 5. RELATIVE ABUNDANCE OF EACH SPECIES OF WHALES. ABUNDANCE IS SHOWN BY THE RATIO TO THE SPERM WHALE.

Areas	I–II		III–VI		VII–XII	
	no. schools	no. whales	no. schools	no. whales	no. schools	no. whales
Sperm whale (no.)	57	305	116	390	15	64
Baird's beaked w.	0.32	0.31	0.63	0.82	0	0
Killer whale	0.053	0.059	0.20	0.35	0.067	0.16
Globicephalids	1.2	3.2	2.9	17	2.1	9.9
Dolphins & porpoises	2.7	110	4.1	250	8.2	280

none in area VII and in the Sagami Bay. This will be due to the few flight in the warmer season in this warters.

As seen in Table 2, the percentage of schools sighted in the coastal squares is higher than that of the sperm and the killer whale. This will indicate that this species comes closer to the coast.

The number of whales sighted is about 30% of that of sperm whale in areas I-II, and 80% in areas III-VI (Table 5).

Seasonal movement

In the summer season the density of this species is higher in areas III and VI, and rather low in the northern three areas I, II and IV.

The monthly fluctuation of the density of this species shows vague bimodal distribution in areas II, III, IV and VI. The first mode arrives at area VI in May, at areas III and IV in July, and at area II in August. The second mode is not so clear as the first, but observed in September and October. The first peak is considered to show the north bound whales, some part of which will go further north beyond the area I, and the second the south bound. Probably the south bound migration will be started at a same season in all the areas, so the second peak will not be conspicuous.

Though some individuals are still found in November and December in the area VI, no individual is found in Janualy to April in all the coastal waters of Japan. In these months they seem to leave the coast of Japan.

School size

The frequency distribution of school size is shown in Fig. 5. The largest school observed was composed of 30 individuals and the smallest with one.

TABLE 6. SOME CHARACTERISTIC FIGURES OF THE SCHOOL SIZE IN AREAS I-XII

Species	Sperm whale	Baird's beaked w.	Killer whale	Globicephalids
Range of school size	1–25	1–30	1–30	1–500
School size at mode	1	1	1–3	1, 5
Mean school size	4.0	4.5	6.0	19.1
School size at the mode of no. of whales	2–4, 20	2–3, 8∼10	4, (?)	16–25

TABLE 7. MONTHLY FLUCTUATION OF THE RATIO OF SMALL SCHOOLS WITH 3 OR LESS INDIVIDUALS IN BAIRD'S BEAKED WHALE

Month	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Areas I–II								
no. of schools	0	0	0	2	8	7	0	—
% of small schools	—	—	—	50.0	50.0	42.8	—	—
Area III–VI								
no. of schools	2	5	28	12	15	4	6	1
% of small schools	100	80.0	50.0	66.7	53.3	50.0	66.7	100

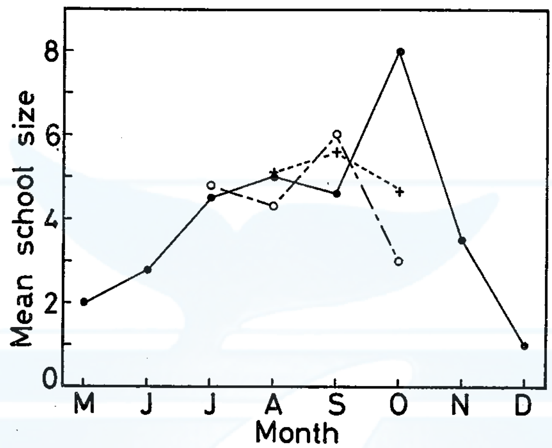

Fig. 9. Monthly fluctuation of the mean school size of the Baird's beaked whale. Cross mark and dotted line indicate the value calcurated combining areas I and II, open circle and dotted chain areas III and IV, and closed circle and solid line areas V and VI.

When the number of the individuals constituting each school size is considered, its distribution have two modes, one at the school size with two individuals and the other at that with 8 or 10 individuals.

As in the case of sperm whale the frequency distribution can be devided into two parts, or the part of the smaller schools and that of the larger. The former schools are composed of 3 or less individuals, and hold 56.0% of the total number of schools and do 22.7% of the total number of the individuals. These informations on the school are shown in Table 6, which shows that the Baird's beaked whale in the adjacent waters of Japan forms relatively larger schools than the sperm whale.

The monthly fluctuation of the percentage of the smaller schools is shown in Table 7, which shows no significant fluctuation. Fig. 9 shows the monthly fluctuation of the mean schools size of this species. It shows slight increase of the mean school size in summer season, but no significant difference between the areas.

Annual fluctuation

Fig. 10 shows the annual fluctuation of the density in the areas I-VI and in the

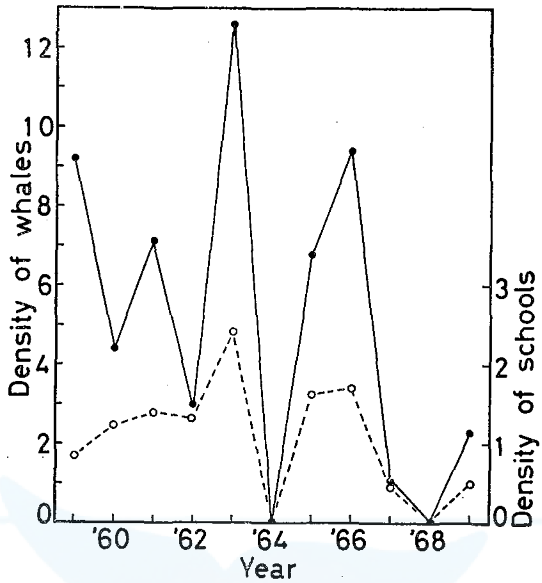

Fig. 10. Annual fluctuation of the density of the Baird's beaked whale (closed circle and solid line) and its schools (open circle and dotted line). Areas I to VI and seasons June to October are combined.

period from June to October, calculated same with the sperm whale. It is interesting to see that the annual fluctuation of the density of this species, especially when the density of whales is compared, shows the reverse correlation with that of the sperm whale. These fluctuation may be, at least in some part, related with some oceanographical conditions.

KILLER WHALE

During the 11 years, only 161 individuals in 27 schools were sighted in the Pacific coast of Japan. As shown in Fig. 17, this species, *Orcinus orca*, distributes in all the area of the Pacific coast of Japan, but most of the sightings were made in the areas I-VI in the months from April to November. Because the killer whale is smaller than the sperm whale or Baird's beaked whale, the ratio of the overlooked schools or individuals may be higher than that in the larger two species. But it seems to be

TABLE 8. MONTHLY FLUCTUATION OF THE DENSITY AND MEAN SCHOOL SIZE OF THE KILLER WHALE IN AREAS I-VI

Month	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
No. of schools	8	0	5	2	1	4	3	3	26
No. of whales	92	0	18	5	1	22	8	5	151
Density of schools	5.25	0	0.52	0.21	0.10	0.15	0.14	0.13	0.25
Density of whales	60.4	0	1.86	0.53	0.10	0.85	0.38	0.23	1.50
Mean school size	1.2	—	3.6	2.5	1.0	5.5	2.7	1.7	5.8

true that the density of this species is far smaller than that of them (Table 5).

The monthly fluctuation of the density of this species is shown in Table 8, but the data is too scarce to get some informations on its migration.

As shown in Fig. 5, Tables 6 and 8, the number of whales in a school ranges from 1 to 30. And the mean school size is 6.0 in areas I-XII, which is larger than the corresponding value of the sperm whale or Baird's beaked whale.

GLOBICEPHALID WHALES

Distribution

The toothed whales other than dolphins and porpoises and the three larger species dealt with in the former chapter are recorded as " smaller whales ". Considering the photographs and information from the crues of the airclaft, the " smaller whales " is thought to indicate mostly the *Globicephala*, *Pseudorca* and *Grampus*. And in this report it is dealt as the globicephalid whales. Though Mr. Takashima says that he has not seen *Ziphius* from the air, it is probable that some smaller ziphioid whales may have included in this category, but the number will be negligible.

As seen in Fig. 11 and Table 2, the globicephalids distributes rather off shore

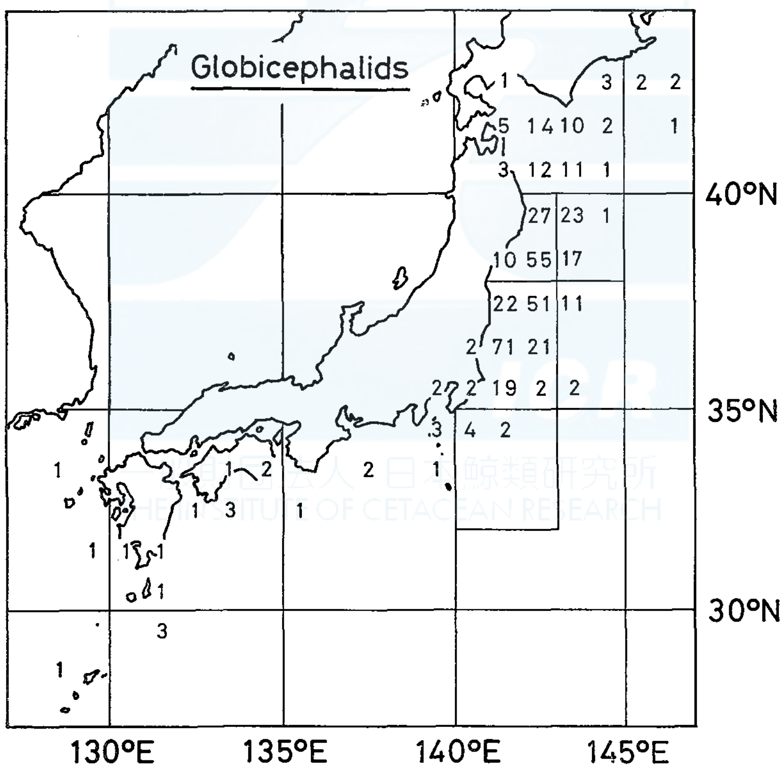

Fig. 11. Number of the globicephalid schools sighted in each 1° squares.

waters, and found in all the waters off the Pacific coast of Japan.

The relative abundance is so high that the number of whales sighted is about 3 to 17 times of that of sperm whales (Table 5).

Seasonal movement

The seasonal fluctuation of the density is shown in Figs. 12 and 13. In the south west waters, generally speaking, the density of the globicephalids is low, but slightly increases in autumn to spring. This is the reverse of the condition found in the north east waters. Same fluctuation is observed also in the Dolphins and porpoises.

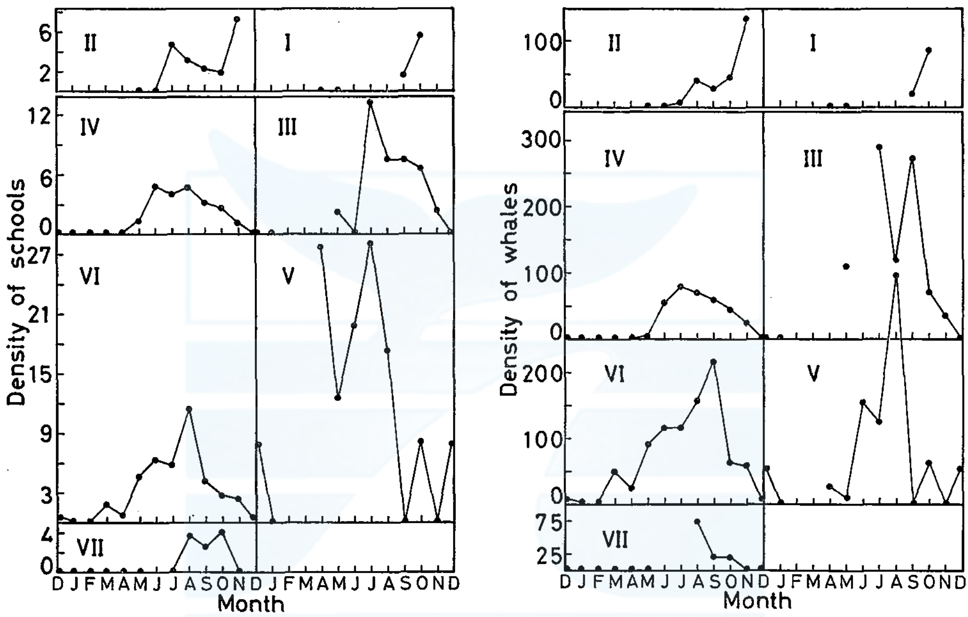

Fig. 12. Monthly fluctuation of the density of the globicephalid whales (right) and their schools (left) in areas I–VII.

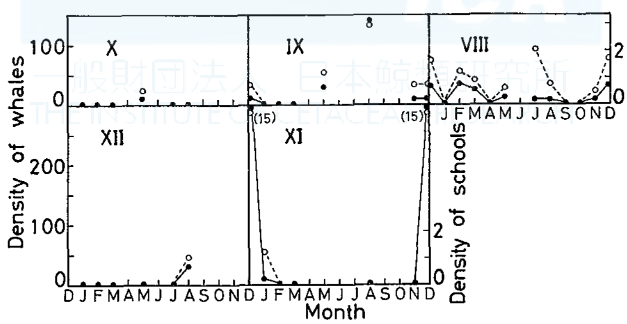

Fig. 13. Monthly fluctuation of the density of the globicephalid whales (closed circle and solid line) and their school (open circle and dotted line) in areas VIII–XII.

This will mean that the globicephalid whales migrate to the southern warters in the winter season. It is reported that, in the winter season, *Pseudorca*, *Grampus* and *Globicephala* migrate in the coastal waters adjacent to the north and west coast of Kyushu, area X, (Fisheries Agency of Japan, 1968, Table 16).

In the north east waters the density of the globicephalids is high in the off shore areas, or the areas III and V, and it is lower in the areas I and II. The density in the areas I-VI increases in summer season, but there is slight delay of the arrival in the northern areas. They arrive at area VI in March, area IV in May, and area II in July. The same tendency is observed also in the off shore areas I, III and V. In the areas III-VII the density decreases in Octorber and December, as the result the duration of high density is longer in the southern areas. This will show the expansion and retreat of range of the distribution.

However, in the areas I and II, the density shows bimodal fluctuation and there is a rapid increase of the density in October and November. It is supposed that this second mode may be composed of some species of the globicephalids, probably *Globicephala*, coming down from the northern warters, and spend the winter season in the northern areas without migrating to far south. According to the sighting records from the ship (Kasuya, unpublished), the range of distribution of *Globicephala sp.* extends from off the coast of Kyushu (areas IX and X) to the waters around 43°N, 177°E via the southern coast of Hokkaido. A part of this northern population might come to the areas I and II in the early winter.

School size

Fig. 14 shows the frequency distribution of the school size of all the globicephalids schools. The number of individuals in a school is a rough estimate, especially in case of large school. The school size ranges from 1 to 500. Its distribution is bimodal, with a mode at 1 and the other at 5. This is a quite unique character observed in the globicephalids schools. But this feature does not seem to be special case seen in the present aerial sighting records. Table 9 shows some characteristic

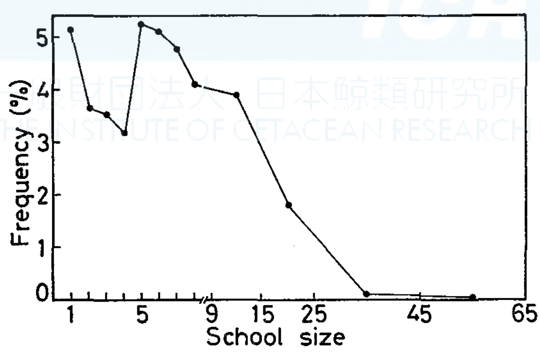

Fig. 14. Frequency distribution of the number of individuals in a schools (school size) of the globicephalid whales sighted in a reas I–XII. The horizontal scale is not in equal interval.

TABLE 9. SCHOOLS OF SOME GLOBICEPHALID WHALES OBSERVED ON THE SHIP

Species	*Globicephala* sp.	*Pseudorca*	*Grampus*
Range of school size	1–100	2–200	3–25
School size at mode	1, 10	—	—
Mean school size	19.6	55.0	11.3
No. of sample	30	6	6

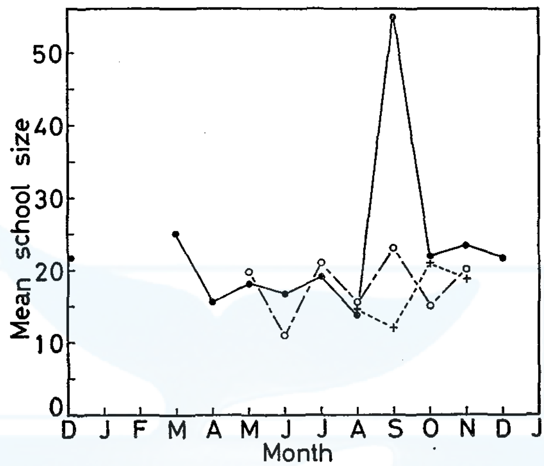

Fig. 15. Monthly fluctuation of the mean school size of the globicephalid whales. For marks see Fig. 9.

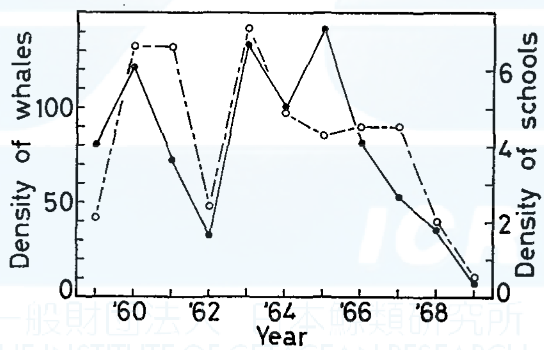

Fig. 16. Annual fluctuation of the density of globicephalid whales (closed circle and slid line) and their schools (open circle and dotted line). Areas I to VI, and seasons June to October are combined.

figures of school size of three globicephalid species in the north Pacific. These datum were cited from Nemoto *et al* (1966), Nishiwaki (1967), Kawamura and Kureha (1970) and Kasuya *et al* (unpublished) which are all obtained from the sighting on the research vessels. Several characters of the school, especially those of *Globicephala* sp. coincides with the bimodal distribution obtained from the aerial sightings (Table 6).

Fig. 15 shows the monthly fluctuation of the mean school size in areas I-VI. It shows slight increase in the Autumn, but no significant difference between the areas. The mean school size in areas VII-XII of all seasons is 20.5. So it can be concluded that there is no significant difference of the mean school size between the areas in the north and the south.

Annual fluctuation

Fig. 16 shows the annual fluctuation of the density of the globicephalid species in areas I-VI. It was calcurated by the same method used in the case of the sperm whale. The density does not show periodical fluctuation as in the case of the sperm and Baird's beaked whales.

DOLPHINS AND PORPOISES

Distribution

In case of the dolphins and porpoises, only the date, locality, size of the school were recorded, and no specification was recorded except few cases. The size of school was grouped into three categories of the " large ", " middle " and " small ". The large school is composed of estimatedly more than 300 individuals, the middle from 50 to 300, and the small less than 50 individuals.

The total number of the sighted large, middle and small schools are 121, 315 and 321 respectively. They are shown in Fig. 17 according to the locality and the school size.

As seen in Table 2, the ratio of the number of schools sighted in the coastal waters is about two times higher than the case of other species. This indicates that the dolphins and porpoises are rather coastal species.

Seasonal movement

In areas II, IV and VI monthly fluctuation of the density is bimodal with spring and autumn peaks. Among these three areas, the spring mode arrives earlier and finishes later in the southern area than the northern one. The autumn mode is conspicuous and arrives earlier in the area II, but appears late and inconspicuous in area VI.

In the area VI, the spring mode attains the peak in May or June, and is characterized by the high ratio of middle and small schools, however, autumn mode is peculiar in the decrease of them. The density of the large school is relatively stable all the year round. As the result, the percentage of the large school is highest in August.

In area IV, though the density in January to April is not available, the spring mode attaines the peak in June and July about one month later than area VI. In area II the spring mode is restricted only in June and July.

The autumn mode in area II begins in September, area IV in October, and area VI probably in November. The lowest density between the two peaks in area

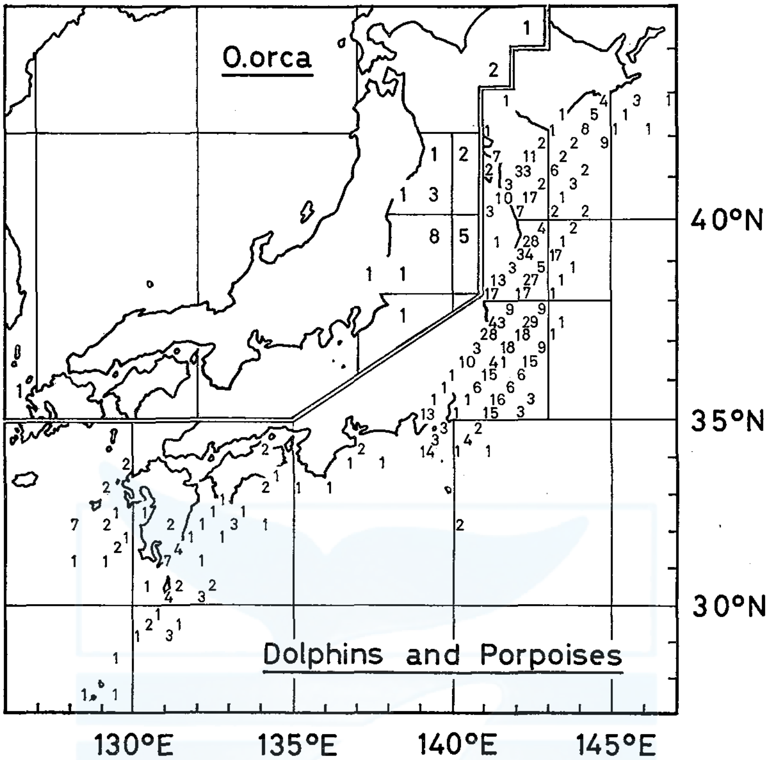

Fig. 17. Number of the schools of the killer whale, and that of dolphins and porpoises sighted in each 1° squares. For the dolphins and porpoises number of large school (upper right), middle school (middle), and small school (lower left) are shown separately.

II is observed in August, in area IV in September, and in area VI probably in October.

In area VII, present data suggests a peak in November and December, but the spring mode was not indicated because of the scarecity of the flight. In other southern areas, area VIII-XII, monthly fluctuation of the density has one mode in the months from January to March or April.

The above features of the density fluctuation suggest that the spring mode in areas II, IV and VI may be composed of the delphinid species from warmer waters. They, in the summer, will extend the range of distribution up to the area II. Then, in the August they start the retreat to the south, passing the area VII and north east part of area VIII in November and December, and may arrive in the west part of areas VIII and in area IX in January and February.

The distribution of the subtropical or tropical delphind species in area VI is indicated by the catch of *Stenella attenuata* at Onahama (36°56′N, 139°55′E) in summer season (S. Uchida, personal communication). The migration of this species is also seen in the fishing result at Sagami Bay (north east part of area VIII)

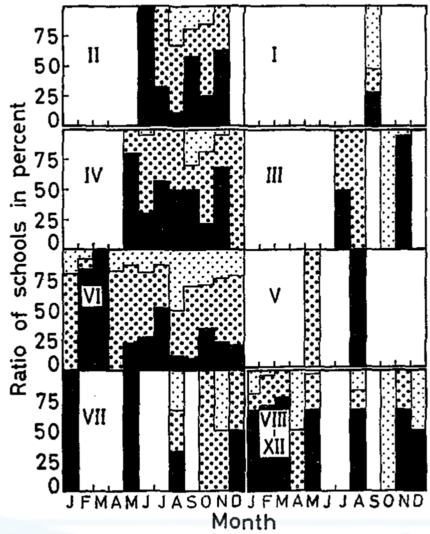

Fig. 18. Monthly fluctuation of the ratio of the number of schools of each sizes in the dolphins and porpoises. Black square indicates the density of the small school, square with larger spots the density of the middle school, and square with smaller spots the density of the large school.

TABLE 10. NUMBER OF *PHOCAENOIDES* SPP. BROUGHT TO KAMAISHI FISHING HARBOR**

Month	Jan.	Feb.	Mar.	Apr.	May
1969*	76	458	89	31	0
1970	85	239	351	109	1
Total	161	697	440	140	1

* calculated from the weight data in 1970. ** approx. 39°16′N 141°54′E.

TABLE 11. RATIO OF EACH SCHOOL SIZE OF THE DELPHINIDS IN ACCORDANCE WITH DISTANCE FROM THE COAST, AREAS I–VI

	Coastal		Intermediate		Off shore	
School size	no.	%	no.	%	no.	%
Large	38	14.4	57	17.4	10	23.2
Middle	122	46.5	143	43.8	20	46.5
Small	103	39.1	127	38.8	13	30.3
Total	263	100.0	327	100.0	43	100.0

in late October to early November before the arrival of *St. caeruleoalba* in November and December (Tobayama, 1969). These two species of *Stenella* had been caught at the Suruga Bay, in the north east part of area VIII and west of the Sagami Bay, in the season from May to July (Nishiwaki and Yagi, 1954; Nishiwaki 1965).

In the areas IX, and the west par of area VIII, *Tursiops* and *Stenella caeruleoalba* are known in all the year round. The concentration of *Legenorhynchus* is seen in winter season at the north east part of area X.

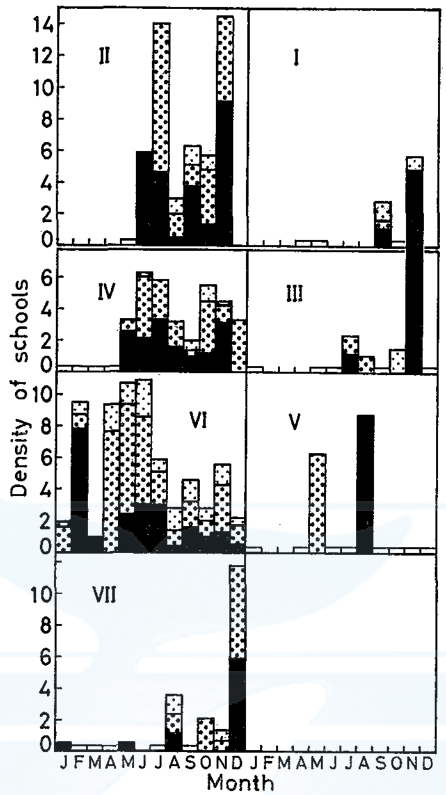

Fig. 19. Monthly fluctuation of the density of the schools of the dolphins and porpoises in areas I–VII. White small squares on the horizontal scale indicate no sighting in spite of the flight. Other marks are same with Fig. 18.

Phocaenoides and *Lissodelphis* are considered to be the species in the colder waters. In areas III, IV and VI, these species are sighted only in the season from September to June. The presence of *Phocaenoides* in winter and its decrease in April to May is also seen in the selling record in Kamaishi fish market (Table 10). In March and April *Lagenorhynchus*, which is considered to live in temperate warter's, migrates in area VI, in July *Tursiops* and *Lagenorhynchus* in area IV, and in September *Phocaenoides* appears again in this area. But some *Phocaenoides* seems to stay in the colder waters adjacent to Hokkaido coast north of 42°N. (Nemoto *et al* 1966; Nishiwaki 1967; Kasuya unpublished).

These informations also suggest the alternations of the delphinids fauna in areas II, IV and VI in June and September.

School size

Fig. 18 shows the monthly fluctuation of the ratio of the schools of three sizes. In areas VIII-XII, the ratio of large, middle and small schools, in the whole year, is 11.5, 23.0 and 65.5% respectively, and the percentage of the small school is slightly higher than that in the northern areas.

In the northern areas the school size changes by the distance from the coast and by the season. Table 11 shows the ratio of the sizes of the schools in accordance with the distance from the coast (for explanation see Table 2). The large school seems to frequent in the off shore waters and the small school in the coastal.

In areas II and IV, the large school is found only in the months from August to October. These large schools seems to be formed on the way to south bound migration by some species in the warmer or colder waters. But there may arise a question whether the low density of schools in this season is due to the annexation of several small or middle schools. To check this problem, the weighted density index is calculated for areas II, IV and VI (Table 12), summing the weighted density index of each school size. The weight of 1, 6 and 30 were used tentatively for small, middle and large schools, assuming the mean school sizes 25, 150 and 750 respectively. But there is still observed the same spring and autumn modes, this will suggests that these two modes are due to the real fluctuation of the number of individuals in that waters.

TABLE 12. WEIGHTED DENSITY INDEX OF THE SCHOOLS OF DOLPHINS AND PORPOISES

Area	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
II	—	—	—	—	0	5.9	*61.3*	41.2	*48.7*	*47.3*	41.6	—
IV	0	0	0	0	6.6	*42.8*	*18.4*	11.4	21.4	*51.4*	17.0	20.0
VI	21.0	36.4	1.0	*98.0*	*83.0*	*105.6*	36.1	*48.0*	*52.2*	30.3	*57.2*	21.7

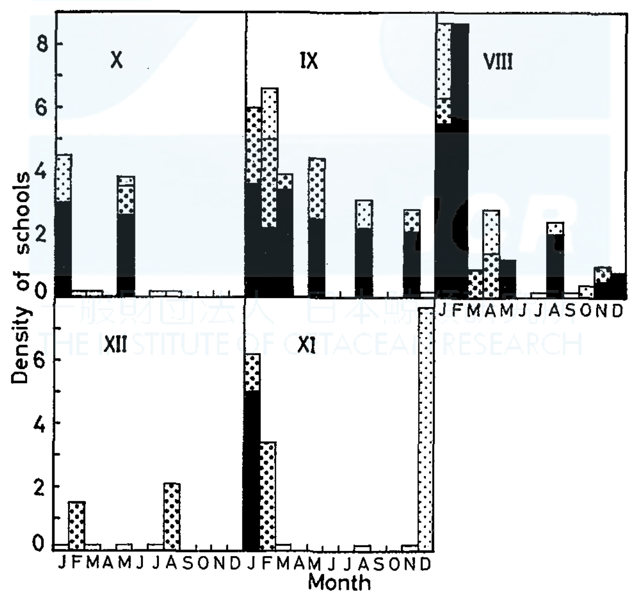

Fig. 20. Monthly fluctuation of the density of schools of the dolphins and porpoises in areas VIII–XII. Marks are same with Fig. 19.

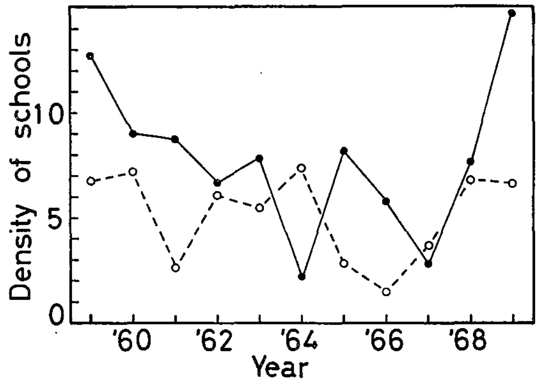

Fig. 21. Annual fluctuation of density of schools of the dolphins and porposises, areas from I to VI are combined. Closed circle and solid line indicate the season from April to July, and open circle and dotted line from September to December.

Using mean school sizes assumed in the above, the relative abundance of the number of individuals of dolphins and porpoises are calcurated in Table 9.

Annual fluctuation

Fig. 21 shows the annual fluctuation of density of the schools in areas I-VI. For the calculation of the density of the spring fauna, number of schools and the flight distance in the period from April to July are used, and for the autumn those from September to December. Though there will be remaining members of the autumn school in Janruay to March, it was ignored because of the absence of reliable density index.

The annual fluctuation of the autumn school is smaller and the density is more stable, however, that of spring school seems to show a long term fluctuation with the cycle of 10 years.

The correlation of the densities of both spring and autumn schools is not observed.

SUMMARY

1. The relative abundance of the species varies according to the season and locality. The ratio of the numbers of the sperm whale, the Baird's beaked whale, the killer whale, the globicephalids, and dolphins and porpoises sighted in the areas I-VI in past 11 years is 1: 0.60: 0.22: 11: 180 respectively, and that of number of schools is 1: 0.51: 0.15: 2.3: 3.6 respectively.
2. The affinity of the cetacea for the coast differes by species, and it decreases in the following order; the dolphins and porpoises, the globicephalids, the Baird's beaked whale, the killer whale, and the sperm whale.
3. Though the mean school size changes by species, locality and season, generally speaking, it increases in the order of the sperm whale, the Baird's beaked whale, the

killer whale, the globicephalids, and the dolphins and porpoises. The large mean school size of the latter species is resulted in both the increase of maximum size of the school and the decrease of the frequency of small sized schools.

4. The density of the sperm whale is higher in the northern areas than in the southwest areas. Most of the schools, probably with females, migrates up to off the coast of Hokkaido in summer and return to the south in autumn and winter. The density of this species in the northern areas fluctuates with the cycle of 4 years.

5. The Baird's beaked whale, off the Pacific coast of Japan, distributes mainly in the waters east of 139°E. It arrives, in the spring, off the Boso Peninsula, migrating in summer to the north beyond Hokkaido, and comes back to the south in winter. The wintering place will not be in the Japanese coastal waters. The annual fluctuation of the density shows the reverse correlation with that of the sperm whale.

6. The killer whale was sighted mostly in the northern waters.

7. The density of the globicephalids is higher in northern waters. In the summer, the range of high density extend to the north and retreats in winter. But it is suggested the existence of some population migrating, in autumn, from the north to the waters off the coast of Hokkaido and probably stay there in the winter.

8. From the density fluctuation of the dolphins and porpoises, it is suggested that species from the warmer waters seems to go up to the waters off the coast of Hokkaido in spring and summer season, on the other hand, those from the colder waters come down as far as area VI in autumn and winter season. The fluctuation of annual density indices of the both groups are independent and the former may show a fluctuation with the cycle of about 10 years.

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EXPLANATION OF PLATES

All the photographs, except Plate IV Fig. 3, are offered by courtesy of Suisan Koku Co., Ltd., Kojimachi, Tokyo, and the copyright belongs to it.

PLATE I

Fig. 1. A school of 21 sperm whales. 2 calves are seen by the mothers in the right sub-school. 41°35′N, 144°50′E, 28 Sept. 1967.

Fig. 2. A school of 5 sperm whales, probably all males. 40°40′N, 142°30′E, 24 Dec. 1960.

Fig. 3. A school of 10 *Pseudorca crassidens*. 33°40′N, 129°40′E, 27 Jan. 1968.

PLATE II

Fig. 1. A school of 12 Baird's beaked whales. 37°20′N, 142°40′E, 1 Aug. 1958.

Fig. 2. A school of 2 Baird's beaked whales. Off Cape Shioyazaki (37°00′N, 141°00′E), 16 May 1958.

Fig. 3. A small school of *Lagenorhynchus obliquidens*. 32°40′E, 128°20′E, 28 Jan. 1968.

PLATE III

Fig. 1. A school of *Globicephala macrorhyncha*. 37°20′N, 142°40′E, 14 June 1966.

Fig. 2. A school of *Globicephala macrorhyncha*. 42°00′N, 143°40′E, 12 Sept. 1961.

PLATE IV

Fig. 1. A large school of *Delphinus delphis*. 41°50′N, 141°50′E, 19 Sept. 1968.

Fig. 2. A school of 17 *Tursiops gilli*. 35°05′N, 139°20′E, 31 Aug. 1970.

Fig. 3. A school of 6 *Neophocaena phocaenoides*. 35°25′N, 139°50′E (by courtesy of Asahi Shinbun, Tokyo).

PLATE V

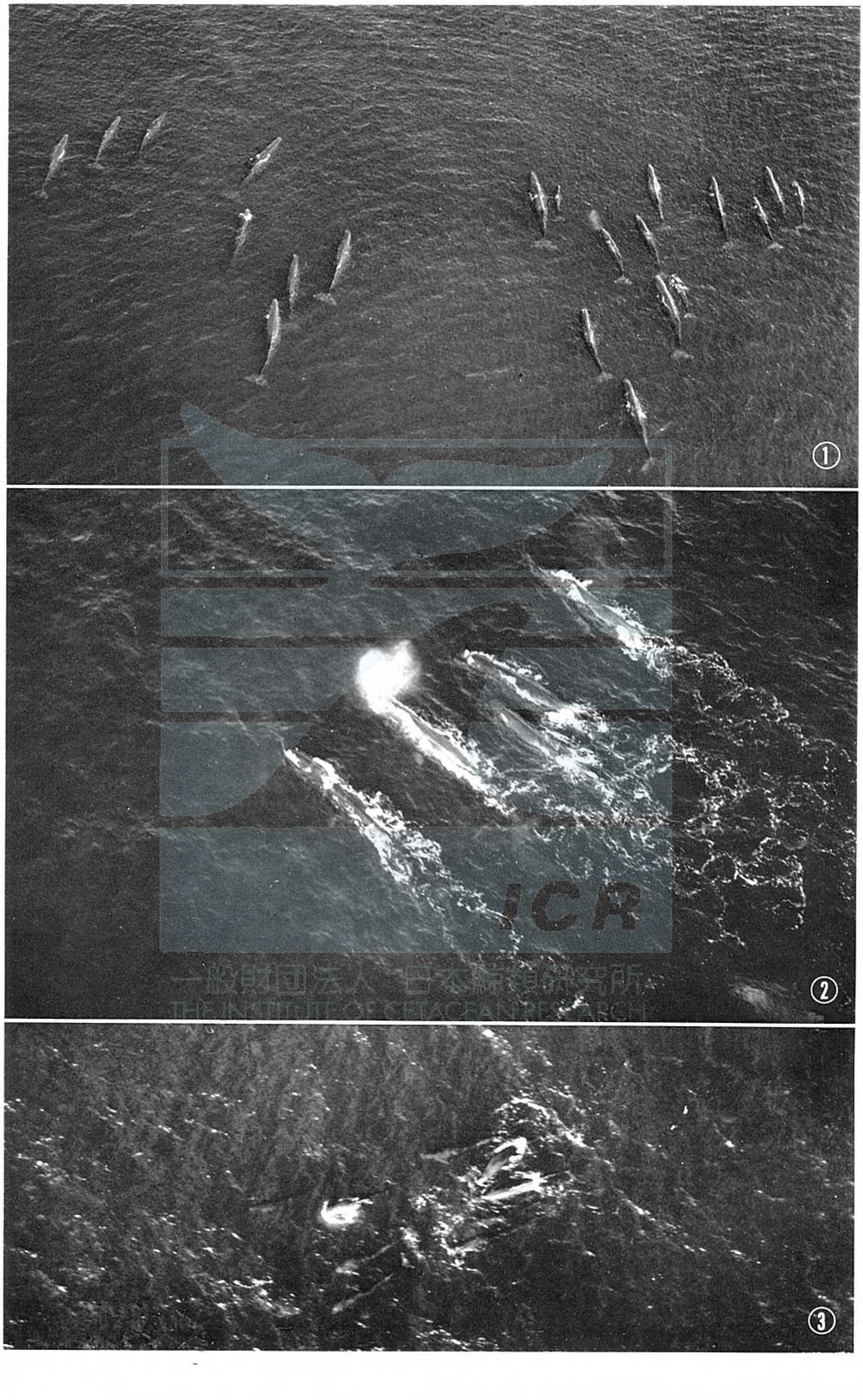
Fig. 1. A middle school of *Lissodelphis borealis*. 35°50′N, 141°20′E, 18 May 1958.

Fig. 2. A large school of *Lissodelphis borealis*. 36°20′N, 141°50′E, 6 Apr. 1960.

PLATE VI

Fig. 1. *Stenella caeruleoalba* attacking mackerel school. 35°14′N, 139°21′N, 6 Feb. 1970.

Fig. 2. A school of 7 *Grampus griseus*. 37°20′N, 142°05′E, 15 July 1963.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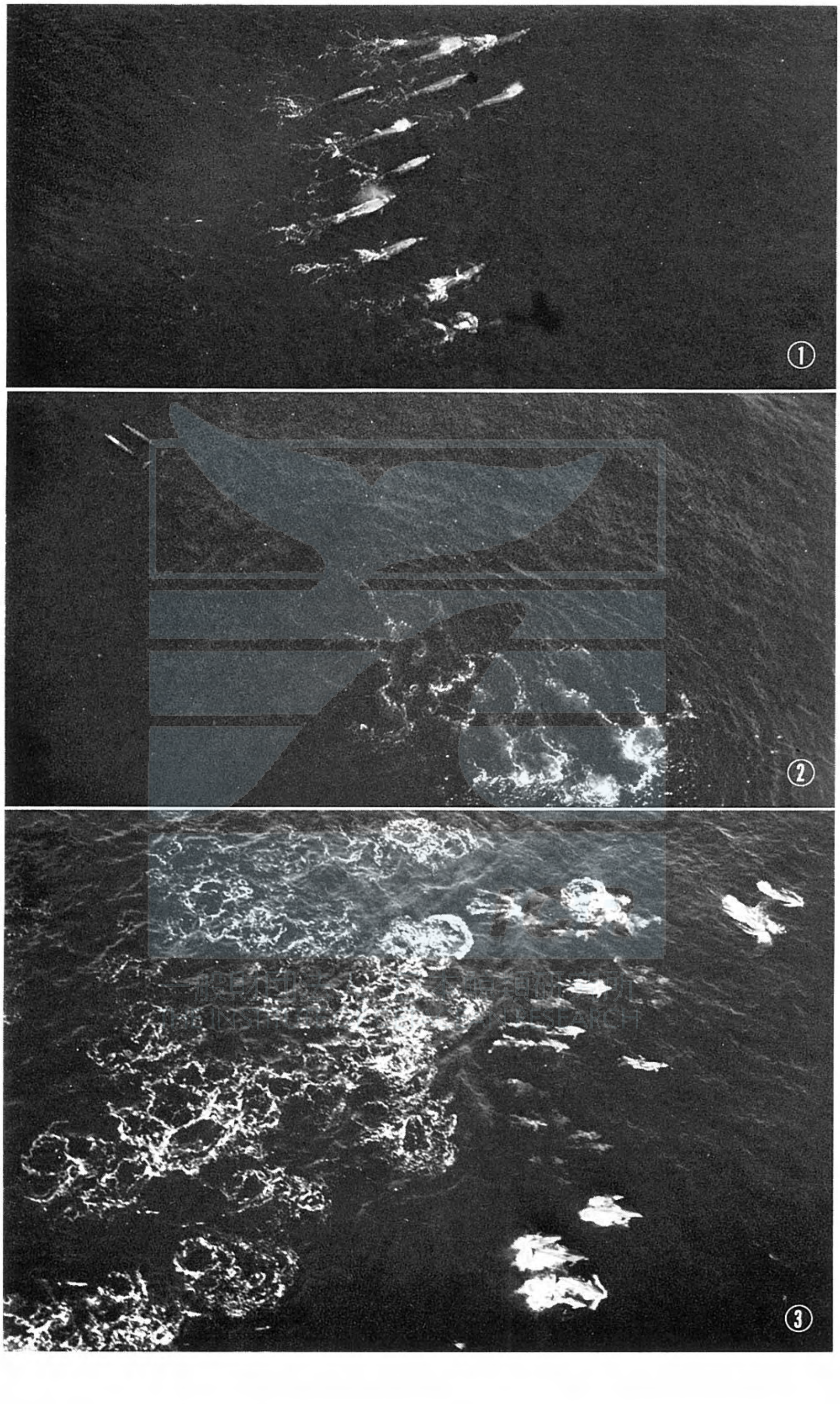
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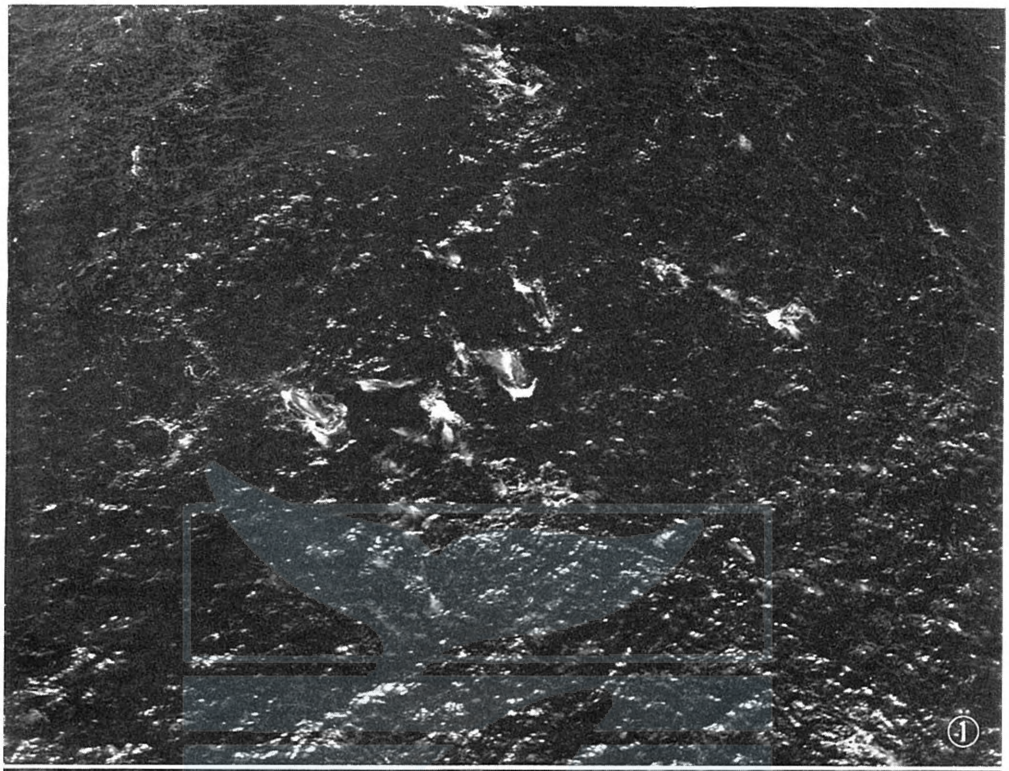
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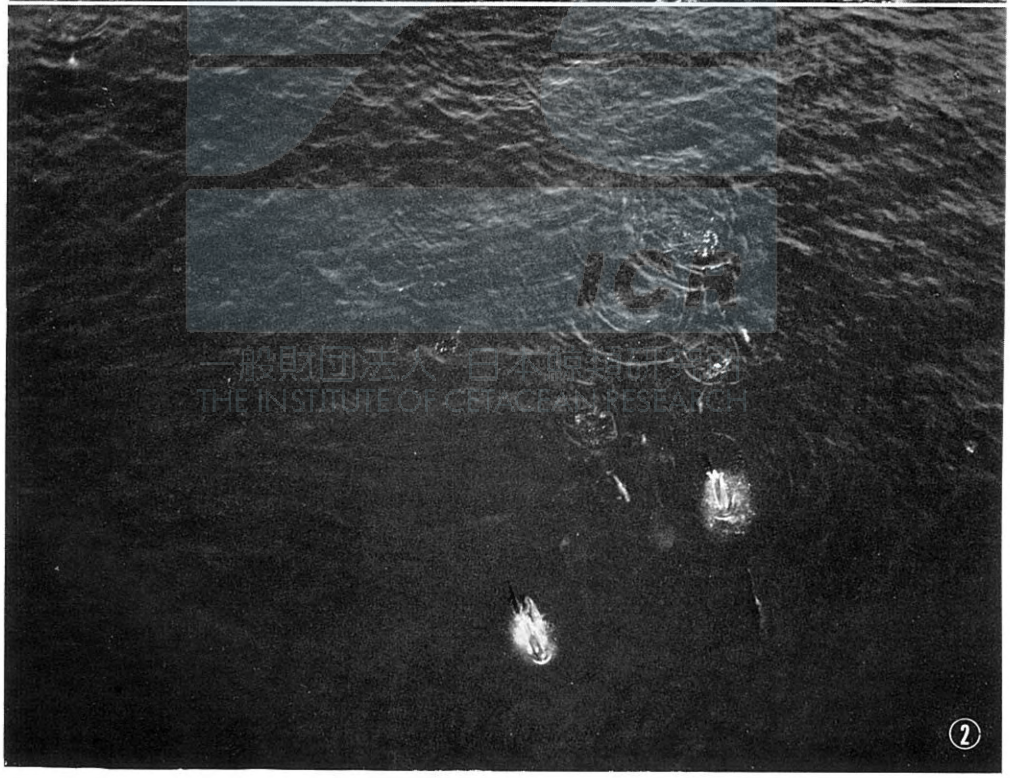
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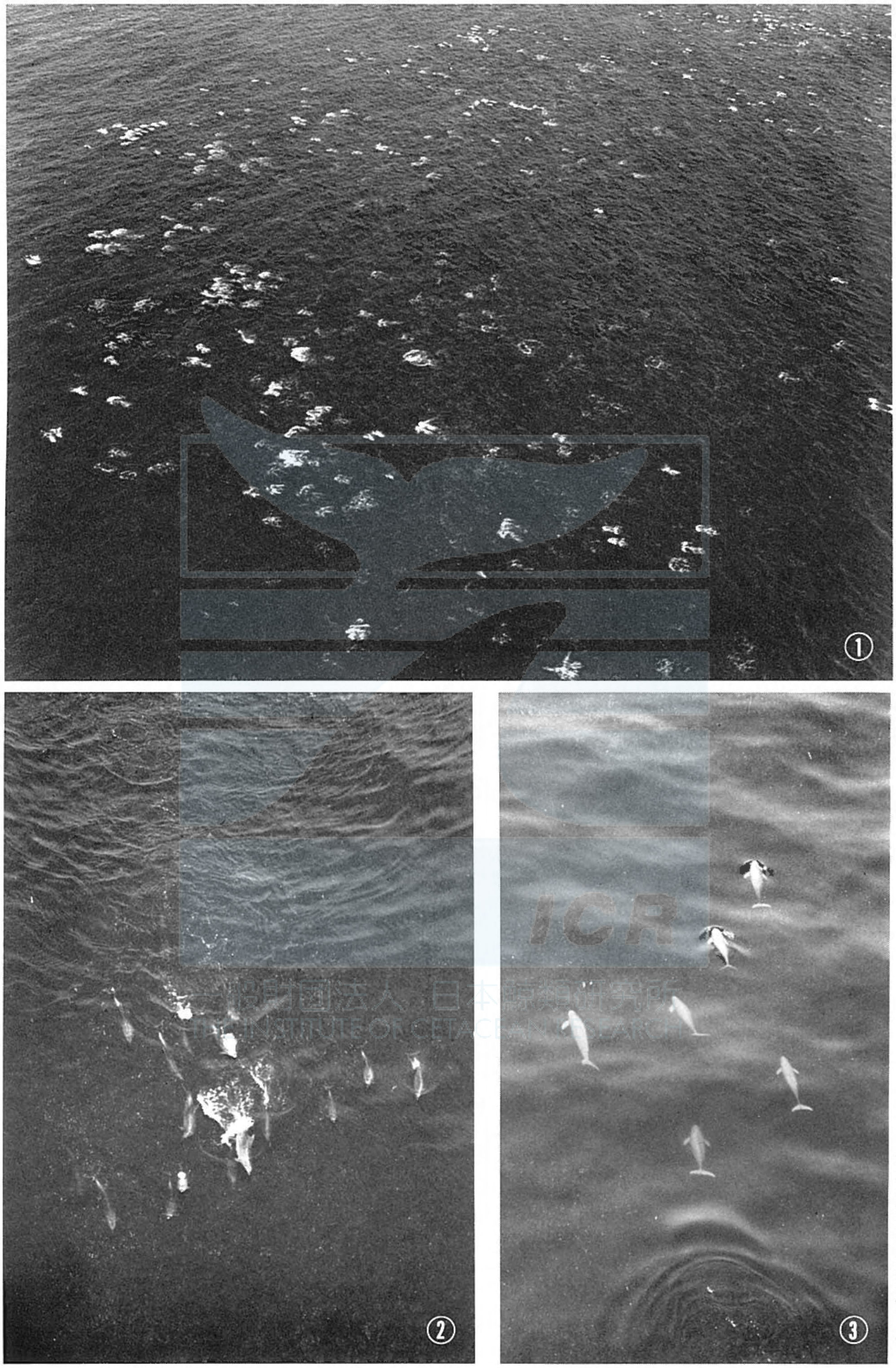
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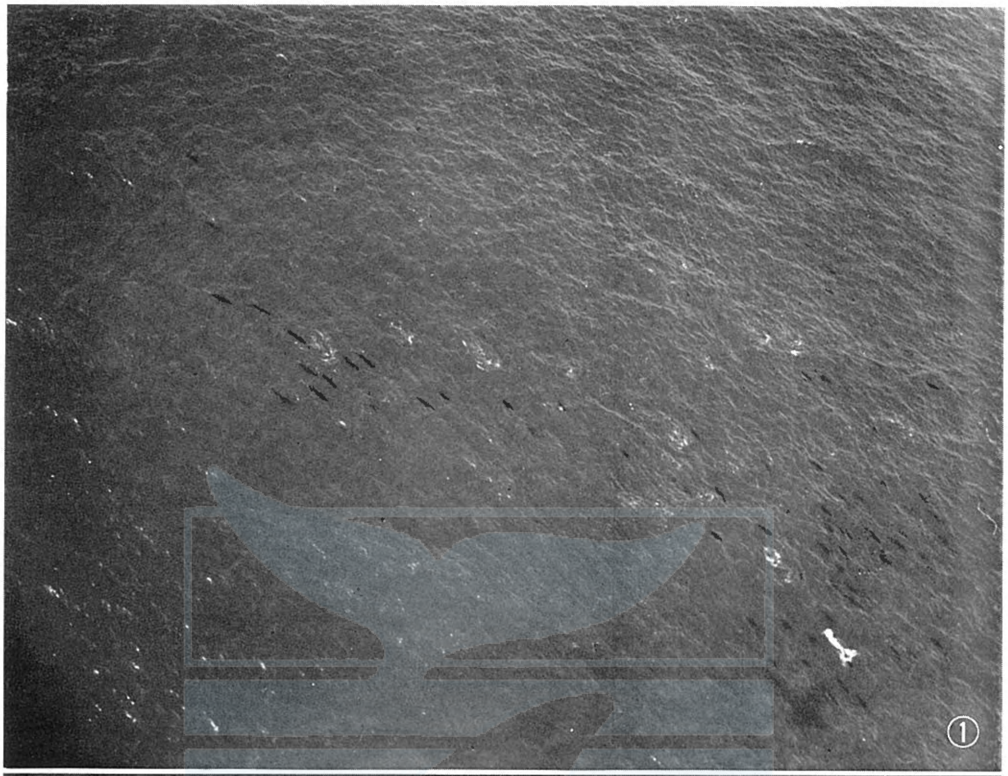
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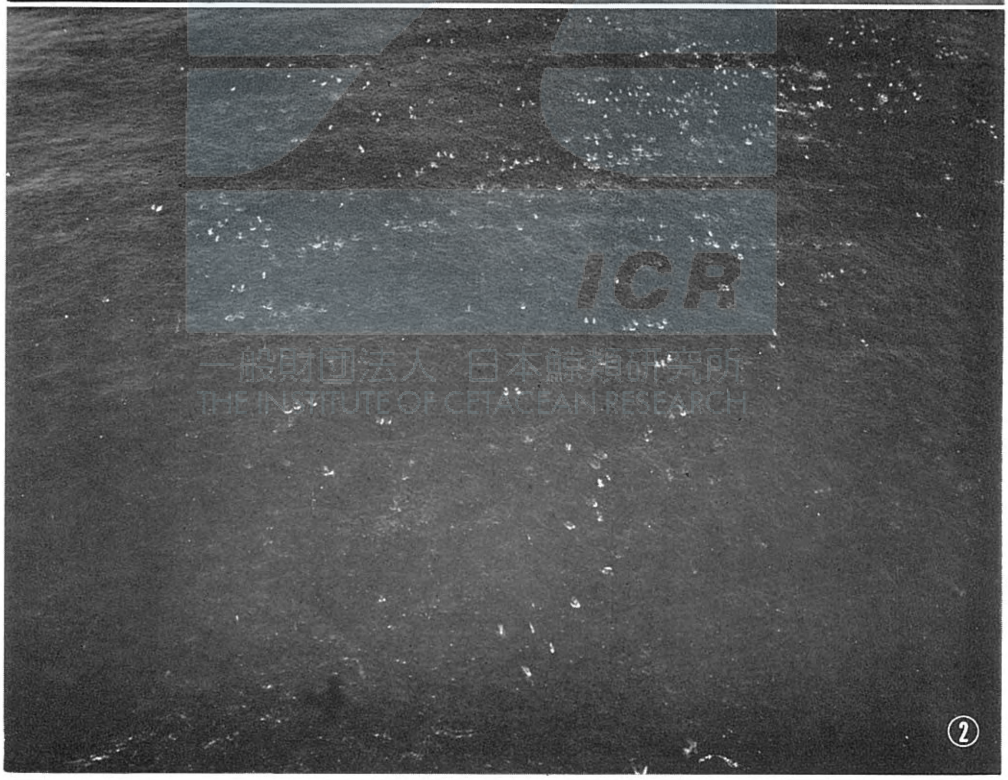
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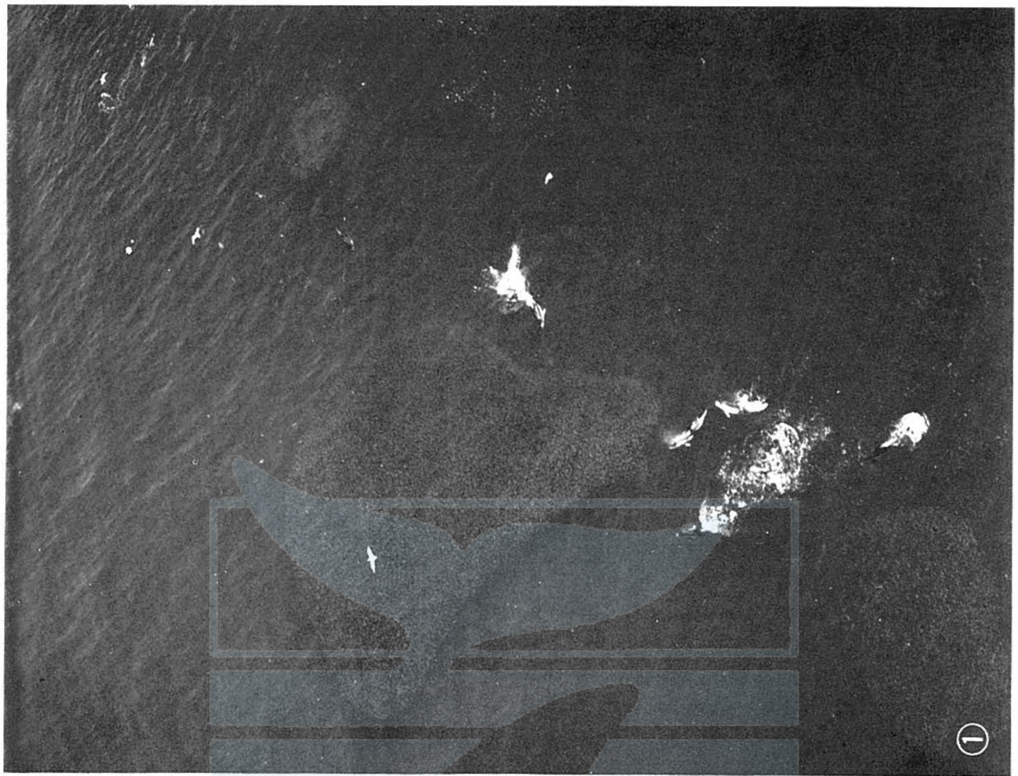
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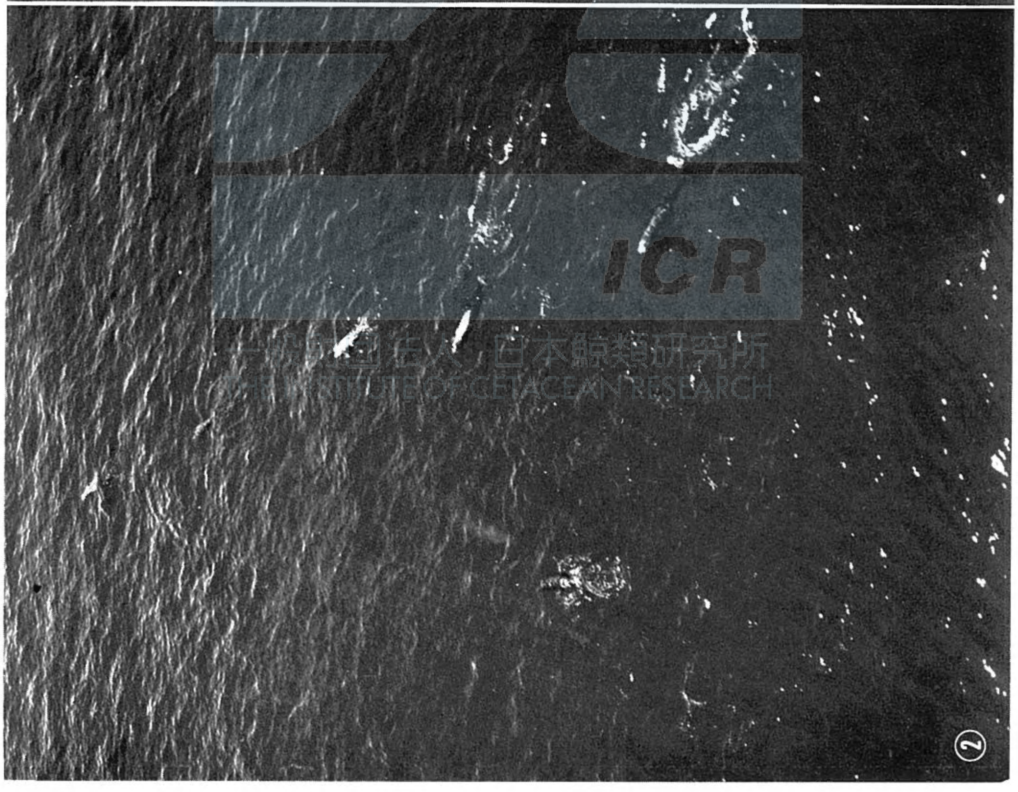
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