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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

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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

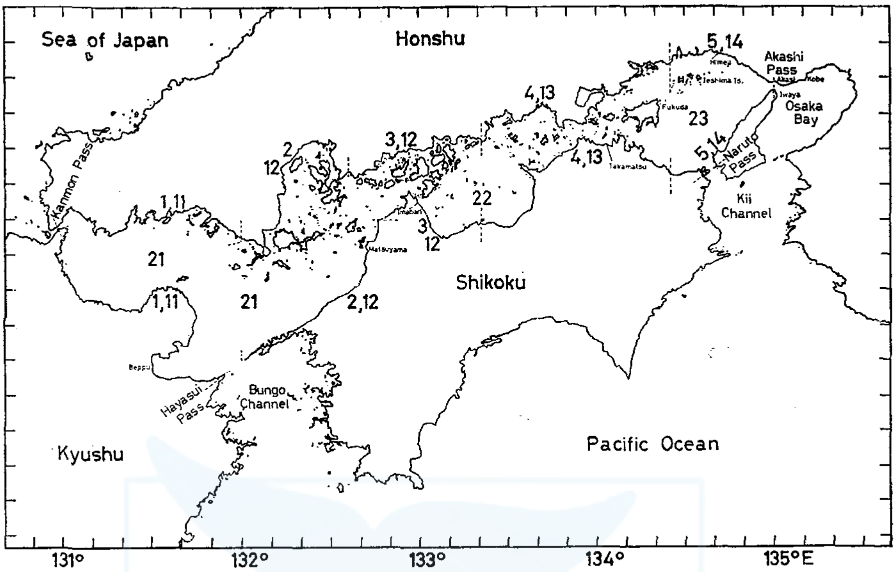

Fig. 1. Geography of the Inland Sea of Japan. Numeral indicates the area number used in this study. The boundary between the strata is not indicated.

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).

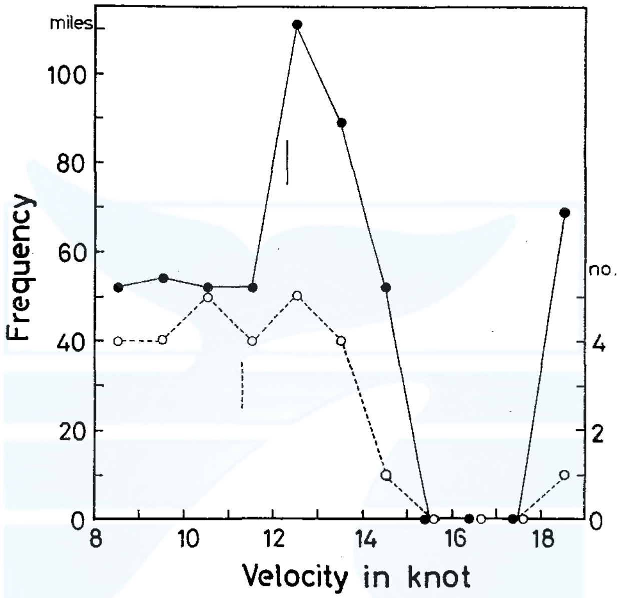

Fig. 2. Speed composition of the vessels used in this study. Closed circle and solid line indicate the frequency weighted with cruising distance, open circle and dotted line nonweighted frequency, and vertical line the average speed.

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.

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

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

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.

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

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

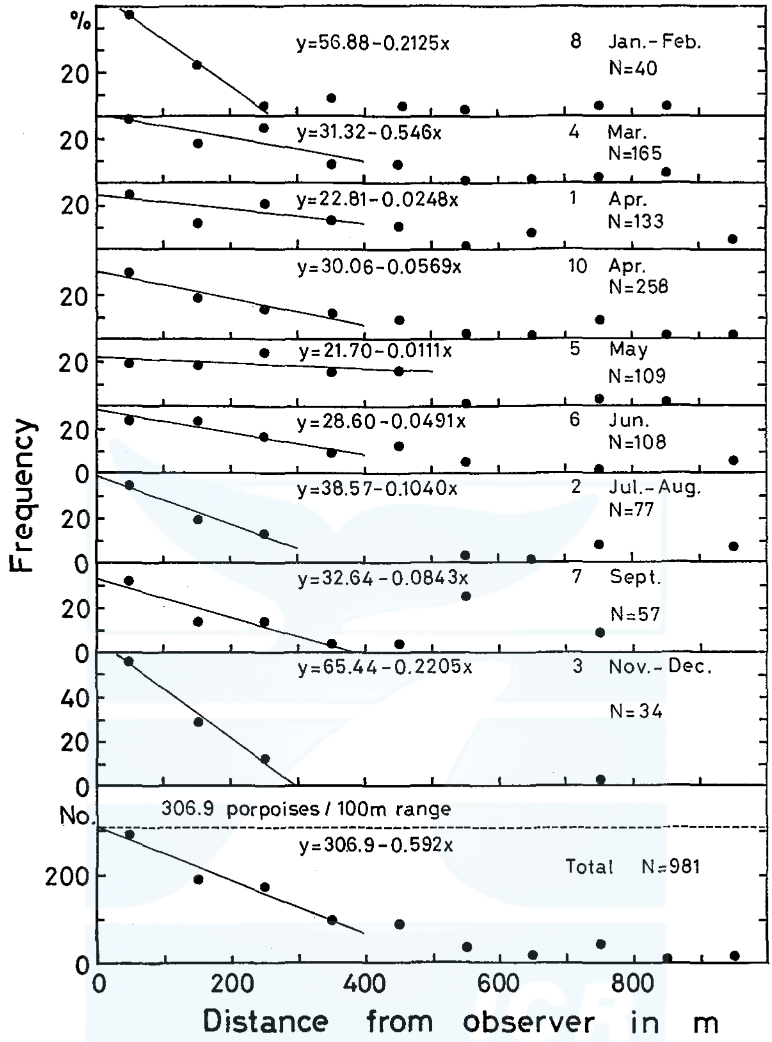

Fig. 3. Relationship between the distance from the observer and the number of the porpoises sighted. Numeral indicates the expedition number. Data of Kasuya and Kureha included.

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

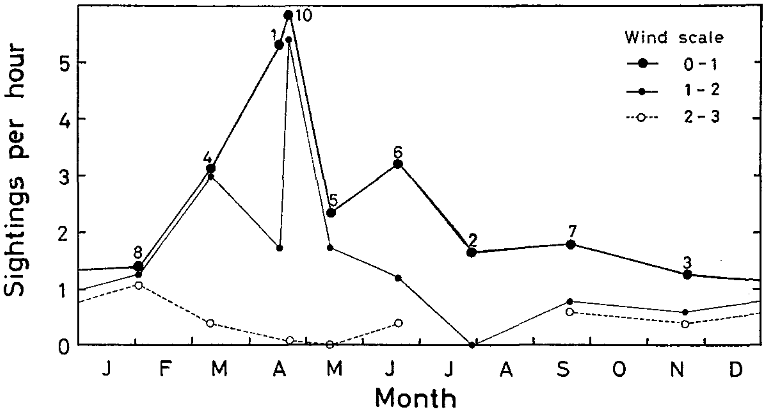

Fig. 4. Relationship between the wind force and the number of individuals sighted per one hour of observation. Upper limit of each wind range excluded. Numeral by the circle indicates the expedition number.

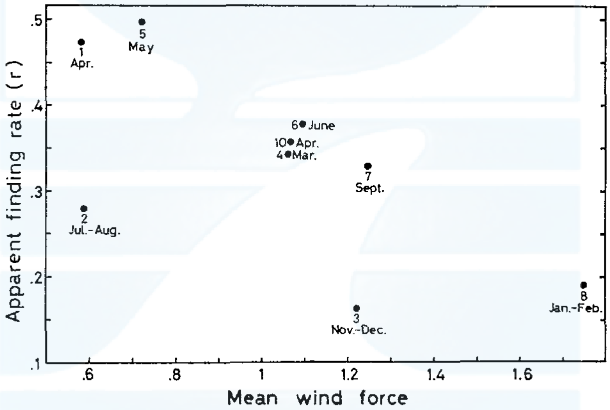

Fig. 5. Relationship between mean wind force and the apparent finding rate (r). Numeral indicates the expedition number.

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.

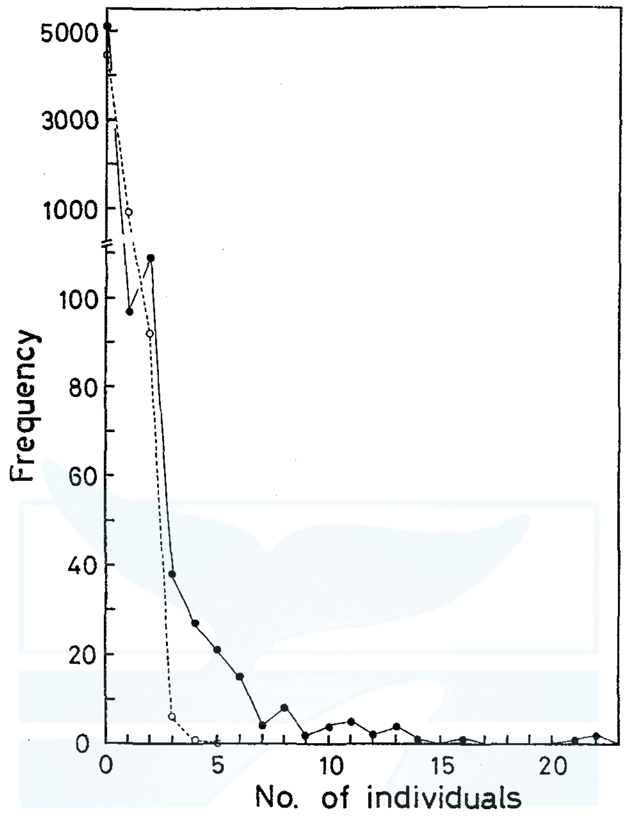

Fig. 6. Frequency distribution of number of sightings in each 1 nautical mile section of the cruise (closed circle and solid line), and the Poisson distribution with the same mean and same sample size (open circle and dotted line).

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

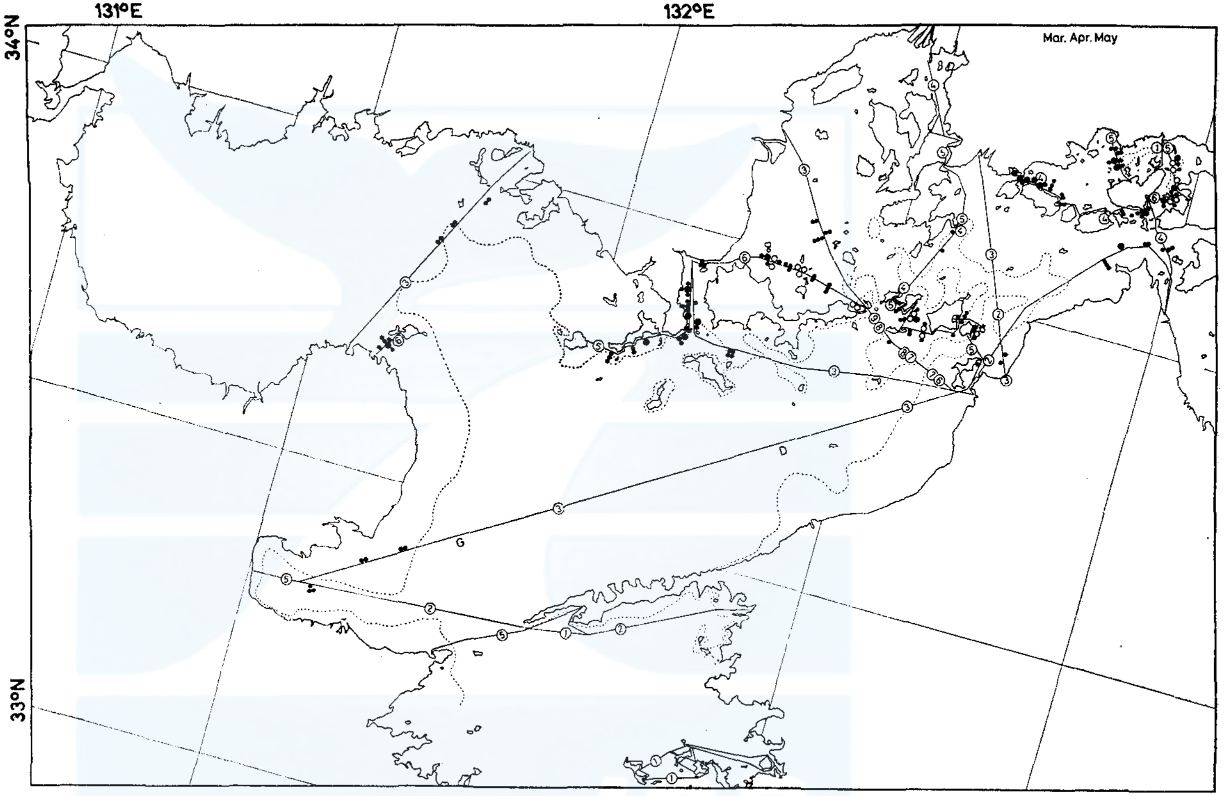

Fig. 7. Observation routes and number of sightings of the finless porpoise (circle), a school of *Delphinus* (D), and a school of *Grampus* (G). March to May. Small closed cicle indicates one individual, large closed circle 5, and open circle 10. Numerals in the circle indicates number of cruises, dotted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

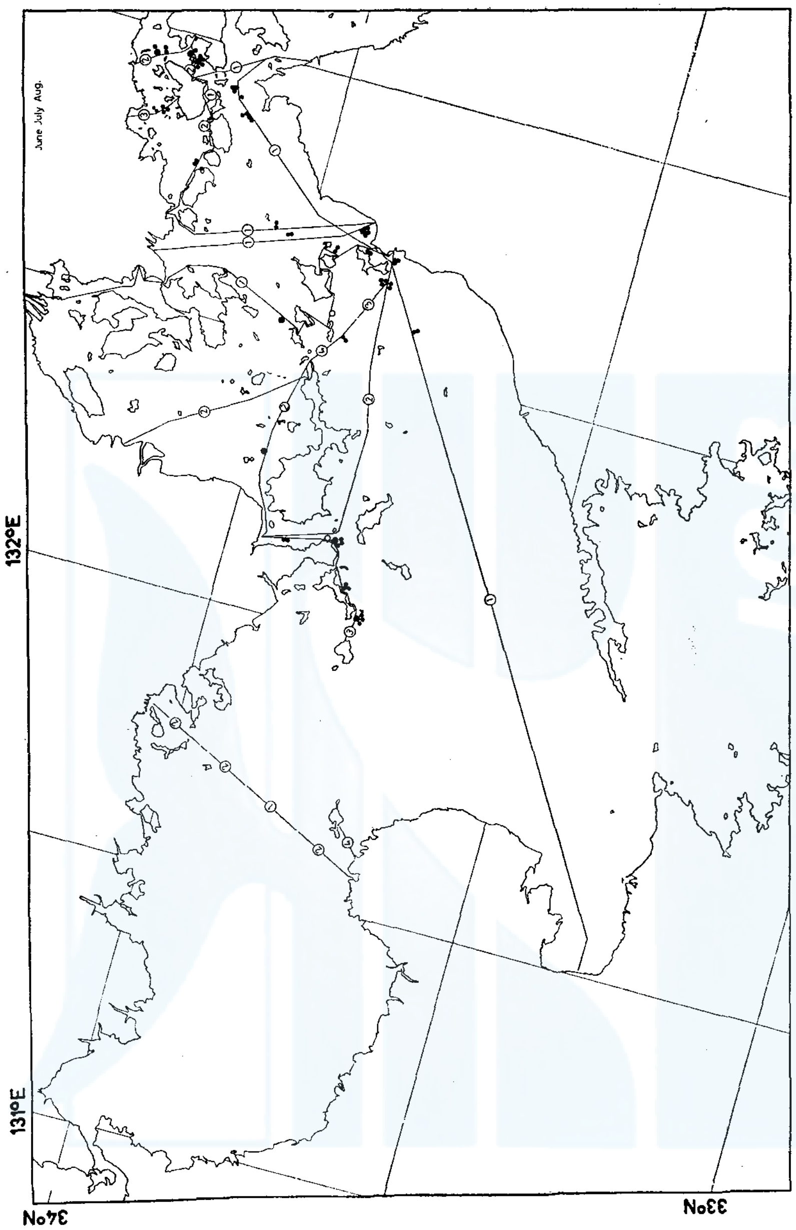

Fig. 8. Observation routes and sightings of the finless porpoise. June to August. For marks see Fig. 7.

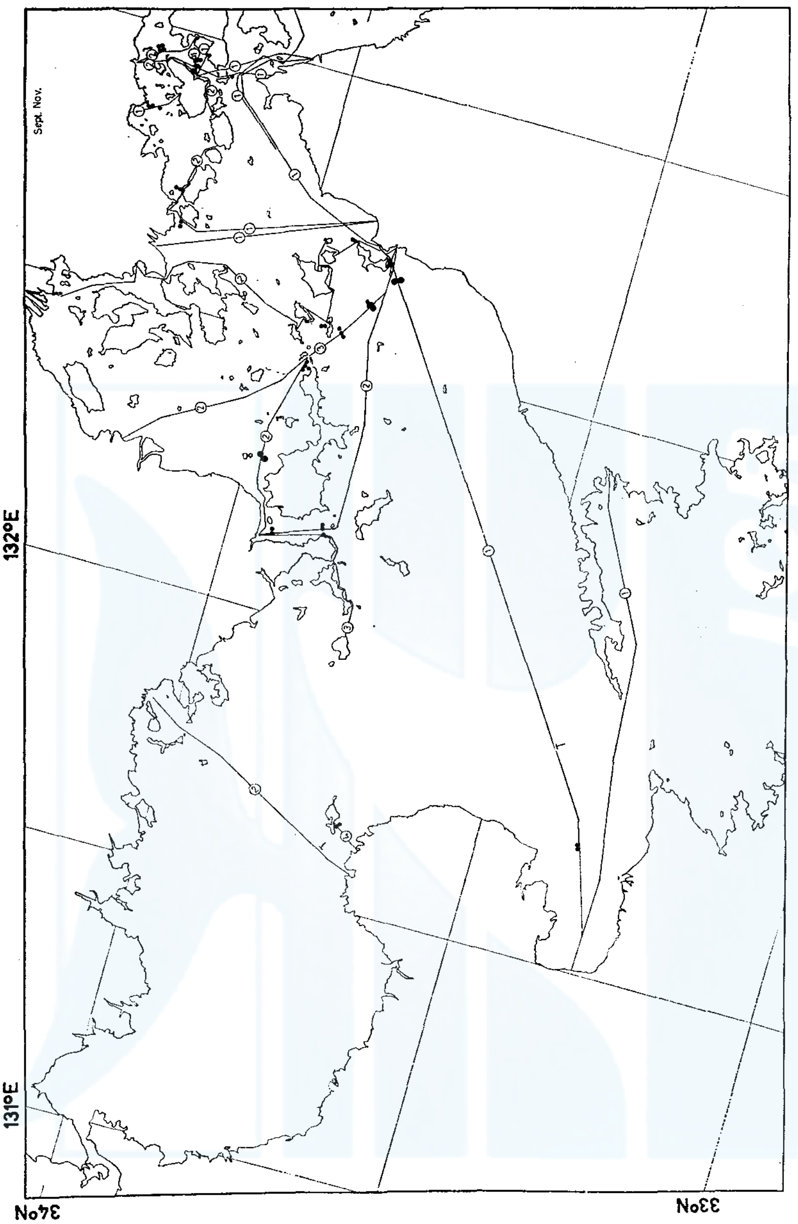

Fig. 9. Observation routes and sightings of the finless porpoise (circle), and two schools of *Tursiops* (T). September and November. For other marks see Fig. 7.

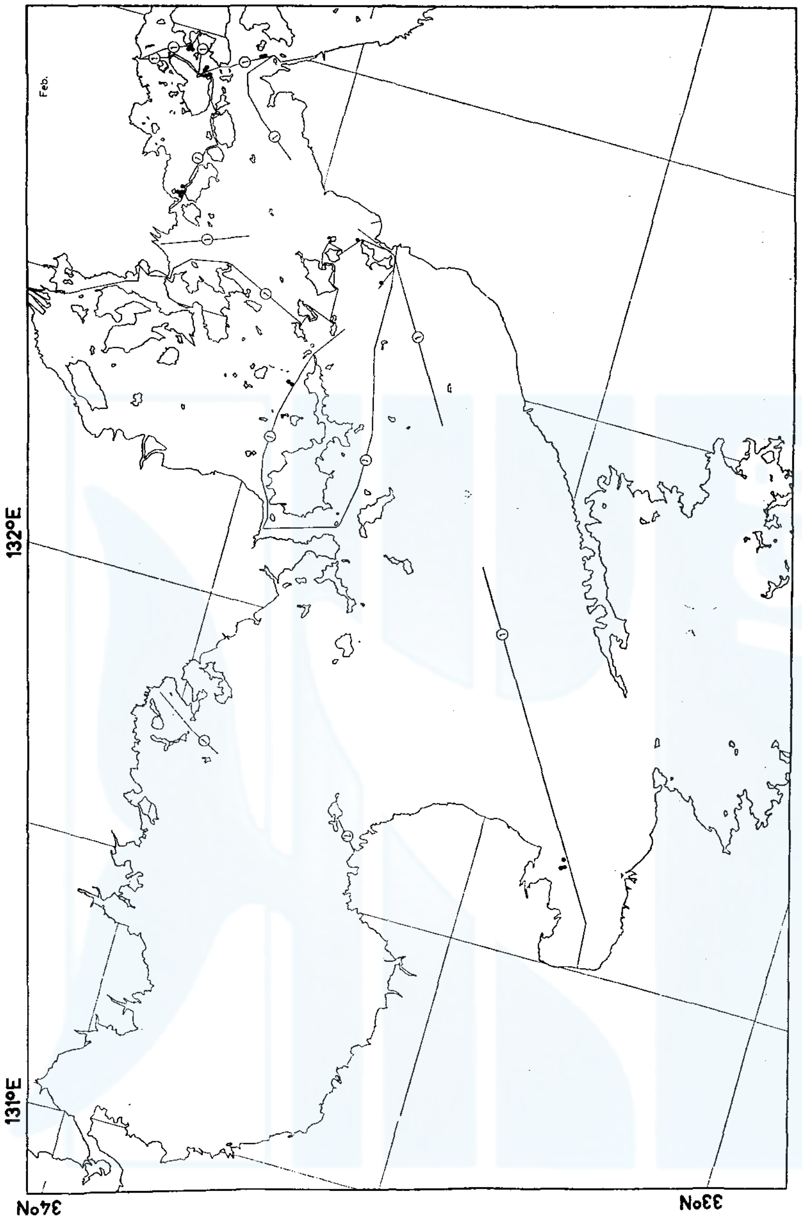

Fig. 10. Observation routes and sightings of the finless porpoise. February. For marks see Fig. 7.

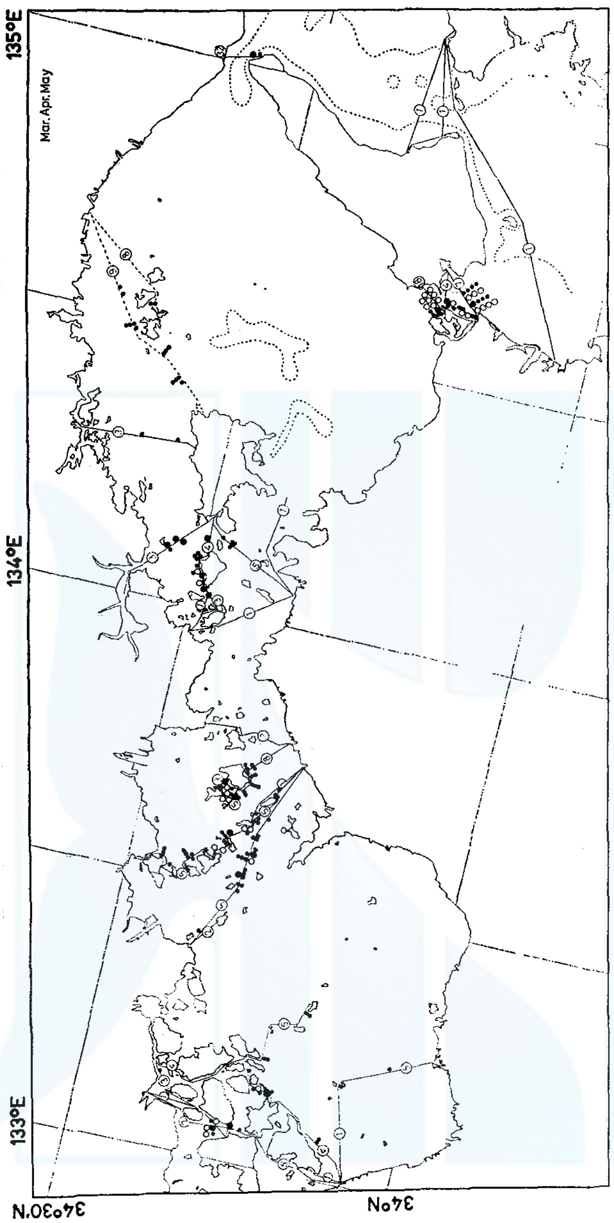

Fig. 11. Observation routes and sightings of the finless porpoise. March to May. The routes indicated by dotted line are those observed by Kureha for the entire study period. For other marks see Fig. 7.

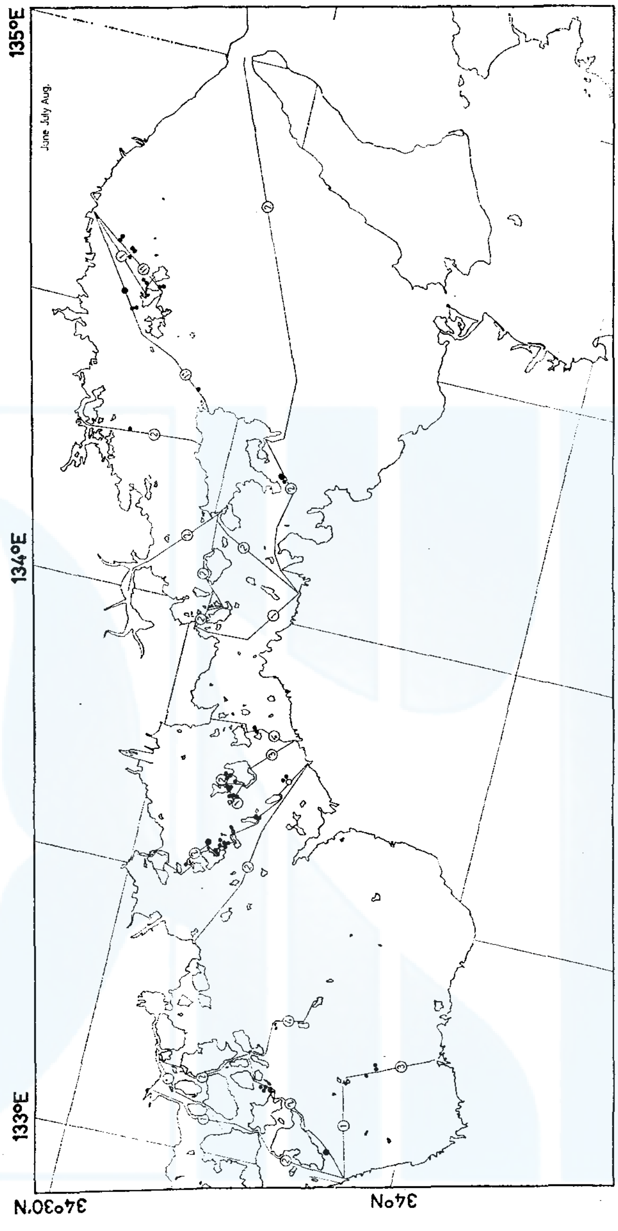

Fig. 12. Observation routes and sightings of the finless porpoise. June to August. For marks see Fig. 7.

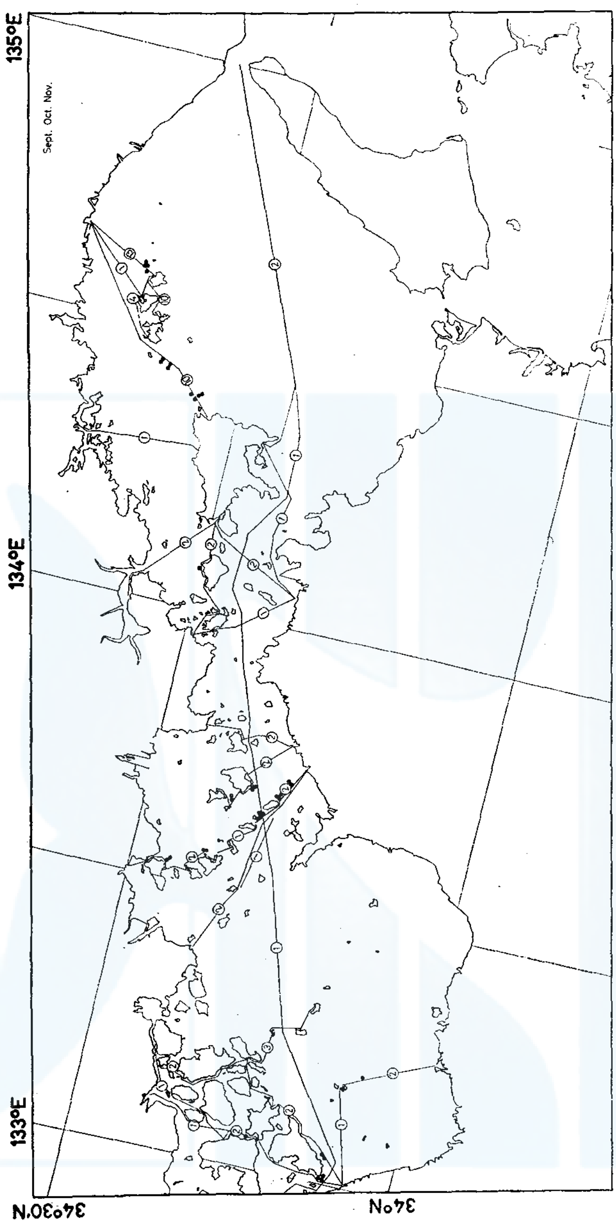

Fig. 13. Observation routes and sightings of the finless porpoise. September to November. For marks see Fig. 7.

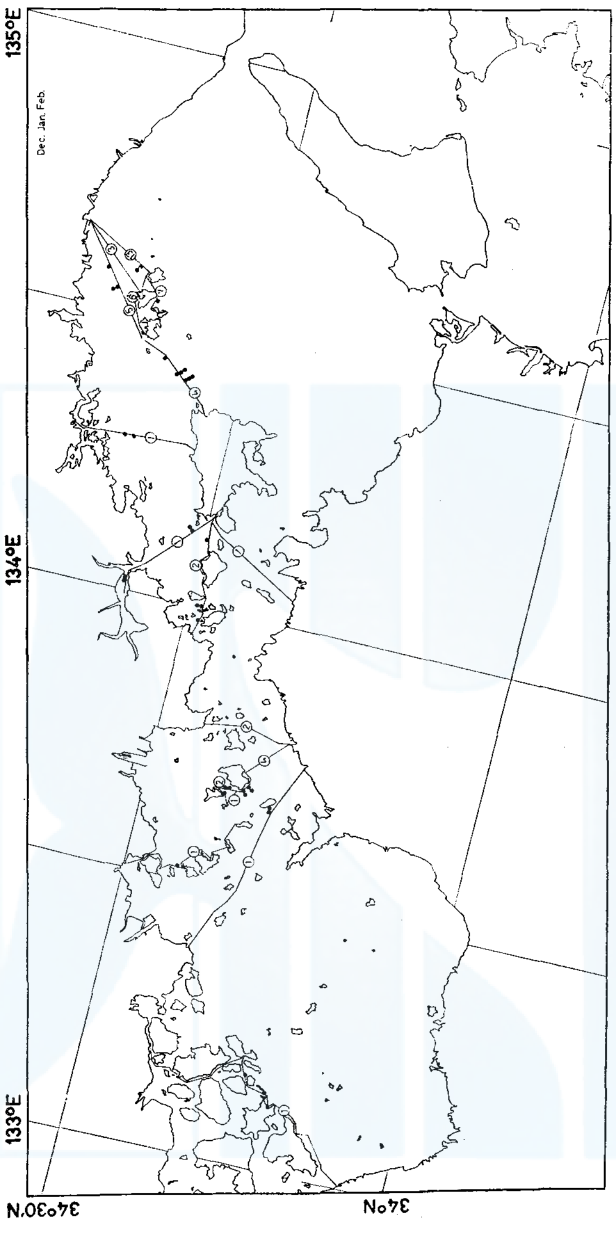

Fig. 14. Observation routes and sightings of the finless porpoise. December to February. For marks see Fig 7.

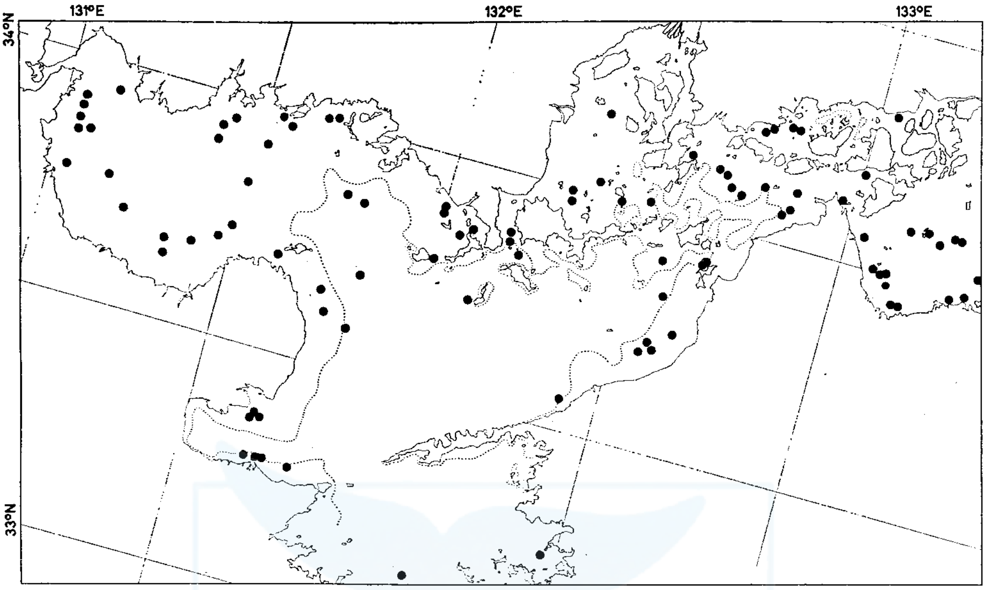

Fig. 15. Aerial sighting record, poisition of the occurrence of the finless porpoise. Each circle indicates one encounter. For effort data see Fig. 20.

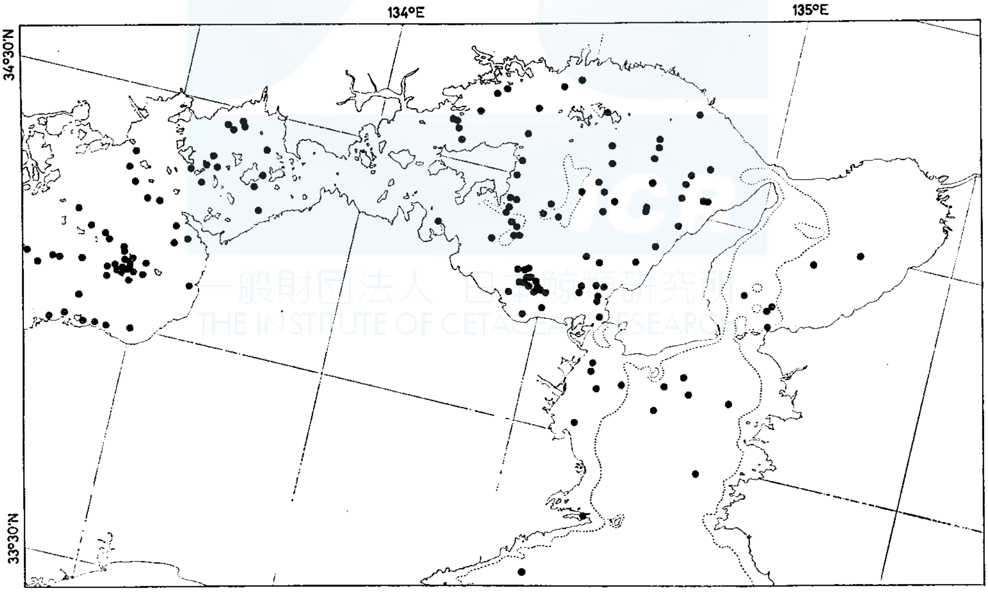

Fig. 16. Aerial sighting record, position of the occurrence of the finless porpoise. For other explanations see Fig. 15.

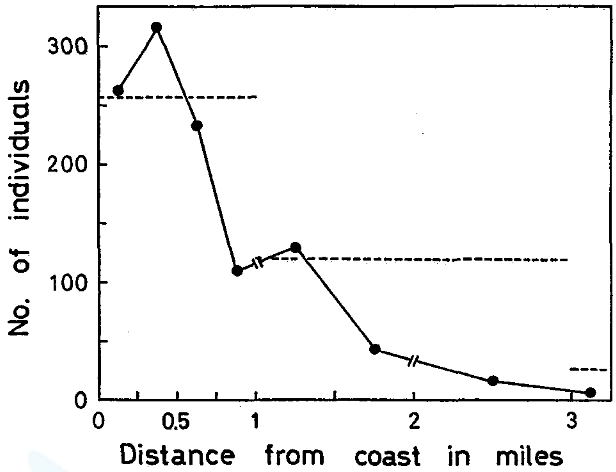

Fig. 17. Distribution of the finless porpoise and the distance from the coast. Closed circle and solid line indicate the actual number at actual position. Dotted line indicates sightings per 1,000 nautical miles of observation, where the position of the vessel was used as that of the porpoise.

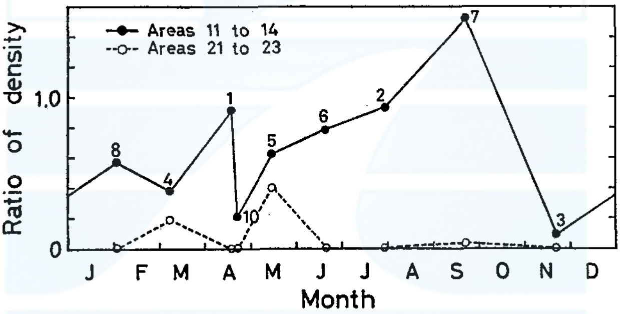

Fig. 18. Seasonal change of the relative density of the finless porpoise in intermediate (areas 11 to 14) and offshore (areas 21 to 23) strata indicated by the ratio to the density in the nearshore stratum. Numeral indicates the expedition number.

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 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

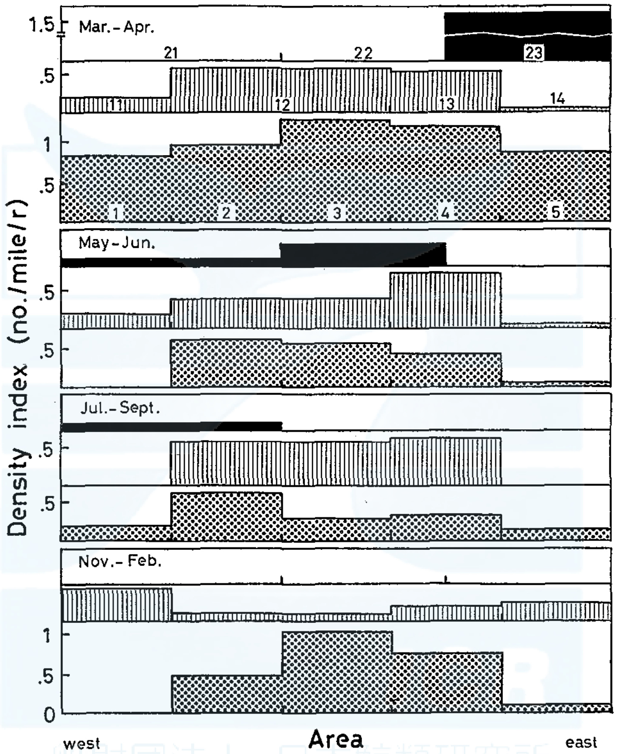

Fig. 19. Seasonal change of the density distribution of the finless porpoise in the Inland Sea.

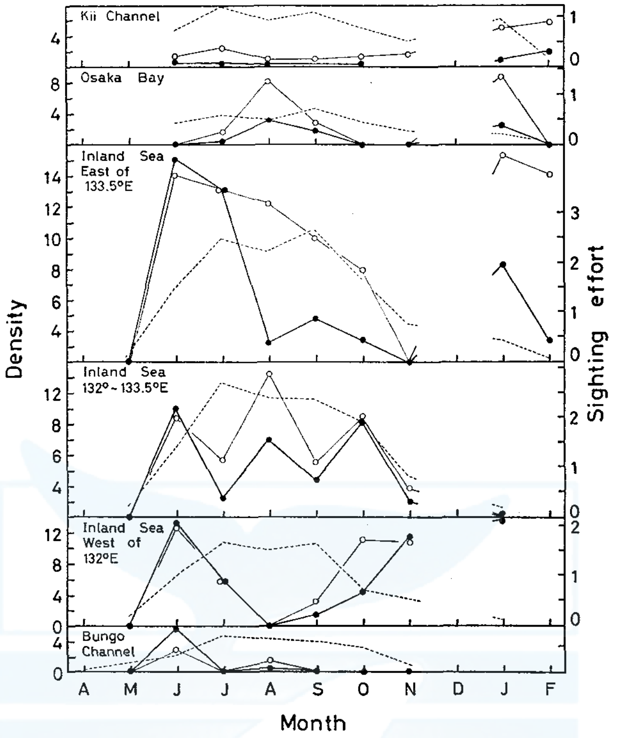

Fig. 20. Aerial sighting records of the finless porpoise. Seasonal change of the number of encounters per 1,000 nautical miles (closed circle and thick solid line) and number of individuals (open circle and thin solid line) per 100 nautical miles. Amount of effort are shown by dotted line (thousand nautical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

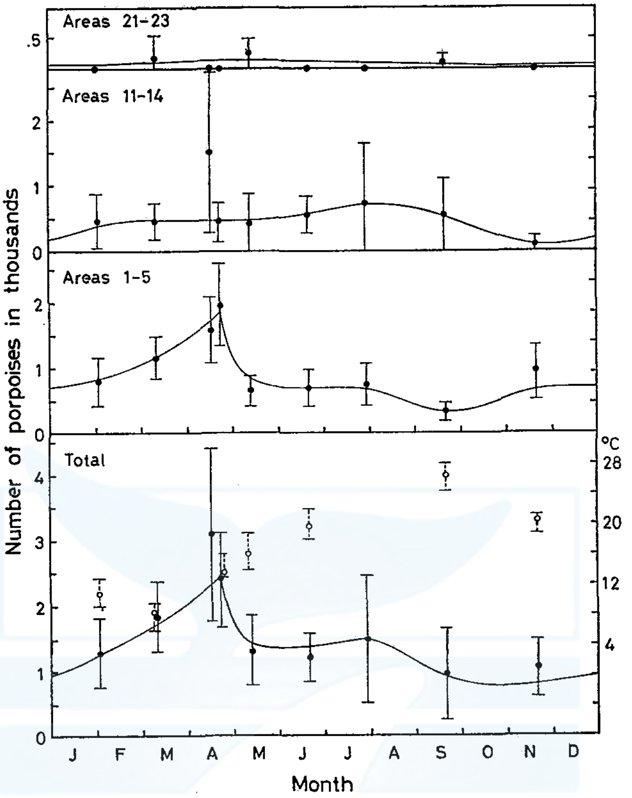

Fig. 21. Seasonal fluctuation of the finless porpoise population in the Inland Sea. Mean population estimates and the 90% confidence range (closed circle and solid line), and range and mean of the surface water temperature (open circle and dotted line) are indicated. Since $k=1$ is tentatively assumed, 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

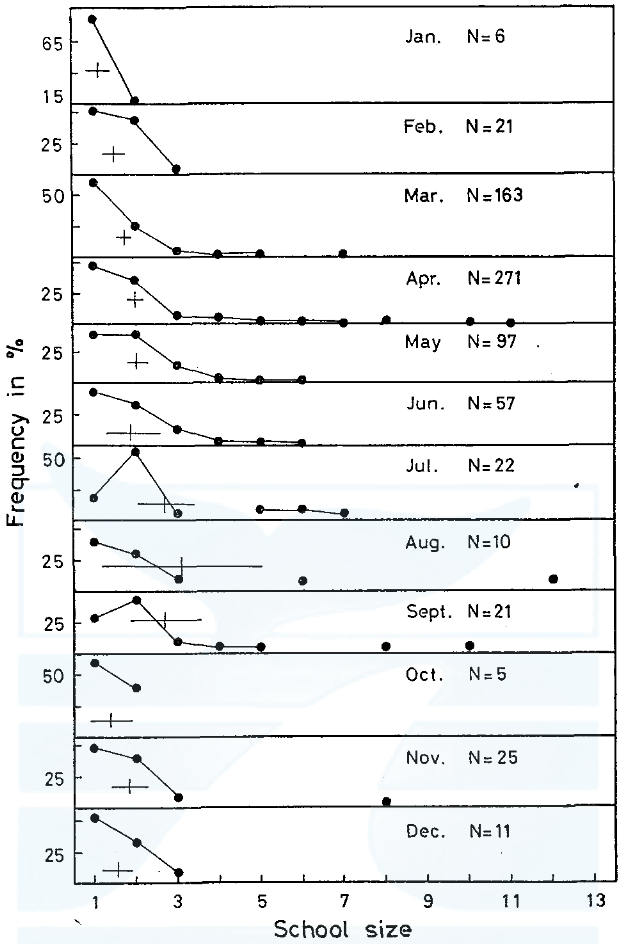

Fig. 22. Seasonal fluctuation of the school composition (closed circle and solid line), mean school size (vertical bar), and 90% confidence range (holizontal bar). All the data obtained in the present study included.

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

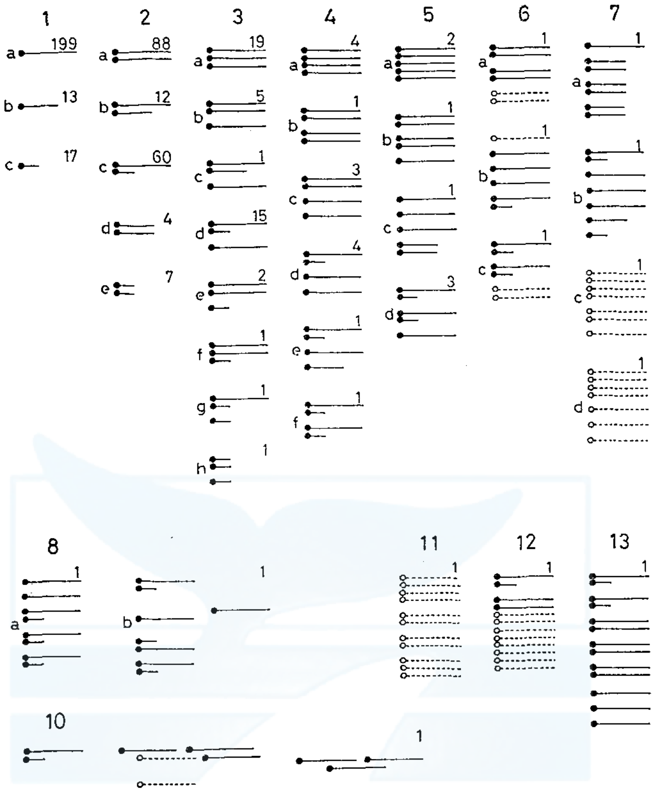

Fig. 23. Schematic figure of the school of the finless porpoise, relative size of the school members and subgroups are indicated. Numeral at the top of column indicates school size, numerals by each type the number of encounters. Two dimensional arrangement of subgroups is indicated only in cases of 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.

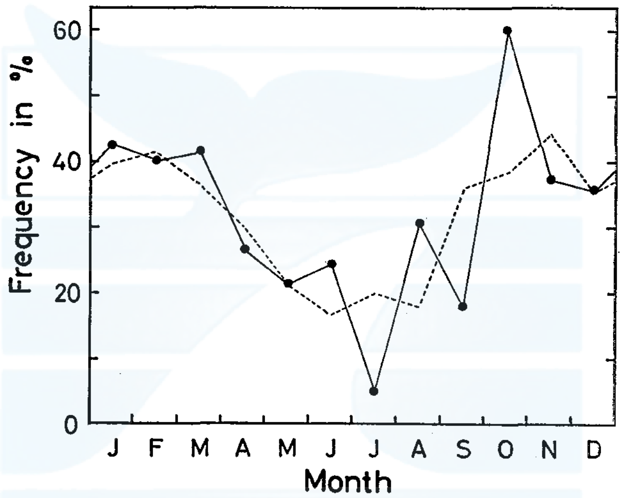

Fig. 24. Seasonal change of the solitary adults. Closed circle and dotted line indicate the ratio of solitary adult to total number of the adults, dotted line the moving average of the three. All the data obtained in the present study included.

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.

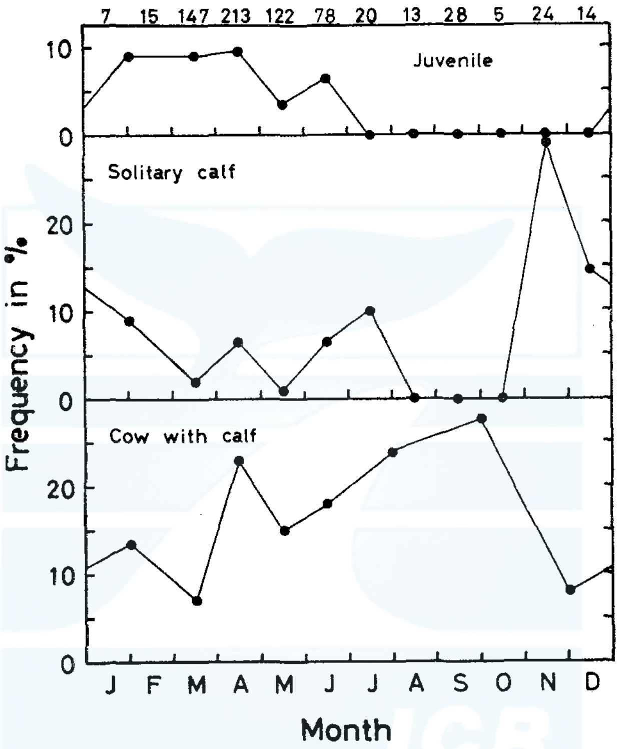

Fig. 25. Seasonal change of the frequency of juveniles, solitary calves, and cows with calf. Frequency is shown by the ratio to the total number of the adult shown at the top. Months with small sample size are grouped.

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×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 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.

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.

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 4,900×0.715×0.5=1,751. The two years breeding cycle gives calves produced in the Inland Sea in one season as 1,751×0.5=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		Area	1	2	3	4	5	Sum
		N. mile^2	245.2	433.7	255.1	358.8	108.0	1,400.8
no.	date	km^2	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	210	421	325	438	94	1,488	1,170 (201)	60	350	179
1	12, IV-23, IV, '76							1,574 (279)			
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 total1)	Grand total2)
14	sum1)	sum2)	21	22	23	sum1)	sum2)		
		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

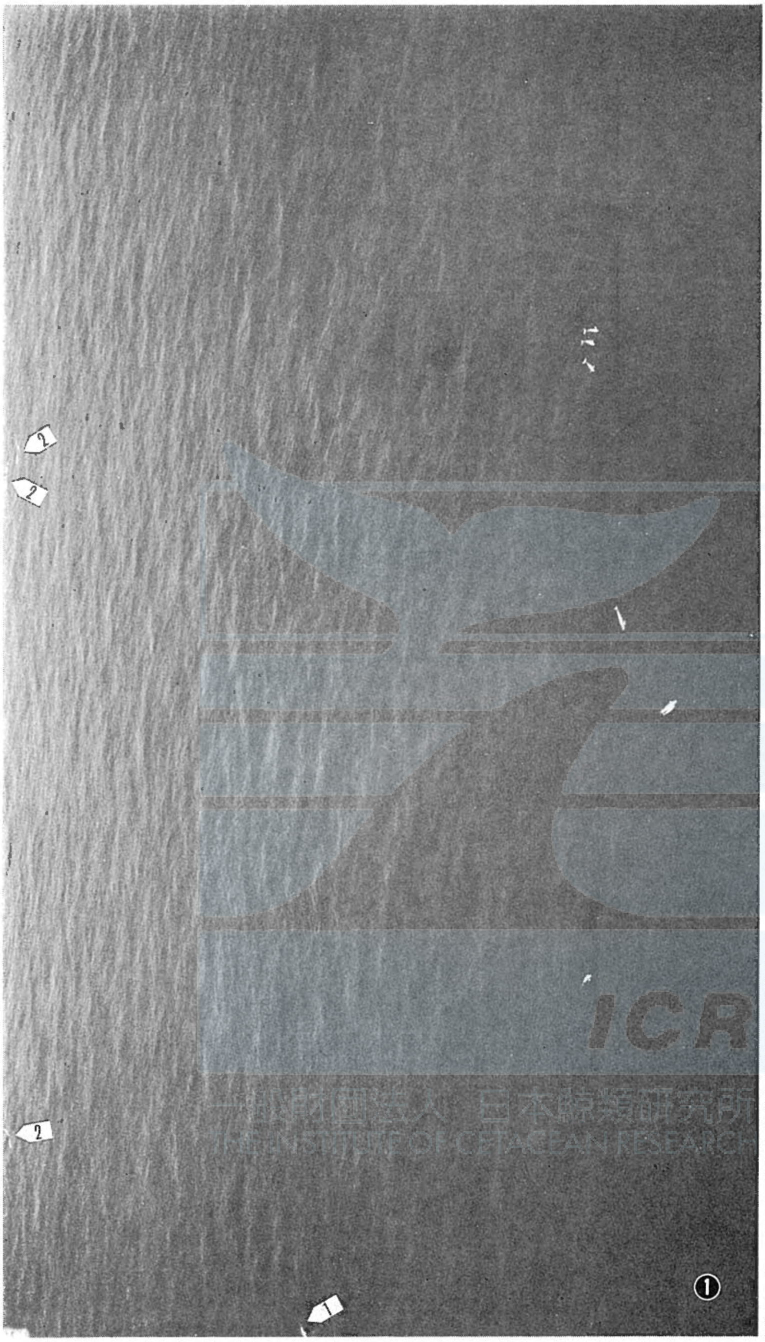
PLATE I

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.



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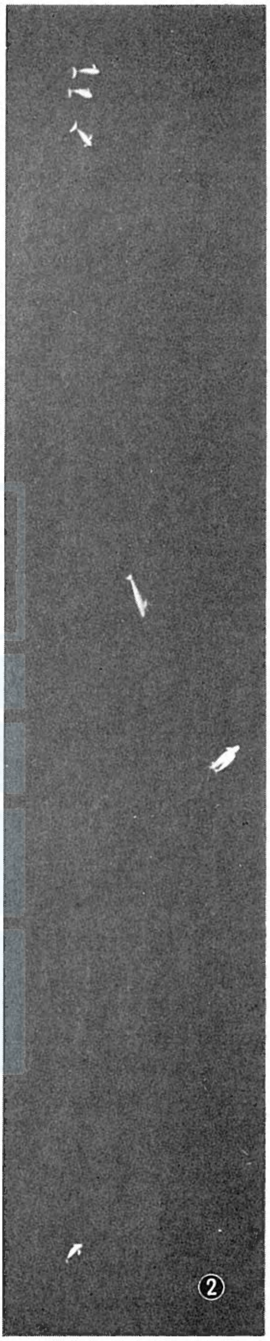

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AGE DETERMINATION, REPRODUCTION, AND GROWTH OF THE FRANCISCANA DOLPHIN, *PONTOPORIA BLAINVILLEI*

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ABSTRACT

An examination was made of 260 Franciscana dolphins taken off the Uruguayan coast. Deposition of dentinal and cemental layers is annual with the formation of an unstainable layer between August and November. Cementum deposition continues after the probable cessation of dentine deposition at four to seven years. Females usually have a 2-year reproductive cycle. Calves are born at a length from 70 to 75 cm after a gestation of about 10.5 months, and weaned before one year of age. Sexual maturity is attained in both sexes at an age between two and three years, which corresponds to the length of 131 cm and weight of 25 to 29 kg in males, and to 140 cm and 33 to 34 kg in females. Physical maturity is attained soon after the onset of sexual maturity. Sex ratio is at parity in immature individuals.

INTRODUCTION

The Franciscana dolphin *Pontoporia blainvillei* (Gervais and d'Orbigny, 1844) inhabits the coastal waters off eastern South America from Valdes Peninsula (42°30'S), Argentina, north to the Tropic of Capricorn near Ubatuba, Brazil (Ximenez, Langguth, and Praderi, 1972).

The purpose of this study was to investigate reproductive parameters and growth in this species. Specific objectives included collection and analysis of information on age of sexual maturity, frequency and timing of calving, growth, and sex and age composition.

MATERIALS AND METHODS

The dolphins examined in this study, 123 females and 137 males, were collected dead, offshore from Punta del Diablo, Uruguay, by local fishermen in gillnets set for sharks. Details on the fishing methods used at Punta del Diablo are given by Van Erp (1969), Brownell and Ness (1970), Pilleri (1971), and Brownell (1975).

Sci. Rep. Whales Res. Inst.,
No. 31, 1979, 45–67

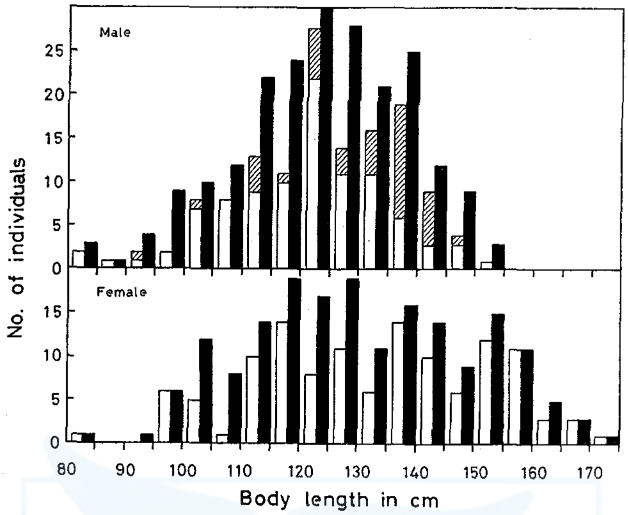

Fig. 1. Body length frequency of *Pontoporia blainvillei*. Right column (black) represents the random sample cited from Brownell (1975), left column the present material, and shaded area individuals of unknown age.

TABLE 1. MATERIALS OF *PONTOPORIA BLAINVILLEI* USED IN THIS STUDY

Month	I	II	III	VI	VII	VIII	IX	X	XI	XII	Total
Male[1]	79[3]	3	2	3	1	3	1	1	0	33	126
„ [2]	0	0	0	0	7	1	1	0	1	1	11
Female[1]	57[3]	7	3	3	0	1	2	2	2	21	98
„ [2]	0	0	0	0	0	4	3	6	6	6	25
Female, %[1]	41.9	70.0	60.0	50.0	0.0	25.0	66.7	66.7	100.0	38.9	43.8
„ , %[2]	—	—	—	—	0.0	80.0	75.0	100.0	85.7	85.7	69.4

[1] : Random sample, [2] : Nonrandom sample, [3] : One aged individual of unknown length included.

Over 400 dolphins were collected by us or a local fisherman Amilcar Olivera (AO) between December 1970 and December 1973. The sample was heavily biased toward December and January (austral summer), because of the seasonal nature of the shark fishery, with minimal coverage during the rest of the year. The body weight and external proportion data were obtained from specimens taken between December 1972 and January 1973. The standard total length of each specimen was measured in a straight line from the tip of the rostrum to the notch in the flukes. The material we collected was a random sample of the catch, but the AO specimens are biased towards adult females exceeding 135 cm in total length. Olivera only agreed to collect a limited number of specimens. Therefore, we asked him, in our absence, to collect all adult females landed.

Tooth preparation

Although the anterior teeth are slightly longer than the others, the difference is not as extreme as in *Platanista*. Three to five contiguous mandibular teeth, starting at approximately the tenth from the front and moving posteriorly, were collected and fixed in 10% formalin solution or 70% ethanol.

The principle of the preparation is to decalcify and stain a thin longitudinal ground section glued with cyanoacrylate monomer on a clear plastic plate (Kasuya, 1978). The tooth was ground down to a thickness of 20 to 30 μm. The decalcification was done with 5% formic acid for several hours at about 25°C. The slide was then rinsed in running water for two hours or longer, stained with Mayer's haematoxylin for 30 minutes, and finally mounted with Canadian balsam. Both anterio-posterior and lingual-buccal sections were prepared for most individuals; they were not significantly different in readability. However, since the teeth are compressed anterior-posteriorly, the chance of missing the pulp cavity is less in the anterio-posterior section.

Reading of growth layers

The age determination was based on the growth layers in the dentine and cementum. Observations of growth layers were made with a compound microscope (40 to 120×), without referring to the biological data. At first, about 20 slides, probably representing new born individuals and very old individuals, were selected, and the standard of reading was established by comparing the growth stage and layer counts of the slides. Then all the slides were read by the same standard. If the number of cemental layers exceeded significantly that in dentine, the former was taken as the age. This only occurred when teeth had narrow pulp cavities. In cases where the counts of dentine and of cemental layers differed only by a fraction of a layer, the dentine count was taken as the age because it is clearer and more reliable than the cemental layer. If the independent readings of the growth layers in the same tissue of two slides from one individual were different, they were carefully compared including the difference of the finish, and then a final decision was made without referring to the biological data. When there was no choice in the interpretation of the fraction of the last incomplete layer, the mean of the two counts was used.

One complete growth cycle was considered to be composed of one broad stainable layer and a narrow unstainable layer. The final fractional layer was estimated by eye to the nearest 0.1 layer. Although this is not highly accurate, it gives a better result when the sample is seasonally biased.

AGE DETERMINATION

Morphology and number of teeth

The number of teeth ranges from 48 to 61 on each tooth row (Table 2). There are no consistent sexual or bilateral differences. However, the number of teeth is significantly different between the upper and lower jaws ($p<0.001$). The excess of upper teeth over the lower varies from −1 to +11 with a mean of 3.3 in females, and from −1 to +9 with a mean of 2.7 in males. This is related to the downward curving of the rostrum. In *Platanista gangetica*, the rostrum is curved upward and the number of lower teeth exceeds the upper (Kasuya, 1973).

The straight length of a tooth is approximately 7 to 10 mm. The pointed crown is compressed anterio-posteriorly and the tip is curved mesially. The root is flattened lingual-buccally and the proximal tip is usually curved, through the growth, towards the posterior direction. The cementum forms a thick cingulum at the cervix of the tooth. In old individuals the root is covered by the cementum leaving small branching canals connecting the narrow pulp cavity and external surface of cementum. (Pl. IV, Fig. 1).

TABLE 2. TOOTH COUNT OF *PONTOPORIA BLAINVILLEI*

Position	Sample	Range	Mean	SD	SE
Male					
Up. left	33	51-60	54.6	2.25	0.39
Up. right	33	51-60	55.0	2.24	0.39
Lo. left	33	48-61	53.3	2.54	0.44
Lo. right	32	49-59	53.4	2.33	0.41
Female					
Up. left	39	50-60	55.4	2.62	0.42
Up. right	39	50-61	55.3	2.67	0.43
Lo. left	38	49-58	53.7	2.26	0.37
Lo. right	38	49-59	53.6	2.40	0.39

Growth layers

When a thin ground section is observed under transmitted light, the growth layers are seen as the alternation of optical density. The decalcification and staining of a thin ground section partially masked with wax indicates that the opaque layer in the cementum and dentine corresponds to the stainable layer (Pl. IV, Fig. 2). The minute layer in dentine is detected more clearly on decalcified and stained slides.

The fetal dentine has a thick, uniform, moderately stainable layer, and the neonatal line is an unstainable layer of about 5 μm width deposited on the inner wall of fetal dentine. Three kinds of layers and presumably cycles are found in the postnatal dentine. The first is the coarse layer and is the most conspicuous. As discussed later, we believe that this layer represents the annual cycle. One cycle of this layer is composed of a thin (about 10 to 20 μm in the first layer) conspicuous unstainable layer and a wide stainable layer. The unstainable layer is clearer near the cusp than at the root. The stainability in the stainable zone is not uniform, but consists of finer layers ranging from 10 to 17 in number with a mode at 12 or 13. This is the second kind of layer, which may correspond to the short cycle cemental layers in the teeth of the Baird's beaked whale, *Berardius bairdii,* suspected by Kasuya (1977) to represent a lunar cycle or an endogenous rhythm of about one month. Some of these fine layers deposited just prior to the unstainable layer of the annual cycle are always stained more strongly than the preceeding stainable dentine which forms the stainable layer of the annual cycle. In other words, the annual cycle of dentine deposition is formed by the enhancement of some of the shorter cycle layers. This cycle is inconspicuous in the third and successive annual layers. There are often observed several narrow layers (third layer) in some of the second kind of layers, but it is almost impossible to count them.

In the cementum, the alternation of narrow stainable layers and wide weakly stainable layers is the only way to read layers. From comparison with the dentinal layers, it appears that the stainable cementum corresponds to the strongly stainable dentine deposited just prior to the unstainable layer of the annual cycle. This cemental cycle is clearest usually on the cusp side of the cingulum.

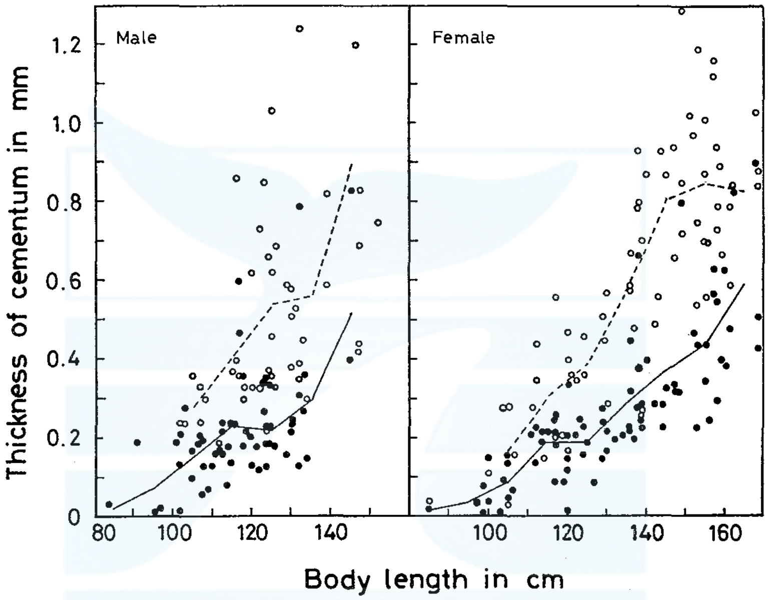

Fig. 2. Scatter plots of thickness of cementum at cingulum on body length. Open circle and dotted line indicate anterio-posterior thickness, and closed circle and solid line ligual-buccal thickness.

Thickness of cemental layers

Figure 2 shows the maximum thickness of cementum at the cingulum plotted against the body length. The cementum was present on all the individuals, which had at least some teeth erupted. There were three juveniles, one female (98.5 cm) and two males (84.5 and 96.0 cm), where 20 to 30 teeth on each jaw were left unerupted. The teeth of these individuals had cementum of 5 to 12 μm in thickness. Their postnatal dentine ranged from 65 to 110 μm in thickness, or 14 to 24% of the mean thickness of the first postnatal dentine shown in Table 3. These data indicate that tooth eruption and cemental deposition starts as early as one or two months after birth.

These is a great deal of individual variation in cementum thickness. This would, in some degree, have been caused by technical problem with preparation.

However, it is clear that the cementum is thicker on the anterio-posterior direction, and that there is no sexual dimorphism of the thickness if compared between individuals of the same body length.

The relationship between the thickness of cementum and age is shown in Fig. 3. The deposition is faster in the first 3 years, and then changes to a slower growth phase which seems to continue until at least 9 years of age. The difference between sexes is not significant.

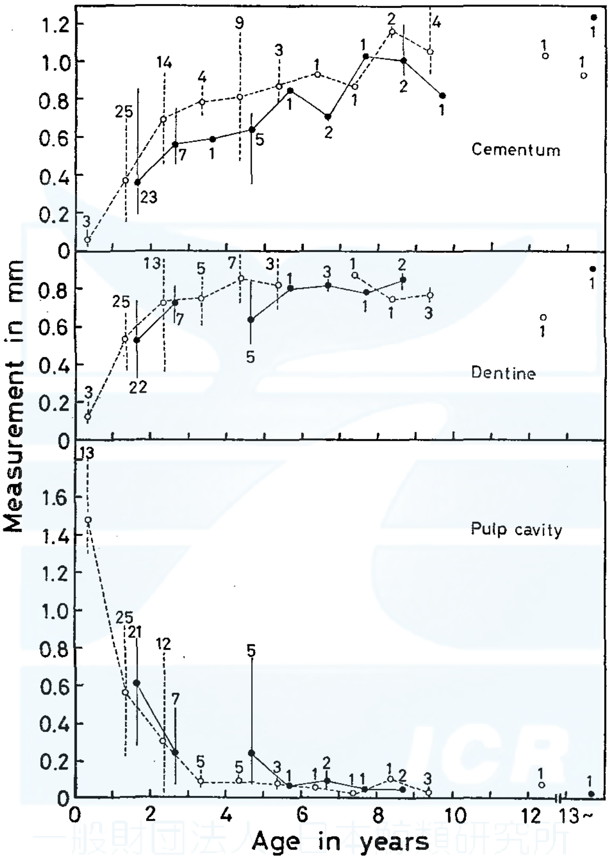

Fig. 3. Relationship between anterio-posterior dimensions of the tooth and age. Closed circle and solid line indicate mean value in males, open circle and dotted line that in females, vertical line observed range, and numerals the number of samples. For further explanations see text.

Thickness of dentinal layers

Figure 4 shows the relationship between body length and thickness of dentine measured at the level corresponding to the proximal end of the prenatal dentine. There was no sexual dimorphism in the thickness nor any difference related to the direction of the preparation. Although the dentine deposition is slow in juveniles under 100 cm in body length, there is a sudden increase in the thickness at lengths

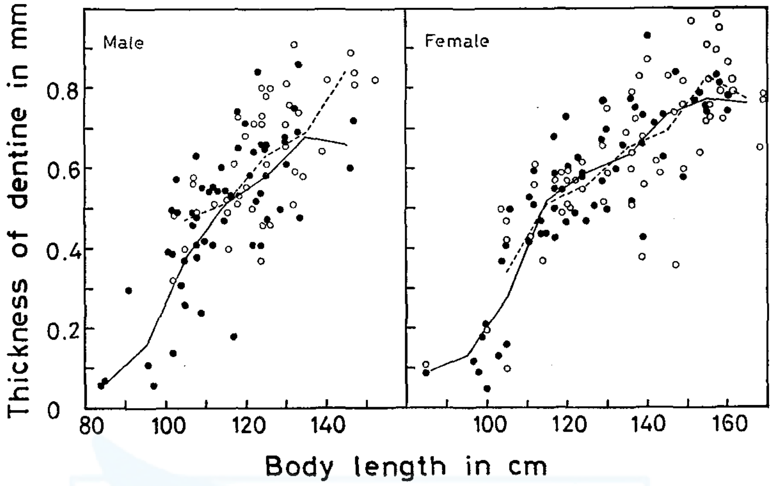

Fig. 4. Scatter plots of the thickness of dentine on body length. For key see Fig. 2.

TABLE 3. THICKNESS OF DENTINAL LAYERS OF *PONTOPORIA BLAINVILLEI* (in μm)

	Lingual-buccal			Anterio-posterior		
	No.	Mean	SD	No.	Mean	SD
Male						
1st	53	432	88.3	36	458	95.6
2nd	28	206	55.7	18	204	57.4
3rd	4	133	10.4	4	100	24.5
Female						
1st	56	462	81.3	55	469	88.8
2nd	27	214	66.4	34	202	71.8
3rd	4	95	32.4	14	102	40.6

of 100 cm in males and 105 cm in females, which is again followed by a slower increase. The body length of rapid dentine deposition coincides with an age of 0.5 to 1.0 years (Fig. 7). The increase of dentine thickness is almost negligible after the age of 4 years, and this is reflected by the change of the diameter of pulp cavity (Fig. 3). The diameter of the pulp cavity attains the minimum of 40 to 100 μm at about 4 years of age. This stage nearly coincides, as mentioned below, with the age when the number of cemental layers exceeds that of dentinal layers of the same individual. Furthermore, in these individuals, the pulp wall is covered by strongly stainable structureless thin dentine. We consider that this is an indication of the cessation of dentine deposition or of the deposition of such a thin dentine that the growth layers in it cannot be counted by the present method.

Accumulation rate of the layer

Figure 5 shows the relationship between the number of layers of dentine and cementum in the same individual. When there are less than four dentine layers, the difference between these two figures is usually less than a fraction of a layer. The number of dentine layers usually exceeds the number of cemental layers by a small fraction because of the difficulty of distinguishing a thin incomplete layer in the cementum. The two figures often disagree after the age of 4 layers in males or 5 layers in females. This suggests that the accumulation rate of the layers in the two tissues is the same up to an age of approximately 4 to 5 layers (=years). After this age, it appears that only the cemental layer retains the same deposition rate. It must be noted, however, that age determination by means of cemental layers is less accurate than by dentinal layers.

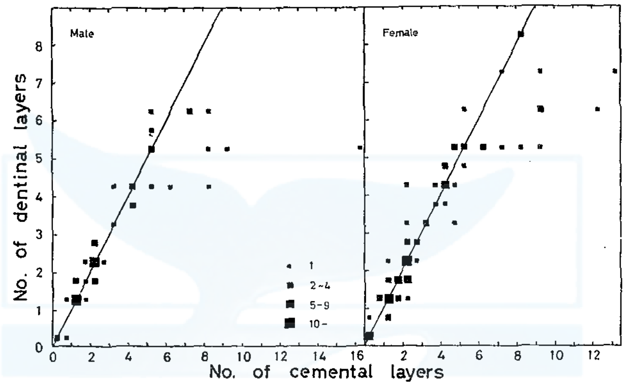

Fig. 5. Relationship between number of growth layers in dentine and that in cementum.

TABLE 4. NATURE OF THE LAST INCOMPLETE DENTINAL LAYER

Month	I	II	III	VI	VIII	IX	X	XI	XII
Unstainable									
Male	7	0	0	0	1	0	0	0	10
Female	10	1	0	0	1	0	2	2	2
Total, no.	17	1	0	0	2	0	2	2	12
„ , %	18.5	14.3	0.0	0.0	66.7	0.0	100.0	40.0	27.3
Stainable									
Male	40	0	1	1	0	0	0	0	13
Female	35	6	3	1	1	2	0	3	19
Total, no.	75	6	4	2	1	2	0	3	32
„ , %	81.5	85.7	100.0	100.0	33.3	100.0	0.0	60.0	71.1

The seasonal frequency of the condition of the last incomplete layer was studied only on the dentinal layers, because the observation is more difficult on cemental layers. Only individuals with less than three growth layers were used. These results are shown in Table 4. There is some difficulty in determining the nature of the last incomplete layer, because of the presence of finer structures in the dentine. This will increase the apparent individual variatiod in the seasonal formation of a certain kind of layer. A sufficient number of samples was available only in December and January, when most of individuals (70 to 80%) were forming the stainable type of dentine. The ratio seems to be higher in January through June, but decreases from August to November when only half of 12 individuals are forming the stainable dentine. These data, together with the fact that the thickness of unstainable layer is less than 5% of the total thickness of one dentinal layer, suggests that the period of the formation of unstainable dentine is rather short in each individual and that it occurs at various times between August and November.

Figure 6 shows the seasonal change of the fractional part of the dentinal layer count. This is estimated by eye at the time of age determination without referring to the biological data or the date of death. The graph indicates that the thickness of incomplete layer increases linearly from November to September of the next year, when the deposition of unstainable layer seems to occur in most of individuals, to complete one deposition cycle.

From the above analyses it is concluded that the coarse dentinal layer is deposited annually. The cemental layer deposition also follows the same cycle.

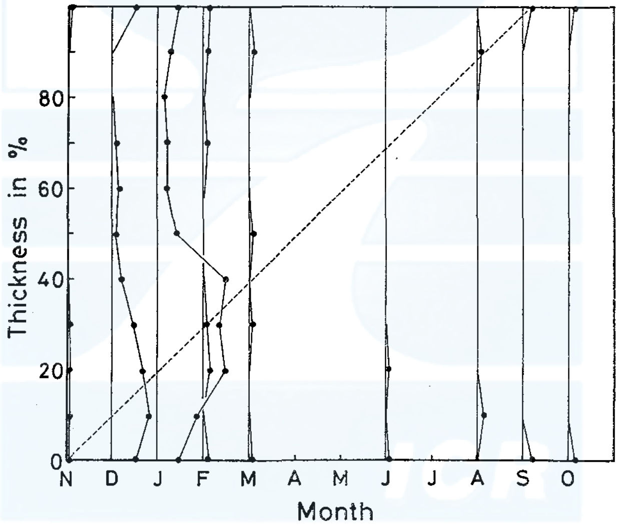

Fig. 6. Seasonal change of the thickness of the last incomplete layers in dentine. For explanations see text.

GROWTH

Length at birth

The largest fetuses encountered were a male and female 68 and 70 cm long, respectively. The three next largest fetuses were 66, 65, and 63 cm. The smallest neonatal animals were two males 84 and 84.5 cm long. The two next smallest dolphins were a male and female, both 85 cm in length. The next was a male 92 cm long. The age of the 84.5 cm neonate was estimated at 0.2 years. Therefore, we conclude that the body length at birth is greater than 70 cm and less than

85 cm, probably in the low 70 cm range.

Postnatal growth in body length

The calves which are born at a length between 70 and 75 cm attain a mean length of 96.2 cm (13 individuals, sexes combined) at the age of about 0.5 year. Although the sexual dimorphism in the body length might be present at the age below 1 year (Table 5), the observed difference is not significant ($p=0.2$). The growth is slower in males and the mean body lengths are significantly smaller than those of females after the age of 1 year ($p<0.001$). No secondary growth spurt is observed in either sex. The present materials indicate that the growth ceases at the age of 4 years (Fig. 7). The mean asymptotic length of 133.3 cm for males and 153.0 cm for females are estimated as the mean body length of individuals 4 years or older.

If the Gompertz equation (Zweifel and Perrin, in press) is fitted for three mean lengths below 3 years by forcing to have the asymptotic length of 133.3 cm, the least squares calculation gives following equation for males:

TABLE 5. AGE AND BODY LENGTH (cm) IN *PONTOPORIA BLAINVILLEI*

Age (yr.)	Mean age	No.	Range	Mean	S.D.
Male					
0≦, <1	0.3	5	84.0-102.0	92.7	8.04
1≦, <2	1.2	48	90.5-134.0	115.7	9.72
2≦, <3	2.2	21	110.0-152.0	128.8	10.59
3≦, <4	3.3	2	118.0-129.0	123.5	—
4≦, ≦16	6.2	21	122.0-147.0	133.3	8.58
Female					
0≦, <1	0.5	8	85.0-105.0	98.4	6.02
1≦, <2	1.3	54	100.0-143.0	122.6	10.64
2≦, <3	2.2	25	120.0-169.0	141.2	14.41
3≦, <4	3.2	6	145.0-160.0	152.2	5.46
4≦, ≦13	6.4	28	137.0-171.0	152.8	9.23

TABLE 6. AGE AND BODY WEIGHT (kg) IN *PONTOPORIA BLAINVILLEI*

Age (yr.)	Mean age	No.	Range	Mean	S.D.
Male					
0≦, <1	0.3	4	10.9-17.2	14.2	2.74
1≦, <2	1.2	21	11.8-24.5	18.6	4.35
2≦, <3	2.2	10	16.3-35.7	24.0	6.40
3≦, <4	3.0	1	17.2	17.2	
5≦, ≦16	8.5	4	19.9-32.2	28.2	5.66
Female[1]					
0≦, <1	0.3	3	11.8-14.9	13.1	1.59
1≦, <2	1.2	26	14.5-30.8	22.9	4.72
2≦, <3	2.3	9	17.7-34.9	26.3	6.76
3≦, <4	3.0	1	34.4	34.4	
4≦, ≦8	5.6	5	29.9-52.1	40.3	8.55

[1] No pregnant female included.

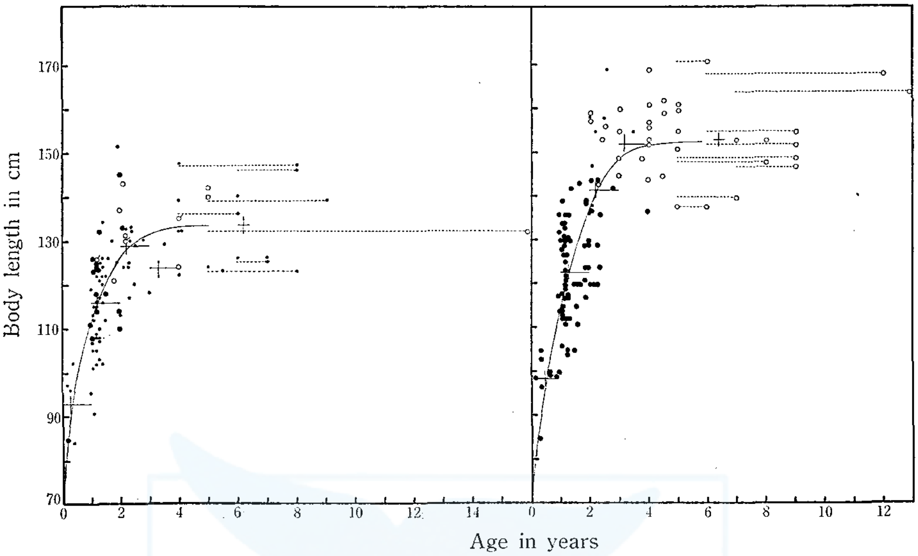

Fig. 7. Scatter plots of body length vs. age, males at the left and females at the right. Immature individuals are indicated by the larger closed circles, mature individuals by open circles, and those of unknown maturity by the smaller closed circles. Dotted line indicates an individual where number of cemental layers (circle at the right end) is used instead of dentinal layers (left end of dotted line). Growth curves are drawn by eye.

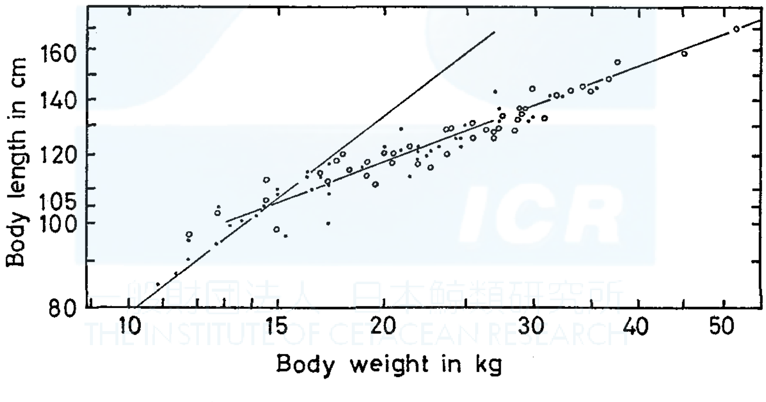

Fig. 8. Scatter plots of body weight vs. body length (the x and y axes are reversed in this graph). Closed circles indicate males and open circle females. For further explanations see text.

$$Y_t = 133.3 \exp(-0.5611 \exp(-1.2447t))$$

where Y_t indicates the body length (cm) at age t years. Although this equation fits well to the male data, the analogous equation for females does not fit the data. This may be due to the fact that the growth of females is more specialized, that is, females grow at a faster rate for a longer period.

Postnatal growth in body weight

The sexual dimorphism of body length suggests the presence of sexual dimorphism of body weight in all the age classes above 1 year of age. However, the observed difference of mean body weight is significant only in the age group from 1 to 2 years and that above 4 years ($p<0.05$). This is because of the large individual variation of body weight and small sample size.

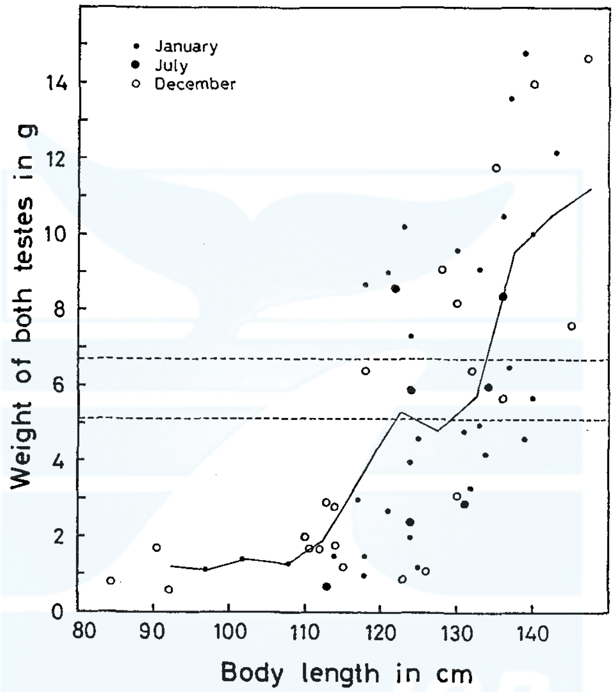

Fig. 9. Scatter plots of combined weight of both testes on body length. Horizontal lines indicate the mean weight at the attainment of puberty or of sexual maturity calculated in this study.

In Fig. 8, the body weights are plotted against the body length. No sexual dimorphism is observed in the relationship. This is reasonably expected from the fact that there is no observed secondary sexual dimorphism in the external proportions of the species (Kasuya, 1974). The correlation seems to change at a body length 105 cm. The relationship of the body weight to body length is expressed by the following equations calculated by least squares,

$$y = 3.459\times10^{-2}\cdot x^{1.2993}, \quad x\leqq105$$
$$y = 6.902\times10^{-5}\cdot x^{2.6347}, \quad x\geqq105$$

where y indicates body weight in kg and x indicates body length in cm. A body length of 105 cm corresponds, on the mean growth curve, to an age between 0.5 and 1.0 year, or probable weaning period as discussed below. If the growth of the body in the longitudinal and transverse directions is the same, the coefficient must be close to 3.0. However, it is much smaller in this species. This indicates that the body of the species becomes slender with the increase of body length and the tendency is more exaggerated during the suckling stage.

Weaning

The stomach contents of only four juveniles were studied. The smallest, male, 84.5 cm, 0.2 years of age, had milk in the stomach. Also present were numerous small unidentified discs of a diameter of about 0.3 mm. Although the origin of these substances is unknown, they may have been derived from some solid food. More than half of the teeth had erupted in this individual. Three other juveniles, 90.5 cm to 104.5 cm in body length and 0.3 to 1.1 years of age, had fish otoliths, squid beaks or shrimps in their stomachs. The presence of milk was not noted.

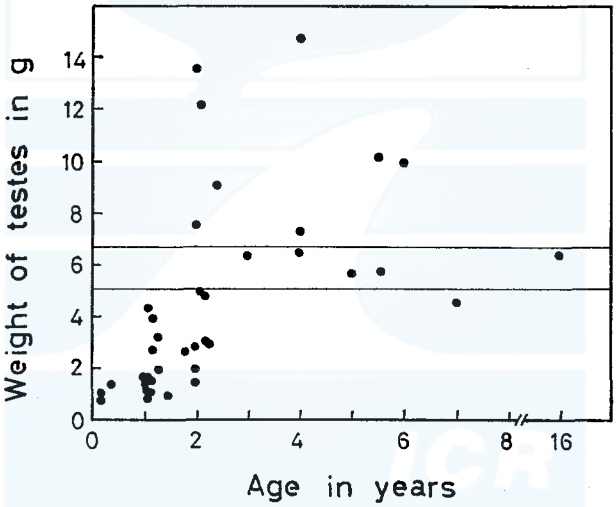

Fig. 10. Scatter plots of combined weight of both testes on age. For horizontal lines see Fig. 9.

These data suggest that the species starts to take solid food at about 3 months after birth. The length of the suckling was not determind. The rapid increase of the dentine thickness at a length of 100 to 105 cm, which corresponds to an age of 0.5 to 1.0 year, possibly coincide with the period when the diet changes from milk to solid food as suggested in *Stenella attenuata* by Kasuya, Miyazaki and Dawbin (1974).

Attainment of sexual maturity in male

Figure 9 shows the relationship between body length and combined weight of both testes. The weight is below 2 g in juveniles, but shows a rapid increase at a length of 120 to 130 cm, which will correspond with the approach of sexual maturity. The present data on the testes weight are limited mainly to the months of January, July and December. The seasonal change of the testes weight was examined between these three months. Since the mating peak of the species is estimated to be in December to February (Harrison *et al.*, Ms.) there is expected a difference of the weight between the winter and summer months. However, as shown in Fig. 9, there is no observed seasonal change in the present materials. This is probably because the sample contains so few adult animals. In case of *Stenella coeruleoalba*, the seasonal change of testes weight is observed clearly only in adults (Miyazaki, 1977).

Figure 10 shows the relationship between age and weight of testes based on 13 males in December, 25 in January and one in February. The increase of the weight is rapid between 2 and 2.5 years of age.

TABLE 7. SEXUAL MATURITY AND WEIGHT OF TESTES IN *PONTOPORIA BLAINVILLEI*

Weight[1] (g)	Immature		Puberty		Mature		Total no.
	no.	%	no.	%	no.	%	
0–2	9	100.0	0	0.0	0	0.0	9
2–4	7	87.5	1	12.5	0	0.0	8
4–6	4	50.0	0	0.0	4	50.0	8
6–8	1	16.7	2	33.3	3	50.0	6
8–10	0	0.0	2	28.6	5	71.4	7
10–12	0	0.0	0	0.0	0	—	0
12–14	0	0.0	0	0.0	2	100.0	2

[1] Lower limit included.

The determination of sexual maturity in males is less accurate than that in females. In the present study it was done based on the histological examination of testis. The epididymal development was used only for a reference. By examining all the available seminiferous tubules in a slide which is usually a cross section of the entire testis, an individual was classified as mature if all tubules contained spermatids or spermatocytes, as immature if no tubules contained them, and as pubertal if some of the tubules contained them. The spermatid and spermatocyte are always observed together and often accompanied by spermatozoa, but the presence of only spermatozoon was not observed. This criterion is similar to that used for *Phocoenoides* by Kasuya (1978), and is not based on direct data if the individual participate in the reproduction.

The development of the ductus epididymis seems to be completed before that of the testis. This is indicated by the facts that the pubertal testis is usually accompanied by an epididymis with a fully developed ductus, and some immature testis by an epididymis with a partially developed ductus.

The relationship between the combined weight of both testes and the maturity is shown in Table 7. The largest immature testes appeared at the weight of 7.6 g and the smallest mature at 4.6 g. Pubertal stage testes at a weighed between 3.1 and 8.7 g. The least squares regression gives 5.1 g as the weight where the frequency of " immature " individuals is 50%, and 6.7 g as that where half of the individuals are " mature ". The former value corresponds to the mean weight of the testes when males reach the pubertal stage (see Fig. 9). In the following analyses of the growth of the male, the identification of maturity is based on the result of the histological examination of the testis. Weight criteria were not used because they did not improve the accuracy of the analyses.

TABLE 8. AGE AND MATURITY IN *PONTOPORIA BLAINVILLEI*

Age (range)	Female					Male				
	Age (mean)	Im no.	Pu no.	M no.	M %	Age (mean)	Im no.	Pu no.	M no.	M %
1≦, <2	1.2	48	0	0	0.0	1.2	12	1	0	0.0
2≦, <3	2.2	10	3	5	27.8	2.1	4	1	3	37.5
3≦, <4	3.2	0	0	5	100.0	—	0	0	0	—
4≦, <5	4.1	1	0	10	90.9	4.0	0	1	1	50.0
5≦, <6	5.0	0	0	4	100.0	5.0	0	0	2	100.0

Im: Immature, Pu: Pubertal, M: Mature.

TABLE 9. BODY LENGTH AND MATURITY IN *PONTOPORIA BLAINVILLEI*

Body length (cm)	Female				Male			
	Im no.	Pu no.	M no.	M %	Im no.	Pu no.	M no.	M %
115–119	—	—	—	—	2	1	0	0.0
120–124	—	—	—	—	5	0	4	44.4
125–129	8	0	0	0.0	2	1	1	25.0
130–134	10	0	0	0.0	4	1	5	50.0
135–139	4	1	2	28.6	1	3	6	60.0
140–144	2	2	4	50.0	0	1	7	87.5
145–149	0	0	7	100.0	1	1	2	50.0

Im: Immature, Pu: Pubertal, M: Mature.

Table 8 shows the relationship between age and maturity. The age of the oldest immature male is 2.1 years, and that of the youngest adult male 2.0 years. The pubertals male appeared between the age of 1.2 and 4.0 years. These data, gether with the principal uncertainty of the definition of sexual maturity of the male, allow us to say with certainty only that the mean age of the male at the attainment of sexual maturity is between 2 and 4 years. However, the scatter plot of testes weight againt age shown in Fig. 10 strongly suggests that the males attain maturity at an age between 2 and 3 years as in the case of the females.

Table 9 shows the relationship between body length and the growth stage. If the unusually large immature male (RLB 835, 145 cm, 35.7 kg, and 2.0 years of age) is excluded, body lengths of the smallest mature male and of the largest immature are 121 cm and 137 cm, respectively. The pubertal males are found between 118 cm and 145 cm. The least squares regression fitted for the data in Table 9 gives 124.8 cm as the length where half of the individuals are immature. The corresponding figure calculated for the ratio of mature males is 131.4 cm. The former corresponds to the mean length at the onset of the pubertal stage defined in this study and the latter to that at the onset of the mature stage. Possibly the mean length at the start of actual adult stage lies between the two values.

If the large immature male (RLB 835) is excluded, the weight of the heaviest immature male is 24.5 kg and that of the lightest mature males 29.0 kg. One pubertal male weighed 24.9 kg (Table 10). Accordingly, the weight of male at the onset of sexual maturity is estimated to be between 25 and 29 kg.

TABLE 10. BODY WEIGHT AND MATURITY IN *PONTOPORIA BLAINVILLEI*

Body weight (kg)	Male			Female		
	Im	Pu	M	Im	Pu	M
21.0-23.9	3	0	0	5	0	0
24.0-26.9	2	1	0	6	0	0
27.0-29.9	0	0	2	6	1	1
30.0-32.9	0	0	2	1	1	0
33.0-35.9	1	0	0	0	1	2
36.0-38.9	0	0	0	0	0	2
39.0≦	0	0	0	0	0	2

Attainment of sexual maturity in female

The sexual maturity of the female was determined by the presence of at least one corpus luteum or albicans in the ovaries. Some immature females with developed Graafian follicles were considered as being at the pubertal stage. The youngest mature female appeared at the age of 2.0 years and the oldest immature at 4.0 years. The pubertal females ranged in an age between 2.1 and 2.8 years. The mean age at the attainment of sexual maturity is calculated from the ratio of adult females in each age group shown in Table 8. The least squares equation is expressed as follows:

$$y = 28.52x - 26.39, \quad 1 \leqq x \leqq 6$$

where x indicates the age in years and y the ratio of adult females in percentage. The age where half of the females are sexually mature, or the mean age at the attainment of sexual maturity, is 2.7 years.

The smallest mature and the largest immature female were 137 cm and 146 cm in length, respectively. The pubertal females were found between 136 cm and 144 cm in body length. The least squares regression of the data in Table 9 gives 140.3 cm as the body length where half of the females are sexually mature. This value is significantly smaller than the approximate length of 147 cm read on the mean growth curve corresponding to the mean age at the attainment of sexual maturity. This difference is caused by the cessation of growth in body length soon after the onset of sexual maturity.

The body weight of the largest non-pubertal immature female was 30.8 kg (1.2 years of age), and pubertal females were found in the range between 29.0 kg (2.4 years) and 33.1 kg (2.1 years). The smallest adult appeared at the body weight of 29.9 kg (4.0 years). All the females were sexually mature above the weight of 34 kg. Accordingly, it is expected that the female attains maturity at a body weight of 33 to 34 kg. The weight calculated for the mean body length at the age at sexual maturity of 2.7 years is about 35 kg, which is close to the above figure.

Attainment of physical maturity

The fusion of vertebral epiphyses to the centrum was examined on a limited number of individuals. The sexually immature individuals were, even if the epiphysis was not examined, reasonably considered in this study as physically immature.

In the present sample only one male was physically mature. It was 132 cm in body length and 16 years of age. The age of the oldest physically immature males was 5 years, represented by two sexually mature males. Their body lengths were 140 and 142 cm, respectively. Because of the scarcity of materials, it was impossible to determine the difference of the age at physical maturity of males and the corresponding value of females below.

The age of the oldest physically immature females was 4.0 years, and the age range of five physically mature females was from 4.0 to 8.0 years. This indicates that females attain physical maturity at the age of about 4 years or about 1 year after the attainment of sexual maturity. The mean length of the female at the attainment of physical maturity will be very close to the asymptotic length of 153.0 cm estimated in the former section. The largest physically immature female was 145 cm in body length, and the length of physically mature females ranged from 148 to 171 cm.

DISCUSSION

Scott (1949) found in cetaceans the following linear relationship between the maximum length of the adult, x in cm, and the neonatal length, y in cm:

$$y = 0.2441x + 44.3 \tag{1}$$

Later, Ohsumi (1966) obtained for several species of odontocetes the following allometric relationship between the mean length of female at the attainment of sexual maturity, x in m, and neonatal length, y in m:

$$y = 0.532x^{0.916} \tag{2}$$

If the asymptotic length of females 153.0 cm, and the mean length at the attainment of sexual maturity, 147 cm, estimated in this study for *P. blainvillei* are put in these equations, neonatal lengths of 81.6 cm and 72.6 cm are obtained from equations (1) and (2), respectively. The extraporation of the growth equation (page 55) gives a neonatal length of 76.1 cm. These, figures, especially the second, are close to the value estimaetd in the former section of this study.

The fetal growth rate and length of gestation can be deduced by the method of Kasuya (1977) or of Perrin *et al.* (1977). When x indicates the neonatal length in cm and y the fetal growth rate in cm/day at the linear part of the growth curve, the following equation was obtained from eight species of odontocetes (Kasuya, 1977).

$$y = 0.001802x + 0.1234$$

Accordingly, the length of time from the date when the extended straight fetal growth line cuts the axis of time to the mean date of birth is calculated by $x/(0.001802x+0.1234)$. If the neonatal lengths 81.6 cm and 72.6 cm are put in the equation, the duration is calculated as 291 and 275 days, respectively. The estimation of length of time from the start of gestation to the date when the extended linear growth line cuts the axis of time has some uncertainty. Hugget and Widdas (1951) estimated for the growth curve indicated by the cube root of the fetal weight that the length of time is 0.2 × (gestation time) for the gestation over 400 days. Laws (1959) indicated that the value will be 90% of the value estimated by Huggett and Widdas (1951), if the growth curve is based on the length. After repeated calculations beginning with a gestation of 350 days (for details see Perrin, Coe and Zweifel, 1976), the values obtained for species ***P. blainvillei*** were 0.130 (for linear growth period of 291 days) or 0.139 (275 days). These figures give a total gestation time of 334 days or 11.0 months (neonatal length of 81.6 cm) and 319 days or 10.5 months (neonatal length of 72.6 cm).

Perrin *et al.* (1977) found the following relationship between length of gestation in months (Y) and length at birth in cm (X).

$$\mathrm{Log}Y = 0.4586\,\mathrm{Log}X + 0.1659$$

This equation and the neonatal lengths of 81.6 cm and 72.6 cm calculated above give gestation lengths of 11.0 and 10.5 months respectively. Presumably the latter figure, 10.5 months, will be closer to the true value. These estimates show a good agreement with the range of 10.5 to 12 months obtained by Harrison *et al.* (Ms.). Further improvement of the estimate will depend on a better calculation of the neonatal length.

The age at the attainment of sexual maturity, 2.7 years, obtained for female *P. blainvillei* is the lowest in any cetacean which has been studied. This may be related to the small body size of the species. The only comparable species is *Phocoena phocoena*, which in the western North Atlantic attains sexual maturity at the age of 4 years (Gaskin and Blair, 1977). The same species in the North Sea is considered to attain maturity at 5 years in males and 6 years in females (Utrecht, 1978).

The age frequency of the present materials is shown in Fig. 11, where only the data of random collection are listed. A mode exists between 1 and 2 years. The frequency of the calves below 1 year of age is only 13 individuals, and the

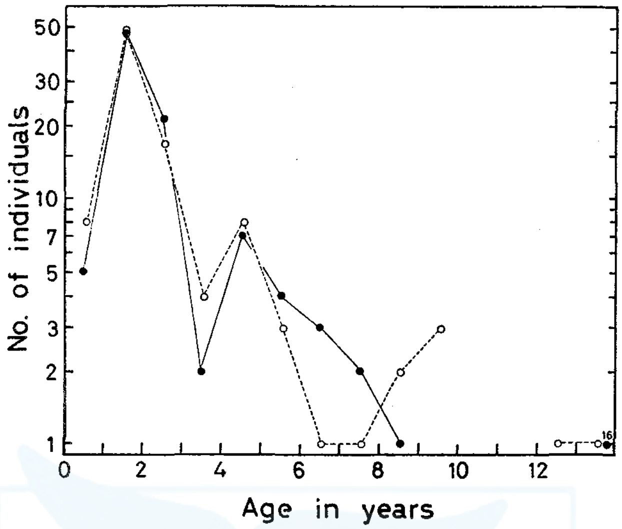

Fig. 11. Age frequency of *P. blainvillei*. Closed circle and solid line indicate males, and open circle and dotted line females. Only the random catch samples are included.

presence of bias in the sample is suggested. According to Harrison *et al.* (Ms.) the parturition peak of the species is in the second half of November to the second half of December (depending on the estimation of the mean neonatal length). Since most of the present materials were obtained in December and January, there should have been more newborn calves if the materials were not biased. The number of pregnant females, namely the number of calves which would have been born in the next year, is close to the number of calves below 1 year of age. This is again an indication of the under representation of pregnant females, and presumably that of other adult individuals of both sexes. This bias may cause an error in the estimation of the mean age at the attainment of sexual maturity, the mean growth curve after this age, and the maximum length of life-span. However, since the correlation between age and sexual maturity is very high in the present species, the bias in the estimation of the first two figures will be slight. Samples bias related to the method of fishing is known in *Stenella coeruleoalba* and *Phocoenoides dalli* (Kasuya, 1978).

Though catchability might be different between the sexes, the difference was negligible in the immature individuals. The ratio of females in the total of 148 individuals below 3 years of age is 50.0%. This is considered to be close to the real sex ratio at the immature stage.

Among 27 adult females dealt with here, the reproductive stage is known in 15 individuals. They are seven pregnant, two pregnant and simultaneously lactating, three lactating, and three resting females. The last category indicates adult females neither pregnant nor lactating. The lactating or resting females are limited to December and January, the parturition season of the species. The data from other months are one pregnant in August, two in October, and two in November. These data suggest that lactation usually lasts a short period, presumably not longer than eight or nine months. This figure is in good agreement with the length of nursing period estimated in the former section. Females which weaned a calf before August or September will become pregnant in the next mating season in January. Accordingly we suspect that a two years cycle of breeding will be most frequent in this species.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. Immature testis. RLB809, body length 111 cm, weight of testes 1.7 g, age 2.0 years. 19 Dec. 1972. Scale indicates 0.1 mm.

Fig. 2. Pubertal testis. RLB821, body length 130 cm, weight of testes 3.1 g, age 2.2 years. 24 Dec. 1972. Same magnification with Fig. 1.

Fig. 3. Mature testis. AO1972–4, body length 124 cm, weight of testes 5.8 g. 29 July 1972. Same magnification with Fig. 1.

Fig. 4. Mature epididymis. AO1972–4. Same magnification with Fig. 1.

PLATE II

Decalified and stained thin sections of teeth. Scale indicates 2 mm, all figures in same magnification. C, cementum. Open circle, neonatal line in dentine.

Fig. 1. RLB600, 0.2 dentinal layers, 84 cm male, 14 Jan. 1971. Immature.

Fig. 2. RLB861, 0.4 dentinal layers, 103 cm female, 4 Jan. 1973. Immature.

Fig. 3. RLB648, 1.5 dentinal layers and 1.8 cemental layers, 105 cm female, 27 Jan. 1971. Immature.

Fig. 4. RLB698, 2.5 dentinal layers and 2.3 cemental layers, 120 cm male, 18 March 1971.

PLATE III

Decalcified and stained thin sections of teeth. Scale indicates 2 mm, all the figures in same magnification. C, cementum. Open circle, neonatal line in dentine.

Fig. 1. AO1971–54, 4.0 dentinal layers and 4.5 cemental layers, 157 cm female, 24 Dec. 1971.

Fig. 2. AO1971–57, 6 dentinal layers and 8 cemental layers, 153 cm female, 30 Dec. 1971. Sexually mature.

Fig. 3. RLB592, 7 dentinal layers and 13 cemental layers, 144 cm female, 14 Jan. 1971. Sexually mature.

PLATE IV

Fig. 1. Decalcified and stained thin section of a tooth. RLB577, 6 dentinal layers and 7 cemental layers, 125 cm male, 5 Jan. 1971. Sexually mature. Scale indicates 2 mm. For other marks see Plate III.

Fig. 2. Decalcified and stained preparation of partially masked tooth. Left half, undecalcified thin section; right half decalcified and stained part. RLB878, 133 cm male, 16 Jan. 1972. Immature. Scale indicates 1 mm. Photographed under transmitted light. For marks see Fig. 1.

PLATE V

Comparison of annual layers in dentine and cementum Scale indicates 0.5 mm, all figures in same magnification. Bar, boundary of prenatal and postnatal dentine. C, cementum. Closed circle, annual growth layers.

Fig. 1. RLB600. Same tooth with Plate II, Fig. 1.

Fig. 2. RLB861. Same tooth with Plate II, Fig. 2.

Fig. 3. RLB648. Same tooth with Plate II, Fig. 3.

Fig. 4. RLB698. Same tooth with Plate II, Fig. 4.

PLATE VI

For explanations see Plate V.

Fig. 1. AO1971–54. Same tooth with Plate III, Fig. 1. Deposition of osteoden-

tine started.

Fig. 2. AO1971–57. Same tooth with Plate III, Fig. 2. Osteodentine nearly fills most of pulp cavity leaving narrow canals.

PLATE VII

For explanations see Plate V.

Fig. 1. RLB592. Same tooth with Plate III, Fig. 3. Deposition of osteodentine started on some part of pulp wall.

Fig. 2. RLB577. Same tooth with Plate VI, Fig. 1. Central part of pulp cavity is almost filled by osteodentine.

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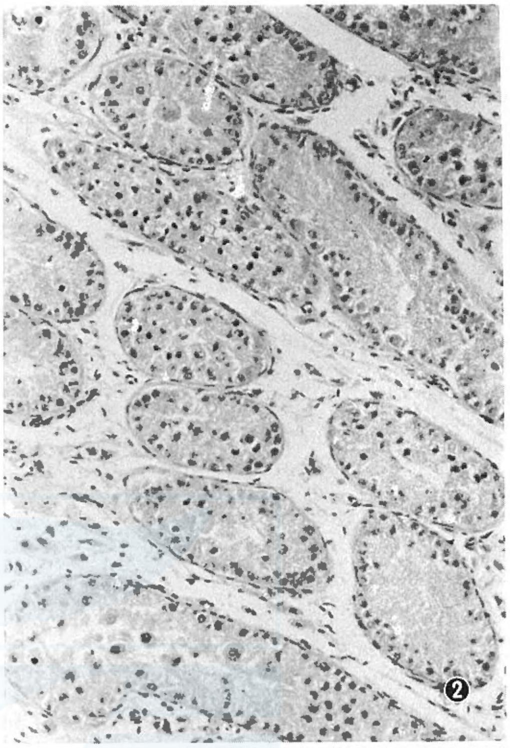
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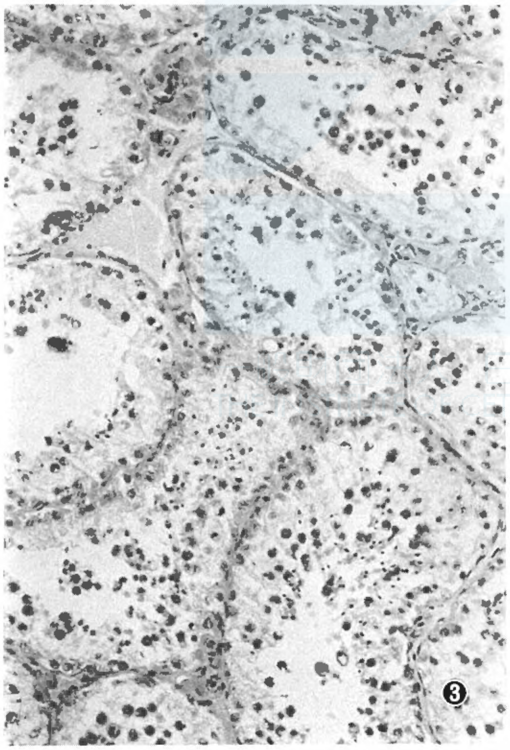
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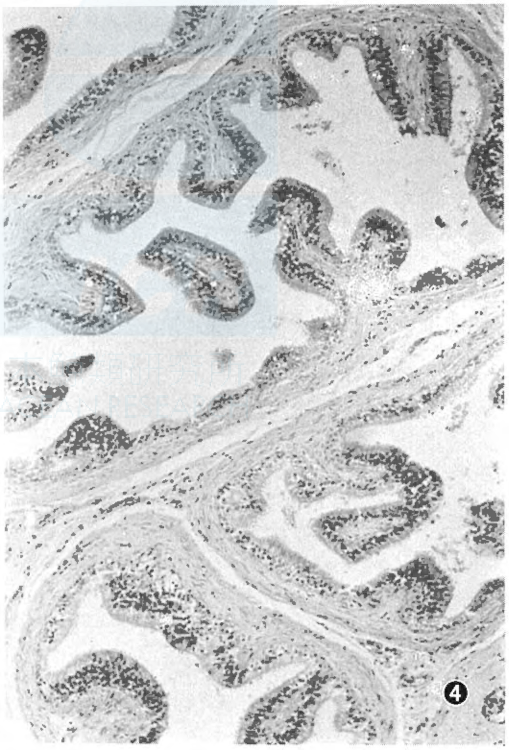
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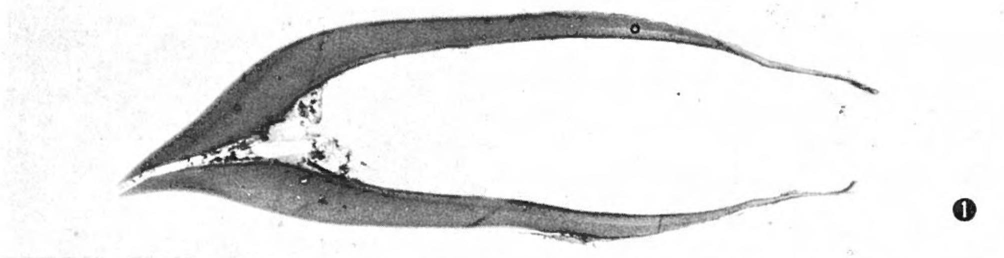

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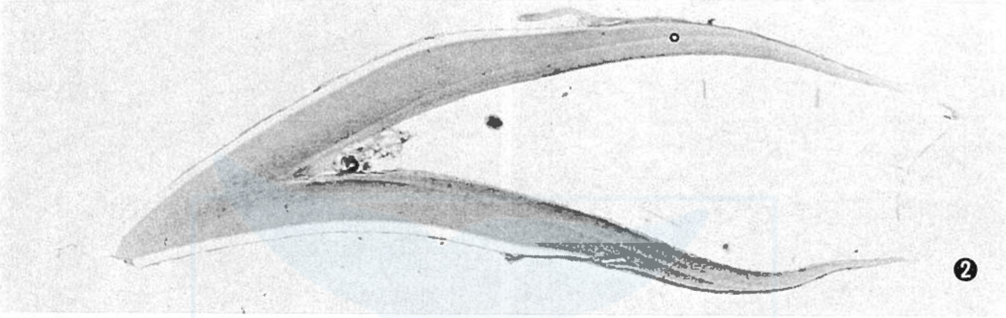

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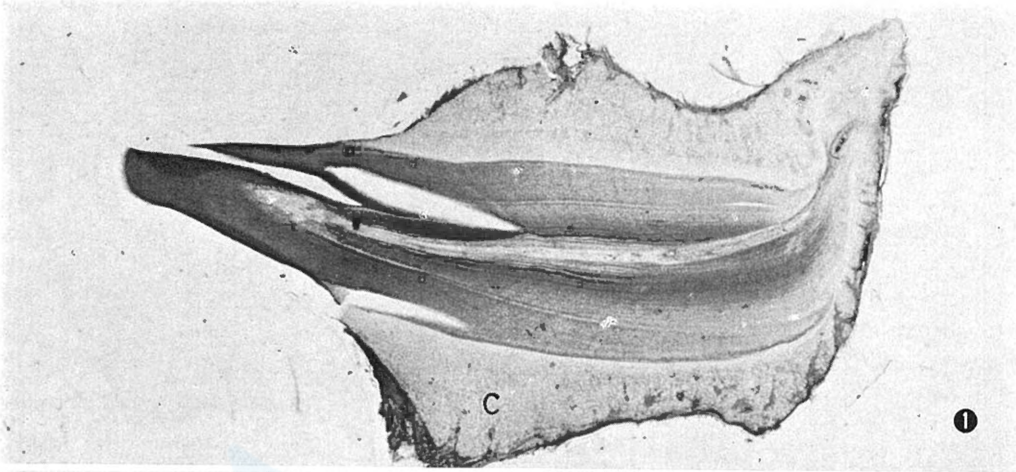

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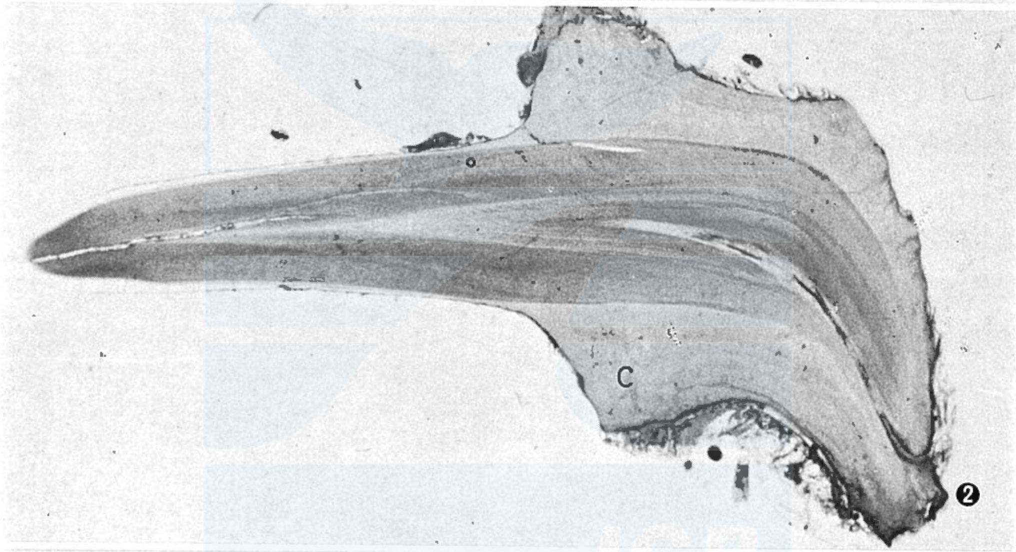

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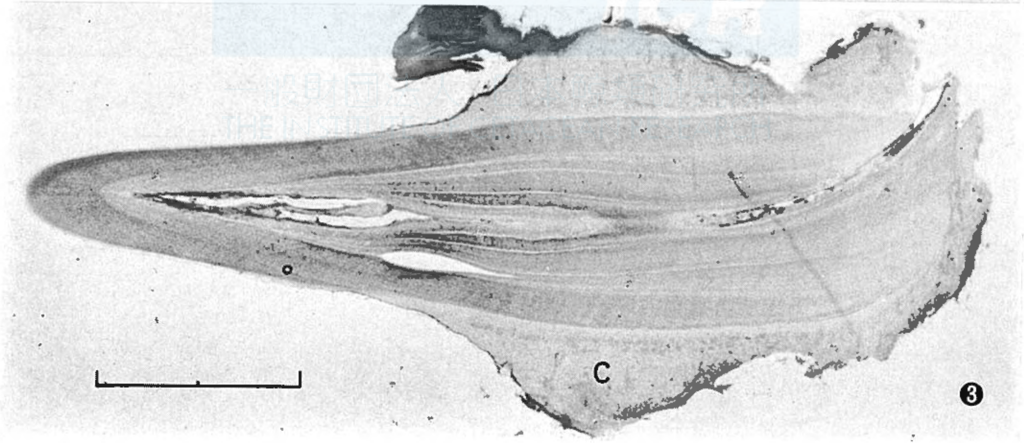

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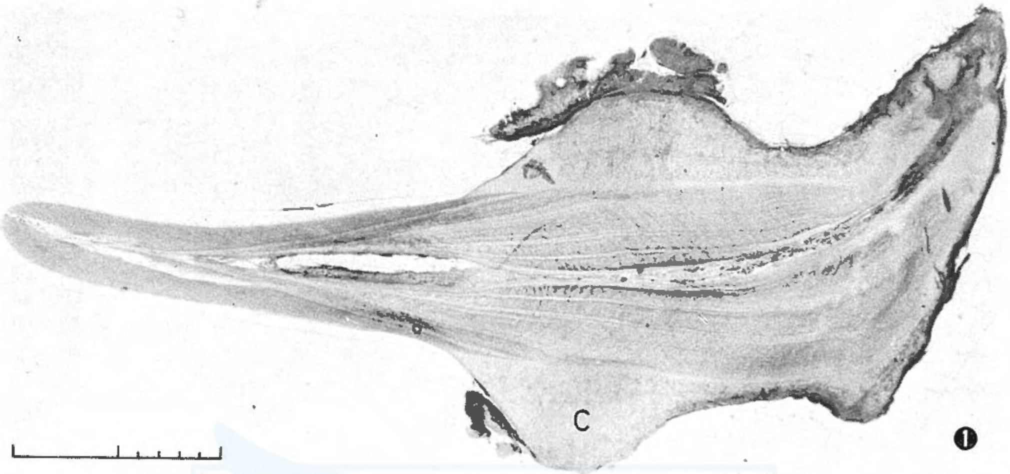

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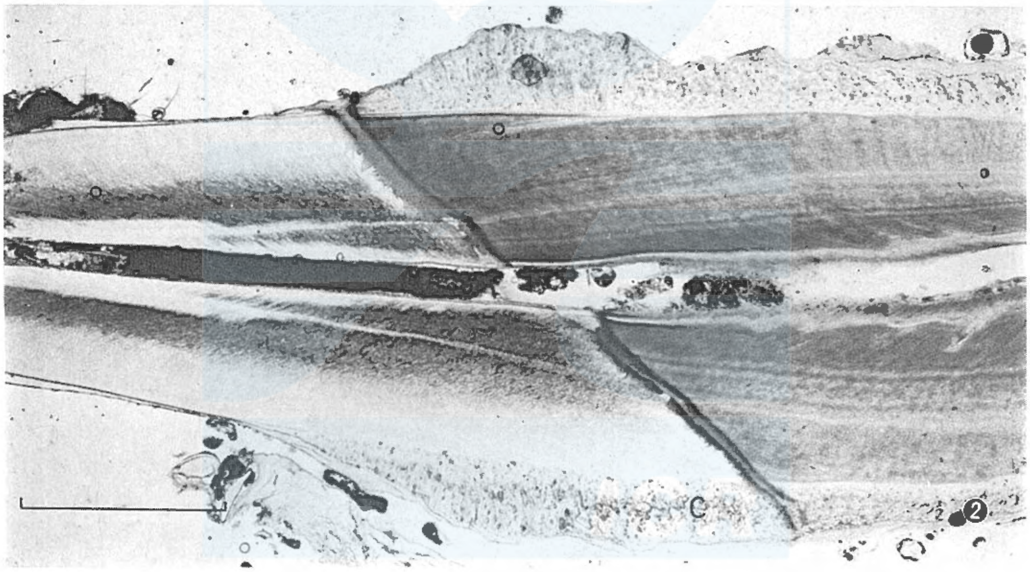

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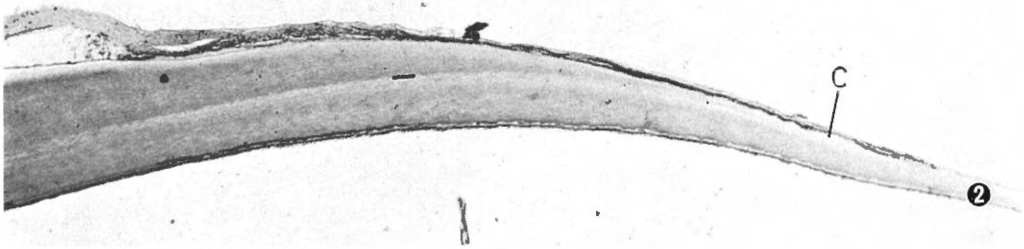

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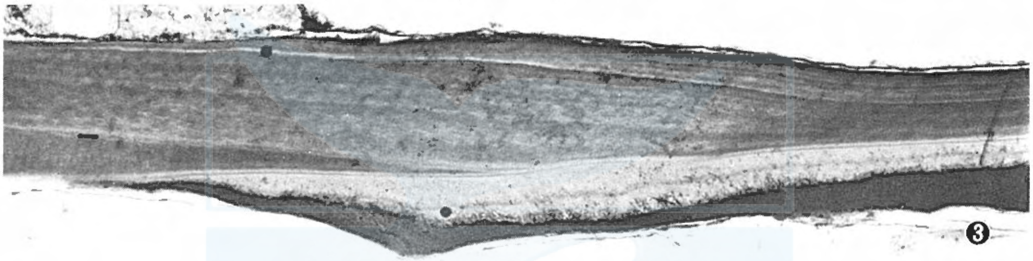

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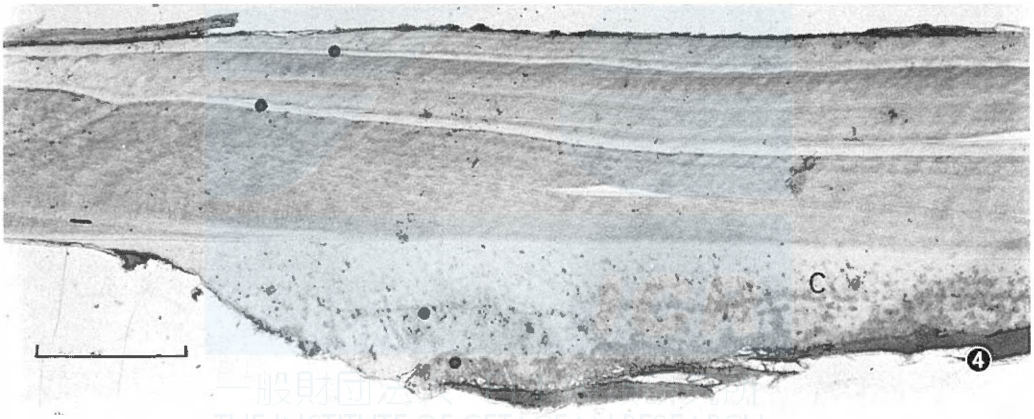

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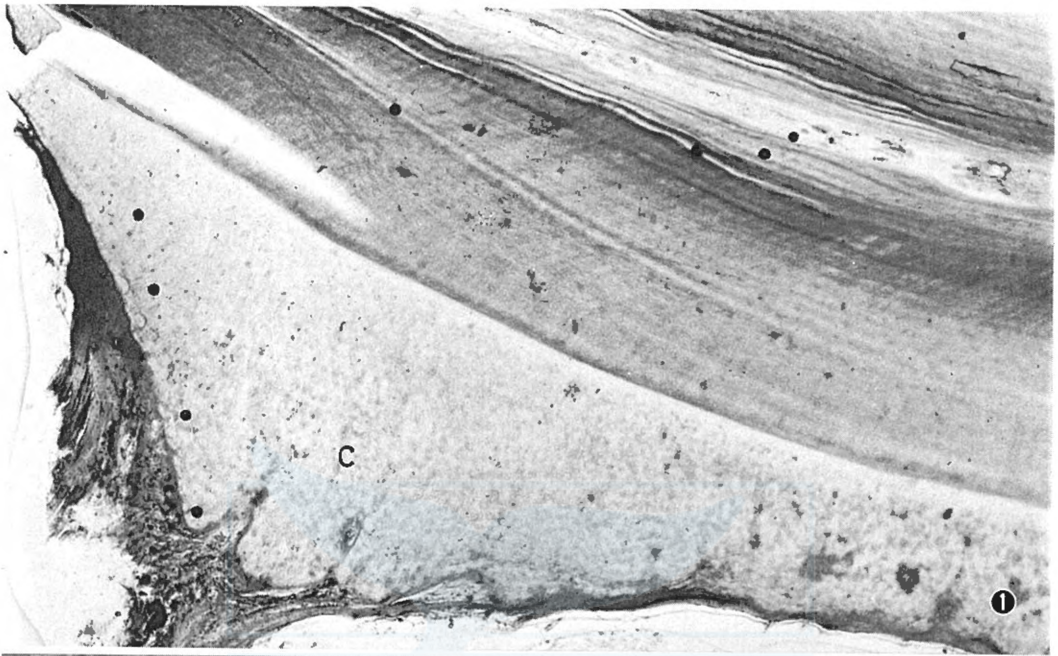
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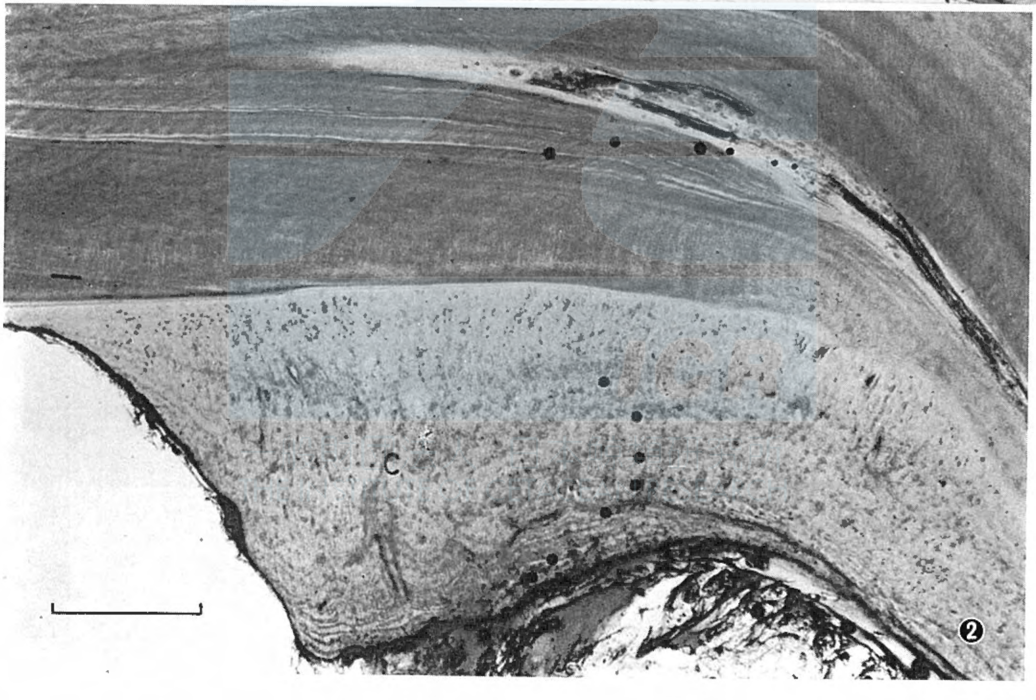
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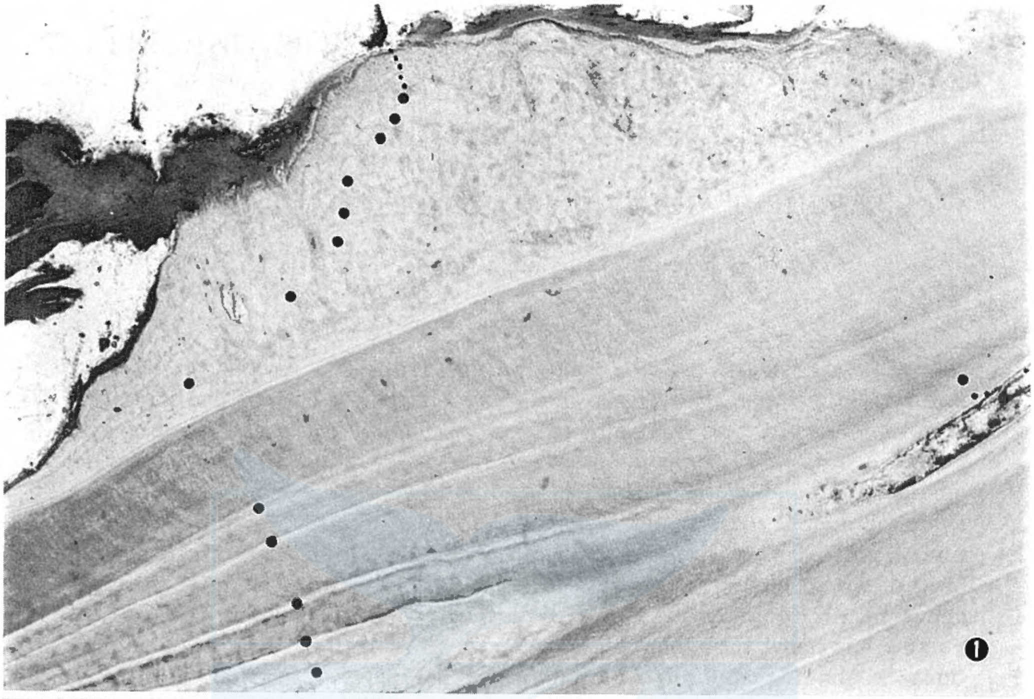
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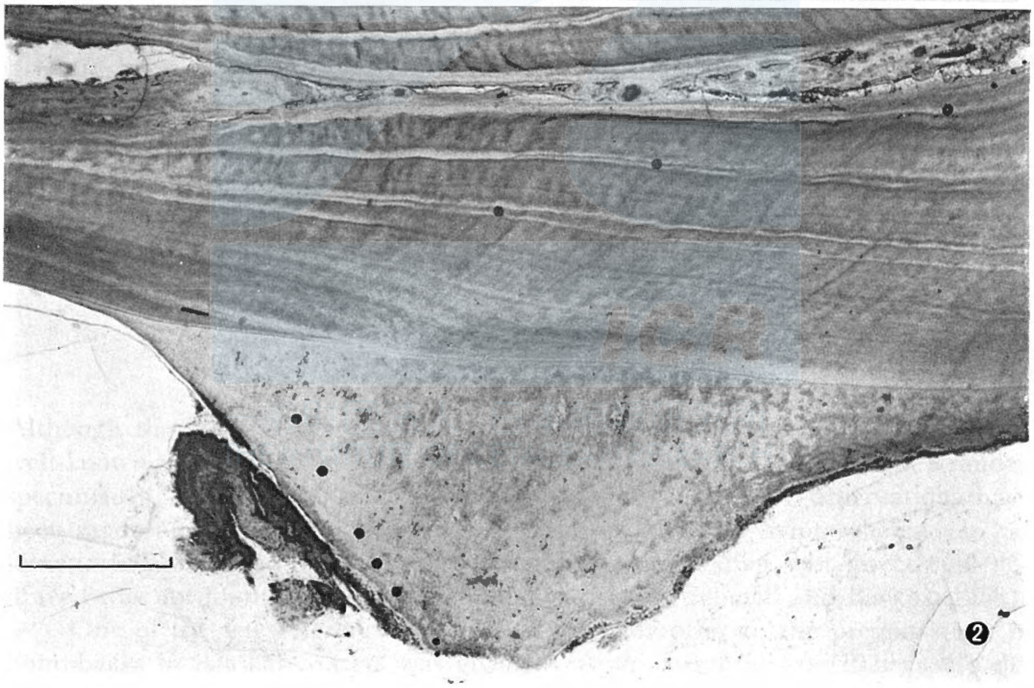
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FEEDING MODES OF THE HUMPBACK WHALE, *MEGAPTERA NOVAEANGLIAE*, IN SOUTHEAST ALASKA

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Sea Search, Ltd., Alaska.

ABSTRACT

Three methods of feeding by humpback whales (*Megaptera novaeangliae*) are described based upon twelve years and over 15,000 hours of observation in Southeast Alaska. " Lunge feeding " is a method used by a single whale or by a group in unison. The whales emerge abruptly through the water's surface, mouth open, as they engulf euphausiids (*Euphausia pacifica*), herring (*Clupea harengus*) or capelin (*Mallotus villosus*). Lunge feeding includes three basic variations: " lateral lunge feeding ", " vertical lunge feeding ", and " inverted lunge feeding "; the adjective refers to the angle of the sagittal plane of the whale to that of the water's surface. Sometimes during lunge feeding a sound described as " castanetting " is produced when the whale's mandibles repeatedly strike the rostral margins producing in air a sound analogous to that of a castanet. " Bubblenet feeding " involves a release of a discrete sequence of bubbles underwater that form a ring or closing spiral at the water's surface. Within the ring or " net ", the target feed is concentrated and contained as the whale emerges, mouth open within the ring. Sequences of sounds have been heard only when two whales fed co-operatively using a bubblenet to capture herring. In " flick feeding ", a whale lashes its tail forward at the water's surface, concentrating euphausiids, then rapidly dives forward into the feed, mouth open. It has been concluded that feeding methods used by humpback whales vary depending on the kind and quantity of feed available.

INTRODUCTION

Although the foods of the humpback whale (*Megaptera novaeangliae*) have become well-known through the examination of carcasses at whaling stations and stranded specimens (Mathews, 1937; Lillie, 1915; Nemoto, 1970), few observations have been made and recorded of the actual feeding behavior of living whales. It has sometimes been suspected that observed whales were feeding, but direct evidence of feed was not found (Perkins and Whitehead, 1977; Schevill and Backus, 1959).

One of the few references to feeding behavior prior to the present study of humpbacks in Alaskan waters was given by Andr. Ingebrigtsen (1929). He described two methods; one in which a humpback swam around in a circle lashing the sea into a foam with its flukes, then diving below the frightened krill only to appear a moment later in their midst with its mouth open. In the second method,

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the humpback whale appeared to dive a short distance below the water's surface and then released air while swimming in a circle. The rising bubbles rose to the surface like a thick wall of air bubbles, and these formed a net.

The present study began in 1966 with observations on feeding humpback whales near Juneau, Alaska and was expanded to adjacent areas of Southeast Alaska over the next twelve years (Fig. 1). We have found that Alaskan humpback whales have a varied diet and employ three basic feeding modes with several variations. Data documenting these feeding modes were gathered during more than 15,000 hours of observation.

DESCRIPTION OF THE STUDY AREA

Southeast Alaska, currently the summer home for approximately 60 humpback whales is characterized by an intricate system of protected bays and inlets with numerous small islands (Fig. 1). The areas under observation include Glacier Bay, Lynn Canal and Frederick Sound. Air temperatures in summer (June—September) average 14°C with a range from 5°C to 27°C; surface water temperatures range from 5°C to 14.4°C. Fresh water runoff from rivers, and melting snow and ice creates variable surface salinities, ranging from 1‰ to 25.9‰ in 1977 and 1978. During the summer daylight lasts for 18 to 20 hours.

Little hydrographic data are available, but the latest charts by the National Ocean Survey and the U.S. Coast Guard indicate depths to approximately 160 meters. Average tidal amplitude is 2 to 3 meters with a maximum of 8 meters.

METHODS

A 3-meter fiberglass skiff powered by a 20 hp outboard was used as an observation platform for the first five years, 1966–1971. Since 1971, the 15-meter *R/V Ginjur*, a wooden-hulled diesel-motored vessel equipped with silencers, has served as the research platform and laboratory for from four to ten observers. Observation distances are commonly 20-meters and sometimes as little as 4-meters. Observations often extend over the full 18 to 20 hours of daylight.

Visually, whales were sighted and approached. Most whales were identified individually by the color pattern of the underside of the flukes in addition to other body characteristics. The whales were tracked visually and their behavior recorded. A battery-operated stop watch was employed to time submergence intervals of whales and to insure that noted behavior is recorded in sequence. Feeding environs, behavior and temporal aspects of the sequences were recorded and photographed. These still photographs aided in the analysis of sequences of events during feeding activities.

The bubblenet has been recorded underwater for further analysis by Dr P. O. Thompson of the Naval Ocean Systems Center, Dr Roger Payne of the New York Zoological Institute and Dr Sylvia Earle of the California Academy of Science.

When whales were feeding, the target feed was photographed within the gape

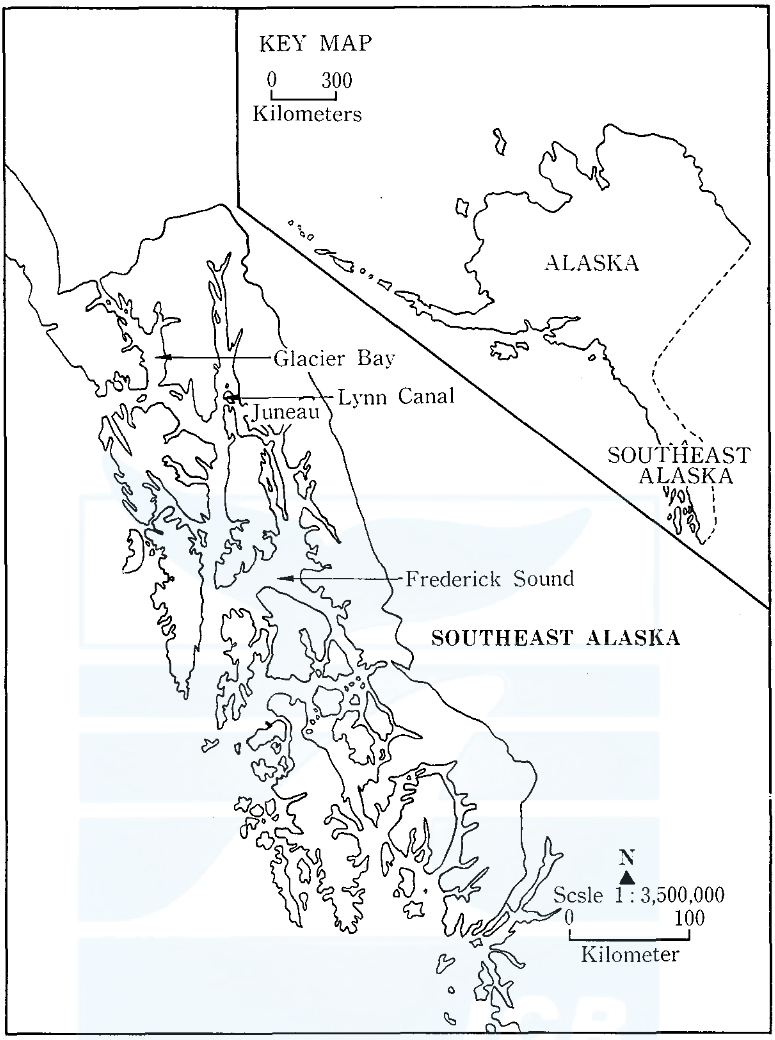

Fig. 1. Map of Study Area in Southeast Alaska.

of the whale's open mouth. Collections of food species were made with plankton tows and fish trawls to verify the species. Samples were submitted to National Marine Fisheries Service, Auke Bay, Alaska, and to the NMFS Laboratory at Tibinon, California for identification. Voucher specimens have been deposited at the California Academy of Science, San Francisco, California.

Feed in Southeast Alaskan waters appears for the most part to consist of euphausiids (*Euphausia pacifica*), herring (*Clupea harengus*), or capelin (*Mallotus villosus*).

DISCUSSION

The main structures involved in the feeding of the humpback whale according to

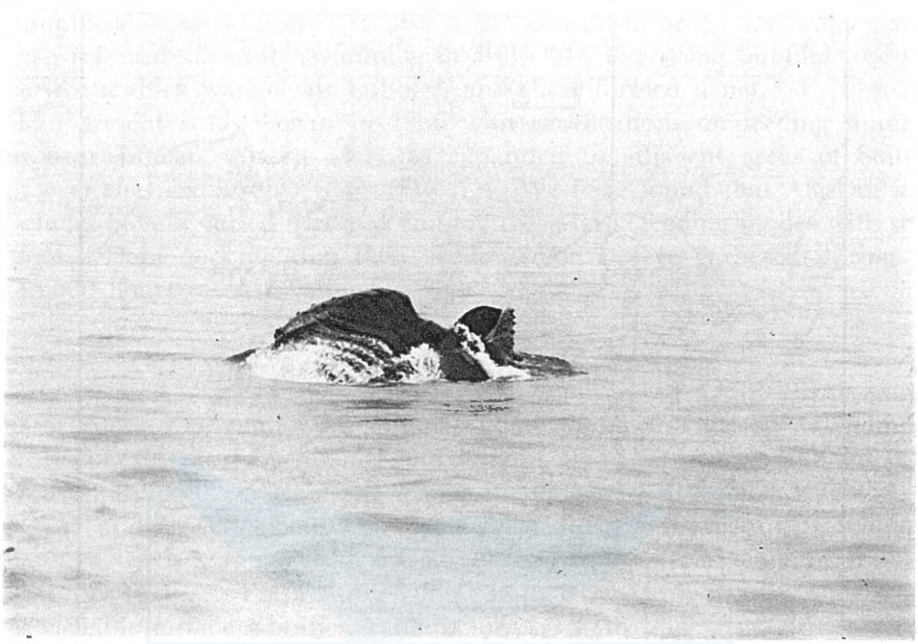

Fig. 2. The expanded throat of the feeding humpback whale.

Fig. 3. The closed mouth as the water is compressed out.

Nemoto (1970) are the baleen plates, the mouth opening, the tongue and the ventral grooves in the throat and abdomen. To feed the humpback whale takes water and feed in through its mouth causing the pleated throat to swell and expand (Fig. 2). The mouth is closed and water is compressed out of the mouth (Fig. 3). The retained feed is then swallowed. Humpback whales are in the " swallower " or " gulper " catagory rather than the " skimmer " catagory (Nemoto, 1970).

In addition, we have observed humpback whales occasionally using both flippers and flukes in feeding. The flipper is thrust toward the open mouth in a scooping fashion. The flukes are employed in one particular mode called, " flick feeding ", that will be discussed later in the text.

Humpback whales employ three different modes of feeding, depending on the species and the density of the feed. The modes are identified here as discrete activities that may vary in terms of body positions or angles of attack.

Lunge Feeding

One of the most commonly witnessed modes is designated as lunge feeding. This mode occurs when the feed is abundant. We have observed lunge feeding on euphausiids (*Euphausia pacifica*), herring (*Clupea harengus*), capelin (*Mallotus villosus*), and mixed schools of the latter two species.

In lunge feeding, the humpback swims vertically at approximately 5-knots through an aggregation of feed, opens its mouth in the upper 3-meters of water and engulfs the feed. The humpback's body is nearly vertical when its mouth is open to receive the food (Fig. 4). During this type of feeding, other species of feed may be incidentally ingested. There were many instances when walleye pollock (*Theragra chalcogramma*) were seen swimming leisurely at the surface feeding on krill. In some cases, the pollock were dispersed at the surface and in other cases they were schooled. When a whale is lunge feeding, it sometimes engulfs these pollock along with the krill. Since the mass of euphausiids seen within the mouth of the whale is far greater than the mass of pollock, the euphausiids appear to be the target feed.

When lunge feeding is employed by the humpback at a frequent rate, e.g., 12 lunges per hour, the results include an audible in-air characteristic occurring as a soft " clap ". The sound is produces by the rostral margin and the mandibular margins striking one another with the cupped effect of the partially filled aural cavity producing a resonance similar to that produced by a castanet, hence we have referred to it as " castanetting ". Castanetting is associated with those feeding procedures which, as in lunge feeding may have a significant amount of vertical motion, i.e., enough to bring the entire labial surfaces above water at the moment of rapid closure.

Other than vertical lunge feeding, there are two other variations in lunge feeding: lateral lunge feeding and inverted lunge feeding (Fig. 5). The adjectives refer to the angle of the sagittal plane of the whale to the plane of the water's surface. The position used appears to relate to the efficient use of body motion at the instant at which the feed is encountered and dense enough to engulf. The

Fig. 4 a. A vertical lunge. Herring can be seen flipping out of the mouth.

Fig. 4 b. A vertical lunge after the mouth is closed.

singular exception to this is the inverted lunge, in which case the taking of breath at the surface is postponed, increasing the length of time the whale spends recovering from one feeding lunge longer than other variations (Fig. 6).

The general direction and distance at which a single, lunge feeding whale will next surface has no apparent pattern. But as the number of whales involved in feeding increases, the direction and body positions become increasingly predictable. When two or more whales are lunge feeding together, the frequency of the lateral feeding lunge is significantly increased, although instances of one whale lunging in a vertical position and its partner ending in the lateral position were not uncommon (Fig. 7).

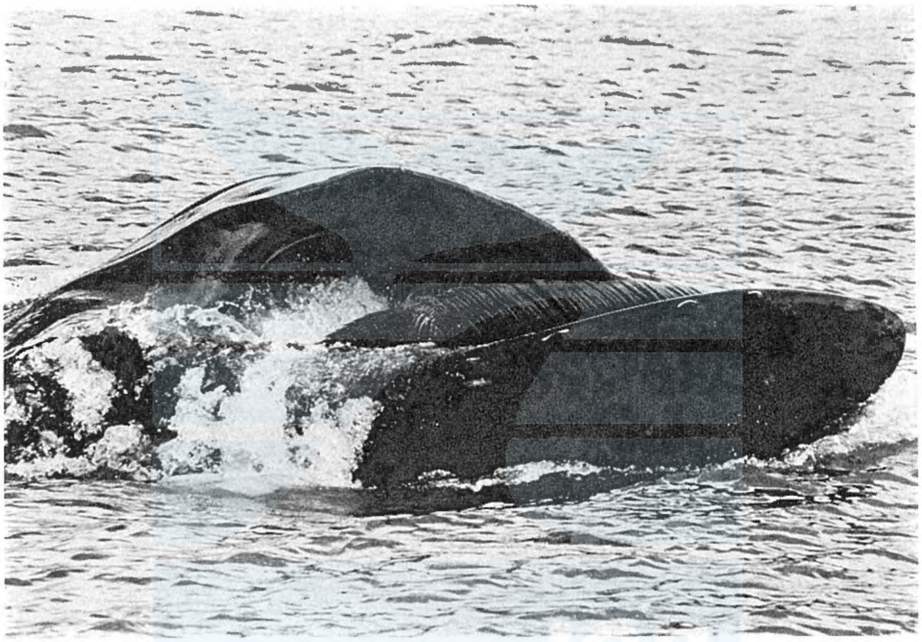

Fig. 5. A lateral lunge.

The least frequently seen configuration is that of the paired vertical lunge, a procedure that has involved up to four whales. These forms of lunge feeding in which two to four whales are involved clearly demand a cooperative routine and an implied communication. Escheloned lunge feeding is such a routine. Two or three whales coordinate their breathing in such a manner that the surface displays of breathing and lunging are synchronous. In this form of " cooperative feeding ", the lunging is reduced and the velocities of the emerging whales are slowed to 3 to 4 knots. They appear at the surface on their sides with their mouths open to nearly 90° so that the mandible of the first whale comes close to resting upon the rostrum of the one " below " it, and so on down for each of the remaining animals.

Although the velocity of the feeding lunge appears to be reduced when ac-

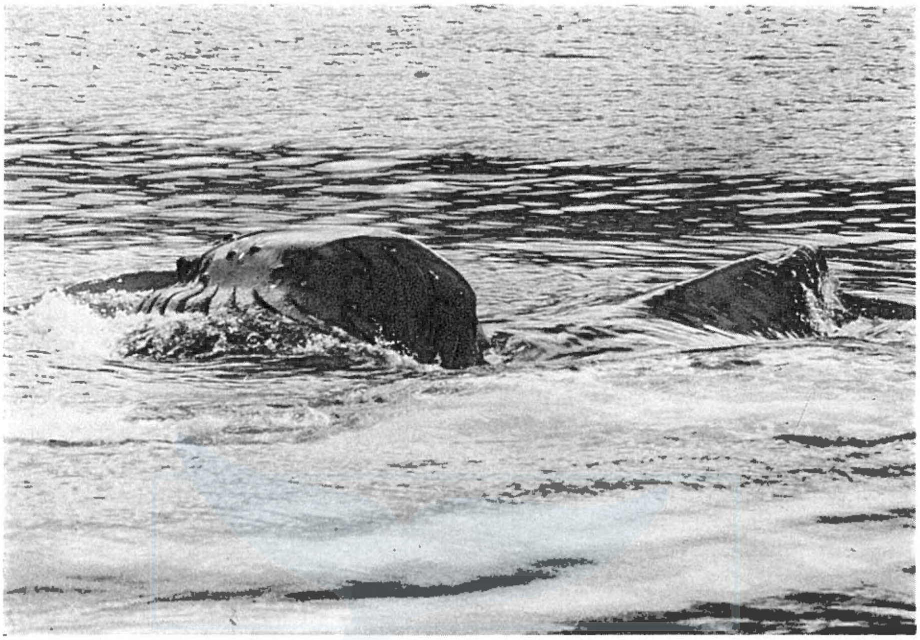

Fig. 6. A inverted lunge.

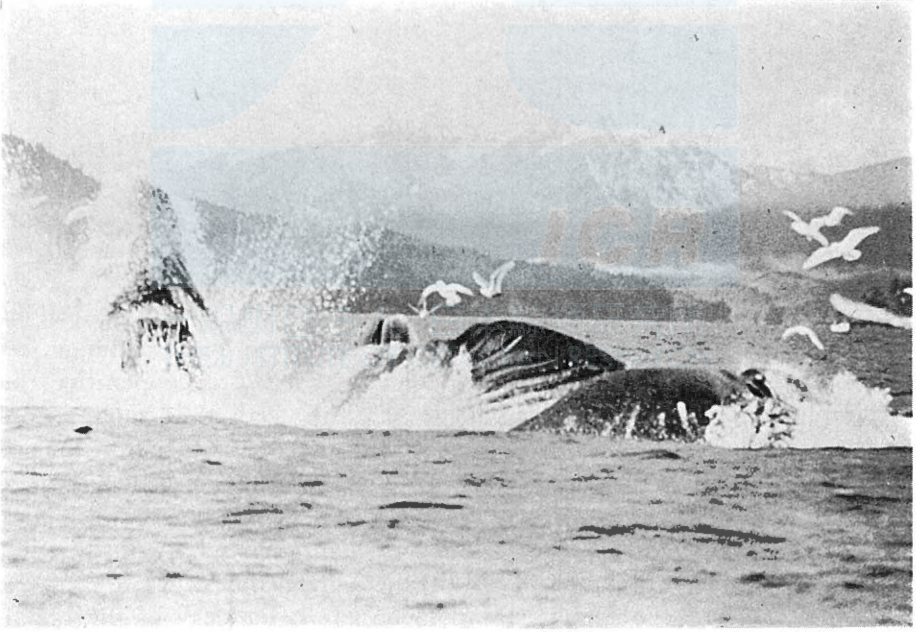

Fig. 7. A cooperative feeding lunge; Three whales are pictured. The gulls are feeding on the wounded herring left by the whales.

complished as a cooperative effort, another factor which has direct bearing on the whales' speed is the motility of the feed. The whale must swim faster to catch faster feed. Euphausiids are the slowest; herring are the fastest. The frequency of lunges is related not only to the species of feed, but also the abundance and distribution of feed. Hence with any given feed the frequency with which lunge feeding is applied to that species is consistent with the increased or decreased levels of availability of that feed.

During the seasonal transitions of feed caution must be exercised to scrutinize the feed involved in each case. In late September to October, although euphausiids are the most common feed taken at the surface, herring are occasionally present. Subtle differences in the feeding behavior were found to be an indicator of a change in conditions. Lunge feeding may have value as an indicator of local feed level rather than as an indicator of the seasonal population fluctuation of a single feed species.

On 20 April 1974, sixteen instances of lunge feeding were observed involving a single whale during one hour. The target feed was herring and the location, the western side of Douglas Island (seven miles from Juneau, 58°13′N 134°30′W) had until recent years supported both a healthy stock of herring and at least six whales during the summer months. In contrast, twenty-eight feeding lunges were observed during 10 minutes on 13 August 1976, in Glacier Bay with euphausiids as the target feed.

Bubblenet Feeding

A feeding procedure having a high degree of sequencial continuity has been called " bubblenet feeding " because of the strong physical resemblance to the deployment and effect of a seining net. The major differences lie in the whale's advantages of being able to blow a new net each time, to deploy the net from below rather than above, and to have its digestive apparatus at the base of the purse. In sequence, the whale apparently locates a body of feed, dives below the feed, and discharges a line of bubbles from its blowhole while swimming in a broad arc which has both vertical and horizontal components. The whale, outswimming the feed, deploys the bubbles while sweeping both ahead of the feed and towards the surface. The feed is blocked from below by the whale's body, laterally by the rising bubbles, and ultimately above by the surface. The feed is thus contained and since it is driven to the surface, it is condensed, by the same action. When the feed is herring, there is a frenzy of fish visibly boiling to the water's surface only within the confines of the blown net. The sequence of surface phenomena is as follows: The bubbles appear as discrete cantaloup-sized spheres rising to the water's surface (Fig. 8). This trail of bubbles forms a large ring or, in some cases, closing spiral that remains visible as smaller, later occurring pea-sized bubbles rise (Fig. 9). As the ring nears completion, the feed can be seen within the diameter of the thickening ring of bubbles. When the feed is herring, the fish flip about on the surface within the ring. If the feed is euphausiids, a blush or roughing of the water's surface occurs within the ring, as the feed leaps into the air. At the

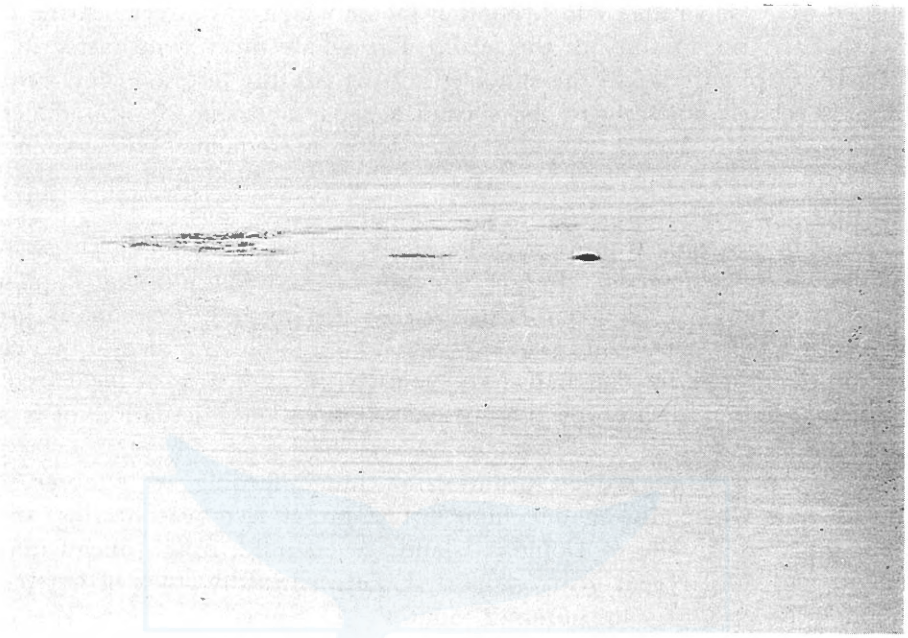

Fig. 8. The first bubbles of a bubblenet.

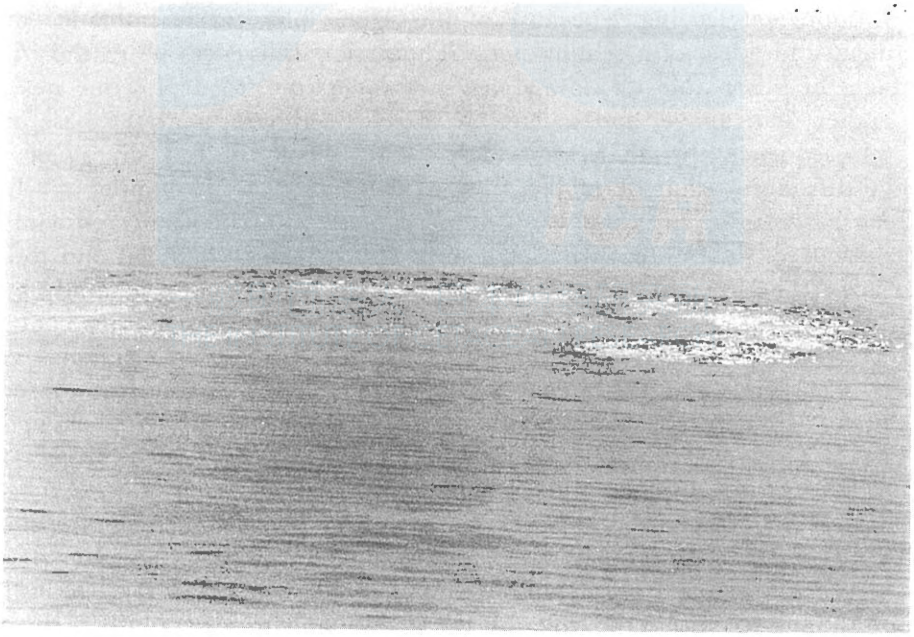

Fig. 9. The later pea-sized bubbles of a bubblenet.

air. At the point when the ring or spiral closes, the whale or whales appear. The whale engulfs the feed just below the water's surface causing a " flash of bubbles ", as the mouth closes underwater (Fig. 10), or it employs a lunge feed. The whale surfaces in a viel of breath far more atomized than usual because the blowhole issues its blast continuously from a submerged point to one which is at the water's surface or above.

Bubblenets have been blown in both clockwise and counter-clockwise directions. The first bubbles appearing at the surface are distinct and range in size from a volley ball to a tennis ball depending upon the feed. Observations have shown that the larger more motile the feed, the larger the initial bubbles in the ring. The bubbles which initially outline the ring are larger than the bubbles which follow after the feed is taken. A period of effervescence occurs directly after the feed is taken and leaves the water foamy in appearance. This is considered to be a phenomenon common to the release of any gas bubbles which in turn are torn as they expand upon rising, the largest appearing at the surface first.

Fig. 10. The flash of bubbles when the mouth is closed underwater.

Bates and Van DeWalder (1964) employed a similar technique to generate bubbles for directing fish by using a perforated pipe through which air was forced at a pressure of 38 to 48 lbs per sq. inch. A jet of approximately 2 cm high was formed underwater. The jet then changed into bubbles about 8 cm in diameter, each of which broke into smaller bubbles arriving at the surface with a diameter of 1 cm or less. Fish exposed to the bubble screen deflector under these conditions exhibited a definite response during daylight hours only. The bubblenet has only been seen and heard via underwater acoustic gear during daylight hours. In areas where whales were seen using the bubblenet during the day, recordings were made throughout the hours of darkness but no bubbling sounds were heard. No observations have been made of the humpback whale feeding after dark.

Bubblenets were observed on 13 July 1974, from 1205 thru 1725 hours ADT at the southern tip of Shelter Island, near Juneau, Alaska. Two adult humpback whales feeding in 16 to 40 meters of water, produced bubbles beneath the surface of the water. The pattern of the bubbles formed a counter-clockwise circle of approximately 30 meters in diameter and required 55 seconds from the time at which the first bubbles were seen on the surface to the last bubbles of the circle. As the circle of bubbles closed, herring appeared at the surface within the circle in a " boil ". The sound produced by the herring at the surface resembled heavy rain on the water. Within approximately three seconds, two humpbacks appeared at the surface on their sides, mouths agape, with their blow holes oriented towards the center of the circle. The angle of the humpback's jaw rostrum to mandible during the feeding procedure frequently reached 90° and the herring could be seen flipping in the water engulfed by the cavernous mouths. The end of the activity was marked by the humpback whales righting themselves, blowing and diving only to repeat the activity within the next five to seven minutes at a distance, usually less than 100 meters, from the previous net. The two whales blew 25 bubblenets in the five hours they were observed. The whales continued to blow bubblenets and feed through the tide change at 1437 hours ADT.

During this incident the two whales were heard " singing " as the bubblenet was blown. The song began with a discernable buzzing pattern. As the final bubbles approached the surface, the song changed to a staccato of higher pitched sounds and a pause of a second or two could be noted prior to the herring's appearance at the surface within the net. This feeding song has been heard several times but only association with more than one whale feeding and when the feed was herring. The song pattern appears to be uniform.

One of the first bubblenets seen in connection with euphausiids was on 21 August 1975, at 1300 hours ADT. A single whale was observed for forty five minutes during which time four bubblenets were seen. The whale was bubblenet feeding midchannel, 4.0 km northeast of Five Finger Light in Frederick Sound. Euphausiids could be seen as a blush or cloud in the water.

The bubblenet when used for euphausiids can be as small as $1\frac{1}{2}$ meters across and is of smaller diameter than that used for herring which is usually around 50 meters. From the first bubble to the sight of the whale within the net the time for euphausiids ranges from ten to forty seconds as opposed to 50 seconds to 1 minute 10 seconds for herring.

Flick Feeding

Flick feeding was first observed in Glacier Bay in 1977. In flick feeding, the humpback whale begans a normal dive raising its flukes well above the surface of the water. When the tail has submerged to the base of the flukes, the tail is flicked

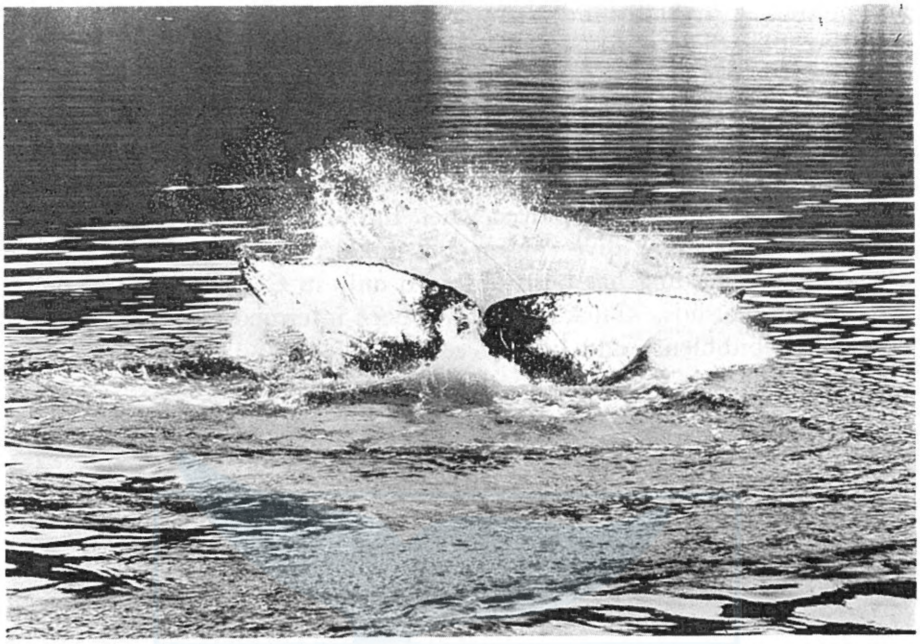

Fig. 11 a. Flick feeding, the tail flicked forward.

Fig. 11 b. The gulp of the mouth following the flick.

forward producing a splash and an internal wave. As the wave moves forward, the mouth of the whale appears at the surface admidst the wave (Fig. 11). The whole procedure occurs in approximately three seconds and follows this sequence: dive, flick, lunge.

Plankton tows have not yet been attempted during the procedure because of the short duration in the feeding mode, but it appears as if it could be a concentrating technique or it could be employed when the target feed is close to the surface and entails a very shallow dive causing the flukes to splash.

This mode of feeding has been observed only in Glacier Bay and only when the feed was euphausiids. Flick feeding has been intermixed with the other modes of feeding, i.e., bubblenet and lunge feeding.

CONCLUSION

Humpback whales employ a variety of feeding modes which appear to relate to the target feed and its density. All of the feeding modes have been observed intermixed and employed by one whale feeding in one location during one observation, e.g., on 28 July 1976, one humpback feeding on euphausiids employed; vertical lunge, lateral lunge, vertical lunge, bubblenet, vertical lunge, during the course of one hour. Similarily, on 2 August 1978, another humpback feeding on euphausiids employed; bubblenet, bubblenet, lateral lunge, vertical lunge, lateral lunge, vertical lunge, vertical lunge, bubblenet, bubblenet, vertical lunge, lateral lunge, flick feed within a twenty minute period. The total feeding time during this observation was two hours.

All of the feeding modes may be used by single humpback whales or by groups. Feed species and abundance varies with location and time of year. Feeding has been seen as early as April and as late as November. Heaviest feeding in Southeast Alaska appears to take place in July and August.

ACKNOWLEDGMENTS

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A SKULL OF BALEEN WHALE DREDGED FROM THE INLAND SEA OF JAPAN

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ABSTRACT

A half-broken skull was dredged by a fishing vessel in the Inland Sea of Japan in August 1978. This skull was studied from the taxonomic standpoint and was thought to be a skull of the Bryde's whale, *Balaenoptera edeni*.

INTRODUCTION

It was reported in a local press in Oita Prefecture dated 27 August 1978 a big bone of unknown animal was dredged by a small fishing vessel while the operation of bottom drag net for shrimps and other bottom fish. The bone was so heavy that the fishermen could not haul it on to the deck they ceased fishing operation and brought back the bone, hanging it outside the boat, to the fishing port of Kizuki City (Fig. 1).

The bone was eventually brought to Kizuki-shiritsu Minzoku Shiryokan (Kizuki Municipal Folklore Museum) for preservation and identification of the animal species. At first they consulted with Oita Marine Palace, a nearby aquarium and was told that the bone may be a skull of a whale and examination by specialist is needed. Then they took photographs of the bone from various angles and sent them to Dr Teruo Tobayama of the Kamogawa Sea World for identification of the species, who in turn passed them to the Whales Research Institute.

From the photograph we understood that the bone is half-broken skull of a baleen whale, but identification of the species is very difficult without close observation of the bone. And this is our great concern in the light of rather poor scientific knowledge of whales hitherto obtained from the Inland Sea, though there is a good reason to think that a number of whales came into the Inland Sea and out annually until about less than one hundred years ago (Shindo, 1975; Omura, 1974). Thus we made a trip to Kizuki City, Oita Prefecture, towards the beginning of October 1978.

OBSERVATION

The skull is completely lacking the maxillaries and premaxillaries. Possibly this

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is caused by loose articulation of bones in the facial region of the skull of the baleen whales, contrary to the toothed whales. Fortunately the vomer is remaining (Pl. I, Figs 1, 2 and 3). Its upper margin and anterior tip are broken to some extent, but presumably only a few centimeters, and thus protruding forward greatly and giving an impression of a flat rostrum in profile. Nasals are completely lacking (Pl. I, Fig. 1). On the inferior side of the vomer there still attached the palatines, to which pterygoids are also attached, but their posterior ends or hamular processes are broken (Pl. I, Fig. 2).

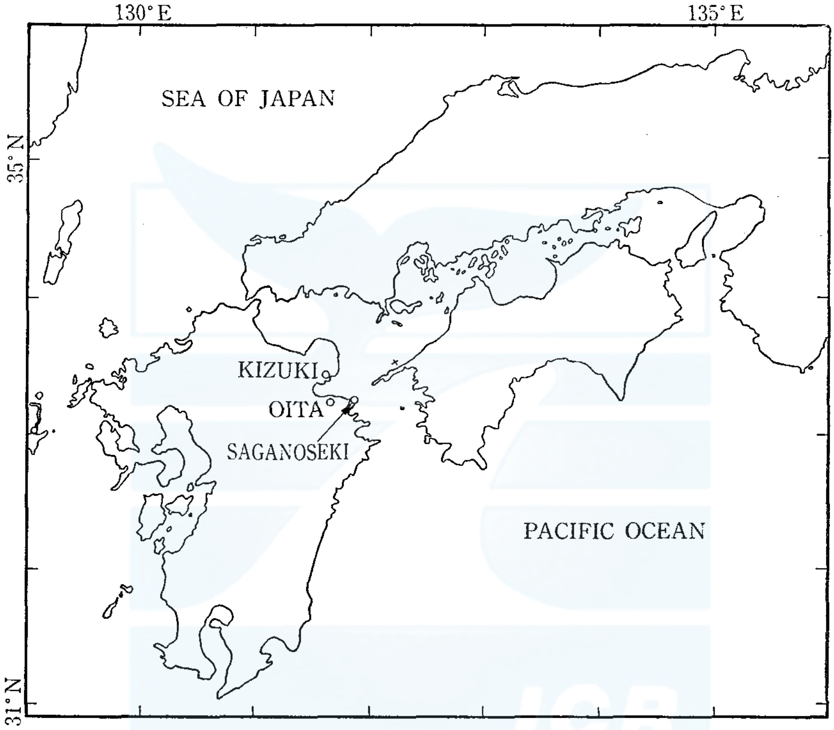

Fig. 1. Chart showing the position where the Kizuki specimen was dredged by a fishing vessel. Marked with a cross.

The brain case of the skull is rather in a good condition. The supraoccipital bone has a broken hole just above the occipital condyles, and its outer margins especially of superior regions are broken to some extent, but still it shows a characteristic feature of the balaenopterid whales, being roughly triangle in posterior view and the surface being relatively flat and having no deep concavity (Pl. I, Fig. 1 and Pl. II). Exo- and basi- occipitals are nearly complete. Temporals are in good condition, except extreme end of the right zygomatic process which is broken slightly. Orbital processes of the frontals are also in good condition, especially in posterior portion and orbits, but the anterior portions are broken. Parietals are also remaining on the lateral sides of the brain case and extend for-

TABLE 1. MEASUREMENTS OF SKULL, KIZUKI SPECIMEN

Measurements	Length in mm	% of breadth
Greatest breadth of skull at zygomatic process	1,287	100.0
Breadth of skull at orbital process of frontal, posterior	1,264	98.2
„ center	1,181	91.8
Breadth of skull at mastoid process of temporal	986	76.6
Length of orbit, right*	195	15.2
„ , left	210	16.3
Length of vomer, from broken tip*	2,125	165.1
Length of palatine, greatest, right	582	45.2
„ , left	583	45.3
„ , along median line	559	43.4
Length of skull from broken tip of vomer to occipital condyle*	2,560	198.9
Breadth of occipital condyle	259	20.1
Height of occipital condyle, right	160	12.4
„ , left	166	12.9
Breadth of foramen magnum	85	6.6
Height „	96	7.5
Height of supraoccipital bone from foramen magnum	623	48.4
Breadth of supraoccipital bone	871	67.7
Vertical height of skull from vertex to vomer	431	33.5
Horizontal length from vertex to occipital condyle	668	51.9

* Least value due to breakage.

TABLE 2. COMPARISON OF THE KIZUKI SPECIMEN TO BRYDE'S, SEI AND MINKE WHALES

Measurements	Kizuki specimen		Bryde's[1]		Sei[1]		Minke[2]	
	Length mm	%	Length mm	%	Length mm	%	Length mm	%
Sex and body length	?		♀45 ft (13.5m)		♀43 ft (12.9m)		♀9.8m	
Condylo-premaxillary length	?		3,480	215.5	3,060	229.4	2,350	187.1
Tip of premax. to anterior end of vomer	?		439	27.2	—	—	290	23.1
Greatest breadth of skull	1,287	100	1,615	100	1,335	100	1,256	100
Breadth of skull at orbit (center)	1,181	91.8	—	—	—	—	1,219	97.1
Breadth of occipital condyle	259	20.1	266	16.5	251	18.8	228	18.2
Height of occipital condyle	163	12.7	174	10.8	167	12.5	143	11.4
Breadth of foramen magnum	85	6.6	53	3.3	84	6.3	79	6.3
Height of foramen magnum	96	7.5	45	2.8	97	7.3	127	10.1
Height of supraoccipital bone from foramen magnum	623	48.4	835	51.7	768	57.5	650	51.8
Length of orbit	210	16.3	234	14.5	233	17.5	207	16.5

[1] Cited from Omura, 1959. [2] Cited from Omura, 1975.

ward beyond the line of the vertex.

We made some measurements of the skull. The greatest breadth of the skull at zygomatic processes of the squamosals, and other measurements concerning breadth of the skull are fairly accurate. Results of the measurements are shown in Table 1 and these measurements are compared with corresponding measurements of the Bryde's, sei and minke whales in Table 2.

DISCUSSION

In profile the skull of the Kizuki specimen is very flat (Pl. I, Fig. 3). Although it lacks maxillaries and premaxillaries the vomer is remaining in almost all its length, and we can safely assume that the ventral border of the vomer represents that of the rostrum itself. From this fact and combined with other evidence we can deny the possibility of the specimen of being Balaenidae as well as Eschrichtiidae. In Balaenidae the rostrum is curved downwards greatly and roughly Tee shaped in dorsal aspect of the skull, but the Kizuki specimen shows no resemblance of these character. In Eschrichtiidae the rostrum is curved downwards in less extent than Balaenidae but more curved than in Balaenopteridae. Further in Eschrichtiidae the supraoccipital bone presents three deep concavities, and on the superior portion two prominent and peculiar rugosities, and also present similar rugosities upon the basisphenoid and basioccipital bones (Andrews, 1914), but the Kizuki specimen has neither such clear concavity nor rugosity. Thus it is clear that the Kizuki specimen belongs to a species of the family Balaenopteridae.

Among the family Balaenopteridae there are two genera of *Megaptera* (one species) and *Balaenoptera* (five species). We can erase the posibility of the humpback whale, *Megaptera novaeangliae*, because of its slender shape of the Kizuki specimen. The skull of the humpback whale is robust and it has maximum relative zygomatic width in the family Balaenopteridae, or 57–66.9% of the condylo-premaxillary length (Tomilin, 1967). In the Kizuki specimen the ratio is less than $1,287/2,560\times 100=50.3$ (see Table 1). The skull length of 2.56 m is the length from the broken tip of the vomer to the occipital condyles. Probably we can add to this figure some 30–40 cm as the length from the tip of premaxillary to the broken end of the vomer (see Table 2), which makes condylo-premaxillary length to be 2.90–3.00 m, resulting the ratio as small as 43–44%. From this fact alone the possibility of the humpback whale will be erased.

We can safely conclude, therefore, that the Kizuki specimen belongs to a species of the genus *Balaenoptera*, and there remains five species to be considered. First of all we can exclude the possibility of the minke whale, *B. acutorostrata*, because of the size of the skull. The condylo-premaxillary length of the minke whale usually does not exceed 2 m (Tomilin, 1967) and the largest skull ever recorded, 2.35 m in length, was obtained from a 9.8 m female in the Antarctic (Omura, 1975). The minimum estimate of the skull length of the Kizuki specimen is 2.56 m (Table 1), but the actual condylo-premaxillary length would have been 2.90–3.00 m as already stated.

The inferior aspect of the skull of the Kizuki specimen denotes two special features important for the identification of the species (Pl. I, Fig. 2). One is the shape of the palatines. In the Kizuki specimen the mesial border of anterior part of the palatines situate near the inferior edge of the vomer and in parallel with the skull axis, but in the posterior portion they diverge outwards and the inner edges do not articulate to the inferior edge of the vomer. In the Kizuki specimen the right palatine was broken at its posterior portion along the edge, but in the left palatine the posterior edge is nearly complete, except a semi-round broken hole just anterior to the curved posterior edge. Such a shape of the palatine is usual in all the *Balaenoptera* species except the blue whale, *B. musculus.* The skull of the blue whale differs from those of other *Balaenoptera* in the shape of palatines which terminate abruptly, without forming left and right processes. Such form of the palatines is observed also in the pygmy blue whale, *B. musculus brevicauda* (Omura *et al.*, 1970). In this feature this species is similar to the humpback whale (Tomilin, 1967). From the above it is clear that the Kizuki specimen is not a blue whale.

Another feature of importance is the shape of the vomer at its posterior end. Tomilin (1967) shows that the posterior end of the vomer is greatly expanded in the adult fin whale, *B. physalus*, differing from the sei whale (Fig. 26 of his book). Since no such expansion is observed in the Kizuki specimen it is also possible that this specimen should not be assigned to the fin whale.

Among five species of the genus *Balaenoptera* we have already excluded three species, i.e. the minke, the blue and the fin whales. The remaining two species or the sei whale, *B. borealis*, and the Bryde's whale, *B. edeni*, are very close relatives and it is very difficult to separate the two only from the skull. One feature of the skull of the Bryde's whale is the flat rostrum, compared with somewhat downward bending rostrum of the sei whale (Junge, 1950; Omura, 1959). The shape of rostrum in the Kizuki specimen, presumed from the vomer left on the skull, resembles the Bryde's whale rather than the sei whale (Pl. I, Fig. 3). Another character separating the two species is the state of the front margin of the nasals. The anterior margin is concave in the Bryde's whale, but straight in the sei whale. In the Kizuki specimen, however, nasals are completely lacking and this character is of no use in this case (Pl. I, Fig. 1).

Miller (1924) considers the unusually deep and narrow sulcus formed at the region of juncture between the squamous and articular portion of the squamosal in his Pablo Beach specimen of the pollack whale (No. 236680, US. National Museum) as a specific character of this species or *B. borealis.* According to Junge (1950) this sulcus is narrower and deeper in most specimens of *B. borealis* than it is in *B. physalus* and *B. edeni.* In the Bryde's whale on the coast of Japan this sulcus is less developed than in the sei whale (Omura, 1959). In this respect the Kizuki specinen denotes sulcus of *B. edeni* type, being wide and shallow. In addition, in *B. edeni* the basicranial part of the skull exposed behind the palatine is much longer than broad (Junge, 1950). This also observed in the Kizuki specimen (Pl. I, Fig. 2). It seems that, from the above, the Kizuki specimen shows some characters of the Bryde's whale rather than the sei whale.

There are, however, some doubts in reliability of such skeletal characters. Mead (1977) found, in several specimens, some of the characters generally used to separate *B. borealis* from *B. edeni* either intermediate or contradictory, particularly the shape of the nasal bones. He examined records of sei whales from the Atlantic coast of the United States and identified the above-mentioned Miller's specimen of the pollack whale (No. 236680, U.S. National Museum) as *B. edeni*. He describes that this was confirmed by an examination of the baleen, which is clearly that of *B. edeni*. The most remarkable difference, however, which separates *B. edeni* from *B. borealis* in the form of vertebrae is the strong backward inclination of the spinous processes in the former (Anderson, 1879; Lönnberg, 1931; Junge, 1950; Omura, 1959). This inclination is observed in vertebrae from about 7th dorsal and increases till its maximum at about 7th lumbar. In the Miller's specimen of Pablo Beach, however, no such backward inclination is observed (Pl. 12 of Miller, 1924). Thus the problem is much complicated and we are not able to conclude whether the Kizuki specimen is really a Bryde's whale or a sei whale.

The sei whale on the coast of Japan, however, does not usually migrate to the south coast of western Japan, but it moves from the Bonin Islands directly to Sanriku and further north. The Bryde's whales, on the other hand, were taken in these regions in the days of old whaling as well as in the days of modern whaling (Omura, 1977). These facts suggest that the Kizuki specimen possibly represents a Bryde's whale, *B. edeni*. Size of this whale is estimated to be 12 m, assuming that the skull is about 25% of the whale body.

Dating of the Kizuki specimen was not made, but there is a record kept at the Japan Whaling Association that two Iwashikujira were taken at Saganoseki (see Fig. 1) in 1926. At present the name Iwashi-kujira only means the sei whale, *B. borealis*, but in these days no distinction was made between the sei and Bryde's whales. In any case this will suggest that the Bryde's whale (or sei whale) usually came into the Inland Sea until about 50 years ago. As far as we know a whaling landstation was established at Saganoseki in 1926, but it was closed soon due to unexpected scarcity of whales coming there.

ACKNOWLEDGMENTS

We are much indebted to Mr Morosuke Ono and Mr Shoichi Abe of the Kizuki-shiritsu Minzoku Shiryokan, who gave us all the help we needed while measuring and photographing the specimen. Our sincere thanks are due to Mr Shiro Takamatsu of the Oita Marine Palace and Dr Teruo Tobayama of the Kamogawa Sea World who gave us the opportunity to study this specimen.

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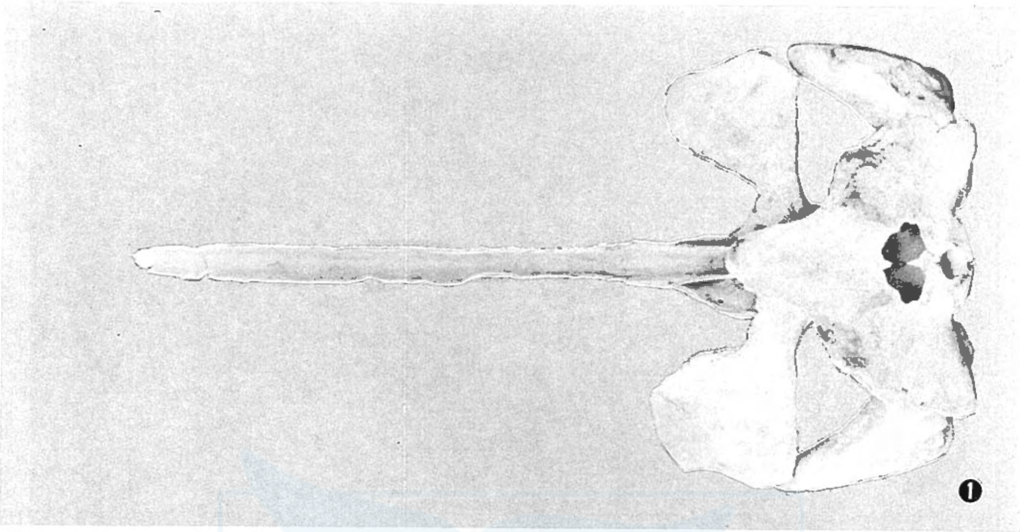
EXPLANATION OF PLATES

PLATE I

Fig. 1. Dorsal view of the Kizuki specimen.
Fig. 2. Inferior view of the Kizuki specimen.
Fig. 3. Lateral view of the Kizuki specimen.

PLATE II

Fig. 1. Posterior view of the Kizuki specimen.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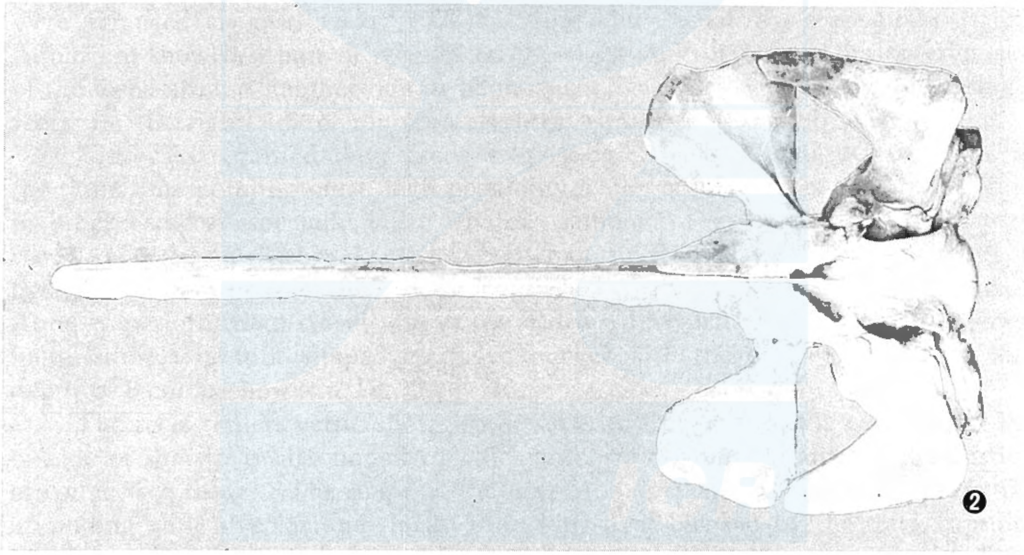
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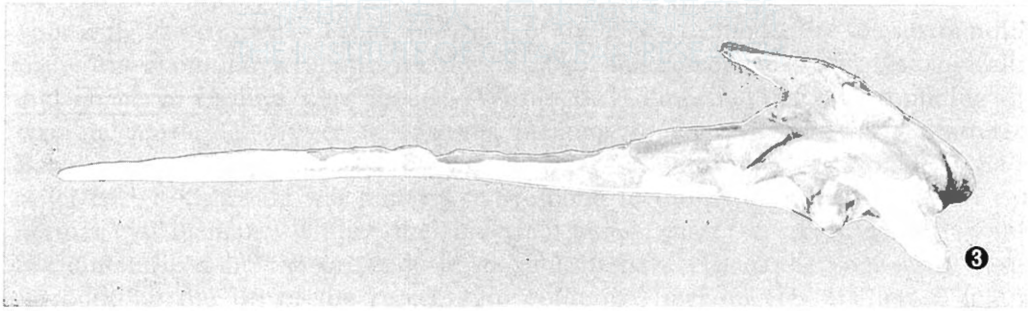
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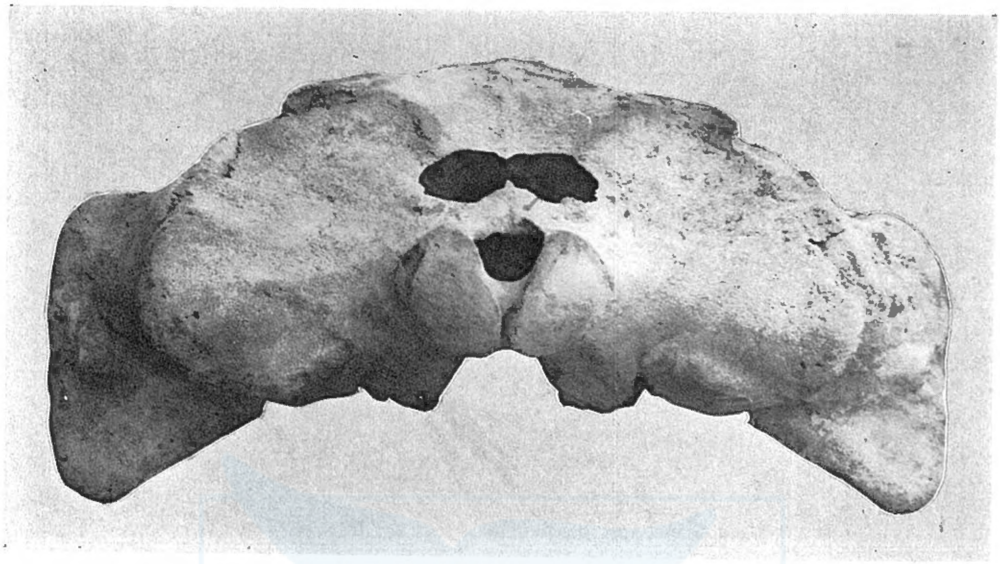

EPIDERMAL CYST IN THE NECK OF A KILLER WHALE

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Two killer whales with small recess in the skin on the anterior rim of the forelimb were reported by Nishiwaki (1973)*. One killer whale in Vancouver Public Aquarium showed a pair of recesses on the right and the left on the anterior rim of the forelimb and another one in Kamogawa Sea World, Chiba showed a single recess on the right side of the cranio-ventral rim of the forelimb (Fig. 1).

Nishiwaki regarded these recesses as vestigial teats in view of their sites, at the same time pointing out a high possibility of the occurrence of similar structure in other cetacea especially killer whales. Among these two killer whales with recess reported by Nishiwaki, the killer whale in Kamogawa Sea World died of liver dysfunction in July 1975 (body length 533 cm, body weight 1,600 kg, male). Autopsy performed to clarify the cause of death revealed the nature of the recess in question as a tube shaped epithelial pocket with the diameter of 5 mm and depth of 8 cm as shown in Fig. 2.

The recess enters vertically from the superficial layer into the corium and the outside of the tip is surrounded by thick and firm capsule-like structure consisting of connective tissue. The shape of the tip of the aberrant epithelium appears like an ending with alveolar and ductal branching as if blocked by the thick capsule-like external wall. The lumen of the tubular recess is filled by abrased epithelium appearing as cerumen. From the origin of the recess to the end of the surrounding tissue, no glandular structure was found at all macroscopically and histologically, and no nerve endings were found. Within the connective tissue surrounding the terminal portion of the recess, however, melanocyte-like cells were found scattered. Based on the present autopsy findings, the recess in the skin of the killer whales reported by Nishiwaki was found to correspond to the pathological picture of epidermal cyst in man. Unlike the epidermal cyst in man the recess in killer whale is characterized by the presence of melanocyte-like cells in the connective tissue surrounding the tip of the recess. No epidermal melanocytes are found in the

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* Nishiwaki, M., 1973. Possible vestigial teats of killer whales. *Sci. Rep. Whales Res. Inst.*, 25: 277–278.

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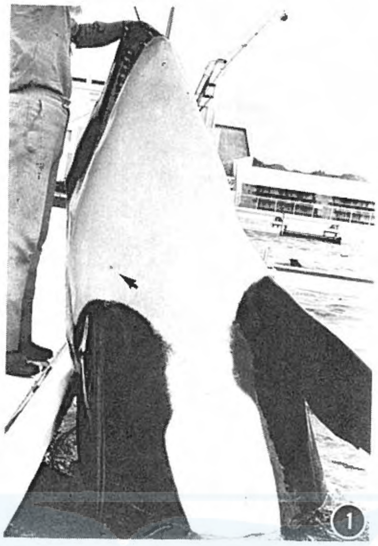

Fig. 1. The belly of the killer whale of a 533 cm length, male in Kamogawa Sea World. Arrow show the small recess on the cranio-ventral rim right of the forelimb.

Fig. 2. Longitudinal section through small recess of killer whale of a 533 cm length, male. Notice the lumen of recess and thick and firm capsule-like structure of connective tissue.

normal corium of the cetacea. No other reports are available on epidermal cyst in the cetacea, and the cause remains unknown. As was pointed out by Nishiwaki, however, demonstration of such cyst in two killer whales being localized in the neck would suggest the need for future observation to decide whether or not such cyst occurs frequently in killer whales.

AN AGGRESSIVE ENCOUNTER BETWEEN A POD OF WHALES AND BILLFISH

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An aggressive interaction or " battle " between a pod of large unidentified whales and a group of billfish, also unidentified (but probably marlin in the family Istiophoridae), was observed in August 1951, near Kahuku Point, the northern most tip of the island of Oahu in the Hawaiian Archipelago. The interaction lasted approximately 5–10 minutes and occurred in calm water at approximately 1230 hours local time, about 0.9 to 1.9 km due north of a position, 21°42.2′N, 158°01′W, on the beach, and about 2.2 to 2.4 km due west of Kahuku Point. Based on charted (U.S. Coast and Geodetic Survey Chart No. 4110) depths, the interaction occurred on the surface over, what is thought to be, water with depths of about 11–35 m.

Splashing, boils of water and the backs of large whales breaking the surface were initially seen. The first evidence that billfish were involved, was the rolling to its right of a whale, such that a billfish, firmly embedded in the whale's left flank, was lifted clear of the water to a near vertical position above the whale. The billfish thrashed back and forth, snapped off its bill and fell into the water as the whale turned upright and submerged. Minutes later another billfish was lifted out of the water to a position about one-half to one-quarter from the vertical above a whale. The whale rolled back into the water with the billfish still embedded. Splashing, water boils and the backs of whales were seen for an additional few minutes, and then abruptly stopped.

Evidence, that interactions between whales and billfish occur, has been occasionally reported in the literature (Ruud, 1952; Jonsgård, 1959, 1962; Nemoto, 1959; Brown, 1960; Machida, 1970; Ohsumi, 1973). The principal evidence has been the finding of the swords of billfish embedded in whales taken by whaling vessels. Sonrel (1870, p. 144) and Brown (1960) recount observed interactions between whales and billfish. The present report provides additional evidence of such encounters, and suggests how both whole and fractured swords result and become embedded in whales.

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CAROTENOID COLORED MINKE WHALE FROM THE ANTARCTIC

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On 16 February 1979, an unusual minke whale (*Balaenoptera acutorostrata*) which had a strange body color was captured by the Japanese whaling fleet in Area IV of the Antarctic. According to information from the catcher boat, this whale was

TABLE 1. BODY MEASUREMENTS AND OTHER DATA OF CAROTENOID COLORED MINKE WHALE

Serial no.	2241
Date of catch	16/Feb./1979
Position of catch	64°40′S, 104°08′E
Post-mortem time	1 hr 50 mins
Sex	Male
Age (yrs.) (number of layers in ear plug)	9++
Thickness of blubber (cm)	5.5
Body proportion (cm)	
Total length, tip of shout to notch of flukes	740
Tip of snout to center of blowhole	115
Tip of snout to center of eye	142
Tip of snout to ear	183
Length of ventral grooves (max.)	402
Umbilicus to end of of ventral grooves	28
Notch of tail flukes to center of anus	205
Notch of tail flukes to tip of dorsal fin	204
Half of the girth, at umbilicus	225
Half of the girth, at anus	135
Dorsal fin, vertical height	39
Flipper, tip to anterior insertion	108
Flipper, tip to axilla	83
Flipper, greatest width	29
Tail flukes, tip to tip	211
Tail flukes, notch to the nearest part of the anterior margin of the tail flukes	55
Half number of ventral grooves, at anterior insertion of each flipper (no.)	29
Skull (cm)	
Length, codyles to tip of premaxilla, straight	176
Breadth, frontal	96
Reproductive organs	
Testis weight (right, left; g)	570, 530
Penis length (cm)	74
Stomach contents	
Food item	Euphausiids
Relative quantity	30%
Relative freshness	Moderately fresh

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swimming with one other whale in a school and the crew could easily recoginize pinkish color on the lateral side of this whale at sea.

The whale taken was a male 7.4 m in total length (serial no. 2241) and it had almost normal viscera, though the kidny fat of this whale was yellow in color. Body proportions and other data from this whale are indicated in Table 1.

In general, the external coloration of minke whales in the Antarctic is gray dorsally and white ventrally (Williamson, 1961; van Utrecht and van der Spoel, 1962; Kasuya and Ichihara, 1965; Ohsumi *et al.*, 1970). However in this case, the ventral surface and other areas normally white in color were pink (Pl. I, Figs 1 and 2), while the blubber, connective tissue and baleen plates (except the black band portion) were flushed with a carotenoid color (Pl. I, Fig. 3). Furthermore the whole skeleton of this whale retained a carotenoid color during flensing, but when dried up, it was difficult to distinguish the color from skeletons of other whale. A whale with such a coloration as this had not seen previously by the crew of the factory ship, even though many of them had much whaling experience.

Though the cause of this unusual coloration was not apparent, judging from the external and internal features it was not caused by congestion or albinism. The post-mortem time (1 hr 50 mins) might influence the coloration of this whale, but it was not apparant too. In order to clarify the cause, pigmentary analysis is necessary as a first step. Specimens of skin, blubber and baleen plates were collected and these were preserved frozen as well as in 10% formalin solution. Detailed results of the pigmentary analysis of these specimens will be reported later.

I wish to express deepest appreciation to Dr P. B. Best, Marine Mammal Laboratory, Sea Fisheries Branch, South Africa for his kind advice and supplying of photograph (Pl. I, Fig. 1).

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EXPLANATION OF PLATE

PLATE I

Fig. 1. A comparison of body colors between unusual and normal whales (Photograph by Dr P.B. Best).

Fig. 2. Lateral view of rostrum and baleen of the unusual whale showing pinkish color and dark pigmented areas.

Fig. 3. Baleen plates and gum layer of the same whale showing carotenoid color.

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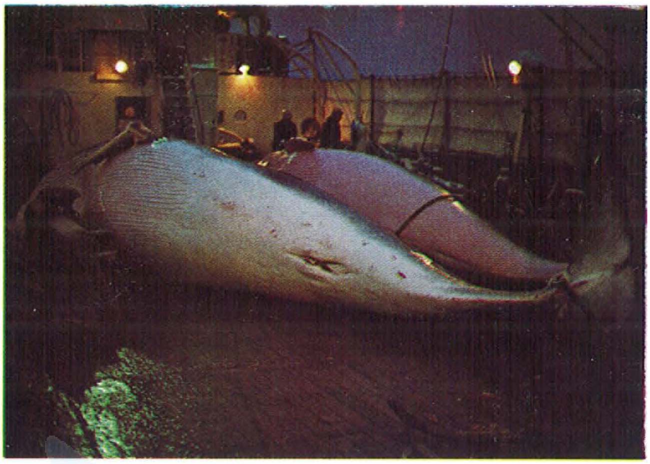

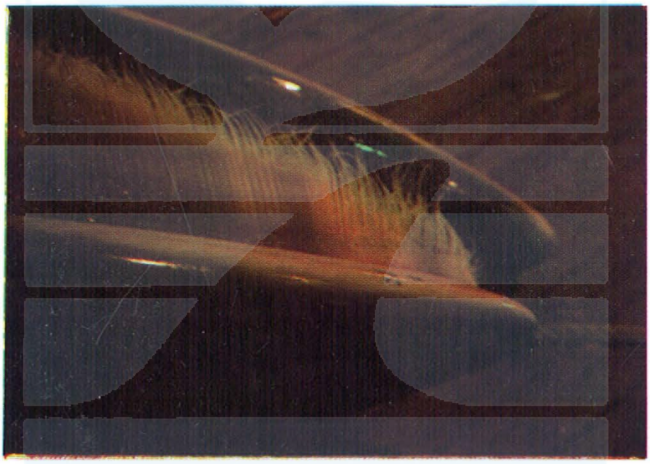

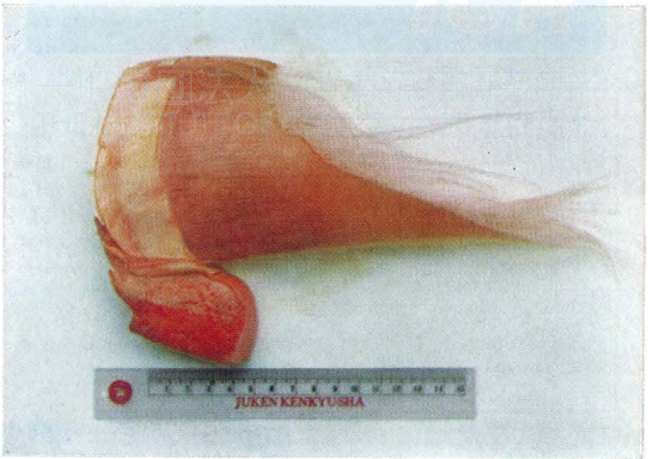
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UNUSUAL MINKE WHALE WITH DEFORMED JAW

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An unusual minke whale (*Balaenoptera acutorostrata*) was captured by the Japanese whaling fleet on 27 January 1979 in Area IV of the Antarctic (serial no. 1645). The rostrum of this whale was abbreviated and bent towards the lower jaw which was rather wide compared with a normal animal (Fig. 1). There are several

TABLE 1. BODY MEASUREMENTS AND OTHER DATA OF UNUSUAL MINKE WHALE COMPARED WITH TWENTY NORMAL WHALES

	Unusual whale	Twenty normal whales	
		Range	Mean
Serial no.	1645	1569-2061	
Date of catch	27/Jan./1979	24/Jan.-9/Feb./1979	
Position of catch	67°09′S, 71°48′E	Antarctic	
Sex	Female	Females	
Age (yrs.) (number of layers in ear plug)	40+		
Thickness of blubber (cm)	4.5	3.5-6.0	4.7
Body proportion (cm)			
Totol length, tip of snout to notch of flukes	870	860-890	873.5
Tip of snout to center of blowhole	100	125-144	134.9
Tip of snout to center of eye	144	158-185	171.9
Tip of snout to ear	181	198-230	215.2
Tip of snout to tip of lower jaw	28	—	—
Length of ventral grooves (max.)	461	436-492	466.5
Umbilicus to end of ventral grooves	49	15-53	28.8
Notch of tail flukes to center of anus	261	217-248	235.0
Notch of tail flukes to tip of dorsal fin	280	238-273	252.4
Half of the girth, at umbilicus	186	191-245	223.8
Half of the girth, at anus	131	130-156	139.7
Dorsal fin, vertical height	33	28-40	34.8
Flipper, tip to anterior insertion	140	121-151	136.4
Flipper, tip to axilla	105	92-110	100.8
Flipper, greatest width	34	30-35	32.9
Tail flukes, tip to tip	219	223-270	243.6
Tail flukes, notch to the nearest part of the anterior margin of the tail flukes	60	55-65	60.0
Half number of ventral grooves, at anterior insertion of each flipper (no.)	24	20-28	25.0
Skull (cm)			
Length, codyles to tip of premaxilla, straight	180	196-223	211.8
Breadth, frontal	116	106-120	112.4
Reproductive organs			
Mammary gland (length, width, depth; cm)	129, 22, 2.9	—	—
Number of corpora lutea and albicantia (no.)	1-12, 0-10	—	—

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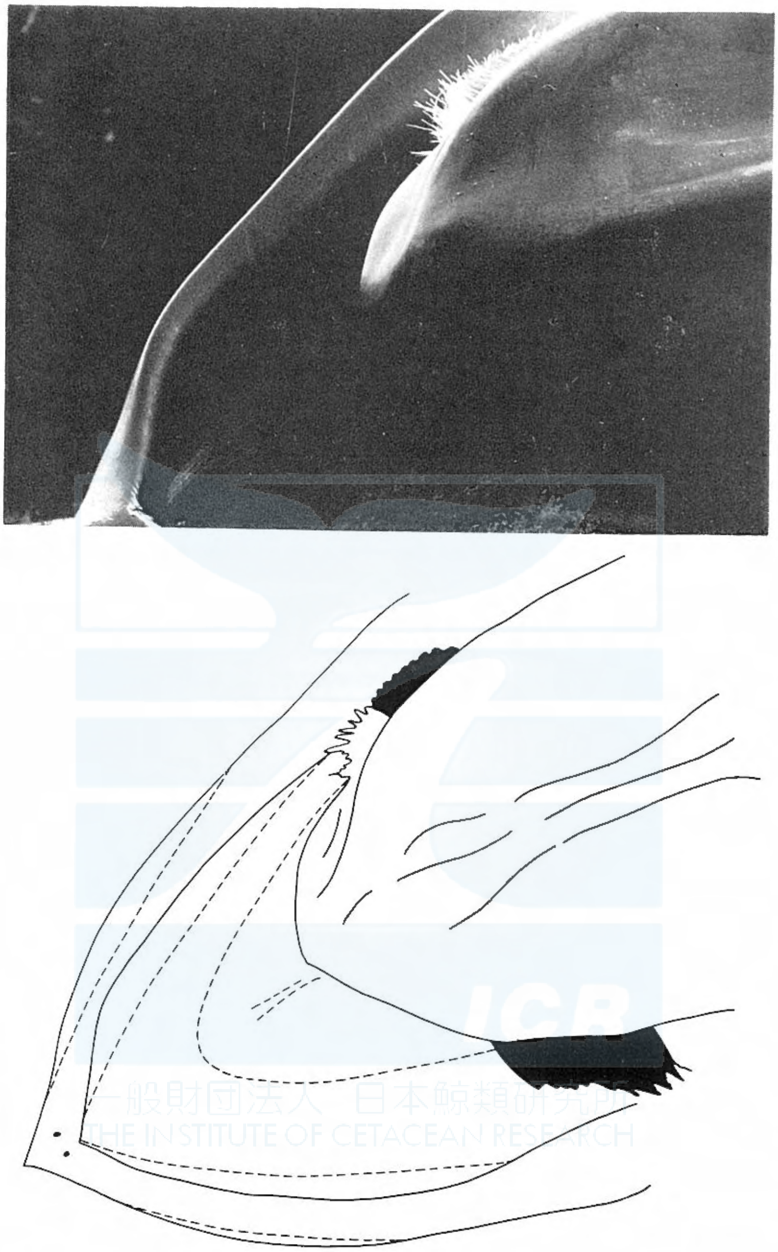

Fig. 1. Upper: Photograph of deformed rostrum and lower jaw. Lower: Tracing illustration of above photograph, dotted lines show contours of normal whale's rostrum and lower jaw.

reports and review of deformed jaws in sperm whales (Nasu, 1958; Spaul, 1964; Nakamura, 1968 etc.) and fin whale fetus (Ohsumi, 1959), but it is a rare occurrence in adult baleen whales.

This whale was an old female of 8.7 m in length and pregnant with one fetus (female, 30.3 cm long). The viscera and fetus of this whale were completely normal. A comparison of its proportions and other data with those for twenty normal whales (all females, 8.6–8.9 m in length) is given in Table 1.

In all three measurements of the head region, namely, the length from tip of the snout to center of blowhole, to center of eye and to ear, whale no. 1645 was shorter than normal. There also seemed to be a significant difference in the length from the tip of the snout to the tip of the lower jaw, but no data were recorded on this measurement for normal whales.

As shown in Table 1, whale no. 1645 has longer tail than normal. This may be indicated that actual body length of this whale is longer than 8.7 m if it had normal jaw. The skull of this individual was shorter than normal, but its breadth fell within the range for whales of the same body length.

Furthermore, although the girth (half, at umbilicus) of whale no. 1645 was less than normal whales, the thickness of the blubber was within the range for normal whales. This indicate that it could feed with little difficulty by such an abnormal mouth.

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THE POST-BREEDING DISTRIBUTIONS OF ICE-BREEDING HARBOUR SEAL (*Phoca largha*) AND RIBBON SEAL (*Phoca fasciata*) IN THE SOUTHERN SEA OF OKHOTSK

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ABSTRACT

The distribution of harbour seal (*Phoca largha*) and ribbon seal (*P. fasciata*) was studied. The field survey was performed from 1 May to 3 June of 1975 in the four pack ice areas along the eastern coast of Sakhalin. In these areas harbour seal was dominant in the southern area and overcomed by ribbon seal in northern areas. The pups of both species appeared in low frequency. However in the southern area, the pups of ribbon seal appeared frequently. The female adult harbour seals were dominant compared with the adult males, and it was suspected that adult females stay longer on the ice floes. In this connection ribbon seal showed the same sex ratio between males and females through all age classes except pups. However, the different sex ratio of subadult seals was observed between areas such as male dominant area and female dominant area. While the group size of harbour seal was composed of small number of individuals (average 1.8 seals), ribbon seal did not form the any group but appeared in solitary.

INTRODUCTION

The harbour seals (Family Phocidae, Genus and Subgenus *Phoca* 1758) were studied from the point of view of taxonomy and systematics in recent years, and it was supposedly concluded that there exist two harbour seal species in the North Pacific. Those are, namely, ice breeding harbour seal (*Phoca largha* Pallass 1811) and land breeding harbour seal (*Phoca vitulina richardsi* Gray 1864). Among these seals, ice living harbour seal is still little known species. Especially the knowledges concerning to their life in the ice region are quite scarce. As a consequence, knowledges on their distribution and migration are some times speculative. Similar to ice breeding harbour seal, ribbon seal (*Phoca fasciata* Zimmermann 1783; Family Phocidae, Genus *Phoca*, Subgenus *Histriophoca*) is also one of the most unknown species.

The unconfirmed knowledges concerning to their distribution and migration

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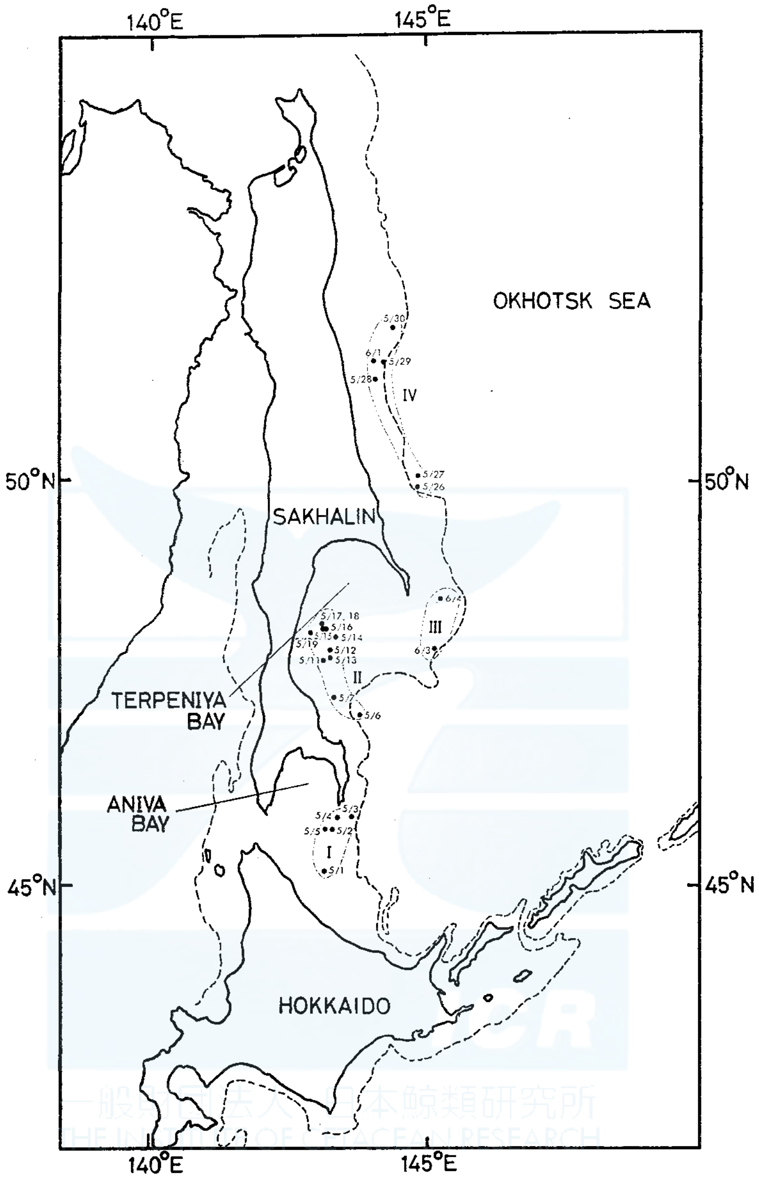

Fig. 1. Sampling was performed in the above 4 areas in the southern Sea of Okhotsk. The figures in each area show the date of sampling. Dotted line shows 200 m isodepth line.

are due to the difficulties in the ice region survey. Especially the latter seal have pelagic habitat visiting coast seldom after the ice floes melt (Burns 1970). Therefore it is still more difficult for us to access to them.

Our objective here are generally to provide some informations on their distribution and migration in the ice floe region and especially to add the informations on their social structures.

Our field studies were dependent on the commercial sealing which started from the first of May continuing for about a month when the breeding season was over and the ice floes were melting and retreating. Therefore, we missed the important breeding season for our purpose. The breeding season of harbour seal was suggested from mid to end of March (Naito and Nishiwaki 1972), and the ribbon seal was from mid March to first of April (Tikhomirov 1971). Therefore we studied the distributions of post breeding season (1–1.5 month later).

MATERIALS AND METHODS

From 1 May to 4 June in 1975, field studies were made in the eastern coast of Sakhalin to analize the harbour seal and ribbon seal distribution. The sealing were first operated from south to north following the retreating pack ice. The pack ice was almost final melting stage in this season, and the pack ice showed relatively low density and they were dispersing. However the sealing boat in some occasion did not penetrate into the pack ice to stop sealing. In this study the areas where the sealing operated were separated into four areas in accordance with the pack ice distribution. These areas were: area I, the south eastern part of Aniva Bay or the first operation area; area II, the mouth of Terpeniya Bay or the second operation area; area III, the eastern mouth of Terpeniya Bay or the last operation area; and area IV, the eastern coast of northern Sakhalin or the third operation area (Fig. 1). Among these areas, except area III the sealing was performed from south to north as season advances. The ice conditions, depth of water, date of sealing of these areas were shown in Table 1.

TABLE 1. THE ICE CONDITION, DEPTH OF WATER AND DATE OF OPERATION OF EACH SEALING AREA. THE ICE CONDITION WAS INDICATED BY THE DEGREES OF ICE COVERED AREA IN SIGHT AND THE ICE COVERED AREA WAS CLASSIFIED INTO TEN DEGREES.

Area	Average amount of ice	Range	Depth of water (m)	Date
I	3.75/10	3/10–4/10	100–200	1–5 May
II	3.40/10	1/10–7/10	60–100	6–19 May
III	3.10/10	1/10–4/10	150–200	26 May–1 June
IV	1/10	1/10	100–150	3–4 June

Through this field work, the right lower jaws were collected from 390 harbour seals and 761 ribbon seals, and preserved in 5–10% formalin. These collected numbers reached at about 40% of total number of seals caught, and these canine teeth sampling was made quite at random for the purpose of this study. In this field study we also made field observations from the upper bridge of the mother boat to collect the data for group size analysis.

Concerning the age determination of harbour seal, the same methods as reported by Naito and Nishiwaki (1972) was followed. However, the method of ribbon seal age determination was newly studied by using the tooth of known age of dead seal which was kept at Kamogawa Sea World in Chiba Prefecture, Japan. The age determinations of the ribbon seals were successfully performed by reading both dentine layers and cementum layers (Naito and Tobayama; unpublished).

Concerning the catch selection in this study, there exist no strong selectivity between each species, for sealing were made only on the ice floes by using the riffle with the scope. However, in general harbour seal was more cautious than the other. The species dealt in this study were only harbour seal and ribbon seal. There distribute ringed seal (*Phoca hispida*) and bearded seal (*Erignathus barbatus*) in these areas. However these seals, if identified by hunters, were not caught owing to the low quality of their fur. Therefore, these species were not studied in this study.

SPECIES COMPOSITION

In this study it was difficult to obtain data to evaluate catch effort such as hunter's skill, catch difficulty by ice or weather conditions and etc., therefore in this chapter only comparative species ratio was treated.

TABLE 2. SPECIES COMPOSITION AMONG HARBOUR SEAL AND RIBBON SEAL IN EACH AREA

Area	No. harbour seal	%	No. ribbon seal	%	Total number
I	122	80.8	29	19.2	151
II	216	33.1	437	66.9	653
III	39	18.2	175	81.8	214
IV	13	9.8	120	90.2	133
Total	390		761		1,151

Species composition of harbour seal and ribbon seal collected in each area are shown in Table 2. The numbers collected in all 4 areas were 390 harbour seals and 761 ribbon seals respectively. This result may indicate that ribbon seal distributed 1.95 times as much as harbour seal in these areas and season. To the contrary, however, each areas showed the different specific structure. As shown in Table 2, area I was considered as a harbour seal dominant area, and area II was possibly considered as both species mixed area. Ribbon seal highly dominant in areas III and IV, showing 81.8% and 90.2% respectively. Therefore it was considered that ribbon seal appeared frequently in northern areas and later season. Although the explanation for this phenomena is still uncertain, it may related with difference of ice utilization by both species. Tikhomirov (1961) and Naito and Nishiwaki (1975) stated that in May and June harbour seal begin to appear in the coastal area coinciding with ice melting season, and Tikhomirov (1961) also reported that ribbon seal seldom descend into the water in May and June when they are moulting. In this connection, it was quite natural that ribbon seal was generally abundant in these areas, and being hunted in later season in areas III and IV where harbour seal was less dominant.

AGE AND SEX COMPOSITIONS

Harbour seal

Age composition of harbour seal is shown in Table 3 and Fig. 2. Of all age classes the pups and one year old seals of both sexes appeared most frequently, and the appearance frequency of older seals gradually decreased. The females seemed to show less gradual decrease, and the oldest seal was 30 years old in male and 33 years old in female.

In general the standing stock of pups should be most abundant. However

TABLE 3. AGE COMPOSITION OF 390 HARBOUR SEALS COLLECTED FROM ALL 4 AREAS

Age	No. males in sample	% in male sample	No. females in sample	% in female sample
0	47	28.0	40	18.0
1	47	28.0	46	20.7
2	11	6.5	19	8.5
3	15	8.9	22	9.9
4	13	7.7	17	7.6
5	5	3.0	13	5.8
6	7	4.1	8	3.6
7	1	0.6	10	4.5
8	3	1.8	5	2.2
9	3	1.8	2	0.9
10	0	0	0	1.3
11	3	1.8	4	1.8
12	1	0.6	5	2.2
13	3	1.8	2	0.9
14	0	0	6	2.7
15	2	1.2	2	0.9
16	1	0.6	1	0.5
17	1	0.6	2	0.9
18	1	0.6	0	0
19	1	0.6	2	0.9
20	0	0	2	0.9
21	0	0	0	0
22	1	0.6	1	0.5
23	1	0.6	2	0.9
24	0	0	1	0.5
25	0	0	1	0.5
26	0	0	1	0.5
27	0	0	0	0
28	0	0	0	0
29	0	0	2	0.9
30	1	0.6	1	0.5
31	0	0	1	0.5
32	0	0	0	0
33	0	0	1	0.5
Total	168	100.0	222	100

in this study pups appeared in same abundance as one year old seals. According to Natio and Nishiwaki (1975), pups are dependent on ice floe even after weaning, and they are much dispersed by ice movements. This suggestion may explain the above result. Concerning the sex ratio, it is very clear that both sex of pups and 1 year old seal appeared almost same frequency and, in the most of other age classes females were dominant. Not shown in Table 3, but the sex ratio is 52.2% females for both pups and one year old seals and 64.8% females for other older seals. This may suggest that the older female seals remain longer on ice floes than male seals. To analyse more precisely, the age was classified into several classes, such as (1) pup class, (2) immature class (1–2 years old), (3) subadult class (3–6 years old), (4) adult class (7–10 years old) and (5) old class (11 or more years old). As seen in Table 5, the sex ratios with 46% and 52.8% female for pup and immature class clearly differ from the ratio with 60%, 74.1% and 69.8% females for sub-adult, adult and old classes. From these facts, it was possibly concluded that the adult female harbour seal remain longer on ice floes.

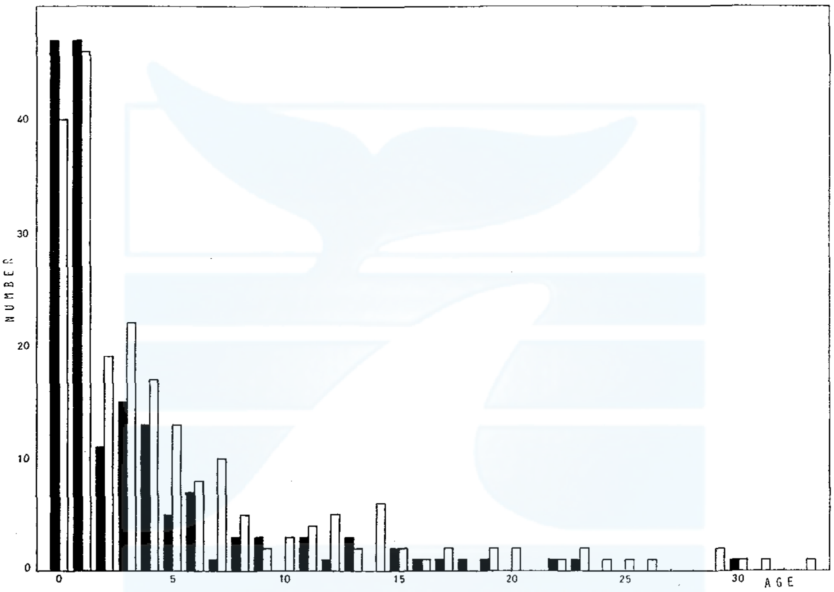

Fig. 2. Age composition of harbour seal. Black column represents the male seal and white column represents the female seal.

Ribbon seal

Age composition of ribbon seal is shown in Table 4 and Fig. 3. A number of pup seals appeared in quite low level as in the case of harbour seal pup. However, after one year old, the both sexes of seal decreased gradually in almost same rate. The oldest seal was 26 years old in male and 22 years old in female. Concerning the longevity of this seal, almost same result was obtained as reported by

TABLE 4. AGE COMPOSITION OF 761 RIBBON SEALS COLLECTED FROM ALL 4 AREAS

Age	No. males in sample	% in male sample	No. females in sample	% in female sample
0	18	4.7	30	8.0
1	90	23.4	96	25.5
2	71	18.5	61	16.2
3	52	13.5	47	12.5
4	49	12.8	35	9.3
5	29	7.6	31	8.2
6	14	3.6	18	4.8
7	17	4.4	16	4.2
8	6	1.6	10	2.7
9	9	2.3	6	1.6
10	7	1.8	5	1.3
11	6	1.6	3	0.8
12	2	0.5	2	0.5
13	4	1.0	4	1.1
14	3	0.8	1	0.3
15	1	0.3	2	0.5
16	0	0	2	0.5
17	1	0.3	1	0.3
18	3	0.8	3	0.8
19	0	0	0	0
20	0	0	0	0.5
21	0	0	1	0.3
22	0	0	1	0.3
23	0	0	0	0
24	0	0	0	0
25	0	0	0	0
26	2	0.5	0	0
27	0	0	0	0
28	0	0	0	0
29	0	0	0	0
30	0	0	0	0
31	0	0	0	0
32	0	0	0	0
33	0	0	0	0
Total	384	100	377	100

Tikhomirov (1971). He reported that the maximum age reached by ribbon seal in natural conditions is 22–26 years.

The low appearance frequency of harbour seal pups was considered in relation to it's ice dependent life and ice movements. In ribbon seal, though uncertain, the same reason may be considered as well. Contrary to harbour seal, sex ratio of pups seemed to be quite abnormal. However this low representation of male pup in Fig. 3 seemed to be caused by small sample size. As well as harbour seal, the difference of sex ratio was compared between several age classes such as (1) pup class, (2) immature class (1–2 years old), (3) subadult class (3–6 years old), (4) adult class (7–10 years old), (5) old class (11 or more years old). These age

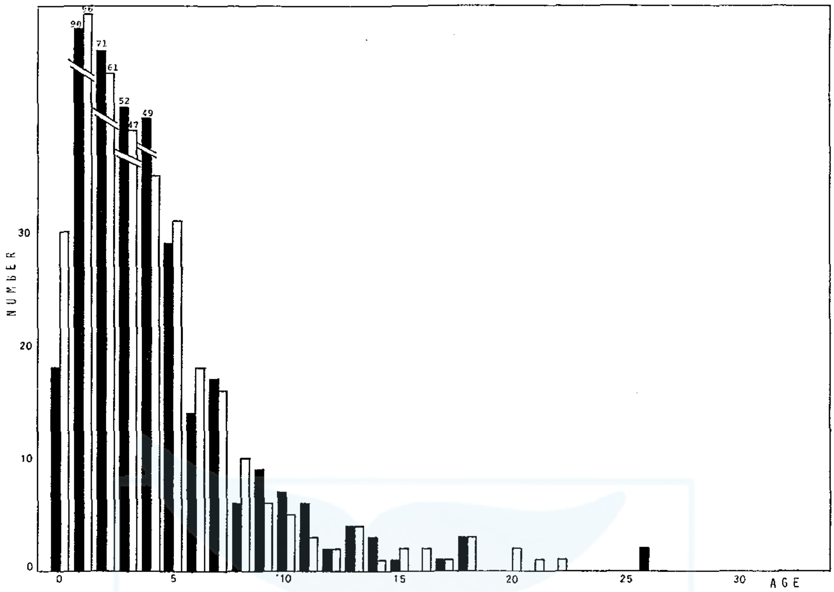

Fig. 3. Age composition of ribbon seal. Black column represents the male seal and white column represents the female seal.

TABLE 5. AGE GROUP COMPOSITION OF 390 HARBOUR SEALS (UPPER) AND 761 RIBBON SEALS (LOWER) COLLECTED FROM ALL 4 AREAS

Harbour Seal

Age class	No. males in sample	% in male sample	No. females in sample	% in female sample	Total No.	% in total sample
0	47	54.0	40	46.0	87	22.3
1-2	58	47.2	65	52.8	123	31.5
3-6	40	40.0	60	60.0	100	25.7
7-10	7	25.9	20	74.1	27	6.9
11-	16	30.2	37	69.8	53	13.6
Total	168	43.1	222	56.9	390	100.0

Ribbon Seal

Age class	No. males in sample	% in male sample	No. females in sample	% in female sample	Total No.	% in total sample
0	18	37.5	30	62.5	48	6.3
1-2	161	50.6	157	49.4	318	41.8
3-6	144	52.4	131	47.6	275	36.1
7-10	39	51.3	37	48.7	76	10.0
11-	22	50.0	22	50.0	44	5.8
Total	384	50.5	377	49.5	761	100.0

classes were settled by considering the sexual maturity data by Tikhomirov (1968). The sex ratios of each age class are shown in Table 5. The sex ratio of 62.5% of female pup is little higher than expectation. However, the ratios of 49.4%, 47.6%, 48.6%, 50% females for immature class, subadult class, adult class and old class indicate that both sexes of this seal appeared in same ratios, and this result was quite different from the result obtained from harbour seal. The ratios for male and female of all classes in total are 50.5% and 49.5% respectional. From these facts it may be concluded that sexual segregation does not occur, even in adult and subadult classes. This result, however, was different from that indicated by Tikhomirov (1961). He described that in some aggregations occasionally the predominance of males and females had been observed. The above mentioned different results may due to the surveyed area size. In this chapter, sex ratios of all seals from all four areas were discussed. However in this study, we compared the age and sex composition between each areas of I-IV to obtain the more detailed knowledge on distribution of these species.

Harbour seal

As seen in Table 6, of all 390 harbour seals 122 seals were collected in area I and 216, 39 and 13 were collected in areas II, III, IV respectively. These sample numbers generally reflect the abundance in these areas and indicate that harbour seal were much abundant in area I and II. Concerning the age compositions, pups appeared to distribute in all areas, with age class ratio between 15.4%–30.8% of totals, and it was presumed that pups showed the scattered distribution in all areas, even in areas III and IV where this seal was less abundant. Immature class (1–2 year class) seals appeared in high frequency in areas I and II with ratio 46.7% and 28.7% and low frequency in areas II and IV with ratio both 7.7%. This may indicate that the immature seals concentrate to a certain degree in areas I and II. The subadult and adult class seals seemed to appear randomly, and old class appeared in areas I and II less frequently with ratio 4.1% and 11.6%, and more frequently in areas III and IV with ratio 41.0% and 53.8%.

It may be true that the distribution of pup widely spreads out and scatters. As already mentioned pups stay on ice floes for a while even after weaning and have ice dependent life (Naito and Nishiwaki 1972) and as a consequence, pup occurrs in far south water along the coast or Japan (Naito 1976). These facts may support above result. In this study some tendency of concentrations by immature seals occurred in southern area and it was not widely known that immature harbour seal tend to concentrate. However the fact that concentration of young harbour seals was annually observed near St. Mathew Island in the Bering Sea (Tikhomirov and Kosygin 1966) may support the result obtained in this study. Furthermore, the imformations from hunters that the immature harbour seals are distributed in concentration should be taken into the considerations. However, we are still short in data to obtain the clear result.

Concerning the sex ratio, there obtained the clear result in this study that older female seals appeared in high frequency in southern area of I and II and both sex of immature seals appeared almost same frequency (Fig. 4 and Table 6). However in northern areas of III and IV, such phenomena were not observed due to shortage of data.

TABLE 6. AGE CLASS COMPOSITION AND SEX RATIOS OF EACH AGE CLASS HARBOUR SEAL IN EACH AREA

	Area I				Area II				Area III				Area IV			
Age class	No. of males (%)	No. of females (%)	Total No.	% in total sample	No. of males (%)	No. of females (%)	Total No.	% in total sample	No. of males (%)	No. of females (%)	Total No.	% in total sample	No. of males (%)	No. of females (%)	Total No.	% in total sample
0	16 (50.0)	16 (50.0)	32	26.2	24 (53.3)	21 (46.7)	45	20.8	5 (83.3)	1 (16.7)	6	15.4	2 (50.0)	2 (50.0)	4	30.8
1-2	27 (47.4)	30 (52.6)	57	46.7	28 (45.2)	34 (54.8)	62	28.7	3 (100.0)	0 (0)	3	7.7	0 (0)	1 (100.0)	1	7.7
3-6	6 (25.0)	18 (75.0)	24	19.7	31 (46.3)	36 (53.7)	67	31.0	3 (37.5)	5 (62.5)	8	20.5	0 (0)	1 (100.0)	1	7.7
7-10	0 (0)	4 (100.0)	4	3.3	4 (23.5)	13 (76.5)	17	7.9	3 (50.0)	3 (50.0)	6	15.4	0 (0)	0 (0)	0	0
11-	0 (0)	5 (100.0)	5	4.1	2 (8.0)	23 (92.0)	25	11.6	10 (62.5)	6 (37.5)	16	41.0	4 (57.1)	3 (42.9)	7	53.8
Total	49 (40.2)	73 (59.8)	122	100.0	89 (41.2)	127 (58.8)	216	100.0	24 (61.5)	15 (38.5)	39	100.0	6 (46.2)	7 (53.8)	13	100.0

TABLE 7. AGE CLASS COMPOSITION AND SEX RATIOS OF EACH AGE CLASS RIBBON SEAL IN EACH AREA

	Area I				Area II				Area III				Area IV			
Age class	No. of males (%)	No. of females (%)	Total No.	% in total sample	No. of males (%)	No. of females (%)	Total No.	% in total sample	No. of males (%)	No. of females (%)	Total No.	% in total sample	No. of males (%)	No, of females (%)	Total No.	% in total sample
0	2 (25.0)	6 (75.0)	8	27.6	12 (41.4)	17 (58.6)	29	6.7	4 (66.7)	2 (33.3)	6	3.4	0 (0)	5 (100.0)	5	4.2
1-2	9 (52.9)	8 (47.1)	17	58.6	100 (50.3)	99 (49.7)	199	45.5	26 (54.2)	22 (45.8)	48	27.4	26 (48.1)	28 (51.9)	54	45.0
3-6	1 (33.3)	2 (67.7)	3	10.3	100 (62.5)	60 (37.5)	160	36.6	34 (48.5)	36 (51.5)	70	40.0	9 (21.4)	33 (78.6)	42	35.0
7-10	0 (0)	1 (100.0)	1	3.5	19 (54.3)	16 (45.7)	35	8.0	15 (50.0)	15 (50.0)	30	17.2	5 (50.0)	5 (50.0)	10	8.3
11-	0	0	0	0	7 (50.0)	7 (50.0)	14	3.2	11 (52.4)	10 (47.6)	21	12.0	4 (44.4)	5 (55.6)	9	7.5
Total	12 (41.4)	17 (58.6)	29	100.0	238 (54.5)	199 (45.5)	437	100.0	90 (51.4)	85 (48.6)	175	100.0	44 (36.7)	76 (63.3)	120	100.0

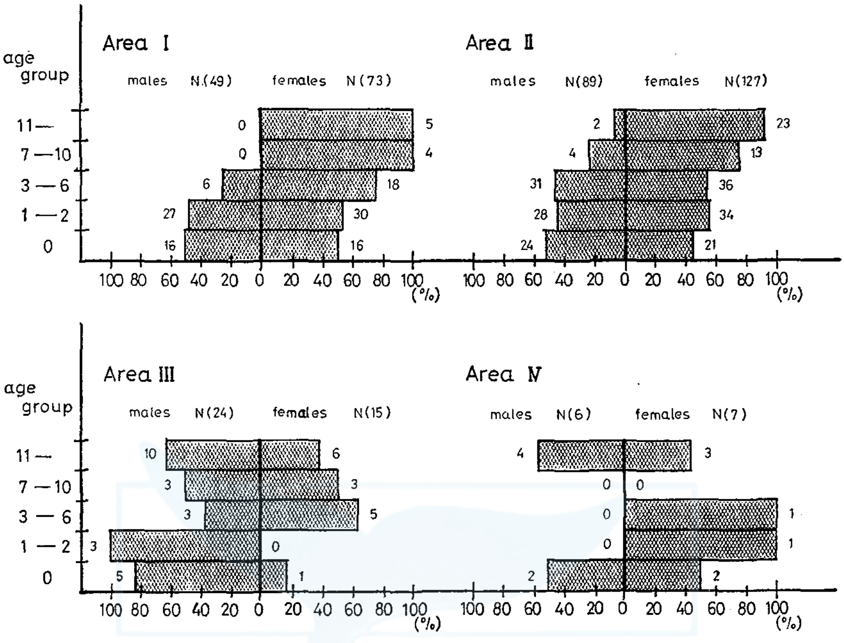

Fig. 4. Sex ratios for age groups of harbour seal in each area, 0: pup class, 1~2: immature class, 3~6: subadult class, 7~10: adult class and 11~: old class

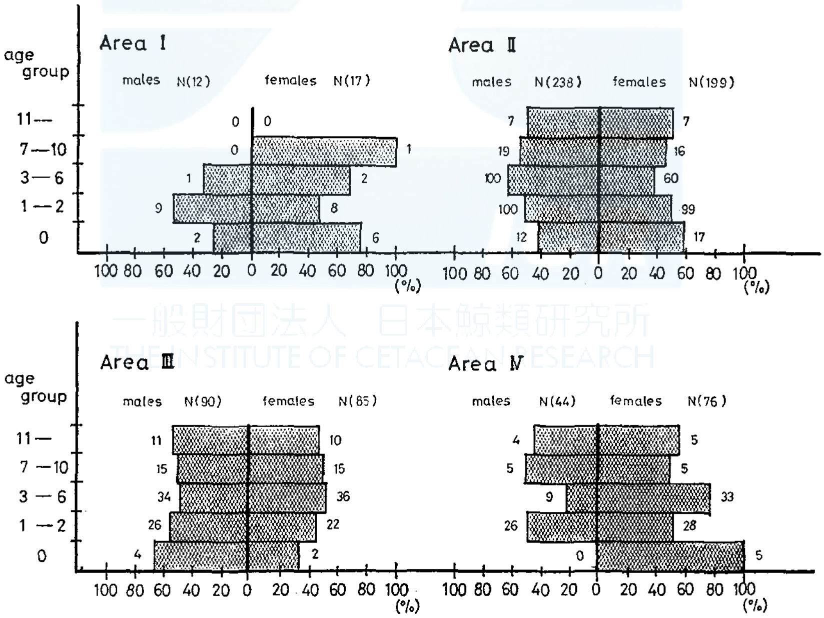

Fig. 5. Sex ratios for age groups of ribbon seal in each area, 0: pup class, 1~2: immature class, 3~6: subadult class, 7~10: adult class and 11~: old class

According to Tikhomirov and Kosygin (1966), south of Nunivak Island in the Bering Sea they found every spring aggregations of female which had recently given birth to their pups. In our study, pups had been weaned almost 1.5–2 month before and such female agregations were not observed. Although our result may indicate that adult females keep some aggregation to a certain degree even after weaning, it may be more reasonable to understand that the female adult seals remain longer in ice floe region while adult male seals shift their habitate from ice region to the coastal region.

Ribbon seal

In the case of ribbon seal, the relative larger number of samples (761 seals) were obtained. Out of 761 seals, 29 seals were collected from area I and 437, 175, 120 seals were from areas II, III, IV respectively. And in area II ribbon seal was most abundant and least abundant in area I (Table 7). Concerning the age composition in each area, as seen in Table 7 appearance frequencies of pup class and immature class were relatively high in area I compared with other three areas. Especially pup class seals appeared high frequency in area I. On the contrary subadult class, adult class and old class seals appeared less frequently in arae I and more frequently in other 3 areas, especially in area III.

From above, it was supposed that the southern area of area I was less abundant area and young seals were predominant like as harbour seal. The area II was the most abundant area and immature and subadult seals were dominant. The area III was relatively abundant and older seals were dominant. The area IV was widely operated area (Fig. 1) and the seals was not abundant, while similar age composition as in the area II of the most abundant area was observed.

At this stage of study, we could not obtain any reasonable explanation for above phenomena.

Concerning the sex ratio, as seen in Fig. 5, ratios for all age classes in area I were fluctuated very much due to the small sample size. From same reason, sex ratio for pup class also fluctuated among each area.

The male and female seals of immature, adult and old adult classes appeared in similar ratio among areas except area I showing the ratios of about 50% for both sexes. However, only subadult seals showed the different ratio among areas II, III and IV. In area II, sex ratio with 37.5% for females were observed, on the other hand, in area IV females were dominant, and ratio of 78.6% for females was observed. Being still uncertain, it was possibly considered that ribbon seal shows sexual segregation of some certain degree. It is necessary to obtain the data from much smaller areas in order to analyze the above problems. In this study, the several hunting boats operated in wide spreaded areas. These hunting boats made operations about twice a day, from 4 AM to noon and from 13 PM to 18 PM. After operation, the seals were boarded on the mother boat where we collected specimens. Therefore we could not make any more detailed analysis for ribbon seal distribution.

GROUP SIZE

In this study we also performed the observations on group size of both species. The group size was estimated by the number of seals laying themselves on the same ice floe. The size of ice floes showed much variations. The largest size was about 150–200 m in diameter.

Harbour seal

The group size of the two species was studied in order to know the social structure of each species. The observations were performed from the top of the mother boat bridge while the hunting boats were out from it. As shown in Table 8, 58.9% of the harbour seal groups was composed of a single seal, and 22.3% was composed of two seals. The larger the group size, the frequency gradually decreased so far, and the maximum group size was 8 individuals. The average group was composed of 1.8 seals.

TABLE 8. GROUP SIZE AND FREQUENCY OF EACH GROUP SIZE OF HARBOUR SEAL AND RIBBON SEAL. TOTAL NUMBER OF INDIVIDUALS OF EACH GROUP SIZE WAS ALSO SHOWN IN THIS TABLE. GROUP SIZE WAS ESTIMATED BY THE NUMBER OF INDIVIDUALS THAT HAULED OUT ON THE SAME ICE FLOE

Group size	No. of sighting		No. of individuals	
	Harbour seal (%)	Ribbon seal (%)	Harbour seal (%)	Ribbon seal (%)
1	66 (58.9)	90 (97.8)	66 (32.5)	90 (95.7)
2	25 (22.3)	2 (2.2)	50 (24.6)	4 (4.3)
3	10 (8.9)	0	30 (14.8)	0
4	5 (4.5)	0	20 (9.9)	0
5	2 (1.8)	0	10 (4.9)	0
6	2 (1.8)	0	12 (5.9)	0
7	1 (0.9)	0	7 (3.4)	0
8	1 (0.9)	0	8 (3.9)	0
Total	112 (100)	92 (100)	203 (100)	94 (100)

The group size observed in this study seemed to be rather small than what it was under the natural condition, because we obtained the data from the area where some hunting boats operated around and more or less the seals were disturbed. As the matter of fact, the largest group size was smaller than the group size of 12 young seals obtained in the same season and same area in 1971 (Naito and Nishiwaki 1975). From above result, unfortunately, we could not analyze the group size from the point of view of sex, age or areas in this study.

Ribbon seal

The ribbon seal showed the distinguishable aspect from the point of view of group size. The group of this seal was composed of a single seal in 97.8% frequency, and only twice a couple of seals laying themselves on same ice floe was observed (Table 8). Even in these two cases, it was not supposed that they were either associated each other or located close together, but observed laying themselves apart on the ice floe.

From these facts, we can conclude that ribbon seal does not form the group but keep a distance each other on ice floes in this season. Thikhomirov (1961) also reported that ribbon seal appear solitary on ice floe.

DISCUSSION

It is generally said that ribbon seal and harbour seal occupy almost similar ice region. However Burns (1970) reported that in the ice edge zone of the central Bering Sea, ribbon seal had been most numerous along the inner (northern) edge of the zone and gradually outcomed by harbour seal towards the southern edge. In the same sense, we also attained the similar result. However, in our study the season was different from the above suggestion as already mentioned high frequency of ribbon seal in northern area may be only due to the longer staying on ice floes compared with harbour seal as suggested by Tikhomirov (1961). We need the much more data for long period in order to obtain the reasonable conclusions.

Concerning the age and sex ratios, we obtained the result that female adult harbour seals occurred in high frequency and to a certain degree age and sexual segregation were observed. On the other hand ribbon seals showed no age and sexual segregation as a whole. However, in some areas, sexual segregation was observed in subadult class. Burns (1978) described that he had seldom seen male and female ribbon seal together. We also observed same as he described. Our above result was based on the data from relatively larger area and the degrees of sexual segregation seemed to be lower estimation than what it was, because we sometimes observed the adult males dominant zone and adult female dominant zone separately in smaller areas. This sexual segregation seems to occur even in breeding season (Tikhomirov, 1961). In Nemuro Strait of eastern Hokkaido, sex ratio of female adult seal exceeded 70% (Itoh unpublished data) in breeding season. Burns (1978) also reported that in breeding season both sex of ribbon seal seldom appear together. The reason why these segregation may occur on ribbon seal is still uncertain. The peculiar pelage pattern of ribbon seal may play some role between both sex as some communication like as reported in harp seal (*Phoca groenlandicus*) (Evans and Bastian 1969). However, we found that not only matured ribbon seal, but also immatured seal appeared in solitary. Probably this seal is ecologically adapted and specialized as pelagic seal. In this study we were quite uncertain on this problems.

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A RECORD OF THE BEARDED SEAL WANDERING WITH SPECIAL REFERENCE TO THE WANDERING SPEED

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The south and north bound wandering around the Boso Peninsula of the bearded seal (*Erignathus barbatus*) was recorded in 1977. Many examples of the seal wandering had been reported in many places where so far apart from normal habitat (Richardson, 1975; King, 1975; Naito, 1976; etc.), and the wandering of seal itself is not so much worth of special mention. However, this record might be of some interest to report here due to the most far south record in the western North Pacific and its consequent observation made possible an estimation of wandering speed.

One seal was first observed by fishermen in the Amatsu fisheries harbor at 4: 00 PM, 6 September 1977 (Table 1). At this time I could fortunately observe the seal at 20 meters distance. It was easily identified as the bearded seal from its outer looking such as characteristic profusion of moustachial whiskers, and anterior insertion of the foreflippers. The sex was also identified as male from existence of opening of male genital organ. The seal was roughly estimated to be as large as 1.5 m and its age was supposed as a young animal. The body color was muddy on dorsal side and brownish yellow on ventral side. The seal disappeared after about one hour stray in the harbor. On the next morning a fisherman found the seal occurred in the Chikura harbor at nine in the morning. I visited Chikura harbor as quickly as possible, however, the seal was already out of the harbor before my arrival. According to the fisherman's information on the body size and color, it was supposed that this seal was the same as I saw the day before. Following informations on the seal were brought from Kisarazu and then from Funabashi in a few days. Therefore, the wandering way of this seal was recorded as shown in Fig. 1 and in Table 1. However, after sighting at Funabashi, the seal was missed and no information was received.

According to Naito (1976), 16 examples of seal wandering were recorded along the coast of Japan (except Hokkaido) since 1949, and only two out of 16 examples were the bearded seals. One was recorded at Tennou-cho Akita Prefecture (39°53′N, 139°57′E) and the other was at Niigata City (38°13′N, 139°24′E). Both were recorded at Japan Sea coast. Therefore, this is the first time for the record of the bearded seal wandering along the Pacific coast of Japan. Futhermore, this observation (Chikura; 34°37′N, 139°58′E) seems to be confirmed as the most far south record in the western North Pacific. However, according to Wang ZheMao (personal communication), one specimen of this species was collected in China. Therefore, being still uncertain where it was collected in China, this collection may be the most far south record. Since the seal was observed at four locations during its wandering as mentioned above, the wandering speed was roughly es-

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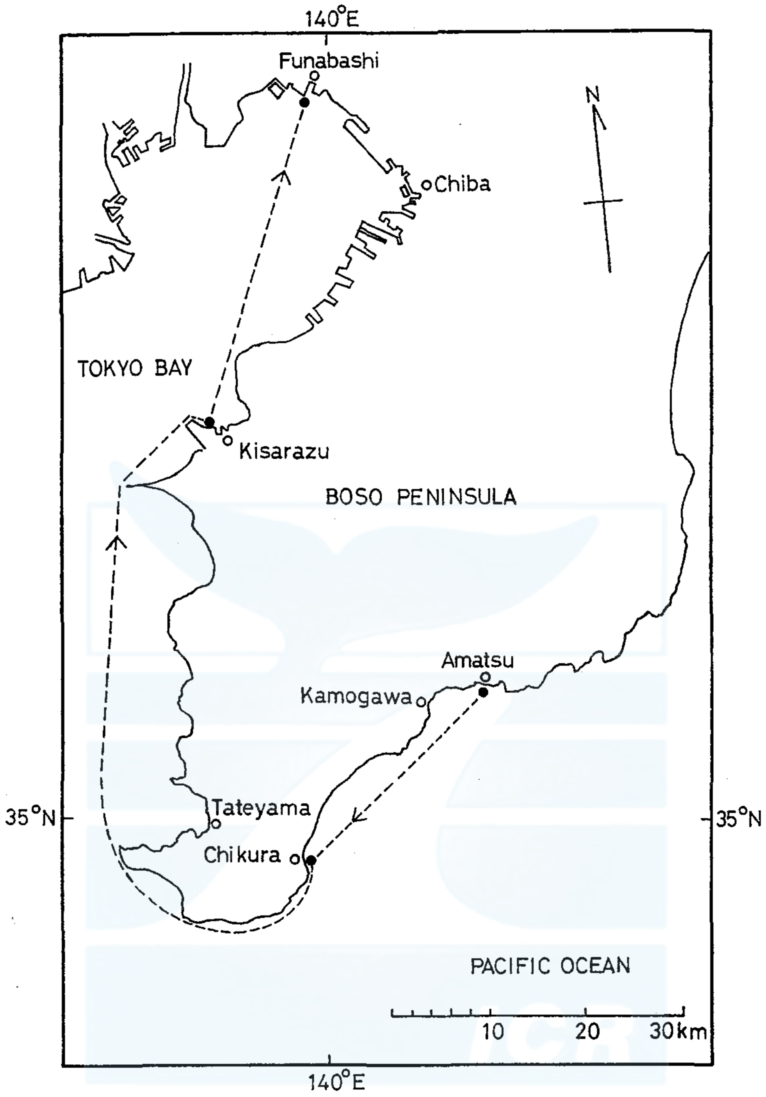

Fig. 1. The bearded seal first appeared at Amatsu and was successfully tracked at Chikura, Kisarazu and Funabashi.

timated. The minimum distance between each location, time lag of occurrences in each location, and the calculated wandering speed are shown in Table 2. The wandering speed between Amatsu and Chikura, and between Chikura and Kisarazu are almost the same, however, between Kisarazu and Funabashi it took about three times longer than that of the former. This difference in the wandering speed may be resulted from the undesirable environmental condition that may caused the unsmooth wandering between Kisarazu and Funabashi e.g. the artificially complicated channels, dirty waters, numerous numbers of ships and a lot of piers.

TABLE 1. THE OBSERVED LOCALITY AND TIME OF APPEARANCE AND DISAPPEARANCE WHILE THE BEARDED SEAL WONDERED AROUND THE BOSO PENINSULA IN 1977

Locality	Date	Time
Amatsu	6 September	16:00-18:00
Chikura	7 September	9:00-11:00
Kisarazu	9 September	16:00-18:00
Funabashi	13 September	13:00

TABLE 2. MINIMUM DISTANCE BETWEEN EACH LOCATION AND TIME SPENT TO REACH EACH LOCATION WERE CALCULATED TO INDUCE THE WONDERING SPEED

Location	Minimum distance	Wondering hours	Wondering speed
Amatsu-Chikura	26.1 km	16 hours	1.63 km/hr
Chikura-Kisarazu	79.1	53	1.49
Kisarazu-Funabashi	36.9	91	0.41
Amatsu-Funabashi (total)	142.1	160	0.88

On the other hand, the areas between Amatsu and Chikura, and between Chikura and Kisarazu are all or partly facing to the Pacific Ocean, and it seems to be clean enough for the seal to make smooth wandering. Therefore, it may be possible to presume that the minimum distance was followed between Amatsu and Kisarazu which is 105.2 km, and the average speed was 1.52 km per hour. This average speed is comparable to neither the swimming speed nor the migration speed, but as a whole it means the minimum moving speed during wandering. The seal may not swim directly on the minimum distance route but may stray here and there during locomotion from location to location. Futhermore the seal may take rest occasionally. Therefore, it is likely that normal swimming speed itself may be several times faster than the wandering speed.

In this study, I was very much indebted to the staff of the Kamogawa Sea World to pursue the seal. They kindly provided me the informations I needed.

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METALS AND ORGANOCHLORINE COMPOUNDS IN THE MUSCLE OF DUGONG FROM SULAWESI ISLAND

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ABSTRACT

The muscle of two dugongs from Sulawesi Island were analyzed of metals and organochlorine compounds. Total mercury in the adult female was 0.005 ppm and 0.002 ppm in the immature female. The ratio of total mercury to the selenium was higher in the older individual. Metal concentrations, except for arsenic, were higher in the adult female. PCB, DDT and BHC were not detected in both dugongs. Concentrations of mercury and organochlorine compounds in the dugong were compared with those of other marine mammals.

INTRODUCTION

In recent years the presence of significant concentration of metals and organochlorine compounds has been reported in seals and dolphins which are high-order carnivores. As the dugong, *Dugong dugon* (Müller), are hervivorous, comparison of metals and organochlorine residues in the dugong with those in other marine mammals appears to throw some light on concentrations through the food chain. On this problem very few study has been made chiefly due to difficulty of collecting the fresh samples. Present study was undertaken to investigate the accumulation of metals and organochlorine compounds in the muscle of dugong, and to compare the data with those of other marine mammals.

MATERIALS AND METHODS

The muscle samples analyzed here were obtained from two dugongs caught in 1975 in Laikang Bay, Sulawesi Island and preserved for the Okinawa Exposition. These animals were kept alive for about 20 days at the Exposition. The biological informations of two individuals are shown in Table 1 and age of them is cited from Kasuya and Nishiwaki (1978), who made age determination of dugongs basing

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on the dentinal growth layers in the larger tusk. Samples (about 2 kilogram per individual) were kept frozen to about −20°C after death until the analyses in 1979. In order to protect against dryness they were glazed twice during cold storage by Dr T. Kasuya. All substance data described here were expressed in wet weight basis.

Mercury: Total mercury was determined directly by a semiautomated flameless atomic absorption spectrophotometer (Itano *et al.*, 1977).

Methylmercury: Methylmercury was analyzed by the gas chromatographic method based on the procedure of Westöö (1967).

TABLE 1. LIST OF MATERIALS

Specimen No.	Captured Date	Captured Place	Death Date	Death Place	Sex	Body Length (cm)	Maturity	Age*
RRM001	25 July, '75	Sulawesi Is.	20 Oct. '75	Okinawa	Female	254	Adult	18
RRM002	26 Aug. '75	Sulawesi Is.	21 Oct. '75	Okinawa	Female	204	Immature	7

* cited from Kasuya and Nishiwaki (1978).

Arsenic, selenium and other metals: Arsenic, selenium and other metals were determined using silver diethyldithiocarbamate method, a fluorometric spectrophotometer (Itano *et al.*, 1977) and an atomic absorption spectrometer, respectively.

Organochlorine compounds: Muscle was ground with anhydrous sodium sulfate, and extracted by blending with n-hexane. The extracted fat was removed by florisil dry column method. Then the sample was cleaned up by silicagel column chromatography and determined by GC-ECD.

TABLE 2. CONCENTRATIONS OF TOTAL MERCURY, METHYLMERCURY AND SELENIUM IN THE MUSCLE OF DUGONGS

Specimen No.	Total mercury ppm	Methylmercury ppm	Selenium ppm	$\frac{\text{Total mercury}}{\text{Selenium}}$
RRM001	0.005	0.004	0.087	0.057
RRM002	0.002	ND	0.074	0.027

The tissue weights used for the determination of total mercury, methylmercury and selenium were 0.2 g, 10 g and 3 g, respectively.

RESULTS AND DISCUSSION

Concentrations of total mercury, methylmercury and selenium in the muscle of two dugongs are shown in Table 2. This Table indicates that total mercury concentrations in the adult female (RRM001) was 2.5 times as much as that in the immature female (RRM002). As the values of total mercury in dugongs were rather close to 0.001 ppm of the detectable limit of this method, these data might be not adequate for a strict analysis. However, it can be definitely said that contamination by mercury in the dugong is lower than that of grey, harbour, hood and harp seals (Sergeant and Armstrong 1973), harbour porpoise (Gaskin *et al.*, 1972), striped dolphin, spotted dolphin, short-finned pilot whale, bottlenose dolphin and finless porpoise (Arima and Nagakura 1979). Concentration of methylmercury of the adult individual was 0.004 ppm and that of the immature was lower than 0.001 ppm of the detectable limit of this method. Ratio of total mercury to selenium in two dugongs was conspicuously lower than that in the ringed seal (Kari and Kauranen 1978), striped dolphin, spotted dolphin, short-finned pilot whale, bottlenose dolphin and finless porpoise (Arima and Nagakura 1979).

Concentrations of nine metals are shown in Table 3. Metal concentration, except for arsenic, were higher in the older individual. On the contrary arsenic showed higher concentration in the immature individual. Denton (personal communication) also obtained the similar result on the North Queensland dugong whose tissue concentrations of metals varied with the age.

TABLE 3. METAL CONCENTRATIONS IN THE MUSCLE OF DUGONGS IN PPM

Specimen No.	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	As
RRM001	32.0	0.094	29.5	0.97	0.25	1.25	0.043	0.120	0.015
RRM002	18.0	0.031	14.8	0.74	0.20	0.55	0.040	0.031	0.050

The tissue weights used for the determination of arsenic and the other elements were 20 g and 10 g, respectively.

Fat contents in the muscle of the adult female and the immature were 0.084% and 0.065%, respectively. These were remarkably lower than those of harbour seal, ranging 0.45 to 5.80% (Gaskin *et al.*, 1973). Since the organochlorine compounds are expected to be most concentrated in the fat of animal tissues, fat was extracted from a large amount of muscle (240 g) for the analyses. However, PCB, DDT and BHC were not detected. The detectable limits of PCB, α-BHC, β-BHC, γ-BHC, p, p'-DDE, p, p'-DDD and p, p'-DDT were 0.001, 0.0005, 0.001, 0.001, 0.0001, 0.001 and 0.001 ppm, respectively. The concentration of organochlorine compounds in the dugong might be extremely lower than in harbour seal (Gaskin *et al.*, 1973). Heinsohn and Brich (1972) reported that stomach contents of dugongs were almost exclusively sea grasses and no animal matter was found. Marine mammals accumulate various pollutants from their environment mostly through food unlike fihes which concentrate pollutants through both food and water. Therefore it is concluded that the difference in contamination by mercury and organochlorine compounds between dugongs and other marine carnivorous mammals is mainly due to the difference of their food.

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ORGAN WEIGHTS OF *DUGONG DUGON*

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When the International Ocean Exposition (1975) took place in Okinawa, two dugongs (*Dugong dugon*) were donated from Indonesian Government to Japanese Government, but these died within a short period of 22 and 23 days after arrival. With the permission of Philippine Government, three more dugongs were subsequently imported to Japan until recently and attempts were made to maintain them. While two of these dugongs died, the remaining one still remains healthy in Toba Aquarium, after two years record history of maintenance in May 1979, daily renewing the record of maintenance of dugong in Japan. Apart from these, a dugong cadaver was brought to Japan from Philippine for scientific studies. In January 1979, moreover, a female infant dugong was caught by a fishing net in the suburbs of Nago, Okinawa (26°32′N, 128°07′E) and an attempt was made to maintain it, but death occurred 33 days later.

TABLE 1. BODY AND INTESTINE LENGTHS AND THEIR RATIOS IN SIX SPECIMENS OF *DUGONG DUGON*

Specimen number	Body length (m)	Small intestine (m)	Large intestine (m)	Ratio
D-1	1.38	5.40	8.80	10.3
D-2	1.55	5.85	7.45	8.6
D-3	1.58	7.30	12.46	12.5
D-4	1.69	6.66	12.70	11.5
D-5	2.04	7.13	12.25	9.5
D-6	2.54	9.60	14.50	9.5

We have conducted a biological survey and investigation on the cause of death in these six animals. In the present paper, the organ weights in these six dugongs and the ratio of each value to body weight was summarized in Table 2. Most of the organs were weighed fresh at autopsy, but some of them were weighed after fixation in 10% formalin solution.

In addition, the length of the intestine (Table 1), and the photographs of external appearance of main organs (Pl. I–IV) were given. The body length was

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TABLE 2. BODY LENGTH, BODY WEIGHT AND ORGAN

Specimen number		D-1	D-2
Body length		135.0 cm	155.0 cm
Sex		M	M
Body weight (at autopsy)		47.0 kg	52.2 kg
Body weight (at capture)			
Locality		Philippines (Luzon Isl.)	Philippines (Luzon Isl.)
Brain		160.0 g (0.340)	
Spinal cord			
Heart		107.0 (0.228)	160.0 g (0.306)
Spleen			9.0 (0.0172)
Lung	l	625.0 (1.330)	425.0 (0.814)
	r		495.0 (0.948)
Stomach			
Small intestine			
Large intestine			
Liver		675.0 (1.436)	755.0 (1.466)
Pancreas		18.0 (0.038)	16.0 (0.0306)
Parotis	l	50.0 (0.106)	
	r	55.0 (0.117)	
Kidney	l		150.0 (0.287)
	r		150.0 (0.287)
Adrenal	l		1.0 (0.00191)
	r		0.8 (0.00153)
Thyroid			
Thymus	r		
	l		
Pituitary		0.6* (0.000127)	
Testis	l		
	r	3.0* (0.00638)	
Epididymis	l		
	r	2.0* (0.00426)	
Ovary	l		
	r		
Integument =(Blubber)		13,000.0 (27.66)	

* calculated from the value after preservation in 10% formalin solution.
Figures in parentheses indicate percentages of body weight.

defined as the length from the tip of the head to the tail base. The body weight was recorded at the time of death. Since body weight undergone a considerable variation according to the condition of maintenance, the body weight at the time of capture was also described together. The detailed anatomical findings of these internal organs currently under investigation will be reported elsewhere in a morphological research journal.

ACKNOWLEDGMENTS

We wish to express our thanks to the Directors and staffs of the Kamogawa Sea

WEIGHT OF SIX SPECIMENS OF *DUGONG DUGON*

D-3	D-4	D-5	D-6
158.5 cm	169.7 cm	204.0 cm	254.0 cm
F	M	F	F
76.5 kg	80.1 kg	120.5 kg	220.5 kg
		155.0 kg	262.0 kg
Okinawa	Philippines (Luzon Isl.)	Indonesia (Sulawesi Isl.)	Indonesia (Sulawesi Isl.)
218.0 g (0.286)	225.0 g (0.280)	250.0 g (0.207)	250.0 g (0.113)
40.0 (0.0528)			
		265.0 (0.220)	500.0 (0.227)
19.0 (0.0362)	29.0 (0.0362)	18.0 (0.015)	28.0 (0.0127)
		900.0 (0.747)	1,650.0 (0.748)
		950.0 (0.788)	1.450.0 (0.658)
910.0 (1.194)		1,950.0 (1.618)	4,250.0 (1.927)
1,440.0 (1.889)		1,800.0 (1.494)	4,000.0 (1.814)
1,900.0 (2.493)		2,600.0 (2.158)	4,450.0 (2.018)
1,125.0 (1.476)	1,780.0 (2.222)	1,650.0 (1.369)	3,150.0 (1.429)
45.0 (0.0591)	40.0 (0.0499)	50.0 (0.041)	45.0 (0.0204)
	263.0 (0.328)	350.0 (0.290)	600.0 (0.272)
	260.0 (0.324)	320.0 (0.266)	500.0 (0.227)
	1.7 (0.00212)		3.5 (0.00159)
	1.5 (0.00187)		3.4 (0.00154)
25.5 (0.0335)	7.0 (0.00873)	11.5 (0.0095)	16.0 (0.00726)
45.5 (0.0597)			
49.0 (0.0643)			
0.6 (0.000787)		0.9 (0.00075)	0.9 (0.000408)
	2.1 (0.00262)		
	1.2 (0.00149)		
			12.0* (0.00544)
18,600.0 (24.41)			

World, Toba Aquarium, Okinawa Marine Park Centre and Sunshine International Aquarium for giving chance for material examination and to Prof. M. Nishiwaki of University of the Ryukyus for his valuable advice.

EXPLANATION OF PLATES

PLATE I

Fig. 1. Ventral dissection of the thracoabdominal viscera. Female, 204 cm length. D: duodenal diverticulum G: gallbladder H: heart S: stomach

Fig. 2. Ventral aspect of the thoracic viscera. Male, 158.5 cm length. Arrow shows the left superior vena cava. A: arch of the aorta.

Fig. 3. Hemisection of heart of a 254 cm length, female. The deep interventricular sulcus is indicated by the arrow.

PLATE II

Fig. 1. Stomach and proximal duodenum. Female, 204 cm length. Cg: cardiac gland Dl: left duodenal diverticulum Dr: right duodenal diverticulum O: oesophagus

Fig. 2. Visceral aspect of the liver. Female, 204 cm length. R: right lobe G: gallbladder

Fig. 3. Ventral aspect of intact pancreas. Male, 169.7 cm length. C: cauda of pancreas

Fig. 4. Digestive tract. Female, 158.5 cm length. C: cecum D: duodenal diverticulum I: small intestine K: kidney L: liver LI: large intestine S: stomach

Fig. 5. Dorsal aspect of the spleen. Female, 204 cm length.

PLATE III

Fig. 1. Ventral aspect of the right kidney. Female, 204 cm length. U: ureter

Fig. 2. Posterior view of the male reproductive tract and urinary bladder of a 135 cm length. B: urinary bladder E: epididymis S: seminal vesicle T: testis U: ureter

Fig. 3. Ventral aspect of the adrenal gland. Male, 155 cm length.

Fig. 4. Visceral aspect of the right ovary of 254 cm length. The ovarian follicle indicated by the arrow.

Fig. 5. Ventral aspect of the pituitary gland. Female, 204 cm length. ×5.5

PLATE IV

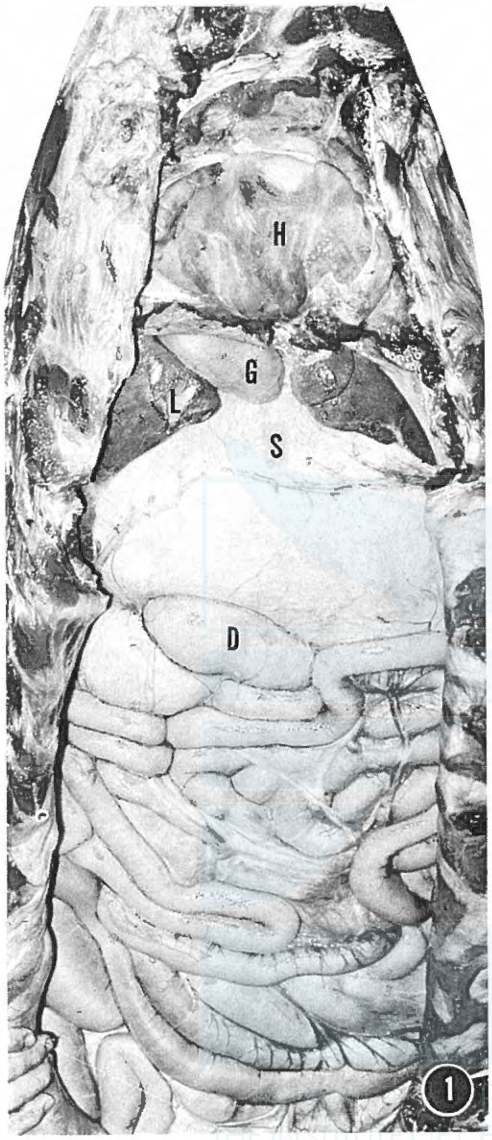
Fig. 1. Dorsal aspect of the brain. Female, 254 cm length.

Fig. 2. Lateral aspect of the brain. Female, 254 cm length.

Fig. 3. Ventral aspect of the brain. Female, 254 cm length.

Fig. 4. Dorsal aspect of the spinal cord. Male, 135 cm length. $C_1 \sim Th_3$ (left) and $Th_4 \sim Th_8$ (right).

Fig. 5. Dorsal aspect of the spinal cord. Male, 135 cm length. $Th_9 \sim Th_{13}$ (left), $Th_{14} \sim Th_{18}$ (middle) and $Th_{19} \sim L_4$ (right).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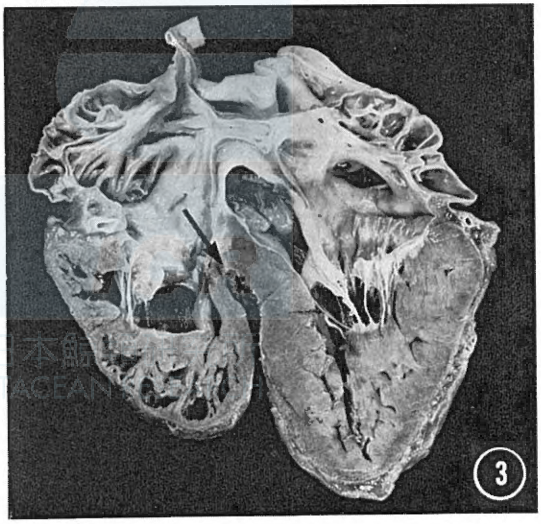
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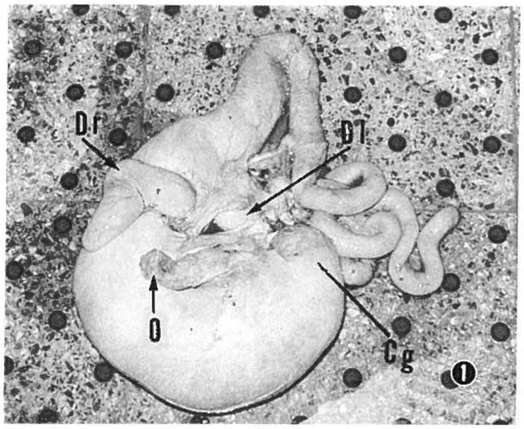
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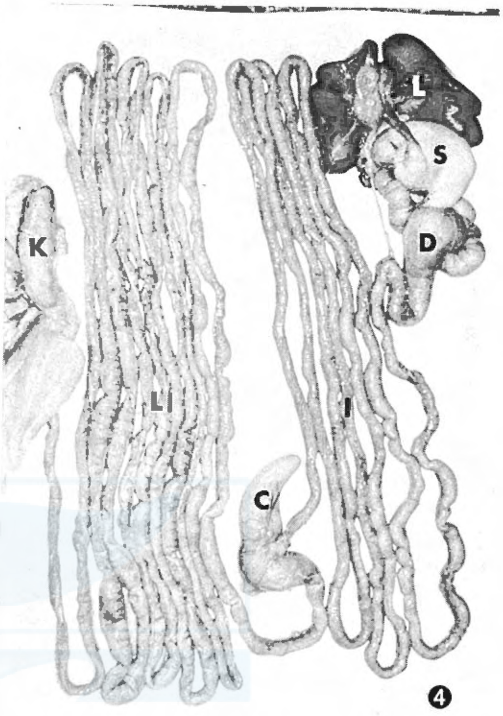
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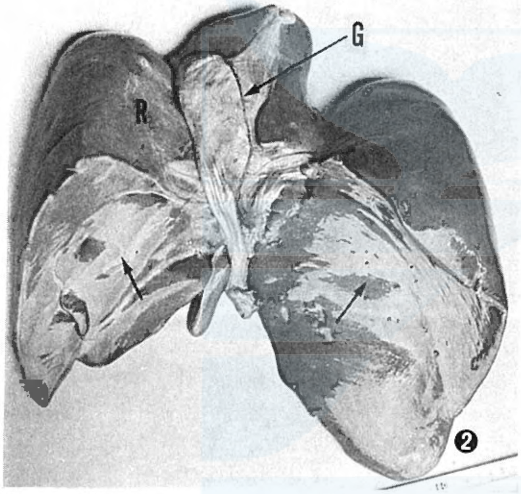
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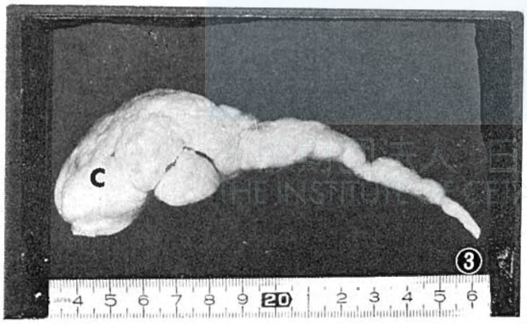
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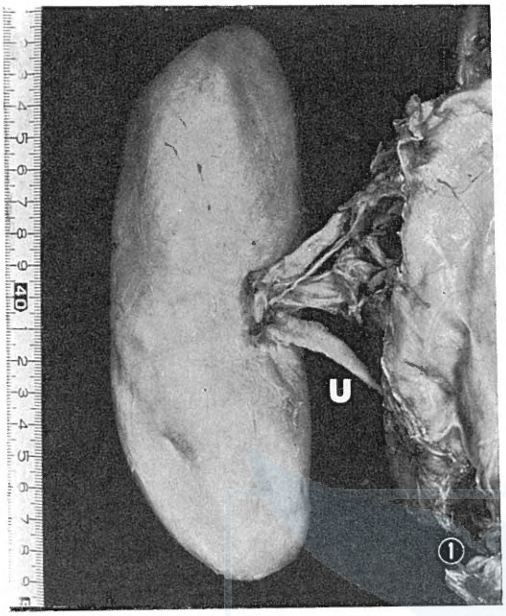
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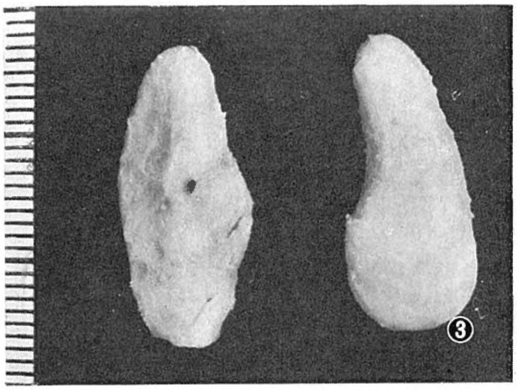
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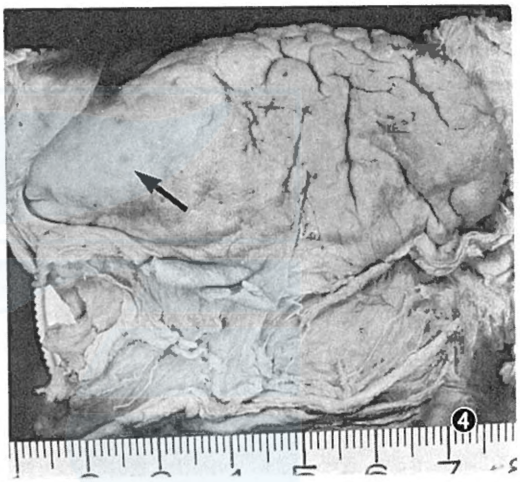
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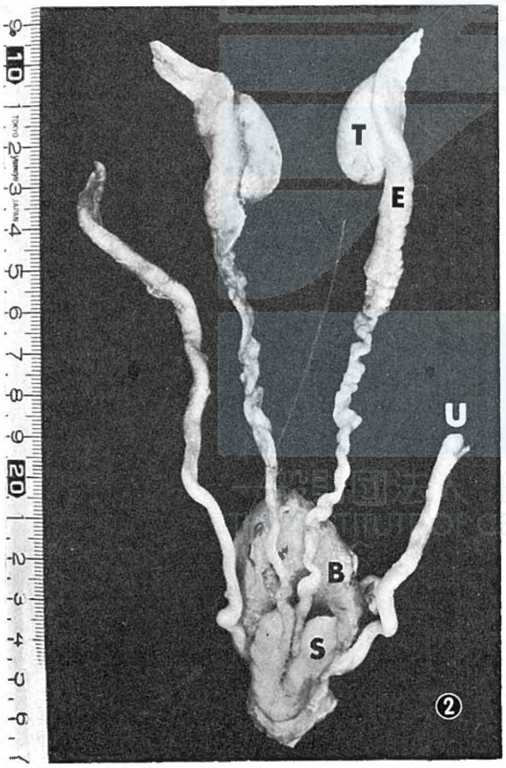
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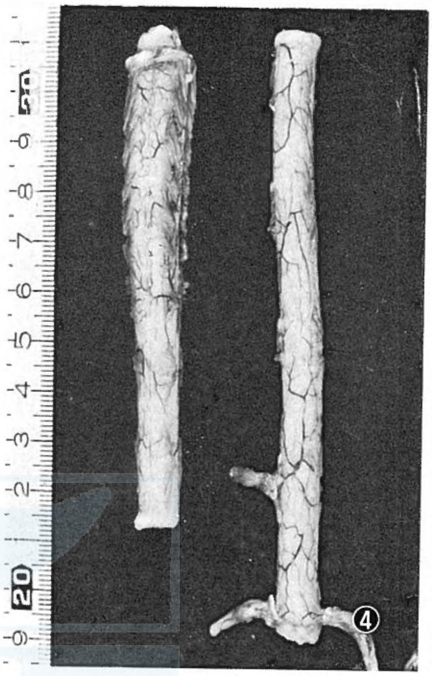
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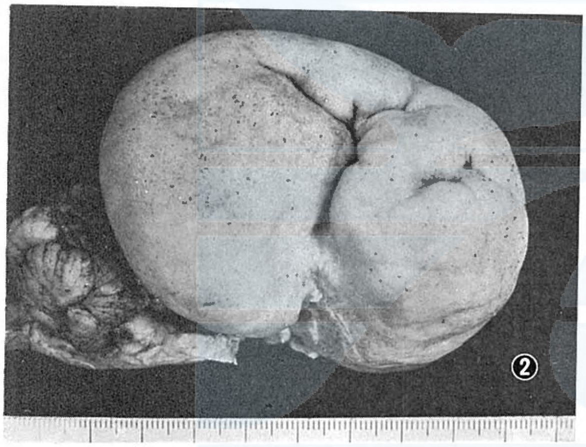
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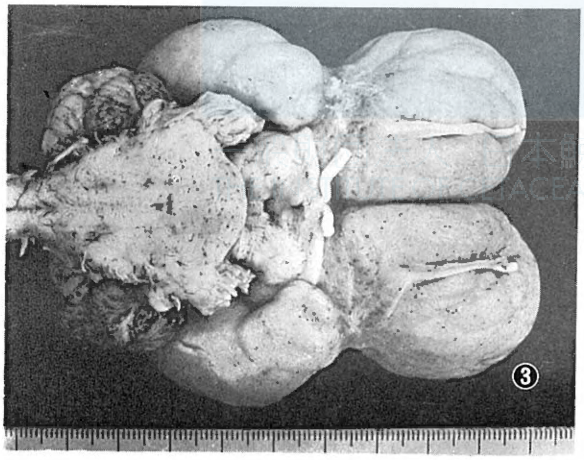
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PRESENT DISTRIBUTION OF THE DUGONG IN THE WORLD

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ABSTRACT

This is a result of hearing surveys on dugong distribution in the past 10 years. The species is distributed widely in the Indo-Pacific Ocean, between the longitude of 30°E and 170°E, and between the latitude of 30°N and 30°S. Although nothing is known on movement and seasonal migration of the species, discontinuity of distribution or of density suggests the presence of at least five populations. They are (1) east Australian and east Papua New Guinean group, (2) west Australia-Molucca-Philippine group, (3) Sumatura-Malaysia-Andaman group, (4) Indo-Sri Lanka group and (5) east African and Madagascar group. Their range might have been continuous before depletion by human activities, and the first three populations may still be continuous dispersely. The forth and fifth group seems to be on the verge of extinction. The total population of 30,000 individuals is roughly presumed by Nishiwaki.

INTRODUCTION

Since the Human Environment Conference of the United Nations held at Stockholm in 1972, conservation of marine mammals has been called loudly. Particularly calls were concentrated on cetaceans. Then conservation on sirenians followed as a matter of concern. Studies on the dugong and the species of manatees have progressed at the same time (Bertram, 1976).

The first step needed for conservation is to clarify the habitat, range of dis-

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tribution, and abundance. The present study will throw a light on the actual status of the distribution of *Dugong dugon* (Müller 1776) in the world.

HEARING SURVEY OVER THE INDO-PACIFIC REGION

Method and area covered

The data are collected from the information through the two expeditions to the Indo-Pacific region in 1977 and 1978, and of that collected by some of the authors individually in recent 10 years.

In 1977, Nishiwaki and Tobayama travelled to Indonesia, Sri Lanka, south India, Kenya, Tanzania, and Madagascar including the Comoro Islands. And in 1978, Nishiwaki, Kasuya, Miyazaki, and Kataoka surveyed Micronesia, Melanesia, Fiji, Indonesia, and Australia. The latter put stress on to know the eastern limit of distribution. Information was collected from local scientists, fishermen and other people who were expected to know the species. Our inquiry consisted of three questions by showing three photographs of dugong. They were, 1: " Have you ever seen or heard of the animals in this area? ", if answer was " Yes ", 2: " Where and when did you do it ", and " How many? ", and 3: " Do you think dugongs are still there? ". If possible, our effort was made to confirm the fragments of skeleton, record in market, or hunting instruments. Palau Islands was not surveyed in the trip, because existence of dugong on the islands was known since long time before (Asano, 1935; Hirasaka, 1933; R. L. Brownell Jr, pers. comm.) and Nishiwaki investigated the islands in 1973 and 1974. In all through the surveys, our best effort was made to eliminate the confusion of other marine animals with dugong.

Result of hearing survey

The information of the dugong distribution obtained in the present study is as follows.

(1) Absence of dugong was concluded on: Johnston I., Saipan, Caroline Islands (Truk Is., Ponape I., Ulithi Atoll, Ngulu Atoll, Nama I., Lukunor Atoll, Satawan Atoll), Marshall Islands (Majuro Atoll, Kusaie I.), Gilbert Islands, Nauru Island, Ellice Islands, Fiji, Surabaja (Java), Borneo (northern and eastern coast), Chon Buri (Bangkok Bay), Chittagong, Dacca, Khulna, Calcutta, Madras, Karachi, Bahrain, Seychelles.

(2) Constant distribution was proven on: Palau Islands, Solomon Islands, New Hebrides, New Caledonia, Papua New Guinea (Lae, Port Moresby), Townsville, Thursday Island, Friday Island, Mulgrave Island, Philippines (Manila, Palawan, Iloilo, Cebu, Tacloban, Polillo Is., Zamboanga), Borneo (west coast), Sulawesi, Bali, Java (Denpasar, Banjuwangi, Serang), Bangka Island, east coast of Malay Peninsula (Songkhla, Surat Thani), west coast of Malay Peninsula (Pinang, Phuket), Rangoon, Ramree Island, Sri Lanka (Colombo, Jaffna), Adams Bridge, Trivandrum, Calicut, Bombay, Madagascar (Tananarive, Nossi-Be I., Majunga), Comoro Islands, Dar-es-Salaam,

Mombassa, Zanzibar, Juddah

(3) Places of rare occurences or of doubtful information taken:

(a) On Guam Island, we met five fishermen or sport divers. A friend of one of the divers, who was also a sport diver, told his encounter under water an animal looks like a sea lion. The sea lion is not distributed in the island. Another information was obtained from a fisherman. He told that he had observed, from a boat, a large animal submerged under water near the southern tip of Guam Island. In the next day he found a long grazing traces in the sea grass at that position. Though the two information may possiblly be a dugong, we consider that further confirmation is necessary before its conclusion.

(b) Among 20 people we met at Yap Island in 1978, only 9 persons knew the dugong. One dugong was captured by a turtle hunter about 15 years ago, and the animal was sold at the market. This information was confirmed individually by eight persons including the hunter and a manager of the market. Another invididual was sighted in 1977 while staying at the bottom by the turtle hunter who witnessed the previous catch at the market. The information suggests that the species occurs in Yap coast very seldom.

The above information are summerized in Fig. 1, together with various past records of the species. Among the descriptions on dugong distribution ever published, that of Husar (1975) is closest to the present result. The important differences are as follows.

In her map, this species occurs in Marshall Is., Gilbert Is., and Ellice Is. Only one doubtfully supported it was a steward of a hotel at Majuro Island. He told us that he had seen an animal looked like dugong in Maloelap Island. However no other information in this region agreed the presence of the species, and we concluded that the species does not inhabit the islands. This conclusion fit to the opinion of Mr B. Puleloa, a District Fisheries Officer of Marshall Islands. The distribution of the species in Micronesia seems to be limited geographically. All information obtained by us certainly deny the distribution of the species in Micronesia except Palau, Yap and Guam Is., and constant inhabitation was only in the Palau Islands.

Dugong does not seem to be distributed in the Laccadive and Maldive Islands (S. Jones, pers. comm.). Though our survey denyed the presence of the dugong at Bahrain, it was recently documented by Gallagher (1976).

Although there has been no study on the diving depth of dugongs, they do not seem to dive so deep as cetaceans do. It may be safe to say that dugongs inhabit the waters not far from shore, namely limited usually within the depth of about 20 meters, however, they will be able to stray or to migrate across the open sea. Distribution of the dugong is parallel to that of the sea grasses, genera *Zostera*, *Cymodocea*, *Thalassia*, or *Thlassodendron* (Heinsohn *et al.*, 1977), though these grasses do not always invite dugongs. At Ponape and Truk Islands in Micronesia, there are abundant sea grasses but people said without exception that they had never seen dugong there. Another example is in the southern districts of Japan

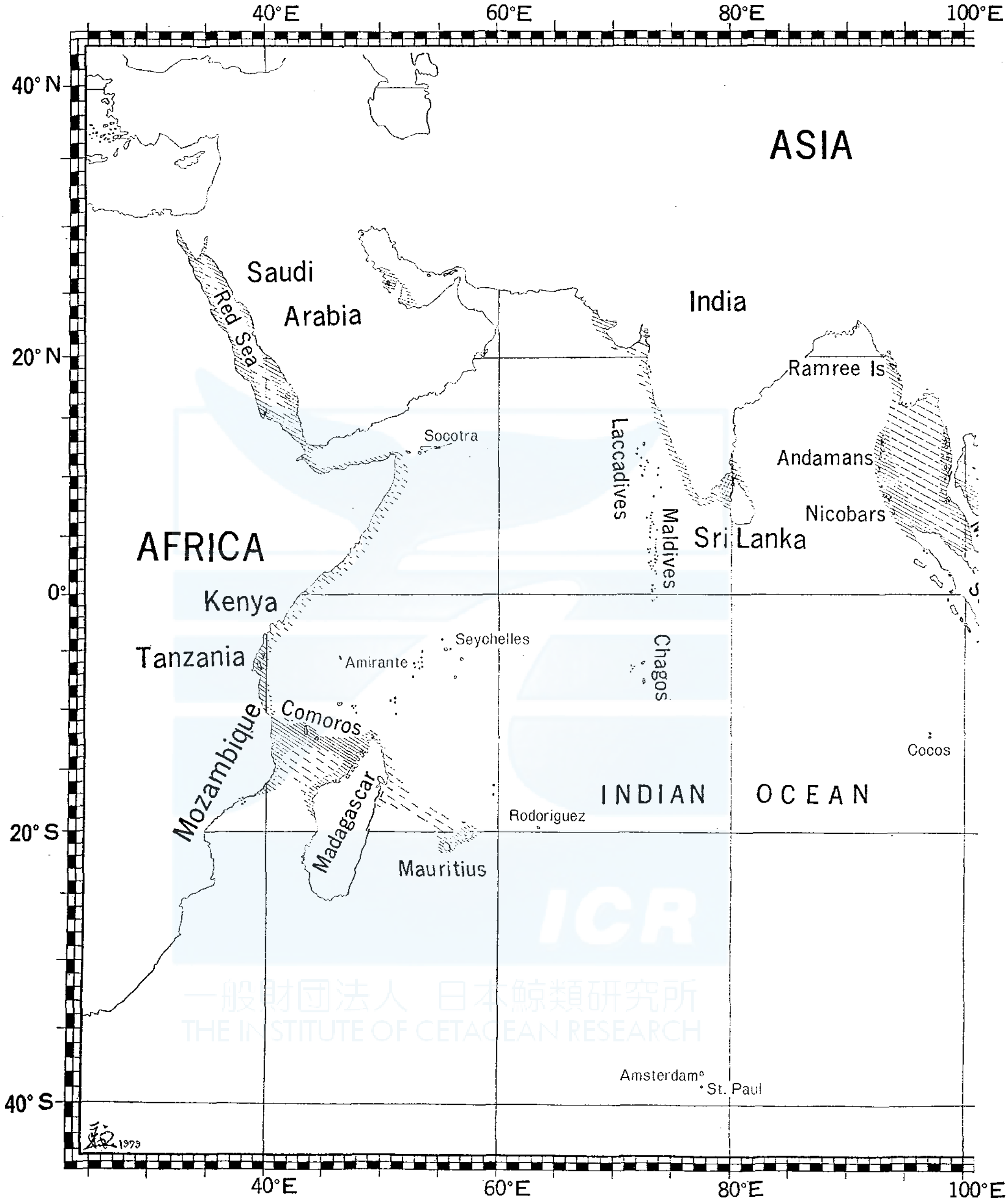
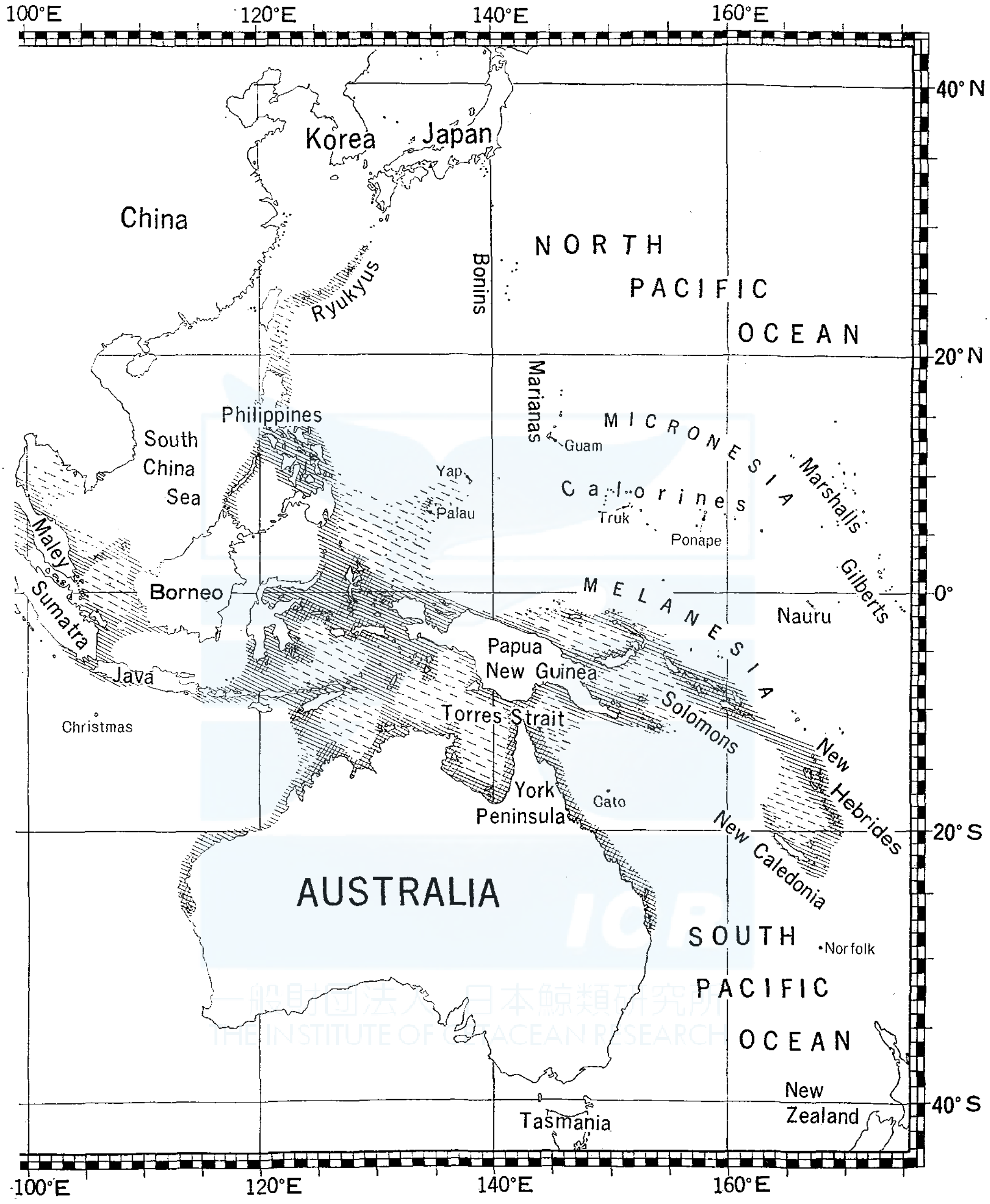


Fig. 1. A map indicating the present distribution of the dugong (*Dugong dugon*) in the world.



▩ abundant, ▧ scarce, ▨ rare or connecting route only.

proper. There are abundant *Zostera* spp. to form a good shelter for various fishes, but no dugong has ever been found in the waters north of 30°N.

Another factor influences the dugong distribution may be the water temperature. The northern limit of the species is at Amami Oshima Islands in the southern Japan or at the latitude of about 29°N. These range nearly coincides with the mean surface water temperature of 23°C. The dugong seems to be sedentary and may not make long seasonal migration affected by the seasonal change of the water temperature. Accordingly, if there is any record of the occurrence of the dugong in the waters below the above mentioned temperature, we shall investigate most carefully whether or not the animal belongs to species of cetacean genera *Orcaella* or *Neophocaena*. In March 1979, an animal belonging to the latter genus was misidentified by local people in western Kyushu as a dead dugong.

The third factor influences dugong distribution may be the ocean current. In the wide area of Micronesia, the Palau Islands situated at the western part, is the only place of constant dugong inhabitation. Though, as mentioned above, Ponape and Truk Islands can be a good habitat of the dugong, there is no evidence of dugong distribution. The North Equatorial Current may be a reason of this distribution pattern. If there found some strayed individuals migrating from Melanesia to Micronesia in the north, they were drifted to the west by the current and eventually, unable to reach to central or eastern Micronesia, but arrived at Palau or other nearby islands. This hypothesis suggests that the dugong population in Palau Islands recruited from the population of Melanesia and Papua New Guinea.

Discreteness of the populations

Little have been known about the discreteness of the dugong population. Following is a tentative separation of populations based on geographical differences in density or hiatus of distribution. It is reasonable to consider that there are smaller local breeding units in each population as it is already indicated in the presence of geographical differences in growth rate observed between the populations on the eastern and northern coasts of Australia (Marsh, in press).

Population 1 seems to be distributed widely and densely along the east coast of Australia from about 30°S to Papua New Guinea. It ranges from west of 170°E, and includes the islands of Melanesia, Solomon Is., New Hebrides and New Caledonia. The southern limit of distribution is at Moreton Bay on the east coast of Australia, or at about 30°S. The western boundary of this population, may presumably be at around 140°E.

Population 2 is considered to range from northwest coast of Australia to Amami Oshima at 29°N which is the northern limit in the Pacific, through west coast of Papua New Guinea and the Philippines. The boundary between the populations 1 and 2, especially on the northern coast of Australia, is not distinct. They are possibly of one continued population.

Population 3 is distributed from the west coast of Borneo and west Java to the both coasts of Malay Peninsula, and from the northern coast of Sumatra Island to the Nicobar and the Andaman Islands, and as north as to Ramree Island. There is no distribution of the species in the Bangkok Bay, which may possibly be related to the muddy bottom and poor sea grass. However the occasional catch along the coast of the Gulf of Thailand was reported by Thiemmedh (1961). Although the distribution along the coast of Cambodia and Viet Nam is unknown, we have heard that some marine mammals were in the lagoon of Cotin China (Viet Name and Cambodia). Presumably they were *Neophocaena* or *Orcaella.* Further investigation in the area is desirable. This population is separated from population 2 by a dispersed distribution area near Borneo and Java or along the longitude of 110°E (Nishiwaki, 1977).

Population 4 ranges from Sri Lanka to the northwest coast of India. The boundary between populations 3 and 4 may be along the longitude of 90°E. This population seems to have had wider distribution in the past, but is apparently decreasing (Bertram and Bertram, 1970; Jones, 1976).

Population 5 ranges from the Red Sea (Gohar, 1957), through east coast of Africa, and Madagascar, to Mauritius. Though dugongs were abundant in former days in the area, they have decreased drastically through the long history of hunting (Gallagher, 1976; Bertram pers. comm., 1979). It was heard that there had been few recent sightings along the coasts of Kenya, Tanzania and the northwest Madagascar (Ligon, 1976), and hunting seems to be still continued. At the Seychelles Islands, a scientist said that there had been some dugongs at the Praslin Islands group in the past but there is no sighting now. At Mauritius, they told us that they seldom saw dugongs. It was told that the species was most abundant, among the east African and Madagascar region, at the Comoro Islands. In the Museum of Tananarive, there was a series of whole skeletons of the dugong collected at the northwest coast of Madagascar. The western limit of the distribution is at the northern part of Red Sea and the northern limit is in the Indian Ocean region is also there.

A presumption on abundance

Following comment on the population abundance was made by M. Nishiwaki.

For conservation of marine mammals, it is necessary to study status of population as well as distribution of them. Because it is nearly impossible to count precise number of marine mammals in the water, estimation of number of animals has to be done based on biological knowledge and statistical records of animal catch. Nishiwaki heard that about 500 animals are killed annually in Torres Strait and York Peninsula area, but there is no statistical record, only scarce data have been collected from the remains of dugong carcasses. In many places protection laws on paper spread, but local people continue to catch dugongs secretly. Secret catch can do nothing for collection of data.

Heinsohn *et al.* (1976), Heinsohn (1978), and Ligon (1976) reported about their aerial countings but they have not published on the population number yet. Some of the present authors were able to join in aerial survey by the thoughtful cooperation of Dr Heinsohn. We counted dugongs as ten individuals per hour from 900 feet altitude and speed of 100 miles per hour at Halifax Bay area. Though data was scarce and accumulation of experiences were little, Nishiwaki dared to make rough presumption over the five populations. His presumption is merely a milestone to future estimations, but he would like to invite opinions and corrections on this presumtion. He estimates the number of dugongs as 5,000 in the east coast of Australia, 6,000 for the Torres Strait and York Peninsula area, and 7,000 in Melanesia. This lead to the total of 18,000 in population 1. Number of dogongs in population 2 is 4,000 in the southern latitude area and 3,000 in the northern latitude area. The population size will be about 2,500 in population 3, 1,000 in population 4, 1,000 in population 5 north of equator, and 500 in the same population south of equator. The number of dugongs all over the Indo-Pacific region may be roughly 30,000 animals. populations 4 and 5 seem to be near to desperation.

It should be emphasized that the accumulation of statistical records of dugong catch and biological knowledge on the species are fundamental matter for conservation of the dugong population.

ACKNOWLEDGMENT

Countless number of scientists, fishermen and laymen helped us and offered the information to us during our travel around the coasts and islands of Indo-Pacific region for hearing survey. We would like to mention some unforgettable names; these people are Mr C. Raticliffe of Seychelles, Mr John Handley of Fiji, Mr Martin Cristian of Ponape, Mr T. Johes of Honiala, Mrs Lymde Tranter of Tarawa, Mr S. Mori of Dar-es-Salaan, Tanzania, and Mr Kazuo Uemura of Toshoku Ltd., Tananarive, Malagasy Republic.

Scientists with whom we met during our survey and exchanged opinions, or those who helped us in collecting data were Mr Skiman Hendrokusumo and Mr Tas'An of Jaya Ancol Oceanarium, Indonesia, Mr Chandima de Alwis of the National Zoological Garden, Sri Lanka, Dr R. L. Brownell Jr of Smithsonian Institution.

While Seminar Workshop on Dugong was held at James Cook University, Townsville, Australia, we were able to meet many distinguished specialists on the dugong and learned latest and reliable knowledge. Especially, our gratitudes are to Drs G. E. Heinsohn, Helen Marsh and David Blair of James Cook University, Dr P. K. Anderson of University of Calgary, Canada, Mr Ephraim Bani of University of Queensland, Dr G.C.L. Bertram of St. John's College, U. K., Mr Murray Elliott of Territory Parks and Wildlife Commission N. T., Mrs Bryget Hudson of Wildlife Division, P.N.G., Drs S. Jones and E. G. Silas of the Central Marine Fisheries Research Institute, India.

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A NOTE ON STAMPS OF DUGONG

The government of the Ryukyus under occupation of U.S. issued a stamp of a dugong picture as a rare animal on 20th April 1966. According to Mr A. Isagawa who designed the picture, the motive of the issuance was to make a serial stamps of animals which were protected by the law in Okinawa at that time.

Another stamp of dugong picture was sold at Dar-es-Salaam, as a simbol of endangered species when the research project members visited there.

Stamps of dugong picture. Left: Issued by the Government of the Ryukyus. Right: Issued by the Government of Tanzania.

一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

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