ISSN 0083-9086

THE
SCIENTIFIC REPORTS
OF
THE WHALES RESEARCH INSTITUTE

No. 37

THE WHALES RESEARCH INSTITUTE
TOKYO · JAPAN

MARCH 1986

Sci. Rep. Whales
Res. Inst., No. 37

THE
SCIENTIFIC REPORTS
OF
THE WHALES RESEARCH INSTITUTE

No. 37

THE WHALES RESEARCH INSTITUTE
TOKYO, JAPAN

MARCH, 1986

THE WHALES RESEARCH INSTITUTE
3-32-11 OHJIMA, KOTO-KU, TOKYO 136

THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE

CONTENTS OF NUMBER 37

目　　次

YEARLY CHANGE IN AGE AND BODY LENGTH AT SEXUAL MATURITY OF A FIN WHALE STOCK IN THE EASTERN NORTH PACIFIC*

SEIJI OHSUMI**

ABSTRACT

The age and body length at sexual maturity were studied on the eastern stock (east of 180° Longitude) of the fin whale (*Balaenoptera physalus*) in the North Pacific by means of two independent examinations of a) proportions of sexual maturity in each age and body length classes and b) age and body length distributions of females with one corpus luteum or corpus albicans in ovaries. Thus, yearly change in these two kinds of biological parameters was analysed by use of data collected from fin whales caught during 22 years from the start to the end of fundamental exploitation of this stock.

Statistically significant yearly change was observed in the ages at sexual maturity which were obtained from both the 50 % maturity and average age of females with one ovarian corpus. The age at sexual maturity was estimated to have changed from 12 to 6 years in females and from 11 to 4 years in males, respectively, from the beginning to the end of the periods of exploitation. The average age of females with one ovarian corpus was 0.5–1 year older than the average age at sexual maturity of females which was estimated from 50 % maturity.

However, no statistically significant trend was observed in the yearly change in the average body length at sexual maturity, and this parameter kept 57.2 and 60.6 feet (17.4 and 18.3 m) for males and females, respectively, during these 22 years. The average body length of females with one ovarian corpus was 0.9 feet (0.3 m) larger than the average body length of females of 50 % maturity.

These phenomena represent that the growth pattern of this whale stock changed from the start of fundamental exploitation. The change in the feeding environments along with the decline of total biomass of baleen whale populations may have affected the growth and maturity of younger animals more strongly than the older.

---

* A draft paper was presented to the International Whaling Commission/Scientific Committee/Minke Whale Ageing Workshop, Cambridge, April 1983 (Document No. SC/A83/AW7).

** *Far Seas Fisheries Research Laboratory, 5-7-1 Orido, Shimizu-shi, 424 Japan.*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 1–16

INTRODUCTION

The age at sexual maturity is recognized as an important biological parameter for the population assessment of whale stocks, and many papers have been reported on this matter, especially since the discovery of teeth (Nishiwaki and Yagi, 1953) and earplugs (Purves, 1955) as age characters for the cetacea in 1950s.

There are several methods to estimate the age at sexual maturity of whales such as: 1) proportion of sexual maturity at different ages, 2) relation between age and corpora numbers in both ovaries, 3) growth curve and body length at sexual maturity, 4) age distribution of females with one ovarian corpus and 5) age at transition phase in earplug. Among them the study of transition phase by Lockyer (1972) provided a new field of studies on the age at sexual maturity.

Possibility of the decline in age at sexual maturity of whale stocks was first suggested by Laws (1962) without direct evidence on the Southern Hemisphere fin whale, and Utrecht-Cook (1966) indicated this kind of phenomenon on the same fin whale stock by use of baleen plates which are recognized not to be so good age character. Lockyer (1972) proved this phenomenon directly on fin whales from the Southern Hemisphere based on the age at transition phase in earplugs. Her paper stimulated whale biologists strongly, and this method has become main tool to study the yearly change in the age at sexual maturity of whale stocks since then. Lockyer (1974) reported the lowered age at sexual maturity in more recent year classes on the Southern Hemisphere sei whale by use of transition phase in earplugs. Masaki (1979), Best (1982) and Kato (1983) all reported the same phenomenon by use of the transition phase of earplugs of the Southern Hemisphere minke whale. However, Cooke and de la Mare (1983) criticized these reports, and they claimed the apparent decline in the age at sexual maturity might be an artifact of the data. They also threw a question on the use of transition phase for studies of the age at sexual maturity of whales.

On the other side, trials to apply other methods than transition phase as indicators of sexual maturity have been continuing (Kato, 1983, Masaki, 1976; 1979, Lockyer, 1983) on the Southern Hemisphere minke, sei and fin whales. This paper aims to find an evidence of yearly change in the age at sexual maturity in the whale without use of the transition phase which has been in large discussion. As such a whale stock, a fin whale stock in the North Pacific was picked up to solve the question.

Fin whales which are distributed in the eastern North Pacific (waters east of 180° Longitude) have been recognized by the International Whaling Commission (IWC) as a stock based on the papers such as Fujino (1960) and Omura and Ohsumi (1964) by means of some methods including blood typing and whale marking. This whale stock began to be exploited along the coasts of California, British Columbia and Alaska from the beginning of this century, but the fundamental exploitation started by pelagic whaling in the waters of the Bering Sea and around Aleutian Is. in 1954 (Japan Whaling Association, 1955). Since then, this fin whale stock continued to be exploited by Canada, Japan, USA and USSR whalers till 1975 when the IWC decided to stop the exploitation. According to Chapman (1976), this stock decreased to 38% of the initial population level by that year. Therefore, this whale stock will be useful for examination of change in population parameters accompanying with the change in population level, because the population level of this stock was estimated to change gradually and largely during relatively long time. In addition to this feature, detailed biological data were collected on each whale caught by Japanese pelagic whaling from the beginning to the end of the fundamental exploitation by the cooperation of many Japanese whale biologists, national inspectors and whaling workers. These data enable us to examine the yearly change in the biological parameters thoroughly.

I would like to express my sincere thanks to these people including technicians who prepared biological materials for this study. I am also indepted to Mr Hidehiro Kato of the Whales Research Institute for his kind review of my manuscript.

MATERIALS

All the materials used for this work were biological data on the fin whales caught in the waters east of 180° Longitude from 1954 to 1975. The following kinds of biological data were used in this study:

Position caught, 1954–1975
Whale species, 1954–1975
Sex, 1954–1975
Body length, 1954–1975 (excluding 1961)
Ovarian corpora numbers: 1954–1975
Weight of testis of each side, 1954–1975
Total age, 1957–1975 (lack of data in 1965)

The position of catch was recorded for each whale in degree and minute. The body length was measured from the tip of snout to the notch of flukes in unit of foot till 1959 and 0.1 m from 1960. Then, foot unit was used in this work converting 0.1 meter unit into foot unit. The females from which both ovaries were collected were used to identify an individual which had one corpus luteum or corpus albicans in total. The sexual maturity of a female was determined as an individual which had at least one corpus luteum or corpus albicans in the ovaries. The sexually immature female was determined as an individual which had neither corpus albicans nor corpus luteum in both ovaries. Other animals were excluded for determination of sexual maturity of females. The male sexual maturity was determined by means of weight of testis, and an individual which had a testis of 2.5 kg and over in any side of testis was regarded as sexually mature based on Ohsumi (1964). If testis of one side was

TABLE 1. NUMBER OF MATERIALS WHICH WERE USED FOR EXAMINATION OF AVERAGE AGE AT SEXUAL MATURITY OF THE FIN WHALE IN THE EASTERN NORTH PACIFIC

Year	Males			Females		
	Immature	Mature	Total	Immature	Mature	Total
1957–58	93	139	232	35	71	106
1959–60	219	257	476	298	271	569
1961–62	183	357	540	255	333	588
1963–64	109	236	345	130	227	357
1966–67	128	110	238	150	93	243
1968–70	46	128	174	74	94	168
1971–73	18	81	99	33	60	93
1974–75	10	69	79	20	42	62
Total	806	1,377	2,183	995	1,191	2,186

TABLE 2. NUMBER OF MATERIALS WHICH WERE USED FOR EXAMINATION OF AVERAGE BODY LENGTH AT SEXUAL MATURITY OF THE FIN WHALE IN THE EASTERN NORTH PACIFIC

Year	Males			Females		
	Immature	Mature	Total	Immature	Mature	Total
1954	71	289	360	103	288	391
1955	122	506	628	168	407	575
1956	65	363	428	105	286	391
1957	83	511	594	130	385	515
1958	156	385	541	170	298	468
1959	114	254	368	157	229	386
1960	169	378	547	230	369	599
1962	110	501	611	114	401	515
1963	104	437	541	126	332	458
1964	92	417	509	120	315	435
1965	141	367	508	156	293	449
1966–67	215	354	569	289	329	618
1968–69	43	225	268	81	143	224
1970–71	69	254	323	101	180	281
1972–73	18	81	99	28	57	85
1974–75	21	93	114	34	65	99
Total	1,593	5,415	7,008	2,112	4,377	6,489

not collected and obtained was less than 2.5 kg in weight, such an individual was excluded from the data for determination of sexual maturity of males. The total age was represented as the total numbers of growth layers in earplug which was read by naked eyes or binocular dissecting microscope after the preparation of the material. The individual of which neonatal line or germinal layer was lost from an earplug was not used in this study. The growth layers in earplug of the fin whale are clearest and easiest to read among all baleen whales.

Tables 1 and 2 show the number of materials used in this study by sex, by maturity and by year.

RESULTS

Proportion of sexually mature whales at each age

Age distribution of sexually immature and mature whales were tabulated on each sex and in each year, and proportions of sexually mature whales at different ages were calculated and plotted in Figs 1 and 2. A curve of change in the proportion was drawn by eye on each graph. Then, the average age at sexual maturity was determined as the age at which 50 % of individuals were sexually mature.

In the early period of exploitation till 1958, sexual maturity started from about 7 years of age and finished by about 16 years of age in the case of males, although the feature in the earliest period was unknown because of no collection of earplugs till 1956. Accompanying with the development of exploitation of this whale stock, the starting age decreased gradually, and it became to be about 2–3 years in the latest period of 1974–75. However, the finishing age of sexual maturity remained almost the same till the middle period of exploitation of 1968–70, and then it became suddenly younger to about 9 years of age in the latest period of 1974–75. The average age at sexual maturity represented as the age of 50 % of sexual maturity gradually decreased from 12.4 to 4.3 years during the periods.

Similar patterns were observed for females. The sexual maturity started from about 9 years of age and finished by about 15 years of age in the early period of exploitation of 1957–58. The starting age of sexual maturity gradually decreased since then, and it became to be about 3 years of age in the latest period of 1974–75. On the other hand, the finishing age remained at almost the same age till the middle period of exploitation of 1968–70, and then it decreased rapidly. It became to be about 12 years of age at the latest period of 1971–75. The average age of females at sexual maturity decreased gradually from 11.2 years in 1957–58 to 5.8 years in 1974–75.

Fig. 3A illustrates yearly change in the average age at sexual maturity in both sexes. The trend in decrease of the age at sexual maturity is clear in both sexes, and there is a trend that they have changed parallelly in each other sex with the difference of about 1.5 years of age. Thus, the figure of males in 1957–58 should be larger than the actual figure. In the case of females the

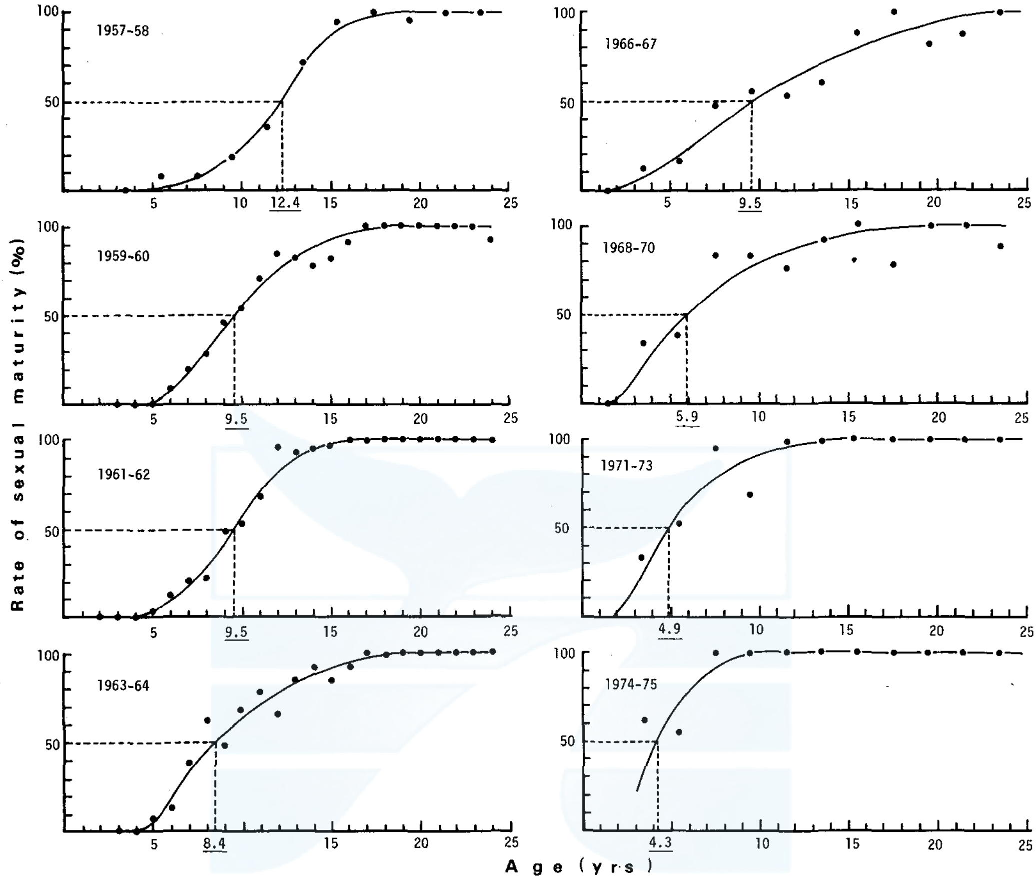

Fig. 1. Average age at sexual maturity of the male fin whale in the eastern North Pacific in each year.

age was about 11 years in 1957–58, and it became to be about 6 years in the period of 1974–75. In males it was about 10 years in 1957–58, and it became to be 4 years in 1974–75. The trend in decline of the average age at sexual maturity was detected statistically with 1 % of risk of error for both sexes. Although there are no data at the start of fundamental exploitation in 1954, the average age at sexual maturity in the period can be estimated to be about 11 and 12 years for males and females, respectively, from a backward extraporation of the line of trend in Fig. 3A.

Age distributions of females with one ovarian corpus

As the sexual maturity of the female is determined as the onset of ovulation, a cetacean female which has one corpus luteum or corpus albicans in ovaries can be regarded as a pubertal or just matured individual. Thus, age distribution

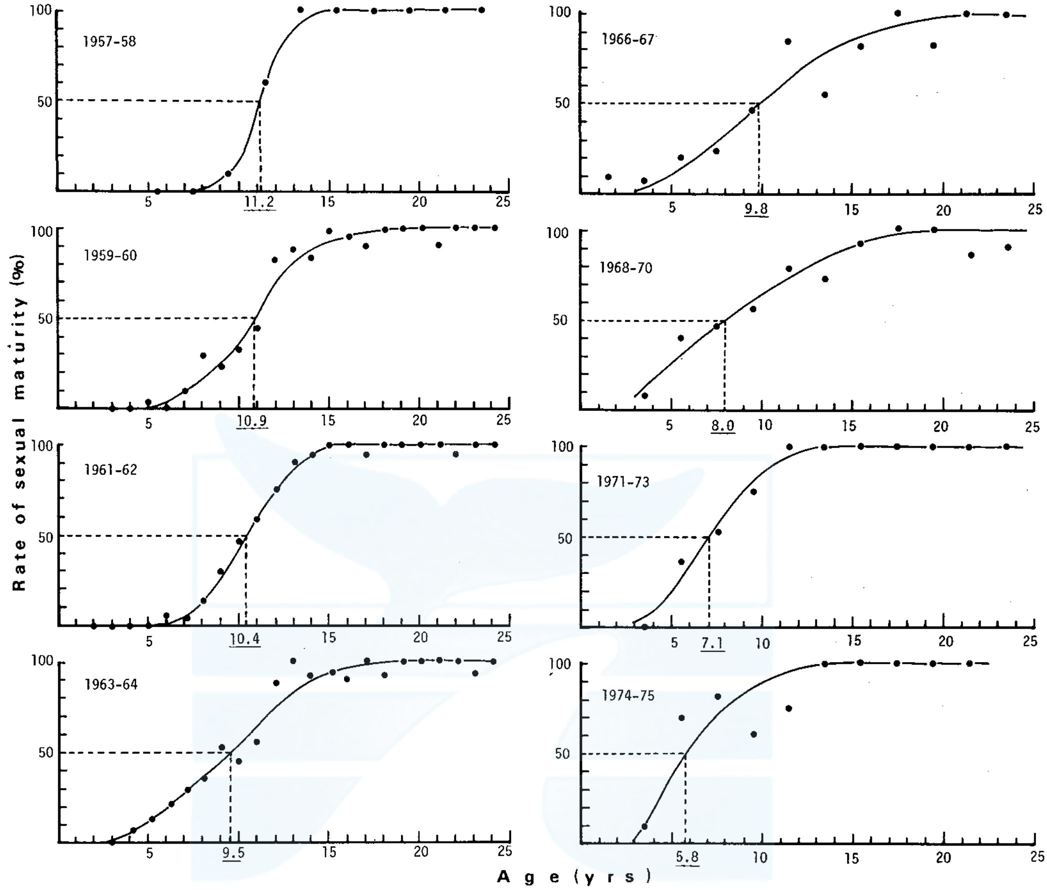

Fig. 2. Average age at sexual maturity of the female fin whale in the eastern North Pacific in each year.

of these animals will indicate the age at sexual maturity independently from the proportions of sexually mature individuals, although the former method will give higher figure, because it includes all females between the first and the second ovulation. On the other hand, it is difficult in the case of males to identify the similar stage to one ovarian corpus like females by means of testis weight, because there is large individual variation in the weight of testis at sexual maturity, so that it is impossible to apply this kind of method for males.

Fig. 4 shows age distributions of females with one ovarian corpus in each period of exploitation. The age showed a normal distribution in the earlier period of exploitation. The attainment of this stage started from 8–9 years of age, and finished by about 20 years of age in the same period. Then, the starting age gradually moved to younger ages, and it became to be about 4 years in the latest period of exploitation. However, the finishing age of this stage

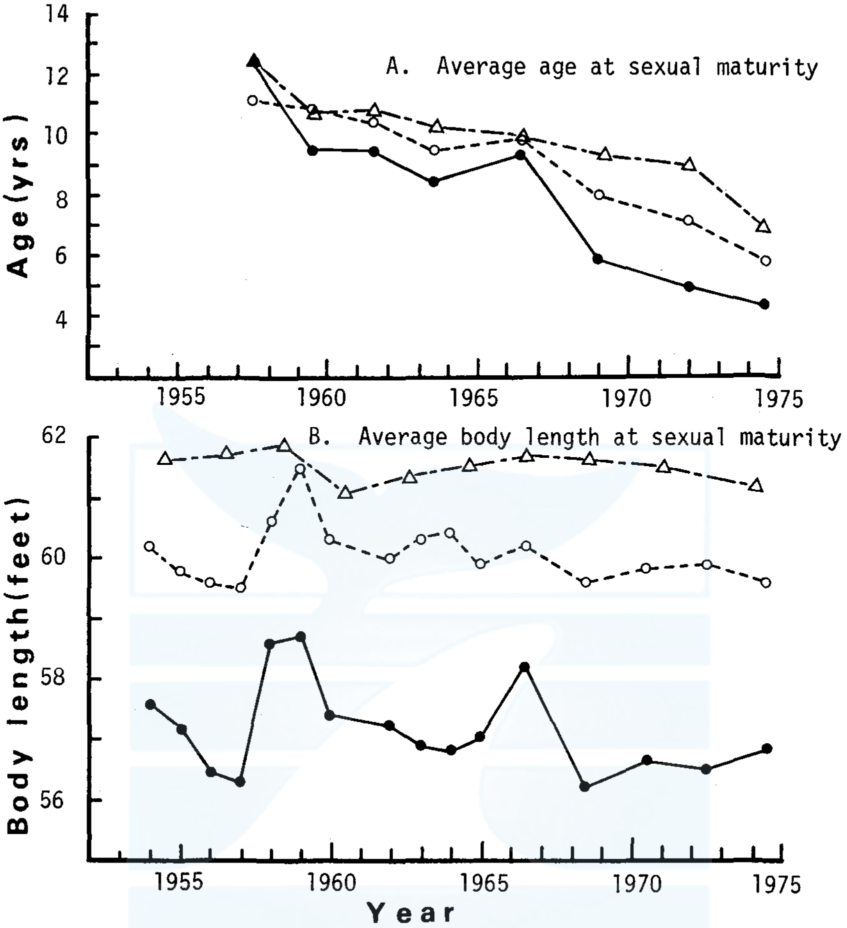

Fig. 3. Yearly change in average age and body length at sexual maturity of the fin whale in the eastern North Pacific. Open circle and broken line: Females, Closed circle and solid line: Males, Cross and chain line: Females which have one corpus luteum or corpus albicans in the ovaries.

remained at almost the same age till the middle period of exploitation, and then it rapidly moved to younger ages in the late stage of exploitation. The range of distribution was relatively narrow in the early period of exploitation, and it became gradually wider to the end of middle period of exploitation. Finally it became again narrow in the latest period. The distribution pattern became gradually skewed to younger side, and the average age of the distributions moved gradually to younger ages accompanying with the exploitation. These phenomena are almost the same as those of the proportion of sexual mature whales as examined in the previous section.

The average age at sexual maturity in each period of exploitation thus obtained in Fig. 4 was plotted on Fig. 3A as same as those in the previous section.

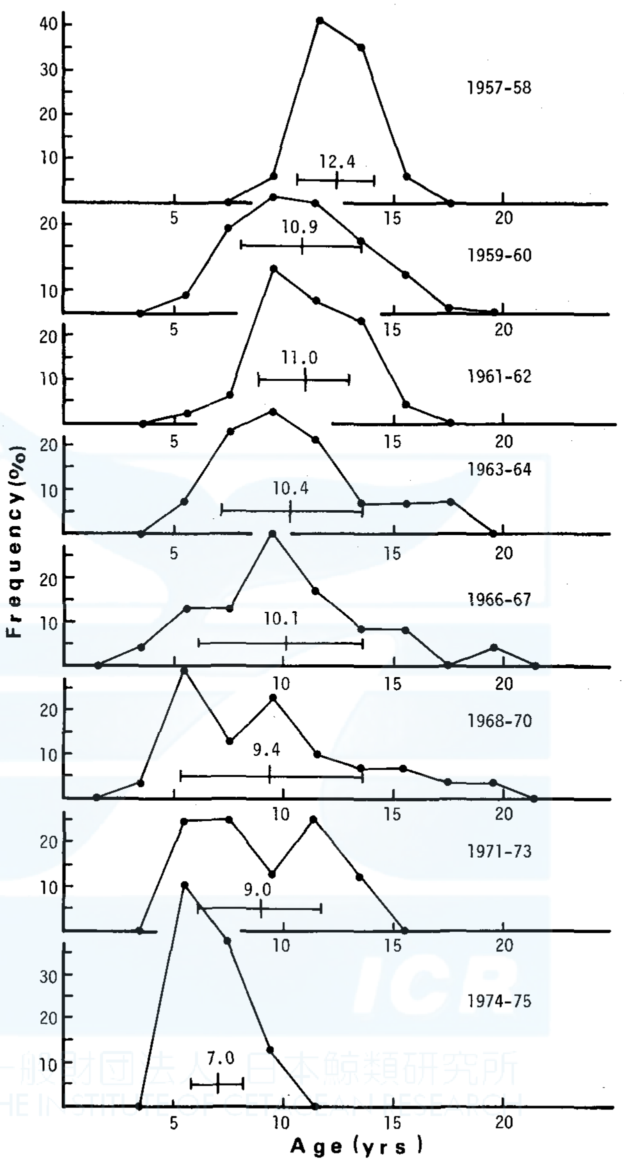

Fig. 4. Age distribution of female fin whales which had one corpus luteum or albicans in the ovaries.

Clear trend in decline in the average ages of females with one ovarian corpus was observed, and it was statistically significant within 1 % of risk of error. The line of average ages runs parallel with that of average ages of females of 50 % sexual maturity, and the former is about 0.5–1 year older than the latter. This means that the average age of females with one ovarian corpus is about 0.5–1 year older than the age at sexual maturity.

From these two independent examinations it can be concluded that the trend in decline of age at sexual maturity was proved for the fin whale stock in the eastern North Pacific.

Proportion of sexually mature individuals in each body length

Size distributions of sexually immature and mature whales were tabulated by sex and by year, and proportions of mature whales in each body length classes were calculated and plotted in Figs 5 and 6 for males and females, respectively. Then, a curve of change in the proportion was drawn by eye on each figure, and the body length at 50 % level of sexual maturity was determined as the average body length at sexual maturity.

Patterns of the curves are almost sigmoidal and similar each other throughout the whole periods of exploitation in both males and females. Males began to be mature from 55–56 feet, and finished maturation by 60–62 feet in body length. As the legal size limit of the North Pacific fin whale maintained at 55 feet for the pelagic whaling throughout the whale periods, this factor will not affect this analysis. The average body lengths of males during the whole periods ranged between 56.2 to 58.2 feet with the average of 57.2 feet (17.4 m). Females began to be mature from 56–57 feet in body length, and most females attained sexual maturity by 63–64 feet. The average body lengths ranged from 59.5 to 61.5 feet throughout the periods of exploitation with the average of 60.1 feet (18.3 m).

Fig. 3B shows yearly change in the average body length at sexual maturity of both sexes. Although some declining trends seem to be seen for both sexes, the trends were not detected statistically within 5 % of risk of error. Therefore, it can be estimated that the body length at sexual maturity was constant throughout the whole periods of exploitation, in spite of the existence of a feature that the age at sexual maturity moved to younger age during the periods.

Size distributions of females with one ovarian corpus

Fig. 7 shows size distributions of females with one ovarian corpus during periods from 1954 to 1975. The smallest body length of these females was 55 feet, and the largest was 69 feet. The distribution patterns of the frequency were almost normal through the all periods, and modes ranged between 60 and 62 feet. All the average body lengths were in a range between 61.1 and 61.9 feet with the average of 61.5 feet (18.6 m). This average figure was 0.9 feet (0.3 m) larger than the average of the average body lengths of females at 50 % maturity as examined in the previous section. This feature coincides with the fact that the mean age of females with one ovarian corpus was higher than that of 50 % maturity. Furthermore, the values of standard deviation were almost the same (1.8–2.7 feet) during all periods.

The average body length in each period was plotted in Fig. 3B to examine the trend in the average body length of females with one ovarian corpus. It was found that there was no trend in change in these values within 1 % of risk

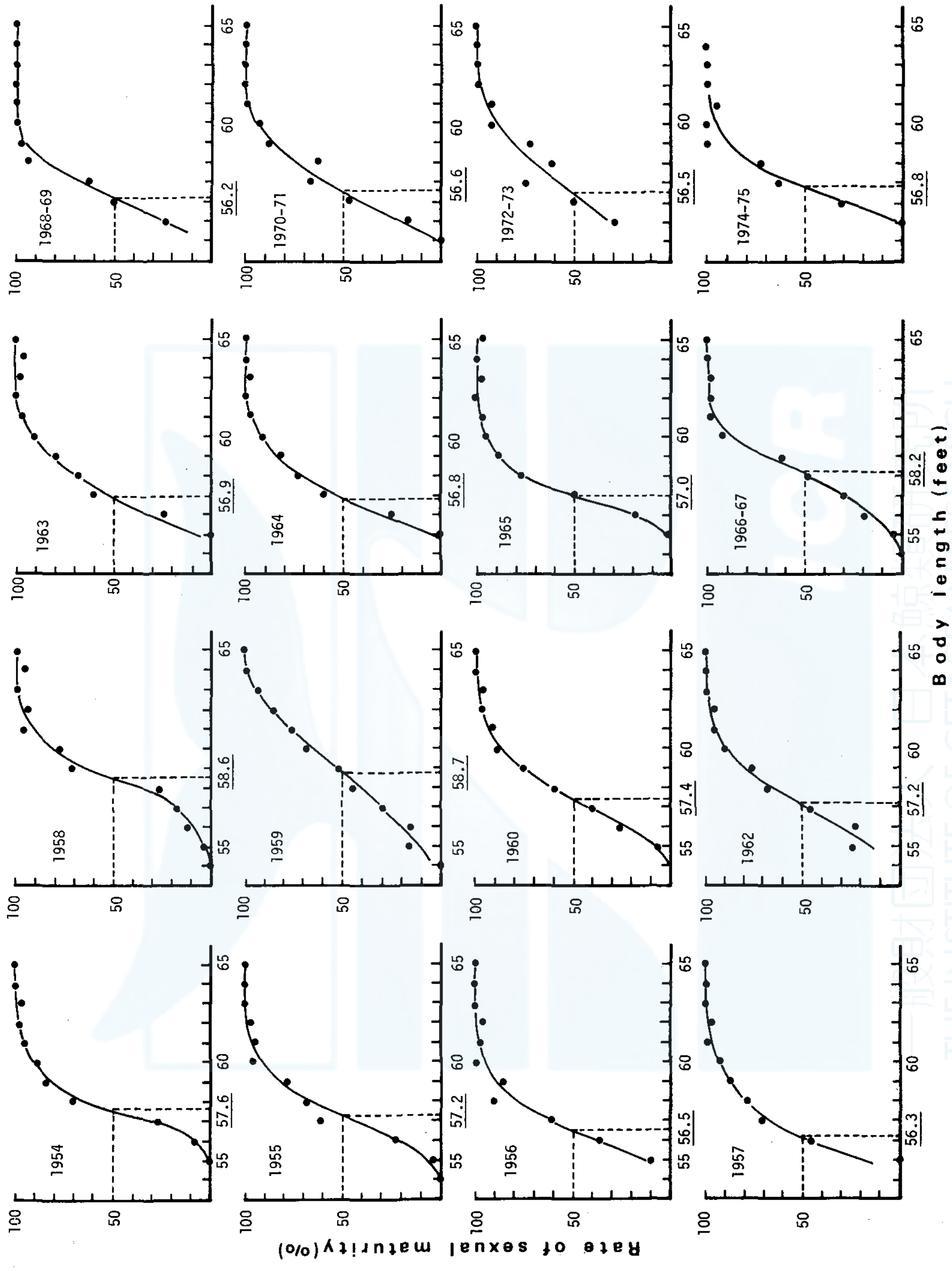

Fig. 5. Average body length at sexual maturity of the male fin whale in the eastern North Pacific in each year.

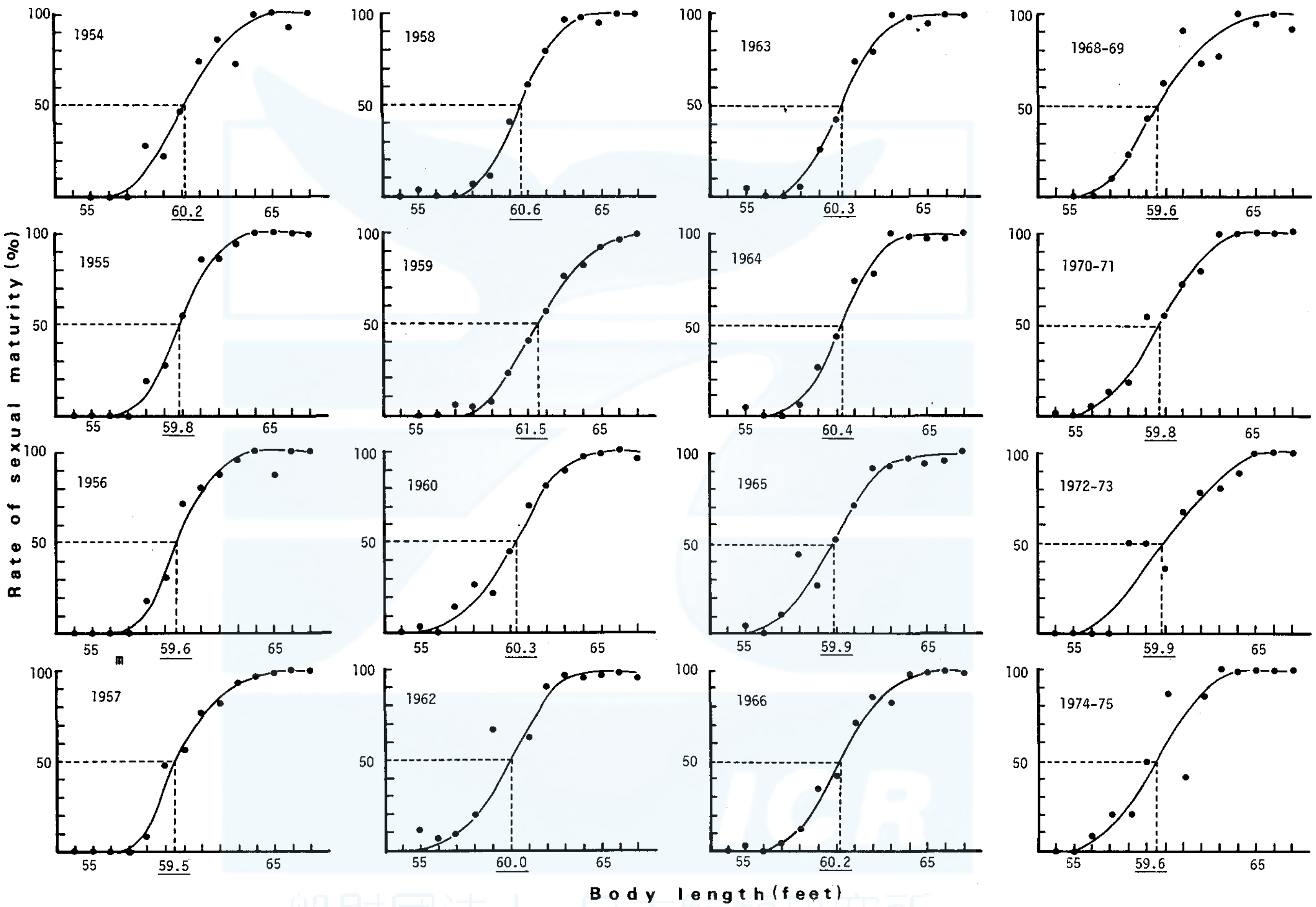

Fig. 6. Average body length at sexual maturity of the female fin whale in the eastern North Pacific in each year.

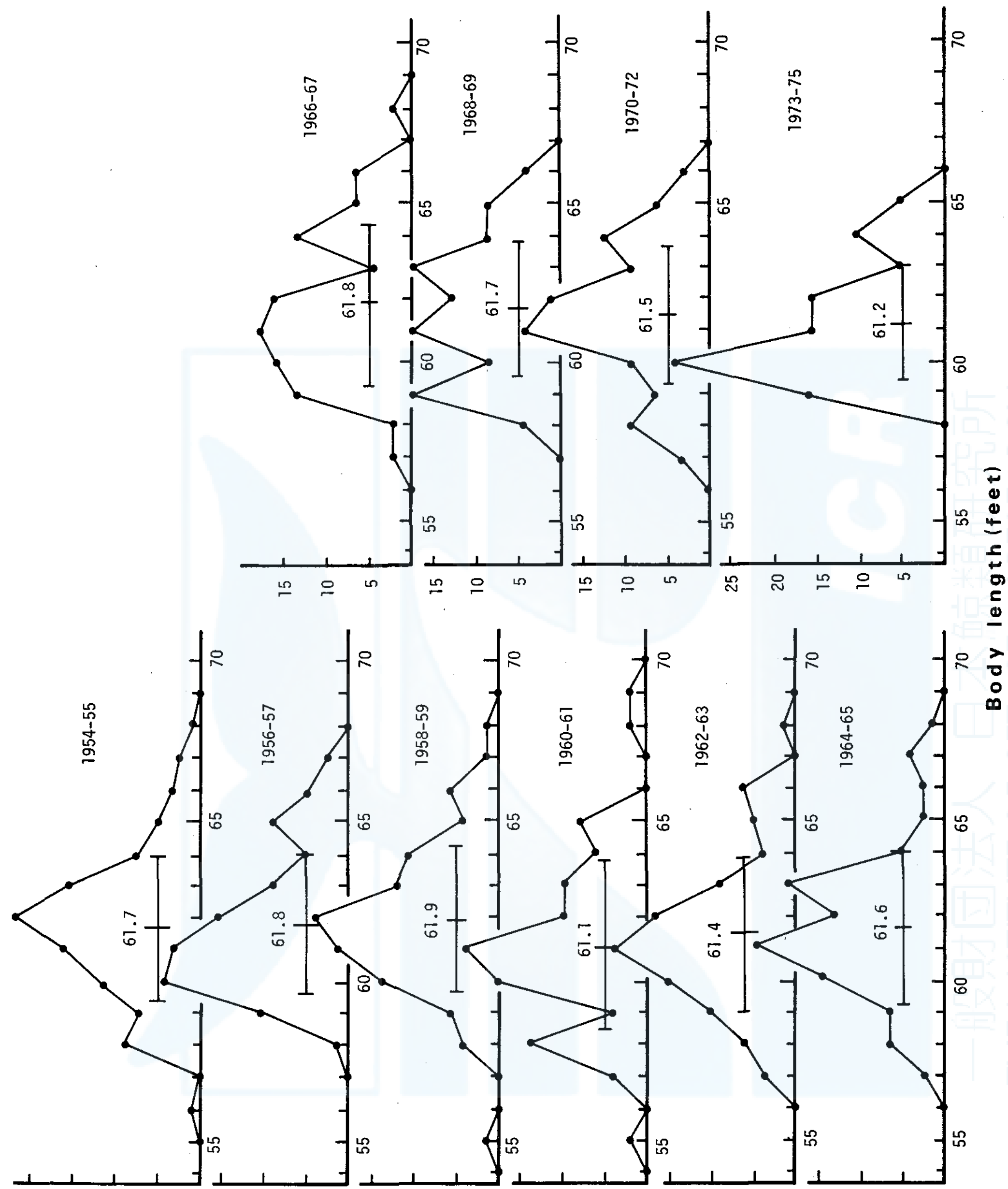

Fig. 7. Size distribution of female fin whales which had one corpus luteum or albicans in the ovaries.

of error, and the line was almost parallel to those of body length of females of 50 % maturity. Thus, this is the evidence that the body length at sexual maturity was constant even in the condition showing the age at sexual maturity declined.

DISCUSSION

This study provided an evidence of yearly change in the age at sexual maturity in a baleen whale stock independently from the use of transition phase in ear plugs. In other word, this supports the reality of similar phenomenon on the age at sexual maturity as examined by means of transition phase, and proves the reasonability of the transition phase as a mark of the sexual maturity as proposed by Lockyer (1972).

It was found from Figs 1 and 2 that the youngest limit of age of mature whales changed rapidly to younger ages from early period of exploitation, but the oldest limit of age at sexual maturity remained unchanged for relatively long periods of exploitation. The similar phenomenon was also observed in the age distribution of females with one ovarian corpus. Fig. 8 shows a schema to illustrate the changing pattern of proportions of sexually mature individuals at different ages during the periods of exploitation as observed in this examination. A similar pattern of age at sexual maturity was observed between African elephants populations in different environment (Laws, Parker and Johnstone, 1975). These phenomena indicate that the change in the habitat of an animal stock affects on the growth and maturity of younger animals more strongly than the older animals. Thus, younger animals attain sexual maturity rapidly, when their habitat has become better than the past. On the other hand, the older animals which had spent their young stage in the past inferior environment remained in the immature stage even in the improved habitat changed.

The analyses of age at sexual maturity were made in this paper based on years when animals were caught. If the same analyses are carried out based on year classes as examined by Kato (1983) for the Antarctic minke whales, clearer result than this paper will be obtained, considering the above possibility. Further studies will be needed on this matter.

An evidence was provided in this study that the average body lengths at sexual maturity kept almost the same size during whole periods of exploitation, in spite of the condition that the average age at sexual maturity decreased significantly in the periods. Lockyer (1972) reported the same phenomenon on the Southern Hemisphere fin whale, but she reached to this result by review of several papers which described on the body lengths at sexual maturity from various regions. The present paper examined this matter by use of the same series of data collected from the same stock. In this sense, this paper will provide the first evidence on this feature in the cetaceans.

Although the average age and body length of females with one ovarian

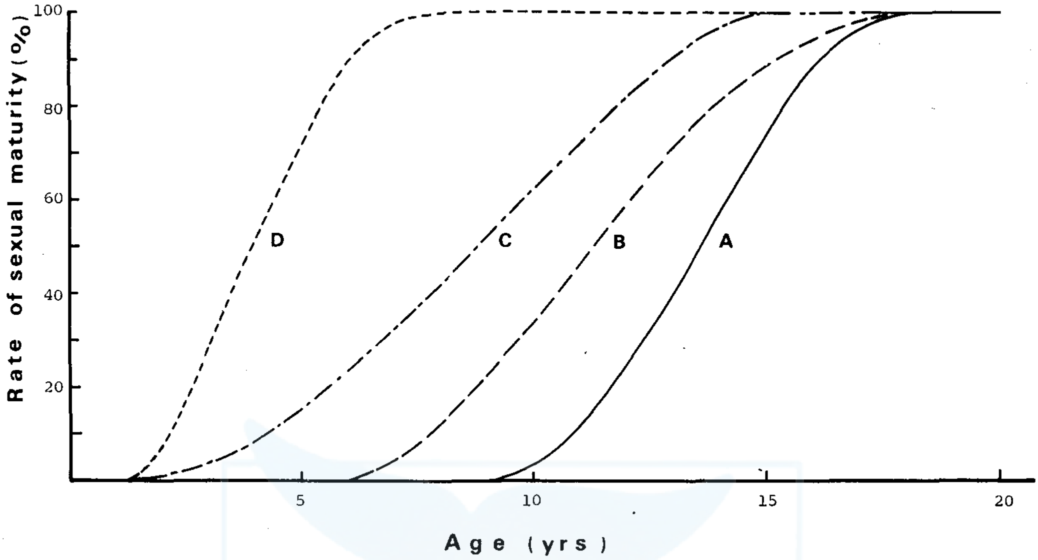

Fig. 8. Schematic figure to represent the change in pattern of proportions of sexually mature whales in each age accompanied with the change in environment of a whale stock. The approximate correspondence to actual seasons is, A: 1957–58, B: 1959–60, C: 1966–70, D: 1971–73

corpus were regarded as one of the indicators of those at sexual maturity, it was found in this paper that they were larger than those of 50 % sexual maturity. The differences were 0.5–1 year and 0.9 feet for age and body length, respectively. The age and body length of 50 % maturity is regarded as the mean value at the instance of sexual maturity, whereas females with one ovarian corpus have been already matured before their catch, so that it will be natural to reach the above result. Anyway, we must recognize that the results of both approaches are somewhat different, but the application of both of these independent methods will be useful to confirm the results of analyses.

The change in age at sexual maturity and no change in body length at the same developmental stage mean that the growth pattern of this whale stock changed during the periods of exploitation, and the whales of this stock grew faster accompanying with the decrease of population level. Furthermore, a whale stock has its fixed body length at sexual maturity, and when an individual which grows fast attains the fixed size of body, it becomes sexually mature, even if it is still young. Contrary to it, an old individual does not attain sexual maturity, unless it grows to the fixed body length.

The fin whale stock dealt in this study decreased its population level rapidly during 22 years from 26 to 10 thousands (Chapman, 1976). Blue, humpback and sei whale stocks which have similar feeding behavior to the fin whale decreased also in the same waters during the periods (Chapman, 1976). The clear decline in the age at sexual maturity and change in growth pattern of the eastern North Pacific fin whale stock reflect change in total biomass of baleen whale populations similar to the Southern Hemisphere fin whales (Gambell, 1975). The decline of total biomass of baleen whale populations provided gradually better habitat and larger amount of intake of food per head of the fin whales, and better nutrition and less stress improved the growth and maturity.

The catch history and change in population level and its habitat are different from stock to stock even in the same whale species. The comparison of the change in biological parameters including the age at sexual maturity will be interesting to be studied in future in conjunction with the difference of biomass and their habitats.

REFERENCES

Best, P.B., 1982. Seasonal abundance, feeding, reproduction, age and growth in minke whale off Durban. *Rep. int. Whal. Commn*, 32: 759–786.

Chapman, D.G., 1976. Estimates of stocks (original, current, MSY level and MSY) as revised at Scientific Committee Meeting, June 1975. *Rep. int. Whal. Commn*, 26: 44–47.

Cooke, J.G. and W.K. de la Mare, 1983. The effects of variability in age data on the examination of biological parameters of minke whales (*Balaenoptera acutorostrata*). *Rep. int. Whal. Commn*, 33: 333–338.

Fujino, K., 1960. Immunogenetic and marking approaches to identifying sub-populations of the North Pacific whales. *Sci. Rep. Whales Res. Inst.*, 15: 85–142.

Japan Whaling Association, 1955. *Report on biological investigations of the whales in the northern part of the North Pacific*. Japan Whaling Association, 280pp. (in Japanese).

Gambell, R., 1975. Variations in reproduction parameters associated with whale stock sizes. *Rep. int. Whal. Commn*, 25: 182–189.

Kato, H., 1983. Some considerations on the decline in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn*, 33: 393–399.

Laws, R.M., 1962. Some effects of whaling on the southern stocks of baleen whales. *In*: E.D. le Cren and M.W. Holgate (eds) *The exploitation of natural populations*. Blackwell Scientific Publications, Oxford. 399pp.

Laws, R.M., I.S.C. Parker and R.C.B. Johnstone, 1975. *Elephants and their habitats. The ecology of elephants in North Bunyoro, Uganda.* Claren Don Press, Oxford. 366pp.

Lockyer, C., 1972. The age at sexual maturity of the southern fin whale (*Balaenoptera physalus*) using annual layer counts in the ear plug. *J. Cons. int. Explor. Mer.*, 34(2): 276–294.

Lockyer, C., 1974. Investigations of the ear plug of the southern sei whales (*Balaenoptera borealis*) as a valid means of determining age. *J. Cons. int. Explor. Mer.*, 36: 71–81.

Masaki, Y., 1976. Biological studies on the North Pacific sei whale. *Bull. Far Seas Fish. Res. Lab.*, 14: 1–104.

Masaki, Y., 1979. Yearly changes in biological parameters of the Antarctic minke whale. *Rep. int. Whal. Commn*, 29: 375–395.

Nishiwaki, M. and T. Yagi, 1953. On the age and the growth of teeth in a dolphin (*Prodelphinus caeruleo-albus*) (I). *Sci. Rep. Whales Res. Inst.*, 8: 133–146.

Ohsumi, S., 1964. Examination on age determination of the fin whale. *Sci. Rep. Whales Res. Inst.*, 18: 49–88.

Omura, H. and S. Ohsumi, 1964. Review of Japanese whale marking in the North Pacific to the end of 1962, with some information on marking in the Antarctic. *Norsk Hvalfangst-Tid.*, 53(4): 90–112.

Purves, P.E., 1955. The wax plug in the external auditory meatus of the Mysticeti. *Discovery Rep.*, 27: 293–302.

Utrecht-Cook, C.N. van., 1966. Age determination and reproduction of female fin whales, *Balaenoptera physalus* (Linnaeus 1958) with special regard to baleen plates and ovaries. *Bijdr. Dierk.*, 35: 39–100.

EARPLUG TRANSITION PHASE AS AN INDICATOR OF SEXUAL MATURITY IN FEMALE ANTARCTIC MINKE WHALES*

SEIJI OHSUMI**

ABSTRACT

The transition phase in the earplug of the minke whale (*Balaenoptera acutorostrata*) was examined on its meaning as an indicator of the sexual maturity by use of earplug materials of 360 females caught in the Antarctic Areas III and IV in 1971/72–1981/82 Seasons.

It was confirmed from seven kinds of examinations that the transition phase can be regarded as an indicator of the sexual maturity of the minke whale. However, few whales form the transition phase in sexually immature stage, when they grow near the body length or age at sexual maturity. The transition phase becomes to be identified fully by the time of accumulation of 4–5 growth layers after its formation. Ten to fifteen percent of sexually mature whales do not form identifiable transition phase in earplugs for their life.

Annual ovulation rate was estimated from age at capture, age at transition phase and number of ovarian corpora to change from 1.9 in the early stage of sexual maturity to 0.9 in the oldest stage of life in recent years.

INTRODUCTION

Growth layers of the earplug have been used as the best age character of baleen whales since the discovery of the layers by Purves (1955). Ichihara (1966) suggested for the fin whale that the age when width of growth layers suddenly declines might indicate the age at sexual maturity. Lockyer (1972) confirmed this through the comparison of growth layers and biological data of the Southern Hemisphere fin whales, and named the phase where the growth layer width changes abruptly as 'transition phase'.

Masaki (1973) found the presence of the transition phase in earplugs of the Antarctic minke whale as already reported on other *Balaenoptera* whale species. Masaki (1979) further studied the age at sexual maturity of the Antarctic minke whale, and indicated that the age at sexual maturity suggested by the transition phase agreed well with the age obtained from the data of

---

* A draft paper was presented to the International Whaling Commission/Scientific Committee/Minke Whale Ageing Workshop, Cambridge, April 1983 (Document No. SC/A83/AW8).

** *Far Seas Fisheries Research Laboratory, 5-7-1 Orido, Shimizu-shi, 424 Japan.*

reproductive tract. Kato (1983) used the transition phase to estimate the yearly change in the age at sexual maturity of the Antarctic minke whale, and compared the results obtained from other independent methods. Best (1982) confirmed the correlation between sexual maturity and presence of transition phase in earplugs of minke whales off Durban, and he also studied yearly change in age at sexual maturity by use of the transition phase.

Although these authors indicated the usefulness of transition phase as a mark of the sexual maturity of the Southern Hemisphere minke whale, it has been understood that there are some need to examine further on this matter through the discussion in the Scientific Committee of the International Whaling Commission in the beginning of 1980s (Anon., 1983). This paper will examine if the transition phase in the earplug can be used as an indicator of the sexual maturity of the Antarctic minke whale. As the materials only females were used, because the sexual maturity can be more easily identified.

Mr Hidehiro Kato of the Whales Research Institute provided me with earplug materials and biological data for this study. I would like to express my sincere thanks to him for his endeavor to select these materials. I am largely indebted to Dr Toshio Kasuya of the Far Seas Fisheries Research Laboratory who kindly criticized my manuscript and made many suggestions.

MATERIALS AND METHODS

The materials used in this study were earplugs of 360 female minke whales caught by Japanese whaling expeditions in the Antarctic Areas III (0–70°E) and IV (70–130°E) in 1971/72–1981/82 Seasons and stored in the Far Seas Fisheries Laboratory. Mr H. Kato selected these materials under the principle agreed by the Scientific Committee for use in the Minke Whale Ageing Workshop which was held in Cambridge in April 1983 (Anon., 1984). The selecting procedure of these earplugs was described in detail by Kato (1984). In this case stratified sampling of two readability classes and nine corpora count classes (18 strata) was adopted: 20 samples were allocated to each stratum. The earplugs were read by myself for total number of growth layers (age at capture) and the number of growth layers before the transition phase (age at transition phase). Each half-sectioned earplug was put in water and read for these two kinds of layers under a binocular dissecting microscope for three times without referring to any biological information of the whale, and finally decided the best numbers of these layers on each whale as the average.

The body lengths were measured in 0.1 m unit on board of the whaling factory ships. The numbers of corpora lutea and corpora albicantia in the ovaries were counted in the Far Seas Fisheries Research Laboratory or by biologists on board of factory ships. These data have been stored in the Far Seas Fisheries Research Laboratory, and used to determine the sexual maturity of the materials. The sexual maturity was determined by the presence of corpus luteum or albicans in the ovaries. Among them a female having one or two

TABLE 1. APPEARANCE OF TRANSITION PHASE ACCOMPANIED WITH SEXUAL MATURITY AND AGE AT CAPTURE OF THE ANTARCTIC MINKE WHALES

Age	Immature			Mature			Total		
	–	+	Total	–	+	Total	–	+	Total
3	4	–	4	–	–	–	4	–	4
4	5	–	5	–	–	–	5	–	5
5	9	–	9	3	–	3	12	–	12
6	7	–	7	2	1	3	9	1	10
7	4	–	4	3	2	5	7	2	9
8	6	–	6	2	1	3	8	1	9
9	2	–	2	4	3	7	6	3	9
10	–	1	1	5	9	14	5	10	15
11	1	–	1	4	11	15	5	11	16
12	–	–	–	2	14	16	2	14	16
13	–	–	–	2	10	12	2	10	12
14	–	–	–	3	17	20	3	17	20
15	–	–	–	1	15	16	1	15	16
16	–	–	–	1	13	14	1	13	14
17	–	–	–	1	17	18	1	17	18
18	–	–	–	–	14	14	–	14	14
19	–	–	–	1	10	11	1	10	11
20	–	–	–	3	8	11	3	8	11
21	–	–	–	–	10	10	–	10	10
22	–	–	–	–	11	11	–	11	11
23	–	–	–	4	10	14	4	10	14
24	–	–	–	–	9	9	–	9	9
25	–	–	–	3	9	12	3	9	12
26±	–	–	–	7	69	76	7	69	76
Unknown	–	1	1	1	4	5	1	5	6
Total	38	2	40	52	267	319	90	269	359

Remarks: –: Transition phase not appeared, +: Transition phase appeared.

ovarian corpora was recognized as a whale just after the attainment of sexual maturity, and used as an indicator of a stage of attainment of sexual maturity.

RESULTS

Transition phase and sexual maturity

Among 360 females used in this study, an earplug of a whale had an abnormal pattern of growth layers, and it was impossible to read age at capture or at transition phase. This whale was omitted from the later analysis. Earplugs of other 6 whales were incomplete missing either germinal or neonatal layer, and their age at capture was not estimated, although some of their transition

TABLE 2. APPEARANCE OF TRANSITION PHASE ACCOMPANIED WITH ACCUMULATION OF CORPORA LUTEA AND ALBICANTIA IN THE OVARIES OF THE ANTARCTIC MINKE WHALES

Number of corpora	−	+	Total
0	38	2	40
1	9	2	11
2	7	10	17
3	2	7	9
4	1	8	9
5	5	13	18
6	1	12	13
7	–	11	11
8	1	19	20
9	2	7	9
10	3	10	13
11	–	21	21
12	–	7	7
13	–	10	10
14	1	15	16
15	4	12	16
16	3	15	18
17	1	9	10
18	1	11	12
19	4	12	16
20	2	13	15
21±	5	43	48
Total	90	269	359

Remarks: −: Transition phase not appeared,
+: Transition phase appeared.

phase could be identified (Table 1).

As shown in Tables 1, 2 and 3, 40 whales were sexually immature. Among them two (5.0 %) had transition phase, and others (38 whales, 95.0 %) did not. This indicates that most of the immature whales have no transition phase in the earplugs, but few immature whales have already formed it.

These tables also show that 267 whales (83.7 %) have transition phase among 319 sexually mature females, but it is not detected on remaining 52 whales (16.3 %). Some of the latter may have transition phase actually, but the post-transition phase could not be thick enough to be identified, because transition phase has just formed on the individuals which were soon after the attainment at sexual maturity. In addition to it, there are old whales of which transition phase was not detected at all.

TABLE 3. APPEARANCE OF TRANSITION PHASE ACCOMPANIED WITH SEXUAL MATURITY AND BODY LENGTH OF THE ANTARCTIC MINKE WHALES

Body length	Immature			Mature			Total		
(m)	–	+	Total	–	+	Total	–	+	Total
6.9– 7.0	1	–	1	–	–	–	1	–	1
7.1– 7.2	2	1	3	–	–	–	2	1	3
7.3– 7.4	5	–	5	–	1	1	5	1	6
7.5– 7.6	4	–	4	–	1	1	4	1	5
7.7– 7.8	8	–	8	–	3	3	8	3	11
7.9– 8.0	2	–	2	2	6	8	4	6	10
8.1– 8.2	5	–	5	8	8	16	13	8	21
8.3– 8.4	3	–	3	7	32	39	10	32	42
8.5– 8.6	5	1	6	4	38	42	9	39	48
8.7– 8.8	3	–	3	16	54	70	19	54	73
8.9– 9.0	–	–	–	3	48	51	3	54	57
9.1– 9.2	–	–	–	3	32	35	3	32	35
9.3– 9.4	–	–	–	6	25	31	6	25	31
9.5– 9.6	–	–	–	–	14	14	–	14	14
9.7– 9.8	–	–	–	2	3	5	2	3	5
9.9–10.0	–	–	–	–	2	2	–	2	2
10.1–10.2	–	–	–	1	1	2	1	1	2
Total	38	2	40	52	267	319	90	269	359

Remarks: –: Transition phase not appeared, +: Transition phase appeared.

TABLE 4. COMPARISON OF PRESENCE OF TRANSITION PHASE AMONG SOME REPORTS

Sexual maturity classification	Lockyer (1972) Fin whale Females		Best (1982) Minke whale Both sexes		Present paper Minke whale Females	
	Sample size	%	Sample size	%	Sample size	%
Immature	27	0.0	21	4.8	40	5.0
Pubertal*	47	19.2	12	16.7	28	42.9
Other mature	177	96.5	94	83.0	291	87.6

Remarks:
*: One to two corpora in ovaries or both mature and immature tubules in testes.

Correlation between ovarian corpora number and transition phase

Table 4 shows that the proportion of whales having transition phase is 42.9 % in early stage of mature females (one or two ovarian corpora), which is lower than that of older mature whales (87.6 %). This suggests that there will be some correlation between ovarian corpora number (or time after maturation) and proportion of individuals having transition phase.

Fig. 1B shows this correlation using data in Table 2. The proportion of

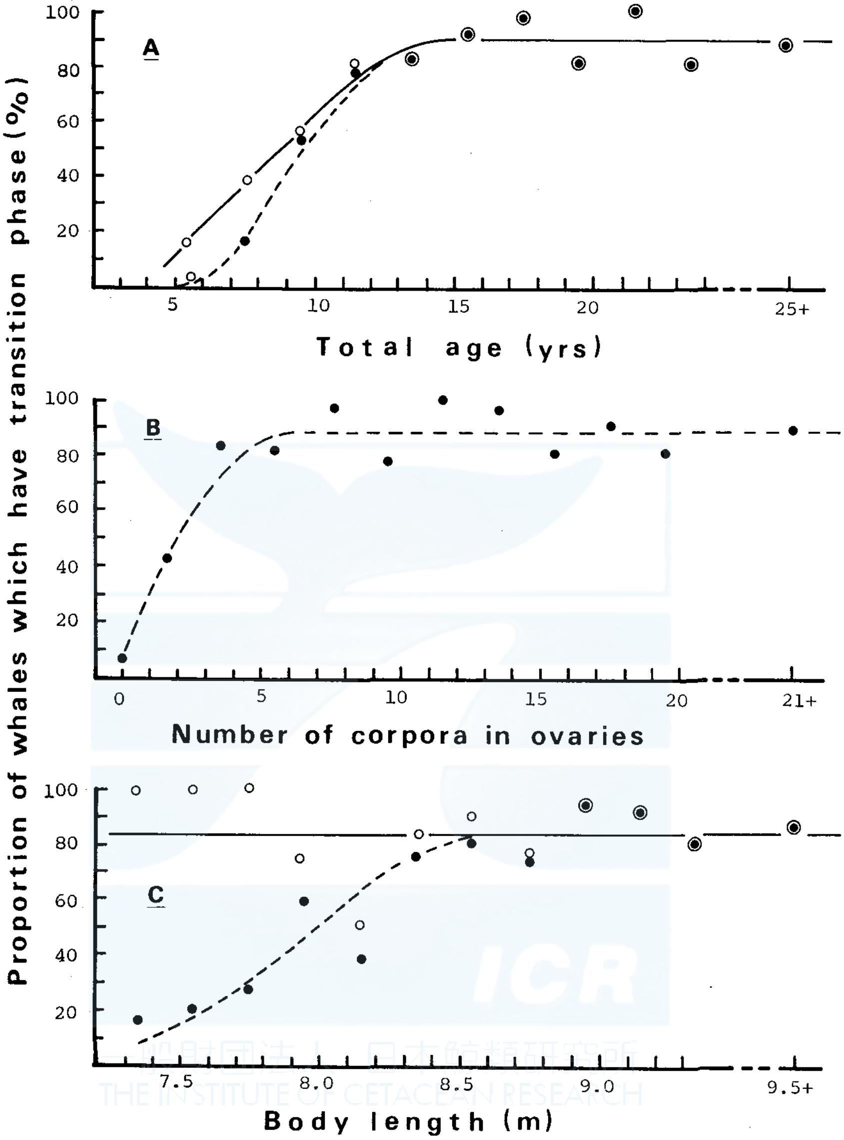

Fig. 1. Proportions of whales which have transition phase in earplug to total whales in each growth stage. A: Based on total ages, B: Based on corpora number in ovaries, C: Based on body length. Open circle and solid line: Sexually mature whales, Closed circle and broken line: Total whales.

individuals which have transition phase in earplug increases rapidly till accumulation of 4 or 5 corpora, then it becomes constant at a level of 87.9 % individuals with five corpora. This indicates that the transition phase is difficult to be identified at the beginning of its formation, although it is formed around the attainment of sexual maturity, but it can be detected fully after the stage of 4 or 5 corpora number, if it is formed in an individual.

Correlation between age at capture and transition phase

Table 1 shows frequency distributions of ages at capture of 359 females used in the present analysis. Ages of sexually immature whales are distributed in the range of 3 to 11 years. Two immature whales have transition phase. One of them is 10 years old. The age of another whale is unknown, because germinal layer was missing from the earplug. This whale is estimated to be at least 14 years old from remaining part of the earplug. These two whales indicate that the transition phase may be formed in some whales after a certain age when most whales attain at sexual maturity, even if the whale remains in the immature stage.

At the ages of 6–9 years, all the 19 immature whales had no transition phase, but seven individuals in 18 mature females had it. This means that the correlation of transition phase with age is lower than that with sexual maturity. Although sexually mature whales were found from 5 years of age, sexually mature whales with transition phase appeared from 6 years of age. This is reasoned by that the transition phase is difficult to identify at the beginning of its formation.

Fig. 1A shows age related change in proportion of whales with transition phase in earplugs. The proportion increases from the age of 5–6 years to 13–15 years, and then it becomes stable at a level of 89.8 % over 14 years as in the case of corpora numbers mentioned above. The increase in the proportion with the age (5 to 14 years) will be related with the increase in the proportion of sexually mature whales as well as the increase of detectability of transition phase. The proportion is higher than that calculated including immature whales. This means that the formation of transition phase is related more with the sexual maturity than the age. However, even in the sexually mature whales the proportion of whales having transition phase increases with age the same as in the case of ovarian corpora.

Ages of full identification of transition phase

Due to the definition of the earplug transition phase, it is reasonable to consider that the detection of transition phase becomes easier after several growth layers have been accumulated after the phase.

Fig. 2 shows a frequency distribution of times after transition phase (age at capture minus age at transition phase). The recognized shortest time after transition phase is one year which is represented by only three whales, but the highest frequency is at 5 years. This indicates that the presence of transition phase can be rarely recognized when one growth layer is accumulated after the phase, but most usually recognized after the deposition of 2 to 5 layers. The transition phase can be fully identified, if it exists, when more than 4 layers are accumulated after its formation.

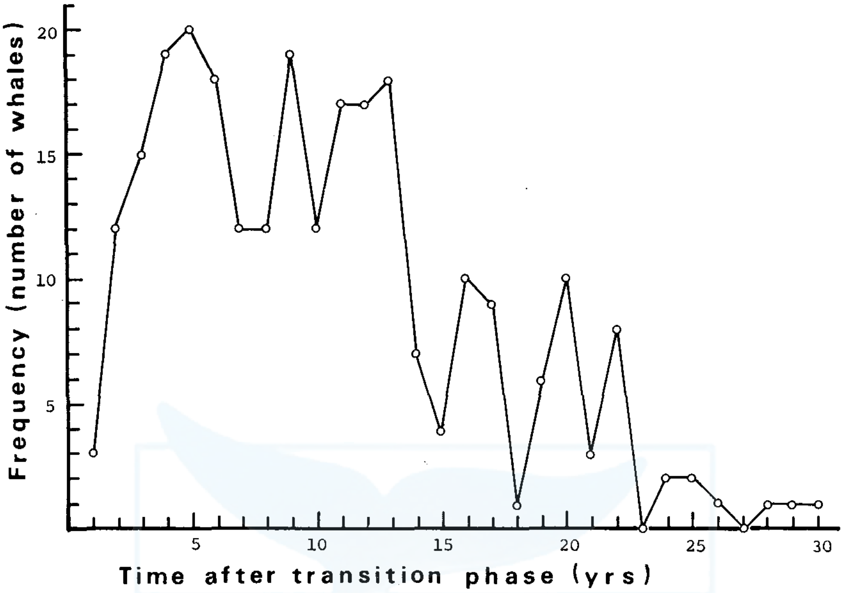

Fig. 2. Frequency distribution of ages after transition phase in earplugs of the female Antarctic minke whales.

Correlation between body length and presence of transition phase

Table 3 shows frequency distributions of body lengths of the present material. Whales without identifiable transition phase are found in all size classes. Fig. 1C shows the relationship between body length and proportion of whales having transition phase. In the length range of 7.4 to 8.6 m, the proportion increases with increasing body length. Above 8.7 m of body length the proportion is constant at the average of 84.5 %.

Fig. 1C also shows the proportion of whales with transition phase calculated using only sexually mature whales. Although the sample size is small (11 whales) for whales below 8.0 m, it is considered that there is no correlation between the proportion and body length, suggesting that the formation of transition phase is not directly related with the body length.

Comparison of age of whales just after sexual maturity and age at transition phase

Table 5 shows distribution of age at capture of whales with one and two corpora in ovaries. The range of the ages is from 5 to 15 years with average of 9.4 years. Among 28 whales which have one or two ovarian corpora, 12 whales are identified with the transition phase in earplugs, and the distribution of ages at transition phase of these whales is also shown in Table 5. The ages ranged from 4 to 10 years with an average of 7.7 years. This figure is less than the average of ages at capture of these 12 females, because these whales have passed some time after the attainment of sexual maturity before the capture

TABLE 5. AGE DISTRIBUTIONS OF THE ANTARCTIC MINKE WHALES IN SEVERAL CASES

Age	Total ages		Ages at transition phase			
(yrs.)	*	**	≤ 13 yrs	≤ 15 yrs	Total yrs.	**
3	–	–	–	–	–	–
4	–	–	–	2	3	1
5	2	3	2	3	4	1
6	1	2	10	11	21	1
7	1	4	11	13	23	3
8	1	2	8	14	34	–
9	2	3	16	27	53	4
10	2	4	3	9	44	2
11	–	4	–	2	25	–
12	1	1	–	1	21	–
13	1	2	–	–	16	–
14	–	2	–	–	12	–
15	–	1	–	–	3	–
16	–	–	–	–	5	–
17	–	–	–	–	1	–
18	–	–	–	–	2	–
19	–	–	–	–	1	–
Total	11	28	50	82	268	12
Average	8.55	9.39	7.70	8.04	9.73	7.67
S.D.	2.54	2.85	1.36	1.61	2.65	1.89

Remarks: *: One corpus in ovaries, **: One or two corpora in ovaries.

but the age at transition phase can be closer to the age at the attainment of sexual maturity. However, the deviation between the two is 1.7 years.

In this table frequency distributions of ages at transition phase are shown for 82 whales of age at capture of 15 years (upper limit of ages at capture of whales with one and two ovarian corpora in Table 5) and younger. The average of the ages at transition phase in this case is 8.0 years with range of 4 to 12 years. This is almost the same as that (7.7 years) of the same kind of ages in the case of whales with one and two ovarian corpora, and 1.4 years less than the average age at capture of females with one and two ovarian corpora.

Comparison of estimated and read total ages

Lockyer (1972) examined the meaning of transition phase of fin whales by comparison of total earplug growth layers with ages of the animal at capture calculated using age at transition phase, number of ovarian corpora and average annual ovulation rate of the stock. The same method is applied in this study.

The age of a female at capture is calculated from following equation:

$$t_e = t_t + (c/r) \ ..... \ (1)$$

Where, t_e is calculated age at capture, t_t is age at transition phase, c is ovarian corpora number and r is annual ovulation rate. The data of t_t and c are available from the carcass. The problem is the value of annual ovulation rate. According

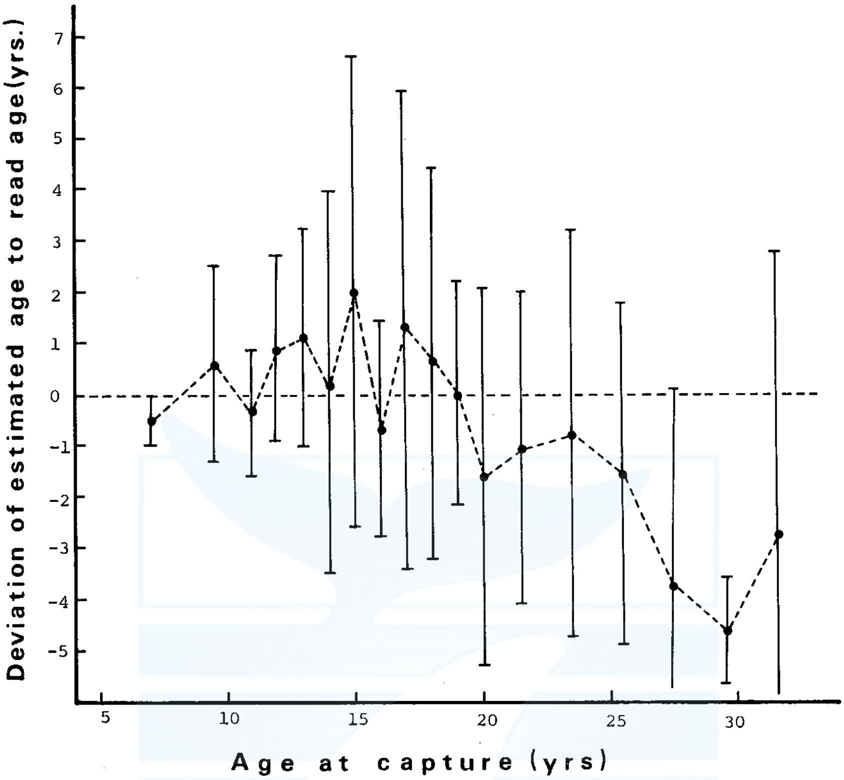

Fig. 3. Comparison between estimated and read total ages for the Antarctic minke whale. Closed circle: Average deviation of estimated age to read age, Range: Standard deviation.

to Masaki (1979), individual variation of annual ovulation rate ranges from 0.835 to 1.401 in the Antarctic minke whale. Best (1982) estimates the mean ovulation rate of minke whales off Durban at 0.811. Kato (1983) reports that the ovulation rate of the Antarctic minke whale increased from 0.77 (1952–54) to 1.25 (1967–69). Recently Kato (1985) showed a figure of 1.17 as the annual ovulation rate, although he indicated the rate declines with age.

If the age at capture thus calculated is close to the total growth layers of the same individual, the counted age at transition phase is proved to be close to the age at sexual maturity under the condition that the annual ovulation rate is true. A series of simulations was carried out using various values of ovulation rate to obtain the best match between total earplug age and the calculated age at capture. The best match was obtained assuming an annual ovulation rate of 1.4 as shown in Fig. 3. In this case average deviation between these two kinds of ages was around zero till the earplug age at 19 years, although there are large individual variations. This examination suggests that the age at transition phase can be regarded as the age at sexual maturity and the annual ovulation rate of the Antarctic minke whale is 1.4 for individuals below 19 years, which is larger than those ever estimated. The average deviation changes gradually to lower figures in the ages older than 19 years. This phenomenon means that the annual ovulation rate is not constant throughout all ages, and the ovulation rate of older age or earlier born generations had been smaller than 1.4. When an annual ovulation rate is assumed to be 1.0 for the age class of 26–28, the deviation of calculated and counted ages at capture becomes to be close to zero.

DISCUSSION

Presence of immature whales which have transition phase

Two sexually immature females were found among the present materials to have transition phase. There is a possibility of miss-collection or miss-preparation of earplug of one of the whale (No. W-293), because this whale was 7.1 m long (most individuals of this size are sexually immature as shown in Table 3), its age at capture was 14+ with the age at transition phase of 6 years. However, another one is difficult to assume such a possibility, for it is 8.5 m long and 10 years old at capture. Both of these figures leave for the female possibility of being sexually immature. As shown in Table 5, Best (1982) already reported immature minke whales having transition phase. Therefore, it can be concluded that some females will form transition phase in earplug while they are sexually immature, when they attain at certain age and body length. On this connection, Lockyer (1972) and Kato (1985) examined the growth of skull in relation to mechanism of the formation of transition phase in earplugs of the fin and minke whales, respectively.

However, as examined in this study, the sexual maturity seems to correlate in many individuals with the formation of the transition phase, even if they are very small or very young.

Identification of transition phase

All the sexually mature female minke whales do not have always transition phase in earplugs. There are two cases of the absence of transition phase in sexually mature stage. One comes from the difficulty of identifying it soon after its formation. The low proportion of whales with transition phase in females just after the attainment of sexual maturity reflects this (Table 4). The transition phase becomes identifiable after the accumulation of 4–5 growth layers of post-transition phase as examined in this study.

Another is the case where transition phase cannot be recognized for life due to the gradual change of the layer width. These whales comprise 17 % (Best, 1982), or 12.4 % (this study) of adult females. The corresponding figure is only 3.5 % in fin whales (Lockyer, 1972). The frequency will be different between whale species.

Use of transition phase for estimation of ovulation rate

Using several methods, it was confirmed in this study that the formation of transition phase approximately coincides with the attainment of sexual maturity of the Antarctic minke whale. Then, the time after sexual maturity can be estimated from age at capture and age at transition phase. On the other hand, the data on ovarian corpora numbers are available for each whale independently. Then, the mean ovulation rate of each whale is estimated from these data as follows:

$$r = c/(t_a - t_t) \quad ..... \ (2)$$

Where, t_a is earplug age at capture, and other symbols are the same as those of the equation 1.

Fig. 4 shows that the mean annual ovulation rate declines with increasing age at capture. Although the lower limits of the standard deviation are almost constant (0.75 corpora annually) through the age, the upper limits of the standard deviation decrease largely with age. Thus, the standard deviation decreases with age at capture. The mean annual ovulation rate decreases from 1.9 at the beginning of sexual maturity to 0.9 in the oldest ages. The declining trend of ovulation rate has been reported for the minke whale by Masaki (1979), Best (1982) and Kato (1985). The apparent decline of ovulation rate will reflect two causes. One is the true age dependent change, where the ovulation rate decreases with age even under constant environment. The second cause will be the year factor. The change in the environment of the Antarctic minke whale could have been continuously increased the annual ovulation rate of females especially of young females and decreased the age at sexual maturity. Both factors may affect this whale population, and obtained this apparent result, but it is difficult to separate these two factors from the result. Kato, Shimadzu and Kirishima (1985) tried to introduce the change in age at sexual maturity and pattern of change in ovulation rate with age to explain the apparent relationship between the age after maturation and ovarian corpora number.

The present analysis suggests that the annual ovulation rate of the Antarctic minke whale changes from 1.9 in the beginning of sexual maturity to 0.9 in the oldest stage in recent years. As examined in previous section, another kind of examination indicates that the mean annual ovulation rate keeps a value of 1.4 till 19 years of age. Kato *et al.* (1985) show a graph of change in ovulation rate with age of the same whale species that it changes from 1.6 at the beginning of maturity to 0.2 in 40 years of age. On the other hand, Best (1982) has a doubt on the possibility of the existence of ovulation rate of 1.56 and over per conception, because a failure rate will be very high in such a case, if the true pregnancy rate is about 78 %. However, we cannot explain the actual phenomena unless we consider the values of the ovulation rate which was estimated in the present study.

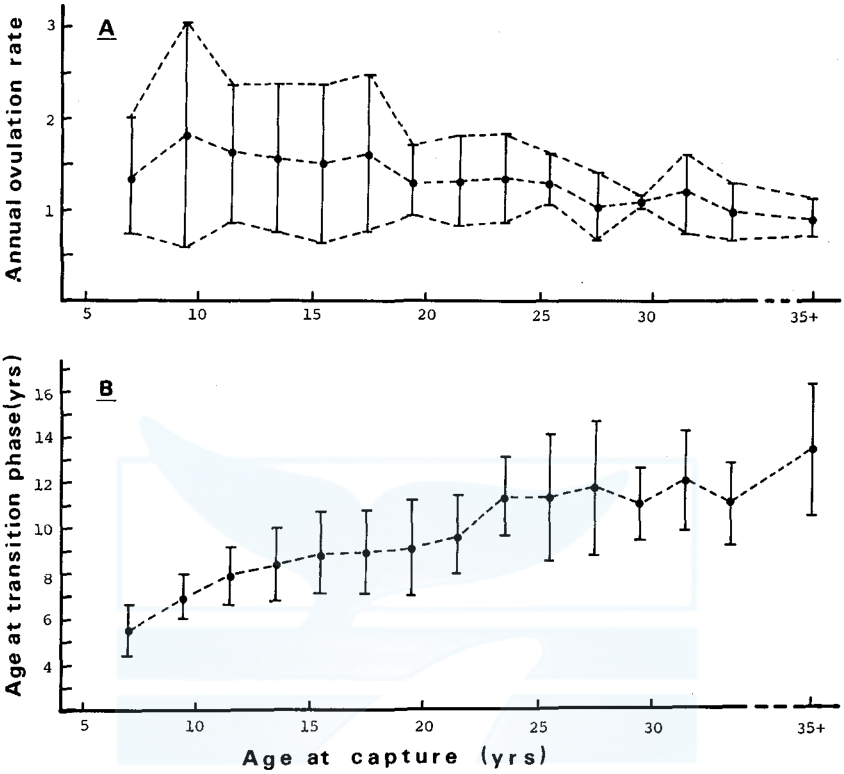

Fig. 4. Estimation of trends in annual ovulation rate and age at sexual maturity under the condition that the transition phase is a mark of the sexual maturity. A: Relation between total age and annual ovulation rate, B: Relation between total age and age at transition phase. Closed circle: Average, Range: One standard deviation.

Transition phase to estimate yearly change in age at sexual maturity

Fig. 4B shows mean and standard deviation of age at transition phase calculated in accordance with age at capture. The mean age at transition phase clearly increases with increase of age at capture. The average age at transition phase in whales of 35 years or over at capture is 13.5 years, but it is 7 years or less in whales captured before 10 years of age. Although this study did not deal with the data based on the year class as examined by Masaki (1979), Best (1982) and Kato (1983), similar values and trend as these papers were observed in this way.

REFERENCES

ANON., 1983. Report of the Scientific Committee. *Rep. int. Whal. Commn*, 33: 43–190.

ANON., 1984. Report of the Minke Whale Ageing Workshop. *Rep. int. Whal. Commn*, 34: 675–699.

BEST, P.B., 1982. Seasonal abundance, feeding, reproduction, age and growth in minke whale off Durban. *Rep. int. Whal. Commn*, 32: 759–786.

Ichihara, T., 1966. Criterion for determining age of fin whale with reference to ear plug and baleen plate. *Sci. Rep. Whales Res. Inst.*, 20: 17–83.

Kato, H., 1983. Some considerations on the decline in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn*, 33: 393–399.

Kato, H., 1984. Sampling procedure for earplugs provided to the Minke Whale Ageing Workshop. *Rep. int. Whal. Commn*, 34: 717–718.

Kato, H., 1985. Further examination of the age at sexual maturity of the Antarctic minke whale as determined from earplug studies. *Rep. int. Whal. Commn*, 35: 273–277.

Kato, H., Y. Shimadzu and K. Kirishima, 1985. Further development of a biological simulation to examine historical change in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn*, 35: 291–298.

Lockyer, C., 1972. The age at sexual maturity of southern fin whale (*Balaenoptera physalus*) using annual layer counts in the ear plug. *J. Cons. int. Explor. Mer.*, 34: 276–294.

Masaki, Y., 1973MS. Some notes on age estimation of baleen whales based upon the earplug. *Doc. No. SC/R1 presented to the Meeting on Age Determination in Baleen Whales*, Reykjavik, April 1973.

Masaki, Y., 1979. Yearly changes of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn*, 29: 375–395.

Purves, P.E. 1955. The wax plug in the external auditory meatus of the Mysticeti. *Discovery Report*, 27: 293–302.

SIGHTINGS OF HUMPBACK WHALES IN GREAT BARRIER REEF WATERS

MARK L. SIMMONS*
AND
HELENE MARSH**

ABSTRACT

Oral history interviews indicate that humpback whales used to winter in Great Barrier Reef waters in such numbers that they were considered a hazard to fishing, and that numbers declined dramatically coincident with whaling on the east coast of Australia in the 1950's and early 1960's. Anecdotal evidence suggests a recent increase in whale sightings in reef waters as well as at the latitudes of the former shore stations. These data suggest that most of the humpbacks which migrate along the east coast of Australia, winter in the Great Barrier Reef lagoon. Recent sightings of humpbacks tend to reflect human usage of the region. In recent years, they have been sighted near many reefs, islands and inshore areas, however, winter concentrations comparable to those seen in some other parts of the world have not been reported. This probably reflects both the vastness of the area and the low whale numbers. Calves have been seen at many places in the Great Barrier Reef lagoon. Some females apparently calve before they reach reef waters. Humpbacks have also been sighted near the northern end of the Great Barrier Reef (10°31′ S) between October and January after the end of the main north-south migration.

INTRODUCTION

The humpback whales (*Megaptera novaeangliae*) which migrate along the eastern coast of Australia en route to their breeding grounds, are part of the Area V stock which spends the summer feeding in Antarctic waters between 130°E and 170°W. The history of the commercial exploitation of this stock has been summarized by Paterson and Paterson (1984), and Bryden (1985). Commercial whaling is estimated to have reduced numbers from 10,000 (Chittleborough, 1965) to less than 500 (Chittleborough, 1965) or 200 (Chapman, 1974). Paterson and Paterson (1984) and Paterson (1985) present evidence, mainly based on

---

* *Queensland National Parks and Wildlife Service, Maritime Estate Branch, P.O. Box 1362 Rockhampton, 4700, Australia.*

** *Zoology Department, James Cook University, Townsville, 4810, Australia.*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 31–46

observations in the vicinity of 27°S, that this humpback population is now recovering. Bryden (1985) on the basis of cliff-top observations at the same latitude tentatively estimated that about 400 humpbacks were migrating up the east coast of Australia in both 1980 and 1981.

Although it is well established that the main northward migratory stream of humpbacks passes through the waters of southern Queensland in June, July, and August (Paterson, 1985; Bryden, 1985), while the southward migrating whales traverse this area in September, October and November (Paterson, 1985), their low latitude destination is unknown. Dawbin and Falla (1949) considered that an area in the Coral Sea north-west of New Caledonia (about 17° to 22°S; 157° to 163°E) was the breeding ground of the humpbacks passing along the eastern coast of Australia. Their opinion was based on examination of the charts of American whalers (Townsend, 1935) who are unlikely to have traversed the dangerous waters of the Great Barrier Reef (Fig. 1) as their preferred target was the sperm whale, which would not be expected to occur in shallow reef waters. Paterson and Paterson (1984) point out that there is no proof of a humpback migratory route between the eastern Australian coast and the Coral Sea, and present evidence that at least some humpbacks calve in the waters of the Great Barrier Reef. However, locations with winter concentrations such as those observed in Hawaii and the West Indies (Winn *et al.*, 1975; Herman and Antinoja, 1977; Tyack and Whitehead, 1982; Whitehead and Moore, 1982) have not been identified.

This paper adds to our knowledge of humpback whale migrations by documenting historical and recent sightings in Great Barrier Reef waters. These observations have resulted from the developing management, surveillance and research activity in the area plus the increased interest of the general public in whales.

METHODS

Oral History

In 1982–83, staff of the History Department of James Cook University conducted a series of taped interviews for the Great Barrier Reef Marine Park Authority. The major objective of this project was to document information on the incidence of the crown-of-thorns starfish, *Acanthaster planci*, on the Great Barrier Reef prior to 1960, however, additional information was recorded which could be of use to marine scientists. Informants were chosen on the basis of their sustained reef experience and included people such as trochus shell divers, fishermen, and charter boat operators.

The interview tapes are indexed by subject. They were made available to us by the Great Barrier Reef Marine Park Authority. Whales were mentioned on 28 of the 69 tapes. Relevant data, such as information indicating specific identification, locations and numbers of whales, presence of calves, and direction of travel were extracted by one of us (M.S.).

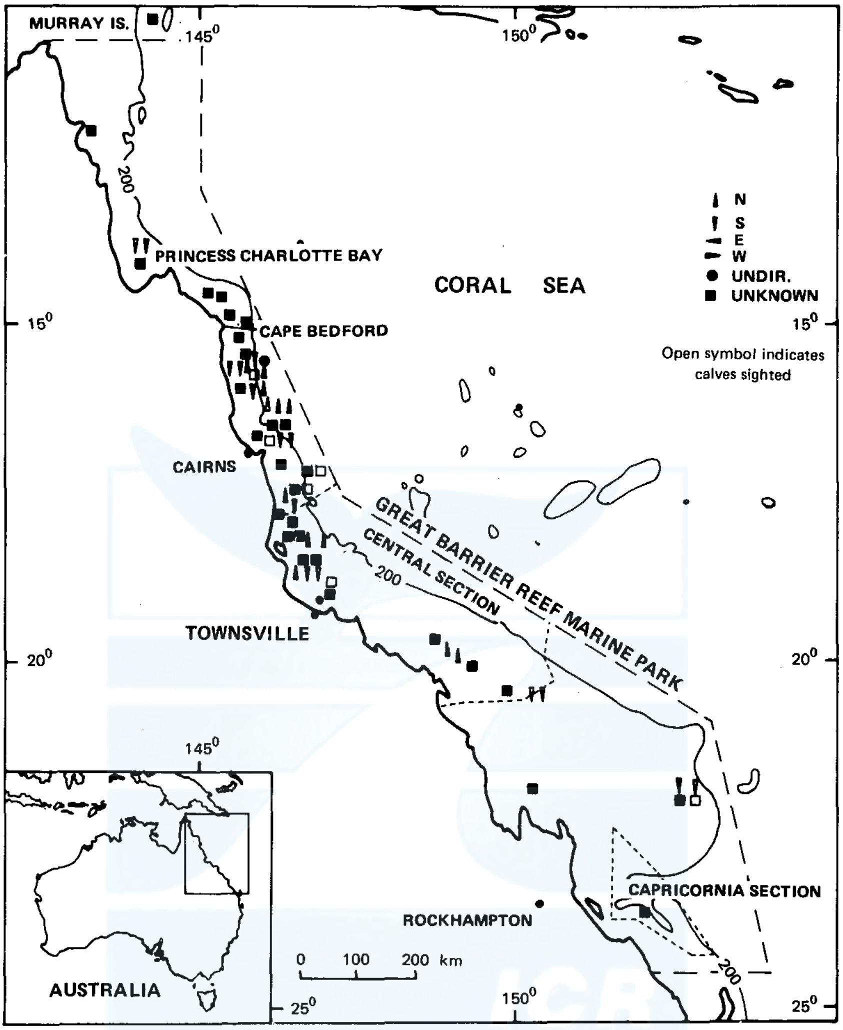

Fig. 1. Map of the Great Barrier Reef area showing the major locations mentioned in the text and the locations where the oral history informants indicated that they had sighted humpbacks. The 200m contourline is shown.

Additional data of this nature were made available by Andrew Smith who has done extensive interviews with residents of the Hope Vale Aboriginal Community near Cooktown (15°30′S; 145°15′E).

Recent sightings

Capricornia Section of the Great Barrier Reef Marine Park

Aerial surveillance: Queensland National Parks and Wildlife Service (Q.NPWS) personnel conducted regular (usually twice weekly) aerial surveillance

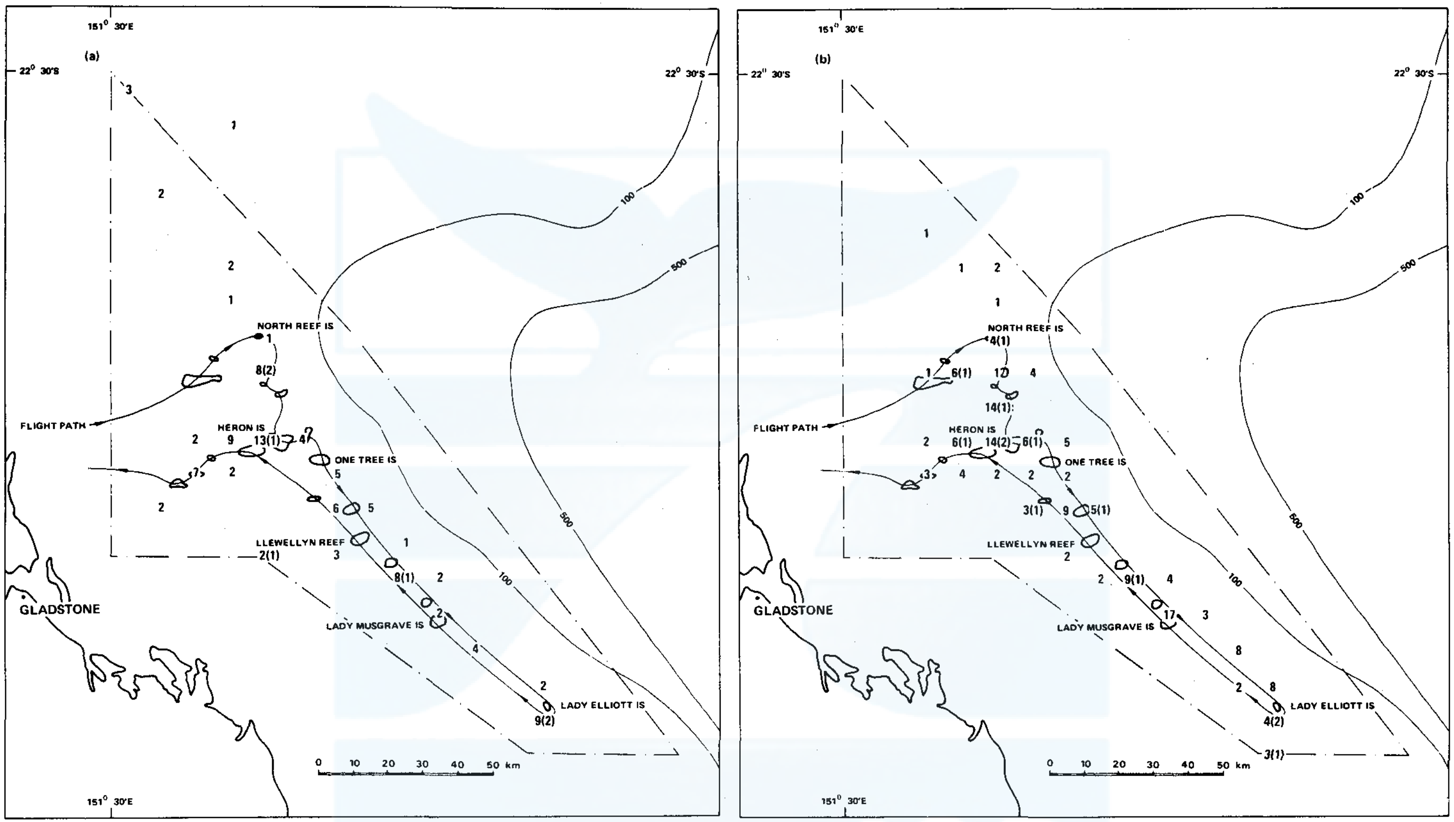

Fig. 2. Locations and numbers of humpback whales sighted in or adjacent to the Capricornia Section of the Great Barrier Reef Marine Park in (a) 1983 and (b) 1984. The numbers do not represent actual group sizes but the total number of humpbacks observed in each 100 km^2 grid square during the year. The corresponding numbers of calves are given in brackets. The routine flight path of the Q.NPWS surveillance flights is indicated.

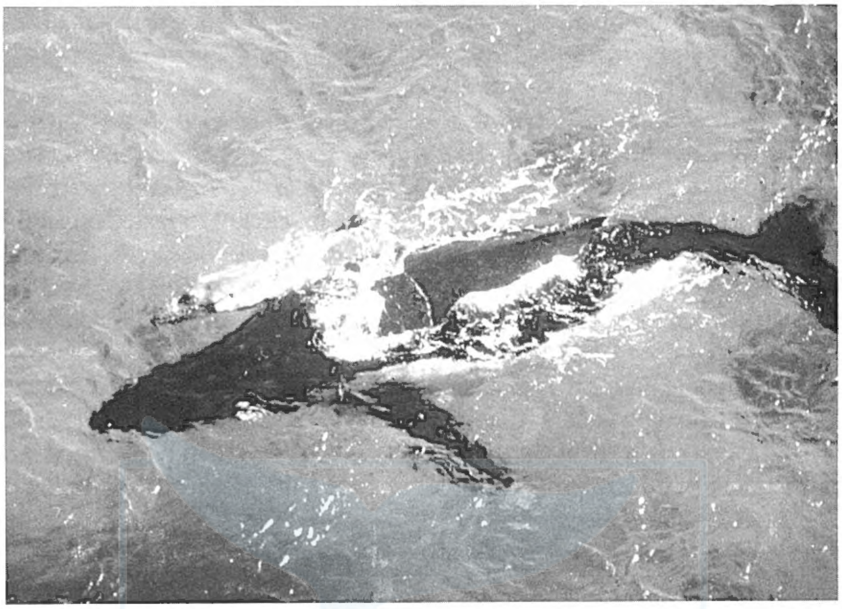

Fig. 3. Aerial photograph of a humpback mother and calf sighted near Wilson Island in the Capricornia Section of the Great Barrier Reef Marine Park during a Q.NPWS surveillance flight on July 20 1985. The light colour and small size of the calf suggest that it was newborn.

of this area in 1983 and 1984. The primary purpose of these flights was to monitor human activities, however they also provided the opportunity to observe natural phenomena, although such observations had a much lower priority. The regular flight plan is illustrated in Fig. 2; once per month the flight was extended slightly southward to cover Lady Elliott Island, the southern extremity of the Great Barrier Reef.

The aircraft used was a high-wing, twin-engine Partenavia. Patrols were flown at a height of 152 m (500′); clearance to descend to 30.5 m (100′) was available if required. The number of observers ranged from one (usually) to three; all crew plus pilot communicated via an intercom system. On some flights, the rear door of the aircraft was removed providing an expanded field of view and greater manoeuvrability for taking photographs for one observer. All photographs e.g. Fig. 3, have been taken using a hand-held 35 mm Canon AE-1 camera fitted with a data back and motor-drive or a Pentax super program fitted with a 300 mm lens.

The aircraft orbited each group of whales to allow photography and the recording of data on location, group sizes (a group was defined as a subjectively distinct clump), numbers of calves (other age groups could not be reliably distinguished), direction of swimming, sizes, behaviour, distinguishing marks, association with other animals, and weather and sea conditions. Thirty-four percent of sightings in 1983 and 38% in 1984 were made on Q.NPWS surveillance flights.

Surface surveillance: Humpback whales were also photographed and observed as detailed above by Q.NPWS field staff during routine boat patrols; sometimes surface and aerial observations were co-ordinated by radio contact between boat and aircraft. Ten percent of observations recorded in 1983 and 7% in 1984 were made during Q.NPWS surface surveillance. A further 10% of observations in 1983 and 7% in 1984 were made incidentally by Q.NPWS staff.

Incidental observations: A public education programme about whales in the Marine Park was conducted by Q.NPWS personnel at Heron Island. Standard whale sighting forms including graphic information on how to identify a humpback whale were prominently available at the Heron Island Resort and Research Station and distributed to dive shop owners, charter boat operators and pilots operating in the area including those from the Australian Coastal Surveillance Centre who regularly patrol the Great Barrier Reef. Australian Coastal Surveillance Centre Staff made 20% of observations in 1983; 15.5% in 1984. Other sources of incidental information included the staff of Lloyd's Helicopters (14% of sightings in 1983; 3.5% in 1984) and the general public (16% in 1983; 24% in 1984).

Other regions of the Great Barrier Reef Marine Park

Incidental observations: Since 1980, standard humpback whale sighting forms have been distributed by a group of biologists at James Cook University and by the Great Barrier Reef Marine Park Authority. The forms have been sent to a wide range of reef users including research workers, fishermen, charter-boat operators, dive-shop owners, aircraft pilots, lighthouse keepers, and observers on the Coastwatch Flights (which traverse the Great Barrier Reef lagoon on 28 days each month). Whale field guides including Leatherwood *et al.* (1976) were distributed to regular observers. All observers were encouraged to forward photographs of sightings.

RESULTS

Oral History

Review of the oral history tapes and the information collected by Andrew Smith confirmed that humpback whales were common in the winter in many parts of the Great Barrier Reef Region prior to the 1960's. Indeed, they were considered a hazard of concern to fishermen. Specific locations identified by informants are summarized in Fig. 1.

Interviews were recorded with 36 men as part of the Oral History Project. Twenty-six of the informants mentioned whales and 23 of these gave information indicating that encounters with humpbacks occurred frequently through the winter months from June to October inclusive. Several interviewees spoke of vast numbers of whales sighted in a single season. For example, Mr Derek Scott spoke of "hundreds and hundreds" of whales, whereas Mr Don Duffy recalled that observing "50 to 60" whales in a single day was not unusual.

Nearly all the informants were emphatic that there was a very significant decline in the number of whales visiting the Great Barrier Reef waters around the 1960's. Some men were remarkably precise in naming the year of the whales' disappearance. For example, Mr Adrian Cummings nominated 1962–63 as the end of the whale era: 1962 was the last year that whales were captured commercially on the east Australian coast (Paterson and Paterson, 1984).

Several informants stressed that although they had not sighted humpbacks in Great Barrier Reef waters for 15 to 20 years, they had seen them again in small numbers in the last five or six years.

Recent Sightings

Capricornia survey: latitude 24° 15′S – 22° 30′S

Locations where humpback whales were sighted within the Capricornia Section of the Great Barrier Marine Park in 1983 and 1984 are summarized in Figs 2a and 2b respectively. Most animals were sighted within 10 km of islands or reefs; it is not known to what extent this pattern is a function of the human usage of the area which in turn also determines the aerial surveillance flight paths (refer Fig. 2).

In 1983, 116 whales were sighted on a total of 50 occasions. Fifty-three individuals (45.7%) were moving north, 44 (37.9%) south. In 1984, there were 58 sightings of a total of 160 individuals. Sixty-three whales (39.4%) were classified as moving north, 49 (30.6%) as moving south. Details are summarized in Table 1. There were no obvious differences between the locations at which northward and southward moving whales were seen. The likelihood that an individual whale was resighted one or more times is unknown.

Table 1 summarizes the monthly sightings for 1983 and 1984. The first sightings for the season were made on June 13 in 1983 and on June 24 in 1984. In 1983, approximately equal numbers of whales were sighted in July, August, September and October, however in 1984 sightings peaked in August. In both years the last sightings were made in the last week of October.

The first group of southerly migrating whales was sighted on August 20 in 1983. In contrast, in 1984 a group of four whales (no calves) was seen travelling in a south-easterly direction on June 30. Although in both years, the majority of animals were travelling north in June/July and south in September/October, two groups of humpbacks were seen travelling north in the second half of October 1984; both groups included one calf.

Calves were first sighted on August 20 in 1983 travelling south, and on August 15 in 1984 travelling north-west. Eight calves were observed in 1983 (6.9% of sightings), 13 (8.1%) in 1984; the difference is not significant (G with William's correction = 0.04; 1 d.f.; $P > 0.5$). More than half the calves (52%) observed in 1983–84 were accompanied by only one other animal, presumably

TABLE 1. SIGHTINGS OF HUMPBACK WHALES IN THE CAPRICORNIA SECTION OF THE GREAT BARRIER REEF MARINE PARK (NEAR LATITUDE 24°15'S – 22°30'S)

Month	Whales sighted			No. of groups travelling in various directions			
	No. groups	No. individuals	No. calves	Northerly	Southerly	Non-directional	Other
1983							
June	4	8	0	3	0	1	0
July	14	32	0	13	0	1	0
August	10	21	1	4	2	3	1
September	15	28	2	4	6	5	0
October	7	27	5	0	7	0	0
TOTAL	50	116	8	24	15	10	1
1984							
June	5	13	0	4	1	0	0
July	15	39	0	9	2	1	3
August	15	54	2	6	5	4	0
September	13	28	8	1	6	1	5
October	10	26	3	2	6	2	0
TOTAL	58	160	13	22	20	8	8

the mother. Single calves were seen with up to six adults. One group of seven animals included two calves.

The observed relative frequencies of the different social groupings identified by Darling *et al.* (1983) is summarized according to direction of travel and month in Fig. 4. Although the frequency of social grouping was independent of the direction of travel (G with William's correction = 15.29; 10 d.f.; $P > 0.10$), it was not independent of month (G with William's correction = 34.73; 20 d.f. $P < 0.025$), largely because calves were not seen until the second half of the season. The most common grouping observed for all directions of travel and in all months was two or three adults. Bryden (1985) noted that the most frequently observed group size of the northern migration at 27°S was two whales; the largest group observed at this time was four.

Other parts of the Great Barrier Reef Region

Details of sightings are summarized in Fig. 5 and Table 2. The sightings coincide with areas of human usage. For example, the high frequency of flights between the coasts and reefs in the Whitsunday Island area undoubtedly contributed to the high humpback sighting rate in this area. It is likely that humpbacks use the Great Barrier Reef lagoon more widely and evenly than these data indicate.

Calves have been confirmed as far north as the reefs off Cairns (about 16°30'S see Fig. 1), and at a wide range of locations in the Central Section of the Great Barrier Reef Marine Park (see Figs 1 and 5). The animals off Cairns were observed in August (Table 2). In contrast to the areas south of 21°S

TABLE 2. INCIDENTAL SIGHTINGS OF HUMPBACK WHALES IN GREAT BARRIER REEF WATERS NORTH OF LATITUDE 23°S (BUT EXLUDING THE CAPRICORNIA SECTION OF THE GREAT BARRIER REEF MARINE PARK) BETWEEN 1980 AND 1984 INCLUSIVE

Month	Whales sighted			No. of groups travelling in various directions[2]			
	No. groups	No. individuals[1]	No. calves	Northerly	Southerly	Non-directional	Other
Between 9°S and 11°S (near Don Cay, Murray Island, 10°31′S, 143°45′E)							
November	3[3]	16[4]	0	0	0	3	0
Between 15°S and 17°S (near Michaelmas Cay, Upolo Cay, Green Island)							
August	3	6	2	0	0	0	2
Between 17°S and 19°S (near Dunk Island, Beaver Cay, Rib Reef, Wheeler Reef, Keeper Reef, Davies Reef, Broadhurst Reef).							
July	7	23	6	1	0	5	0
August	7	15	2	0	0	2	1
September	1	2	0	0	0	1	0
TOTAL	15	40	8	1	0	8	1
Berween 19°S and 21°S (near Cape Cleveland, Magnetic Island, "Yongala" wreck, Cape Bowling Green, Holbourne Island, Whitsunday Islands and associated reefs, Smith Group of Islands)							
July	10	27	5[5]	4	2	2	0
August	14	41	3	2	4	5	1
September	17	31	5	1	7	6	2
October	1	2	1	0	1	0	0
TOTAL	42	101	14	7	14	13	3
Between 21°S and 23°S (near Pompey Reefs, Sarina, Percy Isles, Duke Island Group, Cape Townshend, between Swain Reefs and Capricorn Channel.)							
July	2	4	0	1	1	0	0
August	4	7	1	0	1	3	0
September	13	28	8	8	0	3	1
TOTAL	19	39	9	9	2	6	1

1 if some doubt over number the lowest estimate taken. 2 direction of travel not always recorded.
3 very diffuse groupings. 4 all but one seen outside the outer Barrier Reef.
5 includes one cow seen with two calves.

where none of the 75 humpbacks seen in July have been calves and where calves are first seen in August (Table 1), 11 of the 50 humpbacks recorded between 17° and 21°S in July were calves. The difference is significant (G with William's correction = 20.77; 1 d.f.; $P < 0.001$), suggesting that the whales tend to calve north of 21°S.

Although the proportion of calves (17/113 or 15% of sightings) seen north of 21°S in 1983–84 was higher than that seen in reef waters including Capricornia south of this latitude (28/279 or 10%), the difference is not significant (G with William's correction = 2.81; 1 d.f.; $P > 0.05$).

Group sizes are available for 18 calves sighted between 15° and 21°S. Eleven (61%) were accompanied by only one animal, presumably the mother. Single calves were also seen with two, four and six escorts (on one occasion each). Two calves were seen with two adults (once), and three animals (twice). One adult flanked by two calves was followed by a dive boat for about 15 minutes off the 'Yongala' wreck (south of Cape Bowling Green) on the 31 July 1984.

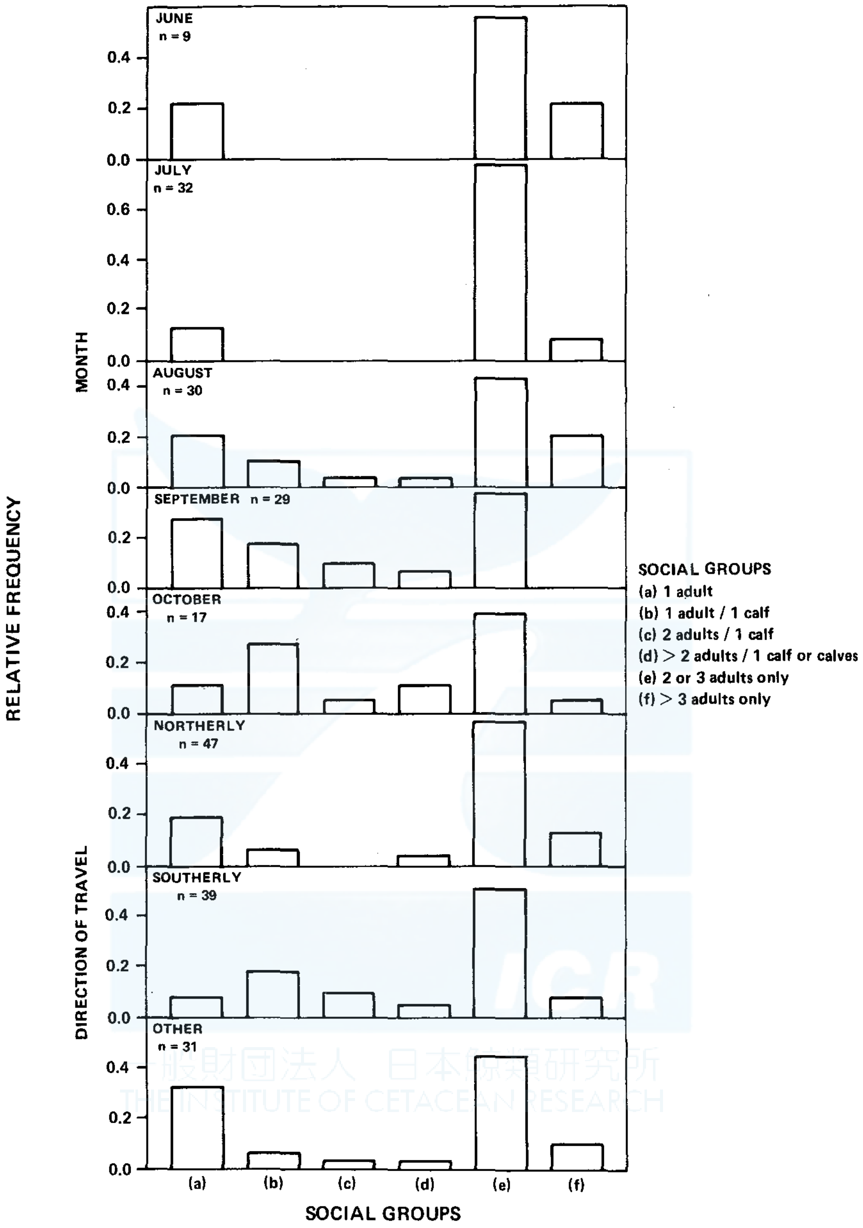

Fig. 4. Relative frequency of the different social groupings identified by Darling *et al.*, (1983) which were recorded in the Capricornia Section of the Great Barrier Reef Marine Park in 1983–84 and summarized according to direction of travel and calender month.

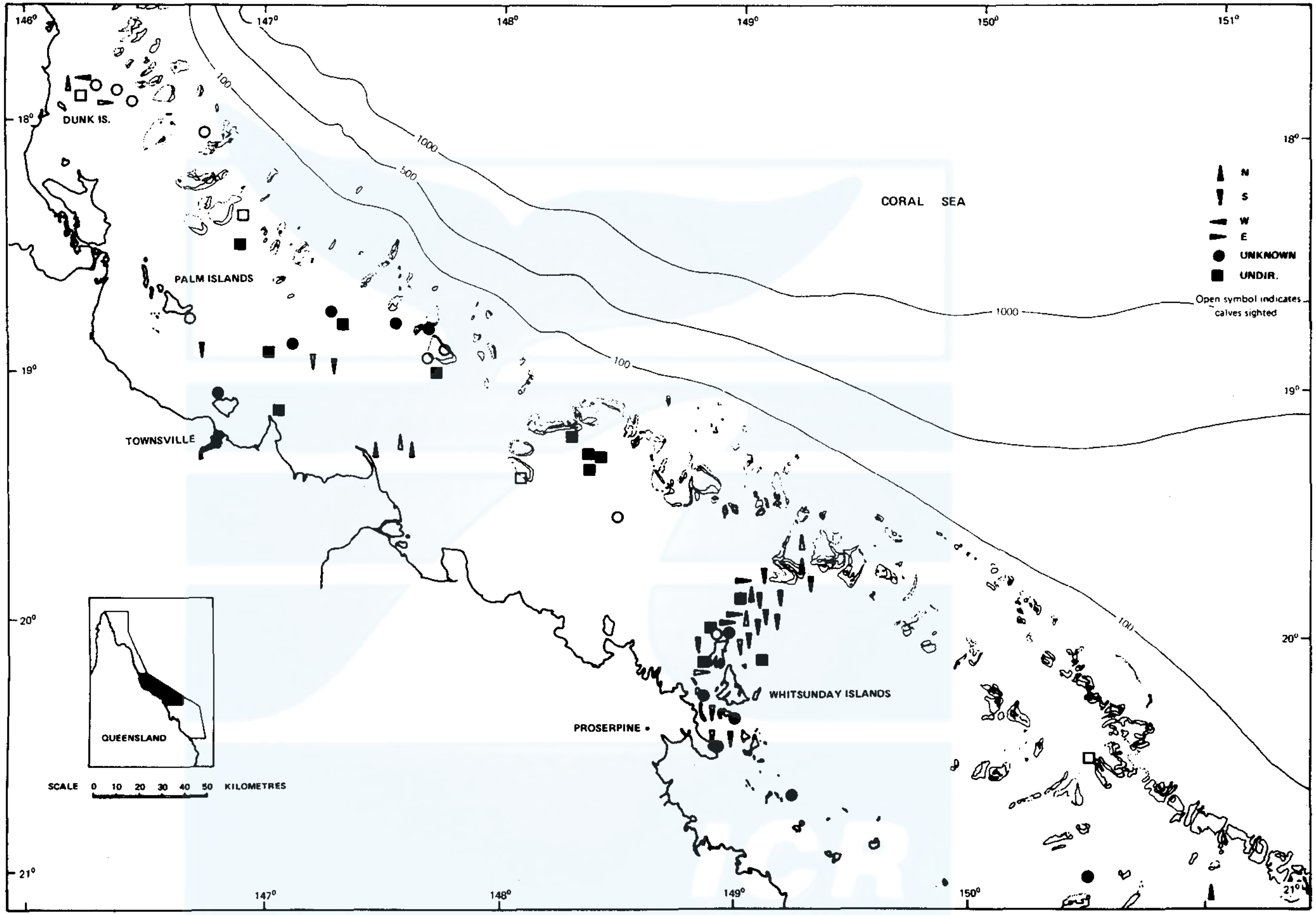

Fig. 5. Location and direction of travel of groups of humpbacks recorded in or adjacent to the Central Section of the Great Barrier Reef Marine Park between 1975 and 1984 inclusive. Groups containing one or more calves have been ringed. The 100m, 500m and 1000m contourlines are shown.

No calves were seen among the humpbacks sighted in the Murray Island area (10°31′S see Fig. 1) in the second half of November in 1981 and 1983 (Table 2). The 1981 sighting made by charter boat operator Mr Perry Harvey was of a very scattered aggregation of 10 to 20 whales. All were outside, but within two miles of, the outer Barrier Reef. Humpbacks were also seen in this area by one of us (HM) during an aerial survey in November 1983. A single animal was observed inside the outer Barrier at approximately 10°31′S; 143°45′E. A diffuse group of five animals was also seen just outside the northern end of the outer Barrier Reef. The simultaneous occurrence of four whale sharks in the same area suggests that it may be rich in plankton in November. A Murray Islander leader, Mr Sam Passi, explained that whales fitting the description of humpbacks are regularly seen between October and January. Most are seen between Murray Island and the outer Barrier Reef. The Murray Islanders have a whale totem indicating that they regard these whales as significant, and suggesting that their occurrence in these waters in the Austral summer is long-standing.

DISCUSSION

"The Great Barrier Reef extends for about 2300 km along the east coast of Queensland (Fig. 1) from about 9° to 25°S with the outer reefs 23 to 260 km from the coast. The Barrier Reef bounds a lagoon, very much broken up by reefs, having a mean depth of 35 m and in which depths of over 60 m are uncommon" (Pickard *et al.*, 1977). The vastness of this region is difficult to comprehend. According to statistics supplied by the Great Barrier Reef Marine Park Authority, the 'Great Barrier Reef Region' has an area of 348,700 km^2 and contains 2,904 gazetted reefs.

Both oral history accounts and recent sightings document the seasonal occurrence of humpbacks over much of this lagoon. Apart from those in the Murray Island area (10°31′S), most recent sightings have been south from about 16°. This may simply be the result of the pattern of human usage of the region. The oral history accounts indicate that humpback sightings used to be commonplace between June and September at least as far north as Princess Charlotte Bay (14°25′S), and that in some areas the whales occurred in such numbers that they were considered a real hazard to shipping. We are unable to determine whether the low number of historical records from the area between Princess Charlotte Bay and Torres Strait is an artefact of the low level of human activity or a reliable indication of whale habitat usage.

Most of the historical accounts agree that humpback sightings in Great Barrier Reef waters dramatically decreased coincident with the period of coastal whaling from east coast shore stations from 1952 to 1962. There is also anecdotal evidence to suggest that numbers are begining to build up again in Great Barrier Reef waters. This apparent recovery is also coincident with the increase in numbers being documented during the east coast migration further south (see Paterson and Paterson, 1984). All this suggests that the humpbacks migrating along the east coast of Australia mostly winter in the Great Barrier Reef lagoon. The observed contemporary absence of winter concentrations of humpbacks from these waters is probably a consequence of both the vastness of the area and low whale numbers.

Our records show that calves tend to be seen north of 21°S earlier in the year than in the Capricornia Section (Tables 1 and 2), suggesting that whales are migrating though the waters of Capricornia en route to their breeding grounds. However, the observation of a humpback cow with a light-coloured, apparently new-born calf in shallow water near Wilson Island (23°18′S; 151°55′E) on July 20 1985 (Fig. 3) suggests that some humpbacks calve in Capricornia. Paterson and Paterson (1984) and Paterson (1985) present evidence indicating that some humpbacks give birth even before reaching Great Barrier Reef waters. They base their conclusion on an eye-witness report of a humpback giving birth at Rooney Point (24°49′S; 153°07′E), and on two separate sightings of humpbacks each accompanied by a small calf tracking north past Cape Moreton (27°02′S) on August 30 1982 and June 27 1984 respectively. A cow and calf were also seen tracking north in the channel near Heron Island (23°26′S; 151°55′E) on July 23 1985. We have also seen whales with calves tracking northward in the second half of the season at other locations in Great Barrier Reef waters.

The breeding areas in Hawaii and the West Indies are characterized by shallow waters (15 m to 60 m deep, see Whitehead and Moore, 1982) with surface water temperatures of 25°C, and 24° to 28°C respectively (Herman and Antinoja, 1977; Whitehead and Moore, 1982). Most of the Great Barrier Reef lagoon is of a suitable depth, but if such temperatures are important, we would expect most humpbacks to calve north of about 14°30′S (see Fig. 6). This seems unlikely in view of the observations discussed above and the lack of recent sightings from the northern area. The distribution of recent sightings of whales with calves north of 21°S (Fig. 5 and Table 2) suggests that calving is occurring over a wide area.

The historical (Fig. 1) and recent sightings (Table 2) of humpbacks in the Murray Island area near the northern tip of the Great Barrier Reef after the end of the main north-south migration along the east coast of Australia is surprising and warrants further investigation, particularly in the light of Paterson's observations of whales tracking north in late September (see Paterson, 1985). The reliability of the observed direction of travel as an indication of the overall direction of migration also needs to be assessed, especially for southward migrating whales whose movement tends to be erratic (Bryden, 1985).

In view of the huge areas involved, and the increasing level of aerial surveillance resulting from the implementation of management plans for the various sections of the Great Barrier Reef Park, we consider that it would be premature to mount dedicated aerial surveys for humpback whales in the

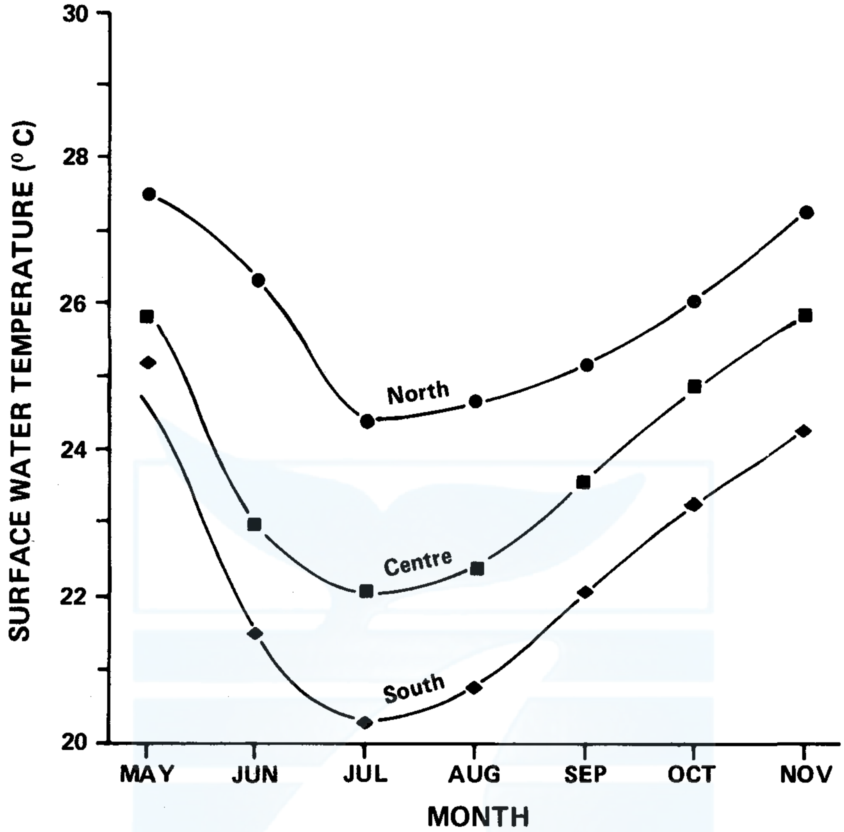

Fig. 6. Surface water temperatures during the Austral winter along the inshore waters of the Great Barrier Reef lagoon (data from Brandon, 1973; figure modified from Pickard *et al.*, 1977). Northern Zone – 10°30′ to 14°30′S; Central Zone – 14°36′ to 19°30′S; Southern Zone – 20°30′ to 24°30′S).

Great Barrier Reef lagoon. The success of such surveys is almost certainly weather-dependent. Bryden (1985) suggests that sighting is much reduced when skies are overcast and winds greater than Beaufort 5. Unfortunately, the occurrence of whales in reef waters coincides with the season of south-east trade winds which means that seas are often rough (Pickard *et al.*, 1977). However, the upgraded incidental sightings programme presently being developed by the management agencies offers an excellent opportunity to systematically acquire more background data and to document the expected recovery of whale stocks.

Improvements planned for this programme include more detailed guidelines for data collection to eliminate some of the problems that emerged during this analysis. We found, for example, that all the data on behaviour, as well as the data on direction of swimming and group size collected outside the Capricornia Section of the Great Barrier Reef Marine Park, were too inconsistent and subjective to be of use. However, the introduction to Australia of the benign research techniques that have been successfully used to study humpbacks in other areas should quickly improve the quality of the data collected.

If humpbacks recover to their pre-whaling numbers, whale watching promises to become a highlight for winter visitors to the reef, and a potential concern for Great Barrier Reef Marine Park management agencies. It is fortunate that the whales migrating up the east coast of Australia are protected by the Great Barrier Reef Marine Park which includes 99% of the reef region. This is the only whale habitat receiving such protection in the Southern Hemisphere (see Johnson and Wolman, 1984).

ACKNOWLEDGEMENTS

Many people and several institutions helped provide the information included in this paper. We wish to thank the following: Peter Arnold, Australian National Parks and Wildlife Service, Vincent Burns, Brian Dalton, George Heinsohn, Great Barrier Reef Marine Park Authority and staff, Heron Island Research Station and Resort staff, Janet Lanyon, Lloyds Helicopters, One Tree Island Research Station staff, Piccolo Aviation, Q.NPWS Maritime Estate field staff, Henry Reynolds, Andrew Smith, and the many members of the public who completed humpback whale sighting sheets. The figures were drawn by Keith Saalfeld. Peter Arnold, Michael Bryden, Wendy Craik and Janet Lanyon made useful comments on the text.

REFERENCES

Bryden, M.M., 1985. Studies of humpback whales (*Megaptera novaeangliae*), Area V. pp. 115–123 *In*: J.K. Ling and M.M. Bryden (eds) *Studies of Sea Mammals in South Latitudes*. South Australian Museum, Adelaide. 132 pp.

Chapman, D.G., 1974. Status of Antarctic rorqual stocks. pp. 218–238 *In*: W.E. Schevill (ed.) *The Whale Problem*. Harvard University Press, Cambridge, Mass. 419 pp.

Chittleborough, R.G., 1965. Dynamics of two populations of the humpback whale *Megaptera novaeangliae* (Borowski). *Aust. J. Mar. Freshwat. Res.*, 16: 33–128.

Darling, J.D., K.M. Gibson and G.K. Silber, 1983. Observations on the abundance and behaviour of humpback whales (*Megaptera novaeangliae*) off West Maui, Hawaii, 1977–79. pp. 201–222. *In*: R. Payne (ed.) *Communication and Behaviour of Whales*. Westview Press, Boulder, Colorado. 643 pp.

Dawbin, W.H. and R.A. Falla, 1949. A contribution to the study of the humpback whale based on observations at New Zealand shore stations. *Proc. Pacif. Sci. Cong., 7th*, 4: 373–82.

Herman, L.M. and R.C. Antinoja, 1977. Humpback whales in the Hawaiian breeding waters: population and pod characteristics. *Sci. Rep. Whales Res. Inst.*, 29: 59–85.

Johnson, J.H. and A.A. Wolman, 1984. The humpback whale, *Megaptera novaeangliae*. *Mar. Fish. Rev.*, 46(4): 30–37.

Leatherwood, S., D.K. Caldwell and H.E. Winn, 1976. Whales, dolphins and porpoises of the Western North Atlantic. A guide to their identification. *NOAA Technical Report NMFS CIRC* 396, 176 pp.

Paterson, R., 1985. Sightings suggest whale numbers increasing. *Australian Fisheries*, 44(5): 43–45.

Paterson, R. and P. Paterson, 1984. A study of the past and present status of humpback whales in east Australian waters. *Biol. Conserv.*, 29: 321–343.

PICKARD, G.L., J.R. DONGUY, C. HENIN and F. ROUGERIE, 1977. A review of the physical oceanography of the Great Barrier Reef and Western Coral Sea. *Australian Institute of Marine Science Monograph Series*, 2. Australian Government Publishing Service, Canberra. 134pp.

TOWNSEND, C.H., 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica*, 19: 1–50.

TYACK, P. and H. WHITEHEAD, 1982. Male competition in groups of wintering humpback whales. *Behaviour*, 83: 132–154.

WHITEHEAD, H. and M.J. MOORE, 1982. Distribution and movements of West Indian humpback whales in winter. *Can. J. Zool.*, 60: 2203–2211.

WINN, H.E., R.K. EDEL and A.G. TARUSKI, 1975. Population estimates of the humpback whale (*Megaptera novaeangliae*) in the West Indies by visual and acoustic techniques. *Can. J. Zool.*, 32: 499–506.

THE LENGTHS AND DISTRIBUTION OF ANTARCTIC SEI WHALES

JOSEPH W. HORWOOD*

ABSTRACT

Data from the Bureau of International Whaling Statistics are used to examine the distribution and lengths of sei whales caught by the pelagic fleets in the Antarctic over the period 1931 to 1978. Over this period peak catches occurred in January but from 1931 to 1950 the peak was in March and from 1950 to 1960 the peak was in February. This difference with time is probably due to an earlier preference for blue and fin whales. Maximum lengths found were 61 feet for males and 64 feet for females. Having stratified the data by latitude, longitude and month it was found that for males there was no difference in the mean lengths between the months January to March but for females mean lengths were longer in January than those in February and March. This may reflect the difference in timing of migration of the different age and sexual classes. In all months and longitudinal bands mean lengths of whales of both sexes were greater south of the Antarctic Convergence. These mean differences ranged from 0.5–3.8 feet for males and 0.9–3.9 feet for females. The distribution of larger whales is similar north and south of the Convergence and the difference is caused by most of the smaller whales staying north of the Convergence.

INTRODUCTION

Following the development of the attached, explosive harpoon large rorquals could be caught and numerous sei whales (*Balaenoptera borealis* Lesson) were caught off Finmark, the Faroe Islands and Iceland before the turn of the century (Collett, 1886; Hjort and Rudd, 1929; Tønnessen and Johnsen, 1982). In the Southern Hemisphere sei whales were first taken from the land stations on the Falkland Islands and South Georgia before larger catches were taken by the pelagic fleets. The first record which I can trace of sei whales caught from the Antarctic land stations, is during February or April of 1906 at New Island in the Falkland Islands (Tønnessen and Johnsen, 1982). Catches by the Antarctic Pelagic fleets remained at less than 1,000 per year until 1957/58 although the land stations at South Georgia usually caught more than the pelagic fleets (Ohsumi and Yamamura, 1978). With restrictions on the capture

---

* *Ministry of Agriculture, Fisheries and Food, Fisheries Laboratory, Lowestoft, Suffolk NR33 OHT, England*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 47–60

of fin whales the fleets took progressively more sei whales and extensive exploitation occurred over the seasons 1963/64 to 1967/68 (Horwood, 1978). Ohsumi and Yamamura record that over the period 1909 to 1978 over 171,000 sei whales were caught from the Southern Hemisphere. Under the regulations of the International Whaling Commission (IWC) sei whales were completely protected from all whaling in the Southern Hemisphere from the start of the 1978/79 whaling season (Anon., 1979).

The distribution of sei whales is seasonal, as is that of the other rorquals, with breeding occurring in the sub-tropical waters and migrations to the polar feeding grounds. The distribution of catches and catch per unit of effort show that in the Antarctic sei whale numbers are highest from January to March and off South Africa are highest in August to October (Bannister and Gambell, 1965; Best, 1967; Budylenko, 1977; Gambell, 1968; Matthews, 1938). Sightings data also confirm this movement (Bannister and Gambell, 1965; Best, 1967; Gambell, 1968; unpublished information provided by Far Seas Fisheries Research Laboratory, Japan; Masaki, 1979). Paiva and Grangeiro (1965, 1970) show a similar winter abundance off Brazil. Marking has shown that sei whales seen in the subtropics do migrate to the Antarctic (Brown, 1977). During the migration, segregation of sexual classes has been observed. Pregnant females leave the warmer waters first, arrive first at the feeding grounds and depart earlier, and older animals generally precede younger ones (Gambell, 1968; Lockyer, 1977).

In the Antarctic, catches of sei whales were predominantly between 40°S and 50°S from longitudes 60°E eastwards to 130°E but at higher latitudes in the rest of the Antarctic (Horwood, 1980a). As shown by Ohsumi (1977) from the North Pacific, Nasu and Masaki (1970) and Kawamura (1974) found the whaling grounds for sei whales to be in temperatures of between 8°C and 18°C, but numerous whales also have been caught south of the Antarctic Convergence (AC). Japanese sighting data show that in some locations sei whales may be found north of 40°S in the whaling season (Masaki, 1980). Within the Antarctic sei whales are not distributed homogeneously and more localized whaling grounds exist. As the whaling season progresses there is a tendency for whaling, and presumably the whales, to be found more to the south (Nemoto, 1959; Kawamura, 1974).

Doi *et al.* (1967) reported on the size distribution of sei whales in the Japanese catch from 60°W eastwards to 170°W (Whaling Areas II–V) over the seasons 1962/63 to 1964/65. They showed that in the catch females were about 4 feet longer than males and that south of 45°S the average length of males in the catch was about 48 feet and the length of females was about 52 feet. North of 45°S the average length of both sexes was much shorter. Similar features were noted by Woolner and Horwood (1980).

The latitudinal segregation by size observed by Doi *et al.* (1967) is not found in the other large rorquals, the catches of which are in higher latitudes. The segregation can be assumed to be of some consequence to the biology of the Southern Hemisphere sei whale but, in addition, the sampling and interpretation of demographic parameters will be affected by the non-random distribution of the whales. The material reported upon by Doi *et al.* (1967) was collected over a limited number of seasons and longitudinal sectors. This study makes use of the material recorded by the Bureau of International Whaling Statistics (BIWS), from pelagic operations since the 1931/32 season, to describe in greater detail the distribution of sei whales and in particular the distribution of lengths. The spatial and within season distribution by sex and age described above have necessitated analyses by month, latitudinal and longitudinal divisions. Of particular interest is the relative sizes north and south of the AC. The rapid increase in exploitation over the middle 1960s resulted in a substantial change in the mean length of whales in the catch within ten degree latitudinal zones (Woolner and Horwood, 1980), and consequently investigations have been carried out before and after this period.

MATERIALS AND METHODS

The data used are the individual catch records originally collated by the BIWS, Norway. They consist of information about each whale caught by pelagic expeditions in the Southern Hemisphere from the 1931/32 whaling season onwards. Each record is from one whale caught and gives details of expedition, date, position, sex, length and foetal data. The lengths are measured in feet from the tip of the rostrum to the notch between the tail flukes and are recorded to the nearest foot. These records are now held by the Secretariat of the IWC. Pelagic whaling for baleen whales in the latitudes 0°–40°S has not been allowed under the International Convention for the Regulation of Whaling, 1946, and so catch data for sei whales are restricted to the higher latitudes. The statistics give 67,853 male sei whales caught, 63,683 females and one unsexed by the pelagic fleets over the period 1931 to 1978 inclusive.

Woolner and Horwood (1980) described changes in the mean length of sei whales from the 1961/62 season with time. Here we are more interested in the spatial distribution of lengths and the effects of the changes with time need to be removed. This has been done by considering two separate time periods, that before and including the 1961/62 season and that after and including the 1968/69 season. Before 1961/62 exploitation was relatively light and mainly restricted to the South Atlantic region. After 1968/69 exploitation diminished and lengths in the catch were stable in most regions (Woolner and Horwood, 1980).

The most important oceanographic feature at about 45° to 50°S in the sector 60°W eastwards to 130°E is the AC and it is likely to be this feature, with its associated hydrographic and biological characteristics that is responsible for the smaller whales staying to the north. South of the AC the waters are colder and contain different food organisms (Kawamura, 1974). Consequently, we are interested in looking at mean lengths to the north and south of the

AC. The position of the AC has been approximated by the position of the 4°C surface isotherm (Machida, 1974) and this can be seen in the Southern Ocean Atlas as the surface averages from January, February and March (Gordon and Molinelli, 1982). Its position is similar to that described by Mackintosh (1946). Marking of sei whales and the distribution of sei and other whales has indicated that different stocks of sei whales can be found in the Antarctic, but the position is ambiguous with substantial mixing of marked whales. Consequently, the region has been divided into twelve sectors of 30° of longitude. This fine division also makes the recognition of the latitudes north and south of the AC easier since the AC varies from below 40°S to above 60°S. The higher position of the AC from 60°W westwards to 180° corresponds to the region where sei whales were caught in the higher latitudes. The position of these sectors and of the AC is given in Fig. 1.

Further arrangement of the data consists in their presentation by months, since previous studies have indicated a differential migration by age and sexual status. Initial inspection of the data is by groupings of two degrees of latitude within each longitudinal sector.

The data thus have been disaggregated into two time periods, all months, 12 longitudinal and 20 latitudinal zones. ANOVA techniques cannot be applied due to the large number of empty cells and unequal variances and so direct comparison of means has been done using Students-t tests and experiment-wise significance levels.

RESULTS

(a) Maximum sizes

From the 131,537 total sei whales recorded in the pelagic data twelve were 60 feet or over. Two were males of 60 and 61 feet. The largest female was measured as 64 feet and was caught when pregnant by boats of the Sovietskaya Ukraina at 68°S 99°W in 1962.

(b) Catch by month

The percentage catch by month over all seasons since 1931 by the pelagic fleets is given by sex in Table 1. It can be seen that peak numbers occur in January and February with large catches also in December and March. No catches occurred until November and after May. Catches in December before 1961/62 were very few and after 1968/69 tended to be restricted to the more northern latitudes. Consequently, subsequent analyses have looked at sizes only in January, February and March.

(c) Size by month within latitude and longitudinal bands

Mean lengths were extracted by the two time periods, the twelve longitudinal zones, three months and two-degrees of latitudes. Within each

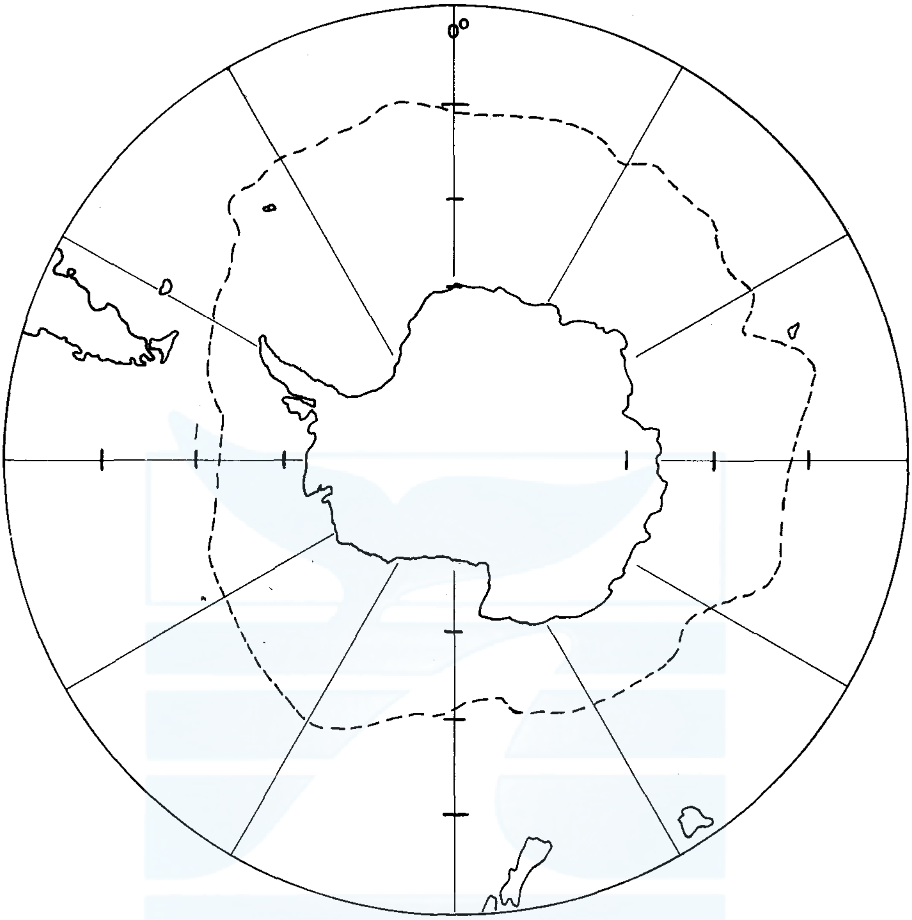

Fig. 1 The Antarctic south of 40°. The dashed line shows the position of the Antarctic Convergence and the radiating lines show the 12 sectors used in the analyses. Ticks are at 50, 60 and 70°S.

TABLE 1. PERCENTAGE OF THE CATCH BY MONTH FROM THE PELAGIC FLEETS, 1931–78

Month	Male	Female
November	0.0	0.0
December	20.0	17.9
January	32.6	28.0
February	28.7	30.9
March	17.7	21.5
April	1.0	1.6
May	0.0	0.1

time period and longitudinal zone the mean lengths in each two-degree latitudinal block were compared by month to see if mean lengths in January were greater than in February, February greater than March and January greater than March. Cells in which less than six whales were caught were ignored. A plus was given if the earlier month was larger and for each sex the plusses and minuses were summed over the entire Antarctic. The results are summarized in Table 2. A signs test can be applied with a chi-square distribution with one degree of freedom and the pair-wise significance level for each comparison is given in Table 2.

TABLE 2. COMPARISON OF MEAN LENGTHS BY TWO-DEGREES OF LATITUDE WITHIN THE 12 ZONES SUMMED OVER THE ANTARCTIC. J = JANUARY, F = FEBRUARY, M = MARCH. A PLUS (+) IS GIVEN IF THE MEAN LENGTH WAS LARGER IN THE EARLIER MONTH

Time	Sex	Months	+	–	Pair-wise probability
≤ 61/62	M	J/F	11	13	> 0.5
≤ 61/62	M	F/M	20	17	> 0.5
≤ 61/62	M	J/M	12	14	> 0.5
≤ 61/62	F	J/F	23	12	0.08
≤ 61/62	F	F/M	22	25	> 0.5
≤ 61/62	F	J/M	18	10	0.09
≥ 68/69	M	J/F	18	15	> 0.5
≥ 68/69	M	F/M	13	17	> 0.5
≥ 68/69	M	J/M	18	8	0.05
≥ 68/69	F	J/F	21	11	0.08
≥ 68/69	F	F/M	15	20	> 0.5
≥ 68/69	F	J/M	22	9	0.02

The signs tests is not powerful but has the advantage of making few assumptions and here the test overcomes any concerns about different sizes between longitudinal zones due to any possible population differences. The results show that in general no differences exist in mean lengths by month of males, but that for females those in January may be larger than those found in February or March. The subsequent analyses retain the segregation by months.

(d) Sizes north and south of the Convergence

Fig. 1 shows the position of the AC as defined by the 4°C isotherm and even after dividing the Antarctic into 30° sectors the AC covers several degrees of latitude in many sectors. For each of the 12 sectors the latitudes taken as above and below the AC are given below (Table 3); this division thus excludes whales caught within the Convergence.

The larger gaps in some of the sectors, e.g. 5, are because there is some variance between the position of the 4°C isotherm from the Atlas and that given by Mackintosh (1946).

Inspection of the data from the early period showed that the catches were very largely south of the AC and do not provide enough material for further investigation. The rest of the analysis is based on data obtained during and after the 1968/69 season.

TABLE 3. DEFINITION OF SECTORS

Sector	Longitude	Above AC: north of latitudes	Below AC: south of latitudes
1	0– 30E	48	54
2	30– 60E	48	52
3	60– 90E	50	56
4	90–120E	50	56
5	120–150E	50	60
6	150–180E	52	62
7	0– 30W	48	54
8	30– 60W	50	60
9	60– 90W	58	64
10	90–120W	58	64
11	120–150W	60	62
12	150–180W	60	64

Only a few sectors have sufficient numbers in two-degree latitudinal sectors in one month to enable an inspection of trends from north to south. They are shown in Fig. 2.

From the data on males no trend is obvious in sector 8 in February (Fig. 2a), but sector 9 in January (Fig. 2b) does show a difference between the lengths of whales caught north of 50°S and those caught south of 58°S. Sector 6 in March has the AC covering ten degrees of latitude and most of the data are from within the Convergence but Fig. 2c shows the lengths south of the Convergence to be larger than the others. Sector 3 in February (Fig. 2d) has no values totally south of the AC but the data from the lowest latitudes indicate smaller sizes. This is not seen in the same sector in the previous month (Fig. 2e) and the southernmost point removes the impression of a consistent trend with latitude.

The data from females in sector 8 in January and February (Fig. 2f and g) also show no trend. However, data from sectors 6, 3 and 2 (Fig. 2h, i and j) all show a discontinuity at about the position of the AC, with larger lengths to the south.

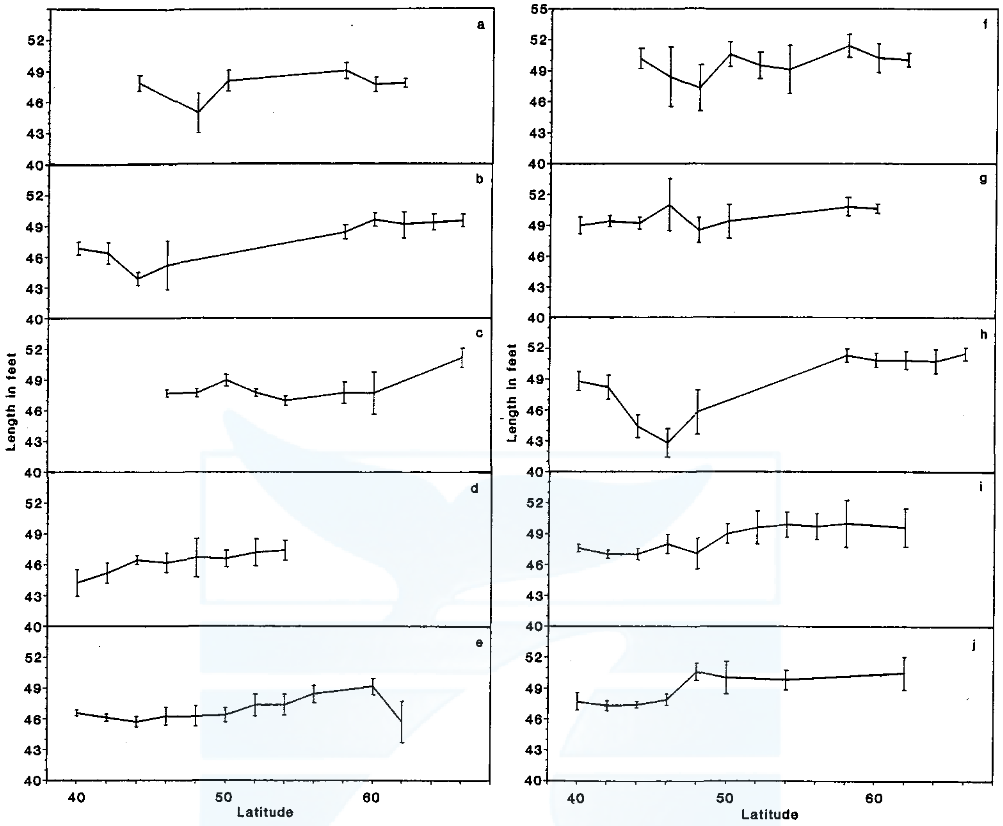

Fig. 2 Mean lengths in feet and ±2 standard errors of lengths by latitude. 40° corresponds to a grouping of whales caught in 40–42°S. Males: a-e. Females: i-j.

(a) February, 30–60°W	(b) January, 60–90°W
(c) March, 150–180°E	(d) February, 60–90°E
(e) January, 60–90°E	(f) February, 30–60°W
(g) January, 30–60°W	(h) March, 150–180°E
(i) January, 60–90°E	(j) February, 30–60°E.

It is possible to aggregate the data over latitudes north and south of the Convergence (as defined above), but retaining the segregation by month and sector. The mean lengths so obtained and the differences of the means are given in Table 4.

Data have only been used if six or more lengths were obtained both north and south of the AC and consequently many gaps are found in the table. In all cases (35) the mean value was greater south of the Convergence. In the light of this further tests are hardly required but for completeness Student's t-tests were done.

In all cases the variance of the lengths was greater in the north, a feature

TABLE 4. MEAN LENGTH OF WHALES NORTH OF THE AC AND IN BRACKETS DIFFERENCES IN THE MEAN LENGTH IN FEET OF SEI WHALES CAUGHT SOUTH AND NORTH OF THE AC BY MONTH AND LONGITUDINAL SECTOR IN THE SEASONS OF 1968/69 AND AFTER. ALL VALUES ARE GREATER IN THE SOUTH. AN ASTERISK INDICATES THAT LESS THAN 6 WERE CAUGHT EITHER NORTH OR SOUTH OF THE CONVERGENCE

Sector	Month		
	January	February	March
(a) FEMALES			
1	*	*	*
2	*	47.5 (2.94)	*
3	47.3 (2.50)	46.7 (2.75)	47.1 (2.80)
4	48.0 (2.67)	47.4 (2.08)	*
5	*	*	*
6	*	*	47.0 (3.87)
7	*	*	*
8	49.2 (1.43)	49.1 (1.23)	*
9	49.5 (1.44)	50.0 (0.87)	*
10	*	47.7 (2.96)	*
11	49.6 (0.91)	49.4 (1.53)	48.6 (2.32)
12	*	49.0 (1.64)	47.2 (3.85)
(b) MALES			
1	*	*	*
2	*	46.1 (2.23)	*
3	46.3 (1.71)	46.1 (1.30)	*
4	46.8 (1.36)	45.5 (1.88)	*
5	47.3 (0.68)	*	*
6	*	*	45.6 (3.79)
7	*	*	*
8	47.2 (0.55)	47.1 (0.84)	44.5 (2.50)
9	47.7 (3.33)	47.4 (0.74)	*
10	*	46.5 (1.01)	*
11	47.9 (1.23)	47.8 (0.50)	47.7 (0.99)
12	*	47.1 (0.95)	46.6 (2.24)

seen in the data of Doi *et al.* (1967), and consequently tests involving unequal variances and unequal sample sizes have been used (Snedecor and Cochran, 1980). An example of the distribution of lengths from the 60°–90°E sector in January is given in Table 5. The t-values are given in Table 6. Very few values are not significant at a pair-wise significance level of P = 0.01. If the males and females are treated as two independent groups then a better test is to look at the experiment-wise significance rates and these are shown in Table 6. A large number are significant even on this basis.

TABLE 5. LENGTH FREQUENCY DISTRIBUTION OF FEMALES CAUGHT FROM THE 1968/69 SEASON AND AFTER IN JANUARY AND IN THE 60–90°E SECTOR

	Length																				
	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
North of AC	1	1	29	41	47	43	65	52	80	85	84	85	91	84	76	25	12	6	1	0	1
South of AC	0	0	0	0	1	2	2	3	4	2	7	5	11	13	14	7	0	3	0	0	0

TABLE 6. STUDENT'S T-VALUES OF COMPARISON OF MEAN LENGTHS NORTH AND SOUTH OF THE AC. THE DEGREES OF FREEDOM BASED ON UNEQUAL VARIANCES ARE GIVEN IN BRACKETS. SIGNIFICANCE LAVELS OF $P \leqslant 0.02$ ASSESSED ON AN EXPERIMENT-WISE BASIS FOR MALES AND FEMALES SEPARATELY ARE GIVEN BY $^{+}$ (EQUIVALENT TO $P \leqslant 0.001$ FOR PAIR-WISE TESTS)

Sector	January	February	March
(a) FEMALES			
1	–	–	–
2	–	7.6 (48)$^{+}$	–
3	7.0 (93)$^{+}$	4.5 (42)$^{+}$	3.3 (10)
4	6.7 (23)$^{+}$	3.4 (83)	–
5	–	–	–
6	–	–	10.7 (247)$^{+}$
7	–	–	–
8	5.7 (329)$^{+}$	2.2 (65)	–
9	2.9 (23)	1.9 (43)	–
10	–	3.9 (21)$^{+}$	–
11	1.7 (49)	5.5 (262)$^{+}$	4.9 (119)$^{+}$
12	–	5.5 (367)$^{+}$	5.1 (35)$^{+}$
(b) MALES			
1	–	–	–
2	–	5.7 (22)$^{+}$	–
3	5.6 (86)$^{+}$	2.9 (30)	–
4	3.0 (16)	3.7 (79)$^{+}$	–
5	1.3 (6)	–	–
6	–	–	13.5 (286)$^{+}$
7	–	–	–
8	2.5 (152)	1.9 (64)	2.8 (11)
9	8.8 (22)	2.2 (52)	–
10	–	4.1 (48)	–
11	3.7 (34)$^{+}$	2.8 (292)	2.6 (48)
12	–	4.5 (254)$^{+}$	3.4 (27)

DISCUSSION AND CONCLUSION

The lengths of sei whales in catches are affected by the location of the catches.

For instance, this study has shown that there are differences north and south of the Antarctic Convergence and Gambell (1968) found that more immature whales were caught off South Africa than off South Georgia. This presents a problem in describing lengths in the population. However, large numbers of sei whales have been caught from many localities and the aggregation of the data from the Southern Hemisphere is likely to yield a better description of the length at age in the population than presentation of the data from single regions. Even so there has been selection for the larger of the young animals and that has forced the construction of 'ideal age-length keys' (Ohsumi and Masaki, 1978). The age length keys have given maximum mean lengths (L_∞) of 48 to 49 feet for males and about 51 feet for Southern Hemisphere sei whales.

The maximum length of each of the whale species is useful to know, at least for identification purposes. Zemski (1980) reported that the maximum sizes of sei whales were 19 m (62 feet) in the Southern Hemisphere and 18 m (59 feet) in the Northern Hemisphere. The BIWS pelagic catch data show 12 whales caught of 60 feet or over. The largest male was 61 feet and the largest female 64 feet. The International Whaling Statistics (IWS, 1967, 1968) show that off Kamchatka a 59 foot male and 62 foot female were caught. Thompson (1928) reported males of 62 and 64 feet in catches from Scottish whaling stations and mentioned that Haldane's notes recorded a male of 65 feet. Thompson (1928) observed, in his section on right whales (p.7), that he suspected that at least some of the lengths of right whales were measured along the arc of the body. No such comment is made about sei whales but it is probable that he was referring to length measurements of all whales. Martin (1983) remarked that the Scottish length measurements were much bigger than any known reliably documented measurement from the North Atlantic. The 12 whales from the BIWS data were recorded over the period 1956–64 and although Clark (1983) has indicated that there might have been differences in measurement by different countries of up to 5 per cent, the techniques of standard measurement were established by this time and the lengths can be accepted. We can conclude that maximum lengths of sei whales are 61 feet for males and 64 feet for females with a possibility that larger ones have existed.

Harmer (1931) and Matthews (1938) showed that over the years 1913 to 1931 peak catches of sei whales at South Georgia occurred in March with reasonable numbers caught in February and April. Gambell (1968) reported peak catches at South Georgia from 1963 to 1965 to be in January and peak catch per effort in the same month. Catches were high from January to March. Gambell (1968) argued that although the wave of migrations of blue and then fin whales past South Georgia affected the desirability of sei whales to the industry the late influx of sei whales was real and this is supported by the low percentage of sei whales with diatom infestation at South Georgia from January to March. The pelagic data over the years 1931 to 1978 show peak catches in January and February with less in December and March and very few in other months. Japanese sightings data from 1965 also confirm that peak abundances occur about January in the latitudes 40°–50°S but with a year-to-year variation that shows the general abundance of sei whales to occur between December and March. At higher latitudes peak sightings occur later. The impression is of sei whales starting to arrive in large numbers in the waters south of 40°S about December and generally remaining until March with a few penetrating further south later in the season. The more southern penetration of sei whales as the season progresses has been noted by Kawamura (1974). Nemoto (1959) considered that relatively large catches of sei whales in 1957 and 1958 in the Antarctic were associated with higher water temperatures in those years and that higher surface water temperature later in the summer allows sei whales further south. The sensitivity of sei whales to cold water and cold weather is well documented (Ingebrightsen, 1929; Nemoto, 1959; Mitchell and Kozicki, 1974).

Laws (1977) suggested that the changes in peak abundance from the 1927–31 period to that in the late 1950s could be due to a relaxation of interspecific competition or some environmental change but Matthews (1938) pointed out that absence of catches in January may well be because of the much greater demand for fin whales. Subsequent catches described by Gambell (1968) and the large majority of the pelagic catches described here were taken earlier in the season but were taken after fin and blue whales had been substantially depleted. Consequently, we cannot tell if the timing of migration has altered. Further inspection of the catch data by ten-year blocks revealed that before 1950 pelagic catches peaked in March, over the period 1950 to 1960 they peaked in February and only later were the large catches taken in January. One factor suggesting that the change is not real is that the catches described by Harmer (1931) and Matthews (1938) and early pelagic catches were over only three months whereas we now see sei whales in substantial numbers over four months. A three-month feeding season is very short. However, temperatures in the Antarctic Peninsula during the late 1920s were the coldest of the century (Horwood, 1980b) and subsequent warming or relaxation of competition may have allowed sei whales to arrive earlier in the season, but even so the late pelagic catches peaking late in the season continued until 1960 and a change in selection by the industry is the likely explanation.

The results given in Table 2 show that for males there is no evidence that migration to or residence in the waters south of 40°S is related to length. For females, however, the average lengths are greater in January than in February or March. This would indicate that larger females arrive earlier. The early migration of older females is documented by Gambell (1968) and Lockyer (1977) but the sexual status of the whales is also important with immature and pregnant females preceding lactating females. Lockyer (1977) shows (her Figure 3) that there is a high incidence of pregnant and mature sei whales in mid-January. The larger whales found in January thus may be the older mature whales which are joined later by the smaller, younger whales. Reasons for this may be that the larger whales can tolerate the slightly colder temperatures found in January or that their sexual condition needs a longer feeding season.

The figures showing the distribution of lengths of whales with latitude do not generally show sharp discontinuities associated with the AC. In some localities the changes are more pronounced than others, such as 30°–90°E, but usually only slight trends can be seen. In contrast, when the lengths are grouped north and south of the Convergence large differences in the mean lengths are found. In January to March in both sexes and in all longitudinal zones, where enough data existed, whales were longer south of the Convergence. In males the means difference ranged between 0.55 to 3.79 feet and in females from 0.87 to 3.85 feet. An example of the distribution of lengths is given in Table 5 and its character is similar to that observed by Doi *et al.* (1967). The difference is generated by the distribution of larger sizes being about the same both north and south of the Convergence but with many smaller whales to the north. This was reflected in the variance of the lengths being always greater in the north. The reason for the segregation is not known. As previously described, sei whale distribution is known to be sensitive to surface temperature. This may be a direct thermal effect in that they do not like cold water or an effect moderated through their food supply. In the Antarctic it is possible that only the larger whales can tolerate the colder waters to the south of the Convergence or that the distribution of the prey species, known to be different south of the Convergence (Kawamura, 1974), can only be harvested by the larger animals.

REFERENCES

ANON., 1979. Chairman's Report of Thirtieth Annual Meeting. *Rep. int. Whal. Commn*, 29: 21–37.

BANNISTER, J.L. and R. GAMBELL, 1965. The succession and abundance of fin, sei and other whales off Durban. *Norsk Hvalfangst-Tid.*, 54: 45–60.

BEST, P.B., 1967. Distribution and feeding habits of baleen whales off the Cape Province. *Investl Rep. Div. Sea Fish. S. Afr.*, 57: 1–44.

BROWN, S.G., 1977. Some results of sei whale marking in the Southern Hemisphere. *Rep. int. Whal. Commn* (Special Issue 1) : 39–43.

BUDYLENKO, G.A., 1977. Distribution and composition of sei whale schools in the Southern Hemisphere. *Rep. int. Whal. Commn* (Special Issue 1) : 121–123.

CLARK, W.G., 1983. Apparent inconsistencies among countries in measurements of fin whale lengths. *Rep. int. Whal. Commn*, 33: 431–434.

COLLETT, R., 1886. On the external characteristics of Rudolphi's rorqual (*Balaenoptera borealis*). *Proc. Zool. Soc. (Lond.)* : 243–265.

DOI, T., S. OHSUMI and T. NEMOTO, 1967. Population assessment of sei whales in the Antarctic. *Norsk Hvalfvangst-Tid.*, 56: 26–29.

GAMBELL, R., 1968. Seasonal cycles and reproduction in sei whales of the Southern Hemisphere. *Discovery Rep.*, 35: 31–134.

GORDON, A.L. and E.J. MOLINELLI, 1982. *Southern Ocean Atlas. Thermohaline and chemical distributions and the atlas data set.* Columbia University Press, New York. 11 pp. + 233 plates.

HARMER, S.F., 1931. Southern whaling. *Proc. Linn. Soc. Lond., Session 142*, 1929–30: 85–163.

HJORT, J. and J.T. RUDD, 1929. Whaling and fishing in the North Atlantic. *Rapp. P.–v. Réun. Cons. int. Explor. Mer*, 56(1): 1–123.

HORWOOD, J.W., 1978. Sei whale catch statistics and estimated recruitment rates. *Rep. int. Whal. Commn*, 28: 391–399.

HORWOOD, J.W., 1980a. Population biology and stock assessment of Southern Hemisphere sei whales. *Rep. int. Whal. Commn*, 30: 519–530.

HORWOOD, J.W., 1980b. Competition in the Antarctic? *Rep. int. Whal. Commn*, 30: 513–517.

INGEBRIGHTSEN, A., 1929. Whales caught in the North Atlantic and other seas. *Rapp. P.–v. Réun. Cons. int. Explor. Mer*, 61(3): 1–26.

International Whaling Statistics, 1967, Vol. 59.

International Whaling Statistics, 1968, Vol. 61.

KAWAMURA, A., 1974. Food and feeding ecology in the southern sei whale. *Sci. Rep. Whales Res. Inst.*, 26: 25–144.

LAWS, R.M., 1977. Seals and whales of the Southern Ocean. *Phil. Trans. R. Soc. Lond. B*, 279: 81–96.

LOCKYER, C.H., 1977. Some possible factors affecting age distribution of the catch of sei whales in the Antarctic. *Rep. int. Whal. Commn* (Special Issue 1) : 63–70.

MACHIDA, S., 1974. Surface temperature field in the Crozet and Kerguelen whaling grounds. *Sci. Rep. Whales Res. Inst.*, 26: 271–287.

MACKINTOSH, N.A., 1946. The Antarctic Convergence and the distribution of surface temperatures in Antarctic waters. *Discovery Rep.*, 23: 179–212.

MARTIN, A.R., 1983. The sei whale off western Iceland. I. Size, distribution and abundance. *Rep. int. Whal. Commn*, 33: 457–464.

MASAKI, Y., 1979. Japanese pelagic whaling and whale sightings in the 1977/78 Antarctic season. *Rep. int. Whal. Commn*, 29: 225–251.

MASAKI, Y., 1980. Additional comments on the result of whale sighting by scouting boats in the Antarctic whaling season from 1965/66–1977/78. *Rep. int. Whal. Commn*, 30: 339–357.

MATTHEWS, L.H., 1938. The sei whale, *Balaenoptera borealis*. *Discovery Rep.*, 17: 183–290.

MITCHELL, E.D. and V.M. KOZICKI, 1974. The sei whale (*Balaenoptera borealis*) in the Northwest Atlantic Ocean. Paper SC/SP74/32 presented to the IWC scientific Committee (unpublished). 49 figs + 48 pp.

NASU, K. and Y. MASAKI, 1970. Some biological parameters for stock assessment of the Antarctic sei whale. *Sci. Rep. Whales Res. Inst.*, 22: 63–74.

NEMOTO, T., 1959. Food of baleen whales with reference to whale movements. *Sci. Rep. Whales Res. Inst.*, 14: 149–290.

OHSUMI, S., 1977. Bryde's whales in the pelagic whaling ground of the North Pacific. *Rep. int. Whal. Commn* (Special Issue 1) : 140–149.

OHSUMI, S. and Y. MASAKI, 1978. Age-length keys and growth curves of the Southern Hemisphere sei whales. *Rep. int. Whal. Commn*, 28: 431–436.

OHSUMI, S. and K. YAMAMURA, 1978. A review on catch of sei whales in the Southern Hemisphere. *Rep. int. Whal. Commn*, 28: 449–458.

PAIVA, M.P. and B.F. GRANGEIRO, 1965. Biological investigations on the whaling seasons 1960–1963 off northeastern coast of Brazil. *Arq. Est. Biol. Mar. Uni. Fed. Ceara, Fortaleza*, 5(1): 29–64.

PAIVA, M.P. and B.F. GRANGEIRO, 1970. Investigations on the whaling seasons 1964–67, off northeastern coast of Brazil. *Arq. Est. Biol. Mar. Uni. Fed. Ceara, Fortaleza*, 10(2): 111-126.

SNEDECOR, G.W. and W.G. COCHRAN, 1980. *Statistical Methods. Sixth edition*. The Iowa State University Press, Ames, Iowa. 507 pp.

THOMPSON, D.A.W., 1928. On whales landed at the Scottish whaling stations during the years 1908–1914 and 1920–1927. *Scient. Invest. Fishery Bd Scotl.*, 3: 1–39.

TØNNESSEN, J.N. and A.O. JOHNSEN, 1982. *The History of Modern Whaling*. (English translation). C. Hurst and Co., London. 798 pp.

WOOLNER, L. and J.W. HORWOOD, 1980. Length at capture of sei whales and areal associations. *Rep. int. Whal. Commn*, 30: 537–544.

ZEMSKI, V.Z., 1980. *Atlas of Marine Mammals of the USSR*. Nauka, Moscow. 184 pp.

DISTRIBUTION AND BEHAVIOR OF BAIRD'S BEAKED WHALES OFF THE PACIFIC COAST OF JAPAN

TOSHIO KASUYA*

ABSTRACT

Aerial sighting records from the last 25 years and ship board sightings in 1984 indicate that the Baird's beaked whales which occur off the Pacific coast of Japan in summer through autumn live in schools of 1 to 30 individuals (average <10). The schools stay underwater for up to about one hour, 4 to 5 times longer than the time at surface. Baird's beaked whales in the area are seasonally distributed on the continental slope at depth of 1,000 to 3,000 m, and north of 34°N latitude under the influence of the subsurface cold Oyashio Current. The whales appear off the Boso Peninsula near the southern limit of their range on the Japanese Pacific coast in early summer reaching a peak in August, and then move north along the continental slope, peaking in October–November off the Pacific coast of Hokkaido. This seasonal movement is discontinuous to that of this species in the Sea of Japan and Okhotsk Sea, suggesting that these three areas are inhabited by separate populations. However, the northern range of the Pacific coast population is still unconfirmed and their distribution in December to May is unknown.

INTRODUCTION

Omura, Fujino and Kimura (1955) analyzed the catch records of Baird's beaked whale, *Berardius bairdii* Duvernoy 1851, by Japanese small-type whaling, and concluded that they arrived off Boso Peninsula in early summer and moved to the north presumably to arrive off the east coast of Hokkaido in early autumn. They also suggested that such individuals might belong to a population which was different from those using the Sea of Japan or in the Okhotsk Sea.

Nishiwaki and Oguro (1971)'s analysis of subsequent data from the same source supported many of Omura *et al.*'s conclusions. In addition, they concluded that Baird's beaked whales were distributed off the Pacific coast of Japan in waters deeper than 1,000 m. Because of the coastal nature of the whaling, no information was available on the offshore limit of the distribution of this species. (see Study of also Kasuya (1971)).

---

* *Far Seas Fisheries Research Laboratory, 5-7-1, Orido, Shimizu-shi, Shizuoka-ken 424, Japan*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 61–83

Ohsumi (1983) analyzed sighting records collected by scouting vessels of the Japanese factory ship whaling fleets and by research vessels chartered by the Japan Fisheries Agency, and concluded that the distribution of Baird's beaked whales off the Pacific coast of Japan extended to offshore waters. His data were later reanalyzed by Kasuya and Ohsumi (1984) who were unable to reinforce this conclusion because sightings in offshore water were scarce and because they observed an area of low density between coastal and offshore high density areas.

The present study analyzes the distribution and migration of Baird's beaked whales off the Pacific coast of Japan using the results of sighting cruises conducted in the summer of 1984 plus aerial sighting records accumulated over 25 years by Fishery Aviation Co. Ltd.

MATERIALS AND METHODS

Aerial sightings

Aerial sightings records of marine mammals were provided by Fishery Aviation Co. Ltd. The records were accumulated during chartered flights to make oceanographic observations (e.g. water temperature, marine pollutant, red tide and floating algae) or to search for fish schools in order to provide information for purse seiners. The data cover the period from April 1959 to December 1983. Information from this series collected before April 1970 was also used by Kasuya (1971).

Observation was conducted at an altitude of 500 m along track lines that were arranged by the person who chartered the flight to scan his objective area. The observers (usually the Fishery Aviation Company personnel) were allowed to diverge from the predetermined track line or to descend for occasional observation or for photography of their sightings. In principle the area was searched using transect of infinite width, but the distribution of observers effort probably changed depending on the main objective of each

TABLE 1. LIST OF AIRCRAFTS THAT COLLECTED AERIAL SIGHTING RECORDS OF BAIRD'S BEAKED WHALES FOR THE PRESENT STUDY

Year	Type of Aircraft*	Engine	Sighting speed	Cruising distance
1953–'58	Piper Tripacer PA22	135Hp	95kt	4.5 hours
1958–'64	Cessna 175	175Hp	100kt	7.5 hours
1965–'79	Cessna 182 Skylane	230Hp	105kt	7.5 hours
1979–'82	Cessna 182 Skylane	230Hp	105kt	7.5 hours
	Aero Commander 680F	380Hp × 2	140kt	7.5 hours
1982–'83	Cessna 182 Skylane	230Hp	105kt	7.5 hours
	Cessna U206G	300Hp	120kt	9.0 hours
	Aero Commander 680F	380Hp × 2	140kt	8.0 hours

* All high wing type.

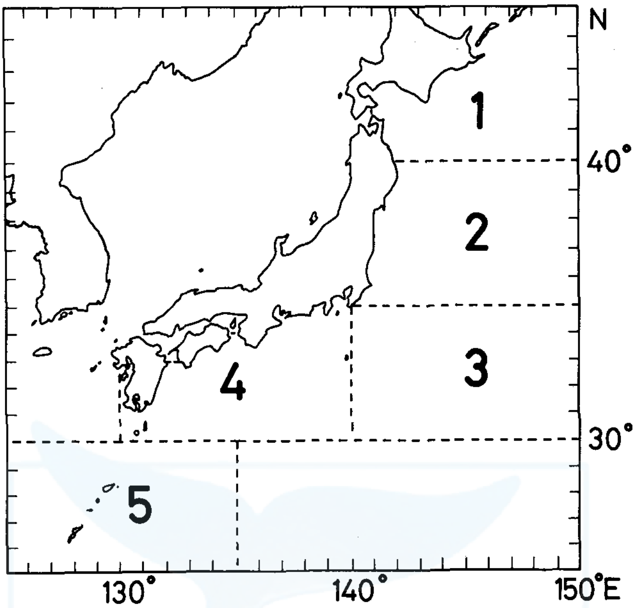

Fig. 1. Geographical areas used in the analysis of the aerial sighting data collected between April 1959 to December 1983.

flight and type of the aircraft used.

There were considerable changes over the years in the size, cruising speed, and range of the aircraft used as detailed in Table 1. In 1965 large engined aircraft was introduced, then in 1979 the company obtained a twin-engined aircraft. These changes resulted in the expansion of the survey area and increased survey effort in offshore waters (Fig. 3).

The number of observers was usually two (pilot and navigator) for single-engine air-craft, and three (pilot, navigator and engineer) for twin-engine aircraft. The view from the front was superior in the latter. Before 1981, both observers in the single-engine aircraft sat in the port seats, causing an unbalanced search effort. Since 1981, however, an observer was located on each side of the single-engine aircraft. In the twin-engine aircraft (used since 1979), the pilot searched front and port side, the engineer front and starboard side, and navigator the starboard side only.

These changes in aircraft and sighting technique, and search area affected sighting efficiency making it impossible to use these sighting records to monitor changes in the relative density of Baird's beaked whales. However, they provide useful information on distribution. The 25 years of aerial sighting data were stratified by geographical area (Fig. 1) and month. Data collected by observers in single- and twin-engine aircraft were separated in Table 2, but were combined in the later analyses.

TABLE 2. AERIAL SIGHTING RECORDS OF BAIRD'S BEAKED WHALES BY MONTH, DIVISION AND YEAR

Division 1	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1959–'63 (single-engined plane)													
NM flown	–	–	–	–	94	–	77	1,845	4,808	3,389	598	–	10,811
No. schools	–	–	–	–	–	–	–	2	3	6	–	–	11
No. whales	–	–	–	–	–	–	–	10	22	27	–	–	59
1964–'68 (single-engined plane)													
NM flown	–	–	–	106	717	63	–	1,083	7,812	4,000	–	–	13,781
No. schools	–	–	–	–	–	–	–	–	3	1	–	–	4
No. whales	–	–	–	–	–	–	–	–	6	6	–	–	12
1969–'73 (single-engined plane)													
NM flown	29	–	–	–	–	–	317	2,720	8,013	6,708	37	–	17,824
No. schools	–	–	–	–	–	–	–	1	4	3	–	–	8
No. whales	–	–	–	–	–	–	–	4	24	20	–	–	48
1974–'78 (single-engined plane)													
NM flown	–	–	–	–	–	112	315	3,202	5,866	3,794	3,159	–	16,448
No. schools	–	–	–	–	–	–	–	–	2	–	1	–	3
No. whales	–	–	–	–	–	–	–	–	40	–	10	–	50
1979–'83 (single-engined plane)													
NM flown	–	–	171	–	–	137	–	555	4,786	1,272	858	61	7,840
No. schools	–	–	–	–	–	–	–	–	2	–	1	–	3
No. whales	–	–	–	–	–	–	–	–	9	–	8	–	17
1979–'83 (twin-engined plane)													
NM flown	–	–	–	–	105	25	128	2,223	6,591	398	–	–	9,470
No. schools	–	–	–	–	–	–	–	–	1	–	–	–	1
No. whales	–	–	–	–	–	–	–	–	4	–	–	–	4
Division 2													
1959–'63 (single-engined plane)													
NM flown	210	–	651	1,035	2,956	4,610	5,476	4,679	2,738	4,568	8,458	1,040	36,421
No. schools	–	–	–	–	1	4	17	9	5	–	1	–	37
No. whales	–	–	–	–	2	12	86	40	20	–	6	–	166
1964–'68 (single-engined plane)													
NM flown	1,865	1,615	387	383	5,256	4,270	3,497	2,532	5,695	7,168	11,569	5,310	49,547
No. schools	–	–	–	–	1	1	11	3	10	3	5	1	35
No. whales	–	–	–	–	2	2	42	16	61	14	15	1	153
1969–'73 (single-engined plane)													
NM flown	1,367	730	233	308	1,106	8,348	4,025	4,904	6,491	5,713	3,779	2,233	39,237
No. schools	–	–	–	–	–	3	5	4	–	2	1	1	16
No. whales	–	–	–	–	–	9	53	16	–	5	4	13	100
1974–'78 (single-engined plane)													
NM flown	–	–	1,560	1,123	1,785	2,298	1,331	2,219	2,156	2,242	4,342	1,679	20,735
No. schools	–	–	–	–	–	1	–	–	–	–	–	–	1
No. whales	–	–	–	–	–	12	–	–	–	–	–	–	12
1979–'83 (single-engined plane)													
NM flown	524	408	1,911	571	5,599	1,066	1,180	957	2,436	4,524	4,825	356	24,357
No. schools	–	–	–	–	–	–	–	6	3	–	–	–	9
No. whales	–	–	–	–	–	–	–	62	10	–	–	–	72
1979–'83 (twin-engined plane)													
NM flown	–	–	2,201	101	7,419	6,379	5,140	4,797	4,539	677	–	–	31,253
No. schools	–	–	–	–	–	1	7	3	–	–	–	–	11
No. whales	–	–	–	–	–	3	75	16	–	–	–	–	94

(Continued)

TABLE 2. (Continued)

Division 3													
1959–'63 (single-engined plane)													
NM flown	–	–	75	185	–	–	–	–	–	–	125	–	385
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1964–'68 (single-engined plane)													
NM flown	1,460	547	462	662	1,447	–	326	783	399	508	1,497	2,167	10,260
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1969–'73 (single-engined plane)													
NM flown	177	48	82	718	1,128	488	379	624	77	438	207	32	4,398
No. schools	–	–	–	–	–	–	3	–	–	–	–	–	3
No. whales	–	–	–	–	–	–	15	–	–	–	–	–	15
1974–'78 (single-engined plane)													
NM flown	158	124	541	1,109	2,761	–	460	42	292	165	81	395	6,128
No. schools	–	–	–	–	–	–	2	–	–	–	–	–	2
No. whales	–	–	–	–	–	–	40	–	–	–	–	–	40
1979–'83 (single-engined plane)													
NM flown	248	257	140	26	3,000	–	625	532	–	–	–	–	4,828
No. schools	–	–	–	–	–	–	–	3	–	–	–	–	3
No. whales	–	–	–	–	–	–	–	9	–	–	–	–	9
1979–'83 (twin-engined plane)													
NM flown	–	232	660	1,525	3,391	699	108	–	–	–	–	–	6,615
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
Division 4													
1959–'63 (single-engined plane)													
NM flown	–	–	220	–	–	–	–	–	–	–	98	–	318
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1964–'68 (single-engined plane)													
NM flown	380	300	310	721	1,000	–	488	2,200	371	1,845	1,771	1,186	10,572
No. schools	–	–	–	–	–	–	–	1	–	–	–	–	1
No. whales	–	–	–	–	–	–	–	2	–	–	–	–	2
1969–'73 (single-engined plane)													
NM flown	2,444	4,833	7,134	6,012	10,346	645	1,069	574	964	2,937	2,814	3,154	42,926
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1974–'78 (single-engined plane)													
NM flown	1,319	3,327	7,861	12,497	9,799	–	1,690	782	749	2,142	3,350	3,778	47,294
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1979–'83 (single-engined plane)													
NM flown	1,740	595	3,560	10,933	8,462	–	573	962	–	5,147	821	617	33,410
No. schools	–	–	–	–	–	–	1	–	–	–	–	–	1
No. whales	–	–	–	–	–	–	15	–	–	–	–	–	15
1979–'83 (twin-engined plane)													
NM flown	–	2,804	663	2,793	2,582	51	–	–	–	–	–	–	8,893
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
Division 5													
1959–'83 (single- and twin-engined planes)													
NM flown	3,938	14,395	19,963	3,847	2,020	–	48	1,096	–	–	384	130	45,821
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–

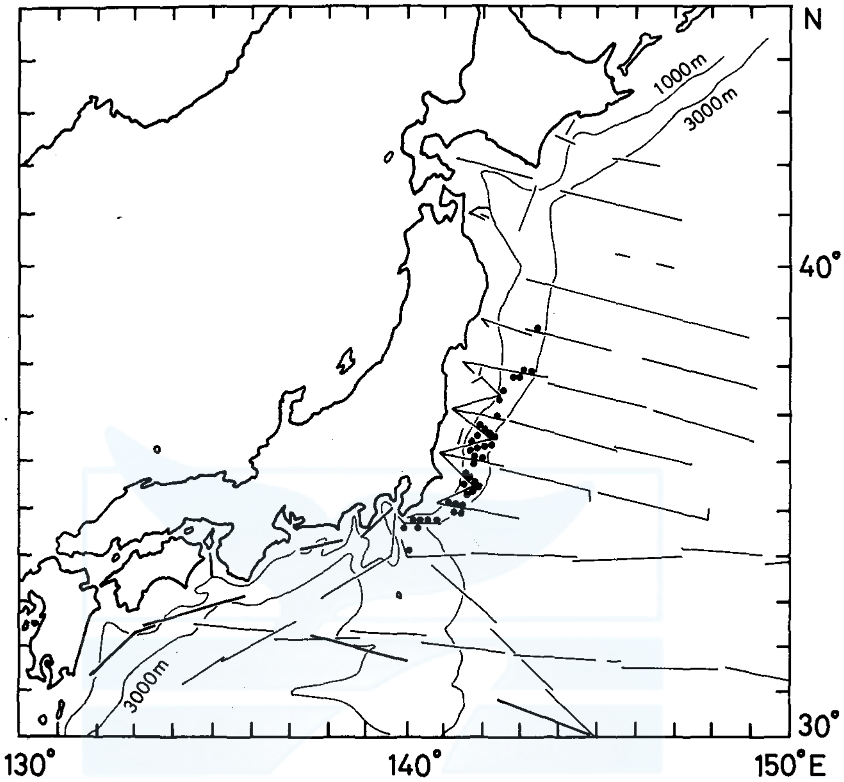

Fig. 2. Track lines of the Baird's beaked whale sighting cruises in 1984 by the *Toshimaru No. 25* (thin solid lines) and *Shonanmaru* (thick solid lines). Each closed circle indicates the position of a Baird's beaked whale school. Only track lines cruised with mast-top observers (normal sighting effort) are indicated.

Shipboard sightings

Data were obtained in 1984 during two whale sighting cruises in the western North Pacific using whale catcher boats *Toshimaru No. 25* (750 gross tons) and *Shonanmaru* (917 gross tons) chartered by the Japan Fisheries Agency. The cruises lasted 88 days (9 June to 4 September) and 80 days (9 June to 27 August), respectively. The track lines in the study area cruised with sighting effort are shown in Fig. 2. Additional areas west of 170°E and north of 10°N were also searched during the cruises as detailed by Miyashita (1985a), but no sightings of Baird's beaked whales were recorded.

I was on board the second cruise of the *Toshimaru No. 25* which surveyed Japanese coastal waters north of 34°30′N from 7 July to 6 August. This survey was conducted from the northern leg to the southern leg of the surveyed grid while the range of the distribution of the Baird's beaked whales was extending from south to north. Each leg was arranged approximately perpendicular to the coastline, i.e. along the expected density gradient of

Baird's beaked whales. I verified all sightings (303 individuals in 42 schools including secondary sightings). In addition, one school of four Baird's beaked whales was sighted on the first leg of the third cruise (from 7 August to 4 September) of the same vessel on 8 August in 34°07′N, 140°00′E. Although I did not verify this sighting, I have used it in the present study.

Sightings were conducted by both vessels during the entire cruising period (from port to port) except for night time and unfavorable weather conditions. Sightings during the second and third cruises of the *Toshimaru No. 25* were conducted using the methodology developed for the Antarctic minke whale sighting cruises (Best and Butterworth, 1980) on a predetermined courses at a speed of 12 knots (second and third cruises of the *Toshimaru No. 25*) or 11.5 knots (other cruises). The length of each leg varied from about 300 nautical miles of major legs to about 60 n. miles of subsidiary legs. The latter were designed to investigate details of the distribution of Baird's beaked whales in the high density area. Each of the former legs was completed spending about 3 days, but the latter a half day. Although the geographically biased density of sighting effort needs to be taken account in estimating the whale population (Miyashita, 1985b), such corrections are unnecessary for the analysis of pattern of distribution of whales in the present study.

All marine mammal schools sighted were approached to confirm specific identification and school structure. Data were collected on the position of the ship at sighting, the direction of the school from the track line, the radial distance from the position of sighting to the school, species, school size, estimated size composition (if available), surface water temperature, visibility, Beaufort scale of wind. Radial distances were estimated visually (for near sightings) or by summing an estimate based on the time required to approach to near distance and visual estimate of the rest of the distance. Position of the vessel was estimated using loran. Two mast-top observers (eye height of observers were 17 m above sea level for the *Toshimaru No. 25*, 20 m for the *Shonanmaru*) and five or six upper wheel-deck observers (*Toshimaru No. 25*, 10 m above sea level; *Shonanmaru*, 11 m) were used during the daytime from 15 minutes after sunrise to 15 minutes before sunset during periods when visibility was over 3 n. miles (usual maximum sighting distance of the Baird's beaked whale) and Beaufort scale less than 5. The mast-top observers rotated positions (mast-top, upper-wheel deck, and recess) every two hours. Two mates were alternately in charge of recording sighting data and position of the vessel. The captain and one to three scientists in charge of sighting spent the entire working time on the upper-wheel deck.

When wind was 5 or more in Beaufort scale or the visibility was less than 0.5 n. mile, observations ceased and the vessel was allowed to drift as far as time permitted. When visibility was between 0.5 and 3 n. miles and the wind less than Beaufort scale 5, sightings were conducted for Dall's porpoise, *Phocoenoides dalli*, using only upper wheel-deck observers. (Sightings of this species usually occur within 0.5 n. mile of the vessel (Bouchet, 1981; Kato, 1983)). No Baird's beaked whales were sighted in the northern area where these poor sighting conditions occurred.

The mast-top observers continuously used 50mm × 7 binoculars. The upper-wheel deck observers used them occasionally (they tended to search close to the boat). Polarized sunglasses were worn by most observers. Through speaker system every sighting was relayed between scientists, observers and a mate on duty; and this communication was also monitored by engineers. The mast-top observers commanded the vessel when it was approaching whale schools.

During the entire *Shonanmaru* cruise and the first cruise (9 June to 6 July) of the *Toshimaru No. 25*, sightings were mostly done under good conditions.

The school size and body length composition was estimated by the mast-top observers. Schools of Baird's beaked whales were identified without difficulty as a group of individuals swimming in a same direction in a close distance and surfacing almost simultaneously (see photographs in Kasuya, 1971; Kasuya and Ohsumi, 1984; Nishiwaki and Oguro, 1971).

Diving intervals were recorded for 18 schools of Baird's beaked whales containing from one to 25 individuals (mean = 9.1) while I was on board of the second cruise of the *Toshimaru No. 25*. We usually started timing at the initial sighting of blows continuing until the school composition was confirmed at a close distance. The number of observed dives ranged from one to six per school. Since whales dive when scared, schools were approached after the main engine was stopped 0.5 to 1 n. mile from the school. The main engine was always slowed down step by step prior to stopping. The vessel usually waited for the next surfacing after stopping its main engine close to the place of the dive. Schools which were chased by the vessel or found close to other school(s) were excluded from the analysis of diving interval because of the possibility that their behavior was unnatural or because the difficulty of identifying individual schools. The resurfaced individual school was identified based on the position and the size of the schools.

RESULTS

Range of distribution and seasonal movements

All the aerial and shipboard sightings of Baird's beaked whales were limited to waters north of 33°N, and most were east of about 140°E. In spite of considerable aerial and shipboard sighting effort few Baird's beaked whales were sighted west of 140°E, and all these were close to 140°E (Figs 2, 3 and 4). These data agreed with the range reported by Omura *et al.* (1955), Kasuya (1971), Nishiwaki and Oguro (1971), Ohsumi (1983) and Kasuya and Ohsumi (1984).

The distribution of Baird's beaked whales was also limited to coastal waters west of 144°E despite considerable searching effort further offshore (to

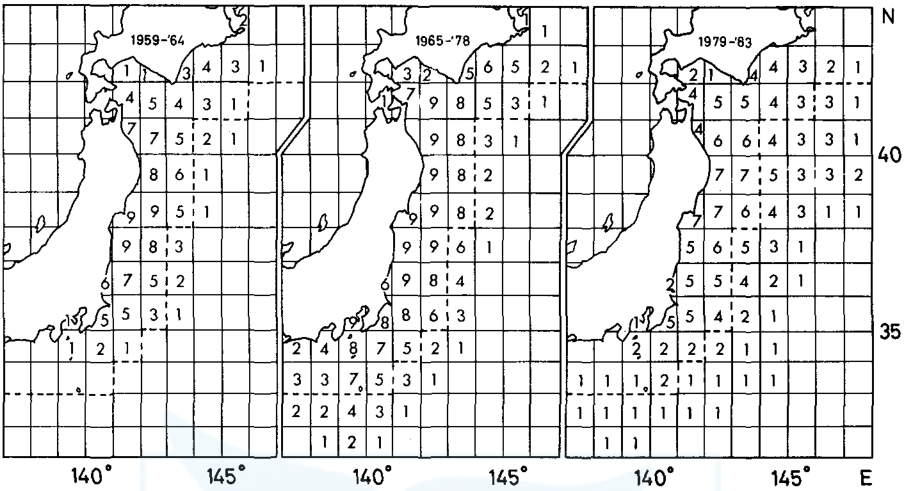

Fig. 3. Distribution of the aerial sighting effort in June to December (1959 to 1983) when most of the sightings of Baird's beaked whale occurred. The index of effort is expressed for each one degree squares of latitude and longitude by the number of times entered by the aircraft while it was conducting sightings (surveyed distance is not indicated). The scale for the number of times entered is, 1: 1–4, 2: 5–9, 3: 10–19, 4: 20–29, 5: 30–39, 6: 40–59, 7: 60–89, 8: 90–129 and 9: 130–169 times in the 27 years. Seasons are grouped based on change in aircraft types.

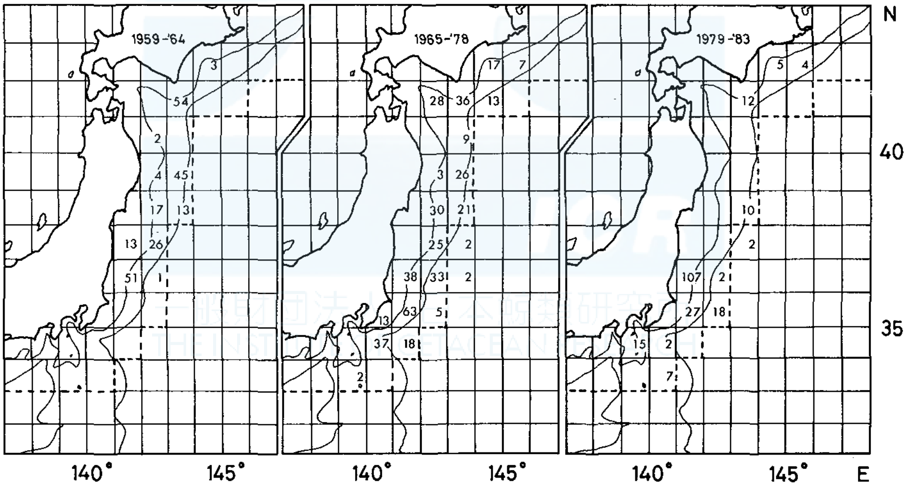

Fig. 4. The number of Baird's beaked whales sighted by the flights indicated in Fig. 3 of this study. The thin solid lines indicate 1,000 and 3,000 m contours, and the dotted lines one degree squares within 60 nautical miles from the coast of the major island. In addition to the sightings listed here, there were recorded in May four individuals in two schools in 36°–37°N, 141°–142°N and 36°–37°N, 142°–143°N, respectively.

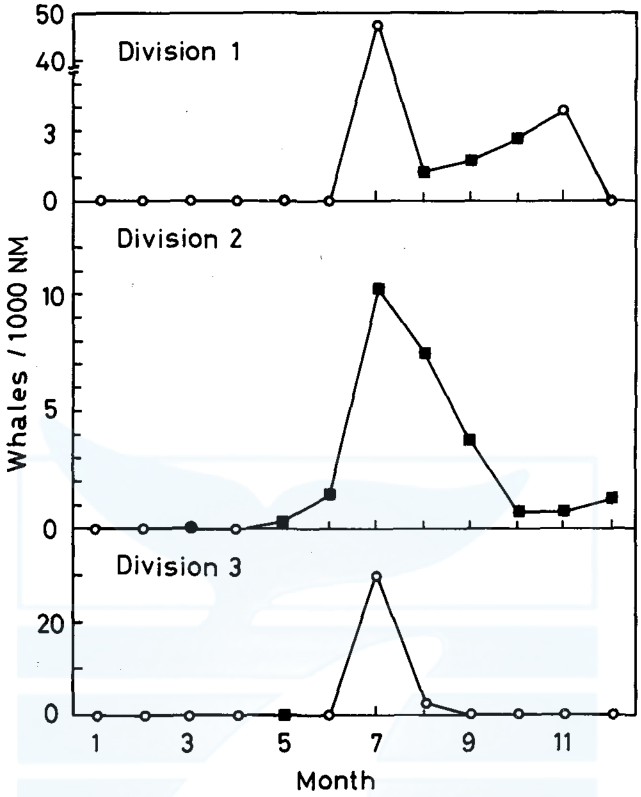

Fig. 5. Seasonal changes in the density of Baird's beaked whales based on aerial sighting records from April 1959 to December 1983. Square: flown for more than 10,000 nautical miles, closed circle: 5,000 to 10,000 nautical miles, open circle: less than 5,000 nautical miles.

160°E). The absence of shipboard sightings of Baird's beaked whales north of 39°N was partially due to the small sighting effort the coastal waters of this region at depths between 1,000 and 3,000 m where the occurrence is expected (see below).

Table 3 and Fig. 5 show the seasonal changes in the density of Baird's beaked whales as observed in the aerial sighting records. The whales arrive in the southern part of the range (Division 2) in May, and the density reaches a peak in July and then declines towards October. This pattern agrees with that suggested by the limited data for Division 3. In northern waters (Division 1), the density apparently increases from August to November, although the absolute density seems to be lower than that in the sourthern waters.

Factors affecting the distribution of Baird's beaked whale

Fig. 2 shows the sighting track line of the *Toshimaru No. 25* and the *Shonanmaru*, the position of sightings of Baird's beaked whale and the

TABLE 3. SEASONAL CHANGE OF THE DENSITY OF BAIRD'S BEAKED WHALES OFF THE PACIFIC COAST OF JAPAN ESTIMATED FROM THE AERIAL SIGHTING RECORDS IN 1959 THROUGH 1983

Month	1	2	3	4	5	6	7	8	9	10	11	12
Division 1												
NM flown	29	–	171	106	916	337	837	11,628	37,876	19,561	4,652	61
No. schools	–	–	–	–	–	–	2	3	13	10	2	–
No. whales	–	–	–	–	–	–	40	14	65	53	18	–
Whales/1,000 NM	0	–	0	0	0	0	47.8	1.2	1.7	2.7	3.9	0
Division 2												
NM flown	3,966	2,753	6,943	3,521	24,121	26,971	20,649	20,088	24,055	24,892	32,973	10,618
No. schools	–	–	–	–	2	10	40	25	18	5	7	2
No. whales	–	–	–	–	4	38	256	150	91	19	25	14
Whales/1,000 NM	0	0	0	0	0.2	1.4	12.4	7.5	3.8	0.8	0.8	1.3
Division 3												
NM flown	2,043	1,208	1,960	4,225	11,727	1,187	1,898	1,981	768	1,111	1,910	2,596
No. schools	–	–	–	–	–	–	5	3	–	–	–	–
No. whales	–	–	–	–	–	–	55	9	–	–	–	–
Whales/1,000 NM	0	0	0	0	0	0	30.0	4.5	–	–	–	–

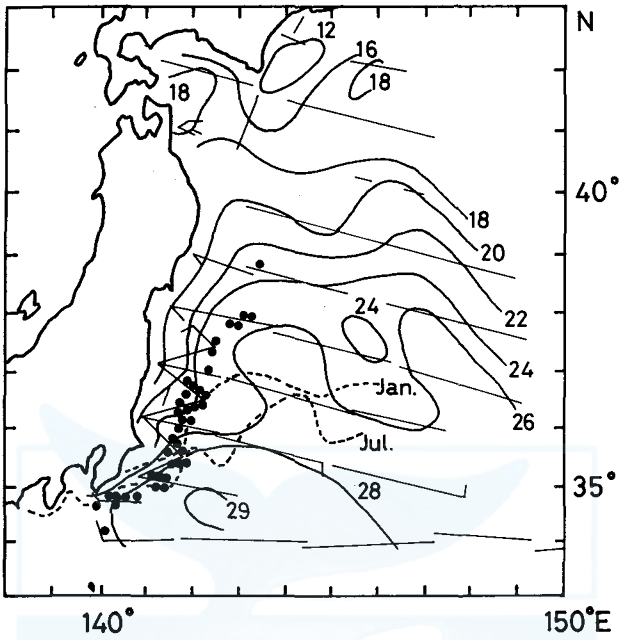

Fig. 6. The oceanographical environment at the position of Baird's beaked whale sighting (closed circle) during the *Toshimaru No. 25* cruise (The track lines are indicated by the thin solid line). The thick solid line indicates the surface water temperature observed during the cruise in July–August 1984 and the dotted line the 15°C isotherm at a depth of 100 m in January and July 1984 (Japan Meteorological Agency, 1984).

topography of the area. The whales were limited to water depths of 1,000 to 3,000 m on the continental slope. The same distribution pattern is seen from the aerial sighting records (Figs 3 and 4). The majority of aerial sightings were recorded in one degree squares (about 60 × 44 to 49 n. miles) which overlap with the above water depth range. Even in recent years when the aerial sighting effort expanded to waters further offshore, the range of sightings of Baird's beaked whales remained constant, indicating that the whales are concentrated in waters between 1,000 and 3,000 m deep at least from June to December. In contrast, Baird's beaked whales are not distributed at these depth off the Pacific coast of southwestern Japan, west of 138°E (Figs 2 and 4) indicating that distribution is influenced by some additional factors.

Fig. 6 shows the surface water temperatures measured during the cruises and the 15°C isotherms at 100 m below the surface in January and July 1984 cited from Japan Meteorological Agency (1984). Baird's beaked whales occurred at surface water temperatures of between 23° and 29°C, but the distribution did not agree with the range of the surface water isotherms.

The southern limit of the sightings coincides with the 15°C isotherm at a depth of 100 m (Fig. 6). The position of this isotherm changes little between

TABLE 4. SCHOOL SIZE FREQUENCIES OF BAIRD'S BEAKED WHALES OFF THE PACIFIC COAST OF JAPAN (DIVISION 1 THROUGH 4) BASED ON AERIAL SIGHTING DATA (1959 TO 1983) AND OBSERVATION ON BOAD OF THE *TOSHIMARU NO. 25* IN 1984

School size	Year						
	1959–'63	1964–'68	1969–'73	1974–'78	1979–'83	1959–'83	1984
1	11	9	0	0	0	20	3
2	9	10	7	0	5	31	3
3	5	7	3	0	1	16	6
4	4	3	2	0	2	11	8
5	4	1	5	0	4	14	4
6	4	2	1	0	3	10	3
7	1	3	1	0	0	5	2
8	3	2	2	0	1	8	3
9	0	0	0	0	0	0	0
10	2	1	3	2	4	12	2
11	1	1	0	0	0	2	0
12	0	0	0	1	1	2	0
13	1	0	1	0	0	2	0
14	2	0	0	0	0	2	0
15	0	0	1	0	5	6	3
17	0	0	0	0	1	1	0
18	1	0	0	0	0	1	1
20	0	0	1	2	0	3	3
25	0	0	0	0	0	0	1
30	0	1	0	1	0	2	0
Total	48	40	27	6	27	148	42
Mean	4.7	4.2	6.0	17.0	7.8	5.9	7.2
SE	0.6	0.8	0.9	3.2	1.0	0.4	0.9

seasons, suggesting that it represents a stable southern boundary of the cold Oyashio Current extending beneath the warm Kuroshio Current, the northern range of which moves widely between seasons.

In August, the warm Kuroshio Current extends to latitude 40°N (represented by 25°C surface isotherm). The northward shift of the concentration of Baird's beaked whales from off the Boso coast (35°–36°N) in July–August to off Hokkaido (40°–43°N) in August through November may be an influence of this summer expansion of the Kuroshio Current. Thus it is probable that the southern range of Baird's beaked whales off the Pacific coast of northern Japan may be in some degree affected by the warm surface water of the Kuroshio Current.

School structure

Aerial and shipboard estimates of the size of Baird's beaked whale schools are listed in Table 4. The shipboard estimates ranged from 1 to 25 with a mode at 4 and a mean of 7.4 individuals. The relatively high frequencies at 10, 15 and 20 represent a rounding effect. These features are not significantly different from the school size frequencies reported by small-type whaling vessels (Ohsumi, 1983).

In the aerial sightings recorded before 1969 there were more singletons than in the aerial sightings in recent years, although the upper ranges of the school size frequencies were not different between the two data sets. Such apparent change in the school size composition could be produced by (1) a real change in school composition, (2) underestimation of school size in earlier aerial sightings, or (3) missing small schools in recent aerial sightings. The school size of the shipboard sightings in 1984 tended to be intermediate of the two patterns. During the *Toshimaru No. 25* cruise in 1984, I encountered several schools whose size apparently increased while the vessel was approaching quietly after stopping the main engine. I therefore consider that the last two cases were more probable for aerial survey which cruised faster than vessels and was done as an supplemental work of the chartered flights. Therefore the historical change in the school size composition of Baird's beaked whale is not known from the present data, school size of the present population is likely to be represented better in the shipboard sighting data.
data.

The body length estimates were made by mast-top observers (who had experience of whaling other than Baird's beaked whale). Of the 283 Baird's beaked whales in 36 schools sighted during the first and second cruises of the *Toshimaru No. 25*, 265 were estimated to be 33 feet (9.9 m) or over, and only 15 individuals (5.7 %) 32 feet (9.6 m) or less (1 individual (0.4 %) at 20 feet, 6 (2.3 %) at 30 feet, 8 (3.0 %) at 32 feet). Three individuals (all estimated to be 30 feet) were accompanying their presumed mothers. According to data presented by Ohsumi (1983), the proportion of small individuals ($\leq$9.6 m) in the catch of whaling in 1977–1981 was 24.7 %, which was higher than the corresponding figure obtained above (5.7 %). Therefore the cruise data are not suitable for estimating birth rate, without further assessment of (1) the accuracy of the body length estimates, (2) the possibility of missing small calves in the tight school, (3) knowledge of the early postnatal growth of the species, and (4) knowledge of the still unconfirmed segregation of animals by growth and reproductive stages.

The pattern of surfacing and diving

While a school was at the surface, blows were usually observed continually, and this was used as an indication that the school was at the surface. Before the vessel arrived at the position of initial sighting, the target school often dived and surfaced several times. In one particular case of a school of eight whales, which was not used in the following analysis, the vessel was within sight of the school recognized by the color of shallow submerged bodies and rings for eight minutes. During the period the vessel followed the school with

TABLE 5. SURFACING INTERVAL OF BAIRD'S BEAKED WHALE SCHOOLS

Time in min.	At surface		Below surface	
	number	percent	number	percent
1	5	14.7	2	6.1
2	5	14.7	1	3.0
3	7	20.6	–	–
4	5	14.7	–	–
5	1	2.9	1	3.0
6	2	5.9	2	6.1
7	–	–	1	3
8	1	2.9	2	6.1
9	–	–	1	3.0
10	–	–	3	9.1
11	–	–	1	3.0
12	–	–	2	6.1
13	1	2.9	–	–
14	1	2.9	1	3.0
15	–	–	1	3.0
16–20	–	–	4	12.1
21–25	–	–	3	9.1
26–30	–	–	3	9.1
31–35	–	–	–	–
36–40	–	–	2	6.1
41–45	–	–	1	3.0
46–50	–	–	1	3.0
51–55	–	–	–	–
56–60	–	–	–	–
61–65	–	–	–	–
66–70	–	–	1	3.0
Not measured	6	17.6	–	–
Total	34	100	33	100
Mean (minutes)	3.9		18.2	

engines off by the force of its inertia. The school was observed to change the direction frequently. However as soon as the vessel slowly started the main engine, the school dived deeply resurfacing after 20 minutes. This illustrates the importance of the method of approaching schools to obtain correct data on diving behaviour of Baird's beaked whales.

The time spent by a school at the surface ranged from about one to 14 minutes, but usually less than five minutes (Table 5) as stated by Matsuura (1942). The longest time at the surface (14 minutes) was for a school of 25 whales. This observation was made while the vessel approached from a distance of 1.5 n. miles to about 400 m as described above. The length of the preceding dive was 22 minutes. The mean observed time at the surface (3.9 minutes)

(Table 5) is subject to error. It may be overbiased as a result of our failure to record short surface times, or underbiased due to our misidentification of surfacings in which the whales were not spouting continuously, as two separate surfacings.

Dive times ranged from one to 67 minutes. The longest dive was recorded for a school of 20 individuals. This record is rather ambiguous. This school dove 3 n. miles from the vessel just after being sighted at 1440 hour on 27 July 1984. It surfaced for one or two minutes at 1457, 1534 and 1546 hour. Then at 1653 (67 minutes after the last surfacing which was brief), one small individual (no body length estimate was available) was seen surfacing about 0.5 n. miles from the vessel. The remaining members of the school were found about 1.5 nautical miles from the vessel at 1704 hour (78 minutes after previous sighting) in the direction in which the small individual was travelling). We were uncertain whether or not the other whales in the school surfaced at the same as the small individual, so we have used the smaller more conservative dive time (67 minutes). I considered that the small individual which surfaced alone at 1653 hour belonged to the larger school because it would be unnatural for the small individual to live alone and it was travelling toward the larger school. I also considered that the school surfaced at 1704 hour was same with that dove at 1546, because the schools were so uncommon that confusion was unlikely (during that day's survey of 7 hours 27 minutes (about 90 n. miles) this was the only school seen).

There were five major modes in the dive times; 1-2, 5-12, 14-29, 37-49 and over 60 minutes. Dives of 1-2 minutes may not have been true dives as discussed above. Excluding these, the mean dive time was calculated at 19.8 minutes (n = 30), which does not significantly differ from the figure in Table

TABLE 6. CORRELATION BETWEEN DIVING TIME AND THE FOLLOWING SURFACING TIME IN SCHOOL OF BAIRD'S BEAKED WHALES

Preceeding diving time in min.	Length of the next surfacing (minutes)									
	1	2	3	4	5	6	7	8	14	Total
1– 5	2		2							4
6–10	1	2	1							4
11–15		2		1						3
16–20			1			1				2
21–25			1		1				1	3
26–30				1						1
31–35										–
36–40			1							1
41–45								1		1
46–50				1						1
Total	3	4	6	3	–	2	–	1	1	20

5 (18.2 minutes) based on all recorded dives. The mean dive time was 4.7 times longer than the mean time at the surface. About half of the observed dives (17 of 33 dives) exceeded 13 minutes.

Although the number of sequential dives observed for each school was too small (maximum was six) to test the randomness of the sequence of long and short dives, there was an apparent tendency for long dives (over 20 minutes) to be followed by shorter ones below 13 minutes (6 dives by 4 schools). (However, one school of 20 individuals made two successive long dives of 41 and 67 minutes separated by 8 minutes of the surface.) Of 9 dives below 13 minutes, 7 were followed by a dive of over 13 minutes, but only one in 6 dives exceeding 13 minutes was followed by a dive of over 13 minutes. The difference was statistically significant (Chi-square test, $0.025 < p < 0.05$).

The comparison of length of a dive and that of the next surfacing revealed that long dives tended to be followed by a long period at the surface (Table 6). Significantly fewer number of short dives (< 15 minutes) were followed by long time (≥ 4 minutes) at the surface (Chi-square test, $0.01 < p < 0.025$).

DISCUSSION

Distribution in the western North Pacific

Baird's beaked whales is known in the eastern North Pacific from the Pribilof Islands to Baja California (Leatherwood, Reeves and Foster, 1983), and in the western North Pacific from the Bering Sea, Okhotsk Sea, Sea of Japan and Pacific coast of Japan north of the Tokyo Bay (Tomilin, 1967; Nishimura, 1970). Nishiwaki's (1967) claims that the northern bottlenose whale, *Hyperoodon ampullatus* (Forster, 1770) might exist in the Sea of Japan and that the beaked whales reported by the whalers in the Okhotsk Sea might represent this species, have not been confirmed (Nishimura, 1970). All 13 beaked whales caught in the Okhotsk Sea that were reported by Japanese small-type whaling boats between 1978–1982 were identified as Baird's beaked whales based on the largest pair of teeth collected from each individuals (Kasuya, unpublished). A skull of beaked whale taken off the Okhotsk coast and identified by a vernacular name of the area has been confirmed as Baird's beaked whale (Dr H. Omura, personal comm. in Oct. 1985). Thus there are no data to indicate the presence of *H. ampullatus* in the temperate and subarctic waters off Japan*.

Baird's beaked whales are known to dive deeply (Ohsumi, 1983) and for long periods (see above). The analysis of stomach contents recorded by whalers (Nishiwaki and Oguro, 1971) or those examined by a biologist (W. Walker, personal comm. in 1985) indicated that they feed mainly on bottom

---

* *This does not deny the possible existence in the tropical western North Pacific of hitherto unidentified Hyperoodon-like odontoceti, which were sighted and photo-recorded during the 1985 sighting cruises (Far Seas Fisheries Research Laboratory, unpublished).*

organisms (principally deep sea fish). The common occurrence of bottom substance such as pebbles in the whales' stomachs and the presence of scars attributable to hard substances other than teeth of the conspecifics on the tip of the upper jaw and melon region (Kasuya and Brownell, unpublished) also suggest bottom feeding. This information together with the distribution of Baird's beaked whales obtained by the present study suggest that the whales feed (at least in early summer to autumn) on organisms living on the ocean floor of a depth of 1,000 to 3,000 m and affected by a subsurface cold current. The distribution of the catch of Baird's beaked whales in the Sea of Japan and southern Okhotsk Sea reported by Omura *et al.* (1955) occurred in the Toyama Bay (Sea of Japan at about 37°N), off the Sea of Japan coast of southern Hokkaido (41°–42°N) and off Abashiri on the southern coast of the Okhotsk Sea. These grounds are also characterized by the presence of deep waters (> 1,000 m) near the coast.

However, Fedoseev (1985) reported that the species was abundant in April and May in the northern Okhotsk Sea north of Sakhalin where water depth is less than 500 m. This will presumably relate to the availability of food species in shallower waters in higher latitudes.

Seasonal movement of stocks in Japanese coastal waters

Fig. 7 shows the seasonal changes in density of Baird's beaked whales summarized using catch data of Omura *et al.* (1955) in 1948–'52 and sighting data of small-type whaling vessels in 1977–'82 reported by Kasuya and Ohsumi (1984). These data agree with the present results as well as those of Matsuura (1942) and Nishiwaki and Oguro (1971). Omura *et al.* (1955) concluded that the Baird's beaked whales which arrive off the Boso Peninsula in May–June move northwards to the waters off Sanriku (38°–40°N) after one month, peaking off the Pacific coast of Hokkaido (42°–43°N) in October and November. Although they were not sure whether Baird's beaked whale off the Pacific coast of Hokkaido belong to the same population as those off Sanriku and Boso Peninsula, the continuity of geographical (Figs 2 and 4) and seasonal (Figs 5 and 7) distribution suggest one population.

In the Okhotsk Sea, the catch of Baird's beaked whales has two peaks, one in May–June and the other in September–October. This bimodal distribution of the catch is unlikely to be caused solely by minke whales being the preferred target as claimed by Kasuya and Ohsumi (1984), because it is also reflected in the number of sightings per 100 operation hours of small-type whaling vessels (Fig. 7). Baird's beaked whales are present in the northern Okhotsk Sea in April–May (Fedoseev, 1985), slightly before their abundance in the southern Okhotsk Sea starts to decline.

The limited catch in the sea of Japan occurred on the two grounds (at about 37°N and 41°N) off Japan, from June to August. This is same as the seasonality of the catch off the Pacific coast in similar latitudes (off Boso Peninsula and Sanriku region).

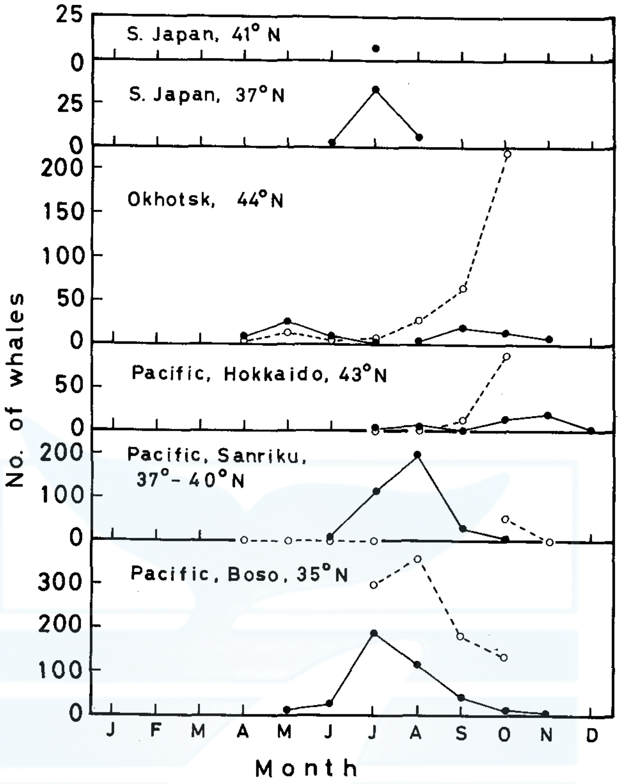

Fig. 7. Seasonal change in density of Baird's beaked whales in the Japanese coastal whaling ground (Sea of Japan, Okhotsk Sea and Pacific coast). The closed circle and solid line indicate the number of whales captured between 1948–1952 (Omura *et al.*, 1955), and the open circle and dotted line number of whales sighted per 100 hours of operation of small-type whaling vessels in 1977–1982 seasons (Kasuya and Ohsumi, 1984). Densities of whales based on less than 200 operation hours have not been indicated.

The seasonal changes in density summarized above could be explained by assuming three populations of Baird's beaked whale; in the Okhotsk Sea, the Sea of Japan, and off the Pacific coast of Japan as proposed by Omura *et al.* (1955), and assuming a seasonal north-south migration within the range of each population. La Perouse and Tatarskiy Straits (between the Sea of Japan and Okhotsk Sea) and Tsugaru Strait (between the eastern Sea of Japan and Pacific Ocean) presumably block migration between the three regions. These straits are less than 200 m deep (the maximum depths of these seas exceed 3,000 m). As Baird's beaked whale is found off the Pacific coast of Japan in the latitude of 33° to 44°N only in the waters between 1,000 and 3,000 m (see above), it is reasonable to assume that these straits will act as barriers between populations.

However, this does not necessarily mean that the Baird's beaked whales in the Okhotsk Sea do not pass through the Kuril Islands, where there is a strait (at about 47°N) exceeding 1,000 m in depth. Sleptsov (1955) reported the occurrence of Baird's beaked whales on the both coast of the Kuril Islands and on the east coast of the Kamchatka Peninsula. Although there are no data on the identity of the stocks in these areas, the likely incomplete isolation or the shorter geological history of isolation between the Okhotsk Sea and the Japanese Pacific coast populations may explain the lack of body length differentiation between the two stocks. According to Omura *et al.* (1955), the whales caught in the Sea of Japan were considerably smaller than those from other areas (modal length 30–32 feet in the Sea of Japan against 34–36 feet in the Okhotsk and Pacific coasts).

Behavior of Japanese Pacific coast "population"

The available data indicate that the Japanese Pacific coast "population" of the Baird's beaked whale is limited to the waters of the continental slope between the southern tip of Boso Peninsula (about 35°N) and the east coast of Hokkaido at 43°N. This distribution is similar to that of local stocks of the "true-type" population of Dall's porpoise, *Phocoenoides dalli* (True, 1885) in this region (Kasuya, 1978; Kasuya and Shiraga, 1985; Miyazaki, Jones and Beach, 1984), and the short-finned pilot whale, *Globicephala macrorhynchus* Gray, 1846, (Miyazaki, 1983; Kasuya and Marsh, 1984; Kasuya, unpublished). Presumably, some marine mammals in this relatively cold triangular-shaped area of coastal waters were isolated from the major subarctic North Pacific area by the island of Japan and by the offshore warm Kuroshio Current.

A seasonal northward movement of the Baird's beaked whale concentration along the continental slope is apparent from both catch statistics and sighting records. This phenomenon can be explained without assuming any significant northward movement of individual whales, by assuming offshore-inshore movements of whales which progress from south to north during July–November season. This assumption requires Baird's beaked whales to be distributed in the offshore waters of latitudes where they are known to be absent from the continental slope. This study showed that the whales were very scarce in the offshore area in summer through autumn. Therefore, this explanation seems impossible, and I consider that they migrate from early summer through autumn along the continental slope off the Pacific coast of Japan. However, this does not deny possibility of offshore dispersion of some individuals in autumn to winter season (see below).

Since the surface water temperature starts to decline in September off the Pacific coast of Japan, it is unlikely that the Baird's beaked whales which arrive off the Pacific coast of Hokkaido (presently identified northern limit of this "population") in September continue their northbound migration.

Although the available data are insufficient, due to scarcity of sighting effort and absence of whaling operation in winter to spring seasons, to suggest where the whales winter after the disappearance from Hokkaido coast in November and till the reappearance off the Boso Peninsula in May. It seems likely that they migrate south and perhaps disperse in offshore waters. The offshore dispersion of the Baird's beaked whales in autumn is suggested by the rapid density decline during the northward migration in August through November (Figs 5 and 7). The magnitude of the density change seems to be too large to be explained on the basis of increased dispersion in the slightly wider 1,000–3,000 m deep continental slope in the northern area (Fig. 2).

Omura *et al.* (1955) showed that males predominated in the catch of Baird's beaked whales by Japanese small-type whaling in all of the fishing grounds mentioned above. Using catch statistics off Boso Peninsula, Ohsumi (1983) showed that males exceeded females in all of the 21 fishing seasons from 1947 to 1967, and that this changed since 1968 toward the dominance of females which lasted only for several seasons. Ohsumi's statistics showed also that the dominance of males in the catch resumed in 1977 as before 1968. Kasuya (1984), using statistics from 1947 through 1983, showed that the fishing seasons of Baird's beaked whales off Boso Peninsula in late 1950's to early 1970's (especially those for 1959 through 1972 seasons) apparently started earlier (in May) and ended later (in December) than the other seasons, and included months when the distribution of the species in the ground was very scarce. I suspect that the sex ratio may not have changed but that there were serious error in the catch statistics for seasons between presumably due in some degree to inclusion of other species such as sperm whales.

However, the dominance of males in the catch was also found in data collected by biologists. Among 29 Baird's beaked whales caught off the Boso Peninsula (near the southern limit of the population) in 1976 and 1977 seasons, 20 were males (Dr Y. Naito, personal communication), and of the 36 whales caught in the same area in 1985 season 24 were males (Kasuya, Brownell, Mead, Walker and Wada, unpublished). This overall sex ratio (44 males against 19 females) is significantly different from parity (Chi-square test, $0.01 < p < 0.025$). This imbalance of the sex ratio in the catch can occur for two reasons (1) geographical segregation by sex as suggested by Ohsumi (1983) or (2) higher catchability of males than females in the same school due to possible difference of ship-avoidance behavior or of position relative to other members of the school. If the first explanation is correct, then the range of the population off the Pacific coast of Japan must extend outside the area confirmed by the present study suggesting that the population is larger than the 4,220 (cv = 0.295) individuals estimated by Miyashita (1985b). However, a dominance of males was reported for samples from three "populations" discussed above and those captured at various parts of the range of their distribution, making the first explanation less likely than the latter (behavioural) explanation.

ACKNOWLEDGEMENTS

Fisheries Aviation Co. Ltd (Tokyo) allowed me to analyze their cetacean sighting records. Dr P. Hammond of the Sea Mammal Research Unit (UK) helped me in planning the cruise track line of the *Toshimaru No. 25* in 1984. Dr H. Marsh of the James Cook University of North Queensland (Australia) criticized the manuscript and corrected the English. Captain S. Suzuki of the *Toshimaru No. 25* and his crew cooperated in the present study during the cruise. Mrs Y. Yamamoto and K. Yano assisted in data analysis and drawing.

REFERENCES

Bouchet, G.C., 1981. Estimation of abundance of Dall's porpoise (*Phocoenoides dalli*) in the North Pacific Ocean and Bering Sea. *NWAFC Processed Rep.*, 81–1, 25pp.

Best, P.B. and D.C. Butterworth, 1980. Report of the southern hemisphere minke whale assessment cruise. 1978/79. *Rep. int. Whal. Commn,* 30: 257–283.

Fedoseev, G.A., 1985. Records of whales in ice conditions of the Okhotsk Sea. IWC/SC/0 4, 8pp.

Japan Meteorological Agency, 1984. *The ten-days marine report*, nos 1346 and 1364.

Kasuya, T., 1971. Consideration of distribution and migration of toothed whales off the Pacific coast of Japan based upon aerial sighting record. *Sci. Rep. Whales Res. Inst.*, 23: 37–60.

Kasuya, T., 1978. The life history of Dall's porpoise with special reference to the stock off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.,* 30: 1–63.

Kasuya, T., 1984. Catch and effort data of the Japanese Baird's beaked whale fishery off the Boso Peninsula. IWC/SC/SM 14, 18pp.

Kasuya, T. and H. Marsh, 1984. Life history and reproductive biology of the short-finned pilot whale, *Globicephala macrorhynchus,* off the Pacific coast of Japan. *Rep. int. Whal. Commn,* (Special Issue 6): 259–310.

Kasuya, T. and S. Shiraga, 1985. Growth of Dall's porpoise in the western North Pacific and suggested geographical growth differentiation. *Sci. Rep. Whales Res. Inst.*, 36: 139–152.

Kasuya, T. and S. Ohsumi, 1984. Further analysis of the Baird's beaked whale stock in the western North Pacific. *Rep. int. Whal. Commn,* 34: 587–595.

Kato, M., 1983. Abundance survey of Dall's porpoise by Japanese salmon research vessels in the North Pacific Ocean in 1982. *Doc. Submitted to the meeting of the Sci. Sub-comm. of the Ad Hoc Comm. of Marine Mammals, INPFC, Tokyo, 20–25, Feb. 1983.* 44pp.

Leatherwood, S., R.R. Reeves and L. Foster, 1983. *The Sierra Club handbook of whales and dolphins.* Sierra Club Books, San Francisco. 302pp.

Matsuura, Y., 1942. On the northern porpoise whale, *Berardius bairdii* Stejneger, in the adjacent waters of "Bosyu". *J. Zool.* (Tokyo), 54 (12): 466–473. (in Japanese with English summary).

Miyashita, T., 1985a. Bryde's whale stock in the western North Pacific estimated using sighting data. IWC/SC/Ba 1, 10pp.

Miyashita, T., 1985b. Abundance of Baird's beaked whales off the Pacific coast of Japan and possible bias of estimate. IWC/SC/SM 13, 11pp.

Miyazaki, N., 1983. Pilot whale off Kinkazan Island. *Abst. Autumn Meeting Jap. Soc. Sci. Fish.*, p. 55 (in Japanese).

Miyazaki, N., L.L. Jones, and J.R. Beach, 1984. Some observations on the schools of *dalli-* and *truei-*type Dall's porpoises in the northwestern Pacific. *Sci. Rep. Whales Res. Inst.*, 35: 93–105.

Nishimura, S., 1970. Recent records of Baird's beaked whale in the Japan Sea. *Publ. Seto Mar. Biol. Lab.*, 18 (1): 61–68.

NISHIWAKI, M., 1967. Distribution and migration of marine mammals in the North Pacific area. *Bull. Ocean Res. Inst., Univ. Tokyo,* 1: 1–64.

NISHIWAKI, M. and N. OGURO, 1971. Baird's beaked whales caught on the coast of Japan in recent 10 years. *Sci. Rep. Whales Res. Inst.,* 23: 111–122.

OHSUMI, S., 1983. Population assessment of Baird's beaked whales in the waters adjacent to Japan. *Rep. int. Whal. Commn,* 33: 633–641.

OMURA, H., K. FUJINO, and S. KIMURA, 1955. Beaked whale *Berardius bairdi* of Japan, with notes on *Ziphius cavirostris. Sci. Rep. Whales Res. Inst.,* 10: 89–132.

SLEPTSOV, M.M., 1955. *Biology of whales and whaling in the Far East.* Pitzepromizdat, Moscow. (Japanese translation published by the Whales Res. Inst., Tokyo, 1955, 51pp.).

TOMILIN, A.G., 1967. *Cetacea.* Israel Prog. Sci. Translations, Jerusalem. 717pp.

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

PERINATAL GROWTH OF DELPHINOIDS: INFORMATION FROM AQUARIUM REARED BOTTLENOSE DOLPHINS AND FINLESS PORPOISES

TOSHIO KASUYA*, TERUO TOBAYAMA**,
TAKESHI SAIGA*** AND TERUO KATAOKA****

ABSTRACT

The early postnatal growth of bottlenose dolphins and finless porpoises was studied using 97 body length records of 61 individuals born in aquariums. The growth rates observed were similar to those estimated independently for wild dolphins assuming that dentinal growth layers are deposited annually. The perinatal growth parameters thus estimated were also close to those predicted using published interspecific relationships. These results suggest that (1) the dentinal growth layers are deposited annually in these species and (2) the interspecific relationships of the parameters can be used to examine the correctness of growth layer interpretation.

INTRODUCTION

Although some studies use daily or monthly growth layers in tooth (Kasuya, 1977; Myrick, 1980; Myrick, Shallenberger, Kang and Mackay, 1984), most odontocete age determination studies are based on annual growth layers in dentine or cementum (Perrin and Myrick, 1980). This approach limits the precision of individual age estimates, and makes it difficult to study the rapid perinatal growth of dolphins, an important component of their reproductive biology.

Some authors attempted to overcome this problem by defining the interspecific relationship between the growth parameters of better known species. Scott (1949) and Ohsumi (1966) tried to estimate neonatal body length from the size of adult whales. Perrin, Holts and Miller (1977) and Kasuya (1977) defined relationships between neonatal length and gestation time or between neonatal length and fetal growth rate. Perrin, Coe and Zweifel (1976) tried to estimate the early postnatal growth rate of dolphins using gestation

* *Far Seas Fisheries Research Laboratory, 5-7-1 Orido, Shimizu-shi, Shizuoka-ken, 424 Japan*
** *Kamogawa Sea World, 1464-18 Higashi-machi, Kamogawa-shi, Chiba-ken, 296 Japan.*
*** *Taiji Whale Museum, Taiji, Higashimuro-gun, Wakayama-ken, 649-51 Japan.*
**** *Toba Aquarium, 3-3-6 Toba, Toba-shi, Mie-ken, 517 Japan.*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 85–97

time and neonatal length. Kasuya (1972), Collet (1981) and Kasuya and Matsui (1984) deduced that delphinoid calves grow about 60 % of the neonatal body length in the first year after birth. However, some of these studies were not free from the age determination problem mentioned above, because growth layer readings were used in the analyses as well as data from known age individuals.

There is still also considerable disagreement concerning the interpretation of growth layers of some toothed whales (Perrin and Myrick, 1980; Jones, Kasuya, Gosho and Miyazaki, 1985). This problem will be solved through examination of growth layers of known age individuals or by comparing growth layer deposition in aquarium-reared individuals and wild individuals assuming that growth does not differ significantly between these two groups at least for the age classes being compared.

In this study, we use data from the bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821), and the finless porpoise, *Neophocaena phocaenoides* (G. Cuvier, 1829), to compare the early postnatal growth of aquarium-reared individuals with that of wild individuals estimated from dentinal growth layer counts assuming an annual deposition rate. We then evaluated published interspecific relationships between the growth parameters as a means of calibrating growth layer readings.

MATERIALS AND METHODS

Body length data of known age individuals were available for 55 bottlenose dolphins and 6 finless porpoises born in aquariums (Tables 1 to 3). Although most body lengths were measured at death, live measurements were obtained from three bottlenose dolphins and two finless porpoises over period of up to 4.7 years. We did not distinguish between deaths due to accident and disease, assuming that the effect of disease might be smaller on body length than on body weight. Parents of these aquarium-reared bottlenose dolphins were obtained from the catch of the drive fishery off the Pacific coast of Japan, and those of the finless porpoise from the intended or incidental take in the Ise Bay or in the Inland Sea (Kasuya, Tobayama and Matsui, 1984). No teeth from the individuals born in aquariums were examined.

Body length frequencies of bottlenose dolphins taken off the Pacific coast of Japan (the same stock as the parents of the aquarium-reared materials) were also available, as well as body lengths and dentinal growth layer counts from bottlenose dolphins from the Iki Island area, which is located in the Tsushima Pass connecting the Sea of Japan and the East China Sea. Although there is no basis for our assumption that these two samples belong to the same population, no significant differences of the body length frequencies, or in the body length at sexual maturity were detected i.e. 50 % of the females off the Pacific coast of Japan were sexually mature at a body length of between 265 and 275 cm (presumably close to the former figure, Fig. 1), while the

TABLE 1. POSTNATAL GROWTH OF MALE *TURSIOPS TRUNCATUS*

Sample No.	Days after birth	Birth yr mo day	Data yr mo day	Body length (cm)	Body weight (kg)	Remarks
1	0	'73. 2. 6	'73. 2. 6.	140.0	29.0	Taiji, Stillbirth
2	0	'76. 6.16	'76. 6.16	126.0	–	Taiji, Stillbirth
3	0	'76. 7.30	'76. 7.30	126.0	–	Taiji, Stillbirth
4	0	'77. 8.12	'77. 8.12	132.0	–	Taiji, Stillbirth
5	0	'84. 6.10	'84. 6.10	116.0	–	Chita, Unknown sex
6	0	'78. 6.14	'78. 6.14	125.0	–	Mito, Unknown sex
7	0	'81. 7.25	'81. 7.25	122.0	–	Taiji
8	0	'77. 7. 5	'77. 7. 5	134.0	–	Misaki
9	3	'81. 7.14	'81. 7.17	133.0	30.0	Taiji
10	4	'84. 6. 3	'84. 6. 7	132.0	23.0	Taiji
11	9	'75. 7.19	'75. 7.28	139.0	–	Taiji, Unknown sex
12	11	'80. 7. 4	'80. 7.15	127.0	–	Taiji
13	21	'82. 9.26	'82.10.17	136.0	–	Taiji
14	63	'78.10.17	'78.12.19	149.0	47.0	Kamogawa
15	147	'75. 7.15	'75.12. 9	181.0	77.0	Taiji
16	154	'77. 6.22	'77.11.24	165.0	–	Taiji
17	189	–	–	183.0	–	Honda (1979)
18	212	'76. 8.17	'77. 3.17	197.5	–	Awashima
19	1164	'79. 2.22	'82. 5. 1	254.0	–	Enoshima
20	297	–	–	197.0	–	Honda (1979)
21	654	'78. 7. 2	'80. 7.16	246.0	–	Shimoda
22	782	–	–	221.0	–	Honda (1979)
23	1418	'77. 8.17	'81. 7. 6	263.0	–	Taiji
24	242*	'76. 9. 9	'77. 5. 9	188.0	–	Kamogawa
	299*		'77. 7. 5	208.0	126.0	
	362*		'77. 9. 6	220.0	136.0	
	422*		'78.11. 5	224.0	161.0	
	472*		'77.12.25	223.0	156.0	
	513*		'78. 2. 4	228.0	–	
	569*		'78. 4. 1	230.0	–	
	595*		'78. 4.27	230.0	–	
	620*		'78. 5.22	234.0	156.0	
	813*		'78.12. 1	245.0	178.0	
	859*		'79. 1.16	–	191.0	
	953*		'79. 4.20	244.0	190.0	
	959*		'79. 4.26	–	190.0	
	1219*		'80. 1.11	250.0	197.0	
	1619*		'81. 2.14	248.0	–	
	1655*		'81. 3.22	265.0	224.0	

*: measured while alive.

TABLE 2. POSTNATAL GROWTH OF FEMALE *TURSIOPS TRUNCATUS*

Sample No.	Days after birth	Birth	Data	Body length (cm)	Body weight (kg)	Remarks
		yr mo day	yr mo day			
1	0	’72. 6.19.	’72. 6.19.	120.0	19.0	Taiji, Stillbirth
2	0	’72. 7. 2.	’72. 7. 2.	140.0	30.0	Taiji, Stillbirth
3	0	’77. 7.20.	’72. 7.20.	128.0	–	Taiji, Stillbirth
4	0	’77. 6. 1.	’77. 6. 1.	115.0	–	Misaki
5	1	’79. 8. 2.	’79. 8. 3.	118.7	–	Shimoda
6	1	’81. 7.28.	’81. 7.29.	121.0	–	Shimoda
7	9	’79. 8.30.	’79. 9. 8.	132.0	–	Awashima
8	10	’76. 6.21.	’76. 7. 1.	130.0	25.0	Taiji
9	32	’76. 6.29.	’76. 7.31.	144.0	30.0	Taiji
10	35	’71.10.30.	’71.12. 4.	139.0	35.2	Taiji
11	37	’71. 6.16.	’71. 7.23.	145.0	44.0	Taiji
12	118	’76. 1. 4.	’76. 5. 1.	165.6	68.2	Shimoda
13	194	–	–	179.5	–	Honda (1979)
14	201	’79. 7.26.	’80. 2.13.	194.0	–	Taiji
15	247	–	–	193.0	–	Honda (1979)
16	262	–	–	193.0	–	Honda (1979)
17	275	’80. 9.17.	’81. 6.19.	200.0	–	Awashima
18	370	’74.11. 1.	’75.11. 6.	226.0	–	Awashima
19	398	–	–	204.0	–	Honda (1979)
20	410	–	–	200.0	–	Honda (1979)
21	578	–	–	235.0	–	Honda (1979)
22	627	’77. 5.20.	’79. 2. 6.	200.0	–	Shimoda
23	808	’82. 8.13.	’84.10.29.	252.0	185.0	Taiji
24	1,032	’75. 7.18.	’78. 5.15.	238.0	–	Awashima
25	1,151	’78. 7. 6.	’82. 3.20.	258.0	–	Shimoda
26	1,345	’81. 7. 5.	’85. 3.10.	262.0	200.0	Taiji
27	1,466	–	–	279.0	–	Honda (1979)
28	1,729	–	–	265.0	–	Honda (1979)
29	1,742	–	–	259.0	–	Honda (1979)
30	354*	’79. 7.28.	’79. 7.17.	200.0	–	Kamogawa
	404*		’80. 9. 4.	202.0	–	
	467*		’80.11. 6.	228.0	–	
	510*		’80.12.19.	218.0	–	
	567*		’81. 2.14.	218.0	–	
	724*		’81. 7.21.	228.0	150.0	
	835*		’81.11. 9.	233.0	160.0	
	944*		’82. 2.26.	238.0	–	
	955*		’82. 3. 9.	239.0	150.0	
	986*		’82. 4. 9.	240.0	155.0	
	1,081*		’82. 7.13.	238.0	140.0	
	1,157*		’82. 9.27.	239.0	130.0	
	1,182*		’82.10.22.	238.5	130.0	

(Continued)

TABLE 2. (Continued)

31	635*	'79. 6.28.	'81. 3.24.	236.0	–	Kamogawa
	833*		'81.10. 8.	253.0	170.0	
	865*		'81.11. 9.	–	180.0	
	1,026*		'82. 4.19.	261.0	210.0	
	1,231*		'82.11.10.	271.0	230.0	
	1,237*		'82.11.16.	–	225.0	
	1,257*		'82.12. 6.	260.0	215.0	
	1,332*		'83. 2.19.	264.0	225.0	
	1,357*		'83. 3.16.	–	220.0	
	1,569*		'83.11. 6.	265.0	245.0	

*: measured while alive.

TABLE 3. POSTNATAL GROWTH OF *NEOPHOCAENA PHOCAENOIDES*

Sample No.	Days after birth	Birth	Data	Body length (cm)	Body weight (kg)	Remarks
		yr mo day	yr mo day			
1	0*	'84.4.16	'84.4.16.	77.5	6.6	Yashima, Male
2	4	'77.5. 9.	'77.5.13.	79.0	7.4	Toba, Male
3	17	'76.4.17.	'76.5. 3.	81.5	7.2	Toba, Female
4	28	'81.4.21.	'81.5.19.	83.0	–	Miyajima, Female
5	1,719**	'79.5. 1.	'84.1.14.	159.5	–	Toba, Male
6	864**	'82.4.20.	'84.8.31.	153.5	39.5	Toba, Male

*: stillbirth, **: measured while alive.

corresponding figure for the Iki Island sample was 267 cm (Kasuya, 1985). Body lengths and estimated ages of finless porpoises from the Inland Sea were also used.

The ages of these individuals were estimated from dentinal growth layer counts in decalcified and haematoxylin-stained sections as outlined in Kasuya and Matsui (1984). Growth layer readings were done without biological data.

BOTTLENOSE DOLPHIN

Gestation time and neonatal length

Body lengths of neonatal bottlenose dolphins (measured within 11 days of birth) ranged from 116 to 140 cm. No differences were detected between the length of stillborn dolphins, those that died within two days and those that died on the third to eleventh days. No differences in neonatal body length was detected between the sexes in the present small sample. Combining the data from these 20 neonates, an average of 128 cm was estimated as the mean neonatal length for this species off the Pacific coast of Japan (Table 4).

Scott (1949) found for both mysticeti and odontoceti the following linear relationship between the maximum body length of adult (among both sexes,

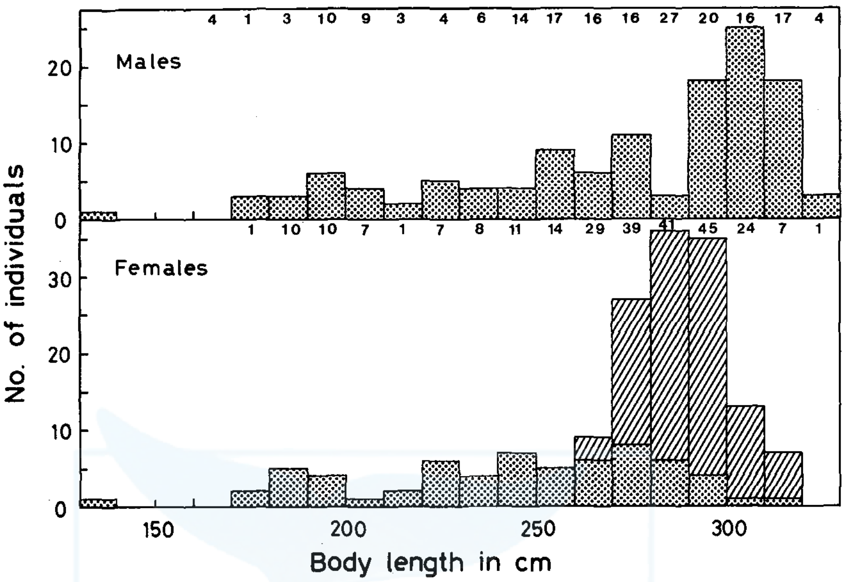

Fig. 1. Body length frequencies of the catch of bottlenose dolphins in the drive fishery off the Pacific coast of Japan (173 males and 165 females sampled from 8 schools driven during 1973 to 1983, represented by the histogram). The parents of the aquarium-reared individuals in the present study were taken by the same fishery. This body length frequency is similar to that of 190 males and 255 females sampled from 6 drivings in the period from 1979 to 1980 in the Iki Island area (indicated by numerals at the top). In the female samples from the Pacific, dotted areas represents sexually immature individuals and shaded areas mature individuals (male maturity was not determined).

X in cm) and the neonatal body length (Y in cm):

$Y = 0.2441X + 44.3$ Equation 1

Of 165 female and 173 male bottlenose dolphins taken off the Pacific coast of Japan and measured by Kasuya, the largest individual was a male of 328 cm and the next largest 325 cm. The former figure and the above equation suggest a neonatal length of 124.4 cm, which is only 3 % smaller than the figure estimated from the neonates in our sample.

Using data from *Physeter, Berardius, Delphinapterus, Phocoena* and several species of Delphinidae, Ohsumi (1966) suggested the following relationship between mean neonatal body length (Y in m) and mean body length of females at the attainment of sexual maturity (X in m):

$Y = 0.532X^{0.916}$ Equation 2

The Iki Island sample suggests 2.67 m as the body length at which 50 % of females are sexually mature. Using this figure and Equation 2, the mean neonatal length of bottlenose dolphins is estimated as 1.31 m (Kasuya, 1985). This is 2 % larger than the estimate obtained above.

The good agreement between observed and predicted neonatal body

TABLE 4. ESTIMATION OF NEONATAL BODY LENGTH OF *TURSIOPS TRUNCATUS* (cm)

Length of postnatal life	Male	Female	Mean
Stillbirth	126.0	120.0	130.3
	126.0	128.0	–
	132.0	140.0	–
	140.0	–	–
After 0 to 2 days	116.0*	115.0	121.7
	122.0	118.7	–
	125.0**	121.0	–
	134.0	–	–
After 3 to 11 days	127.0	130.0	132.2
	132.0	132.0	–
	133.0	–	–
	139.0	–	–
Mean	129.3	125.6	127.8

*: living on 204th day after birth, **: living on 2364th day after birth.

lengths is probably, in part, due to the fact that Equations 1 and 2 were based on sample sets that include *Tursiops*.

Substituting a neonatal length 128 cm (as estimated above) in the equation of Perrin *et al.* (1977) which describes the relationship between gestation time (Y months) and neonatal length (X cm) for five stocks of Delphinidae:

$$\log Y = 0.4586 \log X + 0.1659 \qquad \text{Equation 3}$$

gives a predicted gestation time of 13.6 months, slightly longer than one year (Odell, 1975) estimated for the Atlantic bottlenose dolphin which has a neonatal length about 10 cm smaller than Japanese coastal population (Nakajima, Takahashi, Ogura and Sawaura, 1963; Hohn, 1980). However, there is no reason at present to conclude that the gestation time of the Japanese population is longer than that of the Atlantic, because above Equation 3 describes the interspecific relationship between these parameter in several delphinoid species rather than the relationship among several populations of a single species.

Kasuya (1977) suggested the following relationship between neonatal length (X in cm) and the daily fetal growth rate for the linear part of the fetal growth phase (Y cm/day) for several species of Delphinidae, *Phocoena* and *Delphinapterus*:

$$Y = 0.001462\ X + 0.1622 \qquad \text{Equation 4}$$

This equation and the neonatal length 128 cm calculated from neonates give a fetal growth rate as 0.3493 cm/day or 10.63 cm/month for *T. truncatus*.

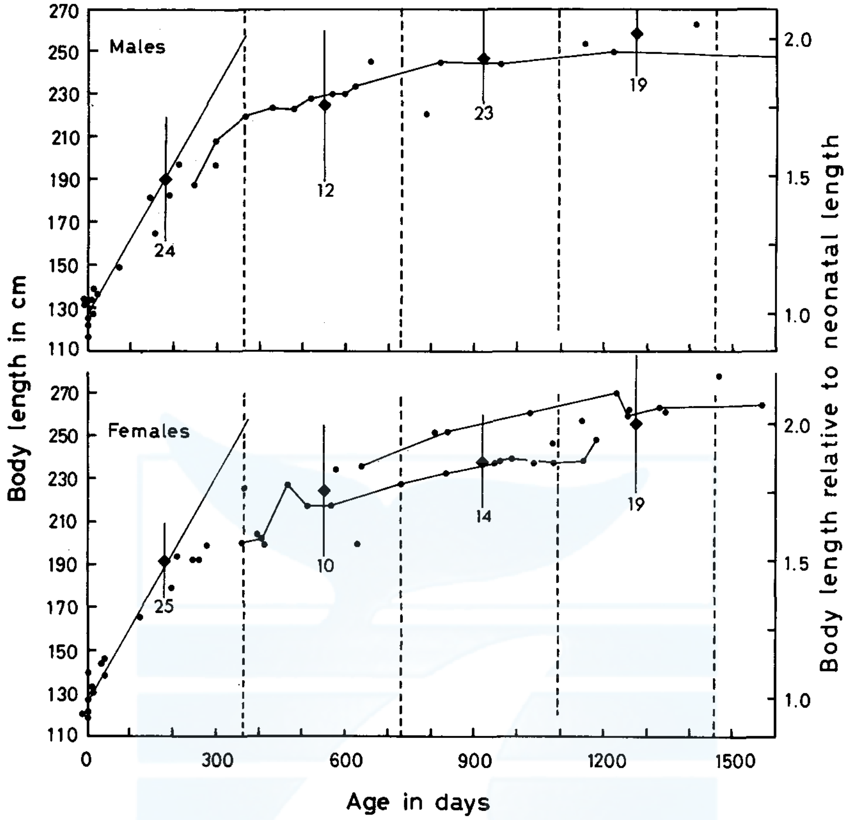

Fig. 2. Bottlenose dolphin body lengths plotted on age. Each independent closed circle represents one aquarium-reared individuals; those connected by solid lines represent repeated measurements of one individual. The diamonds and vertical lines represent the mean body lengths ± 2SD plotted against ages estimated from dentinal growth layer counts (wild individuals taken off Iki Island, for their body length composition see Fig. 1). The numerals indicate the number of individuals whose ages have been estimated. Ages between n and n+1 years were expressed as n+0.5 years (n being integer). The thin solid lines represent extraporation of the linear part of the fetal growth curve through the mean neonatal length (128 cm). Left scale indicates body length in cm and the right scale body length relative to mean neonatal length.

Early postnatal growth

Individual body lengths of aquarium reared individuals and the mean body length of the species from Iki Island area are plotted against age in Fig. 2. The agreement between the two data sets is good, suggesting that (1) the growth in a given range is similar between wild and aquarium-reared individuals and (2) deposition of dentinal growth layers is annual as shown for the Atlantic stock of the species using aquarium reared specimen (Sergeant, Caldwell and Caldwell, 1973).

The rate of increase in neonatal body length decreased with increasing age, and except for some individuals less than 40 days old, the data for most neonates came below the line of the mean fetal growth curve extended through the mean neonatal length. Furthermore, the size of individuals older than 200 days significantly diverged from the line (Fig. 2). These data suggest that the growth rate of postnatal individuals never exceeds that of a fetus during the linear part of its growth.

The mean body length of the present sample of aquarium-reared calves at one year of age falls within the range of 200–220 cm or 1.56–1.72 times the mean neonatal length (Fig. 2). This is in good agreement with the range of 1.55–1.64 times found for five species of Delphinidae (discussed by Kasuya and Matsui, 1984). Perrin *et al.* (1976) deduced, using data of *Physeter, Phocoena, Delphinapterus, Globicephala* and *Stenella*, the following relationship between mean fetal growth rate (X in cm/month), mean postnatal growth rate during the period equivalent to the length of gestation (Y in cm/month) and neonatal length (Z in cm):

$$\log(X-Y) = -1.33 + 0.997 \log Z \qquad \text{Equation 5}$$

Using this equation, a mean fetal growth rate of $X = 128/12$ or $128/13.6$ and a mean neonatal length ($Z = 128$), suggests a mean body length of 184.6 cm at age 12 months or 192.0 cm at 13.6 months. These predicted values are about 10 % smaller than the observed figure and come below the range of individual variation (Fig. 2).

Sexual maturity

A male that lived for 1,655 days (4.5 years) in captivity had left and right testis weighing 15.0 and 14.0 g, respectively. It showed no behavioral signs of puberty, and was considered as sexually immature based on the similarity of its testis weight to those of the immature Atlantic bottlenose dolphin (Harrison, Brownell and Boice, 1972).

The oldest female in the present material lived for 1,182 days (3.2 years) and attained a body length of 238.5 cm, smaller than the smallest sexually mature wild individuals (Fig. 1). There were no corpora in the ovaries. In the Iki Island area, the youngest mature and oldest immature females appeared at ages of 3.5 and 8.5 growth layer cycles (years), respectively (60 individuals in the age range). This material suggested that 50 % of the females were sexually mature at an age of 7 years (Kasuya, unpublished).

FINLESS PORPOISE

Gestation time and neonatal length

Kasuya and Kureha (1979) listed 14 Japanese records of neonates of this species with body length ranging from 68.8 to 97.6 cm ($\bar{x} = 78.6$ cm). Their ages at death were usually unknown. The lengths of four known age neonates

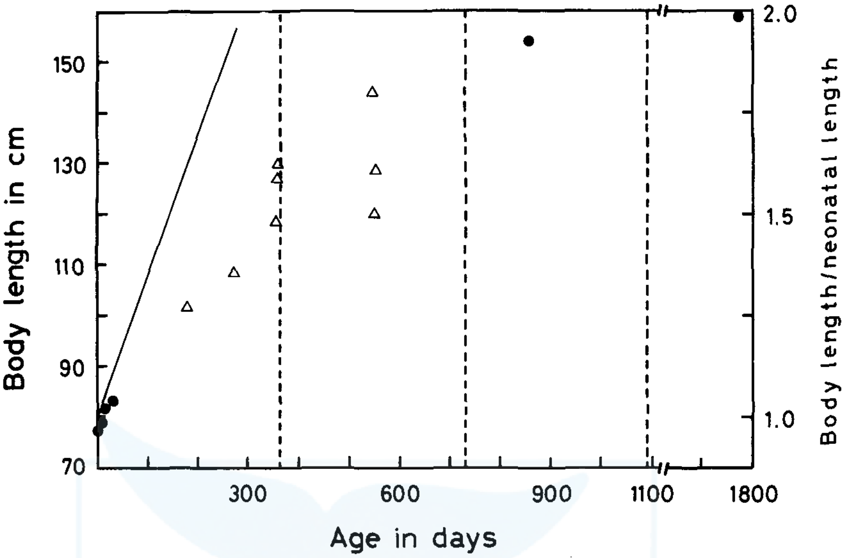

Fig. 3. Body lengths of known-age individual finless porpoises plotted against age (closed circles) and body length of fishery-caught individuals plotted against ages estimated from dentinal growth layer counts (triangles). The ages of the latter were estimated to nearest 1/4 year for animals 1 year or younger and to the nearest n+0.5 years for individuals between n and n+1 years (n being integer, n ≥ 1). The thin solid line indicates the linear part of the fetal growth curve extraporated through the mean neonatal length (80 cm). Left scale indicates body length in cm and right scale body length relative to mean neonatal length.

(some of which were listed in Kasuya and Kureha (1979)) are now available. They range between 77.5 and 83.0 cm (died within 28 days) ($\bar{x}$ = 80.0 cm) (Table 3 and Fig. 3).

Although this sample size is small, the largest individuals available to us were 187 cm (out of seven adult or subadult males) and 164 cm (out of seven adult females). The neonatal body lengths predicted using Equation 1 and either of the above adult sizes, 89.9 or 84.3 cm, seem to be overestimates. This equation may not give reliable prediction for small species such as the finless porpoise. There are no data on the mean body lengths of finless porpoise at the attainment of sexual maturity to use in Equation 2. Therefore we decided to use the mean of the four neonates of known age (80.0 cm) as the mean neonatal length of the finless porpoise in Japanese coastal waters.

The Equation 3 and the above neonatal length suggest a gestation time of 10.9 months. Assuming an error of ±5 cm in this neonatal length estimate, the resultant range in the gestation period is 10.6 to 11.2 months. The error in our estimate of neonatal length has only a negligible effect on the gestation period of small delphinoids calculated using Equation 3.

Using Equation 4, the growth rate at the linear part of fetal growth was estimated using a neonatal length of 80 cm as 0.279 cm/day or 8.49 cm/month.

Early postnatal growth

In Fig. 3 the body lengths of both known age aquarium-reared and wild finless porpoise (which ages have been estimated from dentinal layer count) are plotted against age. All the values for wild individuals fall between those of aquarium-reared individuals suggesting that the dentinal growth layers are deposited annually. All the values are far below the extended fetal growth curve suggesting that the decline in the neonatal growth rate after birth is faster in this smaller species than in the bottlenose dolphin.

Assuming that growth layers are deposited annually the mean body length at one year of age is estimated between 120 and 130 cm or 1.50–1.63 times the neonatal length (Fig. 3). This fits the general rule deduced by Kasuya and Matsui (1984) for delphinoids. The mean neonatal length, 80 cm, and Equation 5 suggest a body length at an age equivalent to the gestation period (about 11 months) as 116.1 cm with a range of 113–126 cm due to the uncertainty about the neonatal length estimate. Although the agreement is possibly better in this smaller finless porpoise than in the bottlenose dolphin, the calculated figure is still smaller than the corresponding figure directly estimated from age determined from dentinal growth layer counts (Fig. 3).

Sexual maturity

Of two individuals still living in the Toba Aquarium, a male which measured 153.5 cm at 2.4 years of age (No. 6 in Table 3) shows no behavioral sign of sexual maturity. Another 4.7-years-old 159.5 cm long male (No. 5) often indulged in sexual play with his mother (but not with other adult females in the tank). His penis was erect but no intromission was confirmed. We regard the maturity of this male as questionable.

Among the six males over 140 cm caught in the wild, four had sperm in their epididymides (body lengths 144, 148, 157 and 187 cm), but two (body length 155 and 165 cm) had no sperm (Kasuya, unpublished). Of nine females taken in the wild, eight individuals measuring between 141 and 164 cm in body length were sexually mature. One immature female was 118 cm long. These are not inconsistent with our observations of aquarium specimens.

DISCUSSION

Our analyses show that the bottlenose dolphin and possibly the finless porpoise have annual cycles of dentine deposition usable for age determination. The growth of the aquarium-reared individuals was, at least in their early postnatal stage, similar to that of the naturally grown individuals. This allows a detailed analysis of early postnatal growth which was not possible based on age determination using annual growth layer counts from wild individuals.

This study showed that the early post natal growth of bottlenose dolphins and finless porpoises follows the established pattern for Delphinoidea and indeed for Odontocetes in general. Some unknown growth parameters of these species can be predicted with various degrees of precision using published equations describing the interspecific relationship of these parameters. The use of these equations enhance our ability to interpret dentinal growth layers deposited in the early postnatal stage. Such layers are often difficult to interpret correctly without data from known age individuals.

The recommended procedure is firstly to examine if the age determination technique for the species being examined suggests an average increase of 55 to 70 % of the neonatal length in the first year after birth. If the neonatal length is not available, it can be estimated from the adult size, preferably using the mean body length of females at the attainment of sexual maturity. The technique of age determination should be questioned if the resultant estimate of postnatal growth exceeds the growth rate of the fetus during the linear part of the fetal growth stage as estimated using Equations 4 and 5.

ACKNOWLEDGEMENTS

We wish to express our sincere thanks to the following aquariums for providing records of dolphins born in captivity: Awashima Aquarium, Chita Beachland, Mito Sea Paradise, Misaki Sea Aquarium, Miyajima Aquarium, Shimoda Sea Aquarium and Yashima Aquarium. Dr H. Marsh of James Cook University kindly repeated checking the draft and corrected English. Dr S. Ohsumi of the Far Seas Fisheries Research Laboratory critically read the manuscript. Mrs K. Yano, S. Toba and Y. Yamamoto helped with data analysis, typing and drawings.

REFERENCES

COLLET, A.S., 1981. Biology of the common dolphin *Delphinus delphis* L. in the NE Atlantic. *Doctoral thesis, Univ. Poitiers,* 156pp. (in French).

HARRISON, R.J., R.L. BROWNELL JR, and R.C. BOICE, 1972. Reproduction and gonadal appearances in some odontocetes. pp.361–429. *In*: R.J. Harrison (ed.) *Functional anatomy of marine mammals* vol. 1. Academic Press, London and New York. 451pp.

HOHN, A., 1980. Age determination and age related factors in the teeth of western North Atlantic bottlenose dolphins. *Sci. Rep. Whales Res. Inst.,* 32: 39–66.

HONDA, M., 1979. Breeding the bottle-nosed dolphin, *Tursiops truncatus,* at Enoshima Aquarium Marineland. *J. Jap. Assoc. Zool. Gardens and Aquariums,* 21 (1): 4–9. (in Japanese).

JONES, L., T. KASUYA, M. GOSHO, and N. MIYAZAKI, 1985. Variability by readers and method of preparation in Dall's porpoise age determination. INPFC Document No. 2878. 19p.

KASUYA, T., 1972. Growth and reproduction of *Stenella caeruleoalba* based on age determination by means of dentinal growth layers. *Sci. Rep. Whales Res. Inst.,* 24: 57–79.

KASUYA, 1977. Age determination and growth of the Baird's beaked whale with a comment on the fetal growth rate. *Sci. Rep. Whales Res. Inst.,* 29: 1–20.

KASUYA, T., 1985. Fishery-dolphin conflict in the Iki Island area of Japan. pp.253–272. *In*: R.J.H. Beverton (ed.) *Marine mammals and fisheries*. Academic Press, London and New York. 354pp.

KASUYA, T. and K. KUREHA, 1979. The population of finless porpoise in the Inland Sea of Japan. *Sci. Rep. Whales Res. Inst.,* 31: 1–44.

KASUYA, T. and S. MATSUI, 1984. Age determination and growth of the short-finned pilot whale off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.,* 35: 57–91.

KASUYA, T., T. TOBAYAMA, and S. MATSUI, 1984. Review of livecapture of small cetaceans in Japan. *Rep. int. Whal. Commn,* 34: 597–602.

MYRICK JR, A.C., 1980. Examination of layered tissue of odontocetes for age determination using polarized light microscopy. *Rep. int. Whal. Commn* (special issue 3): 105–112.

MYRICK JR, A.C., E.W. SHALLENBERGER, I. KANG and D.B. MACKAY, 1984. Calibration of dentinal growth layers in seven captive Hawaiian spinner dolphins, *Stenella longirostris,* based on tetracycline labelling. *Fish. Bull.,* 82 (1): 207–225.

NAKAJIMA, M., K. TAKAHASHI, M. OGURA and H. SAWAURA, 1963. On the growth of infants of the small size toothed whales. *J. Soc. Zool. Gardens and Aquariums,* 5 (1): 16–22. (in Japanese).

ODELL, D.K., 1975. Status and aspects of the life history of the bottlenose dolphin, *Tursiops truncatus,* in Florida. *J. Fish. Res. Bd Can.,* 32 (7): 1055–1058.

OHSUMI, S., 1966. Allomorphosis between body length at sexual maturity and body length at birth in the cetacea. *J. Mamm. Soc. Jap.,* 3 (1): 3–7.

PERRIN, W.F., J.M. COE and J.R. ZWEIFEL, 1976. Growth and reproduction of the spotted porpoise, *Stenella attenuata,* in the offshore eastern tropical Pacific. *Fish. Bull.,* 74 (2): 229–269.

PERRIN, W.F., D.B. HOLTS and R.B. MILLER, 1977. Growth and reproduction of the eastern spinner dolphin, a geographical form of *Stenella longirostris* in the eastern tropical Pacific. *Fish. Bull.,* 75 (4): 725–750.

PERRIN, W.F. and A.C. MYRICK JR (eds), 1980. Age determination of toothed whales and sirenians. *Rep. int. Whal. Commn* (special issue 3), 229pp.

SCOTT, E.O.G., 1949. Neonatal length as a linear function of adult length. *Pap. and Proc. Roy. Soc. Tasmania,* 1948: 75–93.

SERGEANT, D.E., D.K. CALDWELL and M.C. CALDWELL, 1973. Age, growth, and maturity of bottlenose dolphin (*Tursiops truncatus*) from northeast Florida. *J. Fish. Res. Bd Can.,* 30 (7): 1009–1011.


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

CHROMOSOME NUMBER OF TWO COLOR TYPES OF THE DALL'S PORPOISE*

HIROSHI YABU** AND HARUO OGI**

Dall's porpoises, *Phocoenoides dalli* True, *1885*, are commonly distributed in the entire subarctic North Pacific Ocean, Sea of Japan, Sea of Okhotsk and Bering Sea. Of the two major color types known to this species, the *dalli*-type is widely distributed in the subarctic North Pacific Ocean including Sea of Japan, Sea of Okhotsk and Bering Sea. Whereas the *truei*-type is mainly distributed in areas off the Pacific coast of southern Kuril Islands and northern Japan, although some sporadic sightings have been recorded from offshore western North Pacific and Bering Sea (Nishiwaki, 1967; Kasuya 1978; Morejohn, 1979; Kasuya and Jones, 1984; Miyazaki, Jones and Beach, 1984).

Makino (1948) studied chromosomes of a male *P. dalli* using traditional sectioning of testis tissue. Since it was generally accepted in those days that the two color morphs represent separate species (Kuroda, 1954; Houck, 1976), his study was possibly based on the present "*dalli*-type" individuals. The present paper is a preliminary report of a study conducted to further investigate the chromosomal differences between the two color types of the Dall's porpoise.

Materials are ten *dalli*-types (five males of 97 to 156 cm and five females of 68 to 127 cm in body length) and six male *truei*-types (182.1 to 220 cm in body length) taken in May and June 1984 by the RV *Hoyo Maru No. 53* chartered by the Japan Fisheries Agency. Immediately after catching the animals, pieces of gonad, liver and kidney were removed and fixed with acetic alcohol (acetic acid 1 : ethanol 3). These materials were smeared with aceto-iron-haematoxylin-chroral hydrate solution recommended by Wittmann (1965). The metaphase nuclei available for the chromosome count were obtained only in the testis from each two males of *dalli*- and *truei*-types (Table 1).

In both color types, we found very easily the same chromosome number of $2n=44$ in the spermatogonial metaphase and $n=22$ in the secondary spermatocyte metaphase (Figs 1 and 2). The chromosome numbers in many delphinids have been reported as $2n=44$ including characteristic X Y chromosome (Makino, 1948; Wallen and Madin, 1965; Tsuchiya, 1979;

---

* Contribution No. 165 from the Research Institute of the North Pacific Fisheries, Faculty of Fisheries, Hokkaido University.

** *Faculty of Fisheries, Hokkaido Univertsity, Hakodate, Hokkaido, 041 Japan.*

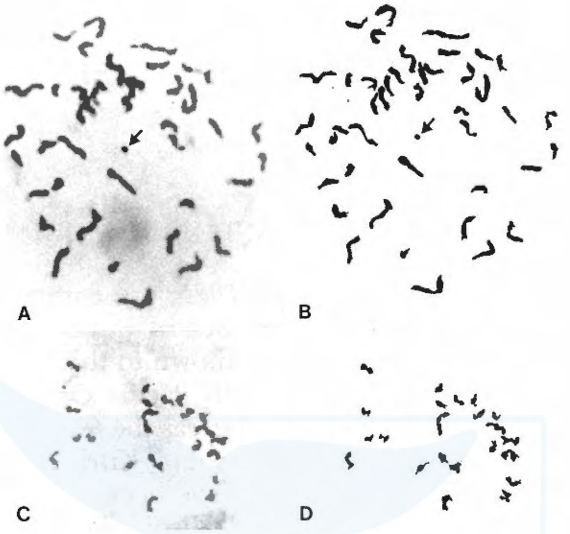

Fig. 1. Chromosomes of Dall's porpoise. × 960
The small chromosome in A and B is indicated by an arrow.
A. Spermatogonial metaphase.
B. Drawing of A.
C. Secondary spermatocyte metaphase.
D. Drawing of C.

TABLE 1. DATA OF DALL'S PORPOISE SPECIMENS AND THEIR CHROMOSOME NUMBERS

Color type	Sex	Body length (cm)	Body weight (kg)	collected on	collected at	Chromosome number 2n	Chromosome number n
dalli-type	Male	200	164	May 16	46°48′N 157°18′E	44	22
	Male	195	142	May 17	48°37′N 164°68′E	44	22
truei-type	Male	216	159	May 12	38°31′N 150°17′E	44	22
	Male	201.5	123	June 14	41°31′N 151°29′E	44	22

Arnason, 1981; Stock, 1981). Our observations in the testis were not enough to discriminate such X Y elements, nevertheless, as seen in Fig. 1 (A and B) and Fig. 2 (A and B), spermatogonial metaphase in the both types comprised extremely small rod-shaped chromosome resembling Y element pointed out by Makino (1948) in *dalli* (True).

The chromosome number of 2n=44 is uniform in all phocoenids, del-

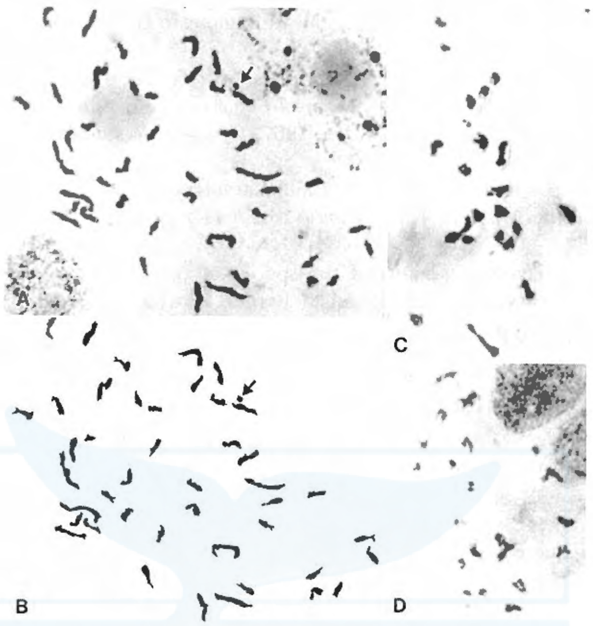

Fig. 2. Chromosomes of *truei*-type Dall's porpoise. × 960
The small chromosome in A and B is indicated by an arrow.
A. Spermatogonial metaphase.
B. Drawing of A.
C and D. Secondary spermatocyte metaphase.

phinids and monodontids studied in the past (Makino, 1948; Wallen and Madin, 1965; Duffield, Ridgway and Sparkes, 1967; Andrews, Dill, Masui and Fisher, 1973; Arnason, 1974; Tsuchiya, 1979). In the above groups, the killer whale in delphinids has quite different chromosomal morphology from other species (Carr, Singh, Miller and McGeer, 1966; Horrall, Taylor and Taylor, 1968; Kulu, Veomett and Sparkes, 1971).

Since Makino's (1948) work, no other studies on the chromosome of Dall's porpoises have been done. Therefore, further chromosomal studies must be needed to know the strict intra-specific relationship between two color-types of the Dall's porpoise.

REFERENCES

Andrews, R.C., F.J. Dill, S. Masui and H.D. Fisher, 1973. The chromosome complement of the narwhal (*Monodon monoceros*). *Can J. Zool.*, 51 (3): 349–353.

Arnason, U., 1974. Comparative chromosome studies in Cetacea. *Hereditas*, 77 (1): 1–36.

ARNASON, U., 1981. Localization of nucleolar organizing regions in Cetacean karyotypes. *Hereditas*, 95 (2): 269–276.

CARR, D.H., R.P. SINGH, I.R. MILLER and P.L. MCGEER, 1966. The chromosome complement of the Pacific killer whale (*Orcinus rectipinna*). *Mammal Chromosome Newsletter*, 22: 208.

DUFFIELD, D.H., S.H. RIDGWAY and R.S. SPARKES, 1967. Cytogenetic studies of two species of porpoise. *Nature*, 213 (5072): 189–190.

HORRALL, J.F., B.K. TAYLOR and K.M. TAYLOR, 1968. Karyotypes of the Pacific killer whale *Orcinus orca* (Linn. 1758), and the Brazilian Tapir, *Tapirus terrestris* (Gray 1843). *Mammal Chromosomes Newsletter*, 9: 244–245.

HOUCK, W.J., 1976. The taxonomic status of the species of the genus *Phocoenoides*. FAO of the UN, Scientific Consultation on Marine Mammals, Bergen, Norway, 31 Aug.–7 Sept., 1976, document ACMRR/MM/SC/114, pp.1–13.

KASUYA, T., 1978. The life history of Dall's porpoises with special reference to the stock of the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.*, 30: 1–63.

KASUYA, T. and L.L. JONES, 1984. Behavior and segregation of the Dall's porpoise in the northwestern North Pacific Ocean. *Sci. Rep. Whales Res. Inst.*, 35: 107–128.

KULU, D.D., I. VEOMETT and R.S. SPARKES, 1971. Cytogenetic comparison of four species of cetaceans. *J. Mamm.*, 52 (4): 828–832.

KURODA, N., 1954. On the affinity of the Dall's and True's porpoises. *Bull. Yamashina Ornithol. Res. Inst.*, 5: 44–46. (in Japanese with English summary).

MAKINO, S., 1948. The chromosomes of Dall's porpoise, *Phocoenoides dalli* (True), with remarks on the phylogenetic relation of the Cetacea. *Chromosoma*, 3: 220–231.

MIYAZAKI, N., L.L. JONES and A.R. BEACH, 1984. Some observations on the northwestern Pacific. *Sci. Rep. Whales Res. Inst.*, 35: 93–105.

MOREJOHN, G.V., 1979. The natural history of Dall's porpoise in the North Pacific Ocean. pp.45–83. *In:* H.E. Winn and B.L. Olla (eds), *Behavior of marine animals*, vol. 3, Prenum Press, New York and London. 438pp.

NISHIWAKI, M., 1967. Distribution and migration of marine mammals in the North Pacific area. *Bull. Ocean Res. Inst.*, 1: 1–64.

STOCK, A.D., 1981. Chromosomal variation and constitutive hetero chromatin in 3 porpoise species genus *Stenella*. *Cytogent. Cell Genet.*, 31 (2): 91–100.

TSUCHIYA, K., 1979. Karyotype of a female Gill's bottle-nosed dolphin *Tursiops gilli.* Dall. *Chromosome Inf. Serv.*, 26: 18–19.

WALLEN, K.H. and S.H. MADIN, 1965. Comparative chromosome analyses of the bottle-nosed dolphin (*Tursiops truncatus*) and pilot whale (*Globicephala scammonii*). *American Naturalist*, 99(908): 349–354.

WITTMANN, W., 1965. Aceto-iron-haematoxylin-chloral hydrate for chromosome staining. *Stain. Tech.*, 40 (3): 161–164.

FIRST RECORD OF SOWERBY'S BEAKED WHALE FROM AZORES

FRANCISCO REINER*

The Odontocete species *Mesoplodon bidens* (Sowerby, 1804) is generally thought to occur naturally in the northern part of the Atlantic, especially between the latitudes of 50° and 60° N. This is suggested by the known strandings on the coasts of Norway, Sweden, Denmark, Iceland, Germany (Baltic Sea), Holland, Belgium, British Isles and France (see Duguy and Robineau, 1982). These strandings are shown in Fig. 1. However, Maul and Sergeant (1977) refer the capture of one of these beaked whales in the waters of Madeira (near the fishing port of Machico) on August 14, 1941, which is a latitude considerably lower than the ones at which we would expect to find this species.

We report on this short note the capture of another specimen, this time in Azores. In fact, an adult female was harpooned by fishermen near Vila Franca do Campo (25° 23′ N; 37° 45′ W), S. Miguel Island, on September 24, 1981. According to local fishermen, three whales (possibly of the same species) were seen around the long reefs near the port, following a N-S swimming course. One of them, presented hereby, stranded on a shallow reef and was later harpooned. The others seem to have continued on their southern route.

The skeleton was removed to the "Museu Regional Dr Carlos Machado". Several difficulties have limited the amount of information we were able to obtain. From the biopsy, however, we learned that the whale was carrying a 54cm long male foetus (11/81 MRCM). Some measurements and photographs had been made on the animal, shortly after death (Table 1; Fig. 2). The skull measurements, based on Moore (1963), are shown on Table 2. Figs 3 and 4 show different views of this skull. The foetus was also measured and

TABLE 1. EXTERNAL MEASUREMENTS OF *MESOPLODON BIDENS* IN CM

Total length, from tip of upper jaw to deepest part of notch on flukes	483.0
Head length	85.0
Girth, maximum	140.0
Length of dorsal fin base	22.0
Width of flukes, tip to tip	116.0
Maximum width of flipper	50.0

---

* *Museu do Mar, Câmara Municipal de Cascais, C.P. 2750 Cascais, Portugal.*

TABLE 2. SKULL MEASUREMENTS OF *MESOPLODON BIDENS* IN CM

Length of temporal fossa	9.0
Length of orbit	8.5
Greatest span of occipital condyles	11.0
Greatest width of temporal fossa approximately at right angles to greatest length	5.5
Breadth of skull across zygomatic process of squamosals	27.5
Width of premaxilae at midlength of rostrum	3.0
Breadth of skull across preorbital processes of frontals	20.2

TABLE 3. EXTERNAL MEASUREMENTS OF *MESOPLODON BIDENS* IN CM (FOETUS)

Total length, from tip of upper jaw to deepest part of notch on flukes	54.0
Tip of upper jaw to anterior insertion of dorsal fin	35.0
Tip of upper jaw to blowhole	9.3
Tip of upper jaw to apex of melon	4.5
Tip of upper jaw to centre of eye	10.0
Tip of upper jaw to angle of gape	6.0
Tip of upper jaw to anterior insertion of flipper	17.0
Height of dorsal fin	2.6
Length of flipper, axilla to tip	9.0
Maximum width of flipper	2.5
Tip of upper jaw to midpoint of genital aperture	38.2
Tip of upper jaw to midpoint of anus	41.0
Width of flukes, tip to tip	14.0

photographed (Table 3; Fig. 5).

We are very grateful to Dr James Mead, National Museum of Natural History, Smithsonian Institution, for his confirmation of the species identification, and to Dr Nestor de Sousa, Director of the "Museu Regional Dr Carlos Machado", for permission to the publication of the foetal measurements and other biometrical data. We also thank Silvino Pacheco and Paulo Oliveira for the photographs, and Dr A. Silva Luís for his encouragement. Manuel dos Santos provided helpful comments.

REFERENCES

Duguy, R. and D. Robineau, 1982. *Guide des Mammifères Marins d'Europe*. Delachaux e Niestlé–Neuchâtel, 200pp.

Maul, G.E. and D.E. Sergeant, 1977. New cetacean records from Madeira. *Bocagiana*, 43: 1–8.

Moore, J.C., 1963. Recognizing certain species of beaked whales of the Pacific Ocean. *Ann. Midl. Nat.*, 70 (2): 396–428.

Moore, J.C., 1966. Diagnoses and distribution of beaked whales at the genus *Mesoplodon* known from North American waters. pp.32–61 *In:* K.S. Norris (ed), *Whales, dolphins and Porpoises*. University of California Press, Berkeley. 789 pp.

Norris, K.S., 1961. Standardized methods for measuring and recording data on the smaller cetaceans. *J. Mammal.*, 42 (4): 471–476.

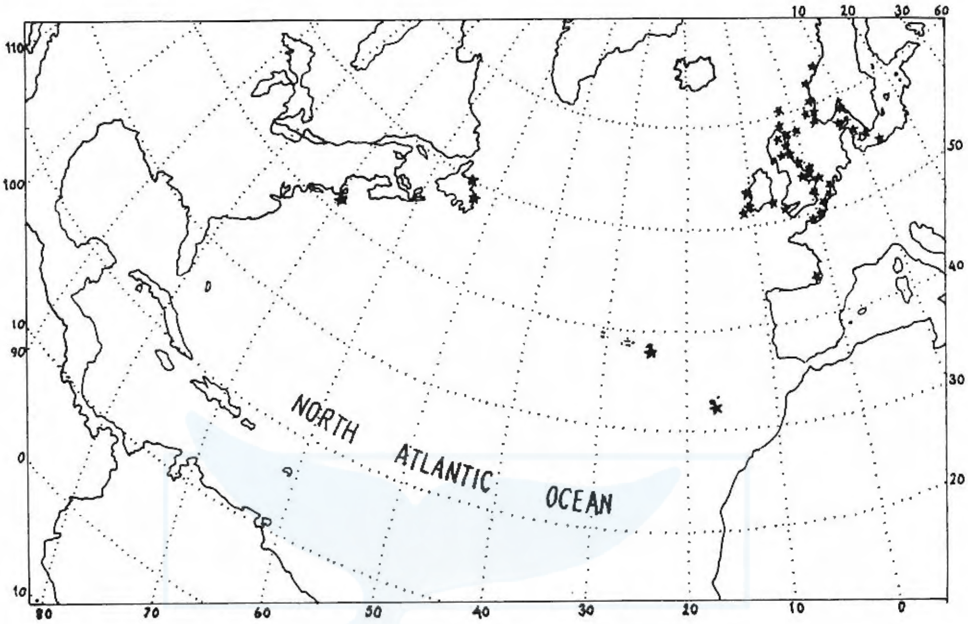

Fig. 1. Chart of known distribution of *Mesoplodon bidens* (based on Norris 1961).

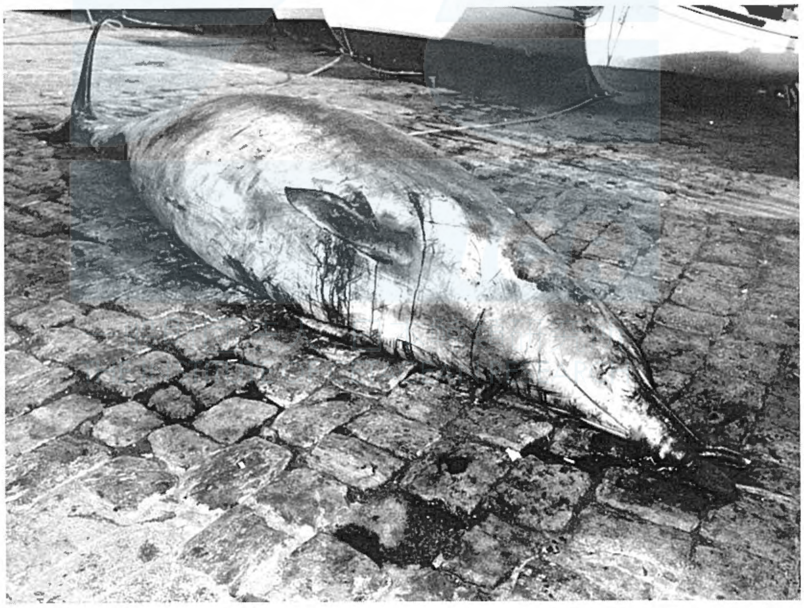

Fig. 2. Ventral view showing two grooves on the throat, characteristic off all beaked whales.

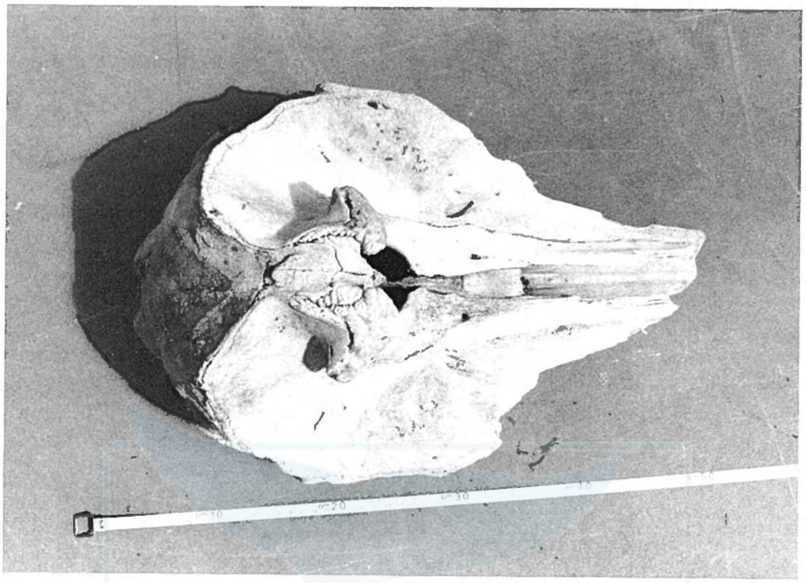

Fig. 3. Dorsal view of the skull.

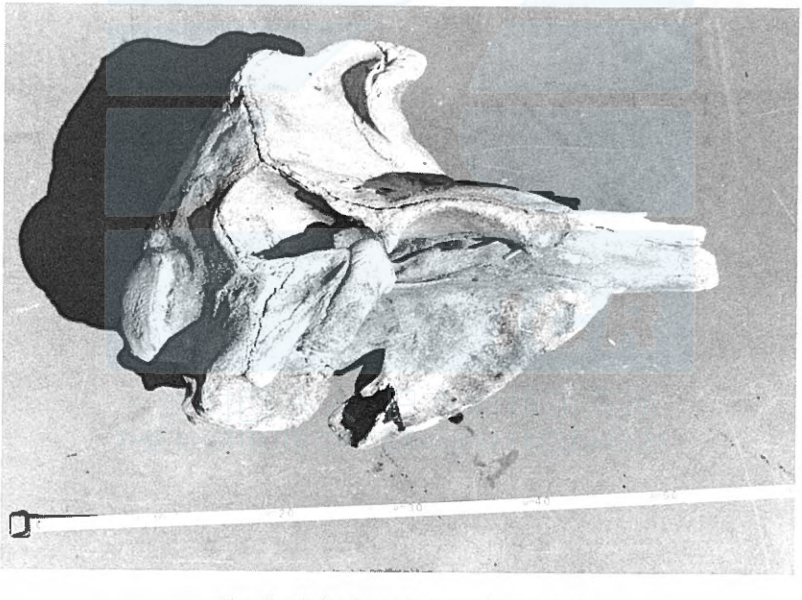

Fig. 4. Right lateral view of the skull.

Fig. 5. Lateral view of male foetus.


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

RECORDS OF BEAKED WHALES (ZIPHIIDAE) FROM THE WESTERN SOUTH ATLANTIC

ALFREDO A. LICHTER*

ABSTRACT

Five genera comprising eight species of the family Ziphiidae (*Tasmacetus shepherdi, Berardius arnuxii, Mesoplodon densirostris, M. layardii, M. hectori, M. grayi, Ziphius cavirostris* and *Hyperoodon planifrons*) have been recorded from the western and southwestern South Atlantic from Brazil to Cape Horn, including the Malvinas (Falkland) and the South Georgia Islands. A review of published records for the area is given and new and unpublished records are presented for *Mesoplodon layardii* (5), *M. hectori* (5), *M. grayi* (1), *Ziphius cavirostris* (8) and *Hyperoodon planifrons* (3). The first known gonad weights are given for *M. layardii*. A mass stranding of *M. hectori* included two adult females and two calves; one of the calves, of 190 cm, the smallest known to date.

INTRODUCTION

The family Ziphiidae, established by J.E. Gray in 1865, comprises five genera, *Tasmacetus, Berardius, Mesoplodon, Ziphius* and *Hyperoodon. Indopacaetus* (Moore, 1968) is now generally considered congeneric with *Mesoplodon* (Mitchell, 1975). Knowledge of many species of this family is scanty due to the comparatively small number of specimens available and the even fewer observations at sea. Nearly all known information has come from strandings. Certain Northern hemisphere species, especially those which were of some commercial interest (*Berardius bairdii, Hyperoodon ampullatus* and *Ziphius cavirostris*) have been fairly well studied, but those from the Southern hemisphere are among the least known cetacea.

Eight species, representing all five genera, have been sighted or found stranded on the coasts of the western South Atlantic, for the purposes of this paper defined as the area from Río do Janeiro (23°S), Brazil, to Cape Horn (56°S), including the Strait of Magellan, the Beagle Channel and the Malvinas (Falkland) and South Georgia Islands. (Fig. 1).

Since few records exist for this region, a summary of published records and new specimens may be of use to future workers.

---

* *Grupo Cetáceos, Fundación Vida Silvestre Argentina, L.N. Alem 968 PB, (1001) Buenos Aires, Argentina.*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 109–127

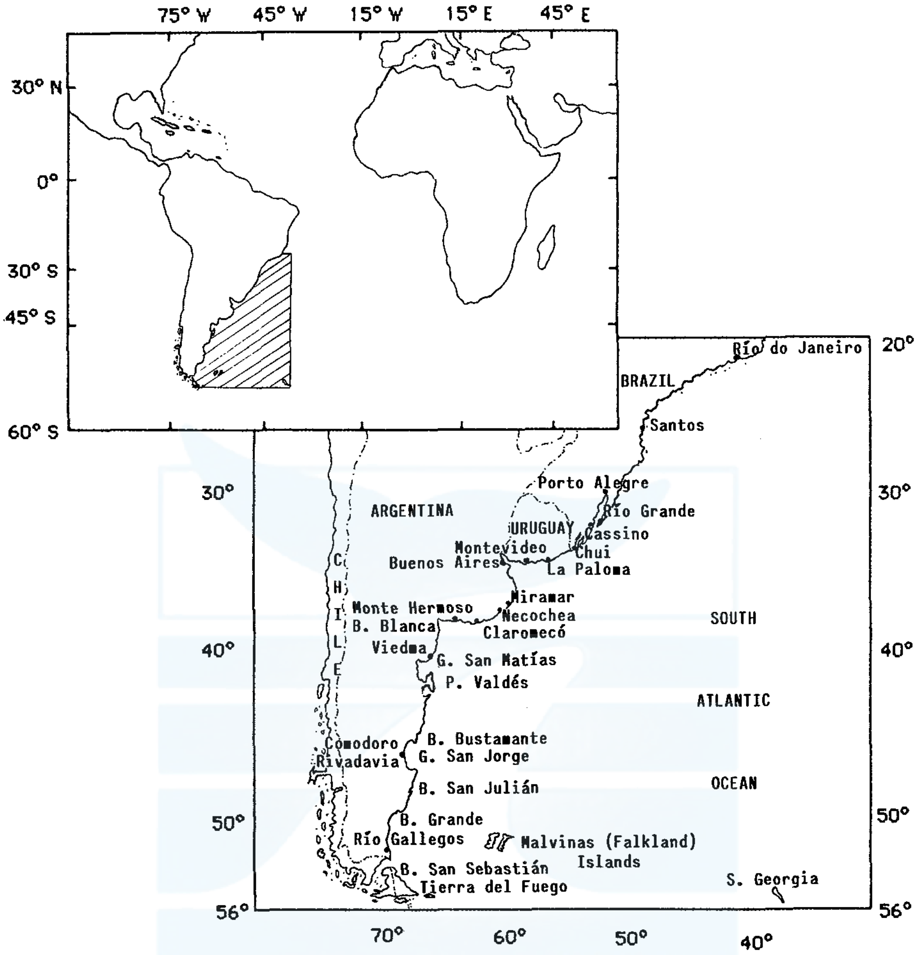

Fig. 1. Map of the western South Atlantic (study area).

MATERIALS AND METHODS

The literature has been searched for records of specimens and sightings of this family within the study area. The following museums were personally checked for specimens:

Province of Buenos Aires: Museo Argentino de Ciencias Naturales B. Rivadavia, Buenos Aires (MACN-BA); Museo de La Plata, La Plata (MLP); Museo de Ciencias Naturales de Mar del Plata; Museo Municipal de General Alvarado, Miramar (MMGA); Estación Hidrobiológica Necochea; Museo Municipal de Monte Hermoso (MMH); Universidad Nacional del Sur, Bahía Blanca (UNS). Museo Salesiano de Pedro Luro, (MSPL); Museo Provincial de Carmen de Patagones.

Provincia de Río Negro: Museo Provincial de Viedma.

Uruguay: Museo Nacional de Historia Natural, Montevideo (MNHN-M) (checked by R. Praderi)

Brazil: Museu Nacional de Río do Janeiro (MNRJ) (checked by L. Lodi); Museu Oceanografico de Río Grande (MORG) (checked by C. Pinedo).

Great Britain: British Museum of Natural History (London-BMNH) (personally checked).

The private collections of J.F. Mermoz (JFM), R. Praderi (RP) and that of the author (AAL) were examined and included.

All the specimens listed in this paper were beach cast or stranded along the coasts of the western South Atlantic Ocean. The great length of these coasts, the lack of population in some areas, and the lack of trained cetologists contribute to the loss to science of many such specimens and information. Most of those that were recovered are in a beach worn state; only a few were examined while fresh.

Only the dates of freshly stranded specimens are taken into consideration, for the analysis of possible seasonal occurrence of these species. Another important aspect to be considered is the difficult access to areas south of 40°S during the winter season.

Sightings of these species for this area are few, but have been presented when known.

Abbreviations used in the Tables are: Ea., estancia or ranch, B., bahía or bay; Pen., peninsula; Dept., department; v., vertebrae; c., complete; N°, number; Col, Collection; IPPA Instituto de la Patagonia de Punta Arenas (Chile); MPC, Museo Provincial de Cipoletti, Río Negro (Argentina); Phys. mat., Physical maturity based on epiphysed fusion or suture fusion of skull: A, adult, J, juvenile. It does not indicate sexual maturity. "Skull" means cranium with mandibles and "cranium" means mandibles are missing.

SPECIES ACCOUNTS

Tasmacetus shepherdi Oliver, 1937
Shepherd's beaked whale. Zifio de Shepherd

The ten specimens of this rare whale were summarized by Goodall (1978). Since then, the known number of specimens has risen to 13: eight from New Zealand, one from Australia, one from Isla Juan Fernández and the specimens from the western South Atlantic listed below (Baker, 1983) (Table 1, Fig. 2).

As far as we know, only one probable sighting, from New Zealand waters, has been reported for this species (Watkins, 1976). No new specimens were found in our review of museums.

Berardius arnuxii Duvernoy, 1851
Arnoux's beaked whale. Zifio de Arnoux.

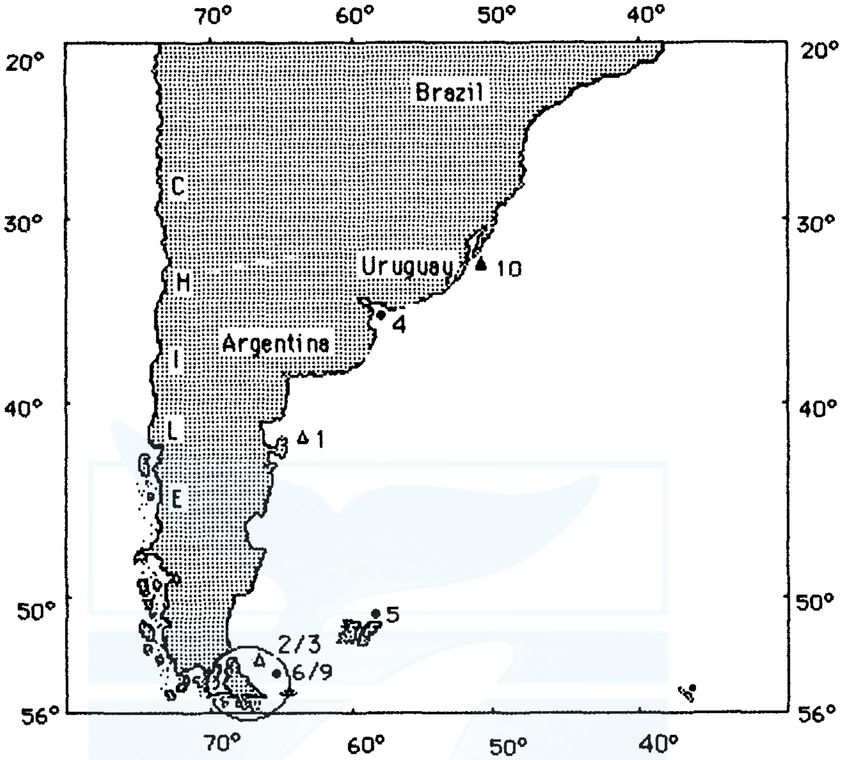

Fig. 2. Distribution of specimens of *Tasmacetus shepherdi* (open triangles), *Berardius arnuxii* (closed circles) and *Mesoplodon densirostris* (closed triangles) in the western South Atlantic. Records from Tierra del Fuego and the Strait of Magellan occur within the open circle.

TABLE 1. RECORDS OF *TASMACETUS SHEPHERDI* FROM THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
			Published records					
			Argentina					
1	USNM 484,878	Península Valdés Chubut	01 FEB 1973	F		1230	complete skeleton	Mead and Payne (1975)
2	RNP 457*	Punta María S, Tierra del Fuego	04 MAR 1977				cervicals	Goodall (1978)
	RNP 582*	Punta María S, Tierra del Fuego	06 NOV 1977				cranium incomplete	Goodall (1978)
3	RNP 666	Isla Gable NE, Beagle Channel	09 APR 1977				cranium, mandible	Goodall (1978)
			15 MAR 1978 09 APR 1978				cervicals, 18v.	

*: Cervicals RNP 457 appear to belong to the cranium RNP 582.

TABLE 2. RECORDS OF *BERARDIUS ARNUXII* FROM THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
Published records								
Argentina*								
4	MACN-BA 54–121	Arroyo del Pescado, Buenos Aires	29 MAY 1918	F		1421	complete skeleton	Marelli (1920) Mc Cann (1975)
5	BMNH 1935.8.23.1	Foul bay, Malvinas (Falkland) Islands.		M?	A		mandible	Hamilton (1952)
6	RNP 472	Río Lainez, Tierra del Fuego	05 MAR 1977				cervicals	Goodall (1978)
7	RNP 693	Punta María 6 N, Tierra del Fuego	03 MAR 1977				cranium, incomplete	Goodall (1978)
Chile								
8	RNP 566	Bahía Inútil, Tierra del Fuego	25 JUL 1977				cervicals	Goodall (1978)
9	IPPA CE-30	Punta Arenas					cranium and v.	Sielfeld (1980)

* Two specimens (BMNH 1935.10.23.2 and BMNH 1937.10.23.1.) from Malvinas (Falkland) Islands appearing in the BMNH cetacean catalogue.
Fraser (1948) cited this species for the South Georgia Island, without specific record.

In the Southern hemisphere strandings are known for Australia, New Zealand, South Africa, Argentina, Malvinas (Falkland) and the South Georgia Islands, Chile and it is also fairly common in Antarctic waters (South Shetland Islands and Antarctica Peninsula) (Fraser, 1948; Brownell, 1974; Mc Cann, 1975 and Goodall, 1978). No new specimens were found during the study, but those formerly known for the area are presented (Table 2, Fig.2).

Mesoplodon densirostris (de Blainville, 1817)
Blainville's beaked whale. Zifio de denso rostro.

This species has a wide distribution in warm and tropical waters in both hemispheres. In the Southern hemisphere, records exist from Australia, Tasmania, Lord Howe Island, the Seychelles, Mauritius and South Africa (Baker, 1983; Leatherwood, Reeves and Foster, 1983). The only specimen of this species that has been recorded for the western South Atlantic was a female of 4.4m, found at Cassino, Rio Grande do Sul, Brazil (32°S) (Castello and Pinedo, 1980) (Table 3, Fig. 2).

Mesoplodon layardii (Gray, 1865).
Strap-toothed whale. Delfín picudo de Layard.

The distribution of Layard's beaked whale (Australia, New Zealand, South Africa, Uruguay, Argentina and Chile) has been described by Goodall (1978), Sielfeld (1979), Ross (1979) and others.

A 450 cm male specimen was found on the shores of the Golfo San José,

Fig. 3. *Mesoplodon layardii* stranded in Comodoro Rivadavia, Chubut, in October, 1973. (Photo MACN-BA).

Península Valdés, on 23 June 1983 by G. Harris, who has contributed the following reproductive data: left testis weight 86.5 gr, length 9 cm; right testis weight 112 gr, and length 12 cm, width 5 cm. These are the first gonad weights known for the species (Mead, 1984). The stomach of this animal was empty; no food habits are known for this species (Goodall pers. comm.).

Total length have been reported for only four specimens of this species, the largest male reaching 584 cm, considerably larger than the male here reported.

The new specimens found during the study are presented in Table 4 (Figs 3, 4).

Mesoplodon hectori (Gray, 1871)
Hector's beaked whale. Delfin picudo de Hector.

Only 15 specimens of this species have been reported from Tasmania, New Zealand, South Africa, Malvinas (Falkland) Islands, Argentina, Chile and California (Baker, 1983). Two probable sightings at 8 miles East Catalina Island, California (2 animals) and at 50/70 miles West San Diego, California (2 animals) were reported by Mead (1981).

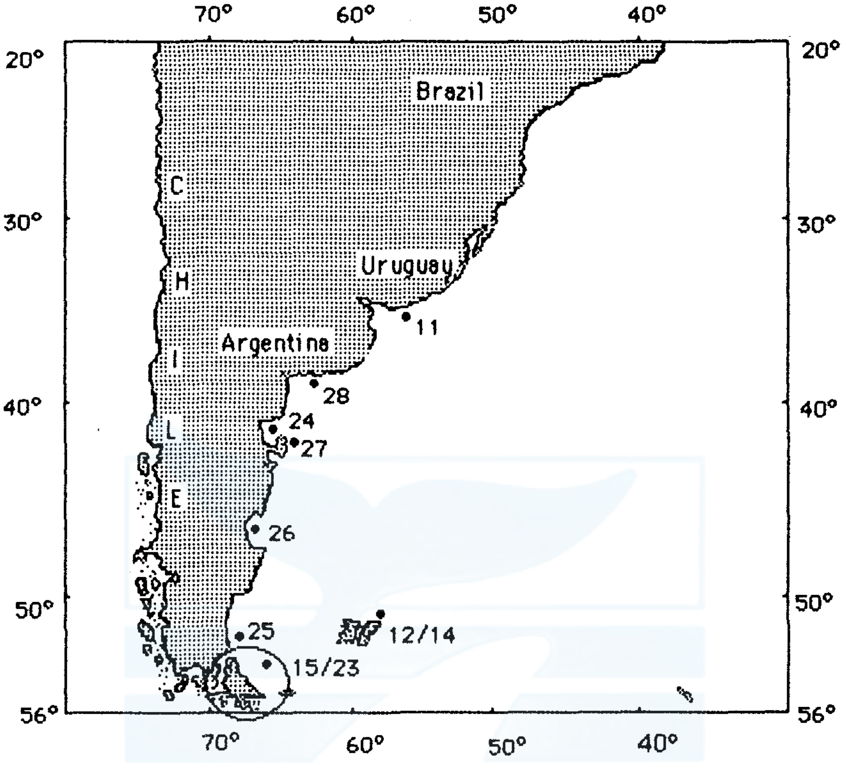

Fig. 4. Records of *Mesoplodon layardii* from the western South Atlantic. Records from Tierra del Fuego, Strait of Magellan and Isla Navarino occur within the open circle.

TABLE 3. RECORDS OF *MESOPLODON DENSIROSTRIS* FROM THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
			Published records					
			Brazil					
10	MORG 062	Cassino, Río Grande do Sul.	05 MAY 1977	F			complete skeleton	Castello and Pinedo (1980)

The new specimens presented here increase the number of known specimens to 20. Specimen UNS 2031 is a very incomplete cranium found near Sauce Grande in the southern Province of Buenos Aires in 1982. Two females and two calves were found at Claromecó, Buenos Aires, Argentina, 38°50′S, 59°53′W, they constitute the first stranding of this species comprising four specimens. The two females, at 415 cm and 400 cm in length, were shorter than the longest reported female (443 cm) (Mead, 1984); specimen

TABLE 4. RECORDS OF *MESOPLODON LAYARDII* FROM THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
			Published records					
			Uruguay					
11	MNHN-M 2471	Isla de la Tuna, Dept. de Rocha	09 FEB 1971	F	A	1040	complete skeleton	Praderi (1972)
			Argentina					
12		Lafonia Pen., Malvinas (Falkland) Islands	– – 1866		J			Turner (1880)
13		Port Sussex, Malvinas (Falkland) Islands	– – 1875		J		cranium, part of skeleton	Turner (1880)
14	BMNH 1965.8.19.2	Bleaker Island, Malvinas (Falkland) Islands	– – 1964	F			skull and skeleton	Strange (1972)
15	RNP 61	Pen. Páramo, Tierra del Fuego	04 JUL 1975	M?	J		cranium, cerv., 14v.	Goodall (1978)
16	RNP 74	Bahía Brown, Tierra del Fuego	31 DEC 1975	F	J		cranium good, 7v.	Goodall (1978)
17	RNP 313	B. San Sebastián, Tierra del Fuego	13 FEB 1976				cranium, 5v.	Goodall (1978)
18	RNP 326	B. San Sebastián, Tierra del Fuego	13 FEB 1976	F	A		cranium, 10v.	Goodall (1978)
19	RNP 659	Ea. San Martín N, Tierra del Fuego	29 JAN 1978				cranium incomplete	Goodall (1978)
			Chile					
20		Río Seco, Punta Arenas	– MAR 1968				photo	Venegas and Sielfeld (1978)
21	IPPACE-10	Cabo Espíritu Santo, Tierra del Fuego	15 FEB 1978				mandibular symphysis	Venegas and Sielfeld (1978)
22	IPPACE-25	Bahía Windhond, Isla Navarino	– MAR 1979	M	A		cranium	Sielfeld (1979)
23	IPPACE-32	Chabunco, Punta Arenas					cranium	Sielfeld (1980)
			Unpublished records					
			Argentina					
24	AAL 004	Las Grutas, Río Negro	– OCT 1970	M	A	980+	cranium incomplete	Col. AAL
25		Río Gallegos, Santa Cruz	– MAR 1972				photo MACN-BA	
26		Comodoro Rivadavia, Chubut	– OCT 1973				photo MACN-BA	
27		Golfo San José, Chubut	23 JUN 1983	M			complete skeleton	G. Harris pers. comm.
28	AAL 007	Monte Hermoso, Buenos Aires	23 MAR 1985			530+	cranium, incomplete	Col. AAL

TABLE 5. RECORDS OF *MESOPLODON HECTORI* FROM THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
			Published records					
			Argentina					
29	BMNH 1949.8.19.1	Malvinas (Falkland) Islands	– – 1949		J	601	skull	Fraser (1950) Hamilton (1952)
30	RNP 172	B. San Sebastián N, Tierra del Fuego	21 DEC 1975		J		nearly c. skeleton	Goodall (1978)
			Chile					
31	IPPACE-23	Bahía Windhond, Isla Navarino	– MAR 1979		J		cranium	Sielfeld (1979)
			Unpublished records					
			Argentina					
32	UNS 2031	Balneario Sauce Grande, Buenos Aires	– MAR 1982				cranium incomplete	Col. UNS
33	AAL 008	Claromecó, Buenos Aires	23 JAN 1985	F	A	712	almost c. skeleton	Col. AAL
34	AAL 009	Claromecó, Buenos Aires	23 JAN 1985	F	A	675	almost c. skeleton	Col. AAL
35	AAL 010	Claromecó, Buenos Aires	23 JAN 1985	F	J	405	skull	Col. AAL
36	AAL 011	Claromecó, Buenos Aires	23 JAN 1985		J	390	incomplete skeleton	Col. AAL

AAL 011 measured 190 cm, smaller than the shortest reported calf previously reported (210 cm) (Mead, 1984). The length of the second calf was 202 cm. More data on these four animals will be presented in a future paper (Table 5, Fig. 5).

Mesoplodon grayi von Haast, 1876.
Gray's beaked whale. Delfín picudo de Gray.

This species has a circumpolar distribution exclusively in the Southern hemisphere, except for a specimen stranded in the Netherlands (Boschma, 1950). Records exist for Australia, New Zealand, the Chatham Islands, South Africa, Argentina and Chile (Table 6, Fig. 5). The only new specimen reported here is an incomplete cranium (AAL 003) collected at Balneario San Antonio in the Province of Buenos Aires.

Ziphius cavirostris Cuvier, 1823
Cuvier's beaked whale. Zifio de Cuvier.

Cuvier's beaked whale has a wide distribution in both hemispheres. There are records in the western South Atlantic for Brazil, Uruguay, Argentina and Chile. For Brazil, besides the record quoted for the study area, there is only one record of a pregnant female from Cabedelo, Paraíba, Brazil (7°S) (Carvalho, 1975).

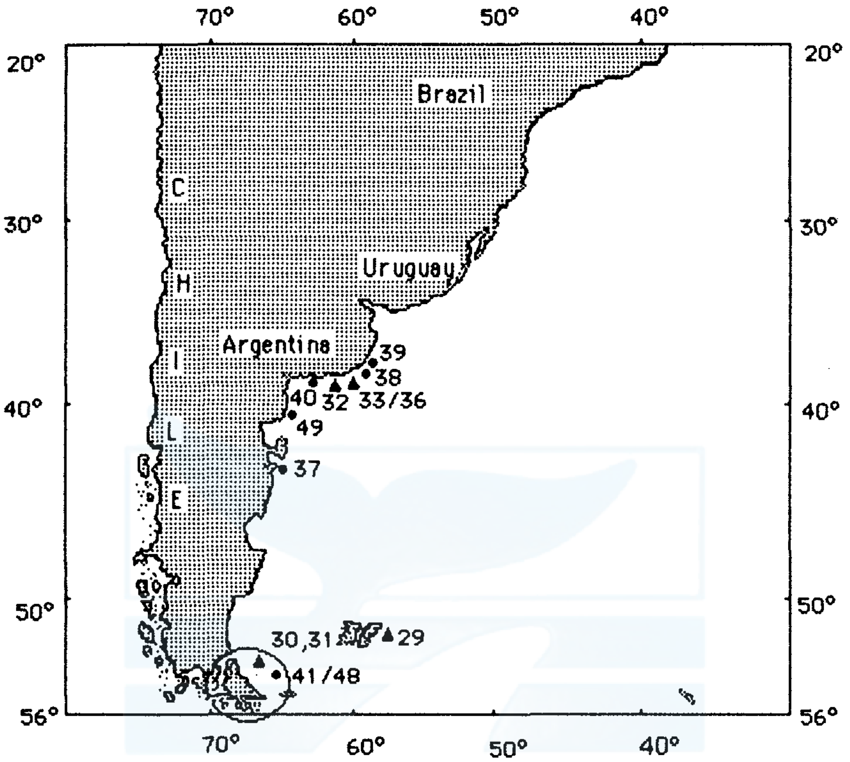

Fig. 5. Distribution of specimens of *Mesoplodon hectori* (closed triangles) and *Mesoplodon grayi* (closed circles) in the study area. Records from Tierra del Fuego, Strait of Magellan and Isla Navarino occur within the open circle.

Eight new specimens are presented in this paper. Specimens MACN-BA 16198, MMGA and MSPL Zc04 are incomplete crania. Specimen MACN-BA P0023 is a skull (without teeth) collected by R. Payne at Bahía San Sebastián in Tierra del Fuego. Specimen MLP 1118 is now on exhibition in the Museo de La Plata.

The three strandings (4 m male from San Julián, Santa Cruz, a mature specimen from Comodoro Rivadavia, Chubut and a mature female from Bahía Bustamante, Chubut) were identified by means of photos (Table 7, Fig. 6).

Hyperoodon planifrons Flower, 1882
Southern bottlenose whale. Zifio nariz de botella.

The distribution of this species covers a great part of the Southern hemisphere and was summarized by Gianuca and Castello (1976). There are records for Australia, New Zealand, South Africa and South America; Leatherwood *et al* (1983) stated that there is evidence of its presence in equatorial waters of the Pacific Ocean.

TABLE 6. RECORDS OF *MESOPLODON GRAYI* FROM THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
			Published records					
			Argentina*					
37		Golfo Nuevo, Chubut	– – 1895				most of skeleton	Moreno (1895)
38	MACN-BA 25-170	Quequén, Buenos Aires	20 JUL 1925		J	450	cranium incomplete	Urquiola de De Carli, Aramayo and Piñero (1970)
39	MACN-BA 25-169	Miramar, Buenos Aires	– JUL 1925				right mandible	Urquiola de De Carli, Aramayo and Piñero (1970)
40	UNS 207	Monte Hermoso, Buenos Aires	– – 1968		A	795	skull	Urquiola de De Carli and Aramayo (1970)
41	RNP 270	Los Chorrillos, Tierra del Fuego	– – 1975		A		6 thoracics	Goodall (1978)
42	RNP 271	Ea. San Martín, Tierra del Fuego	28 JAN 1976	F	A		nearly c. skeleton	Goodall (1978)
43	RNP 328	B. San Sebastián, Tierra del Fuego	13 MAR 1976				cranium incomplete	Goodall (1978)
44	JFM 2-0	Golfo San José, Chubut	12 AUG 1977	F	A	850	skull	Mermoz (1979)
45	RNP 378	Río San Martín S, Tierra del Fuego	21 NOV 1977	F	J		cranium incomplete	Goodall (1978)
46	RNP 379	Río San Martín S, Tierra del Fuego	21 NOV 1977				cranium incomplete	Goodall (1978)
			Chile					
47	IPPACE-26	Punta Wreck, Strait of Magellan	– OCT 1979	M	J	730	skull	Sielfeld (1979)
48	IPPACE-34	Punta Catalina, Tierra del Fuego					cranium	Sielfeld (1980)
			New records					
49	AAL 003	Balneario San Antonio, Buenos Aires, Argentina	15 AUG 1984		A	461+	cranium incomplete	Col. AAL

* 3 New records, including a 449 cm female with a 185.7 cm fetus, were presented for Tierra del Fuego, Argentina by Goodall, Galeazzi and Sobral 1983.

Three new specimens are presented.

Specimen MSPL Hp01 is an incomplete, partially damaged cranium of a juvenile (Fig. 8). MACN-BA P0022, a skull (without teeth) of an adult collected by R. Payne in Tierra del Fuego, and a 7 m male from San Julián, Santa Cruz that was identified by means of photos (Table 8, Fig. 7).

TABLE 7. RECORDS OF *ZIPHIUS CAVIROSTRIS* IN THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
Published records								
Brazil								
50		Santa Amaro, Guarujá, San Pablo	31 AUG 1948	F			pregnant specimen	Paiva de Carvalho (1969)
Uruguay								
51	MNHN-M 1303	Balneario Jaureguiberry, Canelones	05 JAN 1960	M	A	953	skull	Praderi (1971)
52	MNHN-M 2428	Playa Buceo, Montevideo	02 NOV 1967	F	A	890	complete skeleton	Ximenez, Langguth, and Praderi (1972)
53	MNHN-M 1405	Balneario Bella Vista, Maldonado	10 AUG 1969	M	A	890	complete skeleton	Ximenez *et al.* (1972)
Argentina								
54		Coasts, city of Buenos Aires	08 AUG 1865	M	A	680	complete skeleton	Burmeister (1867)
55		B. San Antonío, Río Negro						Moreno (1895)
56	BMNH 1965.7.1.1	Whaler Bay, Malvinas (Falkland) Is.	– – 1964	M			complete skeleton	Strange (1972)
57	RNP 3	Ea. Harberton, Tierra del Fuego	24 SEP 1967	M	A		nearly c. skeleton	Goodall (1978)
58	RNP 60	B. San Sebastían, Tierra del Fuego	03 JUL 1974	F			cranium incomplete	Goodall (1978)
59	RNP 73	Punta María, Tierra del Fuego	05 JUL 1974	F			cranium incomplete	Goodall (1978)
60	RNP 138	B. San Sebastián, Tierra del Fuego	19 DEC 1975		J		c. axial skeleton	Goodall (1978)
61	RNP 177	B. San Sebastián, Tierra del Fuego	21 DEC 1975	M			cranium incomplete	Goodall (1978)
62	RNP 327	B. San Sebastián, Tierra del Fuego	13 FEB 1976	M			cranium, mandibles	Goodall (1978)
63	RNP 377	Río San Martín, Tierra del Fuego	21 NOV 1976	F			cranium incomplete	Goodall (1978)
64	RNP 638	B. San Sebastían, Tierra del Fuego	12 DEC 1977	F			cranium worn	Goodall (1978)
65	RNP 696	Punta María, Tierra del Fuego	14 MAY 1978	M			cranium broken	Goodall (1978)
Chile								
66	IPPA CE-1	Cabo Espíritu Santo, Tierra del Fuego	– – 1974				cranium and v.	Sielfeld (1980)
67	IPPA CE-7	Punta Catalina, Tierra del Fuego	– MAY 1978				cervicals	Venegas and Sielfeld (1978)
Unpublished records								
Argentina								
68	MLP 1118	Necochea, Buenos Aires					c. skeleton	exhibited in Museo La Plata
69		Comodoro Rivadavia, Chubut	– APR 1964		A		Photo	
70	MACN-BA 16198	Ea. Punta Loyola, Santa Cruz	– JUN 1972	M	A	964	cranium incomplete	Col. MACN-BA

(Continued)

TABLE 7. (Continued)

71	MMGA Zc02	Miramar, Buenos Aires	–	–	1973			556+	cranium incomplete	Col. MMGA
72	MACN-BA P0023	B. San Sebastián, Tierra del Fuego	–	MAY	1973	F	A	994	skull	Col. MACN-BA
73	MSPL Zc04	Balneario San Antonio, Buenos Aires	–	–	1979	F?		792+	cranium incomplete	Col. MSPL
74		Bahía Bustamante, Chubut	29	DEC	1984	F	A		Photo	La Nación, 09 JUN 1985
75		Puerto San Julián, Santa Cruz	–	JAN	1985	M			Photo	

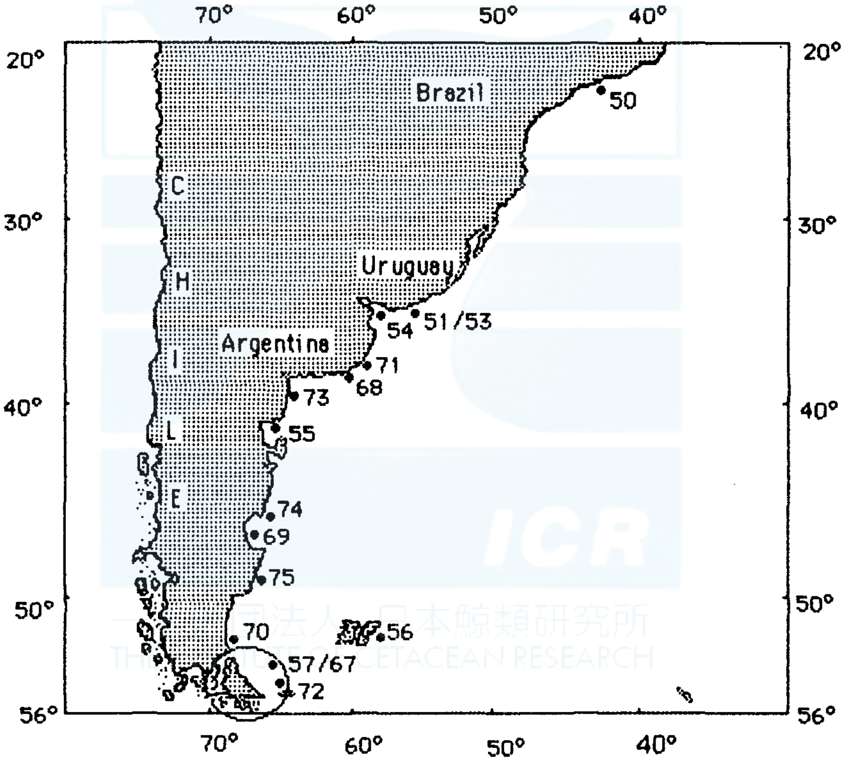

Fig. 6. Distribution of specimens of *Ziphius cavirostris* in the western South Atlantic. Records from Tierra del Fuego area occur within the open circle.

TABLE 8. RECORDS OF SPECIMENS AND SIGHTINGS OF *HYPERODON PLANIFRONS* IN THE WESTERN SOUTH ATLANTIC

N°	Specimen N°	Locality	Date	Sex	Phys. mat.	CBL mm	Type of specimen	Reference
			Published records					
			Brazil					
76	MORG 15	5 Km.N. of Chui, Rio Grande do Sul.	26 MAR 1975	M	A		complete skeleton	Gianuca and Castello (1976)
			Uruguay					
77	RP 339	Pta.Artilleros, Dept.Colonia	19 FEB 1978	M		1170	complete skeleton	Praderi (1980)
			Argentina*					
78	MLP	Bahía Santa Cruz, Santa Cruz					left mandible	Moreno (1895)
79	MLP	Río Chubut, Chubut		F		1100	skull, skeleton	Moreno (1895)
80	MLP 1121	Arroyo Sauce Viejo, Buenos Aires				1150	complete skeleton	Moreno (1895)
81		Leith Harbour, South Georgia Island	03 JAN 1927	M		690	Photo	Fraser (1945)
82	MACN-BA 54-110	Near Gritviken, South Georgia Island	– NOV 1929	M		1440	complete skeleton	Carcelles (1948)
83	BMNH 1934.7.23.3	Vicinity of South Georgia Island	– – 1931	F		1190	complete skeleton	Fraser (1945)
84		West Malvinas (Falkland) Islands					skull	Hamilton (1952)
85		Malvinas (Falkland) Islands					mandible	Hamilton (1952)
86	BMNH 1952.9.30.1	East Malvinas (Falkland) Islands	– AUG 1950	F			complete skeleton	Hamilton (1952) Fraser (1964)
87	MPC	60 Km.SW of Viedma, Río Negro	25 AUG 1965				skull	Brownell (1974)
88	RNP 4	Ea. Harberton, Tierra del Fuego	– SEP 1967				cranium fair	Goodall (1978)
89	RNP 382	Ea. Viamonte, Tierra del Fuego	19 DEC 1976				cranium incomplete	Goodall (1978)
90	RNP 584	San Sebastián N, Tierra del Fuego	21 NOV 1977				cranium, incomplete	Goodall (1978)
91	RNP 585	San Sebastián N, Tierra del Fuego	21 NOV 1977				cranium mandibles	Goodall (1978)
92	RNP 630	San Sebastián, Tierra del Fuego	11 DEC 1977				cervicals (7 fused)	Goodall (1978)
			Sightings					
93		45°15′S, 58°10′W	03 APR 1962				1 animal	Zemskii and Budylenko (1970)
94		44°37′S, 59°03′W	22 DEC 1981				5 animals	Bastida and Bastida (1984)
95		44°45′S, 58°49′W	22 DEC 1981				1 animal	Bastida and Bastida (1984)
96		45°13′S, 58°19′W	22 DEC 1981				1 animal	Bastida and Bastida (1984)

(Continued)

TABLE 8. (Contineud)

Unpublished records

Argentina

97	MSLP HpO1	Isla Verde, Buenos Aires	–	–	1970	J	1030+	cranium incomplete	Col. MSPL
98	MACN-BA P0022	B. San Sebastián, Tierra del Fuego	–	MAY	1976		1236	skull	Col. MACN-BA
99		San Julián, Santa Cruz	–	DEC	1981	M		Photo	

---

* A specimen (BMNH 1961.6.8.1.) from South Georgia Island, appearing in the BMNH cetacean catalogue.

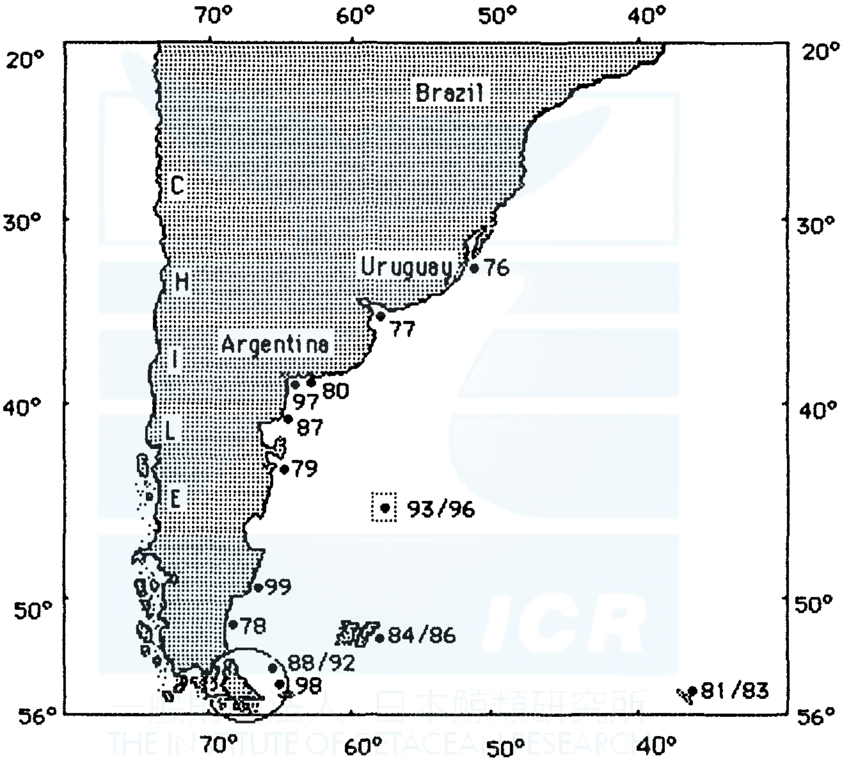

Fig. 7. Distribution of specimens of *Hyperoodon planifrons* in the western South Atlantic. Records from Tierra del Fuego area occur within the open circle. Sightings occur within the area limited by dots.

Fig. 8. *Hyperoodon planifrons*, lateral view of MSPL Hp01, collected at Isla Verde, Buenos Aires, in 1970. (Photo A.A. Lichter).

DISCUSSION

Tasmacetus shepherdi: The 13 known records from the Southern hemisphere, range from Isla Juan Fernandez, Chile, (33°S) (Brownell, Aguayo and Torres, 1976) to Tierra del Fuego, Argentina (55°S) (Goodall, 1978). The northernmost record for the study area is Península Valdés, Argentina (42°S) (Mead and Payne, 1975), and the southernmost is the previously mentioned for Tierra del Fuego.

Berardius arnuxii: Arroyo del Pescado, Argentina (34°S) (Marelli, 1920) is the northern known limit for this species. The southern limit is Antarctic Peninsula (62°S) (Taylor, 1957). Strandings in South African, New Zealand and Australian waters are seasonal (December–March) (Ross, 1979; Baker, 1983). The only known record of a fresh stranded specimen for this area occurred in May (Marelli, 1920).

Mesoplodon densirostris: The southernmost known record is for Tasmania (40°S) (Baker, 1983). The only known record for the study area is for Cassino, Brazil (32°S) (Castello and Pinedo, 1980).

The known South African records amount to 15 (Ross, 1979). Baker (1983) mentioned no records for New Zealand and four records for Australia.

Mesoplodon layardii: The record from Bahía Windhond, Chile (55°S) (Sielfed, 1979) established the southern limit of the known distribution of this species.

The northern limit of this species in the western South Atlantic, Isla de la Tuna, Uruguay (34°S) (Praderi, 1972) lies south of the northernmost record from Walvis Bay, South Africa (23°S) (Turner, 1880). Ross (1979) stated that South of 38°S the records are distributed throughout the year, and North of 38°S the records are distinctly seasonal during the summer months.

The same seems to happen in the study area where records occurred in February (Isla de la Tuna, 34°S) (Praderi, 1972), March (Río Gallegos, 52°S), June (Golfo San José, 42°S) and October (Comodoro Rivadavia, 46°S).

Mesoplodon hectori: The new specimens extend the distribution in the southwestern South Atlantic from Tierra del Fuego (53°S) (Goodall, 1978) to Claromecó, Argentina (39°S). By analyzing the stranding and sighting dates, it is noted that in the Northern hemisphere except for a record in December, strandings and sightings occur between May and September (Mead, 1981). The records herein presented agree with Ross (1979) who indicated a possibly seasonal onshore movements during the summer months. These were immature specimens in the Northern hemisphere during May (Mead, 1981), and in the Southern hemisphere, in January (New Zealand, South Africa and Argentina) (McCann, 1962; Ross, 1979; this paper).

Mesoplodon grayi: The record of Los Chorrillos, Tierra del Fuego, Argentina (53°S) (Goodall, 1978) is the southernmost known record.

The only known date of stranding in the study area was 12 August 1977, for a female of 4.64 m (Mermoz, 1979). In spite that in the Southern hemisphere there are records of this species for almost all the year, the frequent strandings are noted between December and April (Ross, 1979).

Ziphius cavirostris: This cosmopolitan species has a wide distribution in the study area, ranging from Tierra del Fuego, Argentina (55°S) (Goodall, 1978) to Santo Amaro, Guarujá, Brazil (24°S) (Paiva Carvalho, 1969).

The southern known limit would reach the Antarctic area at 62°S (IWC/IDCR V Cruise, J.F. Mermoz pers. comm.).

The western South Atlantic strandings of this species, occur within a period from April to January. This would indicate non seasonal presence of *Z. cavirostris* in this area as well as in New Zealand waters (Gaskin, 1972). Ross (1979) stated that this species moves away from the South African waters in spring and early summer.

Hyperoodon planifrons: In the study area it occurs from Tierra del Fuego, Argentina (55°S) (Goodall, 1978) to Chui, Rio Grande do Sul, Brazil (32°S) (Gianuca and Castello, 1976).

The known distribution for the Southern hemisphere extends from 29°S (Ross, 1979) to the Antarctic area at 70°S (IWC/IDCR V Cruise, J.F. Mermoz pers. comm.). Its presence in South African waters seems to be seasonal during summer months (Ross, 1979). Similarly, records in South West Atlantic, except for a record in August (Brownell, 1974) and a sighting in April (Zemskii and Budylenko, 1970), occur between November and March.

ACKNOWLEDGEMENTS

Thanks are extended to the following for permission to examine specimens under their care: S. Aramayo, UNS; V. Di Martino, MMH; M.C. Sheldrick, BMNH; J.M. Gallardo and J. Crespo, MACN; to R. Praderi and J.F. Mermoz for access to their personal collections and useful data; to G. Harris for information on the specimen of *M. layardii*. Also to L. Lodi and C. Pinedo for having checked the Brazilian museums. R. Payne provided two records of *Z. cavirostris* and *H. planifrons* from Tierra del Fuego. S. Ohsumi, kindly authorized me to use data from IWC/IDCR V Cruise. M. Gerpe, D. Rodriguez and R. Chiesa gave me their photos of *Z. cavirostris* and *H. planifrons*.

R.N.P. Goodall and H.P. Castello read drafts of the manuscript and offered helpful suggestions.

REFERENCES

Baker, A.N., 1983. *Whales and dolphins of New Zealand and Australia*. Victoria University Press. 133pp.

Bastida, R. and V.L. Bastida, 1984. Avistajes de cetáceos realizados por buques balleneros en aguas Argentinas. *Rev. Mus. Arg. Cien. Nat., Zool.*, 12 (22): 211–224.

Boschma, H., 1950. Maxillary teeth in specimens of *Hyperoodon roatietus* (Muller) and *Mesoplodon greyi* von Haast stranded on the Dutch coast. *Proc. Kon. Ned. Akad. Wetens.*, 53 (6): 775–86.

Brownell, R.L. Jr., 1974. Small odontocetes of the Antarctic. pp.13–19. *In*: V.C. Bushnell (ed.) *Antarctic Map Folio Series, Folio 18*. Amer. Geogr. Soc., N.Y. 19pp.

Brownell, R.L., A. Aguayo and D.N. Torres, 1976. A Shepherd's beaked whale *Tasmacetus shepherdi*, from the eastern South Pacific. *Sci. Rep. Whales Res. Inst.*, 28: 127–28.

Burmeister, G., 1867. Descriptión detallada del *Epiodon australe*. *An. Mus. Publ. Bs. As.*, 1 (8): 312–366.

Carcelles, A., 1948. Los cetáceos en aguas argentinas. *Argentina Austr.*, 20 (208): 1–10.

Carvalho, C.T., 1975. Ocorrências de mamíferos marinhos no Brazil. *Bol. Tec. If. S. Paulo.*, 16: 13–32.

Castello, H.P. and M.C. Pinedo, 1980. *Mesoplodon densirostris* (Cetacea, Ziphiidae), primeiro registro para o Atlantico Sul Occidental. *Bol. Inst. Oceanogr. S. Paulo*, 29 (2): 91–94.

Fraser, F.C., 1945. On a specimen of the southern bottle-nosed whale, *Hyperoodon planifrons*. *Discovery Rep.*, 23: 19–36.

Fraser, F.C., 1948. Whales and Dolphins. *In*: J.R. Norman and F.C. Fraser (ed.) *Giant Fishes, Whales and Dolphins, 2nd. Ed.* Putnam, London. 376pp.

Fraser, F.C., 1950. Note on a skull of Hector's beaked whale *Mesoplodon hectori* (Gray) from the Falkland Islands. *Proc. Linnean Soc. London*, 162 (1): 50–52.

Fraser, F.C., 1964. Whales and whaling. pp. 191–205, 7 figs. *In*: R.E. Priestley, R.J. Adie and G. de Q. Robin (eds) *Antarctic Research*. Butterworths, London. 360pp.

Gaskin, D.E., 1972. *Whales, dolphins and seals*. Heinemann Educational Books, Auckland. 200 pp.

Gianuca, N.M., and H.P. Castello, 1976. First record of the southern bottlenose whale, *Hyperoodon planifrons* from Brazil. *Sci. Rep. Whales Res. Inst.*, 28: 119–126.

Goodall, R.N.P., 1978. Report on the small cetaceans stranded on the coasts of Tierra del Fuego. *Sci. Rep. Whales Res. Inst.*, 30: 197–230.

Goodall, R.N.P., A.R.Galeazzi and A.P. Sobral, 1983. Gray's beaked whale *Mesoplodon grayi*, in Tierra del Fuego-Argentina. *Abstracts of the Fifth Biennial Conference on the Biology of Marine Mammals*. Boston USA.

Gray, J.E., 1865. Notices of a new genus of delphinoid whales from the Cape of Good Hope, and of other cetaceans from the same seas. *Zool. Soc. Lond. Proc.*, 1865: 522–529.

Hamilton, J.E., 1952. Cetacea of the Falkland Islands. *Com. Zool. Mus. Hist. Nat. Montevideo*, 4 (66): 1–6.

Leatherwood, S., R. Reeves and L. Foster, 1983. *The Sierra Club Handbook of Whales and Dolphins*. Sierra Club Books, San Francisco, California. 302pp.

McCann, C., 1962. The taxonomic status of the beaked whale *Mesoplodon hectori* (Gray) Cetacea. *Rec. Dom. Mus. Wellington,* 4: 83–94.

McCann, C., 1975. A study of the genus *Berardius* Duvernoy. *Sci. Rep. Whales Res. Inst.,* 27: 111–137.

Marelli, C., 1920. Revisión osteológica de *Berardius arnuxii* Duv. *An. Mus. Nac. Hist. Nat. Bs. A.,* 30: 411–444.

Mead, J.G., 1981. First records of *Mesoplodon hectori* (Ziphiidae) from the Northern Hemisphere and a description of the adult male. *J. Mammal.,* 62 (2): 430–432.

Mead, J.G., 1984. Survey of Reproductive Data for the Beaked Whales (Ziphiidae). *Rep. int. Whal. Commn* (Special Issue 6): 91–96.

Mead, J.G. and R.S. Payne, 1975. A specimen of the Tasman beaked whale, *Tasmacetus shepherdi,* from Argentina. *J. Mamm.,* 56: 213–218.

Mermoz, J.F., 1979. Hallazgo de una ballena picuda de Gray, *Mesoplodon grayi* en el Golfo San José (Chubut, Argentina). *Rev. Mus. Arg. Cien. Nat.,* 12 (10): 137–142.

Mitchell, E., 1975. Porpoise, dolphin, and small whale fisheries of the world. Status and problems. *IUCN Monograph* 3. 129pp.

Moore, J.C., 1968. Relationships among the living genera of beaked whales with classifications, diagnoses and keys. *Fieldiana. Zool.,* 53: 209–298.

Moreno, F.P., 1895. Nota sobre los restos de *Hyperoodon* conservados en el Museo de la Plata. *An. Mus. La Plata, Zool.,* 3: 3–8.

Paiva Carvalho, J. de, 1969. Sôbre a provável ocorrência da "Baleia de Cuvier" no litoral de Sao Paulo. *Rev. Nac. Pesca., Anox,* 82: 8–11.

Praderi, R., 1971. Sobre la presencia de *Ziphius cavirostris* G. Cuvier (Cetacea Hyperoodontidae) en las costas uruguayas del Río de la Plata. *Bol. Soc. Zool. Uruguay,* 1: 52–54.

Praderi, R., 1972. Notas sobre un ejemplar de *Mesoplodon layardii* (Gray), (Cetacea, Hyperoodontidae), de la costa Atlántica del Uruguay. *Com. Zool. Mus. Hist. Nat. Montevideo* 10, 137: 1–7.

Praderi, R., 1980. Adiciones a la lista sistemática de cetáceos del Uruguay. *Resum. Jorn. Ci. Nat., Montevido,* 1: 136–137.

Ross, G.J.B., 1979. The smaller cetaceans of the South East Coast of Southern Africa. Ph D. Thesis, Univ. of Porth Elizabeth, South Aftica. 415pp, 53 figs., 126 tables.

Sielfeld, W.H., 1979. Consideraciones acerca de tres especies de *Mesoplodon* Gervais (Cetacea: Ziphiidae) presentes en las aguas chilenas. *Ans. Inst. Pat., Punta Arenas, Chile,* 10: 180–187.

Siefeld, W.H., 1980. Mamíferos marinos en colecciones y museos de Chile. *Ans. Inst. Pat., Punta Arenas, Chile,* 11: 273–280.

Strange, I., 1972. *The Falkland Islands.* Davis & Charles, Devon. 256pp.

Taylor, R.J., 1957. An unusual record of three species of whale being restricted to pools in Antarctic ice. *Proc. Zool. Soc. London,* 129: 325–31.

Turner, W., 1880. Report in the bones of cetacea collected during the voyage of the H.M.S. Challenger in the years 1873–1876. *The Voy. of H.M.S. Challenger, Zool.,* 1 (4): 1–45.

Urquiola de Carli, M.J., S. Aramayo and M. Piñero, 1970. Importancia del hallzgo de un cráneo de *Mesoplodon grayi* Haast (Cet. Odont.) en la Loc. de Monte Hermoso, Provincia de Buenos Aires. *Re. Com. Inv. Cient. Prov. Buenos Aires,* 1970: 149–158.

Urquiola de Carli, M.J. and S. Aramayo, 1970. Descripción del cráneo de un *Mesoplodon sp.,* hallado en la localidad de Quequén, Provincia de Buenos Aires. *Neotrópica,* 16 (51): 107–118.

Venegas, C. and W. Sielfeld, 1978. Registro de *Mesoplodon layardii* y otros cetáceos en Magallanes. *Ans. Inst. Pat., Punta Arenas, Chile,* 9: 171–177.

Watkins, W.A., 1976. A probable sighting of a live *Tasmacetus shepherdi* in New Zealand waters. *Jour. Mammal.,* 57 (2): 415.

Ximenez, A., A. Langguth and R. Praderi, 1972. Lista Sistemática de los mamíferos del Uruguay. *Anal. Mus. Nac. Hist. Nat. Montevideo,* (28c) 7 (5): 1–49.

Zemskiy, V.A. and G.A. Budylenko, 1970. Ploskolobye butylkonosy iz Antarktiki. pp. 193–202. *In*: V.A. Zemskiy (ed.) *Kity iuzhnogo polushariia (Biologia i morfologiia), Trud. Atlant NIRO, 20.* 234pp.

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

OCCURRENCE OF THE BARNACLES *CORONULA DIADEMA, C. REGINAE* AND *CETOPIRUS COMPLANATUS* (CIRRIPEDIA) ON RIGHT WHALES

JAMES E. SCARFF*

ABSTRACT

On 20 March 1982, a right whale (*Eubalaena glacialis*) was observed off Half Moon Bay, California (37°30′N, 122°03′W). Approximately 300 coronuline barnacles were observed on the whale. By analyzing photographs of the whale, we identified the barnacles as probably being *Coronula diadema* and *C. reginae*, although the possible occurrence of *Cetopirus complanatus* can not be eliminated. It is hypothesized that the right whale acquired the barnacles during association with a humpback whale (*Megaptera novaeangliae*), although the barnacles could have been acquired from one of several other whale species. A review of the literature yielded 22 previous reports of coronuline barnacles on right whales, 10 of *Coronula* spp., 4 of *Cetopirus complanatus*, and 8 of unspecified barnacles. Most of these early reports appear to be descriptions of not barnacles but instead the right whale's callosities or whale lice (*Cyamus* spp.). However, two prior records of *Coronula diadema* and two records of *Cetopirus complanatus* are well documented. A summary of known cetacean host — coronuline barnacle associations is included.

This article describes the first well documented observation of coronuline barnacles on a northern right whale (*Eubalaena glacialis* (Muller, 1776)). The barnacles were tentatively identified as *Coronula diadema* (Linnaeus, 1767) and *C. reginae* Darwin (1854), two species usually associated with humpback whales (*Megaptera novaeangliae*) (Borowski, 1781), although they have been reported from other species (see Table 1). With two exceptions (Tomilin, 1957; Watson, 1981), recent literature reviews on whales (Margolis, 1954; Slijper, 1962; Dailey and Brownell, 1972; Nishiwaki, 1972; Reeves and Brownell, 1982) or barnacles (Pilsbry, 1916; Cornwall, 1955; Tarasov and Zevina, 1957; Newman and Ross, 1976) have reported no coronuline barnacle other than *Tubicinella major* Lamarck (1802) as occurring on right whales.

---

* *1248 8th Avenue, San Francisco, CA 94122*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 129–153

TABLE 1. WHALE BARNACLES AND THEIR HOSTS

Barnacle species	Host species	Source
Coronula diadema	Humpback whale (*Megaptera novaeangliae*) found in large numbers on nearly all individuals.	
	North Pacific	Scammon (1874); Cornwall (1924, 1927, 1928, 1955); Scheffer (1939); Nishiwaki (1959); Rice (1963)
	North Atlantic and Southern Hemisphere	Kakuwa, Kawakami and Iguchi (1953); Tomilin (1957)
	Blue whale (*Balaenoptera musculus*), Fin whale (*B. physalus*) Sperm whale (*Physeter macrocephalus*) found on approx. 1% of the individuals taken in commercial operations.	Wheeler and Mackintosh (1929); Nilsson-Cantell (1930, 1939); Tomilin (1957); Mizue and Murata (1951); Nishiwaki and Oye (1951); Kakuwa *et al.* (1953)
Coronula reginae	Common on humpback whale, rare on blue, fin, sei, and sperm whales (all oceans)	Nilsson-Cantell (1939); Scheffer (1939); Mizue and Murata (1951); Cornwall (1955); Rice (1963)
Cetopirus complanatus	Right whale (*Eubalaena glacialis*) Southern Hemisphere	Darwin (1854); Gruvel (1903); Pilsbry (1916); Nilsson-Cantell (1931)
Crytolepas rhachianecti	Gray whale (*Eschrichtius robustus*) abundant on nearly all individuals. Not reported from other species.	Rice and Wolman (1971) Newman and Abbott (1980)
Tubicinella major	Right whale Embedded in the callosities Southern Hemisphere North Atlantic?	Darwin (1854); Marloth (1902); Gruvel (1903); Pilsbry (1916); Barnard (1924)
Conchoderma auritum	Common on humpback whale, rare on blue, fin, and sperm whales Usually attached to *C. diadema* or *C. reginae*	Cornwall (1927, 1955); Nilsson-Cantell (1939); Rice (1963); Newman and Ross (1971)
Conchoderma virgatum	facultative hyperepizoite which sometimes grows on the stalks of *Penella* spp., a copepod parasite on cetaceans.	Dailey and Brownell (1972)
Xenobalanus globicipitis	resembles stalked barnacle found infrequently on *Balaenoptera* spp., *Globicephala*, and delphinids. cosmopolitan	Pilsbry (1916); Rice (1963); Nilsson-Cantell (1978); Cornwall (1955)

METHODS AND OBSERVATIONS

At about 1030h on 20 March 1982, during a charter whale-watching cruise, Tom Johnson and I encountered a single right whale about 1.5 km SW of

Fig. 1. Side view of left dorsal side of the right whale showing the blowholes, callosities, barnacles, scars and sloughed epidermis (courtesy of Tom Johnson).

Pillar Point, near Half Moon Bay, California (37°30′N, 122°03′W). For two hours, while our separate boats idled in the water, the right whale repeatedly approached each boat in turn to within 5 m. We both were able to photograph at close range the dorsal part of the whale from near the tip of the rostrum to the flukes. The photographs were taken with 35 mm SLR cameras on color transparency film using either a 200 mm lens and Kodachrome 64 (Fig. 1) or a 400 mm lens and Ektachrome 200 (Figs 2 and 3). No attempt was made to collect barnacle specimens because of the risk of harassment to the whale.

The whale was an adult, approximately 16 m in length of indeterminate sex. It showed no injuries or abnormal behavior. The surface water temperature at the time of the sighting was not measured directly, but was estimated by the boat's crew as about 13°C based on measurements made earlier in the week. Two photographs of this sighting have previously been published elsewhere: Fig. 1 (Patent, 1984: P. 30), Fig. 3 (Johnson, 1982).

IDENTITY OF BARNACLES

The several species of barnacles which occur on whales and their reported hosts are shown in Table 1. Inspection of about 60 photographs of the right whale including Figs 1-3 show the barnacles to be similar to *Coronula diadema*, *C. reginae*, and *Cetopirus complanatus* (Mörch, 1852). All three barnacle species have white, more or less radially symmetrical shells and yellow opercular membranes. All are relatively large, being as much as 50–85 mm in diameter

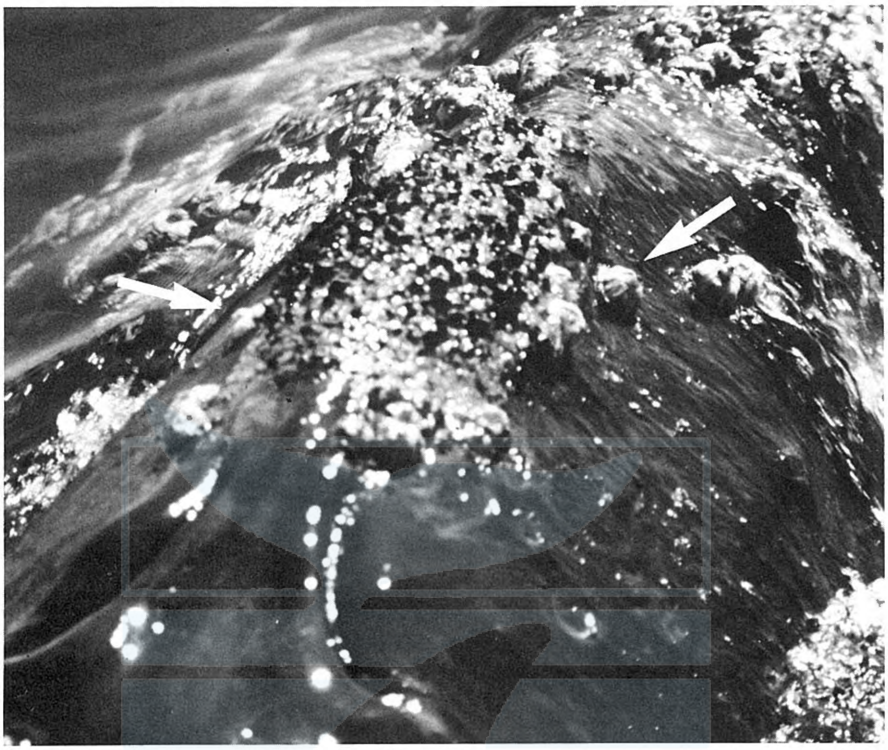

Fig. 2. Dorsal view of right whale looking from the area of the blowholes anteriorly at the callosity, rostrum and left lower lip and showing *Coronula diadema* (right arrow) and *C. reginae* (left arrow).

(Pilsbry, 1916). All can be distinguished from the barnacle *Cryptolepas rhachianecti* Dall (1872) (Fig. 4) commonly found on gray whales, *Eschrichtius robustus* (Lilljeborg, 1861), because *Cryptolepas* is more flattened and the spaces between the ridges radiating from the opercular membrane are not covered over (Newman and Abbott, 1980). In *Cryptolepas*, these ridges often have a darker coloring than surrounding parts of the shell giving the barnacle a striped appearance in contrast to the more uniform coloration of *Coronula* spp.

A fully grown *C. diadema* (Fig. 5) can be distinguished from *C. reginae* (Fig. 6) and *Cetopirus complanatus* (Fig. 7) because of *C. diadema*'s greater height (30–59 mm in the North Pacific), its barrel shape, and its position on the whale with most of its shell emergent from the epidermis (Darwin, 1854; Pilsbry, 1916). Individuals of *C. reginae* are noticeably shorter (13–19 mm) (Fig. 6). This relative shortness is exaggerated *in situ* by the habit of the barnacle to be imbedded in the skin of the whale, reducing the exposed shell (Darwin, 1854; Pilsbry, 1916; Cornwall, 1928; 1955).

Fig. 2 shows several barnacles on the rostrum of the right whale. This photograph also appears in Patent (1984:30). Two barnacles on the right side

Fig. 3. View of left dorsal surface of tailflukes and peduncle of the right whale with *Coronula reginae* and depressions where barnacles had been attached.

of the rostrum have the high, barrel-like shape characteristic of *C. diadema*. In contrast, at least one barnacle on the left side of the rostrum has the greatly flattened shell characteristic of *C. reginae*. Fig. 3 shows several barnacles on the flukes of the whale. These are all flat and appear to have a ridge of skin over the distal edges of the barnacle, characteristic of *C. reginae*.

Cetopirus complanatus (Fig. 7) has rarely been described in the literature. Detailed descriptions with drawings or photographs can be found in Darwin (1854) (as *Coronula balaenaris*) and in Pilsbry (1916) (as *Coronula complanata*). Externally, *Cetopirus complanatus* closely resembles *C. reginae*, sharing the same flattened shape and habit of being deeply embedded in the epidermis (Darwin, 1854; Gruvel, 1905). Pilsbry (1916) reports that two adult *Cetopirus complanatus* in the U.S. National Museum are 53 and 74 mm in diameter and only 12 and 28 mm in height respectively. All but two reports of *Cetopirus complanatus* are from the Southern Hemisphere; the two other reports from the North Atlantic are questionable.

Because of the lack of prior records of *Cetopirus* in the North Pacific and the unlikelihood of a right whale from the Southern Hemisphere migrating to the Northern Hemisphere, I conclude that the barnacles on the right whale were all *Coronula* spp. However, it is impossible to state conclusively that some

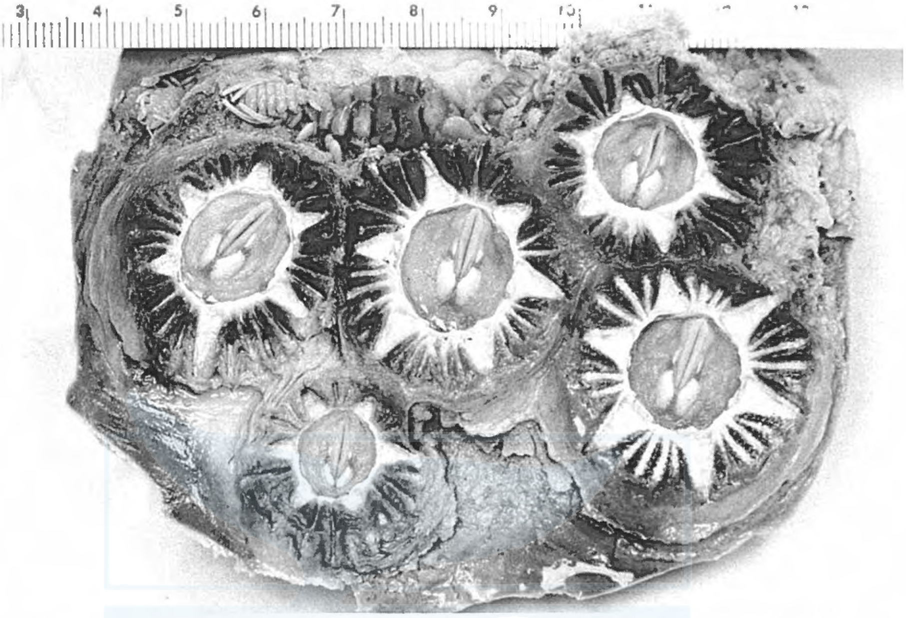

Fig. 4. *Cryptolepas rhachianecti*, species endemic to the gray whale. Ruler in cm. (from the collection of the California Academy of Sciences).

of the barnacles on the whale were not *Cetopirus complanatus* because the subtle external field marks of this species cannot be discerned given the resolution of the photographs.

DISTRIBUTION OF THE BARNACLES ON THE WHALE

There appeared to be a general segregation of the two species into different areas of the whale. The *C. diadema* appeared to be restricted to the areas anterior to the blowholes, whereas *C. reginae* appeared primarily in the area around the flukes, although some also occurred on the head.

C. diadema barnacles were common on the dorsal surface of the whale from the area of the nares to the anterior tip of the rostrum, although they did not appear to grow on the callosities themselves. The barnacles were particularly abundant along the edge of the lower lip (see Fig. 1) and densely distributed laterally as far as could be seen to the area near the eye and the lower margin of the cheek. Barnacles were also observed on the pectoral fins. There were at least 150 barnacles on the right side of the whale and at least 80 on the left side. Of note because of their proximity to the blowholes was a group of five barnacles anterior to the right nares approximately 2 cm from the edge of the blowhole (see Fig. 2).

The above distribution of attached *C. diadema* is somewhat similar to, but

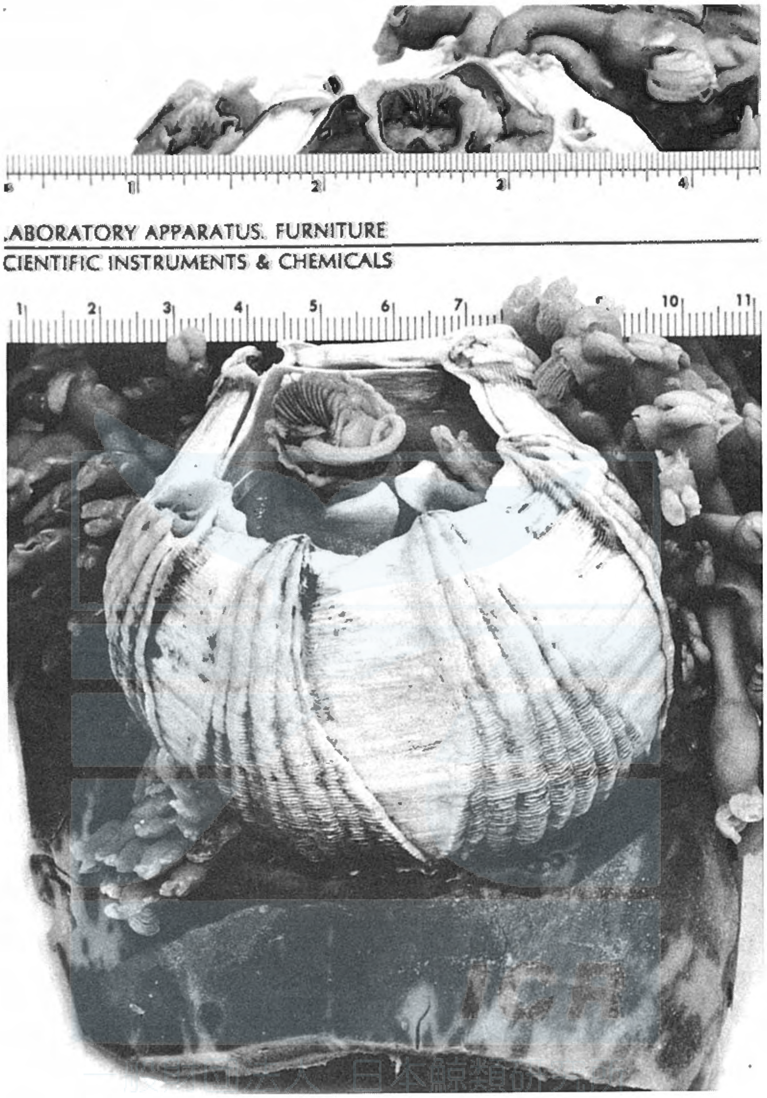

Fig. 5. *Coronula diadema* attached to a piece of skin from a humpback whale with numerous *Conchoderma auritum* attached. Ruler in inches (top) and cm. (bottom) (from the collection of the California Academy of Sciences).

more widespread, than that reported on humpback whales (Cornwall, 1927, 1955; Scheffer, 1939). However, Cornwall (1955:52), states that on the humpback the barnacle "occurs in scattered numbers over the sides, rarely on the dorsal surface."

The *C. reginae* on the right whale were primarily located on, or near, the tail flukes. From the photographs about 70 barnacles were counted on the

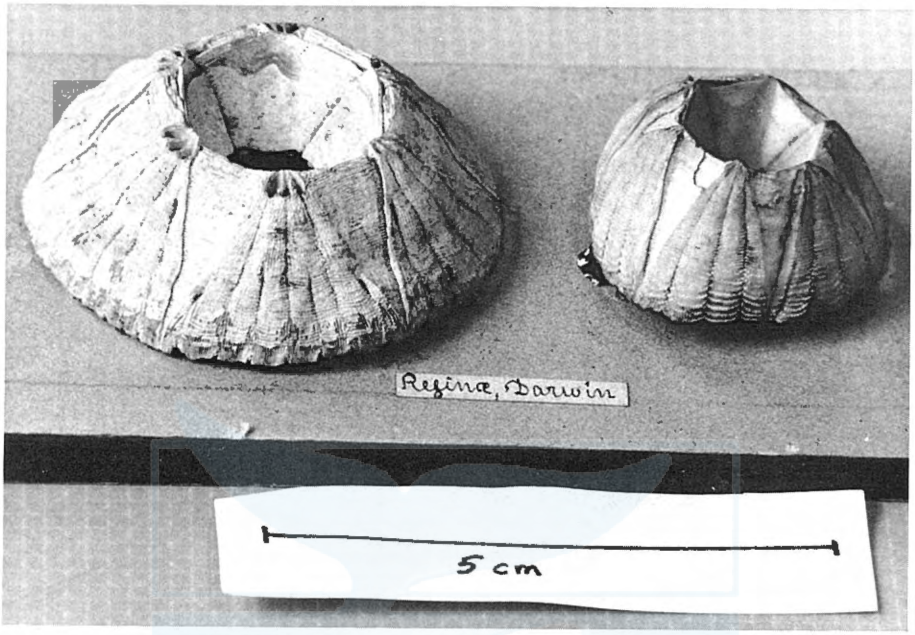

Fig. 6. *Coronula reginae* (from the collection of the British Museum, Natural History).

dorsal surface of the flukes (see Fig. 3) and about 20 on the right ventral surface. On the head of the whale, *C. reginae* appeared to be much less common than *C. diadema*. Although both Cornwall (1955) and Tomilin (1957) state that the occurrence of coronuline barnacles on the flukes of humpback whales is rare, more recent observations suggest that it is not rare, although only a minority of humpbacks with barnacles will have them on their flukes (V. Rowntree, pers. comm.).

There were no attached barnacles in the area between the callosities and the peduncle. However, there were dozens of circular depressions on the dorsal surface from the blowholes posteriorly for at least 8 m. The depressions extended laterally out of view underwater. These circular depressions are visible in Fig. 1. Similar depressions were found on the rostrum adjacent to attached barnacles.

Circular scars on many cetaceans have been described as the result of attacks by lamprey (*Entosphenus tridentatus* and other species) (Nemoto, 1955; van Utrecht, 1959; Slijper, 1962; Rice, 1963; Greenwood *et al.*, 1974) and squaloid shark (*Isistius brasiliensis*) (Jones, 1971). However, because the depressions on the right whale all appear to show healthy dark epidermis in the center, it is unlikely that they were caused by lamprey or shark which typically gouge a large central hole through the epidermis (Nemoto, 1955).

The occurrence of the depressions on the back of the right whale does not argue against barnacles as the cause, for although *Coronula* spp. are

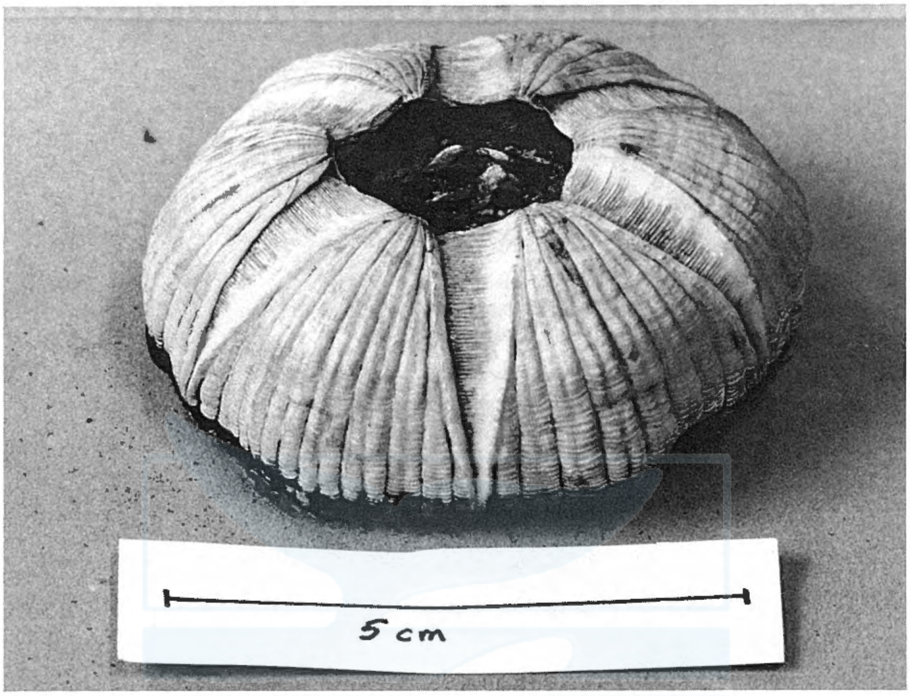

Fig. 7. *Cetopirus complanatus* labelled as *Coronula balaenaris* (from the collection of the British Museum, Natural History)

reported as only rarely occurring on the dorsal surface of humpbacks posterior to the blowholes (Tomilin, 1957), the closely related barnacle *Cryptolepas rhachianecti* "often form[s] a continuous mass on the dorsal aspect of the rostrum and the most anterior part of the back" of gray whale (Rice and Wolman, 1971:100). There was no indication that *Cryptolepas* had been present, but it is reasonable to conclude that *Coronula* could under special circumstances show the same distribution. Support for the hypothesis that the depressions were formed by barnacles comes from the relative abundance of depressions near the attached barnacles.

The whale's molt may be a mechanism by which the barnacles lose their attachment to the whale or it may simply facilitate this process. The right whale's molt has been described in Ling (1974), Reeves and Brownell (1982), and Payne *et al.* (1981). In the right whale we observed, the circular impressions were often contained within irregularly shaped patches of lightercolored skin where pieces of epidermis had sloughed off (see Fig. 1).

Our photographs did not show any *Tubicinella major* (Fig. 8), barnacles found often on right whales in the Southern Hemisphere. Because these barnacles are cryptically buried in the whale's epidermis among the callosities (Marloth, 1902), they may have been present although the species has not been reported from the North Pacific.

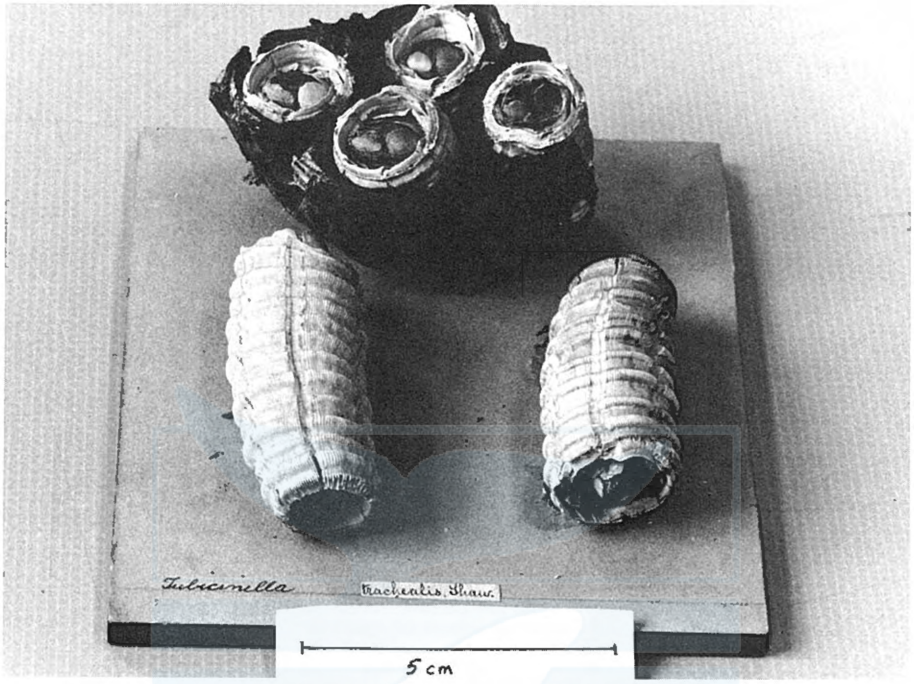

Fig. 8. *Tubicinella major*, species endemic to the right whale, shown embedded in a piece of right whale skin and in a lateral view detached from the whale skin (from the collection of the British Museum, Natural History).

Right whales are usually heavily infested with amphipods of the genus *Cyamus* ("whale lice") (Payne *et al.*, 1981; Reeves and Brownell, 1982). The resolution of our photographs was not adequate to detect individual cyamids, but cyamids appear to have been present on this animal. The small, aggregated, whitish objects concentrated around the dark callosities anterior to the blowholes visible in Figs 1 and 2 are probably cyamids. In the original color transparencies, these objects have a slight brownish tinge characteristic of cyamids.

The stalked barnacle *Conchoderma auritum* (Fig. 5) often attaches itself to the shell of *C. diadema* (Pilsbry, 1916; Cornwall, 1927, 1955; Tomilin, 1957; Newman and Ross, 1971). Because of the large size of *Conchoderma*, if present, it should have been easily detected but was not observed, indicating an absence of this species.

Little is known about the natural history of *Coronula diadema* or *C. reginae*. It is generally believed that most *C. diadema* have a lifespan of one year or less (Cornwall, 1955; Newman and Abbott, 1980). Nishiwaki (1959) found *Coronula* spp. on 211 of 212 humpback whales taken in the North Pacific during the months of January to April. He does not describe the relative size or abundance of these barnacles. Cornwall (1955:52) states that the barnacles "are mostly small in the early summer months, but are considerably larger and many have dropped off or been rubbed off by the end of the summer." Off Madagascar, Angot (1951) reported that on humpbacks taken between mid-June and mid-August (the early southern winter) the *C. diadema* were all large, ranging in size from 2.5 cm to 5 cm in diameter, the latter size being more common. By mid-September, the adult barnacles had disappeared and the whales were covered with the free-swimming larvae of the barnacles beginning to attach themselves. By early October (southern spring), small sessile adult barnacles were well attached.

The life cycle of the closely related *Cryptolepas rhachianecti* is similar to that described above. Rice and Wolman (1971) found that almost all *Cryptolepas* were large on whales taken off California during the southbound migration. Whales taken during the northbound migration bore both large and small barnacles. Our sighting of the right whale occurred during the height of the gray whale's northward migration past Half Moon Bay which is at the south edge of Rice and Wolman's study area. All the barnacles visible in the photographs of the right whale were large. The small size of the larvae and young sessile adult forms would make them difficult to detect at a distance.

HISTORICAL RECORDS OF CORONINE BARNACLES ON RIGHT WHALES

As noted above, there are no reports of coronuline barnacles on right whales in recent literature reviews except Tomilin (1957) and Watson (1981). However, the older literature contains at least 22 such references. These records must be reviewed carefully to cull out those which describe, or appear to describe, callosities and cyamids rather than barnacles.

Callosities are large "wartlike excresences" well described in Ridewood (1901) and Payne *et al.* (1981). In their gross morphology, the jagged projections of epidermis which form a callosity resemble a group of barnacles. They are usually present on the rostrum, behind the blowholes, and on the lower jaw (Reeves and Brownell, 1982; Payne *et al.*, 1981). Callosities are visible in Figs 1 and 2.

Typically, the large callosities are covered by hundreds, or thousands, of cyamids, causing the callosities to appear light-colored, making them not only about the same size and shape as a group of barnacles, but also the same color (see Payne (1976:335) for a close-up photograph of a callosity covered with cyamids with the epidermal projections misidentified as barnacles). All right whales, but no bowheads (*Balaena mysticetus*), have callosities.

Right whale callosities are unique structures, and to a lay observer callosities probably appear more analogous to humpback whale barnacles then to the epidermal tissue of other marine mammals. For example, author and whaler Melville (1851:432) described in *Moby Dick* the large callosity at the end of a right whale's rostrum as "this strange, crested, comb-like incrustation on the top of the mass — this green barnacled thing." Lay observers' use of barnacles as a metaphor to describe callosities with cyamids was often interpreted literally by 19th century scientists lacking personal experience with right whales, resulting in much confusion.

This confusion not only affected knowledge of barnacle distribution; but also significantly delayed recognition of the right whale as a species distinct from the bowhead, and generated erroneous reports of barnacles on right whales. Apparently none of the zoologists writing before 1870 had personally seen a right whale. They based their papers on review only of pieces of baleen and bone, and the stories and drawings of biologically untrained whalers. Not until Scammon (1874) is there a good description of the callosities of a right whale in the Western scientific literature.

One cause for the taxonomic confusion was the rarity of right whales in the eastern North Atlantic by the late 18th and early 19th centuries. Many whalers never caught one (Reeves, 1982). The main target of the contemporary whaling industry was the bowhead with which taxonomists were familiar. So these scientists interpreted whalers' reports of a second, rare, smaller balaenid species with shorter baleen in the North Atlantic as simply representing unusually small bowheads. Most scientists did not recognize the right whale as a species distinct from the bowhead until the 1830's, after the discovery of the right whale grounds in the Southern Hemisphere. The taxonomic debate on classification of the North Atlantic right whale continued until the late 1800's and is well recorded in Allen (1908). What is striking was the willingness of these 19th century scientists to describe without qualification the whalers' reports of barnacle-like growths on right whales as being unquestionably *Coronula* spp.

As a guide to the confusing names applied to right whales and barnacles in this older literature, a selective list of synonyms is presented in Table 2. The current names of barnacles used in this paper follow the taxonomy of Newman and Ross (1976).

A second source of ambiguity in the older records stems from the possibility that general references to barnacles on right whales refer to *Tubicinella major* (Fig. 8) rather than *Coronula* spp. The former species has been reported only on right whales and, with two exceptions, only in the Southern Hemisphere (Marloth, 1902; Pilsbry, 1916; Barnard, 1924). There are two old vague reports of *Tubicinella* being found in the North Atlantic, one on a stranded whale in 1650 from the Faroe Islands (Worm, 1655 cited in Pilsbry, 1916) and one prior to 1850 (Gruvel, 1903). *Tubicinella* occurs typically in among the callosities.

RECORDS OF *CORONULA* SPP. AND UNSPECIFIED BARNACLES

One of the earliest references in the scientific literature to barnacles on right whales occurs in Scoresby (1820). Apparently Scoresby never personally saw a right whale. He believed that the "Nordkaper", as the right whale was called,

TABLE 2. SELECTIVE SYNONYMY OF WHALE AND BARNACLE SPECIES

Current Name	Synonym
Eubalaena glacialis	Right whale, Nordkaper, Sarde, sletbag, *Balaena glacialis, B. biscayensis, B. japonica, B. antarctica, B. australis.*
Balaena mysticetus	Bowhead whale, Greenland whale, Arctic right whale.
Coronula diadema	*Lepas diadema, L. balaenaris, Diadema japonica, D. californica, Coronula biscayensis.*
Coronula reginae	No synonyms (Often not distinguished from *Coronula diadema*)
Cetopirus complanatus	*Coronula complanata, Coronula balaenaris, C. darwini, Lepas balaenaris, Balanus polythalamius complanatus*

was merely a type of bowhead (which he called "mysticetus"). In his review of whales in the North Atlantic, Scoresby describes a "mysticetus" which occurs along the coasts of Africa and South America, within the range of the right whale, but not the bowhead. He wrote that "one striking difference, possibly the effect of situation and climate, is that the mysticetus found in southern regions, is often covered with barnacles (Lepas Diadema [= *C. diadema*] &c) while those of the arctic seas are free from these shellfish." (p. 473). Scoresby makes no mention of the callosities on these southern whales. Apparently he mistook descriptions of callosities for barnacles.

Nine years later, Brandt and Ratzeburg (1829) mention barnacles occurring on right whales. Although their article is cited as authority for the occurrence of *Coronula* barnacles on right whales by both Eschricht and Reinhardt (1866) and Tomilin (1957), the two references in Brandt and Ratzeburg's book to barnacles on right whales are minor, undocumented notes. The first merely paraphrases Scoresby's (1820) comment about southern "mysticetus". The second, in a footnote on page 126, states, without giving a source, that balaenid whales from the east coast of North America are reported to have "head decorations" of *Lepas* (=*Coronula?* =*Cetopirus?*) barnacles. It appears that neither author had firsthand experience with right whales. Brandt and Ratzeburg make no mention of callosities on these whales.

Another early reference to barnacles on right whales occurs in Siebold's (1844) *Fauna Japonica*. Siebold repeats Scoresby's (1820) observation that the southern balaenid whales were "recouverte de bernaches" (covered with barnacles), characteristics which he says are shared by the Japanese right whale, but not the bowhead. Siebold's study contains two good drawings of a right whale done from a porcelain model of a freshly killed whale (plates 28, 29). These drawings show small callosities at the tip of the rostrum and above the eye, typical locations, but show no barnacles. Siebold probably confused callosities with barnacles. This porcelain model is mentioned again by Holder

(1883:127) who cites Siebold for the proposition that the right whale "is subject to cirripeds."

In 1855, a crew member of an American whaling ship described in his diary right whales as having "on the end of their nose...a bunch of barnacles about 18 inches wide. This the whalemen call his bonnet – and when you see a whale just rising out of water it has the appearance of a rock – the barnacles are enormous – as much as two inches deep – the boys often roast them and eat them the same as oysters." (Weir, 1977). Whether this refers to the callosities or barnacles is unclear.

A more extensive discussion of barnacles is found in the monograph on bowheads by Eschricht and Reinhardt (1866). They refer to the "very well authenticated fact of the Nordkaper [North Atlantic right whale] being infested with coronulas" (p. 45) as well as the "indisputable fact" of *Coronula* barnacles being "inseparable from right whales in the Southern Hemisphere" (p. 45). They go on to argue that the presence of *Coronula* barnacles on the North Atlantic right whale and their absence on bowheads supports their conclusion that the two whales constitute separate species (pp. 39, 44–45). Surprisingly, in the extensive discussion of the Nordkaper's field marks, they make no mention of the species's most obvious fieldmark – its callosities.

Eschricht and Reinhardt's descriptions of right whales are not based on firsthand observations of any intact specimens, but on their interpretation of earlier commentaries. Four references, one of which is Brandt and Ratzeburg (1829), are cited to support the contention that *Coronula* barnacles are a fieldmark of the Nordkaper.

The second reference is to an early commentary on whaling near Spitzbergen (Edge, 1625). Edge describes whalers hunting a balaenid whale of smaller size with shorter baleen than the typical bowhead. He describes this animal as having "naturally growing upon his back white things like unto barnacles." (p. 471). Without discussion of their reasons, Eschricht and Reinhardt (1866) conclude that this indisputably is a reference to *Coronula* barnacles on a right whale.

Eschricht and Reinhardt's third reference appears to be to a 17th century account of whaling written in Latin by Icelandic clergymen (Allen, 1908). The passage quoted from this early commentary simply refers to a type of right whale which has "asperis testis," which can be translated as "rough shellfish," adorning its back in a pattern similar to that of a garland of roses or a group of stars. This could easily be an interpretation of a whaler's description of callosities covered by whale lice.

Eschricht and Reinhardt's (1866:35) fourth record is of a right whale captured in 1778 or 1779 by a Danish whaling ship in the western North Atlantic. They state that "the head [of the whale was reported to be]... infested with such a multitude of Cirripeds that it would have been easy, according to the statement of the captain, to gather a whole sackful of these 'white patches' as he called them." This report is supplemented by the statement that

Chemnitz and Martini (1790) confirmed the specimens obtained were coronuline barnacles. This record is discussed in more detail *infra* in the later section on records of *Cetopirus complanatus*.

In his short review of parasites on whales, Beneden (1870) refers to several species of barnacles occurring on right whales in different oceans – *Coronula biscayensis* (=*Coronula diadema*) in the North Atlantic, *Coronula balaenaris* (=*Cetopirus complanatus*?) in the southern seas, and *Diadema japonica* (=*C. diadema*) in the North Pacific. None of these reports is based on firsthand observations by Beneden. The occurrence of barnacles on right whales in the North Atlantic is based on only one thirdhand report from shore whalers. The Southern Hemisphere barnacles are discussed in the following section on *Cetopirus complanatus*.

In the North Pacific, Beneden's conclusion is based entirely on a drawing of a barnacle which appears in a Japanese book on whales and whaling. Beneden does not give a citation for the book, but it is probably Oyamada Tomokiyo's book "Isanatori Ekotoba", published in Japanese in 1829. No English translation was widely available until 1983 (Matthews and Pilleri, 1983). In this recent translation (Yamada, 1983), both the author's name and the book's title are allegedly mistranslated (Omura in press).

The two volumes of the Isanatori Ekotoba contain a detailed and insightful record of Japanese whaling on the west coast of Kyushu, Japan. Right whales were a primary target of this fishery (Omura in press), and the book contains accurate drawings of details of the right whale's anatomy with notes accompanying the drawings. Of particular interest to this study are two drawings in plate 4 of volume II. Along with drawings of the baleen, blubber, and "bonnet" of a right whale are two sets of detailed drawings of barnacles. One of these sets of barnacles is identified in the notes as being a "Sessile barnacle" which "is as large as a sake cup. It is like those living on the sea shore; its shape is pentagonal or hexagonal. Its shell is hard and white. The flesh is edible. It attaches itself to the Right whale like the stalked barnacle." (Yamada 1983:84) The three barnacles pictured closely resemble *Coronula* spp. One has the barrel-like shape of *C. diadema*; one appears flattened like *C. reginae*; and the third is intermediate in form.

The second set of pictures are of stalked barnacles resembling *Conchoderma auritum*. The accompanying note describes them as "Stalked barnacle. Kaki, literally, oyster. The barnacle is four to five inches long with soft, light pink skin; it is used for food. All the white spots on the skin of the Right whale are attached barnacles." This is the only record of a stalked barnacle occurring on a right whale. However, *Conchoderma auritum* is commonly found on humpbacks and is often attached to a *Coronula diadema* (Newman and Abbott, 1980). The described abundance of the stalked barnacles is surprising and is more suggestive of the abundance and distribution of cyamids than barnacles.

The general detail and accuracy of the drawings and notes strongly suggests that Tomokiyo made firsthand observations of right whales and of coronuline barnacles on right whales. There is also one picture of a whale louse (*Cyamus* spp.) which is separately identified making it unlikely that either set of barnacles were misidentified cyamids.

The next reference to barnacles on right whales occurs in Holder (1883:106) who describes secondhand a right whale which stranded on the New Jersey coast as "having but few molluscan parasites." He also writes (p. 118) that "The species is said to bear a 'bonnet' on its snout...seemingly covered by parasitic molluscs." At that time cirripeds were considered molluscs rather than crustaceans. Both of these references appear to be to cyamids on the callosities. Holder did not personally see any right whale.

In his monograph on whales, True (1904) suggests that right whales carry cirripeds. He describes certain "white spots" reported around the tips and surface of the pectoral flipper, the tip of the flukes, the "bonnet", and the genitals as being due to parasitic cirripeds as in the humpback whale. This speculation is not based on firsthand observation. The areas described frequently have white coloration in the absence of barnacles (Andrews, 1908; Omura *et al.*, 1969; Reeves and Brownell, 1982).

An unexpected reference to barnacles appears in a guide written for visitors to the British Museum of Natural History. In this guide, Lydekker (1909:15) describes the skeleton and model of a North Atlantic right whale in museum including the callosity known as the "bonnet", then states that the species "is further characterised by the frequent presence upon its skin of parasitic barnacles (*Coronula*), which are never found on the Greenland Whale." No further explanation is given.

In 1916, R.C. Andrews, assistant curator of mammals at the American Museum of Natural History, wrote: "on the extreme end of the snout the right whale always has an oval roughened area, some two feet in length, called the 'bonnet'. This growth is produced by whale lice (*Cyamus*) and barnacles (*Coronula*), and although it is never absent in this species it is not found on the bowhead." (Andrews, 1916:248). Andrews (1908, 1916) had observed at least one right whale in the North Atlantic firsthand, but his statement seems to be based on previous literature rather than his own observations. This also appears to be a description of the whale's callosities.

Barnard (1924) states that there are specimens of *Coronula diadema* in the South Africa Museum labelled as having been taken from a right whale (S.A.M. Nos. 1323-5, A229, A305). He provides no further details. A review of these and other specimens in the museum revealed only two specimens (No. 1325) from Simon's Town, South Africa (34°S, 18°30′E) labelled as being from a right whale. Barnard's reference to A229 appears to be a typographical error for A299. This latter specimen is probably from a humpback whale, and A305 is labelled as being from a humpback whale. For the other *Coronula* and *Cetopirus* specimens in the museum, no host species is identified (P. Best, pers. comm.).

Freund (1932) states that in addition to cyamids, *Coronula biscayensis* [=*C.*

diadema] is found sometimes on the heads of right whales in large amounts. No further information and no source for this statement is provided.

Matthews (1938), in his study of southern right whales, notes that in addition to cyamids, cirripeds were recorded from one whale which was described by the person who made the observation as having "a mass of encrusted barnacles and lice on the side of the chin." This may simply be another reference to the whale's callosities.

Tomilin (1957:39) states without elaboration that *Coronula* barnacles are not found on bowheads, but "thrive on the warm-loving Black Right whale *Eubalaena glacialis*." He reports these barnacles occurring on right whales in all oceans. Tomilin gives no indication that he personally observed barnacles on right whales. His comments appear to be based primarily, if not entirely, on the article by Brandt and Ratzeburg (1829) discussed above.

Leatherwood *et al.* (1976:52) state in their field guide to North Atlantic cetaceans: "Yellow-brown lice and, less frequently, barnacles grow on the callosities [of the right whale]." No further comments are made and no source is given for this statement. In a companion field guide to Eastern North Pacific cetaceans Leatherwood *et al.* (1982:67) describe the callosities on the right whale's head with no mention of barnacles then state the skin on the right whale's "broad back is free of callosities and generally free of barnacles." No reason is given for why the absence of barnacles was so qualified.

RECORDS OF CETOPIRUS COMPLANATUS

Much less is known about *Cetopirus complanatus* than about either *Coronula diadema* or *C. reginae*. There is one documented record of *C. complanatus* for which the host is described as a right whale (Darwin, 1854). All other museum specimens of this barnacle refer to its host as a whale without describing the particular species (Murray, 1896:449; Gruvel, 1905; Pilsbry, 1916; Barnard, 1924; Newman and Ross, 1976).

Few specimens of this species are in scientific collections (Nilsson-Cantell, 1938; Stubbings, 1967) and those in collections have minimal information on their labels. This species has a particularly long and confusing taxonomic history (Pilsbry, 1916; Newman and Ross, 1976). Its similarity to *Coronula diadema*, and particularly to *C. reginae*, combined with the abbreviated descriptions of early records of coronuline barnacles on right whales, renders many early records highly ambiguous.

Cetopirus complanatus's reported distribution includes the coasts of Chile, South Africa, Australia, and Tasmania (Newman and Ross, 1976). There is one report of this barnacle from Kerguelen Island off the coast of Norway mentioned in Gruvel (1903), and Pilsbry (1916). Nilsson-Cantell (1931) lists two specimens reportedly from the North Atlantic in the collection of the Natural History Museum of Basel. However, this species is not described from the North Atlantic in a later report (Nilsson-Cantell, 1978). There are no reports from the North Pacific.

As noted above, *C. complanatus* closely resembles *C. reginae*, and the two species are difficult, if not impossible, to distinguish from a distance. *C. complanatus* is also closely related taxonomically to *Coronula*. Indeed, most early taxonomists, including Darwin (1854) and Pilsbry (1916), did not distinguish *Cetopirus* as a separate genus. So, many of the early references to *Coronula* barnacles on right whales may be to *Cetopirus* rather than *Coronula*.

The first suggestion in the literature that *Cetopirus* may occur on right whales is in Eschricht and Reinhardt (1866:35–36). They describe a barnacle taken from a right whale in the North Atlantic as being identified by Chemnitz and Martini (1790) as *Balanus polythalamius complanatus*, which as Chemnitz and Martini (1790) use it is apparently synonymous with *Cetopirus complanatus* (Pilsbry, 1916). A barnacle expert wishing to pursue this record is referred to Eschricht and Reinhardt (1866:35,36 fn.1) and Pilsbry (1916:277–78).

The second report of *Cetopirus* on right whales is in Darwin's (1854) monograph on cirripeds. He describes *C. complanatus* as *Coronula balaenaris*. Darwin does not usually specify the host species of the barnacles he examined, but he does so in this case, stating that *Cetopirus* "seems often to be associated with *Tubicinella*. Some specimens thus associated, sent by Mr Bennet to Professor Owen were said to have been attached to the *Balaena australis*" (=*Eubalaena glacialis*) (p. 417). As noted in Table 1, *Tubicinella* has only been reported from the right whale, supporting Bennet's description of the host as a right whale.

Beneden's (1870) statement that *Coronula balaenaris* (=*C. complanatus*) occurs on all the whales in the temperate regions of the Southern Hemisphere is suspect. He describes these barnacles attached to the base of the whale's flippers, but then comments that the barnacles sent to museums in Europe were rarely labeled with the host whale species. Given these statements, it appears likely that the barnacles Beneden refers to are *Coronula* spp. and came from humpback, not right, whales.

Watson (1981) refers to *Coronula balaenaris* (=*Cetopirus complanatus*) as occurring on right whales as an endemic species. He does not give a source for this statement and offers no supporting evidence.

DISCUSSION

There have been few observations of right whales in the last hundred years, particularly few in the North Pacific (Omura *et al.*, 1969; Scarff, in press). In no case have coronuline barnacles been reported in the articles describing the sighting (Andrews, 1908; Collett, 1909; Omura, 1958; Klumov, 1962; Omura *et al.*, 1969; Payne *et al.*, 1981). Barnacles are not visible in the published photographs of any recent sightings (Payne, 1972, 1974, 1976; Gilmore, 1978; Leatherwood *et al.*, 1976; Woodhouse and Strickley, 1982; Reeves *et al.*, 1983). Recent detailed observations of right whales in the western North

Atlantic (Reeves *et al.*, 1983; D. Spero, pers. comm.; S. Kraus, pers. comm.) and in the South Atlantic off Argentina (Payne *et al.*, 1981; R. Payne, pers. comm.) have also failed to result in sightings of barnacles. There are also no recent observations of coronuline barnacles (other than *Tubicinella*) on right whales off the coast of South Africa (P. Best, pers. comm.).

The absence of barnacles in recent sightings and their presence in our sightings form a context in which earlier reports may be viewed. Many of these reports, particularly Scoresby (1820), Brandt and Ratzeburg (1829), Siebold (1844), Eschricht and Reinhardt (1866), and Holder (1883), are probably inaccurate descriptions of the callosities. The reports of Beneden (1870), Tomilin (1957), and Watson (1981) are unconvincing because of their vagueness and secondhand nature.

This leaves only four records: two of *C. diadema* (Yamada, 1829; Barnard, 1924) and two of *Cetopirus complantus* (Darwin, 1854; Chemnitz and Martini (1790) quoted in Eschricht and Reinhardt, 1866). These reports seem reliable. In each case the barnacle was described by an expert and the only question of reliability concerns the description of the whale host. In the case of Darwin (1854), the presence of *Tubicinella* on the same piece of skin with *Cetopirus* serves as an independent check on the host identity. Barnard's record is less compelling, but there is no question regarding the presence of a coronuline barnacle; the only uncertainty involves the identity of the host species. There is no reason other than the rarity of the record to doubt the accuracy of the museum tag because right whales do occur along the South African coast.

Two questions arise from the present observations. First, if coronuline barnacles can occur on right whales, why have there been so few recent observations of these barnacles on this species of whale? Second, where and how did this whale become associated with these barnacles?

In response to the first question, one argument involves the alleged lack of overlap in the winter ranges of coronuline barnacles and right whales. The absence of coronuline barnacles on the arctic bowhead whale (Tomilin, 1957; Marquette, 1977) and their presence on humpback and gray whales, species with more tropical winter ranges, is used to support this view. Nishiwaki (1972:12) states that "Black right whales simply do not migrate into warm water where the larvae of these barnacles is abundant." The opposite view is expressed by Tomilin (1957).

Another factor which may be important is the relative thickness of the epidermis of right whales. Darwin (1854) and Marloth (1902) have described in detail the manner in which coronuline barnacles attach themselves to whales. In the case of *Coronula* spp. and *Cetopirus*, the papillae of the whale's epidermis are pulled up into the ventral, external cavity in the barnacle's shell to form an adhesive seal. The whale's epidermis also grows over the lateral and dorsal surfaces of the barnacle to varying degrees among the barnacle species rather than being sheared by the basel edge of the barnacle's shell. In discussing scars on a right whale, Omura *et al.* (1969:34) mention that the black epidermis of this species is approximately 15 mm thick. In contrast, in balaenopterid whales, it is only 5 mm thick, or less (Ling, 1974: 16). The right whale's thicker epidermis may make it more difficult for the barnacle larvae to attach themselves initially to right whales than to humpback, and it may also be more difficult for the barnacle to maintain its attachment.

The evidence of barnacles on right whales in the early literature is so scant that the barnacles, if they occurred, were no longer common by the early 1800's, even on the unexploited populations of whales in the Pacific and Southern Hemisphere. The barnacles may require dense aggregations of whales as they occur off South Africa and Argentina in order for the nauplia to attach each year. The more dispersed wintering right whales in the Northern Hemisphere may not have consistently achieved the minimum population density necessary for perpetuation of barnacles. The reduction in total population size caused by whaling may have resulted in the extinction of local barnacle populations in the Northern Hemisphere.

About the question of how this whale acquired the barnacles, a clue may be found in the life history of *Coronula* barnacles. The young barnacles probably attached themselves to this whale during late winter 1981, or possibly during winter 1980. At that time the whale must have been in a region where free-swimming larvae of *Coronula* barnacles occurred. Individual free-swimming nauplia may remain in the water for two to four weeks (W. Newman, pers. comm.). Because *Coronula* barnacles have been seen most frequently on humpback whales, at some point during the winter the right whale was most probably in waters recently travelled by humpback whales.

Until recently, such a hypothesis would have seemed improbable because of the separate winter ranges of the two whale species. The known wintering grounds of humpback whales in the eastern North Atlantic are near the Hawaiian Islands (20°N) (Rice and Wolman, 1971) and off the coast of Mexico (20°N)(Rice, 1978). The winter distribution of right whales has traditionally been thought to be north of this latitude. There are very few sightings of right whales in the eastern North Pacific between November and March and most of these were made north of 40°N (Maury, 1852; Townsend, 1935; Scarff, in press). Historically, in the western North Pacific, right whales were found as far south as 30°N (Maury, 1852; Townsend, 1935), although more recently they have been observed only rarely south of 40°N (Omura *et al.*, 1969).

Sightings of right whales off the California coast are rare, the species' wintering grounds in the North Pacific apparently being elsewhere (Scarff, in press). However, there have been recent sightings of three right whales south of 30°N in the eastern North Pacific. On March 11, 1956, two right whales were observed off Baja California at 26°N (Rice and Fiscus, 1968). In 1979, a single right whale was observed on three occasions on March 25 and April 10 in the Hawaiian Islands at 20°N (Rowntree *et al.*, 1980; Herman *et al.*, 1980). Of particular note is that during all three observations, this latter right whale was interacting with humpbacks. The photographs of the right whale we observed off Half Moon Bay were compared with photographs of the animal seen off Hawaii, and because of the presence of a white blaze on the animal seen near Hawaii and its absence on the animal from Half Moon Bay, these appear to be two different individuals.

It is possible that before their decimation by whalers, some right whales migrated further toward the equator than they currently appear to do. There is some indication that a similar phenomenon may have occurred off South Africa (Best, 1981). Perhaps also some humpback whales, perhaps juvenile animals, wintered further north resulting in overlap of the winter distribution of these two species. If either occurred, the early accounts of coronuline barnacles on right whales may be accurate.

Another possibility is that the right whale picked up the barnacles as a result of association with a whale of a species other than humpback, most probably a sperm whale (*Physeter macrocephalus*), but possibly another species (see Table 1). In October 1963, a right whale was observed swimming with two sperm whales off the coast of South Africa (Best, 1970). A second line of support for this hypothesis comes from the observation that two species of cyamid which are typically host specific have been reported on both right and sperm whales (Rowntree, 1984; Best, 1970; Reeves *et al.*, 1983).

In either case, the sighting of a right whale with humpbacks in Hawaii in 1979 and the sighting of another right whale in 1982 with barnacles typically found on humpbacks, suggest that researchers studying humpbacks on their winter grounds should be alert to the possible presence of right whales in the area.

ACKNOWLEDGEMENTS

I thank William Newman for identifying the barnacles from the photographs and for critically reviewing the manuscript. Ray Gilmore, Dale Rice, Peter Best, and Vicki Rowntree all reviewed the manuscript and offered many helpful comments. Peter Best also kindly examined the barnacles in the South African National Museum. Tom Johnson has my gratitude for finding the right whale, for reviewing the manuscript, and for permitting me to use one of his photographs. G.A. Boxshall of the British Museum, Natural History, was extremely helpful in making available Darwin's barnacle collection. I thank Janet Evans of the Academy of Natural Sciences of Philadelphia and Diana McIntyre of the Los Angeles County Museum of Natural History for obtaining obscure references. Lastly, I thank my mother, Iris Scarff, for translating all the articles from French, German, and Russian.

REFERENCES

Allen, J.A., 1908. The North Atlantic right whale and its near allies. *Bull. Am. Mus. Nat. Hist.*, 24: 277–329.

Andrews, R.C., 1908. Notes on external and internal anatomy of *Balaena glacialis. Bull. Am. Mus. Nat. Hist.*, 24: 171–182.

Andrews, R.C., 1916. *Whale hunting with gun and camera.* D. Appleton, New York. 333pp.

Angot, M., 1951. Rapport scientifique sur les expéditions balginières de Madagascar. *Mem. Inst. Rech. Sci. Madagascar ser., A* 6 (2): 439–486. (Tananarive).

Barnard, K.H., 1924. Contribution to the crustacean fauna of South Africa. No. 7. Cirripedia. *Ann. South African Mus. Cape Town*, 20: 1–103.

Beneden (Van), P.J., 1870. Les cétacés, leurs commensaux et leur parasites. *Bull. Acad. Roy. Belgique. ser. 2*, 29: 347–368.

Best, P.B., 1970. Exploitation and recovery of right whales *Eubalaena glacialis* off the Cape Province. *Invest. Rep. Sea Fish. Inst. S. Afr.*, 80: 1–20.

Best, P.B., 1981. The status of right whales (*Eubalaena glacialis*) off South Africa, 1969–1979. *Invest. Rep. Sea Fish. Inst. S. Afr.*, 123: 1–44.

Brandt, J.F. and J.T.C. Ratzeburg, 1829. *Medizinische Zoologie oder getreue Darstellung und Beschreibung der Thiere die in der Arzneimittellehre in Betracht kommen.* A. Hirschwald, Berlin.

Chemnitz, J.H. and F.H.W. Martini, 1790. *Systematiches Conchilien-Cabinet von Martini und Chemnitz.* vol. 8. Bauer and Raspe, Nurnberg (cited in Eschricht and Reinhardt, 1866).

Collett, R., 1909. A few notes on the whale *Balaena glacialis* and its capture in recent years in the North Atlantic by Norwegian whalers. *Proc. Zool. Soc. London,* 1909: 91–98.

Cornwall, I.E., 1924. Notes on West American whale barnacles. *Proc. Calif. Acad. Sci. 4th ser.*, 13 (26): 421–431.

Cornwall, I.E., 1927. Some North Pacific whale barnacles. *Contrib. Can. Biol. Fish. n.s.*, 3: 503–517.

Cornwall, I.E., 1928. Collecting at Cachalot whaling station. *Can. Field Naturalist,* 42: 9–12.

Cornwall, I.E., 1955. The barnacles of British Columbia. *Br. Col. Prov. Mus. Dept. Educ. Handbook No. 7*: 5–69.

Dailey, M.D. and R.L. Brownell, Jr., 1972. A checklist of marine mammal parasites. pp. 528–589. *In*: S. Ridgway (ed.) *Mammals of the sea: biology and medicine.* Charles C. Thomas, Springfield, Illinois. 812 pp.

Darwin, C., 1854. *A monograph on the sub-class cirripedia. vol. 2.* Ray Soc., London. viii + 684pp. 30 plates.

Edge, T., 1625. A briefe discoverie of the northerne discoveries of seas, coasts, and countries. pp. 462–473. *In*: S. Purchas (ed.) *Purchas his Pilgrimes, contayning a history of the world, in sea voyages & land-trauells, by Englishmen & others* [Haklvyatus posthumus]. Part III, Book 3. H. Fetherstone, London.

Eschricht, D.F. and J. Reinhardt, 1866. On the Greenland right whale (*Balaena mysticetus*, Linn.) pp. 1–150. *In*: W.H. Flower (ed.) *Recent memoirs on the Cetacea.* Ray Soc., London. 312 pp.

Freund, L., 1932. Cetacea. *Tierwelt der Nord-und Ostsee* (Lieferung 22, T. 12).

Gilmore, R.M., 1978. Right whale. pp. 62–69. *In*: D. Haley (ed.) *Marine mammals of the eastern North Pacific and arctic waters.* Pacific Search Press, Seattle. 256pp.

Greenwood, A.G., R.J. Harrison and H.W. Whitting, 1974. Functional and pathological aspects of the skin of marine mammals. pp. 73–110. *In*: Harrison, R.J. (ed.) *Functional anatomy of marine mammals, vol. 2.* Academic Press, New York. 366pp.

Gruvel, J.A., 1903. Revision des cirrhipèdes appartenant à la collection du musée d'histoire naturelle. *Nouv. Arch. des Musées ser. 4*, 5: 95–170.

Gruvel, J.A., 1905. *Monographie des cirrhipèdes ou thécostracés.* Masson et Cie, Paris. xii + 472pp.

Herman, L.M., C.S. Baker, P.H. Forestell and R.C. Antinoja, 1980. Right whale *Balaena glacialis* sightings near Hawaii: a clue to the wintering grounds? *Marine Ecol. Prog. Ser.*, 2: 271–275.

Holder, J.B., 1883. The Atlantic right whales. *Bull. Am. Mus. Nat. Hist.*, 1: 99–137.

Johnson, T., 1982. A survivor at sea. *Oceans*, 15 (5): 52.

Jones, E.C., 1971. *Isistius brasiliensis,* a squaloid shark, the probable cause of crater wounds on fishes and cetaceans. *Fishery Bull.*, 69 (4): 791–798.

KAKUWA, Z., T. KAWAKAMI and K. IGUCHI, 1953. Biological investigation on the whales caught by the Japanese Antarctic whaling fleets in the 1951–52 season. *Sci. Rep. Whales Res. Inst.,* 8: 147–213.

KLUMOV, S.K., 1962. Gladkie (Yaponskie) kity Tikhogo Okeana [The right whales in the Pacific Ocean]. *Trudy Inst. Oceanol.,* 58: 202–297. (In Russian with English summary.)

LEATHERWOOD, S., D.K. CALDWELL and H.E. WINN, 1976. Whales, dolphins, and porpoises of the western North Atlantic. *NOAA Tech. Rep. NMFS Circ. 396.* 176 pp.

LEATHERWOOD, S., R.R. REEVES, W.F. PERRIN and W.E. EVANS, 1982. Whales, dolphins, and porpoises of the Eastern North Pacific and adjacent waters. *NOAA Tech. Rep. NMFS Circ. 444.* 245 pp.

LING, J.K., 1974. The integument of marine mammals. pp. 1–44. *In*: Harrison, R.J. (ed.) *Functional anatomy of marine mammals, vol. 2.* Academic Press, New York. 366 pp.

LYDEKKER, R., 1909. *Guide to the whales, porpoises, and dolphins (order cetacea) exhibited in the department of zoology, British Museum (Natural History).* British Museum (Natural History), London. 47pp.

MARGOLIS, L., 1954. List of parasites recorded from sea mammals caught off the west coast of North America. *J. Fish. Res. Board Can.,* 11: 267–283.

MARLOTH, R., 1902. Notes on the mode of growth of *Tubicinella trachaelis*, the barnacle of the southern right whale. *Trans. S. Afr. Philos. Soc.,* 11: 1–6.

MARQUETTE, W., 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaska Eskimos, with a review of the fishery, 1973–76, and a biological summary of the species. Proc. Rep., Natl Mar. Mammal Lab., Natl Mar. Fish. Serv. NOAA. 80 pp.

MATTHEWS, L.H., 1938. Notes on the southern right whale, *Eubalaena australis. Discovery Rep.,* 17: 171–181.

MATTHEWS, L.H. and G. PILLERI, 1983. Introduction to the Yogiotoru Eshi of Yamada Yosei. *Invest. on Cetacea,* 14 (Suppl.): 7–12.

MAURY, M.F., 1852 *et seq. Whale Chart of the World.* (The Wind and Current Charts), Series F. Washington, D.C. 4 sheets, No. 1 (North Atlantic, N.E. Pacific) 1852. Whale Sheet No. 2 (N.W. Pacific) n.d.

MCCANN, C., 1974. Body scarring on Cetacea-odontocetes. *Sci. Rep. Whales Res. Inst.* 26: 145–155.

MELVILLE, H., 1851. *Moby Dick.* Bobbs-Merrill Indianapolis, Indiana 1964. xiii + 730pp.

MIZUE, K. and T. MURATA, 1951. Biological investigation on the whales caught by the Japanese whaling fleets season 1949–50. *Sci. Rep. Whales. Res. Inst.,* 6: 73–131.

MURRAY, J., 1896. On the deep and shallow-water marine fauna of the Kerguelen region of the great southern ocean. *Trans. Royal Soc. Edinburgh,* 38: 343–500.

NEMOTO, T., 1955. White scars on whales (I) Lamprey marks. *Sci. Rep. Whales Res. Inst.,* 10: 69–77.

NEWMAN, W.A. and D.P. ABBOTT, 1980. Cirripedia: the barnacles. pp. 504–35. *In*: Morris, R.H., D.P. Abbott and E.C. Haderlie (eds) *Intertidal invertebrates of California.* Stanford University Press, Palo Alto, California. 690pp. 200 colorplates.

NEWMAN, W.A. and A. ROSS, 1971. Antarctic cirripedia. *(Am. Geophysical Union of the Natl Acad. of Sci.) Antarctic Research Ser.* 14: 1–257.

NEWMAN, W.A. and A. ROSS, 1976. Revision of the balanomorph barnacles; including a catalog of the species. *San Diego Soc. Nat. Hist. Memoir No. 9.* 108 pp.

NILSSON-CANTELL, C-A., 1930. Thoracic cirripedes collected in 1925–1927. *Discovery Rep.,* 2: 223–260.

NILSSON-CANTELL, C-A., 1931. Revision der Sammlung recenter Cirripedien des naturhistorischen Museums in Basel. *Verhandl. Naturf. Gesell Basel,* 42: 103–137.

NILSSON-CANTELL, C-A., 1938. Cirripedes from the Indian Ocean in the collection of the Indian Museum, Calcutta. *Mem. Indian Mus.,* 13 (1): 1–81.

NILSSON-CANTELL, C-A., 1939. Thoracic cirripedes collected in 1925–1936. *Discovery Rep.,* 18: 223–238.

NILSSON-CANTELL, C-A., 1978. *Marine invertebrates of Scandanavia No. 5; Cirripedia Thoracica and Acrothoracica.* Universitetsforlaget, Oslo. iii + 133pp.

NISHIWAKI, M., 1959. Humpback whales in Ryukyuan waters. *Sci. Rep. Whales Res. Inst.,* 14: 49–87.

NISHIWAKI, M., 1972. General biology. pp. 1–204. *In*: S.H. Ridgway (ed.) *Mammals of the sea: biology and medicine.* Charles C. Thomas, Springfield, Illinois. 812pp.

NISHIWAKI, M. and T. OYE, 1951. Biological investigation on blue whales (*Balaenoptera musculus*) and fin whales (*Balaenoptera physalus*) caught by the Japanese Antarctic whaling fleets. *Sci. Rep. Whales Res. Inst.,* 5: 91–167.

OMURA, H., 1958. North Pacific right whale. *Sci. Rep. Whales Res. Inst.*, 13: 1–52.

OMURA, H., in press. History of right whale catches in the waters around Japan. *Rep. int. Whal. Commn* (Special issue).

OMURA, H., S. OHSUMI, T. NEMOTO, K. NASU and T. KASUYA, 1969. Black right whales in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 21: 1–78.

PATENT, D.H., 1984. *Whales, giants of the deep.* Holiday House, New York. 90 pp.

PAYNE, R., 1972. Swimming with Patagonia's right whales. *Natl Geogr.*, 142: 576–587.

PAYNE, R., 1974. A playground for whales. *Animal Kingdom*, 77 (2): 7–12.

PAYNE, R., 1976. At home with right whales. *Natl Geogr.*, 149: 322–339.

PAYNE, R., O. BRAZIER, E. DORSEY, J. PERKINS, V. ROWNTREE and A. TITUS, 1981. External features in southern right whales (*Eubalaena australis*) and their use in identifying individuals. U.S.D.C. NTIS PB81-161093. 77 pp.

PIKE, G.C., 1951. Lamprey marks on whales. *J. Fish. Res. Board Canada*, 8 (4): 275–280.

PILSBRY, H.A., 1916. The sessile barnacles (Cirripedia) contained in the collections of the U.S. National Museum; including a monograph of the American species. *Bull. U.S. Natl Mus.*, 93: 1–366.

REEVES, R.R., 1982. What hope for North Atlantic right whales. *Oryx*, 16: 255–62.

REEVES, R.R. and R.L. BROWNELL, JR., 1982. Baleen whales (*Eubalaena glacialis* and allies). pp. 415–444. *In*: J.A. Chapman and G.A. Feldhamer (eds) *Wild mammals of North America: biology, management, and economics.* Johns Hopkins Univ. Press, Baltimore. 1147 pp.

REEVES, R.R., S. KRAUS and P. TURNBULL, 1983. Right whale refuge? *Nat. Hist.*, 92 (4): 40–45.

RICE, D.W., 1963. Progress report on biological studies of the larger cetacea in the waters off California. *Norsk Hvalfangst-Tid.*, 52 (7): 181–187.

RICE, D.W., 1978. The humpback whale in the North Pacific: distribution, exploitation, and numbers. pp. 29–44. *In*: K.S. Norris and R.R. Reeves (eds) *Report on a Workshop on Problems related to Humpback whales (Megaptera novaeangliae) in Hawaii.* Contract Rep. Mar. Mammal Commn NTIS PB-280794. 90 pp.

RICE, D.W. and C.H. FISCUS, 1968. Right whales in the southeastern North Pacific. *Norsk Hvalfangst-Tid.*, 57 (5): 105–107.

RICE, D.W. and A.A. WOLMAN, 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). *Am. Soc. Mammal., Spec. Publ. No. 3.* 142 pp.

RIDEWOOD, W.W., 1901. On the structure of the horny excresence, known as the "bonnet", of the southern right whale (*Eubalaena australis*). *Proc. Zool. Soc. London*, 1: 44–47.

ROWNTREE, V., 1984. Cyamids: the louse that moored. *Whalewatcher*, 17 (4): 14–17.

ROWNTREE, V., J. DARLING, G. SILBER and M. FERRARI, 1980. Rare sighting of a right whale (*Eubalaena glacialis*) in Hawaii. *Can. J. Zool.*, 58: 309–312.

SCAMMON, C.M., 1874. *The marine mammals of the northwestern coast of North America.* John M. Carmany, San Francisco [republished by Dover, New York 1963]. x + *int.* 319pp.

SCARFF, J.E., in press. Historic and present distribution of the right whale (*Eubalaena glacialis*) in the eastern North Pacific south of 50°N and east of 180°W. *Rep. int. Whal. Commn* (Special issue).

SCHEFFER, V.B., 1939. Organisms collected from whales in the Aleutian Islands. *Murrelet*, 20: 67–69.

SCORESBY, W., JR., 1820. *An account of the arctic regions with history and description of the northern whale-fishery.* Archibald Constable, Edinburgh. 2 vols. 1125 pp.

SIEBOLD, P.F. von, 1844. Les mammifères marins. p.26. plates xxi–xxx. *In*: P.F. von Siebold (ed.) *Fauna Japonica sive desciptio animalum...*, Vol. 1. Amsterdam.

SLIJPER, E.J., 1962. *Whales.* Hutchinson, London. 475pp.

STUBBINGS, H.G., 1967. The cirriped fauna of tropical West Africa. *Bull. Brit. Mus. (Nat. Hist.). Zool.*, 15: 229–319.

TARASOV, N.I. and G.B. ZEVINA, 1957. Barnacles (Cirripedia Thoracica) of the seas of SSSR. Fauna SSSR (Crustacea) *Akad. Nauk. SSSR Zool. Inst. (n.s.)*, 69 (6): 1–268 (in Russian).

TOMILIN, A.G., 1957. *Mammals of the U.S.S.R. and adjacent countries. vol. 9 Cetacea.* Izdatel'stvo Akademi Nauk SSSR, Moskva (trans. from Russian, Israel Program for Sci. Trans., Jerusalem 1967).

TOWNSEND, C.H., 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica,* 19: 3–50.

TRUE, F.W., 1904. The whalebone whales of the western North Atlantic. *Smithson. Contrib. Knowl.* 33. 332 pp.

VAN UTRECHT, W.L., 1959. Wounds and scars in the skin of the common porpoise, *Phocoena phocoena* (L.). *Mammalia,* 23: 100–122.

WATSON, L., 1981. *A seaguide to the whales and dolphins of the world.* E.P. Dutton, New York. 302pp.

WEIR, R., 1977. The adventures of a haunted whaling man. *Amer. Heritage,* 28 (5): 46–54.

WHEELER, J.F.G. and N.A. MACKINTOSH, 1929. Southern blue and fin whales. *Discovery Rep.,* 1: 259–471.

WOODHOUSE, C.D. JR. and J. STRICKLEY, 1982. Sighting of northern right whale in the Santa Barbara channel. *J. Mammal.,* 63: 701–702.

WORM, O., 1655. *Museum Wormianum.* Amstelodami, Apud Ludouicum & Danielem Elzeririos (cited in Pilsbry 1916).

YAMADA, Y., 1983 [1829]. Yogiotoru Eshi. Vol. 2. Tokyo (Translated from Japanese by M. Shibuya). *In*: G. Pilleri (ed.), *Invest. on Cetacea* 14 (Suppl.). Berne, Switzerland. 119 pp.

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

THE DISTRIBUTION OF THE SOUTHERN BLUE WHALE IN RELATION TO RECENT ESTIMATES OF ABUNDANCE

JOSEPH W. HORWOOD*

ABSTRACT

Based on data from systematic sightings surveys for minke whales a recent stock estimate was obtained of blue whales in the Antarctic. This study reviews previous information on the distribution of blue whales and confirms that the time and extent of the surveys was suitable to provide information on the abundance of blue whales. It would appear that the number of blue whales in the Antarctic is less than 2000; much less than previous estimates indicated.

INTRODUCTION

Blue whales (*Balaenoptera musculus* L.) have been caught in the Antarctic since at least 1905 when C A Larsen caught three from the land station at Grytviken in January, (Tønnessen and Johnsen, 1982). Hjort, Lie and Ruud (1932) described how whaling was initially restricted to the shore stations, mainly from islands in the South Atlantic, but in the season of 1923/24 shore based whaling extended into the area of the Ross Sea. True pelagic operations started in the season of 1925/26. After forty years of exploitation all member governments of the International Whaling Commission (IWC) agreed to cease whaling for blue whales in the Southern Hemisphere from the beginning of the 1965/66 season and catches after this date are very small. Tønnessen and Johnsen noted that the recorded catch of blue whales from the Antarctic was over 331,000. Part of this catch is of the pygmy blue whale (*B. musculus brevicaudata*) which is to be found from 0°–80°E and between 40°–55°S (Ichihara, 1966).

The Committee of Three of the IWC undertook a stock assessment of blue whales which was reported by Chapman (1964). The various techniques they used gave different estimates of stock size and were related to different years depending upon the type of data used. Using catch per unit of effort (CPUE) and Schaeffer's method gave an initial, exploited population of about 220,000. Mackintosh and Brown (1956) reported sightings of all large whales south of

---

* *Ministry of Agriculture, Fisheries and Food, Fisheries Laboratory, Lowestoft, Suffolk NR33 OHT, England*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 155–165

the Antarctic Convergence (AC) over the period 1933/34 to 1938/39 and these data led to an estimate of the blue whale population in this region of 33,000, at that time and a standard De Lury analysis, using CPUE, gave an estimate of exploited stock in 1953/54 of 13,000, but a range of 6–10,000 was accepted from subsets of the data. Masaki and Yamamura (1978) reported on sightings of blue whales by Japanese, whaling, research ships over the period 1965 to 1977. They considered that the population of blue whales, south of 30°S, was about 12,000 over that period. Gulland (1981) reviewed these estimates. He deducted the whales sighted in the region where pygmy blue whales were found to give a modified sightings estimate of 5400 and concluded that this estimate combined with others based on analyses of CPUE indicated that the exploited population of blue whales in 1963 was around 4000. His postulated rate of increase of 4 to 5 percent would give a current population of about 10,000.

The techniques used to provide the above estimates utilize rather crude data. The analyses based on CPUE have to accommodate changes in catching efficiency, species selection, time and location of whaling and operations other than searching. The sightings do not come from systematic surveys. Consequently, the estimates should only be regarded as very approximate. In contrast, Butterworth and Dudley (1984) presented an estimate of blue whale numbers based on systematic sightings surveys. The background to these surveys, designed primarily to estimate numbers of minke whales, is given by Best and Ohsumi (1980) and Horwood, Best and Ohsumi (1981). The analysis of Butterworth and Dudley yielded the result that south of approximately 60°S there were about 1000 or 1600 blue whales. The lower figure is based upon 'primary' sightings which are those seen when actively searching rather than those seen whilst engaging in other operations such as confirming the identity of a previously observed school; these others are called 'secondary' sightings. The second figure is based upon both combined and Butterworth and Dudley refer to the value 1000 as negatively biased, in respect of the selection of the number of sightings utilised, and the 1600 as positively biased. Other sources of bias are discussed later. This analysis must be regarded as the most reliable to date and gives a figure much lower than any previous estimate. The numbers are also small in absolute terms especially as the blue whale has not been hunted for twenty years. Numbers in 1965 may have been half as many.

As the estimates are so low it is especially necessary to enquire if the surveys were carried out at a time when and in the locations where blue whales were formerly abundant. Such a concern is expressed by Butterworth and Dudley. In order to clarify this point this study reviews the previous literature on blue whale distributions and reports on the distribution of catches from the data originally held by the Bureau of International Whaling Statistics (BIWS).

PREVIOUS DESCRIPTIONS

Many of the early Antarctic expeditions noted the occurrence of large numbers of whales particularly in the regions of the Antarctic Peninsula and the Ross Sea but most did not refer reliably to the species concerned. From a variety of observations Racovitza (1903) and Hjort (1920) showed that blue whales were common in these two localities. More detailed information arose with the introduction of pelagic whaling. In a series of articles Hjort, Lie and Ruud (1932, 1933a, 1933b, 1934) described the Norwegian pelagic whaling for the seasons 1929/30 to 1933/34. They show that very little whaling took place between 70°–150°W but throughout the rest of the Antarctic whaling concentrated on particular grounds. The highest densities of blue whales were found from 0° eastwards to 170°W. A review of early exploratory cruises seemed to confirm that the region between 70°–150°W held few whales. Their studies show that during October and November catches were mainly north of 60°S but, as the ice receded, catching was mainly south of 60° or 65°S. In the area of the Ross Sea catches were taken primarily between 65° and 70°S. Before January blue whales represented a higher percentage of the catch than fin whales but after January fin whale catches dominated. The position of the catches each month in December to February show that blue whales were taken over several degrees of latitude.

Omura (1973) published the catches of blue whales from the period 1931/32 to 1971/72 by ten-degree squares and Ichihara (1966) has plotted out the catch, by the Japanese pelagic fleets, of blue and pygmy blue whales by rectangles of five degrees of longitude and one degree of latitude from the seasons of 1946/47 to 1962/63. The Japanese catches show that blue whales were caught between 55° and 65°S from 35°E to 105°E, south of 60°S from 105°E to 165°E and south of 65°S from 165°E to 90°W. Substantial catches were taken from 90°W to 180°W, an area where the early Norwegian whaling did not operate.

The early pelagic catch statistics (IWS, 1937) show that from October to December blue whales were usually over 90 per cent of the catch with the proportion of fin whales increasing in January and February. Kellog (1928), Mackintosh (1965) and Omura (1973) interpreted this as a difference in the timing of the migrations of the two species and this is supported by sightings data (Gambell, 1976).

Mackintosh (1966) considered that blue and fin whales were found throughout the Antarctic and were distributed in a very similar way, the only difference was that blue whales tended to frequent slightly colder waters. This opinion is at some variance with the opinions of Ohsumi, Masaki and Kawamura (1970) who considered the distribution of the blue whale to be more like that of the minke whale, a species that is found in greatest numbers around the ice edge. Racovitza (1903) considered that blue whales seek the ice. Nishiwaki and Hayashi (1950) presented the catch of blue and fin whales from the Ross Sea in 1947/48 by one degree squares and showed that the two species occurred together in those waters but Nishiwaki and Oye (1951) also commented that few blue whales were being caught in one expedition as they were whaling on an aggregation of fin whales over 50 miles from the edge of the pack ice. Nemoto (1959) plotted the relative distribution of blue and fin whales between 170°E–162°W for catches from 1949 to 1950 (his Figure 31). Along the ice edge blue whales comprised between 20–100% but over 60 nautical miles away from the ice edge the percentage of blue whales was 8–78%. He reported that "Whalers usually say they hunt blue whales in the pack ice and chase fin whales in the off-waters." Slijper (1962) says that it is well known that blue whales keep to the drifting ice whereas fin whales are found outside it.

B.I.W.S CATCH DATA

The BIWS, Norway, kept a record of all whales caught in the Antarctic from the 1931/32 season. These data are now held on computer by the Secretariat of the IWC. Tillman and Ohsumi (1981) compared the computerized records of Japanese pelagic catches with Japanese government statistics and they found that over the seasons 1939/40 and 1940/41 records published by the BIWS were correct but the computerized records did not include many fin and blue whales taken in these seasons. However, these omissions represent only a small proportion of the total number of records and the following describes the spatial and temporal distribution of pelagic catches of blue whales from the Antarctic based on the computerized records. Tønnessen and Johnsen (1982) recorded that 331,042 blue whales were caught between 1904 and 1978 in the Antarctic. The catch records show that from 1931/32 180,676 were taken by the pelagic fleets. Of these 123,346 were taken south of 60°S and 57,330 were taken to the north of 60°S.

Fig. 1 shows the catch of blue whales by day by the pelagic fleets south of 60°S. Data from 29 February are omitted. Catches reach peak numbers at the beginning of February but are high from mid-December to the beginning of March. However, various commercial, national and international agreements have regulated the beginning and ending of whaling seasons and, consequently, catches will not necessarily reflect abundance on the grounds. The whaling period has varied with species in order to give protection to humpback and blue whales. Table 1 gives the whaling periods for blue whales for the pelagic fleets extracted mainly from various volumes of the International Whaling Statistics. Before the International Agreement for the Regulation of Whaling, 1937, the allowed whaling periods and areas were regulated by whaling agreements amongst companies primarily of Norway and the UK. Not all whaling countries were bound by the periods shown in any one season.

Table 1 shows that before 1948 whaling was allowed from before the second week in December, but after 1950 catches were to be taken from January onwards. Catches of blue whales after 1950 were relatively small,

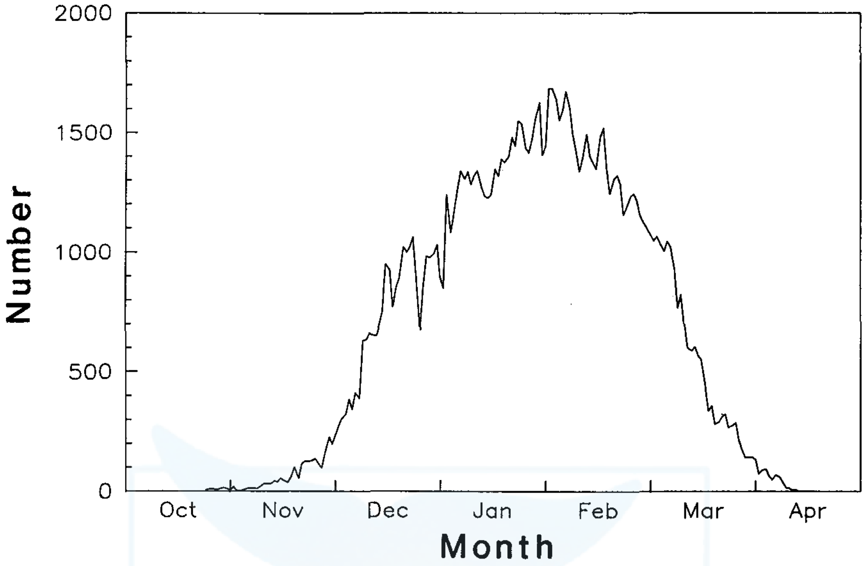

Fig. 1. The catch of blue whales by pelagic fleets in the Southern Hemisphere south of 60°S from the 1931/32 whaling season. The value for 29 February has not been included.

(Horwood, 1981a). Consequently, the pattern from mid-December should not be much affected by the regulations although other operational considerations may have played a part. The rapid decline in catches at the beginning of March does look to have occurred at about the times that the closing dates for the period have operated.

The six research cruises that provided the data for the assessment by Butterworth and Dudley (1984) took place over the seasons 1978/79 to 1983/84 and covered the extreme times of 24 December to 18 February; consequently there is interest in the spatial distribution of pelagic catches over these dates. South of 60°S 75,878 blue whales were recorded as caught between these dates from 1931/32. (Another 114 whales were recorded as having been caught between these dates but their positions of capture are uncertain). The distribution of these catches, plotted as numbers caught in a rectangle of ten degrees of longitude and one of latitude, is shown in Fig. 2. The cross-hatched region is where 500 or more whales were caught. The blank regions represent areas in which less than 50 whales were caught; on average, over a period of 30 years (within the above dates) and in rectangles of about 15,000 square miles, this represents less than two whales caught per year. Unfortunately whaling regulations have also affected the spatial movements of the fleets and these have also been summarised in Table 1.

Pelagic whaling was restricted to south of 40°S from the 1935/36 season but, for two years from the beginning of the 1938/39 season, an area from

TABLE 1. REGULATIONS AFFECTING THE PELAGIC CATCHING OF BLUE WHALES IN THE ANTARCTIC

Season	Whaling period (closing date if different)[1]	Area	Notes
1932/33	20.10.32–30.4.33 (14.4.33)	No restrictions	Geneva Convention 1931 production agreement June 1932[2]
33/34	25.10.33–		Production agreement[2]
34/35	1.12.34–31.3.35	S of 50°S (Norway only)	Norwegian law[2] production agreement[3]
35/36	1.12.35–15.3.36	S of 40°S	Production agreement[3]
36/37	8.12.36– 7.3.37	〃	Production agreement
37/38	8.12.37– 7.3.38	〃	Int. Agreement for Regulation of Whaling June 1937
38/39	8.12.38– 7.3.39	S of 40°S 70°W–160°W closed for 2 yrs.	Protocol of 1938
39/40	8.12.39– 7.3.40	〃	〃
40/41	8.12.40– 7.3.41	S of 40°	〃
41/42	no pelagic whaling		〃
42/43	8.12.42– 7.3.43	〃	〃
43/44	8.12.43– 7.3.44	〃	〃
44/45	24.11.44–24.3.45	〃	Protocol of 1944 (not ratified)
45/46	24.11.45–24.3.46	〃	Protocol of 1944 and 1945
46/47	8.12.46– 7.4.47	〃	Protocol of 1945
47/48	8.12.47– 7.4.48 (31.3.48)	S of 40°S 70°W–160°W closed[4]	Protocol of 1946
48/49	15.12.48– 7.4.49 (26.3.49)	〃	Convention of 1946 and subsequent schedule changes apply to 1966
49/50	22.12.49– 7.4.50 (15.3.50)	〃	
50/51	22.12.50– 7.4.50 (9.3.50)	〃	
51/52	2.1.51– 7.4.51 (5.3.51)	〃	
52/53	2.1.53– 7.4.53 (16.3.53)	〃	
53/54	16.1.54– 7.4.54 (18.3.54)	〃	Longer period for sei and fin
54/55	21.1.55– 7.4.55 (19.3.55)	〃	
55/56	1.2.56– 7.4.56 (4.3.56)	S of 40°S 70°W opened	IWC 10th Meeting
56/57	1.2.57– 7.4.57 (16.3.57)	〃	
57/58	1.2.58– 7.4.58 (16.3.58)	〃	
58/59	1.2.59– 7.4.59 (16.3.59)	〃	

(Continued)

TABLE 1. (Continued)

59/60	1.2.60– 7.4.60 (Netherlands continued until 15.4.60)	″	
60/61	1.2.61– 7.4.61	″	
61/62	1.2.62– 7.4.62	″	
62/63	1.2.63– 7.4.63	″	
63/64	1.2.64– 7.4.64	40°–55°S;0°–80°E	Pygmy blue area
64/65	1.2.65– 7.4.65	All areas closed	Pelagic whaling nations objected and thus restricted to 63/64 area
65/66	–	All areas closed	–

---

1) Actual whaling period is less if quota was reached before the end of the season. (IWS XLVI, LIV)

2) Tønnessen and Johnsen, 1982, pp402–408.

3) Tønnessen and Johnsen, 1982, pp433–439.

4) This appears to be the earliest date that the closed area could be binding following the IWC meeting of December 1946. The agreement was implemented by the 1949/50 season but it also appears that the area was not operated in, in practice, until the season of 1955/56 (Omura, 1973).

70°W to 160°W was closed for two years. This has become known as the Sanctuary. It was also legally closed from about 1947/48 to the beginning of the 1955/56 season. There does appear to have been the intention not to whale in the area of 70°–160°W but legislation did not keep pace with events and Omura (1973) showed that no catches or effort were expended in the Sanctuary over the periods 1931/32 to 1938/39 and from 1945/46 to 1954/55. This then leaves the region with only 10 years of whaling and means that accumulated catches will not portray relative abundance inside and outside this area.

The distributions of Fig. 2 show that catches were mainly taken in whaling Areas II to V, 60°W eastwards to 170°W. Highest numbers were taken from Area II (0°–60°W) between 60° and 63°S, in Areas III (0°–70°E) between 60°S and the ice edge and in a few localities in Area V (130°E–170°W). Very few blue whales were caught from 60°–120°W. From 120°W to 130°E the AC is further south than in the rest of the Antarctic and few blue whales were caught north of 64°S in this region. As noted by Omura (1973) the distributions show substantial heterogeneity with longitude but also the distribution with latitude varies with Area.

DISCUSSION

The estimate arrived at by Butterworth and Dudley (1984), of between 1000 and 1600 blue whales in the Antarctic, was based upon data acquired during surveys for minke whales over the period 1978/79 to 1983/84. In the survey period 30 schools of blue whales were found with an average school size of 1.7, and the positions where these schools were seen are given in Fig. 2. The

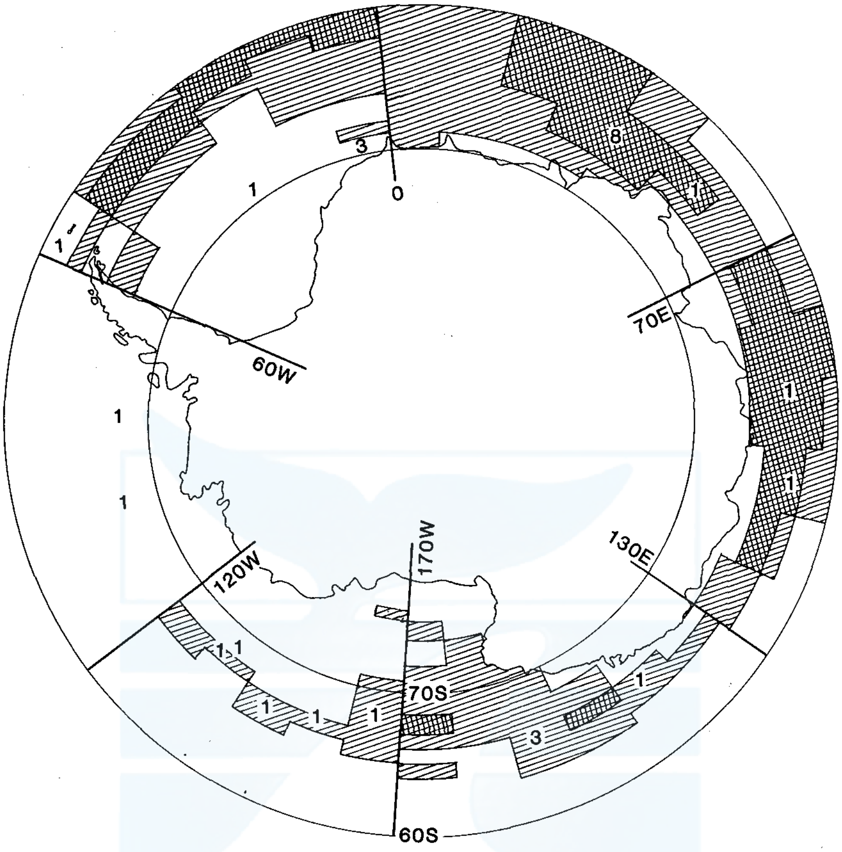

Fig. 2. The distribution of pelagic catches of blue whales south of 60°S from 1931/32 over the period 24 December to 18 February by groupings of 10 degrees of longitude and one degree of latitude. Cross hatched regions are rectangles in which over 500 were caught over the period, hatched regions are where 50 were caught and blank regions where less than 50 where caught. The numbers represent blue whale schools found on the surveys: deleted as the two figures have been replaced by one.

estimate of 1000 was obtained using the 17 primary sightings seen in over 41,000 miles travelled in a searching mode. The higher figure of 1600 was arrived at by ignoring the distinction between primary and secondary sightings but at the same time not increasing the miles travelled.

The review of previous studies has shown that blue whales dominated the early Antarctic catches until the new year, after which catches of fin whales were more important. Sightings data confirm that blue whales do arrive in the Antarctic earlier than do fin whales, and the lower percentage of blue whales in the catch from January onwards reflects more the arrival of fin whales than the departure of blue whales. Fig. 1 shows the distribution of catches of blue whales south of 60°S and it can be seen that over the periods in which the research cruises operated, late December to mid-February, catches of blue whales reached their peak. It has been shown that whaling regulations would not have distorted this feature and that consequently, it can be concluded that south of 60°S the research took place over the time of maximum catches and probably maximum abundance.

The area over which the sightings estimate apply is mainly south of 60°S but in fact only about 75 per cent of the area is used to obtain the estimate. Large areas are not included particularly between 60° and 65°S from 0°–35°W and between 60° and 64°S from 0°–35°E. Whaling Area IV (70°–130°E) was surveyed from 60°S and between 35° to 60°W the region was surveyed south of 58°S but the rest of the Antarctic was surveyed from latitudes below 60°S. However, the previous literature does not precisely define the distribution and behaviour of blue whales. Mackintosh (1966) referred to blue and fin whales as being similarly distributed and all authors agree that blue whales tend to be relatively more abundant near the ice than are fin whales. Surveys for minke whales have shown significant differences in density between sighting transects along the ice and those over 50 miles away from the ice (Horwood, 1981b), and Ohsumi *et al.* (1970) considered minke whales to be distributed in a similar way to blue whales. Other authors have referred to blue whales as being ice loving and the rather imprecise descriptions of blue whale distribution is summarised by Ruud (1956) who reported that "blue whales are supported to penetrate further into the icy regions than any other species".

The distribution of catches gives a more quantitative representation of blue whale distribution than do the previous comments. Fig. 2 shows the distribution of pelagic catches over the period of the sighting surveys. Over most of the Antarctic the whales were caught over several degrees of latitude and in general an extensive latitudinal distribution can be seen. Over the time period of the surveys 20.2% were caught north of 60°S, some of these would have been pygmy blue whales but, from the position of the catches, they would have been few. It can be seen that over late December to mid-February blue whales are distributed from the ice edge to north of 60°S. Longitudinally there is great variation. The evidence suggests that blue whales did not occur in large numbers from the Antarctic Peninsula westwards to the Ross Sea. From 120°W westwards to about 110°E the AC is further south than throughout the rest of the Antarctic and catches have largely been south of about 64°S. Catches are concentrated to the north in the sectors from 60°W to 70°E with large catches to the north of 60°S from 40°W to 60°E. It would therefore appear that the sightings cruises largely covered an area appropriate for estimating the number of blue whales. In some areas large numbers of blue whales were caught much further north than the ice edge and so the surveys, designed to count numbers of minke whales, expended too much effort along the ice edge. This would have resulted in a higher variance than if the survey had been designed for blue whales. In some locations large catches were taken north of 60°S and the estimates from the surveys neglected this component of the population.

Butterworth and Dudley (1984) discuss possible biasses in their analyses and two aspects are particularly important. Firstly not all whales near to the vessel (strictly on the track line) will be seen. For blue whales long dive times will mean that some will be missed but this is mitigated by large, visible blows. Butterworth and Dudley comment that a correction factor discussed for minke whales of 1.35 still leaves the sightings estimates much lower than others. Secondly the area used is 75% of that south of 60°S. The catch data show that significant numbers of whales are likely to have been neglected mainly from 35°W to 35°E due to the survey area being south of about 64°S in this region. At these longitudes substantial catches were also taken north of 60°S.

It is not clear that a substantial correction factor for whales missed near the ship is warranted and cumulative catches over the survey period, but outside the area used for estimation, are about 35% of the total. The review indicates that the surveys for minke whales took place at a time and in locations appropriate to extending the analysis to blue whales and that any correction factors are unlikely to increase the estimate to that given by Masaki and Yamamura (1978). Consequently, it can be concluded that the estimates provided by Butterworth and Dudley (1984), of between 1000 and 1600 blue whales in 75% of the area south of 60°S, are the most reliable to date and that previous estimates were too high. If cumulative catches are used to raise the estimates to blue whales in the area south of 40°S then this still yields a population estimate of less than 2000 animals.

REFERENCES

BEST, P.B. and S. OHSUMI, 1980. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR). Southern minke whale assessment cruise, 1978–79. *Polar Rec.*, 20 (124): 52–57.

BUTTERWORTH, D.S. and S.F.J. DUDLEY, 1984. An estimate of the Antarctic blue whale population from sighting data from the IWC/IDCR cruises. Paper SC/36/PS 11 presented to the IWC Scientific Committee, June 1984 (unpublished). 10pp.

CHAPMAN, D.G., 1964. Reports of the Committee of Three Scientists on the special scientific investigations of the Antarctic whale stocks. *Rep. int. Whal. Commn*, 14: 32–106.

GAMBELL, R., 1976. Population biology and the management of whales. *Appl. Biol.*, 1: 247–343.

GULLAND, J.A., 1981. A note on the abundance of Antarctic blue whales. *FAO Fish. Ser. (5)* (Mammals in the Seas), 3: 219–228.

HJORT, J., 1920. Memorandum on the distribution of the whales in the waters about the Antarctic Continent (1914). Appendix 13. pp95–106. *In*: Report of the Interdepartmental Committee on Research and Development in the Dependencies of the Falkland Islands with Appendices, Maps etc. Command Paper 657 H.M.S.O., London 1920. 164pp.

HJORT, J., J. LIE, and J.T. RUUD, 1932. Norwegian pelagic whaling in the Antarctic. I. Whaling grounds in 1929–30 and 1930–31. *Hvalrådets Skrifter*, 3: 1–37 + plates.

HJORT, J., J. LIE, and J.T. RUUD, 1933a. Norwegian pelagic whaling in the Antarctic. II. *Hvalrådets Skrifter*, 7(5): 128–152 + plates.

HJORT, J., J. LIE, and J.T. RUUD, 1933b. Norwegian pelagic whaling in the Antarctic. III. The season 1932–33. *Hvalrådets Skrifter*, 8: 1–36 + plates.

HJORT, J., J. LIE, and J.T. RUUD, 1934. Pelagic whaling in the Antarctic. IV. The season 1933–34. *Hvalrådets Skrifter*, 9: 1–59 + plates.

HORWOOD, J.W., 1981a. Management and models of marine multispecies complexes. pp339–360. *In*: C.W. Fowler and T.D. Smith (eds) *Dynamics of Large Mammal Populations*. John Wiley and Sons, New York. 477pp.

HORWOOD, J.W., 1981b. Results from the IWC/IDCR minke working and sightings cruise, 1979/80. *Rep. int. Whal. Commn*, 31: 287–313.

HORWOOD, J.W., P.B. BEST and S. OHSUMI, 1981. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR). Southern Hemisphere minke whale assessment cruise, 1979–80. *Polar Rec.*, 20(129): 565–569.

ICHIHARA, T., 1966. The pygmy blue whale, *Balaenoptera musculus brevicaudata*, a new subspecies from the Antarctic. pp79–113. *In*: *K.S. Norris* (ed) *Whales, Dolphins and Porpoises*. University of California Press, Los Angeles. 789pp.

International Whaling Statistics, 1937. Vol. 8.

International Whaling Statistics, 1961. Vol. 46.

International Whaling Statistics, 1965. Vol. 54.

KELLOG, R., 1928. What is known of the migrations of some of the whalebone whales. *Annual Report of the Smithsonian Institution*: 467–494.

MACKINTOSH, N.A., 1965. *The Stocks of Whales*. Fishing News (Books) Ltd., London. 232pp.

MACKINTOSH, N.A., 1966. The distribution of southern blue and fin whales. pp125–144. *In*: K.S. Norris (ed) *Whales, Dolphins and Porpoises*. University of California Press, Los Angeles. 789pp.

MACKINTOSH, N.A. and S.G. BROWN, 1956. Preliminary estimates of the southern populations of the larger baleen whales. *Norsk Hvalfangst-Tid*, 45(9): 467–480.

MASAKI, Y. and K. YAMAMURA, 1978. Japanese pelagic whaling and whale sightings in the 1976/77 Antarctic season. *Rep. int. Whal. Commn*, 28: 251–262.

NEMOTO, T., 1959. Food of baleen whales with reference to whale movements. *Sci. Rep. Whales Res. Inst.*, 14: 149–290.

NISHIWAKI, M. and K. HAYASHI, 1950. Biological surveys of fin and blue whales taken in the Antarctic season 1947/48 by the Japanese fleet. *Sci. Rep. Whales Res. Inst.*, 3: 132–190.

NISHIWAKI, M. and T. OYE, 1951. Biological investigation on blue and fin whales caught by the Japanese Antarctic whaling fleets. *Sci. Rep. Whales Res. Inst.*, 5: 91–167.

OHSUMI, S., Y. MASAKI and A. KAWAMURA, 1970. Stock of Antarctic minke whales. *Sci. Rep. Whales Res. Inst.*, 22: 75–126.

OMURA, H., 1973. A review of pelagic whaling operations in the Antarctic based on the effort and catch data in 10° squares of latitude and longitude. *Sci. Rep. Whales Res. Inst.*, 25: 105–204.

RACOVITZA, É.G., 1903. *Cétacés. Résultats du Voyages du S.Y. Belgica en 1897–99*. Imprimerie J.-E. Buschmann, Anvers. 142pp.

RUUD, J.T., 1956. The blue whale. *Scient. Am.*, 195: 46–50.

SLIJPER, E.J., 1962. *Whales*. Hutchinson, London. 475pp.

TILLMAN, M.F. and S. OHSUMI, 1981. Japanese Antarctic pelagic whaling prior to World War II: Review of catch data. *Rep. int. Whal. Commn*, 31: 625–627.

TØNNESSEN, J.N. and A.O. JOHNSEN, 1982. *The History of Modern Whaling*. C. Hurst, London. 798pp.

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

AN ANALYSIS OF FOUR LARGE ACCUMULATIONS OF SPERM WHALES OBSERVED IN THE MODERN WHALING ERA

ROBERT A. PATERSON*

ABSTRACT

The phenomenon of large accumulations of sperm whales has been reported only occasionally in the modern whaling era. This paper details four such observations and it is suggested that the available evidence does not strongly support the previously advanced explanations viz. that the accumulations are due to migrations towards feeding or breeding grounds or are the result of social disruption arising from whaling operations.

INTRODUCTION

The occasional occurrence of large numbers of sperm whales was reported by open-boat whalers in the sailing era and was termed "making a passage" (Bennett, 1840; Bullen, 1902). Colnett (1798) considered that sperm whales, observed "making a passage" towards the Galapagos, were going there to breed. This paper discusses four sightings of large numbers of sperm whales made in this century. In view of the relative rarity of such reports it is considered opportune to detail them in full.

REPORTS

Tomilin (1936) noted that he had received a report from Otto Kraul who, in 1912–13 between latitudes 42°–50°S off the Patagonian coast, encountered a colossal herd of sperm whales. They numbered 3,000–4,000, were of both sexes and included calves and juveniles. Kraul, who said this herd was the largest he had ever seen, had extensive whaling experience both as a gunner and expedition manager in both hemispheres and was one of the founders of modern German whaling (Tønnessen and Johnsen, 1982).

The following letter, from William D. Boyer, the third officer of the steamer *Daulton Mann*, was published in *Natural History* (Boyer, 1946):

> During a recent voyage along the west coast of South America this vessel encountered an unusually large school of sperm whales. They seemed to

---

* *P.O. Box 397, Indooroopilly, Queensland, Australia, 4068.*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 167–172

> be, as far as we could determine, in some sort of mass migration. At the suggestion of the ship's Captain, who has sailed this coast for many years and has seen nothing that could compare with this, I shall describe what we observed.
>
> On the morning of August 28, 1945, we were northbound off Aguja Cape, Peru approximately 6°S, 82°W. Shortly before 9.00 a.m. individual groups of from two to six sperm whales were seen dotting the visible surface of the ocean. They were all travelling south. A short while later the number of groups increased until the entire ocean, to all visible limits of the horizon, seemed spotted with them. The sum total was a school of gigantic proportions – all headed south. It took the vessel nearly an hour to travel through the main body of the school, and the ship was proceeding north at full speed. Several times a collision with a whale was narrowly averted, as they apparently held little fear of the ship and as often as not would stay on the surface rather than sound. This afforded close inspection and positive identification of the whales.
>
> During the remainder of the morning small groups or single straggling whales were seen, the last of them being sighted shortly after noon. It is impossible to estimate the number of whales in the school, because the east and west limits could not be ascertained. However, approximately 400 to 600 whales were to be seen at one time from the centre of the school and it can safely be assumed that the entire school consisted of well over 1,000 whales.
>
> I hope that this information may be of interest to you.
>
> I might add that among all the professional seamen aboard, no one had ever seen a similar sight.

During whaling operations off Durban, South Africa in July 1972 aerial searchers reported:

> A most unusual trek of sperm whales was encountered on the 29th of this month. At 0650 that day, two big sperm were found by W26. Searching to the east of the catchers chasing, the aircraft at 0735 found 14 medium sized sperm 15 miles from the catchers, at 105 degrees from Cooper light, 60 miles. Minutes later, the aircraft saw three big sperm 5 miles south of that position. After directing the catchers, the aircraft began a systematic search in the vicinity and soon found three flocks of small sperm. All the whales were trekking between 020 and 045 degrees at speed.
>
> During the following two hours, the aircraft found sperm all along a line running almost parallel to the shelf and extending 40 nautical miles from the position of the aircraft sighting at 0735. This fantastic line of whales comprised 19 separate sightings, with some of the small sperm herds consisting of over 50 whales. In nearly every large flock there were from one to three big bulls, while most flocks included cows with calves.
>
> Our estimate of the total number of whales in this trek is 600, of which 100 were considered to be under catchable size. These figures have been

TABLE 1. COMPARATIVE DETAILS OF THE FOUR SPERM WHALE SIGHTINGS

Location	Patagonia	Aguja Cape	Durban	Tasman Sea
Date	1912–13	28 August 1945	29 July 1972	25 February 1978
Lunar phase	Unknown	5 days after full moon	3 days after full moon	2 days after full moon
Observation method	Ship	Ship	Aerial	Ship
Effect of observation method on whale behaviour	Not recorded	None	None	None
Relation to whaling operations	Unknown	No	Yes	No
Directional uniformity	Not recorded	Yes	Yes	Yes (with exception of one individual)
Estimated numbers	3,000–4,000	1,000	600–700	Not estimated

> confirmed by the catch Leader. In this connection, we feel it is relevant to draw attention to the fact that on many occasions up to 20 percent more whales than the number sighted by the aircraft come to the surface when the catchers reach the whales and start chasing. This applies particularly to herds of small sperm, so that the estimated 600 whales seen on the 29th could represent an actual total of over 700.

Peter S. Cosgrave a marine engineer of Sydney, Australia observed a large concentration of sperm whales in the Tasman Sea and his sighting was reported by Paterson (1981):

> I was bringing a 60 foot twin-diesel vessel from New Zealand to Sydney. On the morning of 25 February 1978, in calm, clear conditions which gave perfect visibility, we sighted whales spouting from horizon to horizon. Distance of observation varied from 10 feet to the horizon and all but one appeared north-bound. The ones closest to us appeared to be mostly in the 25-35 feet range, their colour was a light mid-grey with the dorsal fin somewhat aft of amidships. We continued crossing this stream of whales for the greater part of the day and while I did not time this precisely it covered a period of some seven to eight hours.
>
> Our course was from east to west and our position by observation was 36°S, 156°E. The sighting continued until after we had passed 155°E, indicating that the stream was some 70 miles in width. This position, as you will observe on a chart, is approximately 240–250 miles east of Jervis Bay. I have spent a good deal of time at sea around the world and never before or since have I seen such a concentration of whales. I could not attempt to estimate the numbers; while naturally they were not packed like cattle in a yard, I can only say that at any time one chose to make a 360° sweep one would sight 10 to 18 spouts simultaneously.

In each report, irrespective of the observer's occupation, the impression is conveyed that the sightings were a dramatic event. The sightings were widely separated in time and before discussing their possible significance it is useful to tabulate the comparative data (Table 1).

DISCUSSION

Reports of large accumulations of sperm whales, detailed by Caldwell Caldwell and Rice, (1966) have been relatively uncommon given the world-wide extent of sperm whaling in the last two hundred years. It is possible that details of such sightings have been recorded, but not published. In that regard, it is of note that two of the four reports listed above came from mariners unassociated with the whaling industry. The numerical estimates of open-boat whalers may have been limited because of their pre-occupation with whaling operations or attempts thereat in vessels whose courses were dictated in part by prevailing winds.

In samples of 766 and 1,397 schools of sperm whales, the maximum school sizes reported were 120 (Ohsumi, 1971) and 200 (Gambell, 1972) respectively, while Best (1979) noted that sightings on whaling grounds of school sizes in excess of 100 had become uncommon. It is necessary to consider if the large numbers in the four sightings in this paper represented an unusual aggregation of normal schools or the formation of a super-school, with loss of normal social organization. The sighting reports will be examined to see if they match earlier suggestions that such events were due to mass migration associated with breeding or feeding or to disruption of normal social groupings because of whaling operations.

The Durban sighting, recorded by aerial observers cooperating with whale chasers, is understandably the most detailed with regard to school composition. It appears that there was an accumulation of normal sized schools rather than the formation of a super-school. Comments by the observers such as “a most unusual trek” and “fantastic line of whales” suggest that the events were not those expected during whaling operations, even though sperm whales had been caught off Durban since 1912 and the spotter company had been operating there since 1954. There is no indication if the sighting off the Patagonian coast was associated with whaling operations but those off Aguja Cape and in the Tasman Sea were not. However, large catches of sperm whales, including almost 15,000 animals by pelagic fleets (Garrett, 1980), had been taken off the coast of Peru from 1936 to 1943. Nevertheless, the rarity of such sightings suggests that even if social disruption is the cause, its effects could only be short-lived.

The sightings occurred within latitudes where nursery and harem schools (Ohsumi, 1971) could be expected, although the three dated records occurred outside the peak of the breeding season (October to December) in the southern hemisphere (Best, Canham and Macleod, 1984). It is unlikely therefore that the whales were massed for the purpose of migration to a breeding ground. Details of the observation time off the Patagonian coast are lacking but the whales in the other reports were observed for some hours only and their destinations were not determined.

Holm and Jonsgård (1959) analysed the extensive data available from Norwegian sperm whaling operations in Antarctic waters and noted that catches were greatest near oceanic banks at the phases of new and full moon when greater amounts of squid may have been available. Catches were lowest in the period of the waning moon. A daily catch was considered to be large if 30-40 whales were taken and there was no report of large schools seen by the Norwegians in Antarctic waters during the years 1950-1956.

In the three reports of known date in the present study the observations were made at intervals of two, three and five days after the day of full moon. (The phases of new and full moon comprise seven days, three days before the moon is new or full, the day of new or full moon and three days after.) The steady, uni-directional movement of the whales during the periods of observation suggests that they were not likely to be engaged in feeding.

ACKNOWLEDGEMENTS

Dr P.B. Best has been most helpful with his advice and has kindly allowed publication of the report from Rennies Oceanic Pty Ltd of the Durban sighting. Mr P.S. Cosgrave patiently answered my questions in relation to the Tasman Sea sighting. Ms L. Macfarlane of the Old Royal Observatory, London provided the information concerning lunar phases and Mrs N. Murarenko translated from Russian the report from the Patagonian coast.

REFERENCES

Bennett, F.D., 1840. *Narrative of a whaling voyage around the globe from the years 1833 to 1836*. Richard Bentley, London, 2 Vols.

Best, P.B., 1979. Social organisation in sperm whales, *Physeter macrocephalus*. pp. 227–289. *In*: H.E. Winn and B.L. Olla (ed) *Behaviour of marine animals, Vol.3*. Plenum Press, New York. 438 pp.

Best, P.B., P.A.S. Canham, and N. MacLeod, 1984. Patterns of reproduction in sperm whales, *Physeter macrocephalus*. *Rep. int. Whal. Commn* (Special issue 6): 51–79.

Boyer, W.D., 1946. Letter to the editor. *Nat. Hist.*, 55: 96.

Bullen, F.T., 1902. *The cruise of the Cachalot*. Macmillan, London. 379 pp.

Caldwell, D.K., M.C. Caldwell and D.W., Rice, 1966. Behaviour of the sperm whale, *Physeter catodon* L. pp. 677–717. *In*: K.S. Norris (ed.) *Whales dolphins and porpoises*. University of California Press, Berkeley. 789 pp.

Colnett, J., 1798. *A voyage to the South Atlantic and round Cape Horn into the Pacific Ocean for the purpose of extending the Spermacetti Whale Fisheries and other objects of commerce, by Captain James Colnett of the Royal Navy, in the ship Rattler*. W. Bennett, London.

Gambell, R., 1972. Sperm whales off Durban. *Discovery Rep.*, 35: 199–358.

Garrett, T., 1980. Pelagic whaling off the 'Coast of Peru' 1936–1954. Statistical material compiled by T. Garrett. *Rep. int. Whal. Commn* (Special issue 2): 134–136.

HOLM, J.L., and E. JONSGÅRD, 1959. Occurrence of the sperm whale in the antarctic and the possible influence of the moon. *Norsk Hvalfangst-Tid.*, 48: 161–182.

OHSUMI, S., 1971. Some investigations on the school structure of sperm whale. *Sci. Rep. Whales Res. Inst.*, 23: 1–25.

PATERSON, R., 1981. 'Whale watch' brings encouraging reports. *Aust. Fish.*, 40 (4): 30–33.

TOMILIN, A.G., 1936. Cachalots of Kamchatka Sea. *Zool. Zhur.*, 15: 483–519.

TØNNESSEN, J.N., and A.O. JOHNSEN, 1982. *The history of modern whaling.* Hurst and ANUP, London and Canberra. 798 pp.

FEMALE SEXUAL MATURITY AND DELAYED IMPLANTATION PERIOD OF THE KURIL SEAL

SHINICHI HAYAMA*†, MASATSUGU SUZUKI*, HIROYUKI UNO**
AND TADAYUKI YAMASHITA*

ABSTRACT

Sexual maturity and period of delayed implantation were studied in female kuril seal (*Phoca vitulina stejnegeri*) in Nemuro Peninsula, Hokkaido from 25 September to 1 December in 1982 and from 14 September to 1 December in 1983.

Average ages at the first ovulation and first pregnancy were calculated at 3.7 and 4.6 years respectively using the technique of DeMaster (1978). Furthermore, pregnancy rate in relation to the age was estimated and it was found out that 90.9% of the female Kuril seals at 6 years and older were pregnant.

The period of delayed implantation was estimated by the growth curve of the fetus and the presence of 3 newly implanted embryos, and this indicated that implantation occurred primarily in the late part of September. From this observation, it appears that the period of delayed implantation is approximately around 3 months because mating takes place in June.

INTRODUCTION

The kuril seal (*Phoca vitulina stejnegeri* Allen, 1902) is a synonym of *Phoca kurilensis* Inukai, 1942 (Shaughnessy and Fay, 1977), and is distributed from the Northern Kuril Islands to the Pacific coast of eastern Hokkaido. The population in the Kuril Islands was estimated at less than 2,000–2,500 including those in Shikotan and Habomai Islands (Belkin, 1964), while that in eastern Hokkaido at 200–250 (Niizuma, Naito, Itoo, Wada, Abe, Ohtaishi and Nishiwaki, 1980).

The age at sexual maturity in females is important in the conservation of this species and from the point view of general biology. However, there are no such data on the eastern Hokkaido population of Kuril seals. The purpose of this study is to determine the average ages at the first ovulation and pregnancy, and the period of delayed implantation in the Kuril seal.

---

* *Department of Veterinary Anatomy, Obihiro University of Agriculture and Veterinary Medicine, Obihiro, Hokkaido, 080 Japan.*

** *Institute of Applied Zoology, Faculty of Agriculture, Hokkaido University, Sapporo, Hokkaido, 060 Japan.*

† *Present address: Laboratory of Wild Animal Medicine, Nippon Veterinary and Zootechnical College, Musashino, Tokyo, 180 Japan.*

Sci. Rep. Whales Res. Inst.,
No. 37, 1986, 173–178

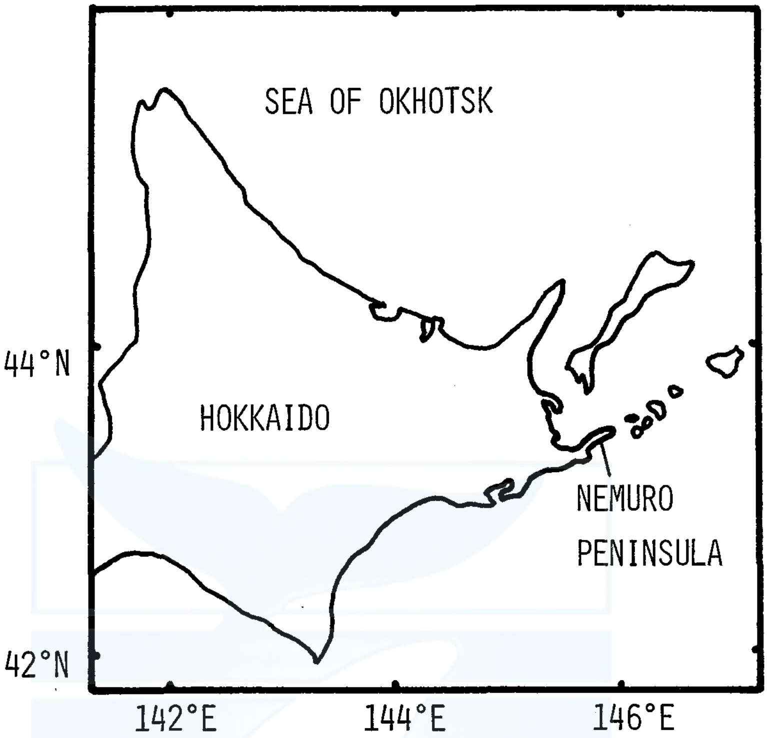

Fig. 1. Sampling was performed in Nemuro Peninsula.

MATERIALS AND METHODS

The field work was conducted at Nemuro Peninsula of eastern Hokkaido from 25 September to 1 December in 1982 and 14 September to 1 December in 1983. A total of 113 female Kuril seals and 29 fetuses used in this study were obtained from those caught accidentally by the salmon trap nets (Fig. 1).

The ovaries were collected and preserved in 10% formalin. Using routine procedures, ovaries were embedded in paraffin, and sections of 10 μm in thickness were taken at every 500 μm interval. These sections were deparaffinized and stained with aldehyde-fuchsin and Masson's trichrome staining method modified by Goldner (1938).

The number and size of corpora lutea and corpora albicantia were recorded. The body length of fetuses was measured from the tip of snout to the end of tail on straight line along the body axis in millimeter. The age was estimated by counting cementum annuli in the canine tooth after being decalcified, and stained with hematoxylin (Mansfield and Fisher, 1960; Bigg, 1969; Naito and Nishiwaki, 1972).

DeMaster (1978) presents a technique to calculate the average age of sexual maturity for marine mammals. The estimate of the average age of sexual maturity in female is as follows:

$$f(x) = t(x)/n(x),$$

where x = age of female, $f(x)$ = estimated probability of ovulating at or before age x, $t(x)$ = number of females in sample of age x who have ovulated, and $n(x)$ = number of females of age x in sample. With this definition of $f(x)$, the estimated probability of first ovulating at age x is,

$$P(x) = f(x) - f(x-1),$$

where $P(x)$ = estimated probability of first ovulation at age x. The average age of sexual maturity is then calculated as,

$$\bar{x} = \sum_{x=0}^{w} (x)\, P(x),$$

where $\bar{x}$ = average age of sexual maturity and w = maximum age in sample.

In addition to estimating the average age of sexual maturity, this procedure can be used to estimate the average age of first pregnancy. However, because the probability of a female being pregnant may never reach unity, there exists a positive probability that at age x a female will reproduce for the first time, even if the difference between the probability of being pregnant for two consecutive age-classes is 0. Therefore, the estimate of the average age at first pregnancy is,

$$z(x) = y(x)/n(x),$$

where $z(x)$ = estimated probability of being pregnant at age x, $y(x)$ = number of females pregnant at age x in sample, and $n(x)$ = number of females in sample. For $x \leqq$ a, where a equals the age at which $z(x)$ reaches its maximum,

$$r(x) = z(x) - z(x-1),$$

where $r(x)$ = estimated probability that a female is first pregnant at age x, and for $x >$ a,

$$r(x) = z(a)\ (1-z(x))^{x-a}$$

The average age at first pregnancy is calculated as before, except that $r(x)$ replaces $P(x)$, and $z(x)$ replaces $f(x)$.

RESULTS AND DISCUSSION

The youngest mature (having experienced ovulation) and the oldest immature appeared at the age of 2 and 4 years respectively (Table 1). Average age at first ovulation was 3.7 years. Average age at the first pregnancy was 4.6 years and the apparent pregnancy rate of females at 6 years or older (n=22) was 90.9%.

In Table 2, the average age at sexual maturity of female harbour seal (*Phoca vitulina richardsi*) was calculated using the data of Bigg (1969, British Columbia), Pitcher (1977, Prince William Sound), and Pitcher and Calkins (1979, the Gulf of Alaska). Due to the limited sample size of the present study, the difference between the two subspecies may not be significant.

The period of delayed implantation in harbour seals was estimated previously as 11 weeks (Fisher, 1954), 2 to 3 months (Harrison, 1960), 2 months (Bigg, 1969), and 11 weeks (Pitcher and Calkins, 1979).

TABLE 1. NUMBER OF OVULATED (NON-PREGNANT) OR PREGNANT FEMALES

Year	1982			1983			Total no. females
Age	No. female samples	Ovulated	Pregnant	No. female samples	Ovulated	Pregnant	
0	14	0	0	23	0	0	37
1	1	0	0	12	0	0	13
2	2	1	0	8	1	1	10
3	9	2	0	10	1	4	19
4	5	1	1	3	1	2	8
5	2	1	1	2	0	2	4
6	4	0	4	0	0	0	4
7	2	0	2	0	0	0	2
8	1	0	1	0	0	0	1
9	1	0	1	0	0	0	1
10	1	1	0	1	0	1	2
10+	3	0	3	9	1	8	12
TOTAL	45	6	13	68	4	18	113

TABLE 2. AVERAGE AGES (YEAR) AT THE FIRST OVULATION AND PREGNANCY OF HARBOUR SEALS COLLECTED IN BRITISH COLUMBIA (BIGG, 1969), PRINCE WILLIAM SOUND (PITCHER, 1977), THE GULF OF ALASKA (PITCHER AND CALKINS, 1979), AND KURIL SEALS IN HOKKAIDO

	Hokkaido	British Columbia	Prince William Sound	Gulf of Alaska
First ovulation	3.7	3.3	3.7	5.0
First pregnancy	4.6	3.3	4.4	5.6

The relationship between fetal length (Y in cm) and the date of catching (X, number of days after the 1st of October) for the present 29 data is expressed by the following least squares regression (Fig. 2).

$$Y = 3.91\ X + 28.04 \qquad r = 0.898$$

This regression cuts the axis of time at −8 (22 September) when implantation seems to occur. Mating takes place in June in this population (Naito and Nishiwaki, 1972), and this was confirmed when 3 mature female kuril seals collected between 24 September and 29 September had newly implanted embryos.

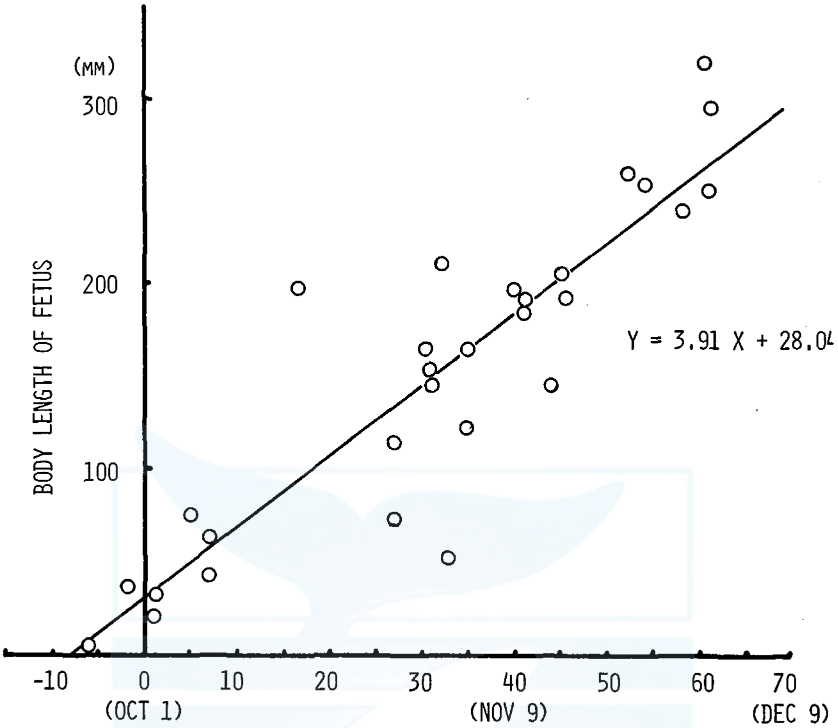

Fig. 2. The growth curve of prenatal Kuril seal.

ACKNOWLEDGEMENTS

Mr J. Shimazu, Shimazu Fur Co., Mr N. Kanazawa Fur Co. and Mr S. Taguchi, Kyouei Fisheries Co. helped us in collecting specimens. Drs J. Yamada and N. Kitamura, Department of Veterinary Anatomy, Obihiro University of Agriculture and Veterinary Medicine, gave us valuable advice. Mr N. Hachiya, Faculty of Department of Dentistry, Hokkaido University, helped us in age determination. Dr A.A. Rayos, Department of Veterinary Obsterics and Gynecology, Obihiro University of Agriculture and Veterinary Medicine, made careful revision to the manuscript. The members of the Marine Mammal Research Group and the Kuril Seal Research Group gave us their help and kind advice. We wish to express our sincere gratitude to all these persons.

This work was primarily supported by Nippon Life Insurance Foundation.

REFERENCES

Belkin, A.N., 1964. A new species of seals, *Phoca insularis* sp. n. from the Kuril Islands. *Doklady Akad, Nausk SSSR.*, 158(2): 1217–1220 (in Russian).

Bigg, M.A., 1969. The harbour seal in British Columbia. *Bull. Fish. Res. Bd. Can.*, 172: 33.

DeMaster, D.P., 1978. Calculation of the average age of sexual maturity in marine mammals. *J. Fish. Res. Bd. Can.*, 35: 912–915.

Fisher, H.D., 1954. Delayed implantation in the harbour seal, *Phoca vitulina. Nature, Lond.*, 173: 879–880.

Goldner, J., 1938. A modification of the Masson trichrome technique for routine laboratory purpose. *Amer. J. Path. Bd.*, 14: 237–243.

Harrison, R.J., 1960. Reproduction and reproductive organs in common seals (*Phoca vitulina*) in the Wash. East Anglia. *Mammalia.*, 24: 372–385.

Mansfield, A.W. and H.D. Fisher, 1960. Age determination in the harbour seal, *Phoca vitulina. Nature, Lond.*, 186: 192–193.

Naito, Y. and M. Nishiwaki, 1972. The growth of two species of the harbour seal in the adjacent water of Hokkaido. *Sci. Rep. Whales Res. Inst.*, 24: 127–144.

Niizuma, A., Y. Naito, T. Itoo, K. Wada, H. Abe, N. Ohtaishi and M. Nishiwaki, 1980. Number and present status of the Kuril seal, *Phoca kurilensis* Inukai 1942, along the Pacific coast of the eastern Hokkaido. *J. Mammal. Soc. Japan.*, 8(2,3): 97–104.

Pitcher, W.K., 1977. Population productivity and food habits of harbour seals in the Prince William Sound-Copper River Delta area, Alaska. *Final report to U.S. Marine Mammal Commission No. MMC-75103. USDC NITS.* PB-226 935: 36.

Pitcher, W.K. and D.G. Calkins, 1979. Biology of the harbour seal, *Phoca vitulina richardsi,* in the Gulf of Alaska. *Final report prepared by U.S. Dept. Interior Bureau of Land Management.* 72 pp.

Shaughnessy, P.D. and F.H. Fay, 1977. A review of the taxonomy and nomenclature of North Pacific Harbour seals. *J. Zool., Lond.,* 182: 385–419.

THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE, TOKYO, JAPAN

NUMBER 1, JUNE 1948

NUMBER 2, DECEMBER 1948

NUMBER 3, FEBRUARY 1950

NUMBER 4, AUGUST 1950

NUMBER 5, JUNE 1951

NUMBER 6, DECEMBER 1951

NUMBER 7, JULY 1952

NUMBER 8, JUNE 1953

NUMBER 9, JUNE 1954

Fujino, K. On the body proportions of the fin whales (*Balaenoptera physalus* (L)) caught in the northern Pacific Ocean (I) (Preliminary report). 121–163

Nishiwaki, M., T. Hibiya and S. Kimura. On the sexual maturity of the sei whale of the Bonin waters. 165–177

Uda, M. Studies of the relation between the whaling grounds and the hydrographical conditions (I). 179–187

NUMBER 10, JUNE 1955

Hosokawa, H. Cross-sections of a 12-mm. dolphin embryo. 1–68

Nemoto, T. White scars on whales (I) Lamprey marks. 67–77

Omura, H. and T. Nemoto. Sei whales in the adjacent waters of Japan. III. Relation between movement and water temperature of the sea. 79–87

Omura, H., K. Fujino and S. Kimura. Beaked whale *Berardius bairdi* of Japan, with notes of *Ziphius cavirostris*. 89–132

Fujino, K. On the body weight of the sei whales located in the adjacent waters of Japan (II.) 133–141

Nishiwaki, M. On the sexual maturity of the Antarctic male sperm whale (*Physeter catodon* L.). 143–149

Ohta, K., T. Watarai, T. Oishi, Y. Ueshiba, S. Hirose, T. Yoshizawa, Y. Akikusa, M. Satô and K. Okano, Composition of fin whale milk. 151–167

NUMBER 11, JUNE 1956

Omura, H. and H. Sakiura. Studies on the little piked whale from the coast of Japan. 1–37

Nishiwaki, M., T. Hibiya and S. Kimura. On the sexual maturity of the sperm whale (*Physeter catodon*) found in the North Pacific. 39–46

Fujino, K. On the body proportions of the sperm whales (*Physeter catodon*). 47–83

Fujino, K. On the serological constitution of the fin whales II. Further studies on blood groups. 85–98

Nemoto, T. On the diatoms of the skin film of whales in the northern Pacific. 99–132

Hoshina, T. and Y. Sugiura. On a skin disease and a nematode parasite of a dolphin, *Tursiops truncatus* (Montagu, 1821). 133–138

Iwai, E. Descriptions on unidentified species of dibranchiate cephalopods. I. An oegopsiden squid belonging to the genus *Architeuthis*. 139–151

Iwai, E. Descriptions on unidentified species of dibranchiate cephalopods. II. A cranchiidae squid of the genus *Taonius*. 153–161

Uda, M. and K. Nasu. Studies of the whaling grounds in the northern sea-region of the Pacific Ocean in relation to the meteorological and oceanographic conditions. (Part I). 163–179

Kimura, S. and T. Nemoto. Note on a minke whale kept alive in aquarium. 181–189

Ishikawa, Y. A characteristic property of whale oils concerning the absorption of gases. I. On the absorption of carbon dioxide by whale oils. 191–213

NUMBER 12, JUNE 1957

Omura, H. Osteological study of the little piked whale from the coast of Japan. 1–21

Nishiwaki, M. Age characteristics of ear plugs of whales. 23–32

Nemoto, T. Foods of baleen whales in the northern Pacific. 33–89

Nasu, K. Oceanographic conditions of the whaling grounds in the waters adjacent to Aleutian Islands and the Bering Sea in summer of 1955. 91–101

Kimura, S. The twinning in southern fin whales. 103–125

Ichihara, T. An application of linear discriminant function to external measurements of fin whale. 127–189

NUMBER 13, SEPTEMBER 1958

NUMBER 14, SEPTEMBER 1959

Fujino, K. and John E. Cushing. Blood typing of dried whale erythrocytes with ^{131}I labelled antibody. 101–106

Ichihara, T. Formation mechanism of ear plug in baleen whales in relation to glove-finger. 107–135

Nasu, K. Surface water condition in the Antarctic whaling Pacific area in 1956–57. 137–143

Ohsumi, S. (Kimura). A deformed fin whale foetus. 145–147

Nemoto, T. Food of baleen whales with reference to whale movements. 149–290

Yamada, M. and F. Yoshizaki. Osseous labyrinth of cetacea. 291–304

Nakai, T. Distribution of amino acid in proteins from various parts of whale body. 305–326

NUMBER 15, NOVEMBER 1960

Nishiwaki, M. Ryukyuan humpback whaling in 1960. 1–16

Ohsumi, S. Relative growth of the fin whale, *Balaenoptera physalus* (Linn.). 17–84

Fujino, K. Immunogenetic and marking approaches to identifying subpopulations of the North Pacific whales. 85–142

Nasu, K. Oceanographic investigation in the Chukchi Sea during the summer of 1958. 143–158

Tokita, K. and ECG Research Group. Electrocardiographical studies on bottlenosed dolphin (*Tursiops truncatus*). 159–165

NUMBER 16, MARCH 1962

Omura, H. Bryde's whale occurs on the coast of Brazil. 1–5

Omura, H. Further information on Bryde's whale from the coast of Japan. 7–18

Nishiwaki, M. Ryukyuan whaling in 1961. 19–28

Nemoto, T. A secondary sexual character of fin whales. 29–34

Omura, H., M. Nishiwaki, T. Ichihara and T. Kasuya. Osteological note of a sperm whale. 35–45

Ichihara, T. Prenatal dead foetus of baleen whales. 47–60

Nishiwaki, M. *Mesoplodon bowdoini* stranded at Akita Beach, Sea of Japan. 61–77

Nishiwaki, M. Observation on two mandibles of *Mesoplodon*. 79–82

Sinclair, John. An early dolphin embryo (*Stenella caeruleoalbus*) in serial sections. 83–87

Nemoto, T. Food of baleen whales collected in recent Japanese Antarctic whaling expeditions. 89–103

Uda, M. Subarctic oceanography in relation to whaling and salmon fisheries. 105–119

NUMBER 17, FEBRUARY 1963

Nishiwaki, M., S. Ohsumi and T. Maeda. Change of form in the sperm whale accompanied with growth. 1–14

Ohsumi, S., T. Kasuya and M. Nishiwaki. The accumulation rate of dentinal growth layers in the maxillary tooth of the sperm whale. 15–35

Ichihara, T. Photometric method for counting laminae in ear plug of baleen whale. 37–48

Yoshikawa, T. and T. Suzuki. The lamination of the masseter of the humpback whale. 49–52

Fujino, K. Intra-uterine selection due to maternal-foetal in compatibility of blood type in the whales. 53–65

Cushing, John E., K. Fujino and N. Calaprice. The Ju blood typing system of the sperm whale and specific soluble substances. 67–77

Nemoto, T. New records of sperm whales with protruded rudimentary hind limbs. 79–81

Nemoto, T. and K. Nasu. Stones and other aliens in the stomachs of sperm whales in the Bering Sea. 83–91

Nishiwaki, M. Taxonomical consideration on genera of *Delphinidae*. 93–103

Nasu, K. Oceanography and whaling ground in the subarctic region of the Pacific Ocean. 105–155

NUMBER 18, MARCH 1964

NUMBER 19, APRIL 1965

NUMBER 20, SEPTEMBER 1966

Tsuyuki, H. and S. Itoh. Studies on the oils contained in blubber of a southern elephant seal. 213–221

NUMBER 21, JUNE 1969

Omura, H., S. Ohsumi, T. Nemoto, K. Nasu and T. Kasuya. Black right whales in the North Pacific. 1–78

Nishiwaki, M. and Y. Hasegawa. The discovery of the right whale skull in the Kisagata shell bed. 79–84

Ohsumi, S. Occurrence and rupture of varginal band in the fin, sei, and blue whales. 85–94

Hosokawa, H., S. Igarashi, T. Kamiya and K. Hirosawa. Morphological characteristics and myelinization of acoustic system in the dolphins (*Stenella caeruleoalba*). 95–123

Mol, T. and P.J.H. van Bree. A short contribution to the history of whaling in Japan during the 17th century. 125–129

Tsuyuki, H. and S. Itoh. Fatty acid composition of finless porpoise oil. 131–135.

Tsuyuki, H. and S. Itoh. Fatty acid composition of many toothed pilot whale oil. 137–141

NUMBER 22, JUNE 1970

Omura, H., T. Ichihara and T. Kasuya. Osteology of pygmy blue whale with additional information on external and other characteristics. 1–27

Nishiwaki, M. and T. Kasuya. Recent record of gray whale in the adjacent waters of Japan and a consideration on its migration. 29–37

Kasuya, T. and D. W. Rice. Note on baleen plates and on arrangement of parasitic barnacles of gray whale. 39–43

Nishiwaki, M. and T. Kasuya. A Greenland right whale caught at Osaka Bay. 45–62

Nasu, K. and Y. Masaki. Some biological parameters for stock assessment of the Antarctic sei whale. 63–74

Ohsumi, S., Y. Masaki and A. Kawamura, Stock of the Antarctic minke whale. 75–125

Kawamura, A. Food of sei whale taken by Japanese whaling expeditions in the Antarctic season 1967/68. 127–152

Nemoto, T. and K. I. Yoo. An amphipod, *Parathemisto gaudichaudii* as a food of the Antarctic sei whale. 153–158

Tobayama, T., S. Uchida and M. Nishiwaki. Twin foetuses from a blue white dolphin. 159–162

Machida, S. A sword-fish sword found from a North Pacific sei whale. 163–164

Tsuyuki, H. and S. Itoh. Fatty acid components of black right whale oil by gas chromatography. 165–170

NUMBER 23, SEPTEMBER 1971

Ohsumi, S. Some investigations on the school structure of sperm whale. 1–25

Kawamura, A. Influence of chasing time to stomach contents of baleen and sperm whales. 27–36

Kasuya, T. Consideration of distribution and migration of toothed whales off the Pacific coast of Japan based upon aerial sighting record. 37–60

Omura, H. A comparison of the size of vertebrae among some species of the baleen whales with special reference to whale movements. 61–69

Omura, H., M. Nishiwaki and T. Kasuya. Further studies on two skeletons of the black right whale in the North Pacific. 71–81

Nishiwaki, M. and T. Kasuya. Osteological note of an Antarctic sei whale. 83–89

Hosokawa, H. and T. Kamiya. Some observations on the cetacean stomachs, with special considerations on the feeding habits of whales. 91–101

Lugassy, A. A., E. Korostoff and J. L. Rabinowits. Influence of incremental lines upon the compressive strength of sperm whale dentin. 103–110

Nishiwaki, M. and N. Oguro. Baird's beaked whales caught on the coast of Japan in recent 10 years. 111–122

Mizue, K., M. Nishiwaki and A. Takemura. The underwater sound of Ganges river dolphins (*Platanista gangetica*). 123–128

Kasuya, T. and M. Nishiwaki. First record of *Mesoplodon densirostris* from Formosa. 129–137

Kawamura, A. and K. Kashita. A rare double monster of dolphin, *Stenella caeruleoalba*. 139–140

Tsuyuki, H. and S. Itoh. Fatty acid components of Ganges river dolphin oil. 141–147

NUMBER 24, NOVEMBER 1972

Omura, H. An osteological study of the Cuvier's beaked whale, *Ziphius cavirostris*, in the northwest Pacific. 1–34

Nishiwaki, M. and N. Oguro. Catch of the Cuvier's beaked whales off Japan in recent years. 35–41

Nishiwaki, M., T. Kasuya, K. Kureha and N. Oguro. Further comments of *Mesoplodon gingkodens*. 43–56

Kasuya, T. Growth and reproduction of *Stenella caeruleoalba* based on the age determination by means of dentinal growth layers. 57–79

Kasuya, T. and N. Oguro. A new tagging method of dolphins. 81–85

Kasuya, T. Some informations on the growth of the Ganges dolphin with a comment on the Indus dolphin. 87–108

Kasuya, T. and A.K.M. Aminul Haque. Some informations on the distribution and seasonal movement of the Ganges dolphin. 109–115

Tsuyuki, H. and S. Itoh. Fatty acid component of various blubber oil of Ganges River dolphin. 117–125

Naito, Y. and M. Nishiwaki. The growth of two species of the harbour seal in the adjacent waters of Hokkaido. 127–144

Ichihara, T. and K. Yoshida. Diving depth of northern fur seals in the feeding time. 145–148

NUMBER 25, SEPTEMBER 1973

Kasuya, T. Systematic consideration of recent toothed whales based on the morphology of tympano-periotic bone. 1–103

Omura, H. A review of pelagic whaling operations in the Antarctic based on the effort and catch data in 10° squares of latitude and longitude. 105–203

Nasu, K. Results of whale sighting by Chiyoda Maru No. 5 in the Pacific sector of the Antarctic and Tasman Sea in the 1966/67 season. 205–217

Kawamura, A. Food and feeding of sei whale caught in the waters south of 40°N in the North Pacific. 219–236

Ohsumi, S. Find of marlin spear from the Antarctic minke whales. 237–239

Seki, Y. An anatomical study on the lower extension of the dorasl vagal nucleus to the upper cervical cord in the sperm whale. 241–249

Tobayama, T., M. Nishiwaki and H. C. Yang. Records of the Fraser's Sarawak dolphin (*Lagenodelphis hosei*) in the western North Pacific. 251–263

Miyazaki, N., T. Kusaya and M. Nishiwaki. Food of *Stenella caeruleoalba*. 265–275

Nishiwaki, M. Possible vestigial teats of killer whale. 277–278

Williamson, G. R. Counting and measuring baleen and ventral grooves of whales. 279–292

Tsuyuki, H. and S. Itoh. Fatty acid component of blubber oil of Amazon River dolphin. 293–299

Naito, Y. Comparison in colour pattern of two species of harbour seal in adjacent waters of Hokkaido. 301–310

NUMBER 26, NOVEMBER 1974

NUMBER 27, SEPTEMBER 1975

NUMBER 28, OCTOBER 1976

NUMBER 29, DECEMBER 1977

NUMBER 30 DECEMBER 1978

245-247

Yamamoto, Y. and H. Hiruta. Stranding of a black right whale at Kumomi, southwestern coast of Izu Peninsula. 249-251

Klima, M. Comparison of early development of sternum and clavicle in striped dolphin and in humpback whale. 253-269

Omura, H. Preliminary report on morphological study of pelvic bones of the minke whale from the Antarctic. 271-279

Kamiya, T., F. Yamasaki and S. Komatsu. A note on the parathyroid glands of Ganges susu. 281-284

Yamasaki, F., S. Komatsu and T. Kamiya. Taste buds in the pits at the posterior dorsum of the tongue of *Stenella coeruleoalba*. 285-290

Kawamura, A. On the baleen filter area in the South Pacific Bryde's whales. 291-300

Kasuya, T. and M. Nishiwaki. On the age characteristics and anatomy of the tusk of *Dugong dugon*. 301-310

Kagei, N., K. Asano and M. Kihata. On the examination against the parasites of Antarctic krill, *Euphausia superba*. 311-313

NUMBER 31, DECEMBER 1979

Kasuya, T. and K. Kureha. The population of finless porpoise in the Inland Sea of Japan. 1-44

Kasuya, T. and R. L. Brownell Jr. Age determination, reproduction, and growth of Frnaciscana dolphin, *Pontoporia blainvillei*. 45-67

Jurasz, C. M. and V. P. Jurasz. Feeding modes of the humpback whale, *Megaptera novaeangliae*, in southeast Alaska. 69-83

Omura, H. and T. Kasuya. A skull of baleen whale dredged from the Inland Sea of Japan. 85-92

Kamiya, T., T. Tobayama and M. Nishiwaki. Epidermal cyst in the neck of a killer whale. 93-94

Major, P. F. An aggressive encounter between a pod of whales and billfish. 95-96

Kato, H. Carotenoid colored minke whale from the Antarctic. 97-99

Kato, H. Unusual minke whale with deformed jaw. 101-103

Naito, Y. and S. Konno. The post breeding distributions of ice-breeding harbour seal (*Phoca largha*) and ribbon seal (*Phoca fasciata*) in the southern sea of Okhotsk. 105-119

Naito, Y. A record of the bearded seal wandering with special reference to the wandering speed. 121-123

Miyazaki, N., K. Itano, M. Fukushima, S. Kawai and K. Honda. Metals and organochlorine compounds in the muscle of dugong from Sulawesi Island. 125-128

Kamiya, T., S. Uchida and T. Kataoka. Organ weights of *Dugong dugon*. 129-132

Nishiwaki, M., T. Kasuya, N. Miyazaki, T. Tobayama and T. Kataoka. Present ditribution of the dugong in the world. 133-141

NUMBER 32, DECEMBER 1980

Kawamura, A. Food habits of the Bryde's whales taken in the South Pacific and Indian oceans. 1-23

Omura, H. Morphological study of pelvic bones of the minke whale from the Antarctic. 25-37

Hohn, A. A. Age determination and age related factors in the teeth of western North Atlantic bottlenose dolphins. 39-66

Yonekura, M., S. Matsui and T. Kasuya. On the external characters of *Globicephala macrorhynchus* off Taiji, Pacific coast of Japan. 67-95

Nemoto, T., P. B. Best, K. Ishimaru and H. Takano. Diatom films on whales in South African waters. 97-103

Kamiya, T. and P. Pirlot. Brain organization in *Platanista gangetica*. 105-126

Yamasaki, F., S. Komatsu and T. Kamiya. A comparative morphological study on the tongues of manatee and dugong (Sirenia). 127-144

Casinos, A. and J. Bou. On a massive stranding of short-finned pilot whale, *Globicephala macrorhynchus* Gray, 1846, on Margarita Island (Venezuela). 145-148

Mermoz, J. F. A brief report on the behavior of commerson's dolphin, *Cephalorhynchus commersonii*, in Patagonian shores. 149-154

Kawamura, A. A review of food of balaenopterid whales. 155-198

Kawakami, T. A review of sperm whale food. 199-218

NUMBER 33, DECEMBER 1981

Omura, H., T. Kasuya, H. Kato and S. Wada. Osteological study of the Bryde's whale from the central South Pacific and eastern Indian Ocean. 1-26

Miyazaki, N., Y. Fujise and T. Fujiyama. Body and organ weight of striped and spotted dolphins off the Pacific coast of Japan. 27-67

Yamasaki, F. and T. Kamiya. The stomach of the Boutu, *Inia geoffrensis*: comparison with those of other Platanistids. 69-81

Watkins, W. A. Activities and underwater sounds of fin whales. 83-117

Omura, H. and Y. Takahashi. A pygmy sperm whale stranded at Tokaimura, Ibaragi, Japan. 119-124

Aguilar, A., L. Jover and E. Grau. Some anomalous dispositions of the Jacobson's organ in the fin whale. 125-126

Kamiya, T., N. Miyazaki and S. Shiraga. First case of dicephaly in Odontoceti. 127-129

Ohtaishi, N. and M. Yoneda. A thirty four years old male Kuril seal from Shiretoko Pen., Hokkaido. 131-135

NUMBER 34, DECEMBER 1982

Sergeant, D. E. Mass strandings of toothed whales (Odontoceti) as a population phenomenon. 1-47

Nishiwaki, M. The mandible of bowhead in Kathmandu. 49-57

Kawamura, A. Food habits and prey distributions of three rorqual species in the North Pacific Ocean. 59-91

Zhou, K. Classification and phylogeny of the superfamily Platanistoidea, with notes on evidence of the monophyly of the cetacea. 93-108

Nishiwaki, M. and T. Tobayama. Morphological study of the hybrid between tursiops and pseudorca. 109-121

Kato, H. Food habits of largha seal pups in the pack ice area. 123-136

Nishiwaki, M., M. Yamaguchi, S. Shokita, S. Uchida and T. Kataoka. Recent survey on the distribution of the African manatee. 137-147

NUMBER 35, MARCH 1984

Lowry, L. F. and K. J. Frost. Foods and feeding of bowhead whales in western and northern Alaska. 1-16

Singarajah, K. V. Observations on the occurrence and behaviour of minke whales off the coast of Brazil. 17-38

Kato, H. Observation of tooth scars on the head of male sprem whale, as an indication of intra-sexual fightings. 39-46

Seki, Y. Anatomical studies on the cell column located closely medial to the nucleus of the spinal root of the trigeminal nerve in the sperm and the pygmy sperm whales. 47-56

Kasuya, T. and S. Matsui. Age determination and growth of the short-finned pilot whale off the Pacific coast of Japan. 57-91

Miyazaki, N., L. L. Jones and R. Beach. Some observations on the schools of *dalli*- and *truei*-type Dall's porpoise in the northwestern Pacific. 93-105

Kasuya, T. and L. L. Jones. Behaviour and segregation of the Dall's porpoise in the northwestern North Pacific. 107–128

Leatherwood, S., R. R. Reeves, A. E. Bowles, B. S. Stewart and K. R. Goodrich. Distribution, seasonal movements and abundance of Pacific white-sided dolphins in the eastern North Pacific. 129–157

Fordyce, R. E., R. H. Mattlin and J. M. Dixon. Second record of spectacled porpoise from subantarctic Southwest Pacific. 159–164

Yamasaki, F. and K. Kito. A morphological note of the intestine of the Boutu, with emphasis on its length and ileo-colic transition compared with other Platanistids. 165–172

Zhou, K., M. Zhou and Z. Zhao. First discovery of a tertiary Platanistoid fossil from Asia. 173–181

Omura, H., M. Shirakihara and H. Ito. A pygmy sperm whale accidentally taken by drift net in the North Pacific. 183–193

Furuta, M. Note on a gray whale found in the Ise Bay on the Pacific coast of Japan. 195–197

Appendix Measurements of body proportion of the pygmy blue whale, left by The Late Dr Tadayoshi Ichihara. 199–203

NUMBER 36, MARCH 1985

Best, P. B. External characters of southern minke whales and the existence of a diminutive form. 1–33

Marsh, H. Observations on the ovaries of an isolated minke whale: evidence for spontaneous sterile ovulation and structure of the resultant corpus. 35–39

D'Vincent, C. G., R. M. Nilson and R. E. Hanna. Vocalization and coordinated feeding behavior of the humpback whale in southeastern Alaska. 41–47

Seki, Y. Anatomical observations on the lower brain stem of the right whale. 49–87

Kito, K. and F. Yamasaki. Duodenal portion of the hepato-pancreatic duct of the Boutu, *Inia geoffrensis*. 89–95

Crespo, E. A., G. Pagnoni and S. N. Pedraza. Structure of a long-finned pilot whale school stranded in Patagonia. 97–106

Kasuya, T. Effect of exploitation on reproductive parameters of the spotted and striped dolphins off the Pacific coast of Japan. 107–138

Kasuya, T. and S. Shiraga. Growth of Dall's porpoise in the western north Pacific and suggested geographical growth differentiation. 139–152

Brownell, R. L. Jr. and R. Praderi. Distribution of Commerson's dolphin, *Cephalorhynchus commersonii*, and the rediscovery of the type of *Lagenorhynchus floweri*. 153–164

Pinedo, M. C. A note on a stranding of the humpback whale on the southern coast of Brazil. 165–168

NUMBER 37, MARCH 1986

Ohsumi, S. Yearly change in age and body length at sexual maturity of a fin whale stock in the eastern North Pacific. 1–16.

Ohsumi, S. Earplug transition phase as an indicator of sexual maturity in female Antarctic minke whales. 17–30.

Simmons, M. L. and H. Marsh. Sightings of humpback whales in Great Barrier Reef waters. 31–46.

Horwood, J. W. The lengths and distribution of Antarctic sei whales. 47–60.

Kasuya, T. Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. 61–83.

Kasuya, T., T. Tobayama, T. Saiga and T. Kataoka. Perinatal growth of delphinoids: information from aquarium reared bottlenose dolphins and finless porpoises. 85–97.

Yabu, H. and H. Ogi. Chromosome number of two color types of the Dall's porpoise. 99–102.

Reiner, F. First record of Sowerby's beaked whale from Azores. 103–107.

Lichter, A. A. Records of beaked whales (Ziphiidae) from the western South Atlantic. 109–127.

Scarff, J. E. Occurrence of the barnacles *Coronula diadema*, *C. reginae* and *Cetopirus complanatus* (Cirripedia) on right whales. 129–153.

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

SUBJECT INDEX

Body and organ weight

Age determination

Population study

Human activity disturbing whales 29: 113–120
History, whaling 21: 125–129
Color pattern, *Phoca* 25: 301–310
Growth, *Phoca* 24: 127–144
  Tursiops 37: 85–97
  Neophocaena 37: 85–97
Foods, *Phoca* 34: 123–136
Maturity, *Phoca* 37: 173–178
Pelage, *Historiophoca* 28: 187–197
Occurrence, phocid seals 28: 175–185
Distribution, *Phoca* 31: 105–119
  Dugong 31: 133–141
  Trichechus 34: 137–147
Diving depth, *Callorhinus* 24: 145–148
Wandering speed, *Erignathus* 31: 121–123
Gerology 7: 69–77, 8: 103–125, 9: 105–120, 11: 85–98, 13: 171–184, 14: 89–100, 14: 101–106, 15: 85–142, 17: 53–65, 17: 67–77, 18: 1–27

Food and feeding

(See also population study)

Baleen whales 5: 81–90, 12: 33–89, 13: 193–199, 14: 149–290, 16: 89–103, 17: 157–170, 19: 45–51, 20: 109–155, 34: 59–91
Balaena mysticetus 35: 1–16
Balaenoptera borealis 22: 127–152, 22: 153–158, 25: 219–236, 25–144
B. edeni 7: 79–85, 29: 49–58, 32: 1–23
Megaptera novaeangliae 31: 69–83, 36: 41–47
Eschrichtius robustus 22: 39–43
Physeter catodon 5: 81–90, 11: 139–151, 11: 153–161, 18: 111–122, 28: 145–151, 32: 199–218
Orcinus orca 29: 107–111
Stenella coeruleoalba 25: 265–275
Balaenopterids 32: 155–198, 34: 59–91
Largha Seal 34: 123–136
Antarctic fish from stomach 12: 225–233
Stone and alien from stomach 17: 83–91
Stomach content in relation to chasing time 23: 27–36
Energy budge 27: 61–79

Whaling ground, environmental

9: 179–187, 11: 163–179, 12: 91–101, 12: 209–224, 13: 215–229, 14: 137–143, 15: 143–158, 16: 105–119, 17: 105–155, 20: 157–210, 26: 271–287, 27: 141–157
Statistical review 25: 105–203
Pack-ice limit 29: 137–141
Sighting
  By boat 25: 205–217, 26: 289–302, 30: 117–178, 30: 179–195
  By air 23: 37–60

Parasite, scar and skin disease

Diatom 4: 14–26, 11: 99–132, 13: 185–191, 29: 101–105, 32: 97–103
Cyamus 28: 153–160
Barnacle 22: 39–43, 37: 129–153
White scar 10: 69–77, 26: 145–155
Skin disease 11: 133–138
Helminthes 11: 133–138, 28: 161–166
Marlin spear 14: 149–290 (p.252), 22: 163–164, 25: 237–239
Aggressive encounter 31: 95–96
Parasite, *Euphausia* 30: 311–313

Chemical study

Enzyme, stomach 1: 3–7
  pancreas 1: 8–10, 1: 11–14, 2: 55–60, 3: 71–78
Whale meat, peptone 1: 15–16
  freshness 1: 17–26, 1: 28–30, 2: 31–34, 3: 63–70, 5: 1–4, 6: 167–176, 7: 23–30, 7: 31–36, 9: 1–10
  tryptophane 2: 51–54
  digestion 2: 61–66
  nutrition: 7: 51–67
  amino acid 13: 303–317, 14: 305–326
  methionine 3: 102–105
Whale blood 1: 38–40, 3: 96–101, 5: 41–47
Whale milk 10: 151–167
Vitamin 1: 31–37, 2: 35–41, 5: 53–59, 6: 187–191, 7: 47–50
Kitol 3: 85–88, 3: 89–91, 3: 92–95, 5: 49–51, 5: 61–69, 6: 193–198, 7: 47–50
Oil, gas absorption 11: 191–213, 13: 309–321
  molecular distillation 2: 42–45, 2: 46–50
Oil, *Eubalaena* 17: 171–190
  Physeter 3: 79–84, 7: 37–46
  Mirounga 12: 235–240, 13: 323–332, 20: 213–221
Lipid, *Eubalaena* 18: 173–180
Fatty acid composition of oil,
  Eubalaena 22: 165–170
  Neopocaena 21: 131–135, 26: 303–306
  Peponocephala 21: 137–141
  Platanista 23: 141–147, 24: 117–125
  Inia 25: 293–299
  Trichechus 26: 307–311
  Krill 28: 167–174
Metal, *Dugong* 31: 125–128
Organochlorine compounds, *Dugong* 31: 125–126

Miscellaneous

Hybrid 34: 109–121
Hind limb 8: 127–132, 12: 197–208, 17: 79–81,

19: 135–136
Hermaphroditism 8: 215–218
Prenatal dead fetus 16: 47–60
Malformed fetus 12: 193–195, 14: 145–147, 23: 139–140, 26: 259–263
Jacobson's organ 33: 125–126
Dicephaly fetus 33: 127–129
Albino 13: 207–209
Carotinoid body color 31: 97–99
Deformed jaw 13: 211–212, 31: 101–103
Vestigial teat 25: 277–278
Strange organ 27: 139–140
Electrocardiogram, *Tursiops* 15: 159–165
Electric shock 6: 177–185
Compressive strength, dentin 23: 103–110
Flattened head harpoon 6: 199–207

AUTHOR INDEX

THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE

昭和61年3月15日　印刷
昭和61年3月30日　発行

編輯者　財団法人　日本捕鯨協会
鯨類研究所
東京都江東区大島3丁目32番11号

編輯責任者　大村秀雄

印刷者　研究社印刷株式会社
埼玉県新座市野火止7-14-8

Printed by
Kenkyusha Printing Co.
Niiza-shi, Saitama 352

定価　4,000 円

Obtainable from Japan Publication Trading Co. Ltd.,
Sarugakucho, Chiyoda-ku, 1-2-1, Tokyo 101