THE POPULATION OF FINLESS PORPOISE IN THE INLAND SEA OF JAPAN

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ABSTRACT

The observation of 1,194 finless porpoises made through 11,549 km of sighting cruises in the Inland Sea and some ancillary observations provided the following informations. The porpoise migrates annually to and from the Pacific coast mainly through the two passes at the eastern Inland Sea. The highest density (4,900 individuals) is found in April at the beginning of parturition season, and the lowest (1,600) in early winter. The ratios of solitary adults, of solitary calves, and of cows with calf show seasonal fluctuation, and allow the analyses of the seasonality of reproduction. Gestation last for about 11 months. Parturition occurs between April and August with a possible peak in April and May. Most of the cows with calf born in April and May are suspected to leave the Inland Sea in summer months. Weaning occurs from December to June after a nursing period ranging from 6 to 15 months. Pregnancies in two contiguous years are not frequent. A 2-year breeding cycle seems to be most common. Annual production of about 870 calves (both sexes), and gross annual reproductive rate of 17.9% are provisionally estimated for the individuals in the Inland Sea.

INTRODUCTION

On the Pacific coast of Japan, the finless porpoise, *Neophocaena phocaenoides* (G. Cuvier, 1829), ranges from the west coast of Kyushu, through Inland Sea, Ise Bay, and Tokyo Bay, to the Sendai Bay (Anon., 1965; Kuroda, 1940; Mizue *et al.*, 1965, 1968; Nakajima, 1963; Ogawa, 1950). Though the incidental catch of the species once numerous in the Tachibana Bay in the western Kyushu (Mizue *et al.*, 1965) has ceased by the change of the fishing method (K. Mizue, pers. comm.), small number of incidental catch and strandings are still common in the above range. The confirmed northern limit of the range is at the Sendai Bay (38°20′N, 141°15′E), but the species is considered to migrate further north (Ogawa, 1950). The species is often trapped in set nets or sighted in the Sendai Bay in June and July, but it is absent in winter season (T. Shimoyama, pers. comm.). The distribution of the species in the Sea of Japan is not confirmed.

The Inland Sea is a well known, and possibly the largest habitat of the finless porpoise in Japan. The species is legally protected since 1930 as a natural monument. However the protection covers only the porpoise in a 1.5 km radius with a center at the southern tip (34°18.3'N, 132°57.1'E) of Awashima Island near Takehara City. The reason of the protection is described in Kaburagi (1932). Namely the angling fishermen of Tadanoumi Town near Awashima used to use the feeding finless porpoise as an indicator of a kind of fish, *Chrysophrys major* Temminck and Schlegel, which is believed to feed on small fish *Ammodytes personatus* Girard as the finless porpoise supposedly does. This fishery, operated in winter season, ceased about 10 years ago by the disappearance of *Ammodytes* in the area (S. Shiromoto, Manager of Tadanoumi Fishermens Cooperative Union, pers. comm.).

In recent years the pollution of the Inland Sea has progressed, and the increased frequency of red tide and gradual change of the fish fauna is indicated (Hoshino, 1972). However the Inland Sea is still a very productive ground of fisheries and aquiculture. The fishery production, excluding aquiculture, in 1977 was 181,902 tons of fish and 102,385 tons of invertebrates and algae (Chugoku Shikoku Noseikyoku, 1978). Though a law was established in 1973 to regurate the amount of the pollutant discharged in the Inland Sea and the regulation was intensified in recent years, there is no indication of improvement of the situation (Anon., 1978).

Since the catch of the finless porpoise is not practically regulated in Japan, the possibly small population of this coastal species might be damaged if there occurs a fishery for the finless porpoise in response to the increase of the demand of live specimens for aquariums. Furthermore the population will not be free from the influence of the pollution progressing in the region. The present study was intended to analyse the distribution, abundance, seasonal movement, and reproduction of the finless porpoise in the Inland Sea, and to provide the basic biological data necessary for the conservation of the species.

MATERIALS AND METHOD

Description of the Inland Sea and area division

The present study covers the Inland Sea proper. It is an area of about 14,300 km² of water with about 3,000 islands scattered in it, and is connected to open sea or other bay by four narrow passes.

The Kanmon Pass is situated at the northwest and opens to the Sea of Japan. It is the narrowest of the four passes, with the minimum width of 0.6 km, depth of 19 m, and maximum current of 8.2 knots.

The Hayasui Pass at the southwest entrance opens to the Bungo Channel which is connected to the Pacific. It is the widest of the four passes, 11.5 km wide and 186 m deep. The maximum current is 6 knots.

The Naruto Pass opening to the Kii Channel at the southeast corner of the Inland Sea has the maximum current of 10.6 knots. The minimum width is 1.3 km, and the maximum depth at the place is 65 m.

The Akashi Pass connects to the Osaka Bay, which is another small inland

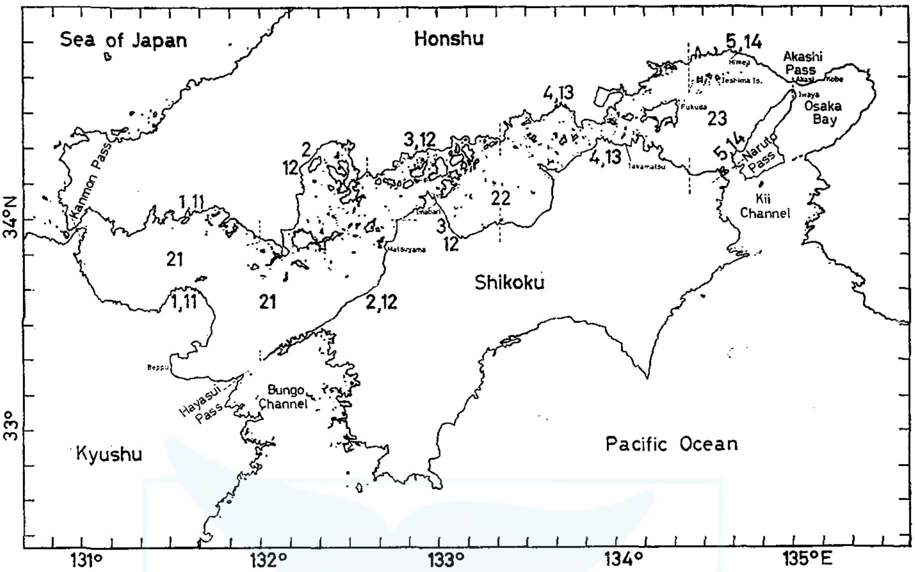

Fig. 1. Geography of the Inland Sea of Japan. Numeral indicates the area number used in this study. The boundary between the strata is not indicated.

water opening at the southern part to the Kii Channel. It has the minimum width of 3.7 km and the maximum depth of 104 m. The maximum current is 6 knots.

As shown in Figs 7 and 11, the depth of the Inland Sea is less than 40 m in most of regions. The mean depth is 31 m. The depth is larger in the western open area north of the Hayasui Pass. The depth of about 98 m, the maximum in the Inland Sea, is recorded in this region.

The water temperature recorded in the present study was between 6.0°C in March and 28.0°C in September. The seasonal change in the surface water temperature is more drastic than the open waters. Because of the inflow of external water from the wide Hayasui Pass and the larger water depth in the western region, the western open area is more oceanic. Namely the water temperature in winter is higher at the western part than at the eastern region, and reversed in summer. The difference of the surface water temperature between the two regions is 3°C to 4°C in both summer and winter seasons.

As the possible result of the oceanic environment, there were often observed some oceanic delphinids in the open water of the western Inland Sea (Figs 7 and 9).

As mentioned in the later section, the finless porpoise is distributed near the coast. Though it is not certain if it is related to the water depth or to the distance from the shore, the areas were divided in the present study based on the distance from the coast and on the group of islands. The entire research area was, at first step, divided into three strata. The first is the stratum of 0 to 1 nautical mile off the coast. This stratum was divided into five areas of 1 to 5, considering the distribution of the islands. The second stratum corresponds to the waters 1 to

3 miles off the coast. This stratum was divided into four areas (areas 11 to 14) by the way mentioned above. Then there remain three independent waters which are more than 3 miles apart from the coast. This is the third stratum and divided into three areas of 21 to 23 (Fig. 1).

Research period and data source

The field observation started in April 1976 and finished in October 1978.

Kureha made the observations between Himeji and Ieshima Islands and those between Himeji and Fukuda, which routes are shown by dotted lines in Fig. 11. He had 24 expeditions in that part. Each expedition covered only a day with more than one trip on each route.

Kasuya had 10 expeditions, 10 to 15 days each, to observe most of the part of the Inland Sea which are not cruised by Kureha.

Kasuya's 9th expedition, 6 to 15 March 1978, was for the observation of the movement of the porpoise at four passes. The 10th expedition, 15 April to 2 May 1978, also includes cruises outside of the Inland Sea. Kureha had four expeditions to the Kanmon and Akashi Passes. Though the results of the observations made outside of the Inland Sea are not included in the Appendix, they are shown in Figs 7 to 14.

The data of some of the Kureha's expeditions in the Inland Sea were combined with those of Kasuya, and used for the population estimation (see Appendix).

A six hours cruise was made on 13 April 1976 in the nearshore waters off the northeastern Shodoshima Island (34°31′N, 134°10′E) on board of a small fishing vessel. Though 47 porpoises were encountered, these data are not used for the population estimation, because the course was altered by the presence of porpoise. They are used only for the analyses of the school composition.

The aerial sighting records of the finless porpoise in the Inland Sea and adjacent waters were provided by the Fisheries Aviation Co. Ltd., Kojimachi, Tokyo. The flights were to monitor the pollution by scanning the area systematically, and covered the years from 1972 to 1978. The season was usually limitted to June to October with a few exceptional flights in other seasons. The observation of the porpoise was made by an experienced navigator at the altitude of 450 m, but lowered to 100 to 150 m for the precise observation. These data were used for the limited purpose to compare the relative density between the areas or between the seasons.

Vessels

With the exception of one trip made by the research vessel *Tanseimaru* (230 gross tons) on 12 November 1976, all the observations were made on various commercial ferry boats. They were either for passengers or for both passengers and cars. The four of the five former cases were generally small (100 to 150 gross tons), and had cruising speed of 8 to 13 knots. The height of observer's eye was from 3 to 4 m. An exceptionally large passenger boat was used between Beppu and Imabari, and between Takamatsu and Kobe. The speed was about 18 knots, and the eye height of observer was about 15 m. Other ferry boats carrying both passengers and cars had large variety of size. However the eye height (6 to 6.5 m) was almost constant, because the roof height of car deck was designed about 4 m. The speeds were between 8.4 and 14.2 knots.

The speed composition of 28 vessels (34 trips) in the 5th expedition, May 1977, is shown in Fig. 2. The mean speed was 11.3 knots (non weighted) or 12.3 knots (weighted with cruised distance).

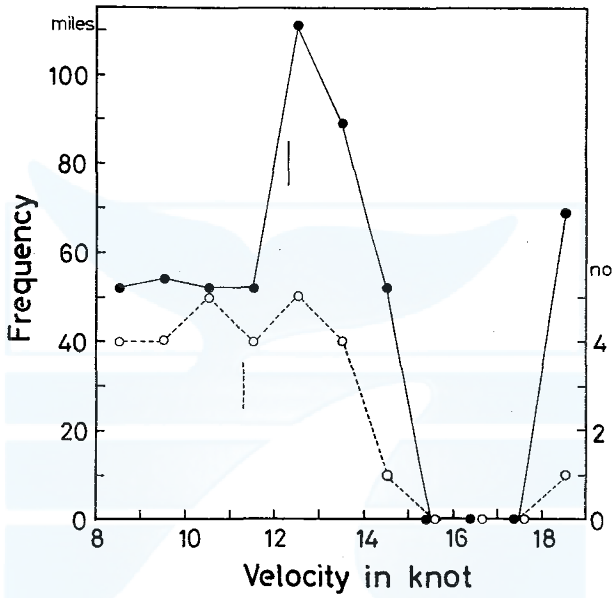

Fig. 2. Speed composition of the vessels used in this study. Closed circle and solid line indicate the frequency weighted with cruising distance, open circle and dotted line nonweighted frequency, and vertical line the average speed.

Though the course was arranged as far as possible to cover the waters evenly, the sighting effort was scarce in the western areas 1 and 11. The sighting effort in offshore stratum (areas 21, 22, and 23) was scanty. Since the first expedition, 12 to 23 April 1976, was exploratory, the areas were covered in the case less completely compared with the following expeditions.

Method of observation

The observer situated at a position where the maximum field of vision is available. It was sometimes the front seat of the cabin. However, in most of the cases, it was the posterior upper deck. Both naked eyes and a binocular (8×, 8.5°) were used alternatively. The former were used for the near side of about 500 m or less, and the latter for the far side between 400 and 1,000 m. Though the field of observation from 270° to 360° was available by moving between port and starboad side, the observation of the front direction was difficult at the posterior upper deck. The time of one scanning was about 20 seconds with binoculars and about 10 seconds with naked eyes. Namely a set of far side and near side scanning took about 30 seconds, if there was found neither porpoise nor symptom suggesting the presence of the finless porpoise. The course of vessel was not altered by the presence of porpoise or of the symptoms.

For finding the porpoise, not only the body of porpoise or wave caused by submerged porpoise, but also the flock of feeding sea birds or the direction of flying sea birds (mainly sea gulls) were extremely usefull. These indications were, if found, carefully inspected with binocular.

When the body of finless porpoise was first confirmed, the time, direction from the vessel (if possible), radial distance from the observer in nearest 10 m, distance from the nearest coast line (if possible), number of individuals in a school, internal structure of the school (if present), the estimated growth stage of each individual, and special behavior of the porpoise (if observed) were recorded. The growth stage was recorded as adult, juvenile (intermediate), and calf. The distinction was made based principally on the body length relative to that of full grown individuals. The first category represents the large individuals, and their estimated length is more than 150 or 160 cm. The last is composed of the newborn calf which shows its typical dark colour or older paler individuals not exceeding 120 or 130 cm in body length. Though the juvenile (intermediate) is expected to indicate the individuals between the two length range or those between 135 and 155 cm, the accuracy will be worse than the other two. If an adult was accompanied by a calf, they were considered as a mother and its calf. These individuals were always swimming in parallel, and usually stayed within the distance of 1 m, which is much closer than the ordinary two adults do.

The position of the vessel was estimated from the relative position of islands or of land marks, or from the fairway buoys.

Surface water temperature was measured two or three times a day on cruising vessel. The wind force was recorded, in Beaufort scale, during entire cruising hours.

The observation was conducted in a wind less than 3 in Beaufort scale, and in a visibility exceeding 0.5 nautical mile (926 m).

Principle of population estimation

When the abbreviations are defined as follows,

D: Cruised distance, nautical miles
N: Number of counted porpoises
P: Number of porpoises present in area of S square nautical miles
R: Finding rate, ratio of porpoises counted to the porpoises present within 0.5 W miles distance from observer (both sides)
r: Apparent finding rate
k: Finding rate at 0 m distance from the course
S: Dimensions of the sea, square nautical miles
W: Observed width, nautical mile

there are following relationships.

$$P = \frac{S}{D \cdot W} \cdot \frac{N}{R} \quad (1)$$

$$R = r \cdot k \quad (2)$$

As mentioned in the later section, r is influenced by the weather and other oceanographical environment. And $N/(D \cdot r)$ is used as an population density index corrected for the seasonal change of the apparent finding rate.

ESTIMATION OF PARAMETERS

Observed width (W)

Several experiments made on a straight river or on a sea surface of known distance suggest that a surfacing finless porpoise is identified from 450 m with naked eyes and from 900 m with binocular at the sea condition of slight breeze (Beaufort wind scale 1). All the sightings in this study, except for two cases, occurred within 1000 m. Accordingly W was assumed in this study as 1 nautical mile. Even if this estimation is biased in some degree, it does not cause any biase in the estimation of population abundance (see equations (1) and (3)).

Apparent finding rate (r)

The swimming of finless porpoise is usually gentle exposing only part of head and dorsal region, and the jumping clear out of water or sprashing is rare. They are usually indifferent to the boat encountered. No bow wave riding was observed. The response to boat is observed as (1) a deep diving or minimum alternation of direction when the cruising courses of the two cross about 5 to 20 m ahead of the animal and collision is anticipated, or (2) a kind of stern wave riding lasting only few to several seconds. The latter occurs occasionally when stern wave passes over the porpoise.

Figure 3 shows the relationship between the number of porpoises counted and the distance from observer. Since the finless porpoise is almost indifferent to the presence of cruising vessel, above relationship is considered to indicate the increase of overlooked individuals with that of the distance.

The frequency of finding is relatively high at the distance below 400 m, and the points come on a straight line (Fig. 3). This is the range where the porpoises are identified with naked eyes. If y intercept of the linear regression is shown by Y_0 in number of individuals per 100 m range, and the number of total porpoises dealt by n, there is expected the following equation.

$$r = n \Big/ \left(Y_0 \cdot \frac{0.5 \cdot W \cdot 1852}{100} \right) \quad (3)$$

Wind will have serious influence on the apparent finding rate. Table 1 shows the seasonal difference of the mean wind force and the number of porpoises sighted per one hour's observation in different weather conditions. It shows that the sighting efficiency rapidly decreases with the increase of wind force. The efficiencies at the wind scale 1 to 2, and at 2 to 3 are 53.3% and 15.3% of that at wind

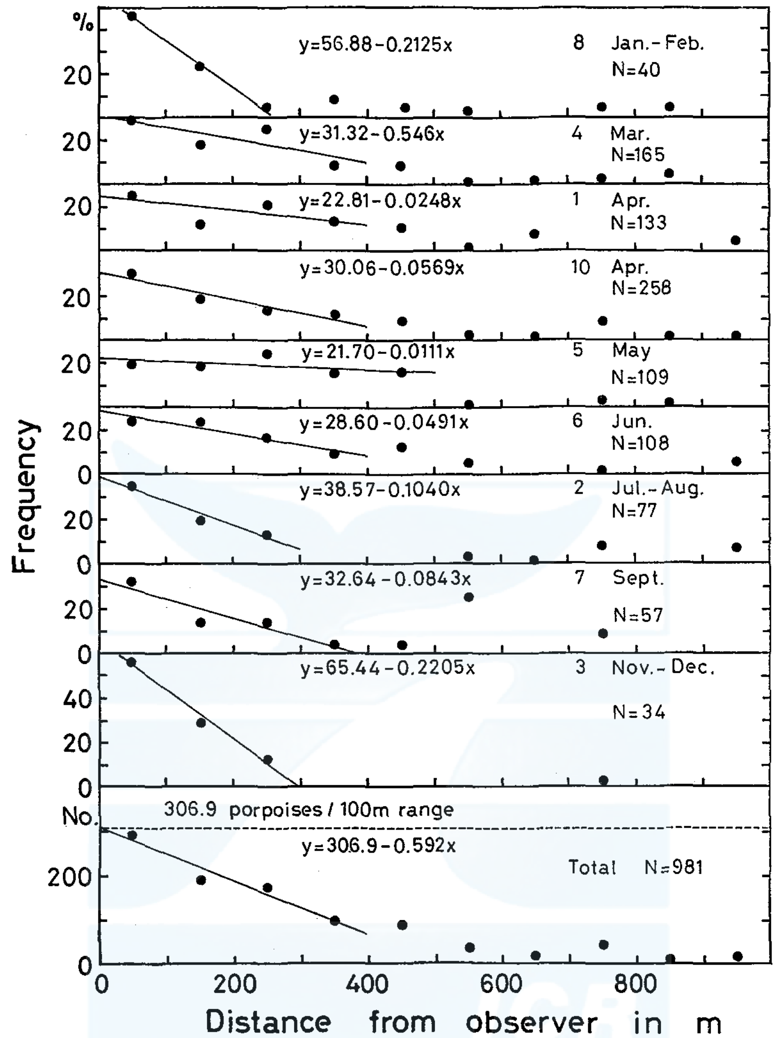

Fig. 3. Relationship between the distance from the observer and the number of the porpoises sighted. Numeral indicates the expedition number. Data of Kasuya and Kureha included.

0 to 1. As shown in Fig. 4, it can be said for any of 9 expeditions that the sighting efficiency was higher in the weather of lower wind force.

The r calculated for each expedition shows a seasonal fluctuation (Table 1). The relationship between the mean wind force and r is shown by a linear regression. However, as shown in Fig. 5, the 2nd (July to August) and 3rd (November to December) expeditions give extremely low apparent finding rates. Though the precise observation of density of sea bird was not recorded, it is worth to note that the extreme scarcity of sea bird in the 2nd expedition was noticed and recorded on several pages of the field book. This may perhaps have a effect to lower the

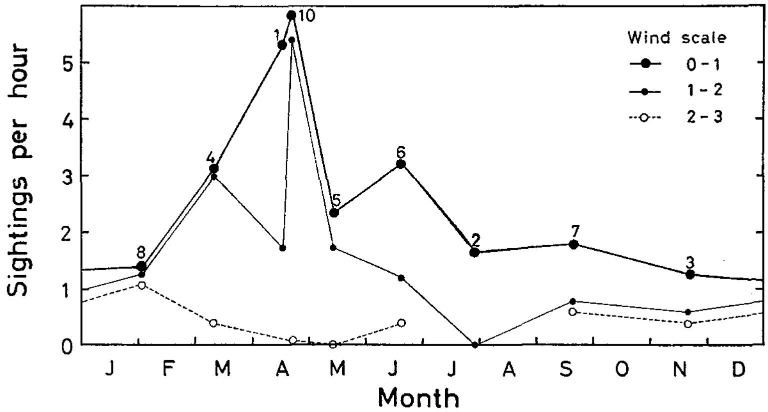

Fig. 4. Relationship between the wind force and the number of individuals sighted per one hour of observation. Upper limit of each wind range excluded. Numeral by the circle indicates the expedition number.

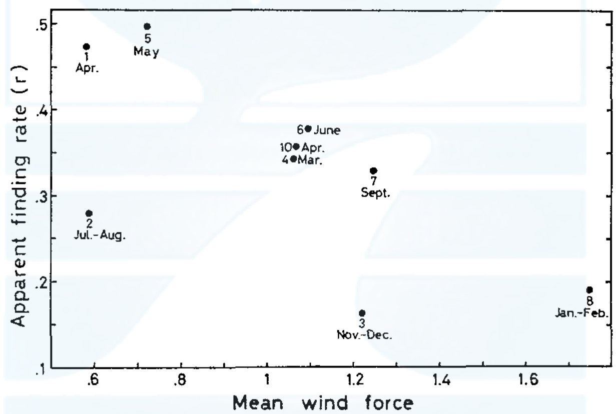

Fig. 5. Relationship between mean wind force and the apparent finding rate (r). Numeral indicates the expedition number.

apparent finding rate.

Though it is not possible to explain the low r value of the 3rd expedition, it is concluded that the apparent finding rate r calculated by the above method reflect the wind force and probably some other oceanographical conditions. So it is unnecessary for r to have further wind force correction. The visibility will not need to be corrected because the observation was made only when the visibility exceeds the observable distance (W/2). There might be personal difference of the r value. However it was confirmed in the previous cooperative works that our sighting ability is not significantly different.

Though it is more reasonable to use perpendicular distance measured from the position of porpoise to the course of the vessel instead of the radial distance between porpoise and observer (Seber, 1973; Doi, 1974), it was not used in the present study mainly from the absence of adequate data. Where the porpoise is densely distributed, the recording of both finding direction and the distance was often impossible for single observer without increasing the overlooked individuals. Only the radial distance at the first sighting was recorded in such a case. When the direction of finding is group into nearest 45° angle, they are distributed as follows.

Direction	Number of individuals	Percent
0°	22	3.2
45°	28	4.1
90°	601	87.7
135°	27	4.0
180°	7	1.0
Total	685	100.0

The finding on stern (180°) or bow (0°) direction is only a few percent of the total, and most of the sightings occurred on the side direction or between 67.5° and 112.5°. This tendency will be more exagerated in the dense area where angle was not recorded. Though the present calculation will slightly overestimate the *r* value, the above analysis of the finding direction suggests that the bias will not be so large compared with the uncertainty of the estimation of *k* value mentioned below.

TABLE 1. EFFECT OF WIND ON SIGHTING OF FINLESS PORPOISE

Expeditions		Sightings[1]		Wind force[2]				Apparent finding rate (*r*)
no.	date	no.	hrs.	0–1	1–2	2–3	mean	
8	27/I–10/II	36	29.86	0.167	0.420	0.413	1.746	0.190
4	2/III–15/III	155	53.93	0.530	0.381	0.089	1.059	0.345
1	12/IV–23/IV	251	49.57	0.920	0.080	0	0.580	0.473
10	15/IV–30/IV	256	55.43	0.618	0.195	0.187	1.069	0.356
5	8/V–19/V	109	50.57	0.827	0.128	0.045	0.718	0.498
6	14/VI–25/VI	101	47.05	0.515	0.380	0.105	1.090	0.378
2	22/VII–4/VIII	76	49.63	0.915	0.085	0	0.585	0.280
7	15/IX–28/IX	57	51.64	0.350	0.551	0.099	1.249	0.331
3	12/XI–21/XII	51	57.00	0.519	0.243	0.238	1.219	0.165
Total		1092	444.68	0.613	0.267	0.120	1.007	0.345
Total, no./hr		—	—	3.174	1.693	0.486	2.456	—
Total, no./hr rate		—	—	1	0.533	0.153	0.774	—

1) Only data obtained by T. K. included. 2) Shown by the ratio of length of time, wind range lower limit inclusive, Beaufort scale.

Estimation of k and R

For the estimation of the population size the true rate of finding at zero distance need to be estimated. Since the mean speed of the vessels is about 12.3 knots, an entire observation field of 1 nautical mile is cruised within 4.9 minutes, and more efficient observation field of about 900 m within 2.4 minutes. On the other hand the surfacing interval of the finless porpoise ranges form 4 to 80 seconds with an average of about 40 seconds (T. Kataoka, unpublished data). Then the number of surfacings expected for one porpoise in an observation field is from 73 to 3.7 occasions with an average of 11, and that in the efficient observation field is from 36 to 1.8 with an average of 3.6. These figures will be doubled for a school of average size (1.97 individuals/school). On the other hand one complete scanning, near side and far side, was made at most once every 30 seconds, and certainly less when porpoise was sighted. This means that one observer can scan the near side and far side ranges only less than five occasions. Then it will be suggested that the finding rate at zero distance (k) must be below 1.

In the present study k was estimated from the relationship between the number of sightings and number of observers on one vessel. This experiment was made in 9th expedition on both sides of the Naruto Pass. The season corresponds to that when the porpoise is most abundant. The weather was calm. The other observer was Mr T. Hiwatari, a graduate student with one week experience of whale watching. The sighting was recorded by Kasuya in two categories. The first is the porpoises found by Kasuya or Kasuya and Hiwatari. The second represents the porpoise which might have been overlooked if Hiwatari had not been there. There was 73 individuals in the first category and 37 in the second category. When X indicates the probability of one surfacing not encountered with a visual angle of one observer, the probability of a surfacing not encountered with the visual angle of any of n observers is shown by X^n (Doi, 1974). Accordingly when p indicates the number of finless porpoises present on the course of a vessel, there will be the following equations,

$$1-k = \frac{p-73}{p}$$

$$(1-k)^2 = \frac{p-(73+37)}{p}$$

and k is calculated as

$$k = 0.493$$

which is rounded to 0.50.

When a school of porpoise is sighted, the scanning has to be stopped in order to have its detailed observation. This means that the presence of a porpoise may obstacle the finding of another school, and that the estimation of k is inversely correlated with the density of porpoise. Because the density of the porpoise around the Naruto Pass, where k value was estimated, was extremely high as indicated in the latter section (Table 2 and Appendix I), true k in calm seasons (expeditions 1, 2, and 5) can be 0.5 or larger. However, since k is suspected to be inversely correlated with the wind, the value for other expeditions will perhaps close to 0.5 or lower.

Though the finding rate R is calculated by

$$R = k \cdot r$$

various uncertainties of the estimation of k and r have to be remembered.

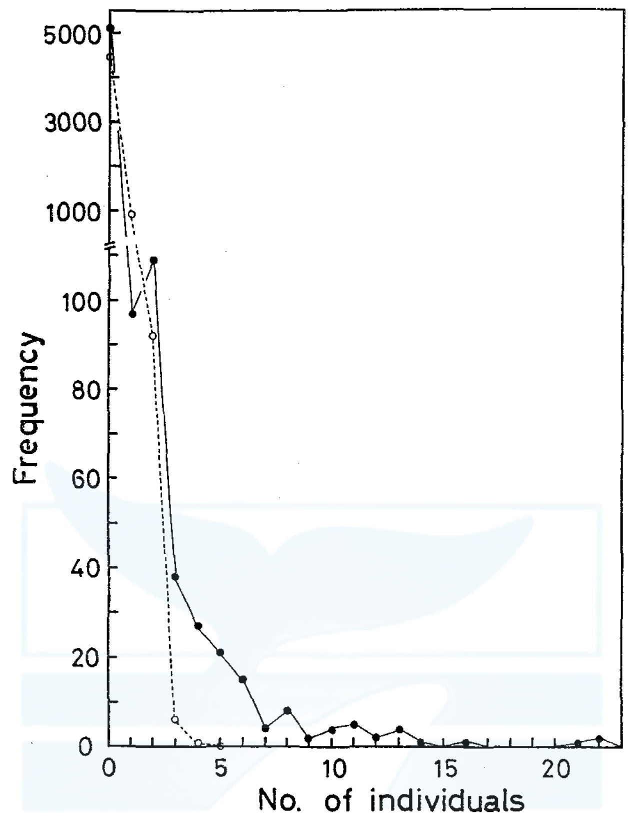

Fig. 6. Frequency distribution of number of sightings in each 1 nautical mile section of the cruise (closed circle and solid line), and the Poisson distribution with the same mean and same sample size (open circle and dotted line).

Confidence range

One of the most important factors causing error in the estimation of population size will be the biase of sighting effort. Since the present study was made on board of commercial regular service vessels, most of the observations were made in the nearshore waters. It was to decrease the effect of this bais that the analyses of the data were often made by each stratum or area.

The other problem is the simple error of the estimation of density index. The distribution of the porpoise is not random even in an area or in a stratum, but as mentioned in the later section more porpoise are apt to aggregate in a small area. When the course of a vessel is divided into contiguous 1 nautical mile sections and number of the finless porpoises encountered in each section is compiled into a frequency distribution, all the individuals in each expedition were found in the sections from 3.0% to 11.5% of the total number of sections. This feature is shown in Fig. 6, where the data of 9 expeditions used for the calculation of the population are compiled. Though this frequency distribution seems to follows the Poisson distribution, it is significantly different from the Poisson distribution of the same mean value (0.203 individuals/mile).

The standard error and the 90% confidence range of the mean number of sightings per observation of one nautical mile was calculated from these frequency distributions, and used to estimate the 90% confidence range of the population in each stratum. The variance of the sum of population estimates of three strata was calculated as the sum of the variances of the mean population estimate of each strata, and then the confidence range of total population was calculated.

RESULT

Geographical and seasonal variation of density

The actual positions of sightings and the course of the vessels are shown in Figs 7–16. In the Inland Sea, the finless porpoise is frequently distributed near the coast, especially off the pointed rocky shore or near narrow passes between the islands. The current of these places is usually moderate. Though the actual density of porpoise may change seasonally, the density in most of these locations is in any seasons higher than that in surrounding waters. There are other kind of waters which is occupied only in spring months by large number of individuals but almost vacant in other seasons. Typical example of these locations are southern part of the Hiroshima Bay (34°N, 132°30′E), between Setoda and Inokuchi (34°17.0′N, 133°03.5′E), and around Nakajima (33°58′N, 132°33′E).

In case of aerial sighting records used in this study, the position of sighting will be less accurate and the porpoises in the nearshore area seems to have been overlooked. However the absence of the species in the deeper part of the Inland Sea is clearly indicated in Figs 15 and 16.

If the distribution of the finless porpoise is analysed in relation to the distance from the coast line, it becomes clear that 82.4% of the individuals were observed within one nautical mile from the coast, 15.5% between 1 and 2 miles, 1.5% between 2 and 3 miles, and 0.6% in waters more than 3 miles from the coast. This general tendency is true even when the bias of the effort is corrected (Fig. 17). The number of individuals sighted per 10 nautical miles of observation is 2.57 individuals in the nearshore stratum (0–1 mile from the coast, areas 1 to 5), 1.19 in the intermediate stratum (1–3 miles, areas 11 to 14), and only 0.24 in the offshore stratum (more than 3 miles off coast, areas 21 to 23). Namely the relative density of the porpoise in the three strata is 1: 0.46: 0.09. However it must be noted that these figures are strongly influenced by the distribution of the porpoise in the season of highest population density.

The relative density of finless porpoise in the intermediate stratum expressed by the ratio to the density in the nearshore stratum is shown in Fig. 18. It gradually increases from the minimum in November to the following September when the density apparently exceeds that of nearshore stratum. This is an indiciation that the porpoise leaves the coastal stratum and the animals are going to be evenly distributed in summer low density season. The decrease of relative density of

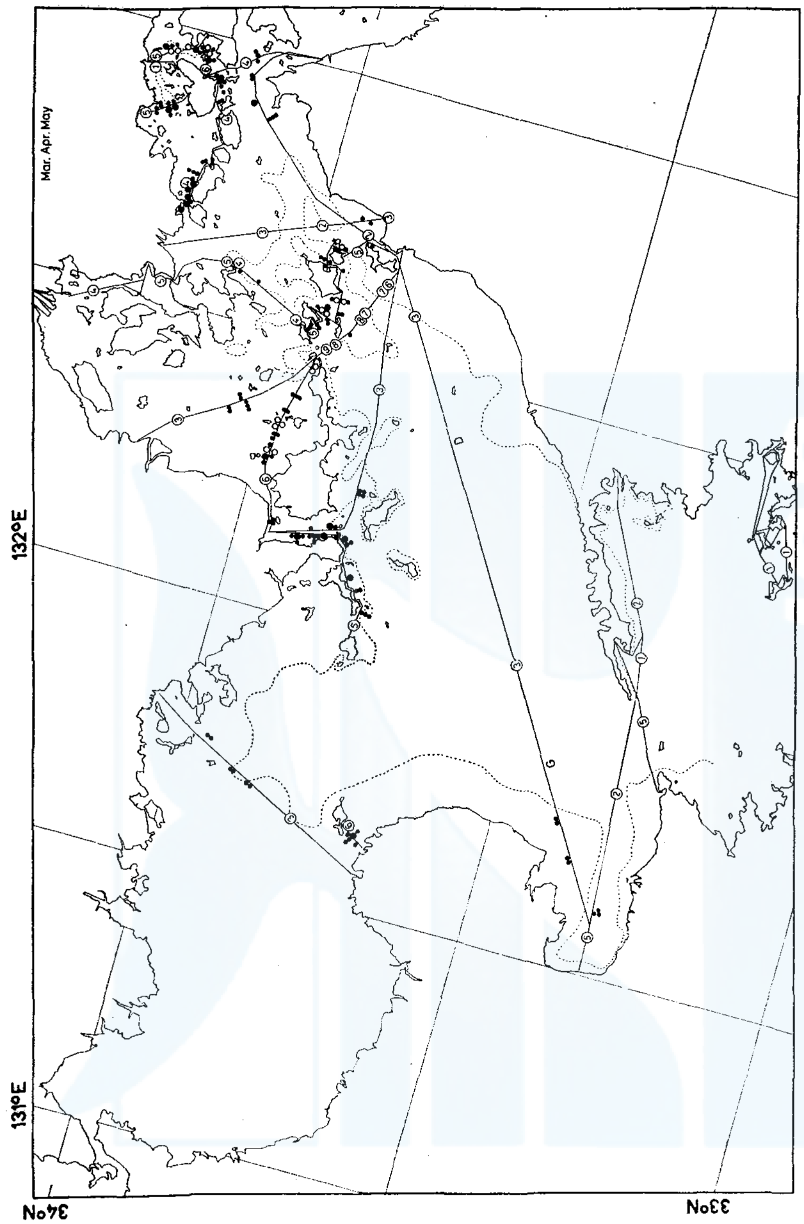

Fig. 7. Observation routes and number of sightings of the finless porpoise (circle), a school of *Delphinus* (D), and a school of *Grampus* (G). March to May. Small closed cicle indicates one individual, large closed circle 5, and open circle 10. Numerals in the circle indicates number of cruises, dotted line the 40 m contour of water depth.

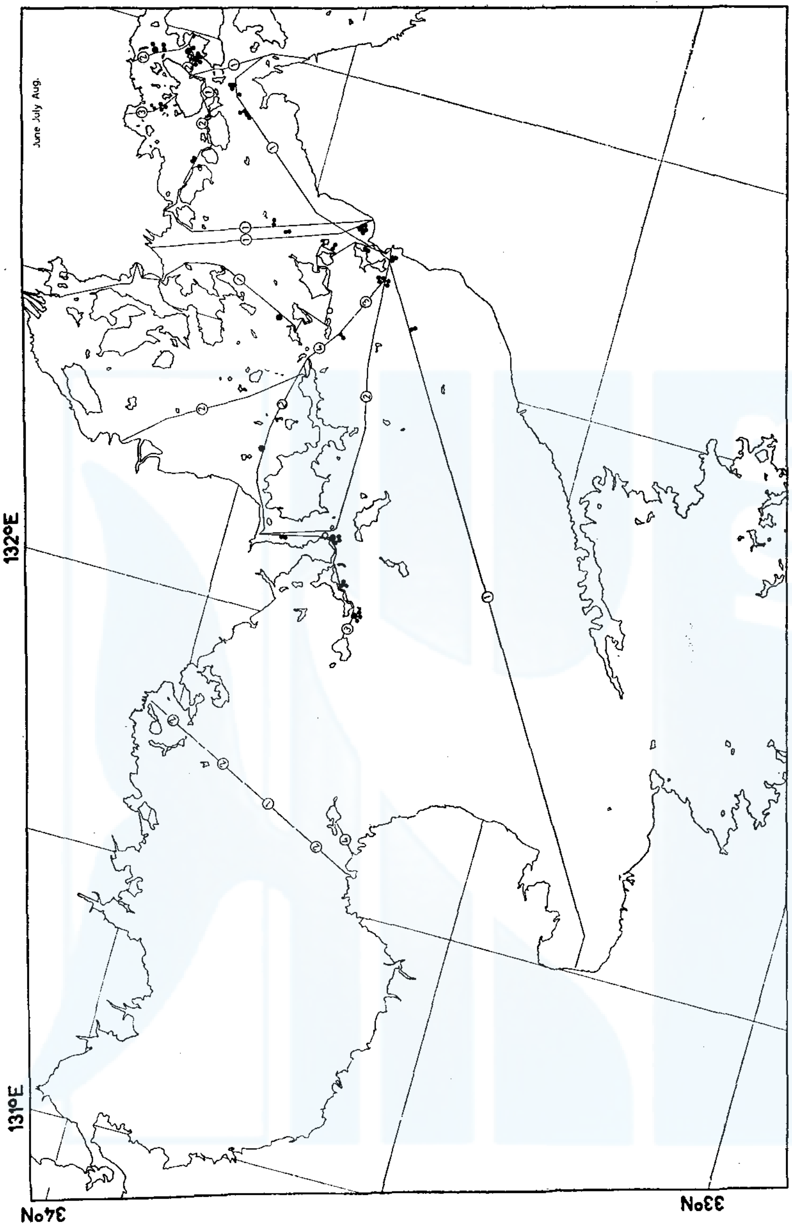

Fig. 8. Observation routes and sightings of the finless porpoise. June to August. For marks see Fig. 7.

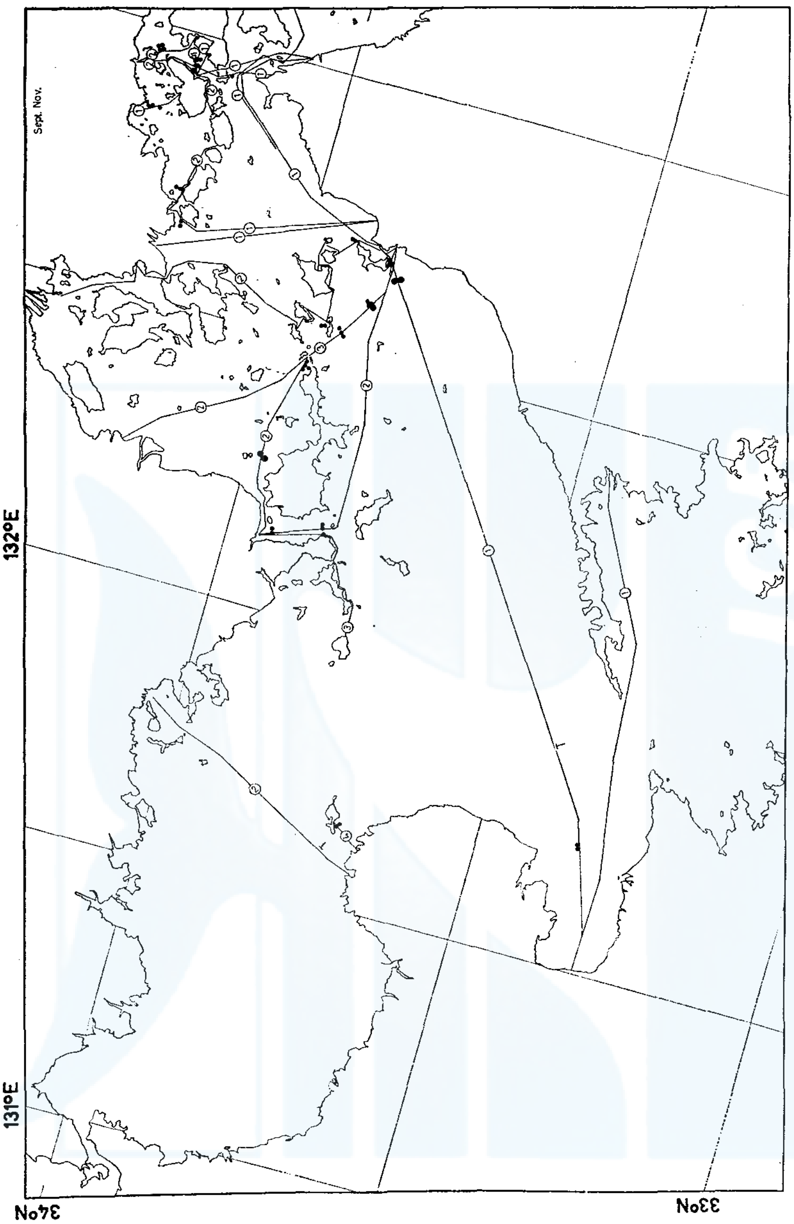

Fig. 9. Observation routes and sightings of the finless porpoise (circle), and two schools of *Tursiops* (T). September and November. For other marks see Fig. 7.

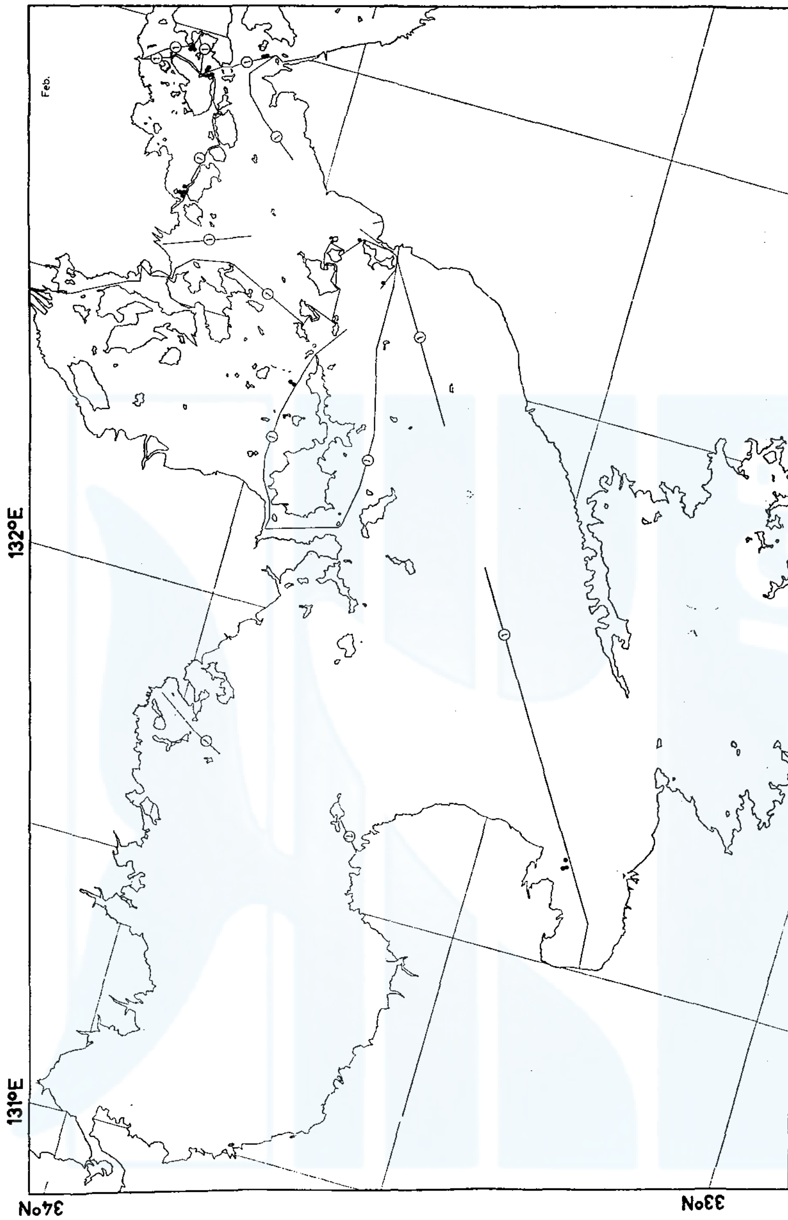

Fig. 10. Observation routes and sightings of the finless porpoise. February. For marks see Fig. 7.

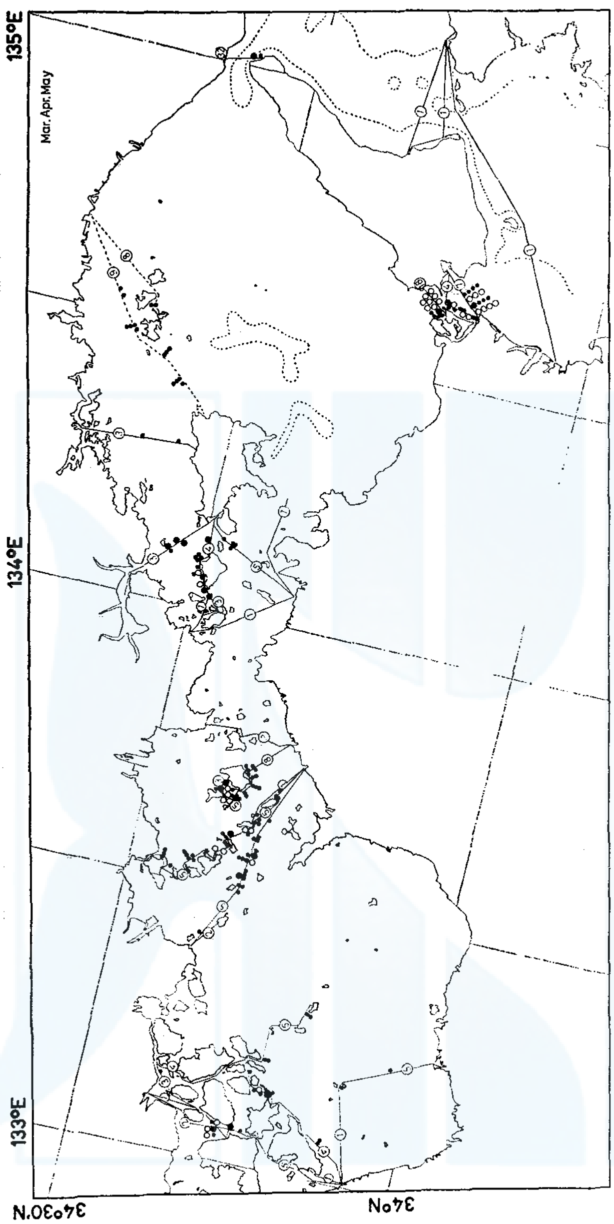

Fig. 11. Observation routes and sightings of the finless porpoise. March to May. The routes indicated by dotted line are those observed by Kureha for the entire study period. For other marks see Fig. 7.

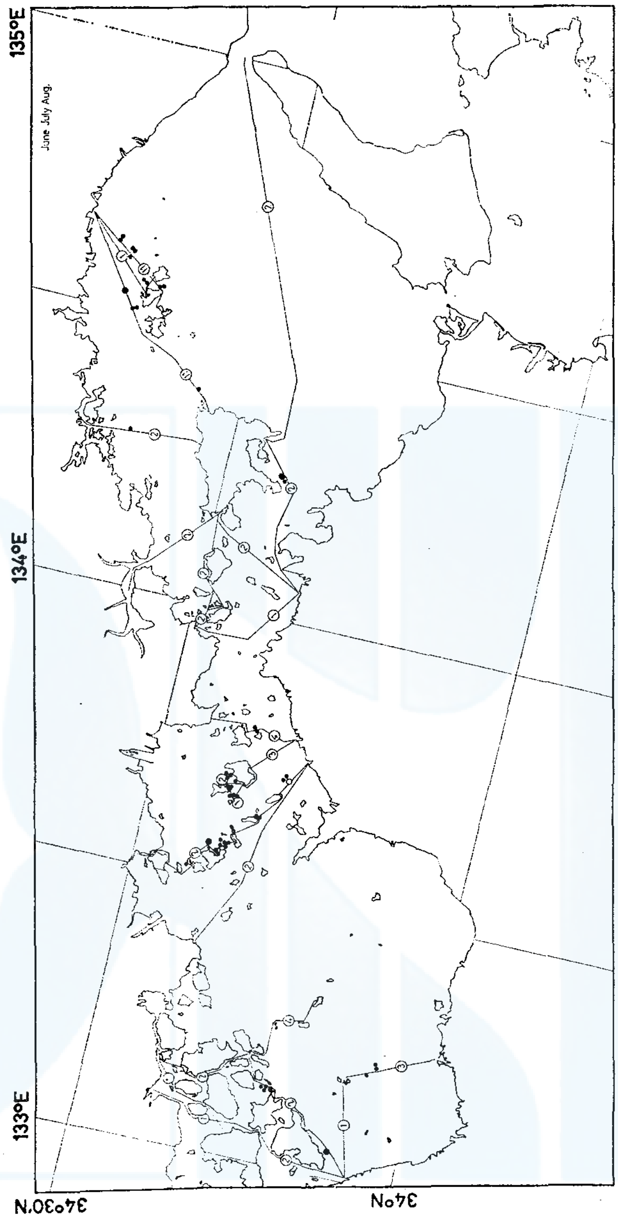

Fig. 12. Observation routes and sightings of the finless porpoise. June to August. For marks see Fig. 7.

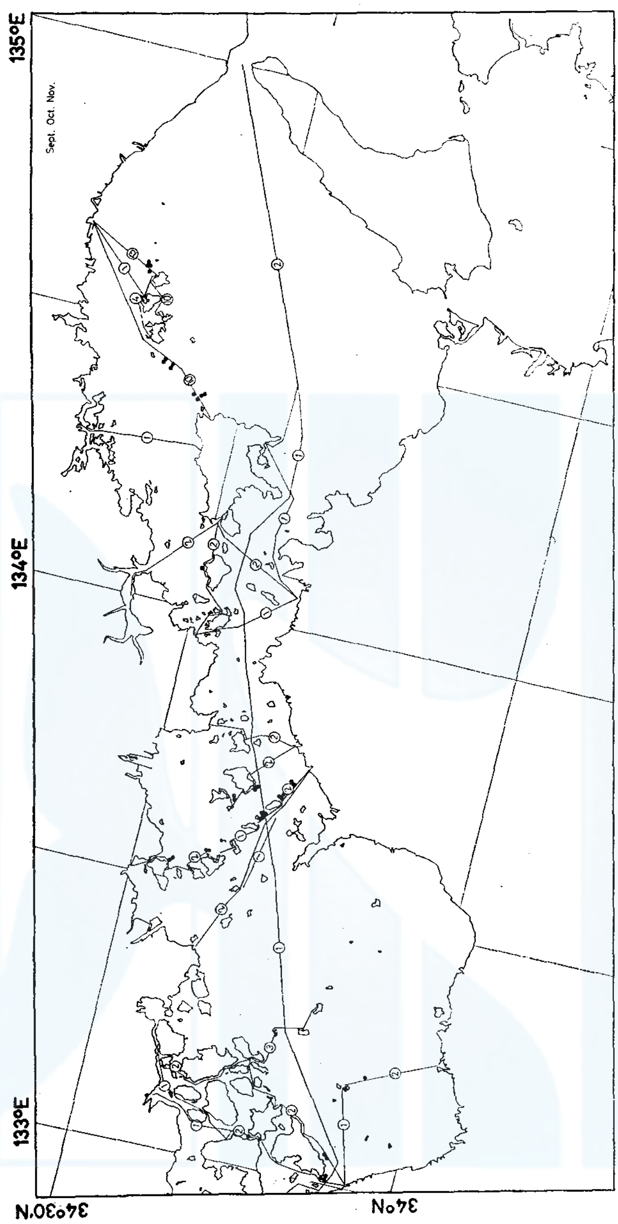

Fig. 13. Observation routes and sightings of the finless porpoise. September to November. For marks see Fig. 7.

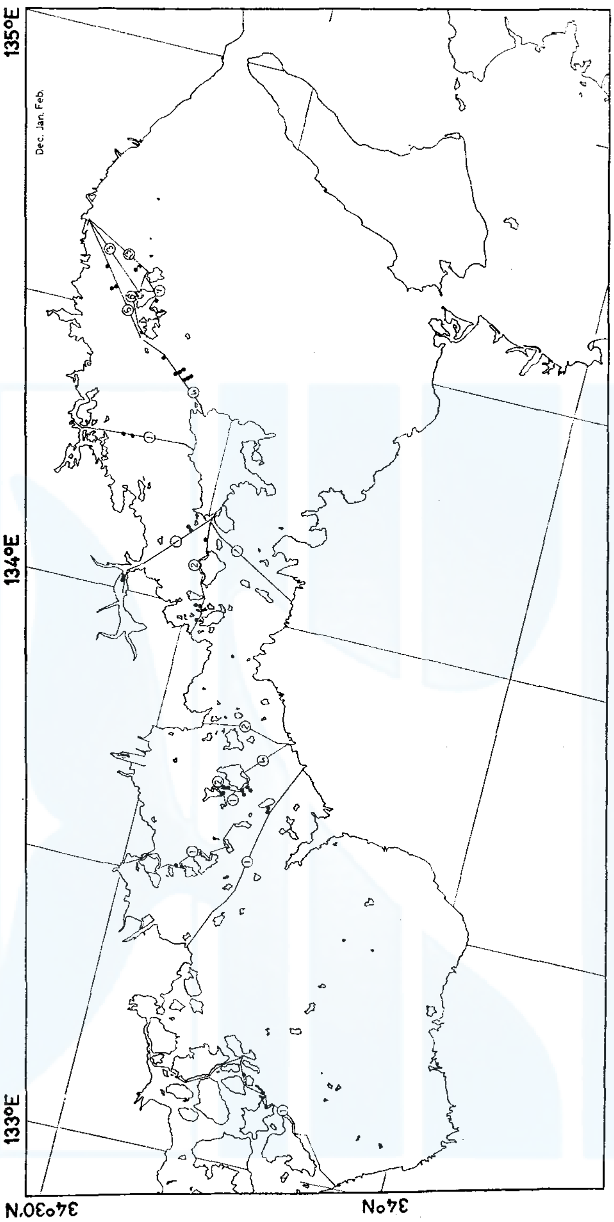

Fig. 14. Observation routes and sightings of the finless porpoise. December to February. For marks see Fig 7.

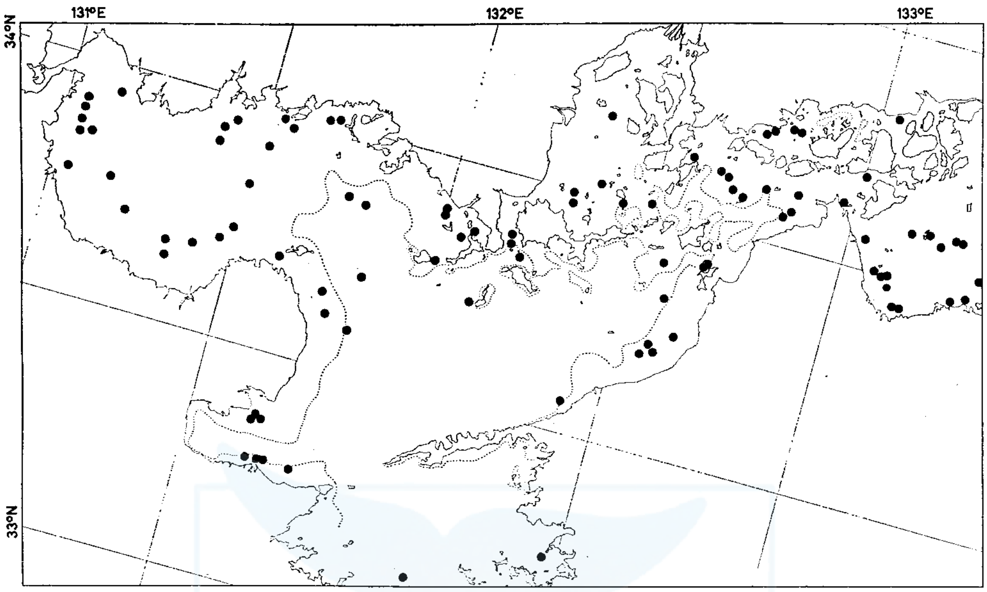

Fig. 15. Aerial sighting record, poisition of the occurrence of the finless porpoise. Each circle indicates one encounter. For effort data see Fig. 20.

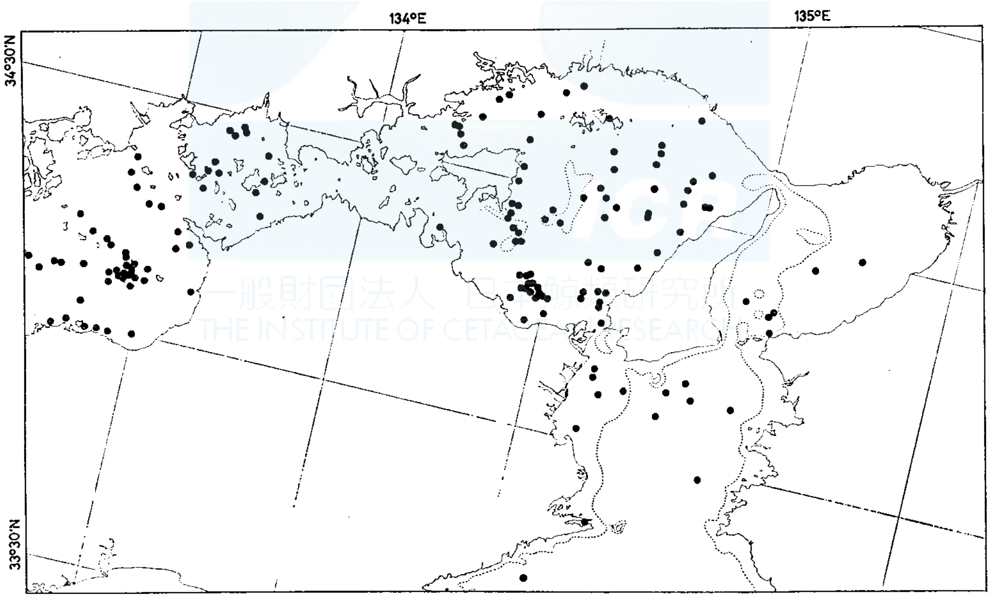

Fig. 16. Aerial sighting record, position of the occurrence of the finless porpoise. For other explanations see Fig. 15.

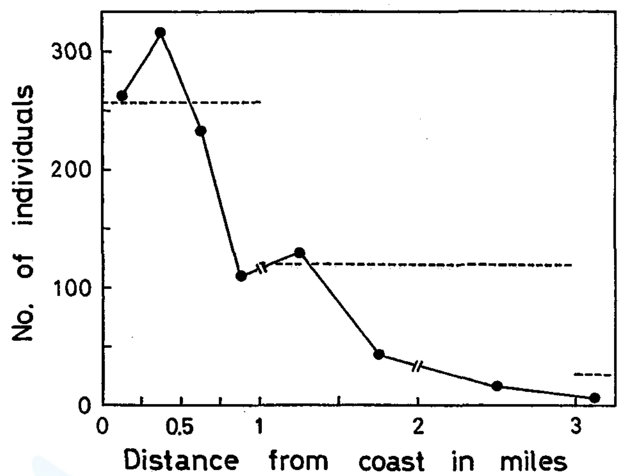

Fig. 17. Distribution of the finless porpoise and the distance from the coast. Closed circle and solid line indicate the actual number at actual position. Dotted line indicates sightings per 1,000 nautical miles of observation, where the position of the vessel was used as that of the porpoise.

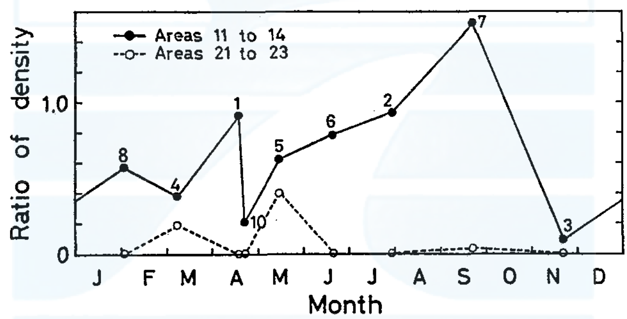

Fig. 18. Seasonal change of the relative density of the finless porpoise in intermediate (areas 11 to 14) and offshore (areas 21 to 23) strata indicated by the ratio to the density in the nearshore stratum. Numeral indicates the expedition number.

intermediate strata in October to December will be the result of the migration to the nearshore stratum. This is followed by the immigration from the external waters to the Inland Sea in December to April mentioned below.

Figure 19 gives the geographical and seasonal fluctuation of the finless porpoise density in the Inland Sea. The density is expressed by the minimum estimate per square mile (tentative assumption of $k=1$). For the estimation of real density, this has to be divided by k or about 0.5. Two or three expeditions are grouped to accumulate sufficient amount of data for each area. Generally speaking, the density is low in the eastern and western areas, through which the Inland Sea is connected to the outer ocean. In the areas of the nearshore stratum the density is highest in March and April, and the highest density is observed in the areas 3 and 4. However the density continues to decrease in all the areas of the nearshore stratum until July-September. The decreasing trend is faster in area 4 in the east than area 2 in the west. This makes, in May to September, the density in area 2 higher than that in area 4, though the actual density is certainly decreasing. In November-February season the density in the nearshore stratum start to increase, again at a higher rate in eastern areas. These features indicate that the large scale seasonal migration in the population starts in the eastern part and is spread to the west.

In the intermediate stratum, the decrease of the density from March to September is not clear, but there is observed a slight increase in the area 13 in the

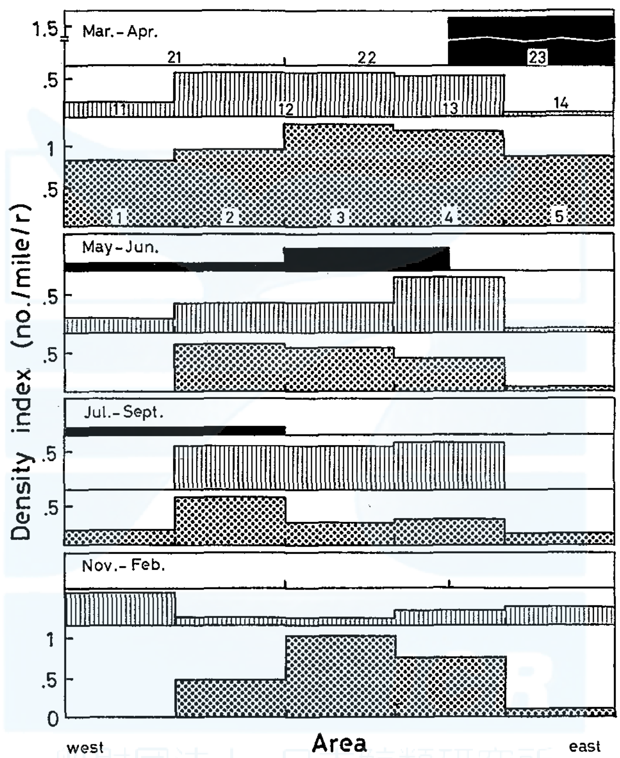

Fig. 19. Seasonal change of the density distribution of the finless porpoise in the Inland Sea.

eastern part of the Inland Sea. In November-February the density in area 12 reaches to the minimum, however in the same season there is observed an increase of density in areas 13 and 14 at the eastern part of the Inland Sea, a possible suggestion of movement to nearshore stratum. The abrupt increase of the density in this season in area 11 at the western Inland Sea is difficult to be concluded because of the scarcity of the observations. However it will be reasonable to suspect from the seasonal trend of the density in both intermediate and offshore strata, and from the presence of similar trend in the aerial sighting records (Fig. 20), that the density in the western part of the Inland Sea stays slightly high in summer and autumn

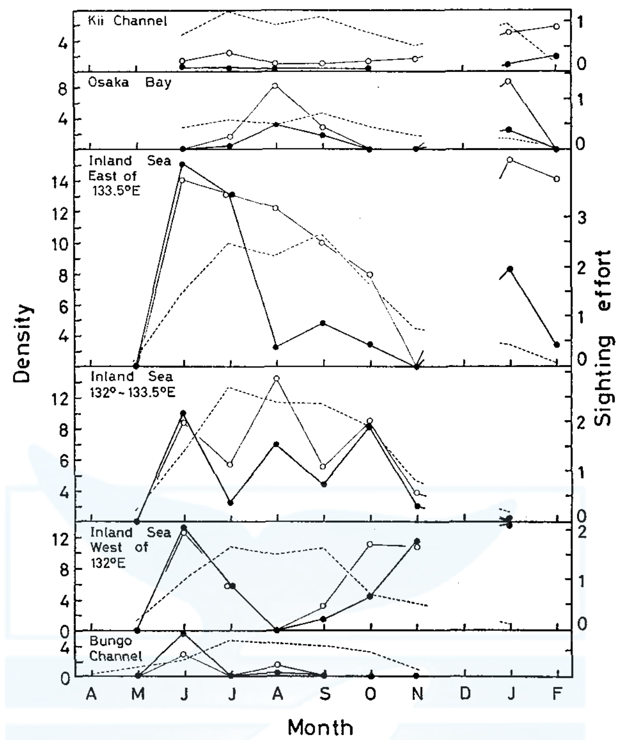

Fig. 20. Aerial sighting records of the finless porpoise. Seasonal change of the number of encounters per 1,000 nautical miles (closed circle and thick solid line) and number of individuals (open circle and thin solid line) per 100 nautical miles. Amount of effort are shown by dotted line (thousand nautical miles).

season and the spring concentration of the species in that part of the Inland Sea seems to start slightly earlier than eastern Inland Sea (see Discussion and Conclusion).

Movements between outer waters

Observations were made at four passes connecting the Inland Sea with outer waters. The intention was to get direct informations on the migration route of the finless porpoise. The season covered both before and after the peak of the population in April. Though the swimming direction was examined, it was found to be insignificant as the indication of migration.

At the Kanmon Pass, 6.4 hrs (15 March 1978) and 11.5 hrs (2 May 1978) land based observations at the narrowest point of the pass provided no sighting.

At the Hayasui Pass, five cruises made on 11 and 14 March 1978 provided no sighting. Two cruises made on 24 and 26 April across the pass did not show the presence of the porpoise, except for the three individuals off Beppu (Fig. 7). Some ancillary cruises in the Bungo Channel gave no sighting of the finless porpoise.

The observation at the Akashi Pass was made by Kureha on board of small ferry boat connecting Akasi and Iwaya across the pass. The result is as follows.

Date	Hour	No. trips	No. sighted
17 Mar., '78	0800–1826	16	5+1
20 Apr., '78	0800–1820	16	0
26 Apr., '78	0800–1823	16	0
12 Oct., '78	0800–1720	14	0

The larger school was sighted at 1040 when the current was flowing eastward. The school was moving westward at the position about 400 m off the coast (Fig. 11). The other solitary individual was found at 1707 at the same position with another school. Both the current and the swimming direction were eastward. The position of these porpoises is same with that of a school of two individuals found by Kasuya and Mr T. Hiwatari during the land based observation made on 7 March 1978. The school was moving westward.

TABLE 2. DISTRIBUTION OF FINLESS PORPOISE AT THE NARUTO PASS

Expedition no.		9 (two observers)			10 (one observer)		
Date		8-9, March, 1978			30, Apr.-1, May, 1978		
Current, flowing to		North	South	Total	North	South	Total
North side	n. miles	8.9	11.9	20.8	17.8	14.8	32.6
	no.	15	26	41	41	2	43
	no./10 miles	16.9	21.8	19.7	23.0	1.4	13.2
South side	n. miles	30.7	21.9	52.6	8.1	25.1	33.2
	no.	47	22	69	24	56	80
	no./10 miles	15.3	10.0	13.1	29.6	33.3	24.1

North side: Inland Sea, South side: Kii Channel.

The observations at the Naruto Pass were made in early March, and April to May (9th and 10th expeditions). The former was done by Kasuya and Mr T. Hiwatari, and the latter by Kasuya. The frequency of the swimming direction seemed to be influenced by the current, turbulance, and topography of the sea than the migration direction. Large concentration of porpoise was usually found in the rapid current flowing from the pass. The presence of large concentration of the porpoise at the Naruto Pass suggests the migration of the species through the pass. For the comparison of the porpoise densities between the two expeditions, the number of observers must be corrected. The number of porpoises sighted by Kasuya at the Naruto Pass was only 73 (9th expedition). This gives the number of sightings per 10 nautical miles as $73 \div 73.4 \times 10 = 9.9$. This is about half of the density observed in April/May expedition. The weather condition will have no relation with this difference, because the wind was between 0 and 1 in both expeditions.

Population estimation

As the data was insufficient to calculate the population size by expeditions

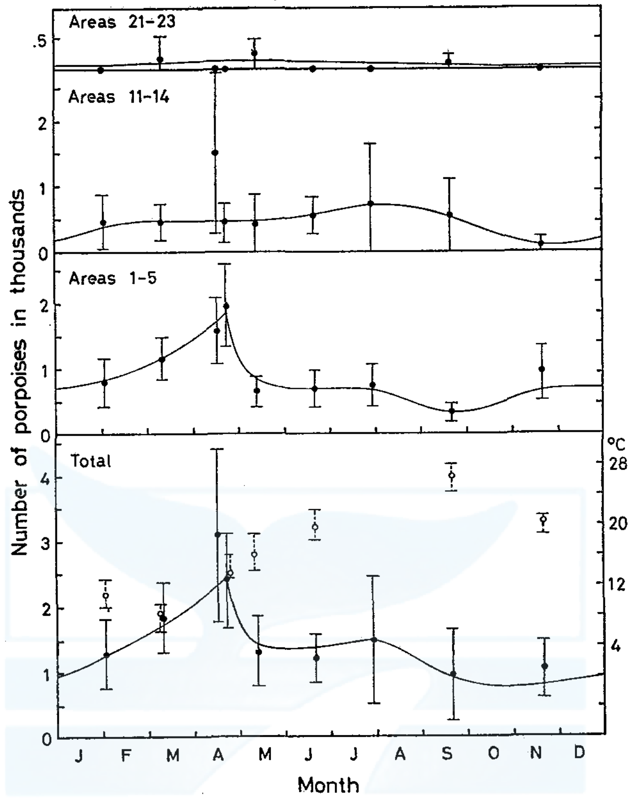

Fig. 21. Seasonal fluctuation of the finless porpoise population in the Inland Sea. Mean population estimates and the 90% confidence range (closed circle and solid line), and range and mean of the surface water temperature (open circle and dotted line) are indicated. Since $k=1$ is tentatively assumed, the population size expressed here is close to the half of the actual estimation. Curves are drawn by eye.

TABLE 3. SCHOOL SIZE FRFQUENCY OF FINLESS PORPOISE IN THE INLAND SEA, AND ADJACENT BAY AND CHANNELS

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Mean
Jan.	5	1												6	1.17
Feb.	11	9	1											21	1.52
Mar.	101	41	9	3	4		3			1	1			163	1.74
Apr.	126	95	19	15	4	4	1	3		3	1			271	2.03
May	38	38	13	4	2	1							1	97	2.04
June	25	19	8	2	2	1								57	1.95
July	4	12	1		2	2	1							22	2.73
Aug.	4	3	1			1						1		10	3.10
Sep.	6	9	2	1	1			1		1				21	2.71
Oct.	3	2												5	1.40
Nov.	12	10	2					1						25	1.84
Dec.	6	4	1											11	1.55
Total	341	243	57	25	15	9	5	5	0	5	2	1	1	709	1.97
Total, %	48.1	34.3	8.0	3.5	2.1	1.3	0.7	0.7	0.0	0.7	0.3	0.1	0.1	100	—

and by areas, data of some expeditions or of some areas were combined. The first method is to group the data of one expedition into three strata and to estimate the population for each stratum. The second is to group the data of two or three expeditions to calculate the population in each area. As shown in Appendix, the two kind of estimations give a reasonable coincidence.

The population abundance in nearshore stratum attains the maximum in April and followed by the decrease to the minimum level in September (Fig. 21). The population level in the intermediate stratum, however, seems to continue to decrease until December. Though this differs in the expression with Fig. 19, both of them indicate the same phenomenon of the porpoise migration. Further discussion on the migration of the species will be made in the later section.

When the value of k is considered as 0.5 (see page 10), the population of finless porpoise in the Inland Sea is estimated as about 2,450/0.5=4,900 in the maximum season in April and decreases to the minimum level of about 780/0.5=1,560 in early winter. The overall population density in April is 4,900/14,260=0.34 individuals/km^2. The approximate density in each stratum in this month is given as 3,710/4,805=0.77 for nearshore stratum, 928/5,061=0.18 for intermediate stratum, and 260/4,394=0.06 for offshore stratum. In the intermediate stratum, however, the highest density of 1,470/5,061=0.29 individuals/km^2 will be attained in August (Fig. 21). Though the direct comparison will not be meaningfull because the body size, food requirement, and the environment can be different, it is worth to note that the above densities are close to those of the Atlantic *Tursiops truncatus*, 0.23 to 0.75 dolphins/km^2, calculated for coastal or semienclosed waters (Barham, 1979).

School size

In order to avoid the influence of the preoccupation, the analyses concernig the school structure and the size frequency of the porpoise were made after the completion of all the expeditions.

The largest school encountered in the present study was composed of 13 individuals. As shown in Table 3, however, most of the schools of this species are so small to give the overall mean school size of 1.97 individuals. About 50% of the encounters were solitary individuals, and the school of 3 or fewer number of animals comprises 90.4%. These figures suggest that the school of this species is slightly smaller than that of *Phocoenoides dalli* which shows the mean school size of 4.62 (Kasuya, 1978).

The seasonal fluctuation of the school size is shown in Fig. 22. The ratio of solitary individuals in the total encounters shows an annual cycle with the highest in January and the lowest in July. The mean school size shows the similar annual cycle.

School structure

The body length of the porpoises in a school is variable, and the relative distance between the members is not same. These characters are considered in the

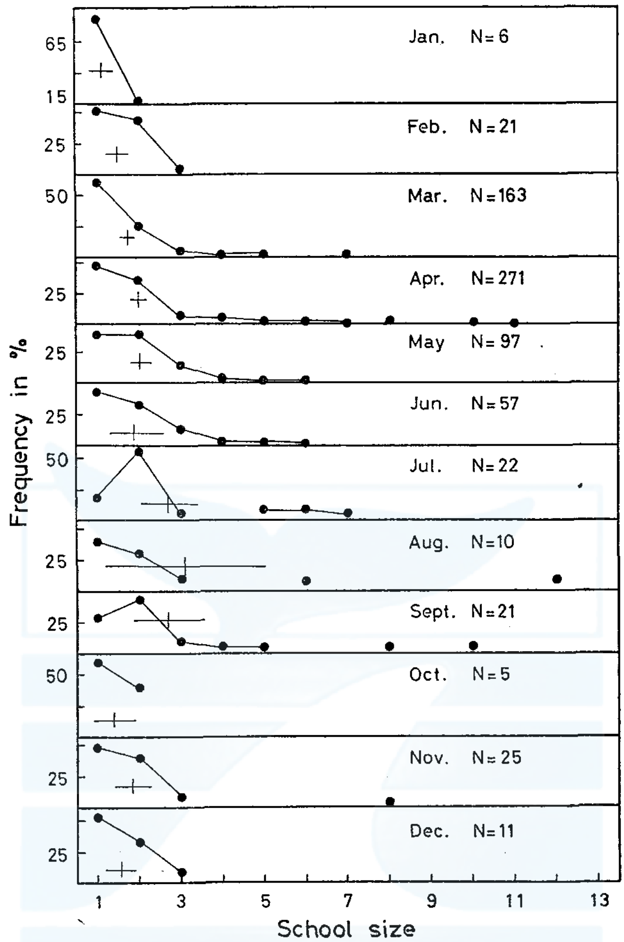

Fig. 22. Seasonal fluctuation of the school composition (closed circle and solid line), mean school size (vertical bar), and 90% confidence range (holizontal bar). All the data obtained in the present study included.

present study as an indication of the internal structure of the school.

Though there was found solitary calf or juvenile (Fig. 23, type 1-b, 1-c), more frequently they were found with another individual of various growth stages. The most common was the combination of a calf and an adult, presumably corresponding to the mother and calf. The less common was the school of adult and juvenile, some of which may represent the combination of the mother and elder calf of the previous season. The school of weaned individuals (types 2-d, 2-e, 3-h), and that of one cow and two juveniles (type 3-g) are scarce.

Most of the adult individuals encountered were solitary or in a pair with another adult individual (types 1-a and 2-a). In some cases, the adult porpoises of up to five individuals were found to aggregate to form a school (types 2-a, 3-a, b, 4-a, b, c, 5-a, b). However, it was more common for the schools of three or more

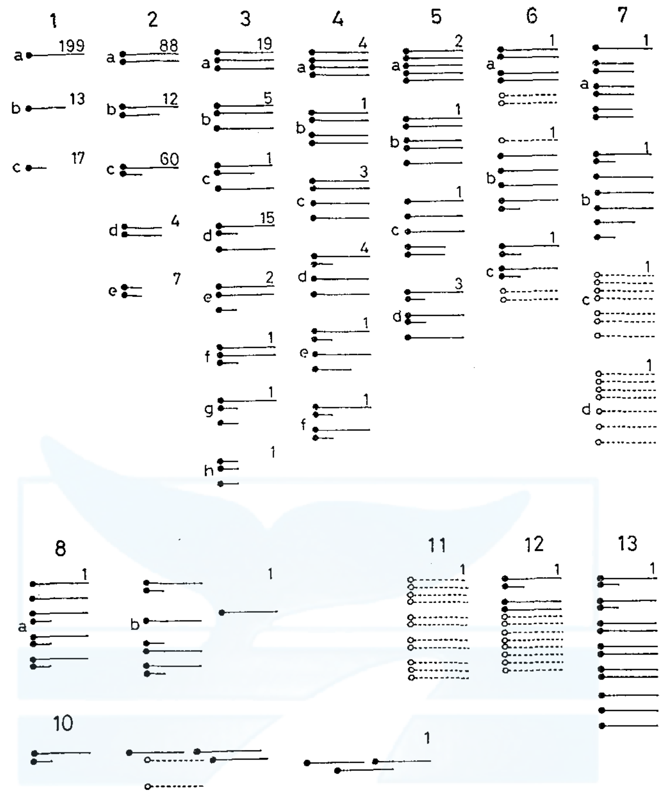

Fig. 23. Schematic figure of the school of the finless porpoise, relative size of the school members and subgroups are indicated. Numeral at the top of column indicates school size, numerals by each type the number of encounters. Two dimensional arrangement of subgroups is indicated only in cases of type 8-b and 10. Long bar, adult; intermediate, juvenile; short bar, calf; open circle and dotted line, size unknown.

individuals to contain the combination of cow and calf. It was frequently observed that a cow with calf was followed by one or two adult individuals. Presumably they represent the case where, after certain length of nursing period, a cow accompanied by the calf (type 2-c) approaches the next oestrous cycle and is attended by adult male(s) (types 3-c, f, 4-d). The number of such schools was 22, or about one third of the number of schools of the cow and calf. This indicates that most of the cows accompanied by the calf, consequently for most of the nursing period, are not attended by adult male.

Another information on the school structure was obtained from a land based observation on 5th March 1977 at Teshima (34°23.5′N, 133°40.5′E) in the Inland Sea. Several finless porpoises, varying between 1 and 6, fed in a small rocky inlet open to south. Their position was about 20 m from the beach. It seemed, at a glance, to be one feeding school with several internal structures. However the subgroups were continuously changing. The subgroup, two or three individuals in it, arrived one after another from the southwest direction, fed together for 20 to 30 minutes in the same area with other subgroups, and then slowly left the place toward southeast offshore direction. Their leaving passage was traced for more than 1 km by the presence of a flock of sea gulls. By this way total of 5 subgroups were confirmed by 2 hours' observation.

From above informations we suspect that the most stable basic unit of the school will not exceed three individuals in number, and they are combinations of the cow and calf or of adult male and female. Probably the school of more than four individuals would have been formed through the aggregation of these fundamental units. An example of the transitional stage is shown in Plate I, Fig. 2, where all the seven individuals will be considered without doubt as one school if the three units were situated slightly closer.

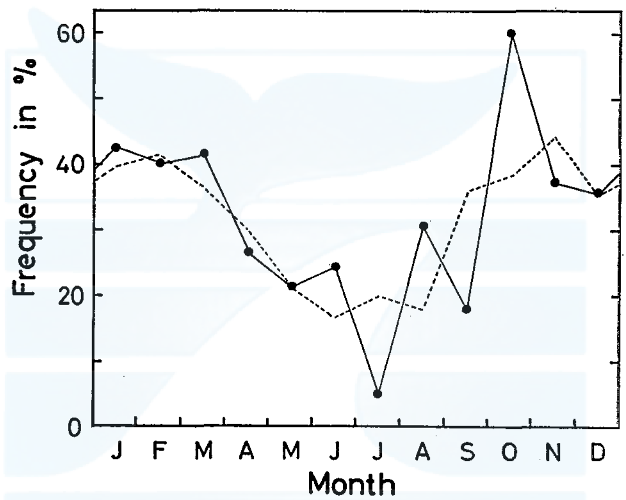

Fig. 24. Seasonal change of the solitary adults. Closed circle and dotted line indicate the ratio of solitary adult to total number of the adults, dotted line the moving average of the three. All the data obtained in the present study included.

Mating Season

Though the copulation was not confirmed, there were several occasions to observe the probable precopulatory behavior of the finless porpoise in the Inland Sea. They were one couple in March, four in April, two in July, and one in September. They suggest that the mating occurs from March to September.

Another indirect indication was obtained from the seasonal change of the frequency of solitary adult. The number of solitary adults was about 40% of the total adults in any months between October and March, but decreased below 30% in April to September, with the lowest frequency in June to August (Fig. 24). This season coincides with the peak of mean school size, and is considered as the mating season of the species in the Inland Sea.

Parturition and weaning season

The parturition season was estimated from the seasonal change of ratio of cows accompanied by the calf to all the adult individuals (Fig. 25). The ratio is stable from November to March at a level of about 10%, and start to increase in April to attain the maximum of about 27% in September, which is followed by a rapid decrease to initial level in October and November. The increasing season, April to August with the center in June, will correspond to the parturition season.

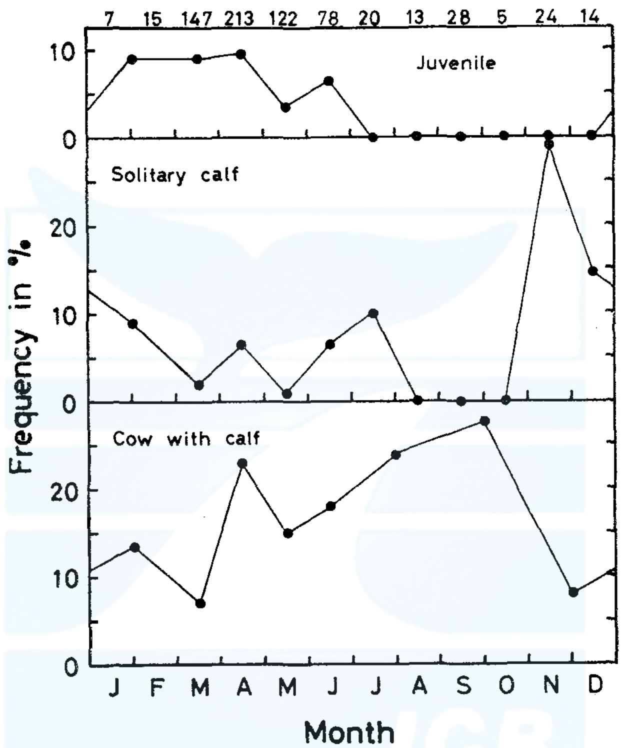

Fig. 25. Seasonal change of the frequency of juveniles, solitary calves, and cows with calf. Frequency is shown by the ratio to the total number of the adult shown at the top. Months with small sample size are grouped.

The rapid decrease of the cow with calf in October and November is followed by a rapid increase of solitary calves in November and December, which tails off towards next summer. This will be the indication of the weaning season. Namely most of the weanig will occur in October and November, but some calves seem to accompany their mother until next spring or summer.

The decrease of solitary calves after December is followed by the high level of juveniles, which will indicate the growth of the weaned individuals.

DISCUSSION AND CONCLUSION

Seasonal movements

The continuity of distribution of the finless porpoise between the Inland Sea and the Kii Channel through the Naruto Pass suggests that the annual migration of the species will be done through this pass. The seasonal change of the density in the Kii Channel appeared in the aerial sighting records suggests a peak before July, low density in August and September, and the winter increase in January and February. This change is similar to that in the Inland Sea. The decrease of the density from April to September in nearshore stratum is faster in eastern areas than western areas, but both the speed of the density decrease and the areal difference of the speed are not large in the intermediate stratum. These observations suggest that most of the migratory individuals start to move, in April, from the coastal stratum to eastern areas of offshore stratum, and then to the Kii Channel. The low porpoise density in the Kii Channel (Table 4) suggests that the finless porpoise will not spend summer in the channel but will be dispersed in wide coastal area facing to the Pacific. The migration into the Inland Sea will occur from January to April (Fig. 21). However the concentration of the porpoise into the nearshore stratum seems to start in November (Figs 18 and 21). In other words, the seasonal migration of the species seems to start in the nearshore areas.

TABLE 4. AERIAL SIGHTING DENSITY OF FINLESS PORPOISE, BASED ON RECORD OF FISHERIES AV. CO., 1972–1978

	Distance flown (n. mile)	Schools		Individuals	
		no.	no./100 miles	no.	no./100 miles
Bungo Channel	3,387	2[1]	(0.06)	21[1]	(0.62)
Western Inland Sea	7,471	45	0.60	376	5.03
Central Inland Sea	12,025	97	0.81	659	5.48
Eastern Inland Sea	12,033	137	1.14	863	7.17
Osaka Bay	3,310	9	0.27	37	1.12
Kii Channel	6,666	14	0.21	50	0.75

1) A school of 20 individuals of doubtful identity included.

The porpoise density in the summer season is slightly higher in western area than in eastern area. This will mean that the coast of oceanic western Inland Sea is in some degree used as the summering ground of the species.

The presence of small number of sightings in July and August in the Bungo Channel (Fig. 20), and the increase of the density in the western Inland Sea in October to November (Figs 19 and 20) suggest that some individuals of the finless porpoise in the Inland Sea will migrate to and from the Bungo Channel through the Hayasui Pass. However, the low density of the porpoise at the Hayasui Pass and large water depth in the Bungo Channel will not give suitable reason to expect such a large number of migrating porpoises as expected for the Naruto Pass and the Kii Channel.

Considering the several sightings at the Akashi Pass and the relatively high density of the porpoise in the Osaka Bay (Table 4), it will be reasonable to consider that the pass is one of the migration routes of the species.

According to the record of the Toba Aquarium, the incidental capture of 30 individuals in the past 13 years in the Ise Bay occurred from September to April with one peak in February to April. This pattern resembles the seasonal density fluctuation in the Inland Sea, and it is suggested that the species migrates seasonally between inshore and open waters. However it is unreasonable to suspect that the species migrates to the offshore open waters, because the species is often sighted or captured within a few hundred meters from the beach facing the Pacific (Kasuya, unpub.) and has not been sighted in the true offshore water.

Any environmental factors controlling the migration of the species mentioned above are not certain at present. In the Inland Sea, the species is found in the surface water temperature between 6°C and 28°C. Such a wide adaptability is uncommon in the pelagic delphinids (Kasuya, 1976). The migration into Inland Sea start in January before the lowest peak of the water temperature, and attains the population peak in April when the water temperature is still lower than the outer waters. These are indications that the migration is not controlled by the water temperature.

It is generally believed by the Inland Sea fishermen, that the finless porpoise migrates to the Inland Sea to eat *Ammodytes personatus*. The fishing ground of *A. personatus* and the distribution of the finless porpoise coincides well. As far as investigated, only the peak of fishing season of *A. personatus* in April or May shows some degree of coincidence with the density of the finless porpoise in the Inland Sea. Though some of the finless porpoises in the Ise Bay were found to feed *A. personatus* (Kataoka *et al.*, 1976) and the porpoise in the Inland Sea had the fish in the stomach (Kureha and Kasuya, unpub.), the frequency is not high to support the hypothesis. Alternative explanation is made below in relation to breeding season.

Breeding season and reproductive cycle

Table 5 gives 17 records of the finless porpoise born in aquarium, incidentally killed, or stranded. The individuals below 100 cm were listed. The higher frequency between 65 and 85 cm suggests the mean length at birth in this range, and the parturition season from April to June. Perrin *et al.* (1977) and Kasuya (1977) gave some methods to estimate the gestation length of odontoceti based on the neonatal length. The former method and the neonatal length of 75 cm give the estimated gestation time of 10.6 months. The lattter gives 10.5 months, assuming $0.135 \times$ gestation time for x-intercept of linear growth line. The mating and parturition seasons estimated from the analyses of the school structure are from April to September and from April to August respectively. They give the rough estimation of gestation time of 11 to 12 months. As this value is close to the estimations made above, it will be safe to conclude in the present study that the pregnancy will last for about 11 months in the finless porpoise.

Furuta *et al.* (1977) state on this species kept in the Toba Aquarium in the

Ise Bay that the copulation occurred most frequently in every April and May in recent several years and this led to a birth in April 1976 (Table 5). This datum and the gestation time of about 11 months suggest the parturition season in March and April. Though this gives a good coincidence with the parturition season indicated by the newborn calves in Table 5, it does not well agree with the season estimated from the frequency of the cows accompanied by the calf. The difference exist in the prolongation of the parturition season until August. An important fact we must remind with this connection is that the analyses of seasonal change of the school structure are not based on the same group of individuals. The most of the porpoises leave the Inland Sea after April, and do not come back to the area until early winter. If it is assumed that the main peak of parturition of the Inland Sea

TABLE 5. RECORDS OF NEWBORN FINLESS PORPOISE BELOW 100 CM IN BODY LENGTH

Body length	Sex	Date	Locality (latitude)	Author
60.0 cm	♀	20, Mar., 1924	China	1
94.8 cm	♀	26, Mar., 1924	China	1
96.4 cm	♀	24, May, 1924	China	1
68.8 cm	—	14, Apr., 1977	Omura Bay, 33°N	2
71.5 cm	♀	24, Apr., 1974	Inland Sea, Fetus	TK 415
72.0 cm	—	3, May, 1976	Inland Sea	KS 76-7
65.3 cm	♀	4, June, 1976	Inland Sea	TK 478
79.0 cm	♀	11, Apr., 1973	Ise Bay, 34°40′N	3
83.0 cm	♀	22, Apr., 1976	Ise Bay, 34°40′N	4
85.5 cm	♂	27, Apr., 1966	Ise Bay, 34°40′N	5
85.0 cm	♂	—, Apr., 1964	Born in Toba Aquar.	5
81.5 cm	♀	17, Apr., 1976	Born in Toba Aquar.	6
91.3 cm	♀	20, May, 1979	Shimizu, 35°N	7
80.0 cm	♂	5, June, 1969	Sagami Bay, 35°15′N	TK 296
69.0 cm	♂	16, May, 1963	Yokosuka, 35°14′N	8
71.5 cm	♀	27, June, 1973	Yokosuka, 35°14′N	TK 396
97.6 cm	—	18, June, 1933	Sendai Bay, 38°20′N	9

1) Howell, 1927. 2) Takemura, p.c. 3) Kataoka *et al.*, 1974 4) Toba Aquarium, unpub. data. 5) Kataoka *et al.*, 1969. 6) Furuta *et al.*, 1977. Measured after death on 3 May. 7) Masaki, p.c. 8) Nakajima, 1963. 9) Ogawa, 1950.

population of the species is in April and May, and that the cows accompanied by the newborn calf leave the sea for the summering ground, then the above disagreement will be explained. This also explains the rapid drop of the ratio of the cow with calf in May. We can, by this hypothesis, duly evaluate the ratio of the nursing cows represented by large number of samples in the months from March to May. Most of the small number of cows which gave birth to the cow after May will spend the summer in the Inland Sea and will contribute to the apparent increase of nursing cows in the waters. Accordingly it will be most reasonable to suspect that at least one of the main factors controlling the migration of the species into the Inland Sea could be the breeding.

Mizue *et al.* (1965) estimated for the finless porpoise in the waters off the west coast of Kyushu that the parturition season will be from late August to early September. Their estimation is based on one lactating female caught in October 1962 and unconfirmed information of the fishermen on the occurrence of newborn calves in early September. It is strange that they did not refer, for the conclusion, their specimens collected in late September to early October mainly from the incidental catch in set net and amounting more than 50 individuals. They write that the smallest individuals they collected were 101.6 cm in females and 112 cm in males. We are not going to deny the possibility of the tailing off of parturition season in September or the presence of small number of newborn calves in the month. However it will be reasonable to consider that if there is a main peak of parturition in August and September, they should have obtained smaller calves in their collection. We feel that it is unrealistic to expect for the finless porpoise in the western Kyushu a parturition season different from that in the Inland Sea.

The length of nursing period is estimated from the seasonal change of the frequencies of nursing cows, of solitary calves, and of juveniles. The ratio of cows with calf decreases and that of solitary calves increase in October and November. This season is a time when the migrating porpoises are still outside of the Inland Sea. Accordingly the change seems to have happened on the resident population. The decrease, from 27% to 7%, is too large to be explained by the weaning of calves which have been nursed since previous winter or about 10% of the adult of that season. Accordingly it must be considered that the calves born in the preceding season are weaned in October and November. Some calves born in the season will be nursed until next June or July as suggested by the increase of solitary calves in the months. This implies that the nursing period will last from 6 to 15 months.

The total number of weaned or suckling calves and that of juveniles attains the equal frequency of about 10% of the adults in March (Fig. 25). The body length separating the two categories is roughly 120 to 130 cm. The age of individuals at this body length can be deduced as follows. Firstly the body length frequency of the individuals stranded or accidentally captured in March to June shows three groups. The smallest is of 14 individuals ranging from 65.3 cm to 97.6 cm and considered as the newborn individuals. The intermediate is composed of total of eight individuals with the distribution of one at 117 cm, three in the range from 125 to 129 cm, one at 130 cm, two from 135 to 139 cm, and one at 141 cm which was an adult female. At least most of the individuals at the lower part of this group will be one year old. The third group is composed of 22 individuals ranging from 145 cm to 188 cm. They must represent older and presumably adult individuals. Secondly, if the body length of 120 to 130 cm is attained at one year after birth, the mean annual growth rate is from 60 to 73%, which is sufficiently close to the corresponding values, 55 to 65% known on several delphinids (Kasuya, 1972; Kasuya *et al.*, 1974) and phocoenids (Nielsen, 1972; Kasuya, 1978). They suggest mean nursing period not exceeding one year and average body length at weaning below 120 or 130 cm.

Though the study of age determination and growth of the species is in progress, the exploratory examination of 25 strandings and accidental catches made after completion of this study shows that the dentine deposition is annual. Namely a narrow layer strongly stainable with haematoxylin is deposited between September and June, and a wide weakly stainable dentine in June to September. This rate is same in cemental layers. The age frequency of the sample is as follows (both sexes); eight individuals between 0 and 0.9 years (65.3 to 130.2 cm in body length), four between 1.0 and 1.9 years (119.8 to 128.0 cm), and one at 3.0 years (length unknown) and 13 between 8 and 23 years. All the individuals in the last category were sexually mature. This supports the above deduction on the growth of juveniles, and indicates low mortality rate after weaning and before 8 years of age. These samples were obtained both inside and outside of the Inland Sea.

Most of the females which have weaned the calf before April will start the next gestation in the mating peak in the April and May. The cows which do not wean the calf before the mating peak will also be attended by some males as analysed in the school structure, and will start the nexst pregnancy by the end of August, or in some cases in the next mating season.

TABLE 6. FREQUENCY OF GROWTH STAGES OF FINLESS PORPOISE IN THE INLAND SEA AND ADJACENT WATERS

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Adult	7	15	147	213	122	78	20	13	28	5	24	14
Juvenile	1	1	13	20	4	5	0	0	0	0	0	0
Calf	0	5	13	62	19	19	8	2	9	0	10	2
Total	8	21	173	295	145	102	28	15	37	5	34	16
Cow with calf	0	3	10	49	18	14	6	2	9	0	3	0
Single adult	3	6	61	57	26	19	1	4	5	3	9	5

The ratio of the females which breed in two successive years, or that of the females which do not breed more than two years are not known. However, the low ratio of cows with calf attended by adult male, rather sharply defined mating season, and relatively short nursing period suggest that the most usual breeding cycle of the population will be about 2 years. Among the five records of the adult females, the three individuals caught in June were not lactating nor pregnant and were either before ovulation with large follicle in the ovary or after recent ovulation, one female caught in November was lactating and simultaneously pregnant with 43.5 cm fetus, and another female in April was not lactating but pregnant with 71.5 cm fetus. These informations suggest that the overlapping of lactation and pregnancy is not common (20% of five females).

The examination of gonads provided the following provisional result. In males, a 144 cm (1.5 years old) individual seemed to be at early pubertal stage, but other four males of 148, 157, 166, and 187 cm were undoubtedly mature. In females all six females from the Inland Sea measuring 141 cm or more were sexually mature. Their body lengths were 141, 154, 162, 163, 164, and 164.2 cm. Though, because of the underrepresentation of weaned immature individuals, the correct estimation of the body length or age at the onset of sexual maturity is impossible, it will be possible to conclude that the individuals clasified as " adult " in this study will be sexually mature so far as they are concerned with the females. Then the rough estimation of the annual gross production is calculated by assuming the equal sex ratio. As shown in Table 6 the ratio of the adult individuals is 71.5% of the total individuals in April. If the " adult " is assumed to be sexually mature, the number of adult females will be $4{,}900 \times 0.715 \times 0.5 = 1{,}751$. The two years breeding cycle gives calves produced in the Inland Sea in one season as $1{,}751 \times 0.5 = 875$ individuals of both sexes. In other words the gross annual reproductive rate seems to be 17.9%. The annual calf production, 25% of the total adult, is consistent with the number of calves and juveniles in the following March, 20% of the total adults (p. 36).

Nothing is known on the population discreteness of the species in the Japanese coastal waters.

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APPENDIX I. RESULT OF SURVEY OF

Expedition no.	date	Area	1	2	3	4	5	Sum
		N. mile²	245.2	433.7	255.1	358.8	108.0	1,400.8
		km²	841	1,488	875	1,231	370	4,805
1	12, IV, '76	N. miles		130.7	119.4	144.5	22.9	417.5
	|	No. sighted		83	74	65	0	222
	23, IV, '76	No./10 miles		6.350	6.198	4.498	0	5.317
2	22, VII, '76	N. miles	17.5	135.2	123.7	122.4	19.0	417.8
	|	No. sighted	0	35	12	13	2	62
	4, VIII, '76	No./10 miles	0	2.589	0.970	1.062	1.042	1.484
3	12, XI, '76	N. miles	17.4	141.6	138.4	88.6	51.0	437.0
	|	No. sighted	0	17	19	13	0	49
	2, XII, '76	No./10 miles	0	1.201	1.373	1.467	0	1.121
4	2, III, '77	N. miles	13.8	135.5	142.7	123.4	71.0	486.4
	|	No. sighted	0	46	44	43	7	140
	15, III, '77	No./10 miles	0	3.395	3.083	3.485	0.986	2.878
5	8, V, '77	N. miles	12.8	122.8	111.5	102.1	28.5	377.7
	|	No. sighted	0	40	24	20	2	86
	19, V, '77	No./10 miles	0	3.257	2.152	1.959	0.701	2.277
6	14, VI, '77	N. miles	13.8	134.4	109.0	117.5	60.4	435.1
	|	No. sighted	0	27	30	21	0	78
	25, VI, '77	No./10 miles	0	2.009	2.752	1.787	0	1.793
7	15, IX, '77	N. miles	14.0	142.5	95.4	144.4	33.2	429.5
	|	No. sighted	2	14	6	12	0	34
	28, IX, '77	No./10 miles	1.429	0.982	0.629	0.831	0	0.791
8	27, I, '78	N. miles	13.7	98.7	67.3	86.6	29.8	296.1
	|	No. sighted	0	2	19	10	1	32
	10, II, '78	No./10 miles	0	0.203	2.823	1.155	0.336	1.081
9	6, III, '78	N. miles	26.5				20.8	47.3
	|	No. sighted	0				41	41
	15, III, '78	No./10 miles	0				19.712	8.668
10	15, IV, '78	N. miles	16.0	156.2	136.3	108.4	55.6	472.5
	|	No. sighted	10	32	81	72	44	239
	30, IV, '78	No./10 miles	6.250	2.049	5.943	6.642	7.914	5.058
X 6	17, I, '77	N. miles					29.8	29.8
		No. sighted					0	0
		No./10 miles					0	0
X13	9, VIII, '77	N. miles				4.7	29.7	34.4
		No. sighted				0	0	0
		No./10 miles				0	0	0
X15	25, X, '77	N. miles				5.0	31.0	36.0
		No. sighted				4	1	5
		No./10 miles				8.000	0.323	1.389
X16	15, XI, '77	N. miles				5.2	22.2	27.4
		No. sighted				0	5	5
		No./10 miles				0	2.252	1.825
X17	13, XII, '77	N. miles				4.7	21.4	26.1
		No. sighted				0	0	0
		No./10 miles				0	0	0

FINLESS PORPOISE IN THE INLAND SEA

11	12	13	14	Sum	21	22	23	Sum	Grand total
332.7	612.1	327.6	203.1	1,475.5	894.6	87.7	298.9	1,281.2	4,157.5
1,141	2,099	1,124	697	5,061	3,068	301	1,025	4,394	14,260
	13.0	34.2	17.2	64.4			0.2	0.2	482.1
	26	4	1	31			0	0	253
	20.000	1.170	0.581	4.814			0	0	5.248
10.0	53.2	35.9	16.3	115.4	7.2	2.2	0	9.4	542.6
0	4	12	0	16	0	0	0	0	78
0	0.752	3.343	0	1.386	0	0	0	0	1.438
24.1	97.3	47.2	32.1	200.7	15.2	11.2	28.3	54.7	692.4
0	0	2	0	2	0	0	0	0	51
0	0	0.424	0	0.100	0	0	0	0	0.737
24.4	92.2	34.2	50.4	201.3	50.0	2.2	3.0	55.2	742.9
2	6	13	1	22	0	0	3	3	165
0.820	0.651	3.801	0.198	1.093	0	0	10.000	0.543	2.221
22.2	71.9	25.3	22.4	141.8	49.6	4.4	1.6	55.6	575.1
4	0	16	0	20	4	1	0	5	111
1.802	0	6.324	0	1.410	0.806	2.273	0	0.899	1.930
22.7	95.2	35.4	57.9	211.2	43.8	4.4	22.9	71.1	717.4
0	27	2	1	30	0	0	0	0	108
0	2.836	0.565	0.173	1.420	0	0	0	0	1.505
19.6	81.2	41.2	32.8	174.8	57.7	2.1	25.3	85.1	689.4
0	19	2	0	21	2	0	0	2	57
0	2.340	0.485	0	1.201	0.347	0	0	0.235	0.827
16.3	51.0	21.9	41.8	131.0	29.8		0.4	30.2	457.3
3	2	0	3	8	0		0	0	40
1.840	0.392	0	0.718	0.611	0		0	0	0.875
17.0				17.0					64.3
0				0					41
0				0					0.638
34.5	91.3	29.7	20.4	175.9	86.5	4.4	2.1	93.0	741.4
3	12	4	0	19	0	0	0	0	258
0.870	1.314	1.347	0	1.080	0	0	0	0	3.480
									29.8
									0
									0
		5.3	28.0	33.3					67.7
		0	5	5					5
		0	1.786	1.502					0.739
		4.3	25.2	29.5			0.4	0.4	65.9
		0	0	0			0	0	5
		0	0	0			0	0	0.759
		4.0	20.9	24.9			0.4	0.4	52.7
		0	0	0			0	0	5
		0	0	0			0	0	0.949
		4.7	21.2	25.9			0.4	0.4	52.4
		6	3	9			0	0	9
		12.766	1.415	3.475			0	0	1.718

Continued . . .

APPENDIX I.

X21	21, VII, '78	N. miles	4.5	35.2	39.7
		No. sighted	0	4	4
		No./10 miles	0	1.136	1.008
X22	17, VIII, '78	N. miles	4.4	29.1	33.5
		No. sighted	0	0	0
		No./10 miles	0	0	0
X23	19, IX, '78	N. miles	4.9	25.7	30.6
		No. sighted	0	0	0
		No./10 miles	0	0	0
X24	17, X, '78	N. miles	7.0	27.0	34.0
		No. sighted	0	0	0
		No./10 miles	0	0	0

X : Survey conducted by K. Kureha in the areas 4, 5, 13, and 14. Four surveys conducted at Akashi and Kanmon passes not listed.

1 : Includes X1, May 5, 25.7 miles, 0 porpoise. 47 individuals in 16 schools observed on a fishing vessel not included (area 4).

2 : Includes X2, Aug. 8, 18.8 miles, 2 porpoises.

3 : Includes X3, Oct. 20, 25.5 miles, 0 porpoise, X4 Nov. 18, 10.2 miles, 0 porpoise, and X5 Dec. 16, 42.3 miles, 0 porpoise.

4 : Includes X7, Feb. 23, 20.4 miles, 0 porpoise, and X8 and X9 Mar. 1 and 22, 116.4 miles, 9 porpoises.

APPENDIX II. MINIMUM ESTIMATION OF PORPOISE

Expedition		Nearshore stratum							Intermediate		
no.	date	1	2	3	4	5	sum[1]	sum[2]	11	12	13
4	2, III-15, III, '77							1,170 (201)			
1	12, IV-23, IV, '76	210	421	325	438	94	1,488	1,574 (279)	60	350	179
9	15, IV-30, IV, '78							1,970 (380)			
5	8, V-19, V, '77	0	257	143	149	6	555	641 (143)	68	226	221
6	14, VI-25, VI, '77							665 (146)			
2	22, VII- 4, VIII, '76	51	250	69	110	14	494	744 (190)	0	343	194
7	15, IX-28, IX, '77							335 (97)			
3	12, XI- 2, XII, '76	0	193	265	239	7	704	950 (261)	139	46	53
8	27, I-10, II, '78							796 (215)			

[1] Calculated for each area after combining the data of two or three expeditions. The r values used are 0.391 (March to April), 0.438 (May to June), 0.306 (July to September), and 0.178 (November to

Continued

4.1	25.5	29.6	0.4	0.4	69.7
0	4	4	0	0	8
0	1.569	1.351	0	0	1.148
4.4	25.0	29.4	0.4	0.4	63.3
0	0	0	0	0	0
0	0	0	0	0	0
4.0	26.9	30.9	0.4	0.4	61.9
0	0	0	0	0	0
0	0	0	0	0	0
4.4	29.0	33.4			67.4
0	0	0			0
0	0	0			0

5: Includes X10 May 12, 59.5 miles, 2 porpoises.
6: Includes X11 Jul. 14, 66.0 miles, 2 porpoises.
7: Includes X14 Sept. 18, 66.4 miles, 0 porpoise.
8: Includes X18 Jan. 20, 517 miles, 1 porpoise, and X19 Feb. 17, 28.7 miles, 3 porpoises.
9: Survey conducted mainly at four straight and waters adjacent to the Inland Sea. Only the Inland Sea records are listed.
10: Includes ×20 Apr. 13 49.3 miles 0 porpoise. Surveys made outside of the Inland Sea excluded.

POPULATION IN THE INLAND SEA, $k=1$ ASSUMED

stratum			Offshore stratum					Grand total[1]	Grand total[2]
14	sum[1]	sum[2]	21	22	23	sum[1]	sum[2]		
		469 (173)					202 (200)		1,841 (332)
12	601	1,502 (752)	0	0	432	432	0	2,521	3,076 (810)
		444 (185)					0		2,414 (432)
6	521	418 (283)	87	23	0	110	232 (135)	1,186	1,291 (344)
		555 (177)					0		1,220 (230)
0	537	732 (560)	90	0	0	90	0	1,121	1,476 (591)
		536 (405)					91 (90)		962 (426)
46	284	89 (88)	0	0	0	0	0	988	1,039 (276)
		474 (248)					0		1,270 (328)

Febraury).
[2] Calculated for each stratum after combining the data of areas. Standard error in parenthesis.

EXPLANATION OF PLATES

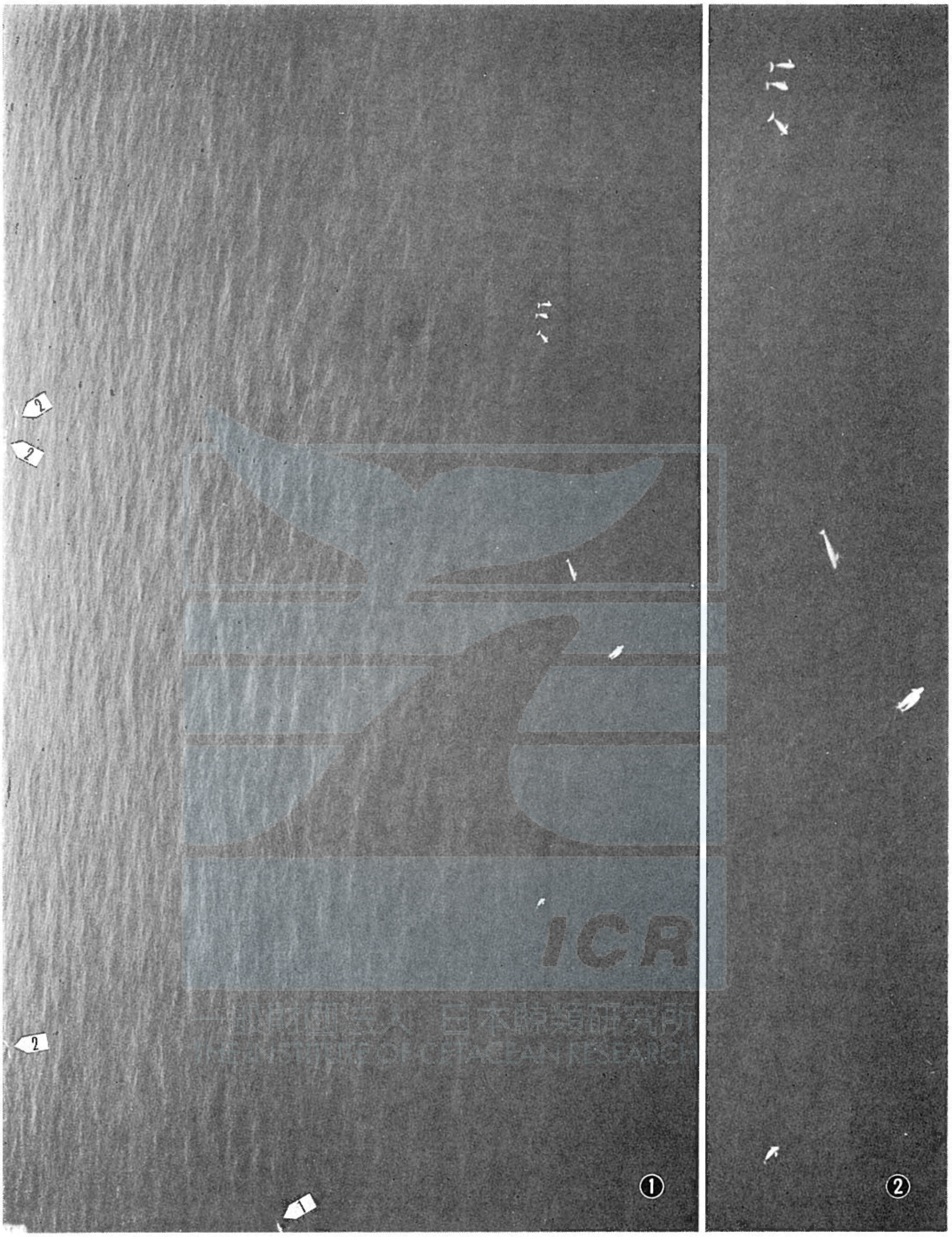
PLATE I

Fig. 1. Aerial photograph of seven schools of the finless porpoise. 1044 hrs, 12 July, 1976. 34°00′N, 132°25′E. Numeral and arrow indicate the position and number of distant individuals. Copyright, Fisheries Aviation Co. Ltd., Kojimachi, Tokyo.

Fig. 2. Closeup of the three schools in Fig. 1. It is also possible to consider them as one school. Copyright, Fisheries Aviation Co. Ltd.

PLATE II

Fig. 1. Aerial photograph of two schools (two and seven individuals) of the finless porpoise. Data are same with PLATE I. Numeral and arrow indicate the position and number of submerged individuals, all adult. Copyright, Fisheries Aviation Co. Ltd.


①
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