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Contribution to the Anatomy of the Organ of Hearing of Whales*

By

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* この研究中 *Berardius* の一部および *Physeter* の材料採集には，昭和 25 年度 文部省科学研究費の援助を受けた．なお当時著者は東京大学の大学院学生であつたため，この研究費は形式上小川鼎三教授に交付されたことを附言する（山田致知）．

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Preface

Since Spitzka in 1886, neuro-anatomists have pointed out cetacean sense of hearing to be extremely sensitive from their stand-point as morphologists. It has been recently revealed by Ogawa and Arifuku (1948, p. 12) that there are noteworthy differences between the two cetacean suborders in the acoustic system within the brain stem, and that the odontocete suborder seems to hear far more sensitively than mystacoceti, though the latter seems probably not inferior to the land mammals. They add, in this connection, that discussions on the mystacocete sense of hearing through the study of that of odontoceti are in no way justified. This must be considered in every research concerning whales, ever so much in the present work.

The superior sense of hearing of whales, however, has been seemingly known since far more ancient days because Herodotus wrote in "Persian Wars" a mythological case of Arion and a dolphin which came to his rescue at his enchanting performance on lyre asking for help. According to the myth, Arion was obviously conscious of dolphins to understand his music and believed that one would come to his rescue when he played accordingly. Another case of music-loving dolphins can be quoted from "Daphnis et Chloe". These myths sound to me to be based on some real knowledge of those ancient people rather than fictional origin.

Whaler's experiences, meanwhile, have endorsed this view from their practical side. It has been well known that Faeroe Islanders pursue schools of blackfish shoreward, by firing guns, beating on pans and shouting to frighten them (Kellogg, 1940, p. 70). In the ancient whaling of Japan from fifteenth through the last centuries, they used wooden hammers to beat their boats in making rythmical noise through which they pursued the prey shoreward freely at will for many miles and finally netted and harpooned. In this way, they had caught giant whales such as sperm whale, humpback, gray and right whales. The similar means of pursuing have lasted up to the present to catch blackfish and dolphins among coast whalers of Japan. Laying these particular cases aside, it has been a common sense of whalers that whales are quite sensitive to sounds, and some have tabooed to make any unnecessary noise, even speaking during pursuits. Practically, objections were raised mainly from this stand-point against noise-making Diesel engines to be replaced in whaling catcher boats instead of steam engines. Happily, whales did not mind the sounds of beating engines so much as had been afraid of, and this has led to the successful revolution in whaling history, especially in establishing the so-called pelagic whaling. It remains, however, still doubtful if whales have been perfectly specialized physiologically to hear the water-borne sounds alone and no longer hear the air-borne ones.

It is granted natural that a large number of anatomists as well as cetologists have participated in the anatomy and physiology of the cetacean organ of hearing of extreme specialization, as Home 1812, Camper 1820, Buchanan 1828, Hyrtl 1845, Claudius 1858, Carte and Macalister 1867, Flower 1867, Beauregard 1893-94, Denker 1902, Boenninghaus 1904, Lillie 1910–15, Abel 1912, Hanke 1914, Kernan 1918–19, Kellogg 1928, Hinoura 1938, myself 1948 and others. However, some larger animals were only occasionally obtained and hardly examined, and to the consequence, observations easily became fragmental or superficial, or sometimes worsely mistaken; lesser animals, usually delphinidae representatives, to the contrary, are more convenient to treat and have been practically routine material throughout. Thus from various specific data and various stand-points of each author, serious disputes have been brought to the fore, particularly concerning the problem how the organ functions. Above all, the so-called acoustic isolation of the organ from the skull in odontoceti seems to have waited for the re-confirmation or criticisms of my own because the suborder *was* seriously different from mystacoceti, of which two species of the genus *Balaenoptera*, i. e., gigantic blue whale, *B. musculus* (Linnaeus) and common rorqual or fin whale, *B. physalus* (Linnaeus) first came to my study. In the meantime, Pacific beaked whale, *Berardius bairdii* Stejneger, first odontocete whale in my study, has made me strongly suspicious of the isolation in odontocete suborder, and further strongly did sperm whale, *Physeter catodon* Linnaeus. Finally, I faced to some delphinidae animals, from which the view of isolation had been derived by previous authors. They were bottle-nose, *Tursiops truncatus* (Montague); Risso's dolphin, *Grampus griseus* (Cuvier); blackfish or pilot whale, *Globicephalus sieboldii* (Gray) and finless black porpoise, *Neomeris phocaenoides* (Cuvier). The seemingly isolation in the delphinidae family has been thus revealed to be the more highly specialized form than other odontocete families.

The present work deals mainly with my observations on the possibly many species of variety obtainable here at present as well as discussions pertaining to the isolation, pointing out how dangerous it is to consider of one or minor species, regardless of others, particularly those within category not less than family. It must be confessed at the same time that my observations are not exceptional and fragmental as has been critically mentioned of the past contributors including myself. It is for this reason that other particulars such as the auricular musculature, nerves, blood vessels and wider soft parts altogether are not touched here, because the wholesale preparation is indispensable, which is, however, usually impossible to carry out.

In the meantime, the sensory nerve endings in the external otic region in some species seem to have escaped the previous contributions and will be described simultaneously in the present work. It is of much interest that the vestigial auditory meatus undertakes some new rôle as an independent sensory organ, probably the pressure gauge which must be essential to the cetacean life in the water.

I do not take the present stage of my work as finished because there remain many blanks to be filled up as will be clearly mentioned on each occasion, and also because I would like to have further additions of new species. However, I have only a faint hope that some new animals might bring new data so important in principles as to necessitate some re-writing in a form favorable or unfavorable. The remaining two families of mystacocete suborder, viz., balaenidae and rhachianectidae seem now almost hopeless to meet. Meanwhile, it is another of my enthusiastic desires to examine the fossil cetaceans, particularly archaeoceti, because they may be expected to present more primitive stages of specialization, but this will remain unfulfilled so far as my field of work is constricted in Japan.

Material and Method

Material treated more or less herewith consists of ten genera, representing three families of odontoceti and one of mystacoceti as follows[1]:

Suborder Odontoceti

Family Delphinidae:

1. *Prodelphinus caeruleo-albus* (Meyen) from Kawana
2. *Trusiops truncatus* (Montague) from Taiji
3. *Grampus griseus* (Cuvier) from Taiji
4. *Globicephalus sieboldii* (Gray) from Taiji
   Globicephalus sp., probably *G. scammonii* (Cope) from Ayukawa
5. *Neomeris phocaenoides* (Cuvier) from Yorishima

Family Ziphiide:

6. *Ziphius cavirostris* Cuvier from Taiji and Otohama

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[1] Some other skull specimens in possession of the Department of Anatomy, University of Tokyo, have been studied for simultaneous reference.

7. *Berardius bairdii* Stejneger from Otohama

Family Physeteridae:

8. *Physeter catodon* Linnaeus from Akkeshi
9. *Kogia breviceps* (Blainville) from Taiji

Suborder Mystacoceti

Family Balaenopteridae:

10. *Balaenoptera physalus* (Linnaeus) from Akkeshi and the Southern Ocean
    B. musculus (Linnaeus) from the Southern Ocean
    B. borealis Lesson from Akkeshi

All material has come to me by courtesy of our whalers with exception of *Neomeris* which haunts abundantly in the Inland Sea of Japan. The remaining genera of the family delphinidae except *Prodelphinus* came from Taiji of Kii together with *Kogia* and *Ziphius* during summer seasons of 1951–52. The town has been historically famed since the ancient whaling of Japan was originated there to catch whales by use of nets. The town is now famous of the fishery of minor odontoceti, of which *Globicephalus* is most popular. It seems of much interest of cetology that the unusual pygmy sperm whale, *Kogia* has never been reported from there until 1951, in spite that a certain number has been annually caught (Yamada, 1952). Also rare *Berardius* was examined in 1949–50 at Otohama near Chikura of Awa, and grotesque *Physeter* and sei whale, *Balaenoptera borealis* at Akkeshi, Hokkaido in 1950. Two gigantic and important balaenopterids, i. e., *B. physalus* and *B. musculus* were studied chiefly during two seasons of the Antarctic whaling as 1947–48 and 1948–49 on board a whaler "Nisshin Maru No. 1".

The organ was usually dissected at whaling stations and necessary material has been brought back for further study after fixation in 10% formalin solution. This has resulted the mentioned fragmental observations for the dissection at the whaling stations had to be usually done quickly not to hinder the flensing operation. Now my sincere thanks are indebted to the authorities concerned as well as the friendly workers to their good assistance and co-operation, without which adequate and timely dissection would have been utterly impossible.

Most of the observations was macroscopic, but it was very often necessary to use some instruments as saws, axes, and chisels, and in laboratory work, dental lathe with burs, abrasive points, wheels and discs has been indispensable to fenestrate or to remove the extremely hard and dense bony tissues without destroying the interior or gross relations.

For histology, the sections were stained by haematoxylin and eosin after routine embedding in celloidin, but for staining nerves I applied the pyridine-method of Bielschowsky. Concerning the internal ear, the observations remain insufficient, particularly in histology due to the difficulties to get fresh materials and to prepare the satisfactory sections[1]. It is for these reasons that this region is here put aside.

Chapter 1. External Ear

1. External Ear Hole:

The opening of the external auditory meatus, porus acusticus externus, is in odontoceti so minute that "one can not introduce the lead of a pencil" (Kellogg, 1928, p. 204) through it, as has been described previously by all researchers. The opening is generally situated caudad or ventro-caudad from the eye[2] (fig. 1), but is really so minute

Fig. 1. Position of the external ear hole of various cetaceans. From *top* to *bottom*: *Neomeris*, *Ziphius*, *Kogia*, *Balaenoptera* (*musculus*).

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[1] The preferable fixation by injecting the proper fixatives was impossible. And in the decalicifying procedure, the gas bubbles were quite harmful to the tissues.

[2] In *Kogia* the aperture is situated behind the eye but a little distance above the eye level.

and practically closed that one can hardly recognize it. In *Physeter*, the opening can be probed with less difficulty with a finger around the suspicious spot because there is felt less resistance to pit the finger due to the well developed peri-meatal lymphoid tissues as will be mentioned later. While in *Balaenoptera* of mystacoceti, it is not hard to mark the opening because it is, although small, much wider than odontoceti and often lies in a short and shallow groove which runs horizontally and parallel to the peculiar longitudinal grooves on the throat and chest regions, about halfway from the eye to the anterior edge of the fore limb. The opening is as big, in *B. physalus*, as to admit the little-finger no further than the distal joint. No auricular sign presents outwardly whatever, though one case of "pinna" similar to those described by Howes in *Phocaena* (1879, p. 468; pl. 29, figs. 1–3) presents in the right opening of one *Ziphius*[1], which does not protrude so far as his illustrations (fig. 2). But this structure is not a pinna in its exact literal sense because it is shown microscopically to be a cord of the deciduous epithelium of the auditory meatus, being degenerated in the center. It is doubtful if this is of identical nature with Howes' or not for he wrote that he had "failed to discover aught else than a few fatty connective tissue fibres". Whereas, other lines are read of a foetal *Beluga* as the "pinna" appears to spring from the integument forming the posterior lip of the aperture rather than altogether behind it. This description seems not to exclude the possibility of the deciduous epithelium, while on one hand, it reveals that Howes established the terminology in its original meaning, viz., auricle. Be this structure of *Ziphius* identical with the pinnae of Howes or not, it is of some significance that sometimes the external ear hole of odontoceti happens to be stuffed in this way.

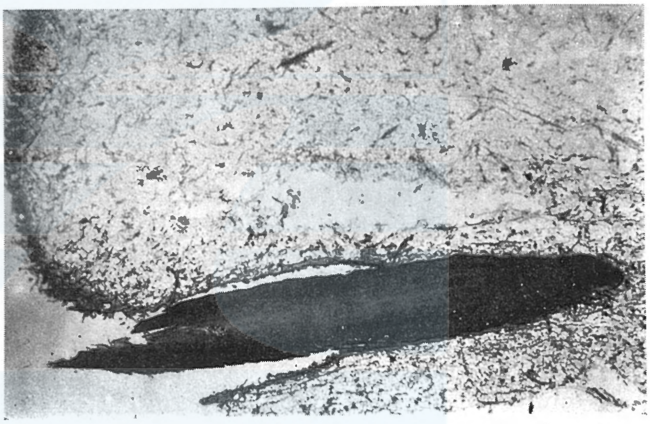

Fig. 2. Pinna-like cord of *Ziphius* protruding from the external aperture (×8).

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[1] This specimen, which came to my study by courtesy of Prof. Ogawa, was caught by a tunny-boat and delivered to him at the fish-market of Tokyo in 1949.

2. External Auditory Meatus:

a. Closure of the Meatus:

It has been well known, as is the case with the external opening, that the external auditory meatus is both in odontoceti and mystacoceti to be extremely vestigial. It is vestigial not only in dimensions but also it is striking that it happens in some whales that the meatus is closed and interrupted during its course. The first reported species in this direction is *Megaptera* by Lillie in 1915. In regard to this problem, I stated suspiciously in my former paper (1948, p. 24) that Lillie (1910) and Hinoura (1938) had overlooked the discontinuance of the meatus, and that Kellogg (1928, p. 204; fig. 24) had seemingly been the only one before me, who was correct in this description. But after my later bibliographic references, I have to correct this because Lillie *en personne*, five years later of his first overlooking in *Balaenoptera*, noticed the perfect closure of the meatus correctly in *Megaptera* (1915, pp. 104–05) and this seems to be original. It is also read in that paper that Burfield and Erik Hamilton noticed the similar closure in *Balaenoptera* (species unknown), but that Carte and Macalister (1867, p. 252) were of opposite opinion in *B. acuto-rostrata*. And for the latter animal, Lillie leaves some question as the closure is easy to overlook, although he states that it may be so in that species. The condition seems same with Hinoura who worked also on the same whale. Also Boas (1912) worked on *B. rostrata* and mentioned that the meatus is continuous but becomes suddenly very narrow under the blubber after presenting the first expansion in the cutis, which expands further noticeably into a large sac right under the blubber. Hanke (1914, p. 492) interpreted this narrowing as was caused by the presence of an unusual cartilage which Boas mentioned.

Concerning the disputes I can agree Lillie, and with stronger presumption I expect the closed meatus throughout the entire family of balaenopteridae to say the least. This is because I added myself in 1950 at Akkeshi, Hokkaido, to the previously reported *B. physalus* (Yamada, 1948, p. 24), a male *B. borealis* of 35-foot length, whose meatus was closed up for an interval of about 19 cm., the lateral portion being 7 cm. and the medial 28 cm., and also because the structure is likewise in *B. musculus* though I have failed to make measurements. The meatus of *Balaena mysticetus* was figured by Gray (1889, p. 301) and recorded as open, but the possibility of the similar closed area is not hereby excluded because the deeper portion has escaped the examination and the lumen of the meatus really goes extremely narrow at the bottom of the blubber. No record of rhachianectidae whales has been known to me.

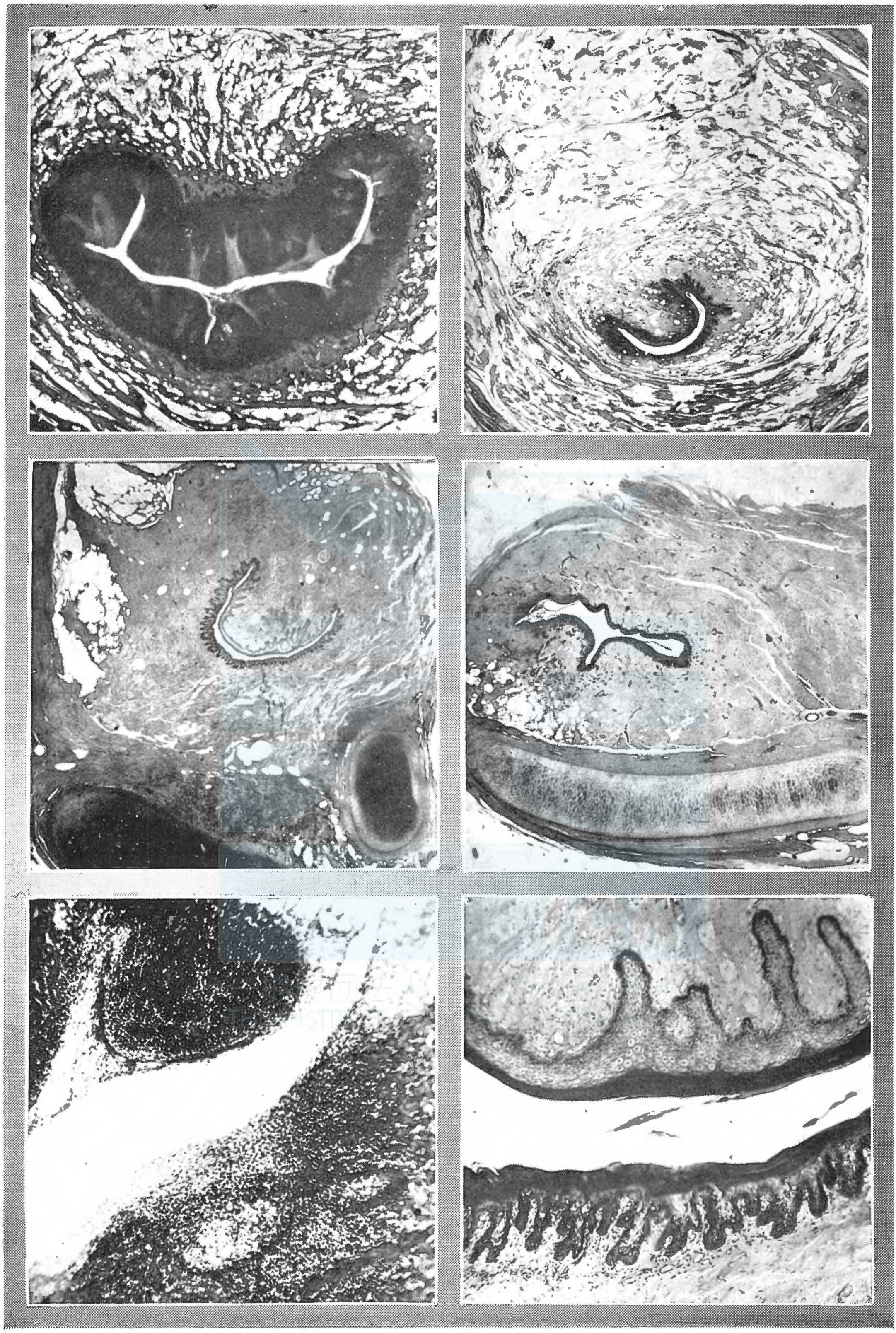
In odontocete whales, on the other hand, any closure of the meatus has never been learned, and it has been widely known that it stretches continuously from the external opening to the tympanic membrane. This has been the settled belief of all authors, but recently a question has been raised by Clarke (1948, p. 979) who established that the meatus of *Physeter* was a short blind sac which penetrated from the external aperture a distance no deeper than the blubber thickness, and which lost altogether the organic connection with the middle ear. This is with no wonder superficial and errorneous as will be revealed later in the following paragraph, but it was good of Clarke that he noticed this because the meatus seems really to end blindly after a little further penetration than his establishment, before it reaches the tympanic membrane.

b. General Peculiarities of the Meatus:

Berardius (fig. 3): The meatus of *Berardius* measures about 16 cm. in length from the external aperture to the tympanic membrane. In frontal section of the head, the course marks somewhat S-shaped slight curve, turning ventrad beneath the squamosal region of the skull after penetrating the blubber, this being seemingly common to all species of cetacea. In the course of the blubber, however, the meatus presents certain complication which seems to be a new knowledge by far. Within the blubber and through the underlying layer, the meatus becomes sheathed by the peculiar fibro-adipose tissue which gradually grows thicker until 2 cm. in diameter just under the blubber. In this sheath, the meatal lumen, which is first round in section, expands gradually but flattened until its maximum breadth at a distance of about 6 cm. from the aperture as seen in the table below. The meatus shifts at the same time to the ventral part of the sheath and the lumen becomes crescentric, being convex ventrad. After the meatus runs 7 cm., the meatal slit gradually diminishes the width and loses its crescentric form, possessing again the round narrowness slightly larger than the first. The peri-meatal sheath of the fibro-adipose tissue is histologically composed of the collageneous fibers mainly in circular direction and the well marked adipose tissue among them. It comes into notice that around

Table of dimensions of a slit-expansion of *Berardius* in mm.

Distance from the external aperture	18	37	58	75	90
Diameter* or width of the meatus	2.3*	3.5	8.0	2.5	2.0*



the sheath some of the auricular muscles insert, which is not touched here at all because the wider treatment is necessary with the superficial cutaneous musculature known as the panniculus carnosus as well as its innervation.

It seems also new and interesting here that the meatal epithelium is, in the region of the crescentric expansion, transformed into a peculiar lymphoid organ similar to the tonsils. Many crypts and the lymphoid infiltrations of the epithelium are well marked, although the so-called germinal centers are not typically clear. This lymphoid organ goes weaker as the expansion diminishes, and at the bottom of the blubber layer, where the sheath is thickest, it appears no more. The lumen is again crescentric, being coated by the stratified squamous epithelium, under which one or two, large or small infiltrations by the lymph follicles can usually be seen in each section. The meatal epithelium is, in the land mammals, the continuation of the exterior integument. It is naturally understood, therefore, that the basement cells of the epithelium are marked by a lot of pigment granules in *Berardius*. It is also characteristic to the epithelium as the continuation of cutis that it is beset by the well developed papillae throughout, which are noticed simultaneously by the abundant blood capillaries. However, when the lymphoid organ as well as the follicles are brought into consideration, the meatal epithelium is of mucous nature rather than a cutis. As the meatus rolls further inward and merges underneath the skull the sheath becomes slender and loses the concentric structure, where two or three rudimental cartilages covers the meatus from below. The cartilages are of irregular form but usually club-shaped.

So far as the crescentric portion of the meatus goes from the end part of the sheath through the cartilaginous portion, there are distributed, in the sub-epithelial tissue, a large number of sensory nerve endings. These endings are distributed most frequently in an interval of 2–3 cm. where the meatus goes under the skull. Microscopically, these endings occur most frequently under the convex epithelium, less frequently on the opposite concave side and few sideways. The facing epithelia differ strikingly: the concave epithelium is thin and beset with numerous but

Fig. 3. External auditory meatus of *Berardius*. *Top left*- Slit-expansion with the sub-epithelial lymphoid organ (×8); *top right*- Fibro-adipose sheath sectioned at its maximum development (×5); *middle left*- Deeper portion with cartilage and abundant sensory corpuscles (×7); *middle right*- Trumpet-like expansion (×7); *bottom left*- Lymphoid organ in section *top left*, note the lymphoid infiltration of the epithelium (×90); *bottom right*- Facing epithelia in section *middle left* (×90).

similarly high papillae than the convex one where it is thicker and presents less papillae which are naturally broader and taller. The famous trumpet-like medial expansion presents also in this species, being filled up with gray paste-like substance which seems homologous with the ear-wax of mystacoceti. No hairs are present in the meatus throughout, and accordingly no sebaceous glands nor any sign of the ceruminous glands exist. These may support the mucous nature of the meatal epithelium in addition to the lymphatic peculiarities mentioned before. Consequently, the paste-like substance and the plug of ear wax as well as the pinna-like formation protruding from the external aperture seem equally to be produced by the meatal epithelia and not the products of glands.

The meatus of *Ziphius* is different because no expansion nor tonsil-like lymphatic apparatus presents, but is otherwise similar to *Berardius*, nerve endings being also present.

Physeter (fig. 4): The meatus of *Physeter* measures approximately 60–65 cm. in cases of 35–40 feet body length. It is striking here that the meatus, after penetrating the blubber thickness, diminishes to a microscopic dimension of 160–170μ at a distance of about 10 cm. from the external aperture. It is unfortunate for researchers that this area is cut up when the blubber is removed. This seems to have caused the failure of Clarke that the meatus is a short blind sac which stays within the blubber layer, but I can understand his condition sympathetically because intensely careful examination is needed, which is pretty hard to expect on the operating deck of a factory ship. To make the matters worse, sperm whales lie perfectly sideways because of the gigantic spermaceti organ, and to the consequence, one of the apertures stays underneath and the other at top, both being difficult to examine in the natural state. However, the meatus is really a fine cord not absolutely hard to pick up with naked eyesight for its oblique course of S-shape, descending toward the under side of the squamosal region through the layer of loose connective tissue under the blubber, thereby running by the rudimental auricular cartilage. This continuous cord of the meatus is further prepared from the surrounding tissues along the meatal furrow of the squamosal bone, in which, however, I could not demonstrate any lumen. Though I could not mark the spot where the meatus comes to a blind end, it seems very much probable that it is practically obliterated as Clarke wrote suspiciously (1948, p. 980).

Within the blubber, the peri-meatal lymphoid organ develops far stronger than *Berardius*, measuring more than 2 cm. in diameter. It happens thus that the external aperture, in spite of its obscure appearance, can be probed with a finger which is pitted into the lumen for the weaker resistance of the lymphoid organ. The organ stretches as far deep as 10 cm. from the aperture, and hereby it is peculiar that it is divided into lobules by the continuous septula of the capsule of connective tissue. The crypts are deep, the infiltrations are commonly

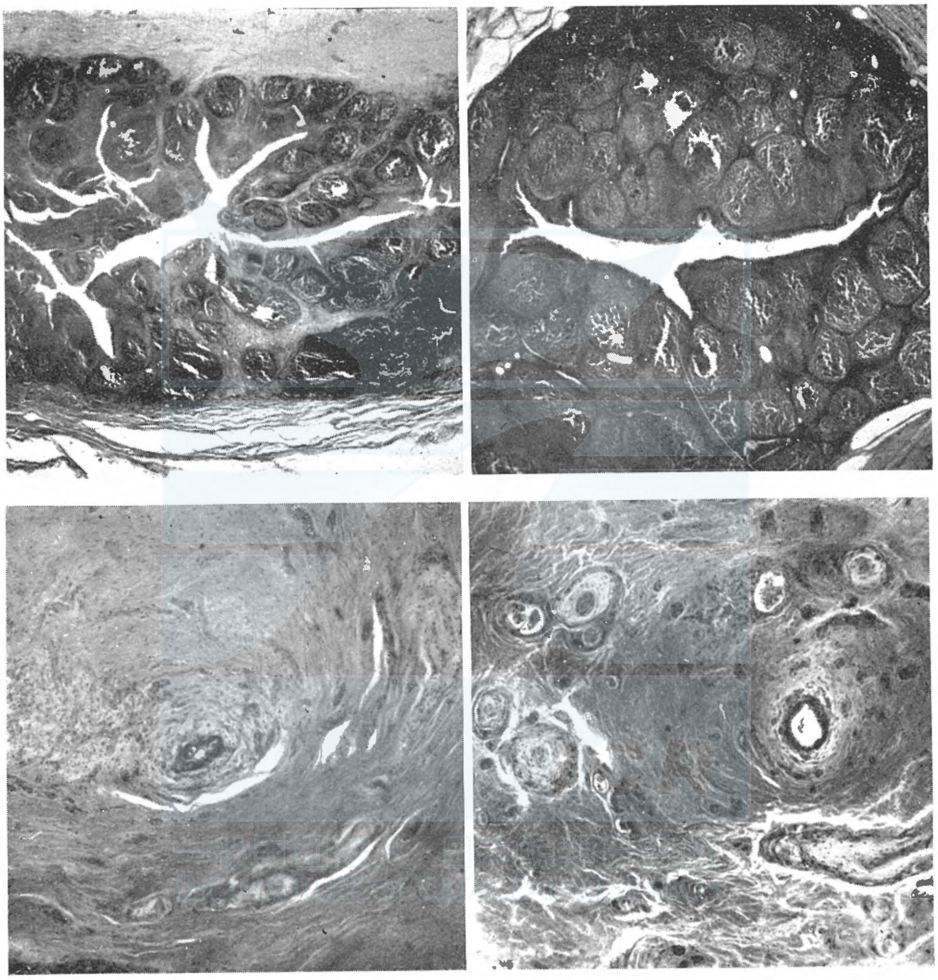


Fig. 4. External auditory meatus of *Physeter*. *Upper row*- Sub-epithelial lymphoid organ (×5 and 7). In the *left* section, the meatus is artificially flattened; *bottom row*- Almost obliterated meatus (×90). Note the sensory corpuscles. In the *left* section, the meatus is coiled up and sectioned obliquely, the stretching sub-epithelial layer is shown to the left with blood capillaries.

shown and a large number of germ centers are present.

The organ seemingly corresponds with the blind sac of Clarke as he wrote, "the sac has somewhat thickened unpigmented walls wherein muscular tissue may be developed: internally, these walls are thrown into transverse folds". It may be homologized that the unpigmented walls of Clarke are of the lymphoid organ, the muscular tissue being questionable but reasonably supposed to have been expected by the pinkish tint of the fresh lobules, and the transverse folds are the lobular arrangements divided by the crypts. The priority of this establishment is naturally delivered to Clarke but it is important to note that he was too hasty to make it public without necessary examinations. Really many disputes in our field seem to have brought the confusions in this way.

Surrounding the lymphoid organ, the sensory nerve endings appear in the capsule of connective tissue. But it is in the deeper portion of the meatus where the lymphoid organ no longer appears that the endings are remarkable both in number and dimensions; at the distance of 15 cm. from the external aperture, the endings are most abundant and well developed, where the meatal lumen diminishes its caliber to 60–70μ and the lining epithelium becomes quite thin, being beset still by the blood capillaries.

Kogia has the similar meatal peculiarities: total length 6.5 cm., of which 2 cm. is blubber portion and the lymphoid area ranges as deep as 4 cm. from the external aperture with the maximum breadth of 0.4 cm. toward the end of the blubber thickness, accordingly that portion penetrates twice further inward than the blubber; the trumpet-like expansion measures 0.9 cm. of the most interior part of the meatus. In the remaining portion, the meatus seems to be obliterated as in *Physeter* but this is not conclusively mentioned for the histologic examinations are remained. Therefore, the nerve endings are not yet known though it is quite possible to expect them.

Concerning other species of delphinidae as well as balaenopteridae, I have nothing particular to mention here for the important problem has been treated in details in the first paragraph (a) of this chapter.

c. The Meatus as the Independent Sensory Organ:

The sensory nerve endings, presenting abundantly around the auditory meatus in the sub-epithelial layer, are the laminated corpuscles. Some of these of *Berardius* at a distance of about 15 cm. from the external aperture are illustrated in fig. 5 after reconstruction. They are very much elongated with some occasional convolutions, each being supplied presumably by a single myelinated nerve fiber.

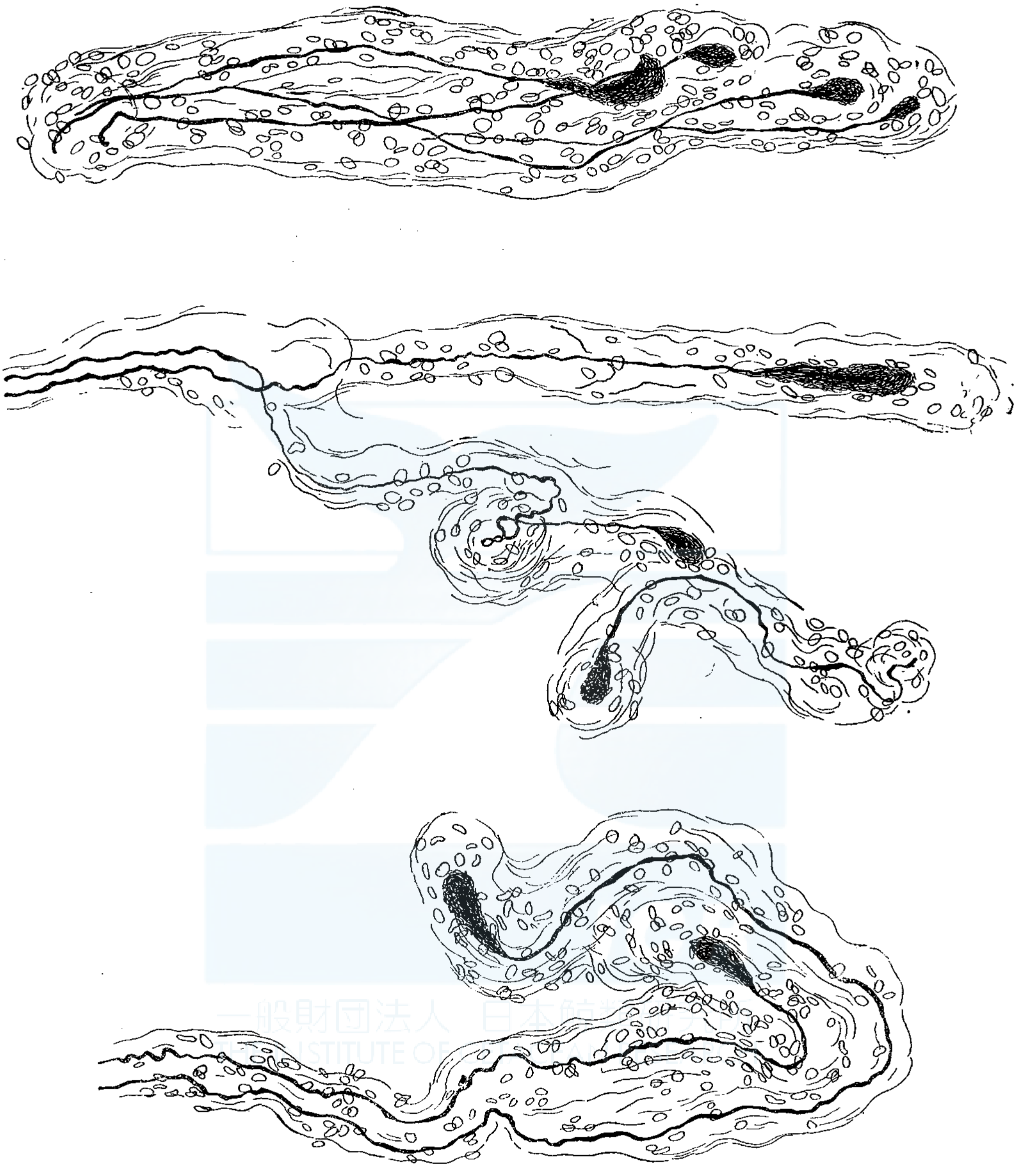


Fig. 5. Peri-meatal sensory corpuscles of *Berardius* (ca. × 230).

Recently some similar sensory corpuscles have been known from the oral cavity including the lips of *Balaenoptera*, described as the nearest ones to the so-called Golgi-Mazzoni's corpuscles, being unlike, however, in the respects, namely the surprisingly elongated and convoluted characters (Ogawa & Shida, 1950, pp. 8-9). The corpuscles now in question resemble to a great extent to those now referred to, but not a single case of termination of the axon has been learned, which is one of the characters of the Golgi-Mazzoni's corpuscles (Boeke, 1934, p. 867). Nor any branching of the corpuscles themselves has been shown. Every termination of the axons is dilated into an elliptical knob with a network of fine fibrils.

The endings of other species are also the similar laminated corpuscles (fig. 6). It is of interest that the lateral portion of the meatus in *Balaenoptera physalus* has also similar endings though scanty in number but well marked. They measure in *Physeter* 60–110μ and in *Balaenoptera* 30–15μ in breadth.

To consider of these sensory nerve endings, the meatus of cetacea may well be attributed with a hitherto unknown sensory function which I expect to be the pressure gauge[1] under water. In regard to these considerations, the manner of distribution of the corpuscles in *Berardius* is of special significance. As mentioned before, the corpuscles are distributed mainly within a rather limited area where the meatus merges underneath the skull, marking a slight curve. From the topographical relations of the meatus chiefly to the solid tissues of the head, it may be conclusively said that the meatus is compressed most remarkably at this region by the immense water pressure against the skull, when the stress caused lengthwise in the meatal cord itself by the same outside pressure seems also to bring some similar effects simultaneously. In this way, the facing walls of the crescentric meatus are regarded to be squeezed against each other, and the deeper the whales dive, the stronger this occurs. It may also be the answering characters that the elongated corpuscles lie mostly lengthwise along the meatal lumen, being particularly abundant under the convex side of the epithelium. These parallel relations of the corpuscles as well as their seemingly most effective distribution similar to *Berardius* are popular in *Physeter* and *Balaenoptera* too. Finally, the enormous development of the corpuscles in those species as *Physeter* and *Berardius*, famous excellent divers[2] in the cetacean order, assures me, on the other hand, of the present functional prospect concerning the new sensory rôle of the auditory meatus.

In conclusion, the auditory meatus of cetacea, which is so vestigial

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1) Lillie (1910) wrote a certain possibility of a pressure gauge to the protruded tympanic membrane of *Balaenoptera*, but his reasons were not clearly mentioned.

2) It has been recorded that a 45-foot sperm whale dived as deep as 3,240 feet where the animal was strangled to death by a submarine cable (Kellogg, 1940).

and retired from its original function, often undertakes probably a new one as an independent sensory organ secondarily specialized. Accordingly, the auditory meatus is in cetacea really unstable in its ontogenetic fortune, for the upper branchial cleft of the early embryonic stages has remained so, otherwise as an open meatus through which the sound waves are conveyed to the tympanic membrane.

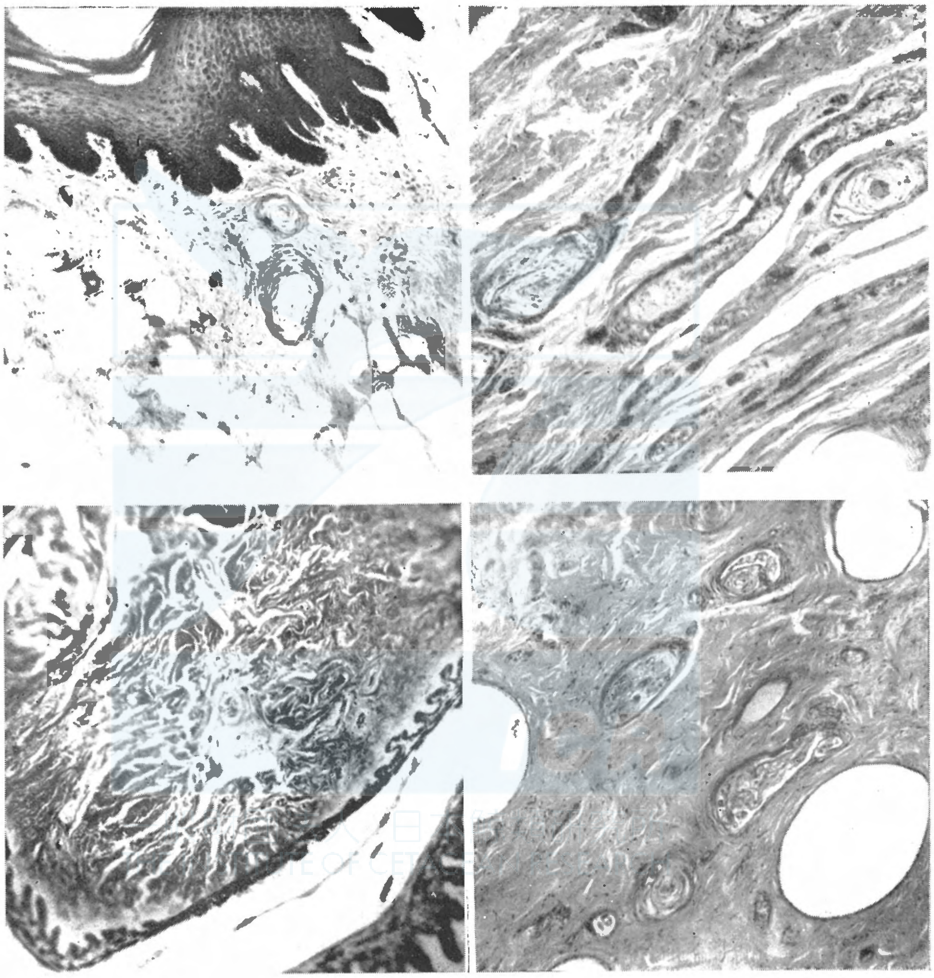

Fig. 6. Peri-meatal sensory corpuscles (×90). *Upper left- Balaenoptera physalus,* the deep portion of the lateral meatus; *upper right- Physeter,* in the capsule of the lymphoid organ; *bottom left- Ziphius* (Bielschowsky's staining); *bottom right- Berardius.*

Chapter 2 Middle Ear

1. The Tympano-Periotic Bone:

Introductory Remarks:

The tympano-periotic bone of cetacea is of special interest for its peculiar morphology and of the great importance in the entire organ of hearing, since the labyrinthic organ is embedded within the periotic, and this, together with the tympanic bulla, confirms the tympanic cavity. The tympanic bone is shaped bullar not unlikely as the many terrestrial mammals but in every way cetacean. By "cetacean", however, I mean two different ways as odontocete and mystacocete; and the periotic bone also can be classified likewise into two. Needless to say, the bone differs more or less in form and dimensions according to the taxonomic genera and families in each suborder. Among them, some have been variously described by the previous authors, yet it seems to me some further treatments of synthetic nature are here necessary throughout the whole order.

In general, I cannot emphasize too much that the cetacean tympano-periotic bone is extraordinarily so compact and so dense like the enamel substance of the mammalian teeth that the bone can be sawed with great difficulty and fortitude; whereas other bones are mostly spongy and impregnated with much oil. In a sense, another nomenclature "petrosal" sounds superb to express the structure, though the term concerns the periotic bone exclusively. The bone is naturally known also by name of "cetolith". Now it is easy to understand the geologic-oceanographic or palaeontologic knowledge (Zittel, 1891–93, p. 162; Bennett, 1931, p. 38) that the isolated tympanic as well as the periotic bones are found in almost all strata yielding cetacean remains, and have been dredged from the floor of the ocean because the bone remains intact long after every trace of the remainder of the whale body has disappeared.

The bone tissue is, in the meantime, pretty fragile, particularly in thin portions. This is clearly noticed on the sawing and chiseling opportunities. One rare case of *Balaenoptera borealis* who was harpooned on the head and came to my experience in 1950 at Akkeshi, Hokkaido was interesting because the tympanic bones were crushed into pieces. In my opinion this phenomenon may throw a side light to the solution of the tympanic function.

a. Family Delphinidae (hereto figs. 7, 8):

The two components of the tympano-periotic bone are ankylosed each other, so each is not natural if treated separately. But here they will be treated so for the sake of convenience.

Globicephalus: The tympanic bone of *Globicephalus* is divided into the bulla and the posterior mastoid process. The bulla presents a semicylindrical form slightly compressed in vertical direction, with its long axis pointing rostro-mesad, broad posteriorly and becoming narrower anteriorly. The lateral border is irregular and thin; whereas the medial is rolled over and massive, which is named by Kellogg (1928) as the involucrum. Toward the posterior extremity of the bulla, the two borders are united altogether, thus forming the neck which is continuous to the mastoid process. This process is the processus petrosus ossis tympanici of Denker (1902) and is called by Schulte and Kernan (1917; 1918–19) as the tympano-mastoid. The process projects horizontally in the lateral direction slightly backward. On the upper side of the process, at its proximal portion, there is a facet, with which the tympanic bone syndesmoses with the periotic. This joint-facet is rhomb-shaped, the short diagonal being located antero-posteriorly and the long one transversely. The facet is usually indented by several ridges which radiate from the anterior angle toward the posterior sides. The ridges are outstanding especially on the lateral half of the facet and concentrate after refraction on its posterior margin toward the tip of the process, while the medial half presents the ridges less markedly, being absent anteriorly.

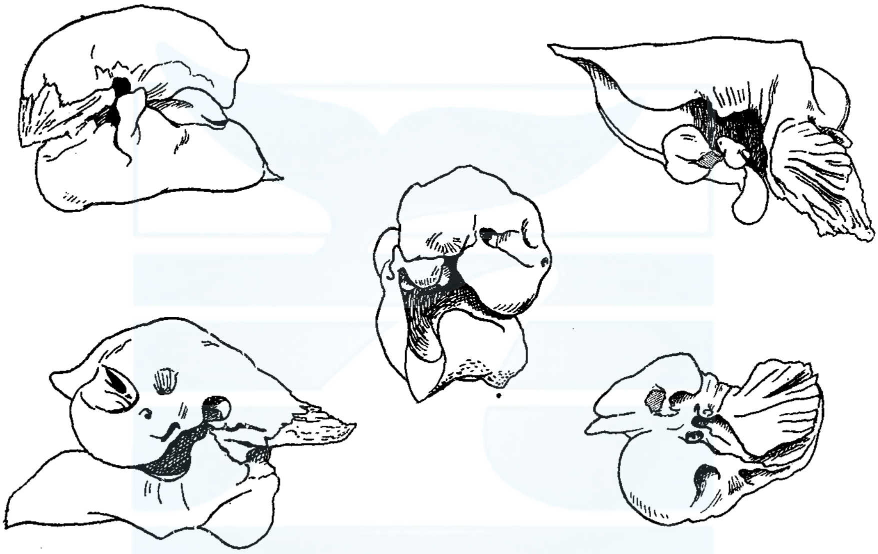

Fig. 7. Tympano-periotic bone of *Globicephalus* (7/8 natural size). Complete bone of right side to the *left*, dislocated left bone to the *right*.

The thin lateral border of the tympanic bulla draws a line convex outward, of which the apical half remains free, the margin rolling inward in a manner of concha. Meanwhile, the proximal half is ankylosed with the tegmental process of the periotic bone. The ankylosis hereof, however, is somewhat complicated by the pea-sized tubercle, figured and marked *P* by Denker as the process for the bony connection with the tympanic bone (1902, tab. 14, figs. 2, 3), which evidently corresponds to the processus tubarius of Boenninghaus and the accessory ossicle of Kellogg, and which I would call hereafter as the tubal tubercle after Boenninghaus' interpretation. On the outer surface of this portion, a marked groove presents in the longitudinal direction, which borders the tubercle from the bulla, and where the lateral border is extremely thin and fragile (fig. 27). Corresponding to the outside groove, the wall protrudes inward in a wavy way. The union between the tubercle and the tegmental process of the periotic is characteristic, namely the two bone portions are seemingly squeezed each other and comes into close contact but are ankylosed only in a limited area (half-toned in fig. 7). Laterally, a bow-shaped fissure presents bordering these two portions, while entally the tubercle is bordered continuously by the same fissure which fades out finally in the posterior side, for the tubercle is here ankylosed with the periotic. This ankylosis is not lamellated but thick, still the union is as fragile as that between the tubal tubercle and the bullar border.

Toward the posterior end of the lateral border, a prominent process juts out upward and outward. The process is somewhat S-shaped, known after Beauregard as the sigmoid process. The upper border of the sigmoid process comes into close contact with the corresponding dam-shaped eminence which protrudes at the base of the tegmental process of the periotic. The hind surface of the sigmoid process and that of the facing eminence of the periotic thus altogether make the anterior border of the large aperture, apertura tympanica of Denker. The neck of the mastoid process of the tympanic borders posteriorly the aperture. In other words, the aperture is practically a deep incisure in the bullar lateral border, between the sigmoid process and the mastoid process, and it is only partly that the periotic borders the aperture in the upper part. The tympanic aperture is divided by the isthmus between the sigmoid process and the facing crest of the mastoid process almost completely in a sand-glass form into two minor apertures, the upper and the lower. The lower aperture is the osseous part of the external auditory meatus and is the genuine tympanic aperture. The upper part, to the contrary, is peculiar to odontoceti and is named by Beauregard as the ductus petro-tympanicus and by Boenninghaus as the hiatus epitympanicus. At the bottom of the tympanic aperture the conical process juts out upward into the aperture. This is the processus conicus posterior of Beauregard and Denker, and the processus medius bullae of Boenninghaus. Both sigmoid process and the conicus process are hollow inside and the margins are similarly rolled inward.

Anterior to the sigmoid process, a minute incisure is present on the margin of the bullar lateral border. The incisure borders a triangular opening[1] in the perfect tympano-periotic combination, the tegmental process of the periotic making the upper side. Along the hind side of the triangle, the malleus is rigidly fused with the bulla, and through the opening the caput mallei can be seen. The opening is located in the bottom of a deep recess, of which the anterior portion continues with the longitudinal groove mentioned above between the tubal tubercle and the bulla. The tegmental process of the periotic and the tubal tubercle in front border the recess from upper side, the bullar lateral expansion in front of the sigmoid process borders it from below, and the sigmoid process from behind. This recess should be noted because it attracted special attention of Boenninghaus as will be discussed in the following chapter as the "sound-funnel" or "Schalltrichter".

The under side of the bulla is shield-shaped pointing with its bottom rostro-mesad. The surface is slightly concave lengthwise and convex crosswise. Of the two side angles of the shield, the lateral is the sigmoid process and the conicus process, while the medial is the hindermost prominent corner of the vertically compressed involucrum. At top of the shield swells a globular prominence mesad, this being hollow inside where it is the posterior end of the tympanic cavity. Between these bilateral prominences a distinctly deep furrow presents on the surface. The bullar shield is smooth on the lateral surface, while medially the surface is rough throughout, affording insertion of the thick fibrous layer.

The upper surface of the medial involucrum presents an impression posteriorly, which becomes gradually deeper as it approaches the neck of the mastoid process. The deepest position of the impression forms a furrow which traverses the involucrum, the site corresponds to the hind corner of the involucrum, namely the medial side angle of the bullar shield in simile. The impression, as well as the furrow, are apparently caused by the passage and expansion of the cavernous body with nerves and blood vessels into the tympanic cavity through the tympano-periotic

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[1] For the interpretation of this opening, see page 58.

fissure between the involucrum and the spheric portion of the periotic. The upper side of the involucrum, in the region of the impression, expands inward a minor limbus-like rolling over the bullar depression, this and the mesad prominent flattened corner of the involucrum suggest that some dynamic invasion, probably by the resistance of the cavernous body, has attacked the involucrum strongly on the spot. Between the thin lateral border and the massive medial involucrum lies the remarkable and longitudinal deep bullar depression which forms the bottom of the tympanic cavity and provides the bulla with a semi-cylindrical form.

The periotic bone consists of three portions, viz., the labyrinthic or cochlear portion, spheric in shape, and the anterior, pro-otic or tegmental process, and the posterior or mastoid process. The mastoid process is the processus tympanicus ossis petrosi of Denker, or can be called as the opisthotic process to introduce Lillie's nomenclature (1910). Whereas Schulte divides the bone into two portions, the cochlear[1] and the vestibular (1917, p. 396).

On the lower surface of the mastoid process presents the rhombic facet which articulates with that of the tympanic in syndesmosis, where the furrows make the facet wavy corresponding to the ridges on the tympanic facet as referred to before. These ridges and furrows seem to tight the articulation, and in many cases this articulation cannot be freed without destroying some of these structures. Anterior to the facet, the epitympanic recess presents a depression, in which mesad the fenestra vestibuli opens, and closely laterad to the window lies the tympanic opening of the facial nerve canal, continuing backward to an S-shaped sulcus on the under surface through the isthmus between the cochlear portion and the mastoid process, where the medial edge of the articulation facet and the lamellated process of the cochlear portion face against each other flooring the isthmus incompletely, until it appears on the medial side of the mastoid process just above the facet's hinder edge. The sulcus then makes a turn laterad and downward around the medial corner of the tympanic mastoid process, leaving a short, sometimes faint depression on its hinder margin.

Within the epitympanic recess, closely behind the posterior end of the fenestra vestibuli, another groove lies medially parallel to the facial nerve sulcus separated from it by a ridge. The groove lodges the stapedial muscle and goes further backward and somewhat mesad and upward, becoming free from the named muscle and affords the communication

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[1] Though the division is originally described of *Kogia*, it comprehends also other odontoceti.

of the tympanic cavity with the posterior pneumatic sinus. The groove goes along with the facial nerve sulcus through the isthmus mentioned above. Laterad to the epitympanic recess, the hiatus epitympanicus of Boenninghaus traverses a furrow between the articulation facet and the dam-shaped transverse eminence of the tegmental process which is in contact with the upper border of the sigmoid process. The furrow of the hiatus borders the epitympanic recess laterally, descending lower than the ceiling-level of the recess. At the ental border of the furrow, a minute ledge expands mesad, on which the short crus of the incus articulates.

The tegmental process is prolonged before the posterior articulation and the hiatus epitympanicus, being bordered posteriorly by the transverse eminence provided on it with a smooth contact surface facing to the sigmoid process of the tympanic. Slightly in front and mesad of this contact surface, a small oval depression is noted facing inward and downward, which lodges the caput mallei in it, so can be called mallear fossa. Further distal under surface of the tegmental process presents two slight concavities both lengthwise, of which the lateral closely contacts with the tubal tubercle, and toward the proximal end of it, the process is ankylosed with the tubercle, the union stretching partly over the medial concavity. The apical end of the tegmental process is bicuspic, the lateral cuspis, pointing rostrad and slightly downward, is regarded to be equivalent to the proper apex, while the medial turns upward like a hook. The tegmental process roofs the tympanic cavity above the bullar depression.

The cochlear portion protrudes downward in a spheric and dome-like form facing against the upper side of the tympanic involucrum. The promontory presents toward the hind border of the portion, mesad to the fenestra vestibuli. On the posterior surface of the dome, opens backward the fenestra cochleae, the contour, however, being somewhat heart-shaped instead of being round.

On the upper side of the periotic, two processes, tegmental and the mastoid, present lengthwise a continuous S-shaped smooth surface, convex and inclined laterad, and the cochlear portion presents a semicircular border attached mesad to the long S-shaped combination of two processes, facing obliquely mesad and upward. The arcade borders a deep fossa in it, the fundus of the internal auditory meatus. The fossa is piriform because the upper portion of the fundus slips off foreward and the facial nerve canal is located apart from the remaining foramina (fig. 12). The poor transverse crest divides the posterior portion of the fundus up and down. The upper foramen is the superior area vestibularis. In the lower portion, the tractus spiralis presents anteriorly, the inferior area vestibularis posteriorly, including the foramen singulare in it. On the border of the cochlear arcade, the infundibule-shaped vestibular aquaeduct opens at the posterior extremity, and at a short distance mesad to it, the minute and oblong cochlear aquaeduct opens.

Finally, some remarks concerning the entire tympano-periotic *in toto*. The tympanic cavity, bordered by the epitympanic recess and the tegmental process of the periotic above and by the bullar depression below, opens rostrad through an aperture which is named by Boenninghaus as the orificium tympanicum of the Eustachian tube. The orifice is bordered above by the tubal tubercle, the tegmental process and the cochlear portion of the periotic, and the bottom being incised between the conch-like free portion of the lateral border and the medial involucrum of the tympanic bulla. The orifice communicates medially backward with the tympano-periotic fissure between the involucrum and the cochlear portion. On the posterior side of the bone, a minute foramen must be mentioned for the chorda tympani nerve. The foramen presents near the medial border of the posterior side of the neck of the mastoid process. The foramen perforates the proximal portion of the involucrum rostrad and upward and presents its interior opening on the ental surface of the involucrum.

The tympanic and the periotic are ankylosed by the thin medial border of the bulla with the tegmental process of the periotic anteriorly and articulates by the posterior facets in syndesmosis. Beyond these, the two components are nowhere in contact but the sigmoid process and the facing periotic eminence, elsewhere they are separated from each other by fissure of varying widths. The peculiar topography of these unions of the tympano-periotic bone is important in relation with the massive and heavy involucral border of the bulla which remains free. I would like to stress the dynamic correlation likely to occur within these structures, in particular that between the involucrum and the thin and fragile union (fig. 27).

Another important remark is that the mastoid process varies in dimensions according to species of delphinidae family, namely it stretches in general shorter than *Globicephalus* in lesser dolphins and porpoises as *Prodelphinus, Steno, Tursiops, Grampus* and *Neomeris* examined by me. I am of prediction that the killer whale, *Orcinus* may have more prolonged mastoid process than *Globicephalus*, and feel sorry, in this respect, to have missed the species. Hyrtl (1845, tab. 9, fig. 10) figured the tympanic bulla of *Delphinus gladiator*, but the mastoid process is unfortunately lacking. Meanwhile it interests me in this connection that another species of *Globicephalus* from Ayukawa, probably *G. scammonii*, has a longer process than *sieboldii* species from Taiji (fig. 8).

I am afraid the above description of the tympano-periotic of *Globicephalus* might be redundant because the family has been most popularly treated by the previous authors. I dared this, however, in order to make it easy to put the bones of various species into better comparison. Within the delphinidae family no remarkable difference presents, but the dimensions and the length of the mastoid process just mentioned seem to be a matter of importance. But to mention any among them, the tympanic bone of *Tursiops* as well as *Prodelphinus*, and probably that of other dolphin species, presents an elliptical foramem preforating the hind wall of the neck of the mastoid process transversely; and secondly the fundus of the internal auditory meatus is distorted and elongated much more than *Globicephalus*, so the foramina line up in the more strongly distorted comma-shaped fossa with more faint sign of the transverse crest (fig. 12). This latter relation, altogether with some remarks mentioned before, may indicate that some external force has influenced the morphology of the bone during development. Practically, the bone of delphinidae shows in common a compression more or less mainly in vertical direction which does not present in other families.

Fig. 8. Developmental series of the mastoid process of the tympanic bone in delphinidae family. From *left* to *right*: *Grampus, Globicephalus sieboldii, G.* sp. (probably *G. scammonii*). Cf. further fig. 17.

b. Family Ziphiidae :

Berardius (hereto fig. 9) :

The tympano-periotic bone of *Berardius* is much larger than *Globicephalus* and other delphinids just described, length of the bulla and the periotic measuring about 6 cm. and 7 cm. respectively. The bulla is more roundish in all directions as compared with that of delphinidae. The under side of the bulla is similarly shield-shaped as delphinids but generally more roundish, even the rostral extremity being round and not pointed. The surface is convex both lengthwise and crosswise though the convexity in longitudinal direction curves less strongly. The transverse convexity is almost perfectly semicircular, provided with no sign of the vertical compression. The globular prominence at top of the shield, namely at the hindermost corner of the bulla, is comparatively larger, and between this and the other medial corner, viz., the posterior end of the involucrum, the furrow is shallower than delphinidae. The sigmoid process bends backward and does not disturb the lateral borderline sideways so strongly as in delphinidae. The margin of the sigmoid process is crowned with an obtuse angle which is situated closely laterad to the less prominent conicus process; whereas that of delphinidae is bordered by a gentle arc-line. In front of the sigmoid process, the lateral border of the bulla is traversed by a striking sulcus seemingly folded-over rostrad by the basement of the process. This sulcus is characteristic to the present family as was so illustrated of the various species by True (1910, pl. 35). The anterior bony union of the tympano-periotic in front of the sigmoid process is less lamellated and relatively thicker and shorter than delphinids, still being extremely fragile. The lateral border more rostrad to the union is strongly rolled inward in a concha and closely contacts with the tegmental process of the periotic within its marked longitudinal impression throughout. The involucrum is slender in its anterior half, while posteriorly it develops extraordinarily thick and continues with the neck of the mastoid process. On the outer, posterior surface of the neck, perforations often occur, where the tympano-hyal cartilage is connected and the wall around being quite thin. This is probably equivalent to the already related striking fenestration in some dolphins. The posterior articulation facets are shaped like a parallelogram rather than a romb and provided with no particular structures as ridges upon them. The facets are rather gentle, being convex with the tympanic and concave with the periotic. The mastoid process of the tympanic markedly expands laterad, backward and downward. Toward the extremity, the process grows irregularly broad and thick. The upper surface of the process is rugged and is sutured with the skull in a notch bordering the squamosal and the exo-occipital bones.

The periotic bone is not far apart from delphinidae family, though the general morphology is characteristic and it is not difficult to identify the family. The comparatively large and pointed tegmental process is quadriangular in crosswise section, being upperly broader. The mastoid

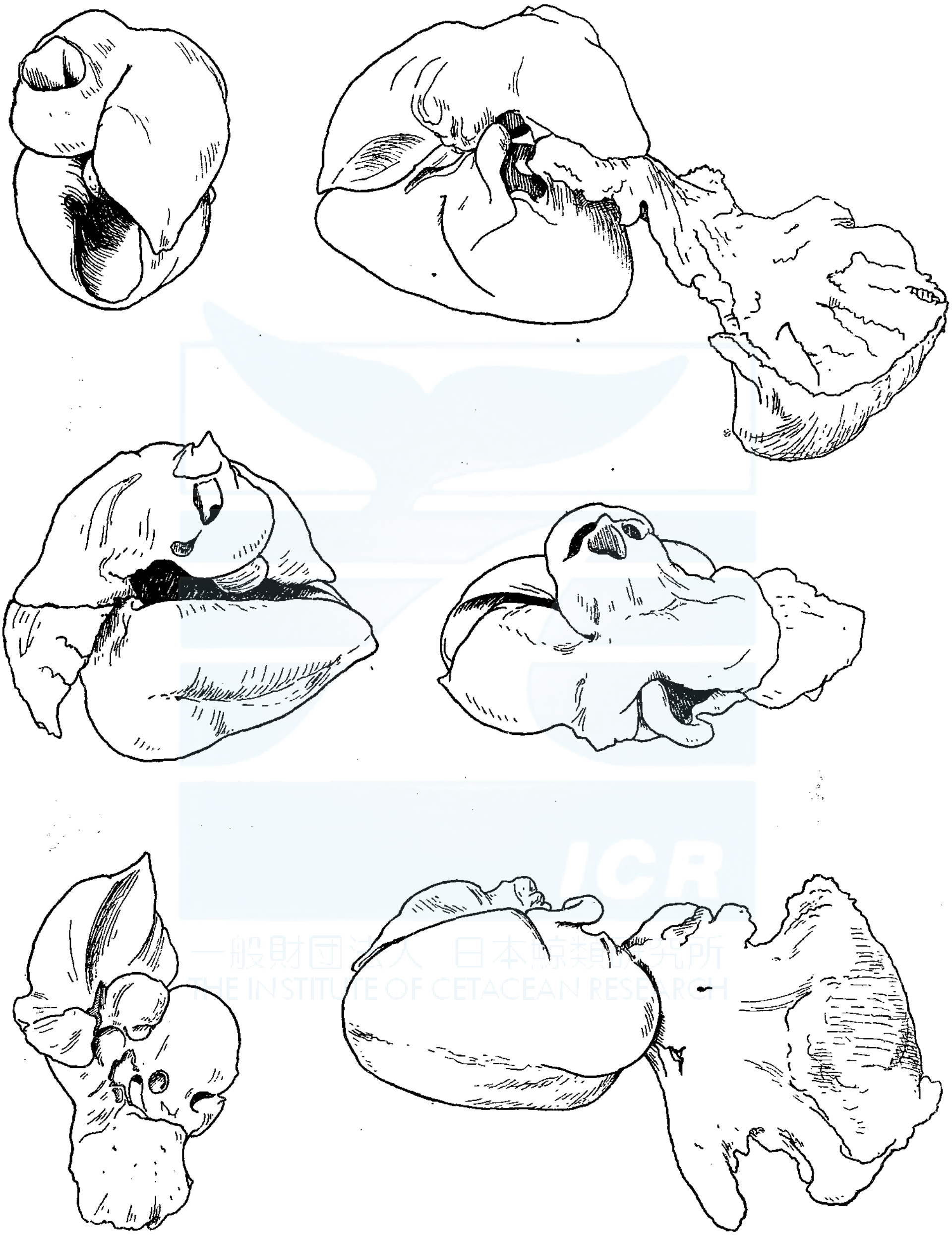

Fig. 9. Left side tympano-periotic bone and right periotic of *Berardius* (ca. 4/5 natural size).

process is bordered from the anterior portions by a slightly prolonged neck than in delphinids. Accordingly, the bone is comparatively long or slender as a whole and the cochlear portion stays in a relatively small scale. Boundaries of the three portions are thus distinct, constricted behind and deeply incised in front. On the lower surface of the bone, scarcely nothing is remarked other than delphinids but the tubal tubercle. This tubercle is located sequestered in the tympanic cavity due to the tegmental prolongation. The tubercle is practically one part of the periotic fused more firmly than in delphinids.

On the upper surface of the bone, the elliptical porus acusticus internus perforates the spheric portion, situated obliquely from the posterior bottom toward the anterior top. The fundus of the meatus presents more distinct transverse crest than delphinids, and the facial nerve canal stays closer to the remaining foramina. No foramen singulare appears independent as is the case with delphinids. The vestibular aqueduct broadens the infundibular lumen in a triangular pyramidal shape behind the internal auditory meatus, bordered from it by a thin lamellated but prominent wall. Mesad and backward to the vestibular aquaeduct, opens the cochlear aquaeduct in comparatively larger dimensions than in delphinids.

Fig. 10. Periotic bone of *Ziphius* (Natural size).

The tympano-periotic bone of *Ziphius* (fig. 10) is much the same with *Berardius* though smaller in scale, so it seems needless to add detailed descriptions concerning it. In general, the bone seems to be somewhat thicker and more stumpy than *Berardius*.

c. Family Physeteridae:

Physeter and *Kogia* represent the third family, the last of the odontocete suborder. However, the intergeneric differences shown in the tympano-periotic bone are pretty noticeable, so each genus will be described here separately.

Physeter (hereto fig. 11):

The tympano-periotic bone of *Physeter* is the largest among all odontocete species examined by me. But the bone of *Orca* apparently exceeds that of *Physeter* as described by Flower (1867, p. 321) and as figures of *Delphinus gladiator* by Hyrtl demonstrate (1845, tab. 9, figs. 8, 10).

In my opinion, however, this is merely outwardly so, the bone of *Physeter* being essentially not inferior because it lacks the prolonged anterior portions whatever. Anyway, the bone is remarkable for its small size in comparison with the entire skull as noted by Flower.

The tympanic bulla is semi-cylindrical in the most literal sense of the word, namely it is not pointed nor tapers rostrad. Above all, the anterior portion of the bulla in front of the sigmoid process, to say the least, is literally cylindrical, amputated somewhat obliquely mesad at the anterior margin. Along this unusual margin, the lateral border ends in a conch-like in-rolling, and the medial one in a stump. The central bottom border between these two borders slightly caves in backward, this occurring in no other odontocete species previously mentioned. The sigmoid process juts out laterad prominently, and practically is of remarkable size and crowned with a corner almost in right angle at the bottom of it. The tympanic aperture is much elongated, apparently due to the vertical expansion of this sigmoid process. The posterior portion of the bulla behind the sigmoid process presents a comparatively confused appearance, still the structures do not differ much apart from two other families. There the bilateral prominences present, being bordered by a shallow groove between them. The medial one is massive and the posterior corner of the involucrum; whereas the lateral is hollow inside and evidently equivalent to those described as globular of the formerly mentioned families. The lateral surface of this hollow expansion is, however, shortened so remarkably that it continues directly with the lower margin of the tympanic aperture. The margin expands laterad between the two processes, the sigmoid and the mastoid, presenting a fossa which faces downward. Such a relation does never occur in other families and accordingly characteristic to this species alone. Because of this external concavity, the conicus process is naturally lacking. And besides, the lower margin of the tympanic aperture is so lamellated into a thin plate that here perforations sometimes occur. It is also characteristic that the lateral portion of the bulla expands also in front of the sigmoid process less markedly, corresponding to the shortening tendency as seen strongly behind the sigmoid process. To the consequence, the so-called "sound-funnel" of Boenninghaus is less developed than others. The medial half of the bullar under surface is rough throughout as in other families but much more complicated. The bilateral prominences, above all, present a marked tuberosity or tuberosity-crest transversely, which affords the fibrous connection to the bulla more firmly. From the posterior lateral corner of the upper side of the bulla, the mastoid process projects, which is peculiarly composed of a large number of distinct thin plates, commonly held together at the attachment, and radiates laterad, backward and downward. The process interdigitates with the squamosal and the exo-occipital bones so firmly

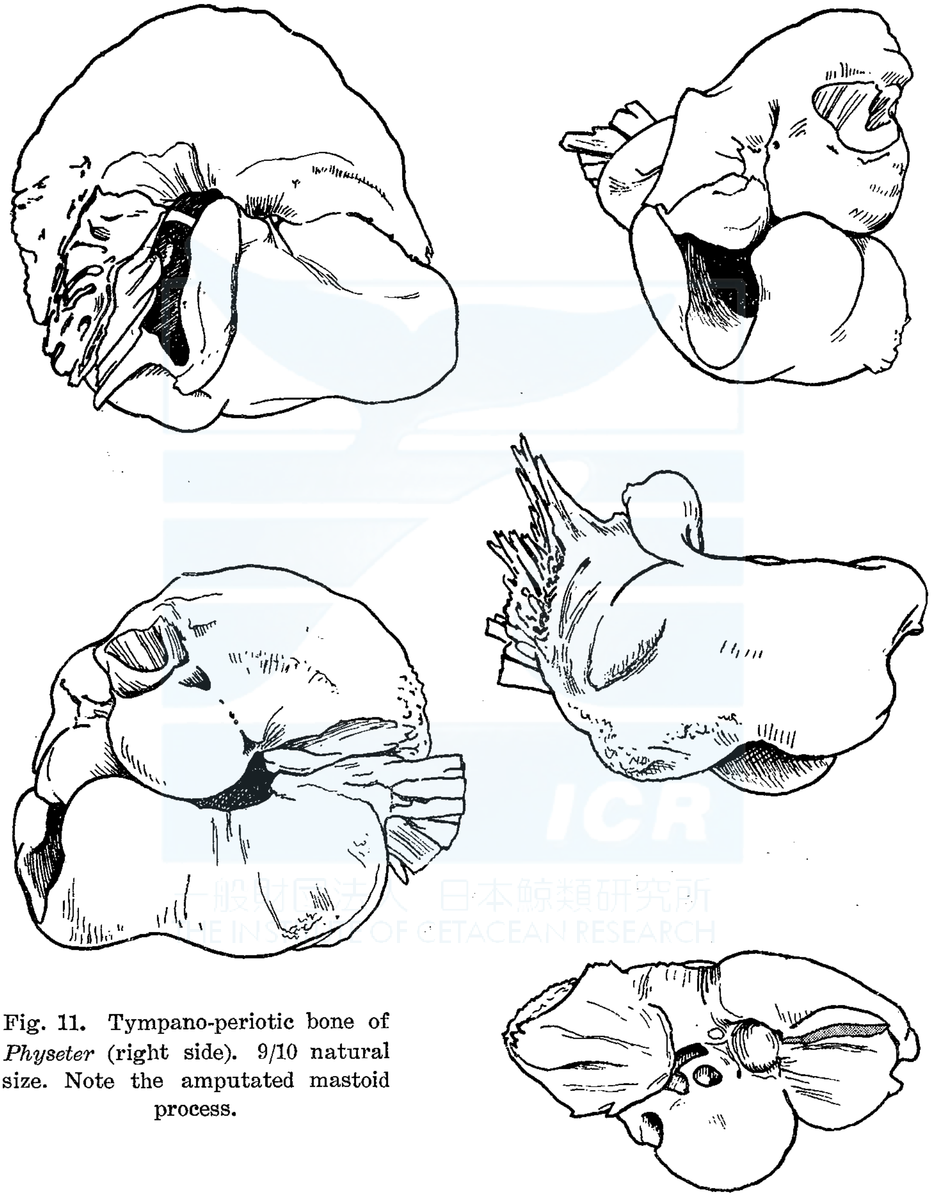

Fig. 11. Tympano-periotic bone of *Physeter* (right side). 9/10 natural size. Note the amputated mastoid process.

each other that the tympano-periotic cannot be separated from the skull without destroying this connection of the mastoid process. These conditions have been correctly described by Flower alone so far as known to me (1867, p. 321), who simultaneously pointed out imperfect figures of the bone by Camper and Owen, in which the process is broken off (footnote, same page).

The lateral view of the periotic is shaped like a helmet, of which the anterior peak corresponds to the tegmental process and the posterior to the mastoid process. It is peculiar too that the mastoid process of the periotic stretches its pointed extremity downward over the same process of the tympanic, both sides of the process being provided with rough tuberosities toward its margins continuing sideward with the complicated upper side of the mastoid process of the tympanic. The syndesmotic articulation facet of the periotic is diamond-shaped though in some cases often irregular, but its curvature is somewhat like a saddle, namely concave lengthwise and rather convex corsswise, presenting a central longitudinal crest which divides the surface into two oblique side slopes. Otherwise the articulation facets of the periotic as well as the tympanic present not prominent signs of the ridges and corresponding negatives which radiate backward from the anterior corner of the diamond. In other words, the long crest just mentioned may be interpreted as an extreme one of these ridges. Along the furrow of the epitympanic hiatus, several striations traverse the bone in a way which likely to associate us with some filed artifacts but in reality not. The medial border of this epitympanic furrow marks a crest which stretches between the mastoid process posteriorly and the posterior rim of the mallear impression anteriorly. The crest is well developed but is equivalent to the ledge described in *Globicephalus* because an oval facet for the articulation with the short crus of the incus presents on its under side. In contrast to the previous families, this facet is characteristic for its slight elevation instead of impression. It is of some interest, in this relation, that a serial development is noticed from a thin osseous ledge to the thick crest as traced through *Globicephalus, Berardius* and *Physeter*, each representing other members of its own family with it. The epitympanic recess is relatively deeper and narrower as compared with the former families. Above all, the sulci lodging the facial nerve and the stapedial muscle are of remarkable depth, but the ridge between them develops less than other families, and the posterior boundary of the fenestra vestibuli borders sharply these sulci at their confluence. In front of the fenestra as well as the facial nerve canal opening, a round impression presents, the mallear impression which lodges the caput mallei in it. Anterior to this impression, a large tubal tubercle presents between the cochlear sphere and the tegmental process, being fused at its posterior upper part with these portions, elsewhere the tubercle is bordered from them by fissures but in close contact. This contact relation of the tubal tubercle to the cochlear sphere does not present in delphinidae family. The tegmental process, that is, the anterior peak of the helmet in simile, is pointed and turns steeply downward, but is extremely so short that the upper side of the periotic continues directly with the rostral margin of the bulla at its in-rolled lateral border across a fine fissure. It happens quite peculiarly, to the consequence, that the tubal tubercle as well as the cochlear portion present almost in a vertical plane together with the tegmental process and the bullar rostral margin.

The internal auditory meatus is free from those distortions as seen previously and is really round in contour. The foramina presenting in the fundus are as described before, but the vestibular aquaeduct, though less developed in caliber but similarly infundibularly shaped, is involved within the meatus. Serial distortions of the internal meatal foramina can be shown in the similar order of family-series, as is the case with the ledge-to-crest series of the articualtion of the periotic with the short crus of the incus, as *Prodelphinus*, *Globicephalus*, *Berardius* and *Physeter* (fig. 12). The cochlear aquaeduct, which is minute in comparison with other families, presents closely posterior to the internal auditory meatus.

Fig. 12. Serial distortions of the internal auditory meatus (right side). From *left* to *right*: *Prodelphinus, Globicephalus, Berardius, Physeter*.

The anterior bony union of the tympano-periotic components is again lamellated and relatively broad, measuring about 1.5 mm. in thickness and not less than 15 mm. in breadth. The union is continuous with the lateral border of the tubal tubercle and is fused, as in the previous cases but in broader extent, with the tegmental process posteriorly. Another remark with the physeterian tympano-periotic *in toto* is the contact relation of the cochlear portion to the bullar anterior involucrum in the tympano-periotic fissure. This is practically almost contact and a sheet of paper is hardly inserted through it, still this is not so strictly contact, for the facing massive bones can be swayed against each other by the opponent fingers of a hand, though slightly yet to a visible and sensible extent. These contact surfaces usually present impressions which border the tympano-periotic fissure.

Kogia (hereto fig. 13):

The tympano-periotic bone of *Kogia* is the smallest of all species examined by me, to exclude its enormous mastoid process, and probably so throughout the whole order. The bulla and the periotic are of almost equal size, measuring 2.6–2.8 cm. in length. Therefore, the bone is remarkable for its small size both relatively and absolutely.

Schulte (1917, pp. 394–398) described the bone into fine details and few is added here, but descriptions should be arranged in order to make coincide with the foregoing ones, particularly in regard to the terminology including the terms of direction. Schulte mentioned that the long axis of the bulla was nearly transverse, and consequently two borders are described as rostral and caudal respectively. The fact is, however, that the axis is pointing rostro-mesad, though stronger than other species, so the customary terms are seemingly preferable in the present paper.

The bullar semi-cylinder of *Kogia* can be expressed to be crushed or sharply folded into the usual two borders along a longitudinal crest. In spite that the bulla is pointed at the rostral extremity of this crest, the whole border of the rostral margin resembles that of *Physeter*. The lateral border of the bulla shows a transverse expansion along its rostral margin but the general contour of this side is shaped like an irregular parallelogram. The surface is rather flat but slightly convex crosswise, being marked by three elevations. The first presents on the rostral expansion of the parallelogram which is constricted a little distance behind the margin. The sigmoid process is greatly developed and massive, and really a tubercle of rather peculiar form like comma. The process is turned foreward, probably due to the remarkable thickness, and consequently the "sound-funnel" of Boenninghaus appears deeper. The tympanic aperture is very narrow and shaped like a sand-glass in which the hiatus epitympanicus is broader, whereas the lower genuine aperture is like a slit which stretches backward in an acute incisure along the neck of the mastoid process. The conicus process is obscure or lacking[1]

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[1] More or less strong process of the tympanic aperture may occasionally present between the lower margin of this aperture and the posterior side of the sigmoid process, when the conicus process becomes less obscure.

and the lower margin of the tympanic aperture expands laterad only faintly but in the manner of *Physeter*. The posterior portion of the bulla behind the sigmoid process presents a wider elevation which is the posterior one of the three related elevations. This portion is homologized as the globular hollow prominence of others and borders the posterior side of the parallelogram, of the lateral border of the bulla.

The involucrum is comparatively very massive, being broad posteriorly and gradually tapering rostrad. The tendency of in-rolling of the bullar borders is generally so remarkable that the whole border, with exception of the lateral border, strongly rolls. The posterior end of the involucrum forms a thick prominence. This has been described of the foregoing species as the medial one of the bilateral prominences of similar size, but in *Kogia* it is smaller in comparison with the lateral hollow one. The bullar depression inside between the two borders is very narrow and somewhat complicated.

The neck of the mastoid process is very much shortened and strongly strangulated. The process is enormously expanded in a shape of a fan laterad, backward and downward; above all the downward expansion rolls further foreward so as to cover the bullar hind border from below. The articulation facet presents proximally on the upper surface of the process as is in other cases. The surface is smooth and slightly concave lengthwise. Its form is a rhomb with rounded angles. From the two posterior sides of this articulation facet, radiate ridges, around score in number, within an approximate angular expansion of 85° laterad and backward. Somewhat similar ridges can also be seen in a deep and narrow depression between the bullar posterior border and the foreward and downward expansion of the process on the lower side of it. These structures suggest us of the widely radiating platal formation of the same process of *Physeter*, which is seemingly embedded this time wholly in the routine spongy bone tissue. Toward the border of the mastoid process, the upper surface of it, which is proximally provided with the just mentioned ridges, suddenly becomes elevated along the margin, the surface of this elevation faces obliquely laterad and syndesmoses in a notch of the squamoso-occipital border with the skull.

The periotic bone of *Kogia* is of peculiar shape, but resembles that of *Physeter* greatly, and it is in a sense practically a miniature of the latter. The periotic bone of *Physeter* bows deeply downward in a helmet-like manner as mentioned before; whereas that of *Kogia* is flattened and angulated in tubercles. To enumerate these tubercles, they are: two on the cochlear portion of which the major one protrudes out of the spheric

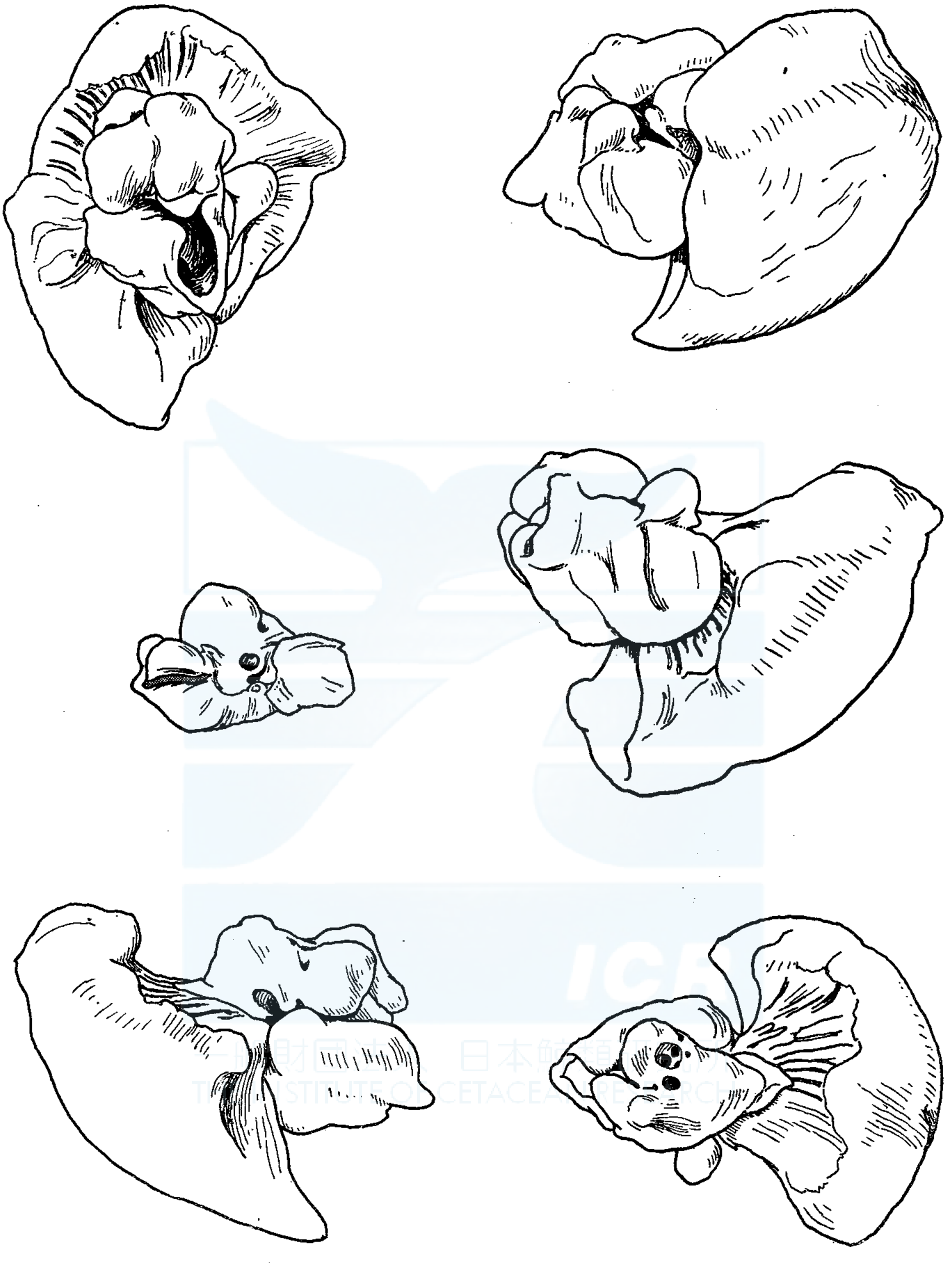

Fig. 13. Tympano-periotic bone of *Kogia*. Complete left side bone and dislocated right side periotic (*middle left*), somewhat larger than the natural size. Ankylosis artificially fractured is shown in half-tone as in other figures.

surface mesad, while the minor one upward in front of the internal auditory meatus; the tegmental process presents another one on its upper side at the symmetric position against the last mentioned one across the fissure which borders the tegmental process and the cochlear portion; the anterior extremity of the tegmental process presents another major one which protrudes mesad at a short distance medial to the proper apex; posteriorly the backward slope of the upper surface presents a remarkable prominence, which being prominent in longitudinal direction and so seems to be equivalent to the long crest of *Physeter* along its mastoid process; finally a prominent tubercle on the lateral border which is equivalent to the transverse dam-shaped eminence at the base of the tegmental process of other species. Here the contact is imperfect between the sigmoid process and this last tubercle. The anterior union between the bullar lateral border and the tegmental process or the tubal tubercle is quite similar to that of *Physeter*. The internal auditory meatus is bordered less distinctly and the facial canal as well as the vestibular aquaeduct open separately from the proper meatus.

d. Family Balaenopteridae :

Balaenoptera (hereto fig. 14) :

The tympano-periotic bone of *Balaenoptera* has been thoroughly described since Dwight (1872) by many authors including myself. The bone is enormous in size and weight as compared with odontoceti, still remarkably small in comparison with the huge head of the animal. The proportion differs greatly according to species. The tympanic bullae measure in length 13.1 cm. in *borealis*, 13.4–13.7 cm. in *physalus*, and 13.7–15.7 cm. in *musculus* species; and in greatest breadth 9.3 cm. in the first, 10.1 cm. in the second, and 9.8–11.2 cm. in the last species. Thus, it is noticed that the dimensional difference of the bulla remains comparatively little in spite of the remarkable difference of the body length, and consequently length of the head according to species.

The bulla of *B. physalus* is rather renal and of cowrie-shell form. It appears too like a man's profil facing laterad, in which the facial contour is figured by the irregular lateral border. From anterior to posterior, marked formations are: largest convex elevation appearing like forehead; then a transverse furrow becoming shallower downward, this looks like eye; about halfway of the border-line, the sigmoid process juts out laterad like nose; and continuing closely downward to this process, another elevation looks like cheek; behind the sigmoid process, the border protrudes laterad like mouth; and finally the posterior corner is prominent like chin. The lateral mouth-like protrusion of the border behind the

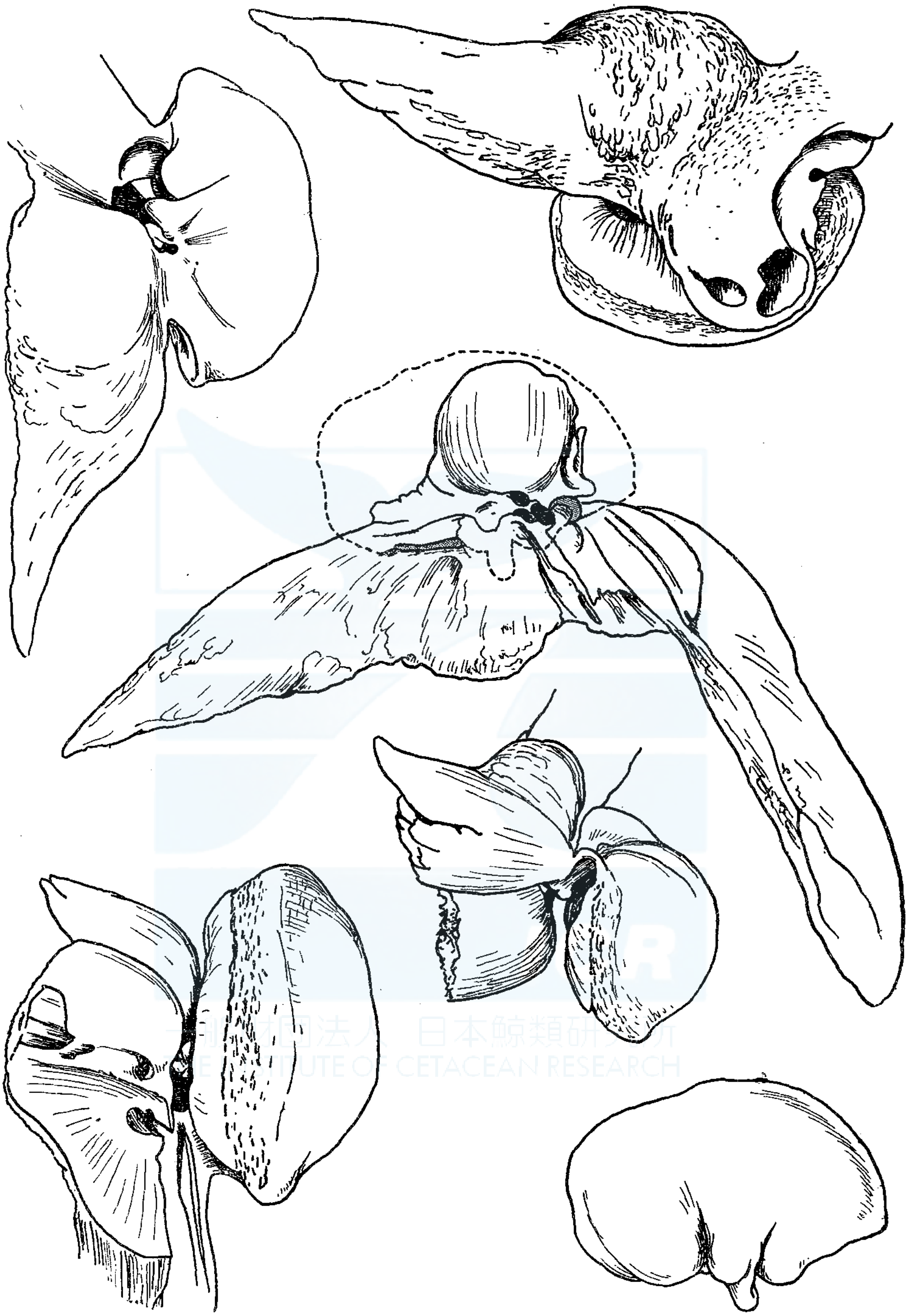

Fig. 14. Tympano-periotic bone of *Balaenoptera physalus* (ca. 1/3 natural size).

sigmoid process may be homologized as the conicus process which commonly presents in odontoceti with an exception of physeteridae, the margin rolling likewise inward. The sigmoid process stays about 5 mm. apart from the periotic, where the process in odontoceti comes into contact with the transverse eminence at the base of the tegmental process. The tympanic aperture, therefore, communicates with the triangular opening anterior to the sigmoid process, which is, in odontoceti, mostly[1] independent as previously described.

The medial border is an enormously developed involucrum like odontoceti but far heavier, broad posteriorly becoming narrower anteriorly. On the upper side of the involucrum, two distinct areas are present. The lateral area, facing upward to the tympanic cavity, is broader and smooth, traversed by faint wrinkles of which only a few are well marked. This area is somewhat but sharply elevated than the medial area which is narrower than the lateral and extraordinarily coarse and rugged with tuberosities, affording strong insertion of thick fibrous layer to the bulla. The anterior portion of the involucral border turns gradually laterad until it is continuous with the lateral border in the end. It is characteristic to *Balaenoptera* that the bulla is anteriorly thus closed. While at the posterior extremity, the two borders are united above the hindermost portion of the bullar depression like odontoceti, and the posterior pedicular union fuses the bulla here to the periotic. This posterior pedicle is thin but is curved just like the neck-portion of the mastoid process of the odontocete tympanic. This pedicle is peculiar too with the anterior one to the present genus. The anterior pedicle is obviously homologous to the anterior union as described of odontoceti and is broad but as thin. It should be emphasized here that no articulation presents in *Balaenoptera* between the tympanic and the periotic, which presents in all odontoceti.

The periotic bone is divided as well into three marked portions as the anterior pro-otic or tegmental process, the cochlear portion and the opisthotic or mastoid process. The general peculiarity of the bone is the surprisingly prolonged or extended development of the mastoid process which is wedged between the squamosal and the exo-occipital bones of the skull. The posterior pedicle is situated at the base of this mastoid process, where the process turns strongly laterad. The pedicle has a fossa concave laterad in its curvature, which is visible through the

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1) The sigmoid process of *Kogia* usually does not touch the tegmental process. To the consequence, the triangular opening, which is now a slit, communicates with the tympanic aperture like *Balaenoptera*. See p. 36.

tympanic aperture. The epitympanic recess is rather a deep sinus which caves in sharply and markedly between the posterior pedicle and the cochlear portion, presenting its oblong aperture to the tympanic cavity. The recess stretches backward in a narrow sulcus along the medial border of the posterior pedicle and finally opens in the posterior side of the bone. This sulcus is bordered downward by a slit-like fissure as is the case with *Globicephalus*, of which I mentioned as isthmus because of its more incomplete formation. No saying, the facial nerve canal and the fenestra vestibuli open at the bottom of the recess, and the backward stretching sulcus lodges the stapedial muscle as well as the facial nerve in it. No mallear impression presents but the well preserved meatal furrow traverses the under side of the bone, bordering the tympanic aperture in its ceiling. The contour of the tympanic aperture is not sand-glass shaped like odontoceti, because any marked portion like the epitympanic hiatus of odontoceti does not develop at all in the aperture above the tympanic membrane.

The tegmental process is somewhat pyramidal and tapers rostrad, slightly curving laterad. At the base of this process, a remarkably large tubercle protrudes laterad, which does not touch the sigmoid process as mentioned before, though this tubercle resembles the dam-shaped transverse eminence of odontoceti. The highly lamellated anterior pedicle fuses the basement of this process with the lateral border of the bulla. The tubal tubercle is utterly obscure.

The cochlear portion expands mesad from the confluence of other two processes, and is marked by a spheric dome-shaped eminence corresponding to the interior labyrinth. The lateral part of this dome slopes backward and its free margin borders sharply a remarkably large recess which presents on the posterior side of this portion lodging in it a considerably large mass of cartilaginous structure between this and the exooccipital bones. The fenestra cochleae opens in the posterior slope of the dome. The internal auditory meatus is composed solely of the nervous foramina, others being excluded outside the meatal formation. The vestibular and the cochlear aquaeducts present backward in this given order and the facial nerve canal anterior to the meatus. Concerning the upper side of the periotic bone, no particular mentioning seems necessary but the rugged and coarse nature throughout, which resembles somewhat the rocky mountain side.

The above description seems to be comprehensive of other species of *Balaenoptera* for the differences among them are quite slight. The bone of *musculus* species is most strongly bulit, while that of *borealis* less strongly, in both of which the tegmental process does not taper so sharply as in *physalus* (fig. 15). It can be added finally that *Magaptera* as well as *Balaena* seem to resemble *Balaenoptera* in outline as are illustrated by Hyrtl (1845, tab. 3, figs. 1, 2) and Hinoura (1943, fig. 12).

Fig. 15. Tympano-periotic bone of other balaenopterids. *Left*- Left side of *B. musculus*; *right*- Right side of *B. borealis*.

2. Relations of the Tympano-Periotic Bone to the Skull:

In earlier stages of development, the tympano-periotic bone of cetacea remains in a relatively large territory within the cranial basis like other mammals. But the further the development goes, the less becomes its relative size, and finally it happens that the bone is forced out of the cranial basis, this occurring particularly stronger in odontoceti than mystacoceti.

This procedure can be traced in *Globicephalus* as follows:—In the cranial basis of a foetal *Globicephalus* shortly prior to the birth, a major foramen concerned to the tympano-periotic bone is bordered by the alisphenoid, the basi- and exo-occipital and the parietal bones (fig. 16, top). After birth this foramen becomes strangulated in its anterior portion into a form of sand-glass by the approaching development of the alisphenoid, basi-occipital as well as the parietal (center). The foramen is thus divided finally into separate foramina by the completion of approach (bottom). The tympano-periotic bone is now perfectly excluded out of the formation of the cranial basis, and consequently the eighth nerve comes out of the brain case penetrating the cranial basis through the posterior foramen with other nerves, VII and IX–XI; whereas the anterior one is now the foramen ovale. As the animal grows further, the oto-cranial flange around the foramen develops taller, and accordingly the tympano-periotic bone is forced to shift with it further downward for the mastoid process is connected with the flange in the squamoso-occipital notch. In the meantime, the contraction of the foramen goes parallel and the one time foramen becomes at last a perfect canal. The condition resembles that of the development of the visual organ to a certain extent because of the surprising prolongation of the nerve. The periotic bone, which is first connected directly to the meninges along the margin of the internal auditory aperture, now becomes an organ which stays perfectly outside the brain case. It is noteworthy that the unfinished state remains in some smaller species. In *Neomeris*, for example, the foramen stays still undivided and the periotic bone keeps the direct connection with the meninges

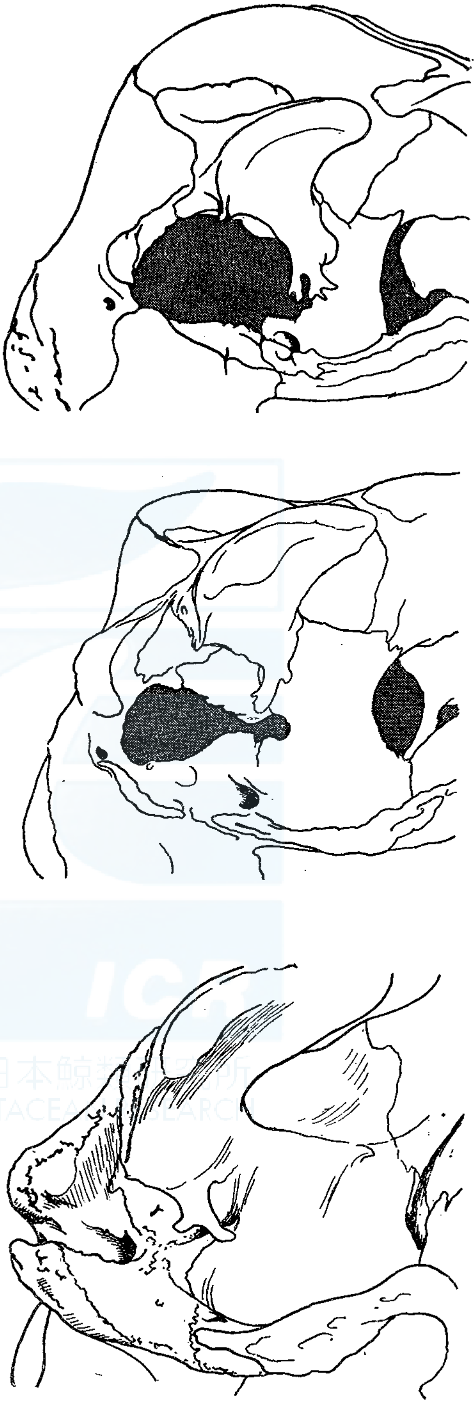

Fig. 16. Development of the cranial basis of *Globicephalus*.

through which the brain is visible when the tympanic cavity is opened. It seems also likewise in *Phocaena* judging from the descriptions of Boenninghaus. The connection between the tympano-periotic bone and the oto-cranial flange with the mastoid process of the former in the squamoso-occipital notch of the latter is of connective tissue as Boenninghaus described correctly (1904. p. 226). This connection naturally becomes un-united after maceration but is quite important as will be revealed by putting it into comparison with other families. This will be proved to be a specialized form of highest extreme.

For this comparison, any species will do good if it is of other families than delphinidae because those species have a more developed mastoid process as has been described before, and the process really connects the tympano-periotic bone far stronger to the skull in the same notch of the oto-cranial flange (figs. 24, 25). However, some species presents only loose connection which becomes usually ununited after maceration, while others more tight connection for its syndesmosing characteristics. Here it should be reminded that certain species of *Globicephalus* has a longer mastoid process which shows a probable intermediate form between the extreme delphinidae and the remaining other species (figs. 8, 17). Hyrtl's remark concerning *Delphinus gangeticus* of its wedging process (1845, pp. 34–35) seems, in this connection, most likely to be a stronger case of this kind, but unfortunately no detailed descriptions are given, which are needed here for comparison[1]. Mystacocete species has a more markedly developed mastoid process which is of similar relation to the skull, in which the connection is far stronger. Only one remark seems enough here to note that the process of mystacoceti is peculiarly of periotic and not of tympanic (fig. 17).

The second connection of the tympano-periotic bone to the skull is seen anteriorly between the tegmental process of the periotic and the so-called falciform process of Beauregard of the squamosal bone. The latter process remains falciform in delphinidae but develops thicker in ziphiidae as well as *Physeter* into a club-shaped or digitiform process (figs. 16, 24). The process extends downward over the upper side of the tegmental process, and is closely related in this way to the periotic bone and holds this securely under it by a strong connective tissue. Curiously this process as well as the fibrous connection thereof are lacking in *Kogia* alone (fig. 25). Similar relation to connect the tympano-periotic bone to the skull other than the mastoid process is found also in *Balaenoptera* in a different way as was already mentioned and dia-

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[1] The process is said to be of periotic. Confer further p. 64.

grammatically illustrated in my former paper (1948, p. 28, fig. 1b). To supply or to correct that, the tegmental process of the periotic, being coated and continuing with a thick cord of connective tissue, penetrates the lateral border of a large fossa, wherein the tympano-periotic bone as well as the sinus system lodge, in the rostral direction to the exterior periost which lines the infratemporal fossa through a canal bordered by the pterygoid and the squamosal bones (fig. 18). The periost now in question is directly continuous with that of the mandibular fossa where it develops surprisingly well in order to tight the mandibular articulation which lacks any joint cavity or disk whatever. This second connection of *Balaenoptera* seems to strain the organ strongly to the skull and most likely to be the similar connection though it occurs peculiarly in a different form in comparison with odontoceti.

Beside the above men-

Fig. 17. Various development of the mastoid process. From *top* to *bottom*: *Grampus*, *Berardius*, *Physeter* (ventral view), *Kogia*, *Balaenoptera*. Periotic component is marked by toning. Cf. fig. 8.

tioned two major connections, the formation of the sesamoid ossicles are peculiarly learned in some species. The most striking development of these bones is shown in *Balaenoptera* and has been already mentioned in my former paper (1948, p. 29, fig. 1 a). They are large and small and irregularly shaped and scores in number and distributed within the layer of connective tissue between the upper side of the periotic and the facing surface of the skull, abundant chiefly in the cochlear area but also in the proximal part of the tegmental process. The extremely rugged surface all over the upper side of this area of the periotic bone is now fully understandable as the closely related feature to this remarkable structure. The sesamoid ossicles present also in *Physeter* likewise in the same layer lining the contact surface of the periotic to the skull, and in ziphiidae too some really appear in occasions, particularly in aged individuals, though much weaker in development.

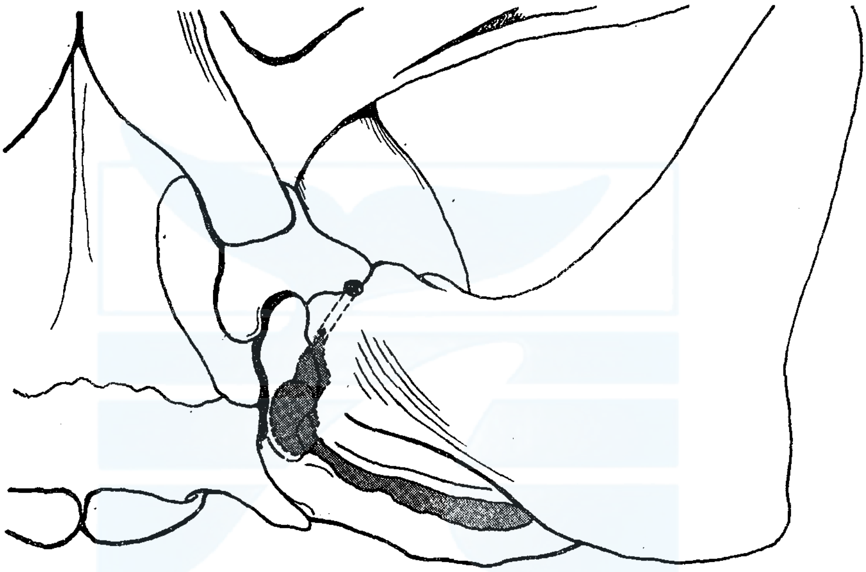

Fig. 18. Cranial basis of *Balaenoptera physalus* (based on the skelton in possession of the Zoo of Osaka). Tympano-periotic bone in half tone.

Considering these peculiarities throughout the entire order with the structure of the tympano-periotic bone altogether, it seems that the organ is planned after one major principle, probably that the tympano-periotic functions as a vibrating organ as a whole. This will be discussed in the following chapter in details over again, but it seems of much significance and interest of morphology that so many characters coincide well each other, partly however, in developmental series, among different species, despite the genera, families and suborder.

3. Tympanic Cavity:

a. Tympanic Ossicles:

The tympanic ossicles are peculiar both in odontoceti and mystacoceti for their stumpy and thick development as well as the ankylosed relation of the malleus to the lateral border of the tympanic bulla. Above all, this ankylosis has been disputable whether it is of the manubrium mallei or the anterior process of Folius. The dispute, however, now seems to be settled to the latter as mentioned by Boenninghaus (1904) and Lillie (1910). I myself stand on this side too because of the mode of attachment of the tympanic membrane to the malleus. The tympanic ossicles do not differ in their general formation from the usual mammlian principle (Hyrtl, 1845; Doran, 1879), but they are in every way cetacean, of which some inter-subordinal differences should be mentioned.

The malleus of odontoceti (fig. 19) has generally a proportionally large caput which presents a large articulation surface with the incus in its posterior part of the upper side. This surface is divided sharply into two facets bordered nearly by a right angle, both being slightly convex, of which the upper vertical one is much broader. The incudomallear articulation is a compound articulation because the facets are so sharply marked from each other and no movements can be expected. The anterior part of the upper side of the caput lies in the already mentioned mallear depression of the periotic bone, being closely related to it. The manubrium is reduced to a minute process or tubercle and is connected with the triangular ligament of Beauregard to the tympanic

Fig. 19. Right side malleus of (from *left* to *right*) *Globicephalus*, *Berardius*, *Physeter*, *Kogia*, *Balaenoptera* (*physalus*) (twice natural size).

membrane. The tympanic membrane is in odontoceti concave, while in mystacoceti curiously protruded like a finger-sac laterad, in both cases the membrane is pretty thick and obviously cannot vibrate. The vibrating possibility of the tympanic membrane can be excluded also by the closure or practical obliteration of the external auditory meatus. The membrane, which receives sound waves through the external auditory meatus no more, now becomes vistigial and seemingly thickened. In both cases the membrane is forced remarkably laterad and between its internal surface and the malleus the triangular ligament has been well known (figs. 22, 23). This ligament is in odontoceti literally triangular and arises from the lower margin of the membrane stretching rostro-mesad toward the manubrium within the tympanic cavity. The ligament is, on the other hand in mystacoceti, rather a strong cord and arises from the upper interior surface of the protruded tympanic membrane. From these relations, the manubrium is aways identified with more or less difficulty. But this has escaped curiously from the researchers' notice in the past including Cuvier as well as Beauregard, until Denker who described this tubercle as the "Falz" although he did not regard it as the manubrium (1902, p. 435). In my examination, the manubrium always presents, though in both species of physeteridae and in *Berardius* it is utterly rudimenal and hardly identified. The neck portion, collum is pretty well preserved in delphinidae because of its marked development of the muscular process, while in other species this portion is obscure or quite lacking. At any rate, the muscular process affording the insertion for the tensor tympani muscle usually presents at the anterior end of the malleus. This is a minute process in *Berardius* and in *Physeter*, but in *Kogia* it is an utterly minute recess instead, and in other delphinids the similar recess can be seen at top of the muscular process. The malleus of *Balaenoptera* is much larger but does not differ so strikingly from odontoceti that particular treatments seem unnecessary but to point out that the ossicle has more developed manubrium and the muscular process and is flattened as a whole antero-posteriorly and that the bone has some comparable common appearance to delphinidae. The synostotically ankylosed anterior process of malleus is rigid and easily broken by a slight force. The process is directed laterad as has been well illustrated by Boenninghaus (1904, p. 264). This seems to have been caused by the forced transfer of the bullar border laterad together with the tympanic membrane.

The incus of odontoceti (fig. 20) is usually stumpy and short, being divided into the corpus and two crura, the long and the short ones. The corpus presents the articulation surface with the malleus, which faces laterad and is divided by a transverse crest into two concave facets corresponding to those of the malleus. From the corpus two crura extend backward and laterad. The former is the long crus and the latter the short one. The short crus is directed sideward, but in *Berardius* whose bone is medium sized, it is really longer than the long crus though much more slender. In *Globicephalus*, whose bone is minute, both crura are of almost of similar length, yet the short crus is usually more slender than the long one, and it seems only in *Physeter* that the short crus stays in every way short but comparatively thick, in this species the ossicle being largest of all odontoceti. The incus of *Kogia* is somewhat smaller than *Globicephalus* as well as *Grampus* and slightly bigger than *Prodelphinus*, but it is really a miniature of *Physeter*, being more strongly compressed in its long axis. In both secies of physeteridae, the short crus curves peculiarly more mesad than other families. The short crus presents on its free end an oblong and minute characteristic facet upward for the articulation with the already mentioned facet of the periotic bone (cf. pp. 23, 31). In this respect, Boenninghaus is obviously errorneous because he described that the short crus was for the connection with the tympanic bulla (1904, p. 268), on which some comments will be repeated in the next chapter. The long crus turns near its end suddenly upward and there is another lenticular articulation facet as minute and of similar shape as that of the short crus. The facet articulates the incus with the head of the stapes.

Fig. 20. Right side incus of (from *left* to *right*) *Globicephalus*, *Berardius*, *Physeter*, *Kogia*, *Balaenoptera* (*physalus*) (twice natural size). Note the short crus of odontoceti with an articulation facet on its end.

The incus of *Balaenoptera* is less stumpy but is exceedingly larger than odontoceti, and probably the largest in the entire mammalian class. The short crus is now reduced to a minute and pointed process, accordingly it lacks the facet whatever as seen in odontoceti. In the meantime, the long crus curves upward and its end is provided with a renal or lenticular articulation facet which connects the incus with the stapes.

It is summarized, to the consequence, that the incus of odontoceti is strikingly different from *Balaenoptera* not only in its size but also in one more important respect, that is, the peculiar prolonged development of the short crus, and the articulation facet on its free end. This articulation is very much interesting not only morphologically but also to the functional side because some important mechanical rôle such as fulcrum in the ossicular movements can presumably attributed to it. I believe therefore, that this structure stands strongly on the affirmative side concerning the also disputable function of the tympanic ossicles.

The stapes also, is in odontoceti, short and stumpy in general (fig. 21). This tendency is most striking in *Physeter*, of which the two crura are so thick that no intercrural spatium can be seen, but instead, small depressions indicate the position of the spatium on both sides of the ossicle. The most striking stapes is of *Kogia*. Kernan (1918, p. 266) referred to the ossicle of a foetal *Kogia* as it is not fenestrated; while he illustrated the ossicle with a dimple which indicates the fenestra (fig. 16 of his paper). But in adult kogiids, not a slightest sign of dimple nor crura can be seen and the bone is practically an extremely thick stump. In delphinidae the crura are well developed but the ossicle is here thinner than the foregoing species, and the minute spatium still exists inter-crurally. But some of delphinidae species may present obliteration of the spatium since Denker described such case of *Phocaena* (1902, p. 436). Of the same species, however, Boenninghaus is opposite because the spatium still remains as a minute opening (1904, p. 269). Therefore, considering either of the case of *Kogia* together with the remark of Kernan, or of *Monodon* and other species by Rapp (1837), Hyrtl (1845) and Doran (1879), obliteration may occur as the individuals grow older. While, *Berardius* seems to be exceptional in this respect because I have never experienced any obliteration, and the spatium is as narrow but usually exists. In this species, the stapes is far taller than other odontocete families and the crura are distinct. The stapes

Fig. 21. Right side stapes of (from *left* to *right*) *Globicephalus*, *Berardius*, *Physeter*, *Kogia*, *Balaenoptera* (*physalus*) (twice natural size).

of *Ziphius* is similarly tall but the spatium is usually closed. The capitulum has a minute tuberosity facing backward on the upper end of the posterior crus, which affords the insertion of the stapedial muscle. And at top of the capitulum, a minute elliptical articulation facet presents downward usually in a more or less twisted direction mesad, and consequently approaching the transverse direction to the body axis more or less. The basis of the stapes is comparatively well developed in odontoceti, in a form renal or elliptical. The basis presents a sharply prominent annular margin toward the labyrinthic vestibule, which causes a more or less strong concavity of the basal surface. This concavity occurs most strikingly in ziphiidae. Due to the prominent annular margin, the basis is encircled by an edge of certain depth in a cylindrical way, and to the consequence, the basis lodges relatively deep in the fenestra vestibuli. This margin is incised characteristically in its posterior lateral part, apparently related to the ampulae of the two semicircular ducts of the labyrinth, viz., the lateral and the superior (fig. 26).

The stapes of *Balaenoptera* is some several times larger than odontoceti and seems to be the biggest among mammals like the other two ossicles. The bone is still typically cetacean because of its thick and stumpy development and of the minute intercrural foramen.[1] It is relatively tall, and in this respect, comparable to those of ziphiidae. But distinct differences of this bone from other odontoceti are the comparatively more slender crura but the larger spatium and capitulum as well as the not concave basal surface. The surface is flat throughout with only slight elevations. Therefore, it is rather convex though slightly, being conclusively opposite against odontoceti. But it should be kept in mind that the basal surface of *Balaena* is concave according to Hyrtl (1845, p. 72).

Some disputes have been known concerning the connection of the stapedial basis with the border of the fenestra vestibuli. This is a problem whether an oto-sclerosis occurs in cetacea or not. Hyrtl who discovered the synostosed stapes of *Monodon* and some other delphinidae species, mentioned that the stapes is rather broken and thus comes out of the window and not slips out, whereupon Denker is a denier (1902, p. 436). Boenninghaus revealed that the annular connection is of synchondrotic nature like other articulations within the ossicular chain but that synostosis can occur in occasions (1904, pp. 271–272). I myself regard that synostosis may occur, but the fact is that such cases seem

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[1] A thin bone plate is stretched between the crura. The intercrural foramen is a fenestration of this bone plate.

hardly to happen so far as learned by me. I can mention, therefore, that the stapes is easily broken leaving its part of the basis in the fenestra, but this seems greatly due to the peculiarly deep and close fitting of the stapes in the fenestra for the sharply prominent margin of the stapedial basis as has been just described. I stress further in this connection that much care and attention are needed to pull the stapes out of the fenestra *vestibuli* without destroying its basis, for this is quite easily broken when some other dimensional force is given than the lengthwise one.

b. Tympanic Cavity with Pneumatic Sinus.

The tympanic cavity is both in odontoceti and mystacoceti rather a limited room of some complexity, expanding between the tympanic bulla and the periotic, ental depression of the former bordering the bottom and the epitympanic recess of the latter the ceiling. The cavity expands in odontoceti through the tympano-periotic fissure, and the hiatus epitympanicus as well as the anterior aperture, i. e., the orificium tympanicum of the Eustachian tube of Boenninghaus, with large and small expansions known commonly by name of the pneumatic sinus. From the lateral tympanic membrane, the tympanic ossicles stretch continuously mesad across the cavity to the fenestra vestibuli. Beside these, the peculiar cavernous body, the corpus cavernosum tympanicum develops well in odontoceti within the cavity. This cavernous body arises with a broad origin from the medial mucous layer lining the lateral wall of the striking crest of the basi-occipital bone, which extends downward and borders the middle ear medially, and stretches into the tympanic cavity through the tympano-periotic fissure. Therefore, this is a mucous fold of the middle ear, in which the cavernous structure is well developed. Posteriorly the body presents a chord-like free margin, in which run some branches of the ninth nerve of relatively large caliber supplying the tympanic plexus with blood vessels rostrad (cf. p. 21). Anteriorly the body gradually diminishes continuing through the tympanic orifice of the Eustachian tube with the medial mucous wall of the middle ear without any distinct demarcation. Both species of ziphiidae have most striking development of this structure which presents less strongly in delphinidae and least in physeteridae (fig. 22). Histological examinations prove that this structure is really the cavernous body, wherein nerve bundles of the tympanic plexus can be shown running strongly undulated. From these observations, it is most likely that the cavernous body can be distended so remarkably as to fill up the entire tympanic cavity as demonstrated after intravascular injection by Boenninghaus (Denker, 1902. p. 439). But the relation of the cavernous body to the fenestra cochleae seems important to note because Boenninghaus described that this window was usually stuffed or covered by the cavernous body, and consequently he attributed to this structure a special and important rôle (1904, pp. 274, 286) to which I will refer afterward and deny it though such tendency often presents in delphinidae species to a certain extent. The cavernous body is so well developed that it can be examined easily and correctly if the bottom of the bulla is properly fenestrated or removed.

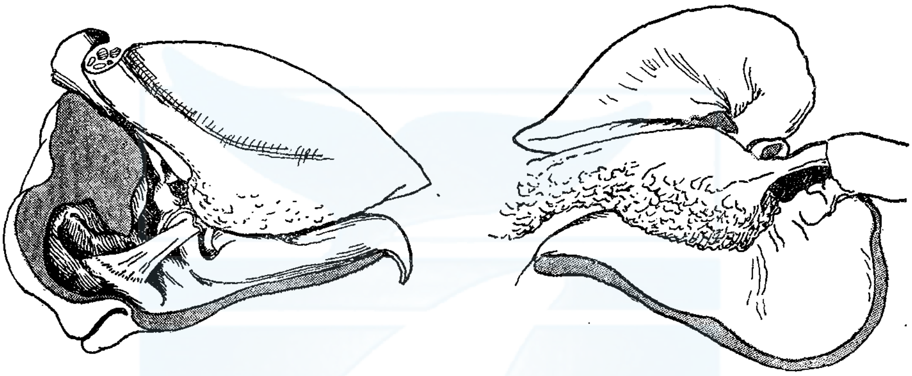

Fig. 22. Left side cavernous body of *Globicephalus* (*left*) and *Berardius* (*right*). In *Globicephalus* the triangular ligament and the chorda tympani nerve are illustrated.

But the tensor tympani muscle seems problematic in odontoceti because its existence has been quite disputable. For instance, Hyrtl (*Monodon, Delphinus*), Boenninghaus (*Phocaena*), Kernan (*Tursiops*) and Kellogg (*Monodon*) are affirmative authors; whereas Cuvier (*Phocaena*), Beauregard (*Delphinus*), Denker (*Phocaena*) and Kernan (*Kogia*) are deniers. Here it is noticed as curious that concerning the same species some workers stand opposite against each other. Such a dispute may bring a speculative decision by itself that this muscle really exists. And really this decision is correct.

The tensor tympani muscle of odontoceti arises from the medial side of the tubal tubercle and runs backward ending in a fine cord of tendon which is inserted into the muscular process, tubercle or recess of the malleus already described. The muscle is naturally minute and really rudimental throughout and in occasions it may go more or less degenerated. But every time I examined the fibers under microscope during dissection, striations were clearly certified on its fibers. I have made this examination not for an intention to establish degenerations but to certify the scanty fibers of unknown nature if they are really muscular or not, which come into sight after preparing the cavernous body off from the tubal tubercle, and which are quite uncertain to identify. Probably this deep position of the muscle under the cavernous body, connected firmly to the tubercle, may have been the reason of the overlooking, but the tendon can usually be observed with less difficulty (fig. 23). The most recommendable way to ascertain the existence of the muscle is simply done by confirming the minute muscular process, tubercles or recess which presents on the anterior serface of the malleus. This is recommended because no preserving of material nor careful preparation is necessary and the macerated bones are good enough. These topographical peculiarities of the tensor tympani muscle reveal well that the interpretation as well as the terminology of Boenninghaus of the

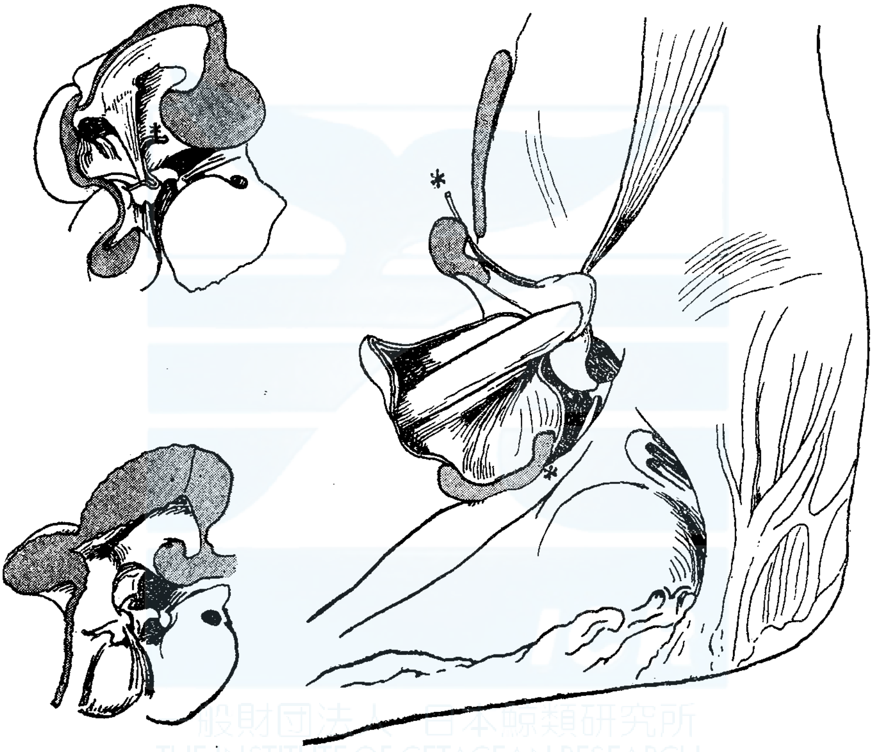

Fig. 23. Tympanic muscles. *Left top*- Left side of *Globicephalus*; *left bottom*- Left side of *Kogia*; *right*- *Balaenoptera*, right side. Chorda tympani nerve is illustrated in *Globicephalus* and *Balaenoptera* marked *.

processus tubarius and the orificium tympanicum of the Eustachian tube are quite proper and correct. While in mystacoceti no disputes have been known against the existence of the muscle which is strongly and aponeurotically degenerated. This reason may be that the muscle can be easily identified submucously, though it is much more vestigial than odontoceti.

The stapedial muscle is, in the meantime, pretty well preserved both in odontoceti and mystacoceti. The muscle arises in both cases from the already mentioned sulcus in the epitympanic recess and runs rostrad ending in a similar tendon like the tensor tympani muscle and is inserted into the minute elliptical tuberosity at the capitulum stapedis. It may be generally surmised that this muscle still functions (fig. 23).

It must be added with some significance that the tympanic cavity is very often, and in cases almost perfectly, filled with a striking glomerular mass of nematodes, which is sometimes partly forced out of the tympanic cavity into some attaching sinuses. One case of *Neomeris* was quite extreme in this respect, but less extreme parasites are seemingly common to *Grampus* and *Globicephalus* to say the least. These parasites have been well known since Rapp (1837). In one individual of *Kogia,* I observed a large number of distoma.

From the tympanic orifice of the Eustachian tube of Boenninghaus and from the tympano-periotic fissure as well as the hiatus epitympanicus, the tympanic cavity of odontoceti communicates with the pneumatic sinus system. To mention them with exception of delphinidae family, they are commonly four in number (figs. 24, 25), of which the pterygoid sinus is greatest. This sinus may well be interpreted as an expansion of the proximal part of the Eustachian tube according to the relation of the tensor tympani muscle mentioned before. The sinus expands enormously in the as big pterygoid fossa of the pterygoid bone. The mucous layer of this sinus is well marked for the trabecular framework as seen commonly throughout the surface. In its medial wall, the mucous layer presents under it a striking vascular plexus which is characterized by a strong framework affording apparently an enormous distension of the wall. This submucous framework attains its fullest development at the rostral corner of the sinus. Under the lateral wall, the pterygoid muscles lie submucously, being covered by the surprising adipose body from outside, which fills up laterally the mandibular hiatus and stretches on one hand further backward until it comes contact to the lateral under side of the bulla, where to the bottom of the so-called "sound-funnel" of Boenninghaus the adipose body has some particular connection by the concentrating but scanty connective tissue fibers with the periost

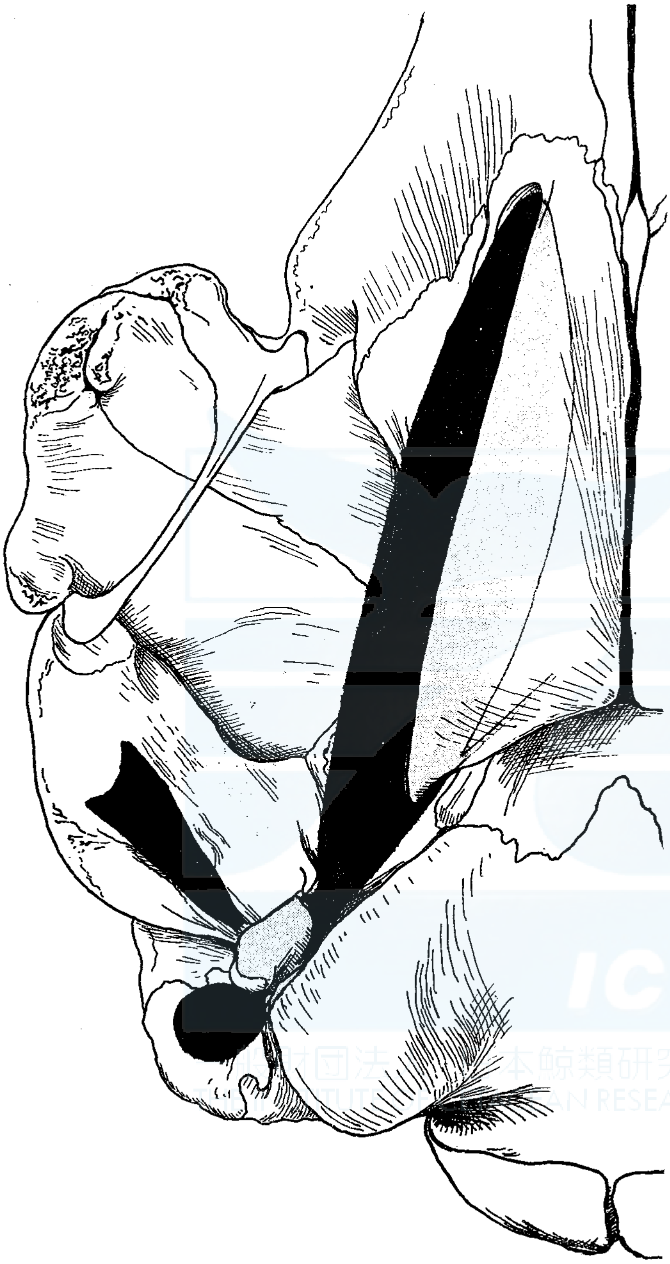

Fig. 24. Diagrammatic distribution of the pneumatic sinus in *Berardius*, based on the specimen in possession of the Dept. of Anat., Univ. of Tokyo (about 1/16 natural size), the otic region is reconstructed. Note the falciform process of the squamosal bone, which lacks in *Kogia* (fig. 25).

thereof. From these topographical relations between the mandibular adipose body and the lateral wall of the pterygoid sinus, I guess that the movements of the lower jaws may effect strongly upon the distension of the pterygoid sinus. The Eustachian tube begins in front of the tympanic orifice at the proximal lower part of the medial wall of this sinus and ascends through a marked incisure of the pterygoid bone and opens into the nasal passage. At the pterygoid entry of the tube, the mucous layer presents a plica which presumably functions as a valve not to force out the enclosed air under high pressure when the animal dives to depths.

Other sinuses are minor and not so peculiar as the pterygoid one but in a different way in their mural structures, and naturally seem not to afford so much dilating possibility like that with exception of the epitympanic one. They have commonly the trabecular connections across the lumen between the facing walls, strongly in particular in corners. The epitympanic sinus, which is probably analogous with the sinus moyen of Beauregard, expands laterad under the zygomatic process of the squamosal bone in close contact with its surface. The sinus is situated above the mandibular articulation and accordingly may be put in expansion and compression by the mandibular movements. The sinus is continuous with the tympanic cavity through the hiatus epitympanicus which opens directly above the tympanic membrane in the tympanic aperture. The peri-

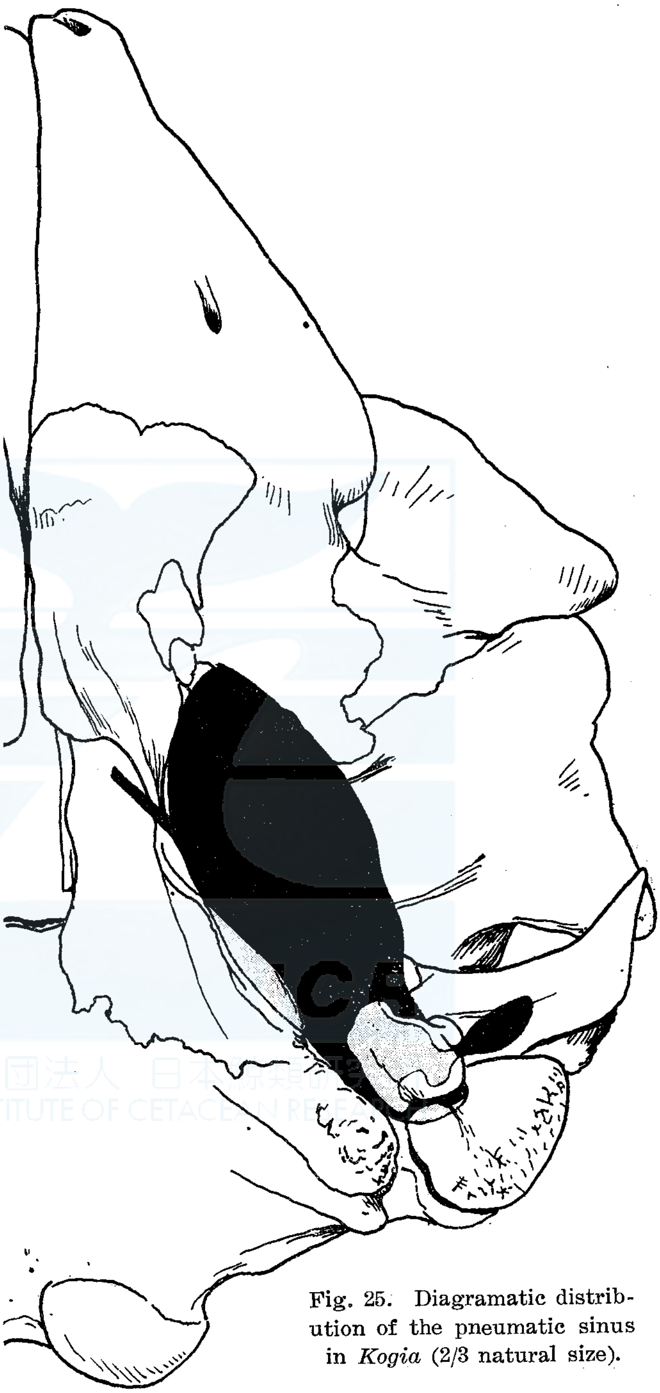

Fig. 25. Diagramatic distribution of the pneumatic sinus in *Kogia* (2/3 natural size).

petrosal sinus[1] is communicated with the tympanic cavity through the tympano-periotic fissure. The sinus is expanded upward surrounding the cochlear portion of the periotic bone so irregularly with abundant trabecular connections across its lumen. This sinus is peculiar to odontoceti and of some historical meaning because the view of the acoustically isolated tympano-periotic organ or labyrinth seems to have been originated from its unusual expansion. The posterior sinus expands in an oval form under the mastoid process of the tympanic bone, and continues with the tympanic cavity through the posterior portion of the tympano-periotic fissure around the medial side of the neck of the mastoid process. The ground layer of this sinus is characteristically cartilaginous because the tympano-hyal cartilage is here flattened into a similar-shaped plate and is continuous with the posterior surface of the neck of the tympanic mastoid process. The sinus is similar to the epitympanic one but differs strikingly from it by this underlying cartilage. The lumen is flattened too and the facing mucous walls are so close that they are usually connected by the trabeculae. The sinus system of delphinidae, particularly the pterygoid sinus, is specialized much more and presents some further expansions as the maxillar, frontal and temporal other than the above mentioning as has been fully demonstrated by Boenninghaus (1904).

The tympanic cavity of mystacoceti is more simple because so well developed cavernous body as seen in odontoceti is lacking whatever. But the mucous layer lining the ceiling of the cavity is rugged complexly with various folds and vesicular formations as described in my former paper (1948, p. 26). Therefore, it is now conclusively mentioned that the tympanic cavity of mystacoceti has no structure so perfectly fill it up like the cavernous body of odontoceti does, but only slightly. The tympanic orifice of the Eustachian tube is not so well marked as in odontoceti nor the tubal tubercle. This tubercle seems to have been united with the tegmental process because the tensor tympani muscle arises from the furrow between the process and the cochlear sphere. The pneumatic sinus system is weaker in development but of some peculiarity of mystacoceti itself. The pterygoid sinus of *Balaenoptera* expands greatly, but relatively in less dimensions in comparison with odontoceti, within the pterygoid fossa which stays rather isolated from the exterior of the sinus, being perfectly covered behind the pterygoid process by the enormously thick layer of connective tissue together with the bulla and other sinuses from below. Thus the sinus seems in *Balaenoptera* free from the mandibular movements and differs from odontoceti con-

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[1] The peribullar sinus of Beonninghaus is involved here.

siderably. However, the sinus is capable of distension pretty well because its wall is beset with the cavernous tissue with vascular network which is developed peculiarly in it. The peribullar sinus communicates with the tympanic cavity, and also with the pterygoid sinus anteriorly. It does not occur that the sinus expands so far upward around the periotic bone as in odontoceti. Posteriorly the tympanic cavity as well as the peribullar sinus expand laterad into a blind sac stretching around the medial side of the posterior pedicle, so this may be called as the posterior sinus for its relation with the tympanic cavity similar to odontoceti. On the upper wall of this sinus the vesicular formations and the vascular trabeculae similar to those of the tympanic cavity usually hang.

As has been described before and in my former paper too (1948, p. 25), the otic region is separated and protected in *Balaenoptera* by the thick layer of connective tissue. This has been also mentioned in *Megaptera* by Lillie (1915, p. 106). Lillie divides this layer into the interior yellow elastic and the exterior spongy tissues, and notices furthermore between the bulla and these layers another fatty tissue. The structure is the same in *Balaenoptera* but such a demarcation seems not always proper nor necessary in this genus because the development of the spongy tissue varies and is not constant. This layer, which borders downward upon the pharyngeal cavity, is continuous on the other hand laterally with the strong fibrous connection of the mandibular articulation. The layer connects interiorly the medial border of the bulla very firmly to the basi-occipital bone, thus bordering the floor of the peribullar pneumatic sinus. But between the under side of the bulla and this layer the connection is quite loose but fatty as apparently called by Lillie accordingly. Similar fibrous connection presents commonly in odontoceti too and is called by Boenninghaus as the "Bindegewebsplatte der Bulla", who stressed simultaneously the firm connection between the medial border of the bulla and the cranial basis by this tissue (1904, pp. 229–230). Now it is well and fully understood that the medial side of the bullar under surface is strongly coarse without exception. Whereas the lateral side of the bulla is smooth and the connection becomes suddenly loose. The already mentioned adipose body of the mandibule in odontoceti extends so far as this region. While, mystacoceti has no such adipose body for the mandibular hiatus is not specially deformed. However, the similar tissue structures are seen in the impression in front of the sigmoid process, which is in odontoceti the "sound-funnel" of Boenninghaus.

The chorda tympani nerve is another very interesting problem in the present field, but I have not perfectly succeeded to examine it. In

Globicephalus the nerve really exists (fig. 23) and the minute perforation is observed in the caput mallei (fig. 19) as described by Boenninghaus (1904, p. 267) closely in front of the articulation surface. But I could not ascertain the penetrating relation of the nerve through it probably because of the condition of the material. In ziphiidae as well as physeteridae, the nerve did not come under my notice, nor the malleus is perforated. It should be noted in this connection that the perforation does not appear in *Grampus* too. Boenninghaus remarked simultaneously that such a perforation occurs characteristically in odontoceti alone, though some insectivores have the nerves which do penetrate the anterior process of the malleus (Hyrtl, Doran). However, a pinniped, *Lobodon carcinophagus* Gray of the Antarctic[1], is interesting because it has so resembled malleus that it is hardly distinguishable from delphinidae, wherein the perforation really presents at the exactly same spot of the caput. Therefore, this species may well be expected to present the similar relation of the chorda tympani nerve. While in *Balaenoptera*, there is the nerve but no mallear perforation can be seen. At any rate, I am of opinion that the triangular opening in front of the sigmoid process between the tympano-periotic components, which is in *Balaenoptera* communicated with the tympanic aperture over the margin of the sigmoid process, may afford the pathway to the nerve, therefore it may well be interpreted as the Huguier's canal in the human anatomy. In reality the strange but common structure of the concentrating scanty fibers of the mandibular adipose body toward the bottom of the "sound-funnel" of Boenninghaus appears to have some meaning, and further the outwardly curious extention of the adipose body as far as the bottom of this recess seems to be understood if the just mentioned interpretation be allowed, to the establishment of which I should go further.

Chapter 3 How the Organ Functions

1. Introductory Review:

As stressed by the previous authors, and as described in the present work, the external auditory meatus of whales cannot be allowed to transmit any sound waves through it to the tympanic membrane or to some apparatus of conduction within the middle ear. The external auditory meatus is extremely vestigial, being closed up during its course (mystacoceti) or toward the medial extremity (physeteridae), or being

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[1] I had an opportunity to examine this animal during my last whaling trip by favor of Maj. J. A. Crombie of the U. S. Army, an Allied observer on board the ship, who hunted seals several times.

so narrow that there exists no lumen of some significance (delphinidae and ziphiidae). The tympanic membrane which is so thick or curiously protruded and the indirect connection of the malleus with the membrane but ankylosed relation with the tympanic bulla hardly expect the vibrating possibilities of the membrane nor those of the malleus.

Denker (1902, pp. 433-434) demonstrated, through Bezold's experiment in *Phocaena*, that the vibrations of the tympanic membrane could never be transmitted into the tympanic ossicles. But other authors had tried, before Denker, to conclude the transmitting pathway to take over that of the normal mammalian principle. In this direction, Camper (1762) alone was exceptional, who was of opinion that sperm whale could hear by way of the external auditory meatus and the tympanic membrane. In the meantime, Buchanan (1828) considered whales to hear through the Eustachian tube. Buchanan's view, however, was later protested by Claudius (1858) because the nares open only intermittently at times of breathing, and usually stay closed under water. Denker did not forget to note further that usually loud noises are unfavorably accompanied by every breathing. Meanwhile, Boenninghaus (1904, p. 287) accepted Buchanan with a proviso that it might happen momentarily when the animal swallows, otherwise the tube remains closed even when the nasal passages open to the air.

Obviously, these views are wholly errorneous after our present knowledge because they argued from a premise that whales would hear the air-borne sounds and not the water-borne ones. Anyway such a premise have been regarded improbable by the later authors.

Claudius (1858) stated that vibrations borne in the water and accepted by the entire head, put the air in the pneumatic sinus of the middle ear into strong resonance, which is transmitted into the labyrinth by way of the chain of ossicles or the secondary tympanic membrane in the fenestra cochleae. It is important here that the acoustic isolation of the entire tympano-periotic organ from the skull is noticed first by Claudius. Later Denker (1902, pp. 444-445) agreed this view in outline, being apart from Claudius in one respect that he was suspicious about the vibrating possibility of the triangular ligament which was allowed by Claudius.

Boenninghaus comes next in 1904. After careful and detailed work on harbor porpoise, he concluded a new theory that the sounds are accepted with the formerly related ''sound-funnel'' (Schalltrichter) which is said to function as a substitute of the absent auricule, and the sounds, after reaching its bottom, namely the anterior process of the malleus, are transmitted by the ossicular chain into the vestibule. According to him, the conduction through the chain is molecular and the stumpy and compact comparatively large ossicles developing rather progressively should favor the conduction through that chain. He stressed too, like Claudius and Denker, the acoustic isolation of the labyrinth and that the isolation is essential to shut out the energetic interference by the strong vibration of the whole skull. He added further that the partial connection between the tympanic and the periotic restrains the conduction from the bulla to the cochlea to a least extent: the peculiar fusion of the two components within the tympano-periotic organ is thus involved in the category of the labyrinthic isolation. He was of opinion that first by the isolation fine hearing comes possible to whales. He precautiously enumerated further possible interferences and mentioned how each is removed. Boenninghaus seems to have dealt with the sinuous problem with much considerations because he accepted that the air-filled cells are quite easily and strongly resonated under water—these were very much annoying structures to his Schalltrichter theory. Hereupon the thick mucous layer with the developed vascular network and the cavernous tissue within the tympanic cavity as well as the sinus system remove the interference, and the fenestra cochleae is protected by the cavernous body from the invasion of the resonating air in the sinus. Next those possible interferences come into question in relation to the conduction through the ossicular chain, which might be caused by the tympanic membrane through the triangular ligament and by the tympanic bulla through the short crus of the incus (pp. 283–284). The latter is particularly un-understandable because the crus has no connection with the bulla but with the periotic, of which Boenninghaus was obviously incorrect. It is a matter of much importance here to note that the so-called "sound-funnel" of Boenninghaus did not occupy Denker's attention, and to the contrary that the pneumatic sinus which was regarded indispensable as resonator by Denker, was neglected by Boenninghaus being attributed by the different hydro-static function. In spite of the detailed and earnest-minded work with circumspect considerations, the view of Boenninghaus could not exceed delphinidae and was really so hard to understand that soon later a serious confusion was brought into our field.

In a book published in 1912, Abel (p. 458) quoted Boenninghaus by mistake or after his own modifications that the sounds, penetrating the soft parts to the tympanic bulla, are hold of by this apparatus and further transmitted upon the tympanic membrane and into the ossicular chain to the fenestra vestibuli. Concerning the mystacocete organ of hearing, Abel considered the mastoid process of the periotic to function not only as a fulcrum but also as a propagating apparatus. Boenninghaus must have seemed awkward to Abel who was apparently of intention to synthesize the cetacean organ of hearing as a whole in one definite principle or in a series of modifications.

Two years before Abel, Lillie (1910, p. 781) published his view, on treating of mystacocete whales, *Balaenoptera musculus* and *B. sibbaldii*, as whales probably receive sound vibrations by means of vibrating bony surfaces because the tympanic bula is a relatively dense and heavy sounding-box and could easily be set into vibration. It is noteworthy that Lillie did never refer to the so-called isolation of the organ of mystacoceti whatever, and that his view is practically similar to Abel's. Further Hanke (1914, pp. 522–523) concluded that *Balaenoptera* indicates an adaptation attained in a different way from odontoceti[1], because the tympano-periotic bone is not forced aside out of the formation of the cranial basis as is the case with odontoceti, but is supported firmly with the skull with two processes. Concerning the odontocete organ, he gives in entirely to the view of the acoustic isolation of the tympano-periotic which he confirmed himself of some dolphins in reference—*Delphinus delphis* and *Tursiops tursio* (p. 488).

Matthes (1912) had good reasons, in this connection, in criticizing Abel severely. He, as a devoted supporter of Boenninghaus, denounced Abel, particularly in two points. One was Abel's mistake that the tympanic membrane, which had been excluded once by Boenninghaus out of the conduction system, was brought into it again. Another point was the mastoid process of mystacoceti as the fulcrum as well as the propagating apparatus because this Abel's view practically violated the precept of Boenninghaus that the labyrinth was acoustically isolated.

In the meantime, Kernan reported in 1918 (p. 267) of a foetal *Kogia* and emphasized concerning the present question as, "it is important to recall that the os tympanum and the periotic are nowhere in contact with the other bones of the skull and that they are surrounded by numerous cells capable of distention with air. So it seems necessary to suppose that sound waves must reach the internal ear through a cushion of air immediately related to the periotic, though not necessarily that contained in the tympanum alone". Kernan seems to have been influenced at that time more than necessary by Denker of the question of isolation. But Boenninghaus seems not to have influenced Kernan because strangely to this German author few had made references and his name being never

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[1] His intention was to make mystacoceti clear, in concert with Boenninghaus, but the material was limited in foetuses.

given in Kernan's paper too. I cannot understand at all concerning this, how and why Kernan came to consider this way, since Schulte described (1917, p. 394) the well developed tympano-mastoid which fits between the squamosal, the exo-occipital and the oto-cranial flange of the basi-occipital, presenting its broad base in the lateral surface of the skull.

Kernan wrote, however, one year later in the Laryngoscope (1919, p. 512), without correcting his previous view of isolation, that the tympano-mastoid, "an outgrowth of one of the bones related to the organ of hearing, should be noted, as it had in all probability much to do with the ability to hear". This is because the process "appears largely on the surface of the skull in a notch between the squamosal and exooccipital". He concluded that (p. 520) "sounds are evidently transmitted to the cochlea through the solid tissues of the head. The possibility of this is increased because in both forms[1] the auditory bones themselves present on the surface of the skull a considerable bony process. In both, moreover, the periotic and tympanic are but loosely connected to the other bones of the skull. Thus they can receive only such sound waves as impinge directly on themselves. Since the malleus is firmly fused to the tympanic it would share the vibrations of that bone, transmitting them through the other ossicles to the oval window".

Finally Kellogg (1928, p. 204) wrote that "whales have acquired an organ of hearing in which resonance must play an important part", and that "water-borne sound vibrations transmitted to the air contained in the tympanic bulla cause it to function as a sounding box, and its vibrations reach the cochlea by way of the ossicular chain and the vestibule". And further Kellogg noticed (p. 206): "the porpoises, dolphins, sperm whales, beaked whales and their relatives all have the ear bones attached to the skull by the ligaments".

These are the outline of the past disputes concerning the question how the organ functions. Now that any experiment is almost impossible, I would not like to advance my own view if it would practically add one more dispute toward the confused problem. The mentioned situation of the problem, however on one hand, urges me to do it because it sounds to me quite unfavorable to leave the confused disputes to the future as they are at present. The experiments will become possible in time and surely the cetacean organ of hearing will foreward some suggestions to the science of hearing sense, in particular to the physiology, above all, to that of the bone conduction of sounds because the organ is in every way mammalian in principles and the seemingly different structures are

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1) Odontoceti and mystacoceti.

nothing but the wonderful re-modelling, that is to say, consequences of adaptation to life in the water.

The views of the previous authors can be summarized and classified as follows:— a) Classic views of Camper and Buchanan who regard the function similar or not far apart from that of the land dwellers. These are so simple and lacks the sound foot-steps on the morphological data that they will be set outside of the present considerations. b) Schalltrichter theory of Boenninghaus is peculiar, being supported by Matthes and Hanke, but not by others, at least originally not. c) Resonance theory with which Claudius, Denker, later Kernan (1918) and Kellogg took part. They are mostly of opinion except Kellogg that the air in the pneumatic sinus is brought into resonance which is transmitted to the cochlea by way of the fenestra vestibuli, though Kernan does not states clearly so. According to Kellogg, the resonating air in the sinus makes the bulla a resonating sounding box, the vibrations herein being transmitted to the vestibular window by way of the ossicular chain. d) The so-called osteo-tympanic conduction such as Lillie, Abel and Kernan (1919).

2. General Accounts on the Question of Acoustic Isolation:

The first of the matters which my criticisms would deal with hereafter is the question of the acoustic isolation of the labyrinth or the tympano-periotic organ from the skull. This is most important because every branch of further discussions in the entire problem gets influenced in essentials by this matter. As is obvious through the foregoing pages, some authors have clung to this view of isolation. It is important here that most of those authors participated almost exclusively in the family delphinidae. It is true that the tympano-periotic organ of delphinidae is connected with the remaining skull only by fibrous tissues including the meninges; consequently the bone becomes isolated after maceration. It is true also that delphinids are convenient material due to their small size, but it cannot be exaggerated that one should be fully shy and careful to discuss the whole order according to the results obtained from dolphins or porpoises. It seems to me very much instructive that nobody has ever advanced practically such theory as the isolation of the hearing organ in mystacoceti.

At any rate, the tympano-periotic bone of whales is connected to the skull by the mastoid process of either periotic or tympanic as described in the previous chapter in details—with concessive exception of delphinidae family to admit the so-called isolation. The shape of the mastoid process as well as the size and manners of attachment to the skull are naturally different specifically and individually. According to my experience, the tympano-periotic bone of family ziphiidae and *Kogia*, whose mastoid process develops well, becomes often separated after maceration; this seems usual in *Kogia* or likely to occur when the animal stays immature. Concerning these cases, do the exponents of isolation theory insist the bone to be still isolated because the connection is of merely fibrous? This may sound as my pin-prick trick, but I do believe the principle is the same both in delphinidae and other families. If the connection in delphinids would be interpreted as isolated acoustically, whole order must have the hearing organ acoustically isolated though usually weaker in scale. The so-called acoustic isolation is wholly un-understandable.

Hyrtl (1845, pp. 34–35) remarked *Delphinus gangeticus* as exceptional in this respect since its periotic is provided with a process which wedges the bone between the squamosal and the occipital. I do not know that fresh-water dolphin has the process of either the periotic like mystacoceti, or the tympanic like ziphiidae and physeteridae, but this remark of Hyrtl is quite suggestive toward the present dispute. It is important that a single exception has been known against the isolation theory whether the process is really of periotic or tympanic. How can the fact be explained that within a family all have the tympano-periotic organ acoustically isolated but one—*Platanista*?

3. Concerning the Schalltrichter Theory of Boenninghaus:

As referred to before, Boenninghaus was right in description of the fibrous connection of the tympano-periotic to the skull, still he interpreted it like other connections, no particular meaning being ascribed to it. This is, in my opinion, because he participated solely in *Phocaena* and some other species of delphinidae. He concluded (1904, p. 281) the acoustic isolation of the labyrinth, by putting special weight in the lack of direct connection of the tympano-periotic to the skull and in the partial separation of the tympanic and the periotic components, plus in the peculiar topography that the periotic stays perfectly apart outside the cranial basis. Such an isolation was essential to Boenninghaus, because it was indispensable to exclude the bone-conduction which might interfere with the normal vibrations of his own, transmitted through the Schalltrichter and the ossicular chain to the fenestra vestibuli. If single case of *Platanista* or some other family would have come to his reference work simultaneously, he would have changed his conclusion of the acoustic isolation into some other form.

The situation of Boenninghaus is thus understood, but it is my undissolved question if the view of isolation has been derived from many imperfect descriptions including Hyrtl's, in which the mastoid process of the tympanic is broken entirely off. It seems to me, in this connection, that Kellogg (1928, p. 206) was such a case, as he wrote all members of odontocete suborder to lack those connections which are in reality well developed in ziphiidae and physeteridae to say the least.

With the end of a discussion about the acoustic isolation, the theory of Boenninghaus receives the most fundamental head-lines of the criticisms. But the *Schalltrichter* overlaid by the soft parts seems so strange to attribute to it a function to concentrate sounds, as was practically misunderstood by Abel. According to Boenninghaus, the sounds reach the bottom of the *Trichter* after penetrating the soft parts over it, but it is almost impossible to accept his view that the sounds selectively put the malleus alone into direct vibration on its anterior process at the bottom of the *Trichter*. The simultaneous vibration of the bulla to which the malleus is ankylosed is, in his opinion, damped by the soft parts covering directly its surface. How can the vibration of the malleus alone be undamped in spite of its rigid connection with the bulla?

4. Concerning the Resonance Theory:

This theory also argues the problem on assumption of the isolated organ as is the case with the Schalltrichter theory, consequently it does not comprehend mystacocete organ in it, may it sound probable in odontoceti. This is really easier to accept and the sound is received by the solid tissues of the head and further puts the air in the pneumatic sinus system including the tympanic cavity into resonance. This resonance was a serious problem to Boenninghaus who interpreted that the cavernous body as well as the thick mucous layer of the middle ear function as an eliminator of the annoying resonance from interference. For the propagation of the resonance into the cochlea, seemingly possible paths are the fenestra cochleae, particularly the secondary tympanic membrane stretched in the window, and the ossicular chain.

The physiology of the secondary tympanic membrane is usually learned as to set the cochlear liquid into vibration by its countervibration in response to the movements of the stapedial basis. But the relation is different in cetacea of which the stapes is synchondrosed in the fenestra vestibuli and no movements of the basis are accepted to occur against the cochlear liquid but the molecular vibrations. This relation seems inconvenient to the resonance theory, may the secondary tympanic membrane do vibrate. Now that the stapes is so firmly secured in the window, it seems hard to find out the counter-vibrator of the secondary tympanic membrane elsewhere of the two aquaeducts of the internal ear. Of these aquaeducts, the vestibular or endolymphatic duct is better suited to the rôle due to its topographical relations, but the duct is so slender and seems really impossible to meet such a function (fig. 26). While the cochlear or perilymphatic aqueduct is usually developed much better and the vibration may well be caused in the cochlea by the combined movements of the secondary tympanic membrane and the liquid in the aquaeduct. But the liquid vibration thereby apparently does not cover the most important part of the organ—the organ of Corti, hence it is far from the expected function.

Boenninghaus (1904, p. 286) denies the conduction of the resonating vibration of the air in the pneumatic sinus system into the cochlea through the fenestra cochleae because the window is clogged by the cavernous body. I mention that the window is not always clogged entirely by the cavernous body nor overlaid by the thickened mucous layer. Nay, to the contrary, it seems favorable to the resonance theory when the window is only imperfectly covered.

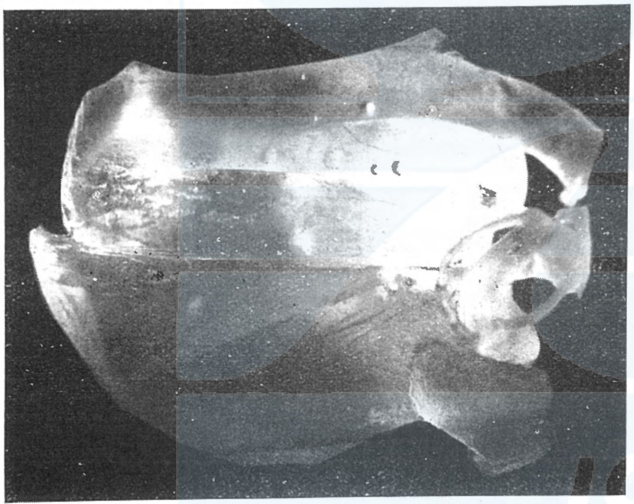

Fig. 26. Cast of the labyrinth of *Berardius* (right side) to illustrate the topographical relations as well as the dimensions of the cochlear and vestibular aquaeducts (ca. × 3.3).

Denker was reasonable to advance his resonance theory because he overlooked the existence of the tensor tympani muscle which remains in a perfect form though small or quite vestigial. The case of Denker may be judged therefore as he has put no value to the ossicles. Laying the difficult-to-find tensor tympani muscle aside, always perfect stapedial muscle suggests that the tympanic ossicles stay not functionless. For what purpose does the stapedial muscle outlive the ossicles if they became really functionless? If Denker had noticed these muscles and thought as far as the ossicles, he would have never risked to put these structures out of his considerations.

Naturally Kellogg is different, who believes the existence of the tensor tympani muscle and the function of the ossicles. He is of opinion that the ossicles really transmit the vibration of the tympanic bulla caused by the resonated air in the middle ear. But these are the theories based on the isolated tympano-periotic organ from the skull, to which I cannot yeild.

5. Concerning the Osteo-Tympanic Conduction:

The last views of Lillie (1910), Abel (1912) as well as Kernan (1919) belong to the category of the so-called osteo-tympanic conduction and seems really to outlive the foregoing theories. However, the fact has been against my expectation that this view has a few supporters, and to make the matters worse, that even the concerned authors themselves gave only insufficient remarks which seem like one kind of mere ideas. This view is noted since it has been originally advanced from the side of mystacoceti, and odontoceti has been later introduced into this by Kernan. The outline goes in the following way. The sound vibrations are first received by the solid tissues of the head directly from the water, then transmitted through the mastoid process into the tympano-periotic organ. The malleus which is rigidly fused to the bulla transmits the vibration of it further to the fenestra vestibuli.

Lillie seems to have advanced the view with little confidence because he referred five years after his first publication to some other possibilities (1915, pp. 107–108), either that the sound vibration could be transmitted to the elastic lids of the external nares, being further transmitted into the tympanic cavity through the Eustachian tube, or that it could be conducted from the alae of the external nares to the bullae. At that time, the tympanic bulla should act as a sounding-box which is connected to the fenestra vestibuli by the chain of ossicles. The former view appears similar to that of Kellogg which has been just commented in the last paragraph. Whereas the latter is different considerably from his original view (1910) in which it was the bony surface that received the vibrations from the water.

Abel's view concerning mystacoceti is exactly of this category but he never succeeded to bring any satisfactory solution into our field to involve the odontocete suborder, as has already been quoted in review by myself.

Finally Kernan is curious indeed and hardly understood because in 1918 he advanced once the resonance theory in *Kogia*, but became suddenly converted one year later to another not typical view of the present category. May it be allowed, he became then too bold to mention that the tympano-periotic bone presents a *considerable* bony process on the surface of the skull both in odontoceti and mystacoceti. In my opinion he has made more successful and presumable approach than anyone else did, but his view does not explain delphinidae, in which any *considerable* process of the tympano-periotic organ does never exist, which appears largely on the surface of the skull. Therefore, delphinids seem to lack those portions whatever on which sounds might directly impinge. Moreover to make the matters worse, nobody of this category in general has mentioned how the tympanic bulla could be regarded as a sounding box and how significant the auxiliary structures were.

My anatomical remarks mentioned hereafter in review as well as the functional considerations will make this view more probable than the previous theories, being less in troubles. The tympanic bulla is of very striking relation to the periotic bone. The connection is extremely so fragile between these components that they can be easily broken and separated by a slight force as is well learned during treatments both in odontoceti and mystacoceti. In odontoceti the connection is made by the anterior synostosed union and the posterior syndesmosed articulation; while in mystacoceti by two thin pedicles, the anterior and the posterior. In *Physeser*, whose anterior union is comparatively strong, the bulla can be swayed against the periotic by hand to an extent visible and sensible. This experiment can be safely tried because the bullar involucrum is in so close relation to the cochlear portion of the periotic that these two portions come into contact before the union goes broken. While in *Balaenoptera* the bulla is very often dislocated by the inevitable shocks in sawing operation of the huge skull by the steam-driven bone-saw into cubes as big as convenient to handle. One extreme and unusual case was already related of a sei whale in the beginning of the second chapter, whose bullae were not only dislocated but crushed into pieces by the harpooned shock on the head.

From these experiences I have come to a belief that the tympano-periotic bone of cetacea is specially planned according to some important dynamic principle. This dynamic is apparently that of a seismographic principle. When the solid tissues of the head receive the sound vibrations from the water, the entire tympano-periotic organ may be put under seismic influences, when the proportionally heavy involucral border of the bulla acts as a weight of pendulum because that border lies medially exactly at the pendulous remote position to the lateral thin and fragile union or unions (fig. 27). The separated relation of the bulla to the bordering crest of the basi-occipital bone is thus well understood. According to this dynamic the malleus stays relatively still in the vibration, and the seismographic amplitudes are caused between the malleus and the periotic bone. These amplitudes are transmitted by the remaining ossicles to the fenestra vestibuli, when in odontoceti the short crus of the incus seemingly functions as a fulcrum of more effective conduction by its articulated connection with the periotic bone. It is for this reason that I believe the significance of the tympanic muscles in the not unusual physiology though the tensor tympani muscle is often more vestigial.

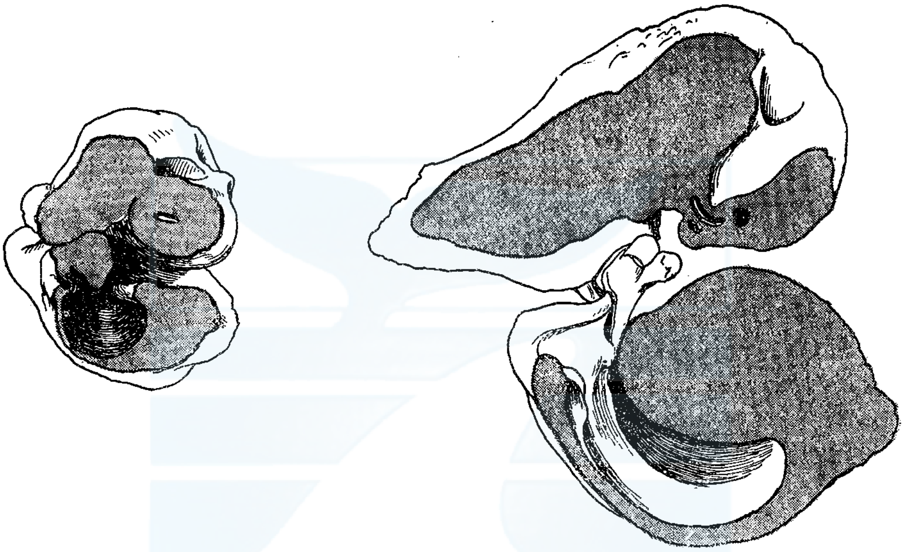

Fig. 27. Transverse section of the tympano-periotic bone (right side). *Left- Globicephalus*; *right- Balaenoptera.*

The specially stressed characteristic connections of the tympano-periotic bone with the skull most probably amplify the vibrations of this entire complication of bone components, the "tympano-periotic organ" as a seismometer. In these connections the tympano-periotic organ is without doubt isolated from the skull, strongly in particular in odontoceti, but the isolation is *never acoustic* because the propagating connection is indispensable, which is wonderfully achieved by the mastoid process between this organ and the skull. Really the neck of the mastoid process is quite easily broken and by some authors described as it is; while the falciform process of the squamosal bone in odontoceti as well as the pro-otic fibrous cord straining the tegmental process to the infratemporal periost in mystacoceti similarly protect the entire organ from excessive vibration. Delphinidae species can never be exceptional but is a specialized case of the same principle.

I can enumerate further some concerning auxiliary peculiarities by which the organ can be set in good and noiseless vibrations as: the well developed peripetrosal pneumatic sinus of odontoceti, the remarkable formation of the sesamoid ossicles between this organ and the cranial basis in *Balaenoptera* together with some larger odontocete species, and the cartilaginous buffer body behind the cochlear portion of the periotic bone in *Balaenoptera*. The entire pneumatic sinus system may be one of these auxiliary structures. The function of the sinus system has been variously surmised by the foregoing authors, namely Denker (1902), Boenninghaus (1904) and Hanke (1914) mentioned the sinus to make the submergence of the head or its sustention above the water surface easy by regulating the head weight. Kernan (1918) did likewise, but he added another one to afford additional surface for the absorption of oxygen by the blood. Kellogg (1928) explained the sinus to regulate the pressure of the entire pneumatic cavity of the middle ear.

I myself agree with Kellogg because the sinus system develops far better in odontoceti for its deeper submergence, than mystacoceti both in dimensions[1] and in its mural structures, including the cavernous body, probably in order to regulate the pressure of air inside the sinus system in wider range. I would like to point out with some stress that the largest pterygoid sinus is in odontoceti generally covered by the enormous mandibular adipose body, and the particularly close topographical relations of the epitympanic sinus to the mandibular articulation because, as has been mentioned in the last chapter, these relations seemingly indicate that the entire sinus system is strongly influenced by the movements of the lower jaw. These may not be positively related to the auditory function but it may be indirectly significant to that that the pressure of air in the sinus is seemingly raised temporarily when the animal opens the mouth for feeding under water, when the pterygoid opening of the Eustachian tube becomes closed by the mucous valve to prevent the interior air from leaking out. Thus the sinus system resists against the enormous pressure of the water, still it seems to happen that some amount of water soaks into the sinus because the interior of the sinus is often found foaming and bacause really one little fish as well as krils have come to my examination in the sinus, the former in one *Physeter* and the latter in some cases

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[1] Though I did never try to gauge the pneumatic sinus system of either suborder, it is apparent that odontoceti greatly exceeds mystacoceti in proportion.

[2] I am not entirely confident of these discussions of the sinus problem because these observations could be abnormal cases.

of *Balaenoptera physalus*[2]. Meanwhile, the air of the middle ear cavity might be resonated as is insisted so in the resonance theory but I cannot take it as essential to the auditory function of cetacea because the already mentioned cases of the glomerular parasites often fills up every corner of the tympanic cavity in some odontoceti, when the resonance can never be transmitted into the cochlea but the conduction of sound waves through the ossicular chain is not bothered at all.

The remarkable difference of the organ of hearing between odontoceti and mystacoceti lie, in the structure of the labyrinth, particularly in the arrangement of the cochlear spirals and in the development of the secondary lamina spiralis of Hyrtl. The surprising development of the secondary lamina in odontoceti has been repeatedly learned by many authors since Hyrtl (1845). Above all, Kolmer (1908) revealed that this extreme case occurs only in odontoceti. Whereas, concerning the first mentioned difference, no remarks have been known to me. It occurs in odontoceti that any apical portion of the cochlear canal never lies above the more basal portions and this is also peculiar to this suborder (fig. 28).

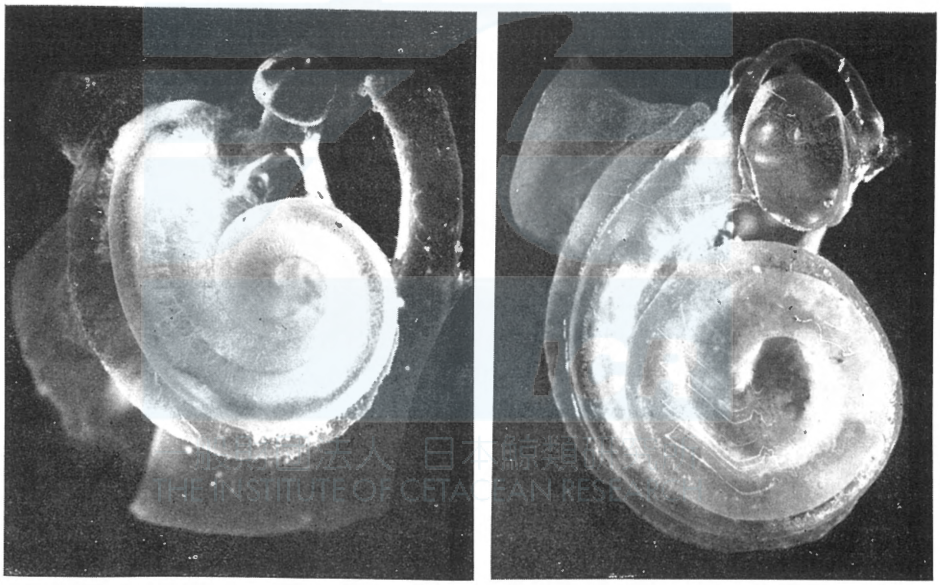

Fig. 28. Cast of the labyrinth (right side). *Left- Berardius* (ca. ×3); *right- Balaenoptera* (ca. ×2.5), showing the different coiling manners of the cochlear canal.

Here is a minor experiment of myself concerning *Berardius* which will contribute a little morphological datum toward the cetacean audiogram. Owing to this last mentioned characteristic of the odontocete cochlea, the macerated bones can be operated along the full cochlear length with dental lathe and various points. This procedure must be carried out, however, with finest care because the delicate bony laminae as well as the modiolus are quite easily broken or vanish by the slightest touch of the rotating points. When the preparation is finished successfully, the spiral laminae both primary and secondary appear in the canal, opposing against each other so closely across the lengthwise spiral slit which gradually broadens toward the apical end. According to the histology, the width of the spiral slit seems well to be regarded almost equal to that of the actual basilar membrane. The increasing widths of this spiral slit can now be measured (fig. 29)[1]. In *Berardius* this slit increases the width very gradually in its basal portion and stretches as far as ca. 8/10 length of the whole canal.

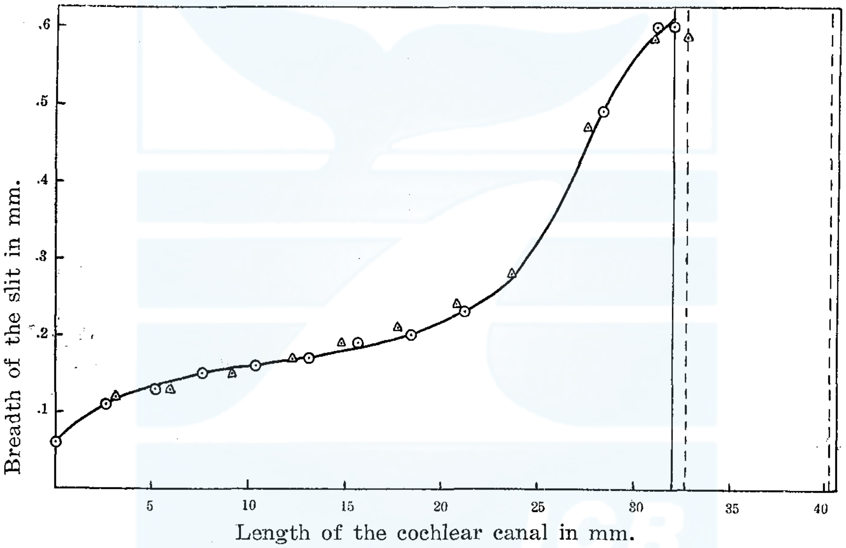

Fig. 29. Increasing curve of breadth of the spiral slit in *Berardius*. The curve shows *case 1.* (left cochlea) which is illustrated to coincide well with *case 2.* (right cochlea of another animal) marked by *triangles* and *perforated lines*. The curve naturally does not exceed the range of the secondary spiral lamina, the region being limited at 79% (*case 1.*) and 82% (*case 2.*) of the entire length of the cochlear canal which measures 40.6 mm. and 40.1 mm. respectively.

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[1] After the grinding procedure, the spiral slit is marked with Indian ink at regular intervals along the margin of the primary lamina. Then possibly high photographic enlargement (usually around 40×) is made, on which the measurements are based as follows: First, measure the widths of the spiral slit at previously marked spots directly under microscope; secondly calculate the mean magnification of the photograph according to widths, actual and printed; thirdly measure the marked intervals on the photograph and; finally divide them by the calculated magnification; from these quotations desired intervals can be approximately reckoned.

According to Kolmer (1908) the basilar membrane of *Phocaena* measures 50μ at the basal end, 100μ at the middle height and 270μ at the apical end in breadth. Therefore the membrane expands more than five times. In the meantime, it seems different in *Berardius* because the breadth of the spiral slit increases not less than ten times within the range of the secondary spiral lamina. It would be premature to compare the differences between *Phocaena* and *Berardius* in this way, between the actual membrane and the bony slit, but the present increasing curve of the slit shows something about the actual widths of the basilar membrane, which Kolmer did not make clear. In this respect, Guild has been the only one worker who originated the prominent graphic reconstruction method (1927). According to his data, the basilar membrane of guinea pig increases its width not in an uniform inclination, the rates of change being actually greatest in the basal portion, becoming less and finally decreasing as it approaches the apical end (tabs. 1 and 2 of his paper). Therefore, *Berardius* is quite contrary to guinea pig to say the least, and after consideration of this curve I have come to a belief that the audiogram of *Berardius* is utterly different from our common knowledge of the terrestrial mammals, in other words, that this whale must hear the high tones, possibly supersonics, in particularly fine distinction. This is probably similar in other odontoceti and with less probability in mystacoceti. I feel gratified in this direction that recently this possibility has been proved through observations of dolphins by Kullenburg and Fraser in succession (1947)[1].

According to them (Kullenburg, p. 648; Fraser, p. 759) dolphins squeak in high tones which I myself also experienced at Taiji of blackfish when they are hauled ashore and killed by fishers. Further Fraser noticed some possible signs of supersonics emitted by dolphins. Another experience of his own is interesting that dolphins with no doubt hear the supersonics because a school of *Delphinus delphis* suddenly dashed away at great speed instantly when the ship's supersonic echo-sounding machine was switched on.

The water-borne sounds can be reasonably expected to be the most effective and significant stimulus to their life in the water, since the speed of sounds under water is said as fast as 1,450 m./sec. and about 4.4 times faster than in the air, and moreover, since the vibration becomes

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[1] A postscript: W. N. Kellogg and R. Kohler of the Oceanographic Institute, Florida State University, reported quite recently the first experiment of this nature of some captive *Tursiops* at the Marine Studios, and their results are really of special interest and make me confident of the present work very strongly. Pertaining to the particulars, confer the original paper in the Science, vol. 116, no. 3010 (Sept. 5, 1952).

damped far less in the water than in the air, and these high tones are extraordinary in energy because of their immense frequency of vibration. So it seems to be hypothetically expected that whales not only communicate each other by means of some sounds but also navigate safely by the supersonic soundings even at night and search their food by the sounds emitted by those creatures.

6. Notes on Archaeoceti:

Finally it is of much interest of morphology to bring archaeoceti into the present considerations in order to throw a light upon the evolution which the living whales have undergone. Kellogg (1928, p. 202) wrote in this direction that the initial stages in the transformation of the hearing organ of whales are unknown, because the earliest known zeuglodonts have the osseous portions of this organ as highly developed as any of the living whales. This summarized conclusion of Kellogg excites a question how *any* whales out of the two living suborders are put into comparison with zeuglodonts, because he regards that these suborders are different, namely odontoceti lacks the osseous connection between the tympano-periotic bone and the skull; whereas mystacocete tympano-periotic is wedged by the mastoid process of it between the squamosal and the exo-occipital bones.

According to Pompeckj (1922), the periotic bone of zeuglodonts seems to be ankylosed to the lateral inner side of the skull by the processus superior, and the periotic takes part in the formation of the brain case by the whole medial or cerebral surface. The figured skull of the oldest known archaeoceti, *Protocetus atavus* (Fraas, 1904) from middle-eocene Egypt is also worthy of reference toward the present question. Both sides tympanic bullae present in the cranial basis, oblong or renal in shape, long axis lying almost parallel to that of the skull. The tympano-periotic bone of this fossil cetacea is obviously not outside of the cranial basis as seen in the living cetaceans especially in odontoceti. The borders of the bulla are in contact everywhere with the adjacent bones of the skull, and no room can be seen as to suggest any possible pneumatic sinus. Frankly speaking, the osseous portions of *Protocetus* appear not to differ remarkably from our knowledge of land mammals, and rather resemble mystacoceti than odontoceti. It may well be emphasized as remarkable in cetacea that both bullae have remained up to the present in the fossilizing procedure, and this shows more clearly than anything else that the bullae are most likely connected with the periotic bone or with the skull far more firmly than mystacoceti and, no saying, than odontoceti. If *Protocetus* possessed the similar bullae fused by thin unions with the periotic bone, those remained bullae should be said quite miraculous.

Since I have no means to examine any zeuglodonts whatever, it may not be qualified to pick up fossil cetaceans here, but these bibliographic references go so far as to make me expect that archaeoceti will show some earlier stages of the transformation, in spite of the pessimistic remarks by Dr. Kellogg.

Summary

The organ of hearing was studied in ten genera of cetacea, with special reference to the problems of lasting disputes. The observations and discussions are summarized as follows.

The external auditory meatus is closed in mystacoceti in wider specific range than has been established before. The obliteration seemingly occurs also in physeteridae. At any rate the meatus is extremely vestigial, with which the past contributions coincide well. However it is of special new interest both anatomically and cetologically that the vestigial meatus can be regarded as the independent sensory organ, probably the pressure gauge, for the abundant distribution of the laminal sensory corpuscles in the subepithelial tissues. These corpuscles are well marked particularly in odontoceti but also mystacoceti presents some (cap. I).

The tympano-periotic bone is different between two suborders to some extent but in general principle the structure resembles well each other. The bone is composed of two components, the tympanic bulla and the periotic bone. The bulla is semi-cylindrical (odontoceti) or of cowieshell form (mystacoceti) and is in both forms delicately connected at its lateral border with the periotic bone. In odontoceti the connection is the anterior synostotic union and the posterior syndesmotic articulation; while in mystacoceti the bulla is connected by two thin bone pedicles. In both cases the connection, which is quite fragile, sustains the entire bulla of which the dense and heavy involucral border is located medially at the most remote position from the union (cap. II).

The mastoid process, which is in odontoceti of tympanic, and in mystacoceti of periotic, expands laterad in more or less dimensions. The process is in odontoceti usually flattened and broad, but in mystacoceti thick and stout, long and club-shaped. In either case the process obviously acts as a fulcrum of the entire tympano-periotic bone in connecting it with the remaining skull. The odontocete mastoid process is sutured in the squamoso-occipital notch of the oto-cranial flange of the skull from below; while that of mystacoceti is wedged firmly between the same bones of the skull. The connection seems more tight in larger species, and really in delphinidae the process is quite short. One particular case of odontoceti is *Physeter* whose mastoid process is composed of thin plates which sustain the entire bone by interdigitation (cap. II–1).

The main portion of the tympano-periotic bone becomes forced out of the formation of the cranial basis during development, and is, in the final state, more or less separated or isolated from the cranial basis. This isolation is stronger in odontoceti and only partly in mystacoceti. But however strong the isolation may be, it is not acoustical as insisted so by many authors in the past. It seems just outwardly so in delphinidae whose mastoid process is extremely shortened (cap. II–2).

Concerning the further relations of the tympano-periotic bone to the skull, both suborders seem similar or to have some structures in common. The falciform process of the squamosal bone of odontoceti is closely connected with the upper side of the tegmental process of the periotic with one exception of *Kogia* to which the process is lacking. While in mystacoceti, the tegmental process of the periotic is strained to the infratemporal periost outside the otic region by a strong fibrous cord through a canal bordered by the pterygoid and the exo-occipital bones (cap. II–2).

These two peculiarities differ greatly from each other morphologically but functionally seem similar. The peculiar sesamoid ossicles sometimes develop between the periotic and the under side of the skull. They are most abundant and well marked in *Balaenoptera*, while less ossicles occur also in some larger odontoceti (cap. II–2).

In the tympanic cavity of odontoceti the cavernous body is well marked expanding through the tympano-periotic fissure into the cavity. In *Balaenoptera* instead, various folds and vesicular formations of the mucous layer are present. The tympanic ossicles are generally short and stumpy, of which the malleus is ankylosed to the bullar lateral border by its rigid anterior process. The incus of odontoceti is different from mystacoceti for its longer crus breve. This unusually long crus breve articulates with the periotic bone. The tympanic muscles never lack in any form examined by me (cap. II–3).

The pneumatic sinus system develops well but far stronger in odontoceti. The sinuses are in odontoceti usually four in number, of which the pterygoid is the largest and most peculiar in its trabeculated mural structure; an interpretation may be well understood that this sinus is the expanded proximal portion of the Eustachian tube, to this interpretation some structures of the tympano-periotic bone are affirmative. The pterygoid sinus is greatest also in mystacoceti and can be similarly interpreted. Other sinuses expand more posteriorly and communicates with the tympanic cavity through the tympano-periotic fissure, but in odontoceti the epitympanic sinus is peculiar for its communication through the epitympanic hiatus. The peripetrosal sinus of odontoceti is also peculiar corresponding to the downward isolation of the tympano-periotic bone. Naturally this sinus does not exist in *Balaenoptera* and stays as the peribullar sinus (cap. II-3).

The entire otic region including the sinus system is covered in odontoceti by the adipose body of the mandibule from lateral side and by the fibrous layer from under side; while in mystacoceti the fibrous layer develops dominantly and this region seems really isolated by that enormous layer of fibrous tissue. The sinus system seems to be closely related to the mandibular movements in odontoceti (cap. II-3).

From these observations I believe that the tympano-periotic bone is in both suborders a dynamic unit of seismographic principle. The heavy involucrum is the weight of pendulum, when the malleus stays relatively still and this resulting ampulitudes between the malleus and the periotic, which are conducted further into the labyrinth through the ossicular chain (cap. III-5).

The past disputes concerning the function are classified as: a) classic view, b) resonance theory, c) *Schalltrichter* theory and d) osteo-tympanic bone conduction. The first view is wholly errorneous because substitute path was searched for to transmit the air-borne sounds to the tympanic membrane. The second and third theories have many troubles because they thought the tympano-periotic bone to be acoustically isolated. Obviously the view of myself mentioned in this paper belongs to the last one. But nobody has advanced detailed considerations how the peculiar structures of the tympano-periotic organ are surmised to function (cap. III-1～5).

Finally one minor experiment in *Berardius* shows something about the audiogram of cetacea. That is, the basilar membrane is indirectly revealed to increase its breadth very slowly in the basal part of the cochlea, which seems quite contrary to the guinea pig. Thus here is an important belief that this whale must hear high tones, possibly supersonics, in particularly fine distinction (cap. III-5).

My sincere thanks and respects are indebted to two professors, Dr. Teizo Ogawa of Tokyo and Dr. Ryoji Ura of Okayama, whose kind encouragements and facilities have led me to this finish of work. Also the many kindnesses of my colleagues, whaling authorities as well as friendly workers at many whaling stations are memorable indeed.

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Biological Study on Humpback Whales in the Antarctic Whaling Areas IV and V.

By

HIDEO OMURA

Introduction

Humpbacks in the southern hemisphere tend to be separated into distinct five populations. The divisions between populations are not of course between the tropics and the Antarctic, but between different sectors of the southern hemisphere which include both the Antarctic and the tropics as shown in Fig. 1. For a rational limitation of the catches it is therefore necessary to consider separately the separate populations, and their condition from time to time (IWC. 1951). Our biological knowledge on these populations, however, are at present rather very scarce. Matthews (1937) made investigations on Humpbacks around South Georgia and off South Africa and recently Australian scientists had inaugurated the scientific work at the whaling landstations on the coast of West Australia (IWC. 1952).

Japanese whaling expeditions had operated in the antarctic whaling areas IV and V in the pre-war days and operating mainly in the area V in the post-war days. Humpbacks were also taken by Japanese expeditions and biological observations were made by inspectors or biologists. Based on such observations some reports were already published by Matsuura (1940), Omura (1944), Mizue and Murata (1951), Ohno and Fujino (1952) and Kawakami and others (1952).

The present account deals with the data collected during the seasons 1950-52 by Japanese inspectors or biologists, comparing with the reports listed above, in order to give some light to the problem of these populations.

Material

Numbers and sex ratio of Humpbacks taken by Japanese whaling expeditions after the war are shown in Table 1. All Humpbacks were caught in the area V and all of them were examined biologically by usual method of investigation.

The data of three seasons were treated together instead of splitting into each season, because the number of Humpbacks taken in each season is rather small. However, though the Humpback whaling was operated in the period from 22 December 1949 to 4 January 1950 in the 1950 season, in the latter two seasons catch of Humpbacks was only permitted in the

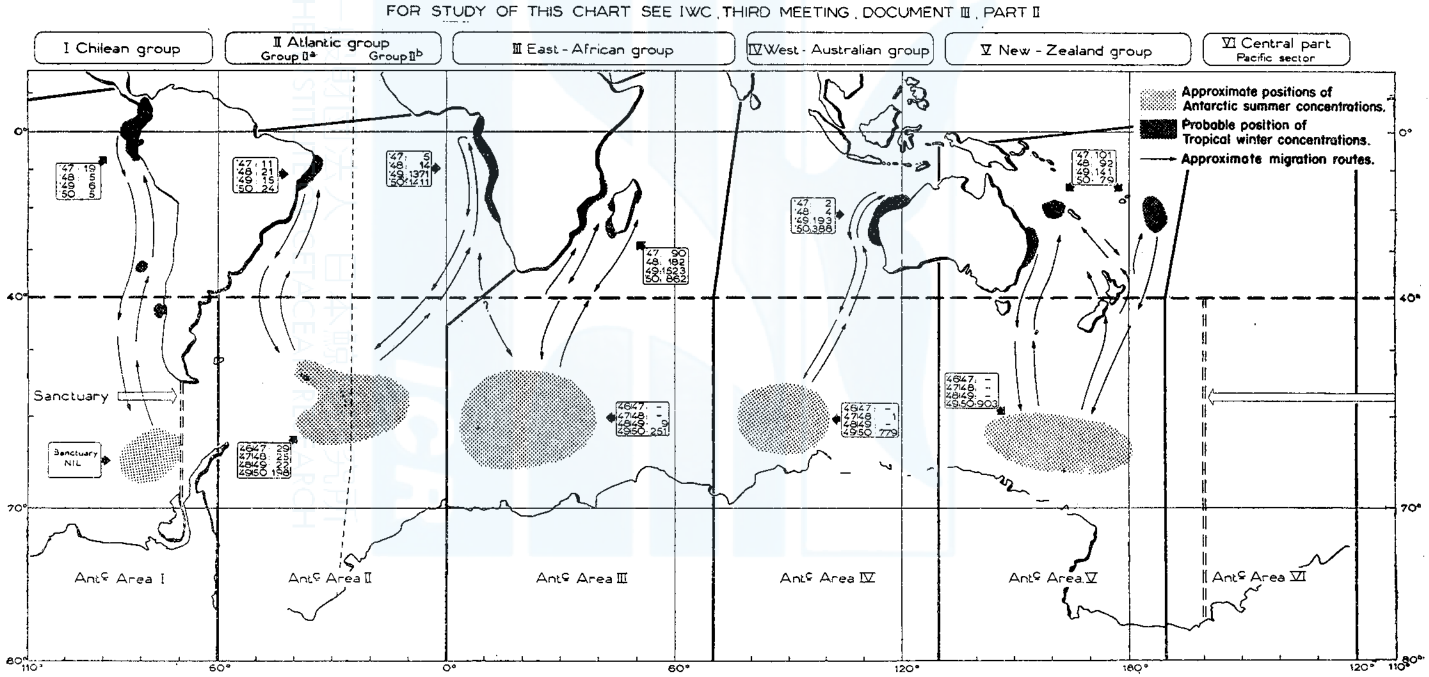

Fig. 1. Distribution of Humpback populations in the Southern Hemisphere.

begining of February, so the data was treated in two groups of different months when such is deemed necessary.

Table 1. Number and Sex Ratio of Humpbacks taken by Japanese Antarctic Whaling Expeditions in the Post-war Seasons.

Seasons	Number of			Sex Ratio		
	Males	Females	Total	Male	Female	Total
1950 (22 Dec. '49—4 Jan. '50)	24	43	67	35.82	64.18	100
1951 (2 Feb. '51—7 Feb. '51)	2	7	9	22.22	77.78	100
1952 (1 Feb. '52—5 Feb. '52)	16	21	37	43.24	56.76	100
Total	42	71	113	37.17	62.83	100

Sex Ratio

Females were most abundant in each season than males as shown in Table 1. It can be said that the whales taken were not a representative sample of the population, but such tendency is seen also in total Antarctic.

Table 2 shows the sex ratio of humpbacks taken in various grounds in the southern hemisphere, based on the figures of the International Whaling Statistics. Fig. 2 was drawn based on the same data with figures of Table 1.

As shown clearly in Table 2 and Fig. 2, females are always preponderant over males in the Antarctic and converse in the case of outside Antarctic with some exceptions. Though it is impossible for each population in the southern hemisphere to compare the sex ratio of those in the Antarctic and those of in its northern migratory areas situated along the shores of the southern continents in the neighbourhood of the tropics, because the sex ratio of humpbacks in the Antarctic is not shown separately to each Antarctic whaling area in the above mentioned statistics, but our catch results in the area V were more females were caught than males against more males were caught in the seas off New Zealand, which is deemed northern migrating area of the same population. We have no recent data concerning the population in area IV, but according to Matsuura (1940) 70.17 per cent of the total 248 humpbacks examined by him in the season 1938/39 were females. On the contrary nearly the same per cent of the total catch are males in the seas off West Australia. The reason for the preponderance of females in the south and of males in the north, therefore, is probably to be sought in the whales' habits of breeding and migration, suggesting that the females go north for parturition and paring,

Table 2. Sex Ratio of Humpbacks taken in various Grounds in the Southern Hemisphere in the recent three Seasons.

(Source: International Whaling Statistics)

Season / Sex Ratio / Ground	1951 or 1950/51						1950 or 1949/50						1949 or 1948/49					
	Actual number			Per cent			Actual number			Per cent			Actual number			Per cent		
	Males	Fe-males	Total	Males	Fe-males	Total	Males	Fe-males	Total	Males	Fe-males	Total	Males	Fe-males	Total	Males	Fe-males	Total
Antarctic	685	947	1,632	41.97	58.03	100	984	1,147	2,131	46.18	53.82	100	9	22	31	29.03	70.97	100
Natal	54	49	103	52.43	47.57	100	71	80	151	47.02	52.98	100	118	72	190	62.10	37.90	100
Cape Province	5	4	9	55.56	44.44	100	3	4	7	42.86	57.14	100	7	8	15	46.67	53.33	104
Madagascar	0	0	0	0	0	0	239	468	707	33.80	66.20	100	818	515	1,333	61.37	38.63	100
French Congo	536	568	1,104	48.55	51.45	100	803	600	1,403	57.23	42.77	100	872	484	1,356	64.31	35.69	100
West Australia	908	309	1,217	74.61	25.39	100	250	137	387	64.60	35.40	100	135	58	193	69.95	30.05	100
New Zealand	72	39	111	64.86	35.14	100	52	27	79	65.82	34.18	100	89	52	141	63.12	36.88	100
Brazil	18	10	28	64.29	35.71	100			(24)						(15)			
Peru	0	1	1	0	100	100	0	0	0	0	0	0	0	0	0	0	0	0
Chile	1	2	3	33.33	66.67	100	4	1	5	80.00	20.00	100	2	1	3	66.67	33.33	100
Total of outside Antarctic	1,594	982	2,576	61.88	38.12	100	1,422	1,317	2,759	51.92	48.08	100	2,041	1,190	3,231	63.17	36.83	100

and immediately proceed south again towards the feeding grounds when these are accomplished. The males, on the other hand, probably linger on the breeding grounds as already stated by Matthews (1937) and Mackintosh (1942). The sex ratio of foetuses is 28 males and 25 females against total of 53 foetuses of three seasons. In the total Antarctic, of the 408 foetuses in the season 1950/51 for which sex was stated, 53.43 per cent were males and 46.57 per cent females. We can not conclude from above facts that there might be any significant difference in numbers between males and females consisting of the populations.

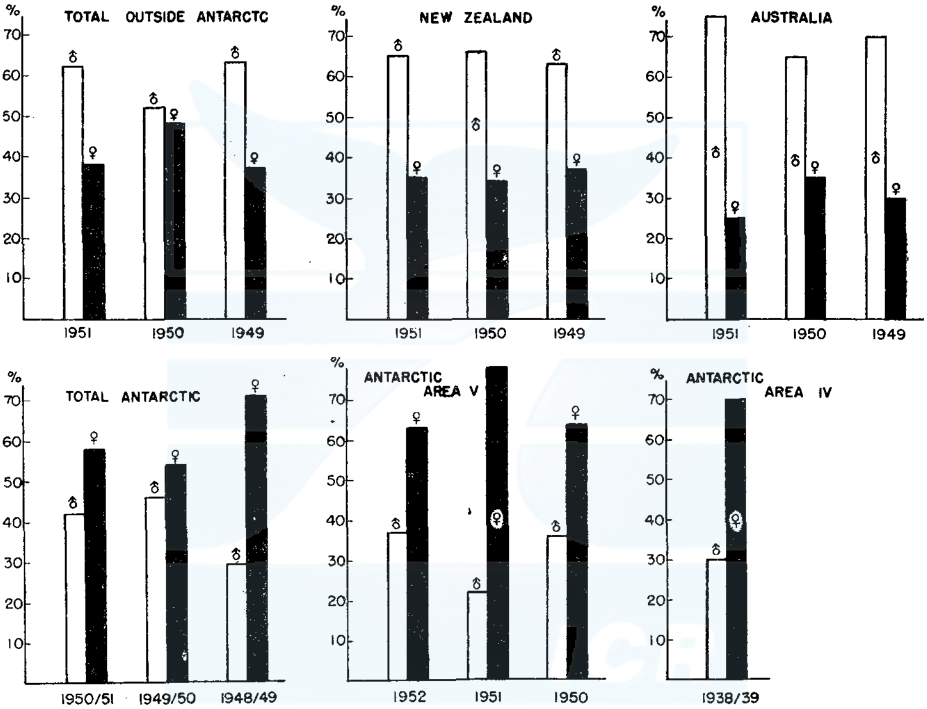

Fig. 2. Sex Ratio of Humpbacks in the Southern Hemisphere.

Thus, the sex ratios of humpbacks are different according to various grounds and very high percentage of pregnant females are caught in the Antarctic areas IV and V, as will be mentioned later. Such facts should be born in mind when contemplating the ways of protection of the humpbacks in the southern hemisphere.

Colour

Observation on the colour of humpbacks based on the types of colouration used by Matthews (1937) were made. Also in pre-war days such observation were made by Matsuura (1940) and Omura (1944). Table 3 shows the results of such observation together with the figures listed in the Matthews' report (1937).

Table 3. Percentage Occurrence of Colour Groups of Southern Humpbacks by different Authors.

Geographical Areas \ Colour Group		1	1—2	2	2—3	3	3—4	4
South Georgia and South Africa	(1)							
Males	(25)	4.0	0.0	12.0	4.0	8.0	12.0	60.0
Females	(28)	0.0	0.0	3.6	0.0	3.6	32.0	61.0
Total	(53)	1.8	0.0	7.5	1.8	5.6	22.6	60.2
Antarctic Area IV, 1938/39	(2)							
Males	(65)	1.4	0.0	27.7	38.5	12.3	16.9	3.1
Females	(141)	0.1	0.0	29.1	38.3	19.1	11.4	1.4
Total	(206)	1.0	0.0	28.6	38.3	17.0	13.1	1.9
New Zealand	(3)							
Males	(17)	5.9	23.5	17.6	17.6	11.8	11.8	11.8
Females	(13)	0.0	23.0	7.7	7.7	30.5	30.5	0.0
Total	(30)	3.3	23.2	13.3	13.3	20.0	20.0	6.6
Antarctic Area V, 1940/41	(4)							
Males	(78)	3.8	3.8	17.9	5.2	43.6	16.7	9.0
Females	(123)	13.8	0.7	13.8	11.4	35.0	15.5	9.8
Total	(201)	10.0	2.0	15.4	8.9	38.3	15.9	9.5
Antarctic Area V, 1950—1952	(5)							
Males	(42)	14.3	11.9	9.5	52.4	2.4	2.4	7.1
Females	(69)	10.1	17.4	10.1	36.2	8.7	13.1	4.4
Total	(111)	11.7	15.3	9.9	42.4	6.3	9.0	5.4

(1); Matthews (1937) (2); Matsuura (1940) (3); Lillie (Cited from Matthews 1937).
(4); Omura (1944) (5); Total of 1950—1952.

Most striking point in Table 3 is the fact that the South Georgian and South African whales are more commonly darkly coloured than otherwise. Australian scientists (IWC. 1952) state that an analysis of their observations taken in 1949 and 1950 show the West Australian humpbacks to be a little lighter in colouration than the South Georgian and South African humpbacks, but lacking the lightest coloured types given by

Lillie for New Zealand humpbacks. Their data are not published yet, but their statement seems to be the case judged from our data. Matthews (1937) describes that the females tend to be darker than the males, but such is not clear from the data obtained. Fig. 3 was drawn based on Table 3, but more simplified. In Fig. 3 ''White'', ''Intermediate'' ''Black'' include the Lillie's groups of 1 and 1–2, 2 to 3, 3–4 and 4 respectively. From Fig. 3 we may say that the South Georgian and South African whales are most darkly coloured. ''White'' group is very scarce in the area IV as South Georgia and South Africa and mostly belong to ''Intermediate''. Those in the area V, most of them belong to ''Intermediate'' as those in area IV, but they contain each about 20 per cent of ''White'' and ''Black'' groups.

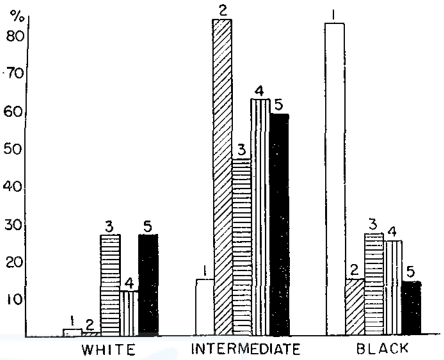

Fig. 3. Occurrence of Colour Groups.
1. South Georgia and South Africa.
2. Antarctic Area IV, 1938/39.
3. New Zealand.
4. Antarctic Area V, 1940/41.
5. Antarctic Area V, 1950—1952.

Weight of testes

The weight of each testes of male humpbacks was measured and the result is tabulated in Table 4. Fig. 4 shows the geometric mean in kilograms against each body length group. As shown in Fig. 4 the mean weight of testes increases up to 45 feet, but drops at 46 feet. However, as the

Table 4. Mean Weight of Testes calculated according to each Body Length.

Body Length in Feet	Number of Measurements	Range (kg.)	Geometric Mean (kg.)	Standard Deviation	Coefficient of Variation
38	6	0.8— 3.1	1.35	1.026	76.0
39	14	1.1— 4.2	2.21	1.057	47.8
40	8	1.4— 4.2	2.35	0.998	42.5
41	6	2.8— 4.7	3.42	0.789	23.1
42	12	1.3— 5.7	4.05	1.439	35.5
43	10	3.9— 6.1	4.67	0.690	14.8
44	18	3.5— 7.1	4.93	1.155	23.4
45	6	3.8—11.1	6.04	3.082	51.0
46	4	3.3— 6.6	4.68	1.481	31.6

numbers measured of 45 feet are few and the coefficient of variation is rather large, so it might be safe to say that the weight of testes increases according to body length until about 44 feet attained and thereafter the weight differs individually. The coefficient of variation against 38 and 39 feet are also rather large. It's cause may be lying in the fact that they include both immature and mature whales, whose testes weight differ considerably. We do not know the difference of testes weight according to mature and immature whales, because the histological examination is not completed yet, but the Australian scientists (IWC. 1952) state that the whales with a testes weight above 2000 grams were considered mature. This figure of 2 kilograms may be used here as index of sexual maturity. There is one whale of 42 feet whose testes weight is 1.3 kilograms, but such may be exceptional case. Other whales of same body length all have the testes weight of over 2 kilograms. Mizue and Murata (1951), Ohno and Fujino (1952), Kawakami and others (1952) deem a whale attains sexual maturity when the sum of both testes weight reach 2 kilograms. This figure, however, may be too low as the index of sexual maturity.

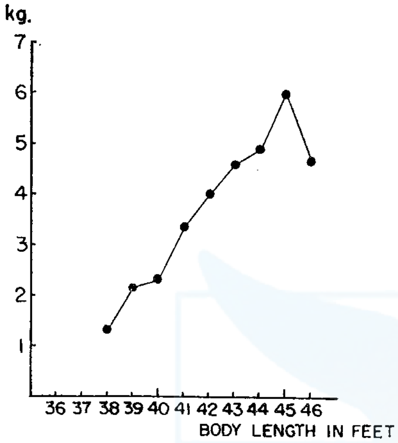

Fig. 4. Geometric Mean Weight of Testes.

Number of corpora lutea in the ovaries

Numbers of corpora lutea in both ovaries of each whale were calculated. Fig. 5 shows the occurrence of the number of corpora lutea against to each body length. Fig. 6 shows the frequency of number of corpora lutea together with the data by Matsuura (1940) for comparison. In most cases the number of corpora lutea is up to 10, with some exceptions. There is a whale with 32 corpora lutea in the ovaries, including one functional corpus luteum. As no foetus was found from the uterus of this whale, it may be on the very early stage of pregnancy or ovulating. No more such case was observed, but Matsuura (1940) reports three such examples among 89 matured females. Numbers of corpora lutea are, in general speaking, increase with the increasement of body length. Larger whales than 45 feet have mostly five or more corpora lutea in the ovaries, as is the case in Matsuura's report. As shown in Fig. 6, the peak lying between three and five, but in Matsuura's case the occurrence of one corpus luteum

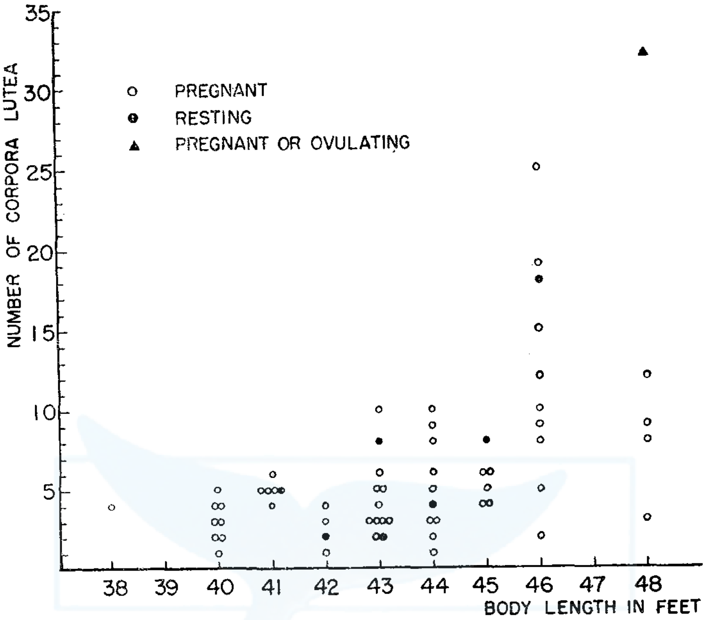

Fig. 5. Occurrence of Numbers of Corpora lutea in each Body Length Group.

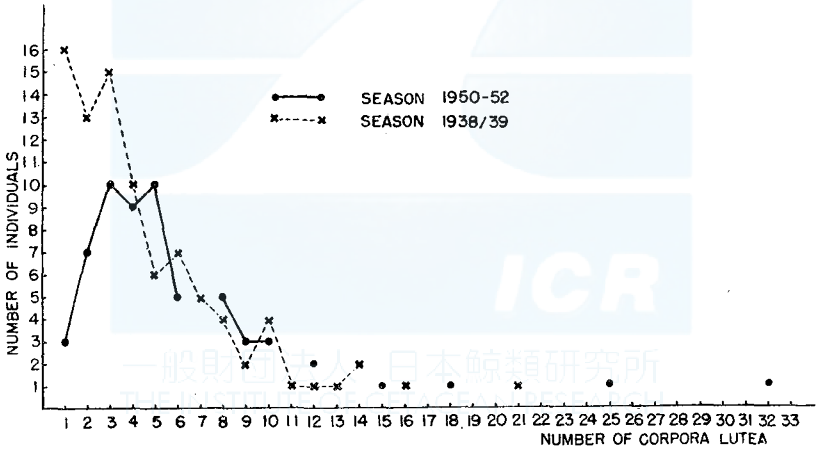

Fig. 6. Frequency of Number of Corpora lutea.

is most frequent. It can not be concluded, however, from this fact that the constitutions of populations in areas IV and V are different from each other. It should be explained from the fact that in the post-war seasons the selection of larger whales has been done better than before, consequently the whales taken were not a representative sample of the population.

Fig. 7 shows the size distribution of the females taken. The figures of the season 1938/39, which are based on Matsuura's reports, does not show the size distribution of all whales taken by Japanese expeditions in that season, but only those taken by Kyokuyo-maru. It is clearly shown in Fig. 7 that more smaller whales were taken in the season 1938/39 than post-war seasons. Considerable number of immature whales were taken, and it seems to represent the population more correctly than post-war seasons. Anyhow, only few whales with one or two corpora lutea are taken recently and it seems good for propagation of the stock, because such whales can contribute for maintenance or increasement of the stock of the population.

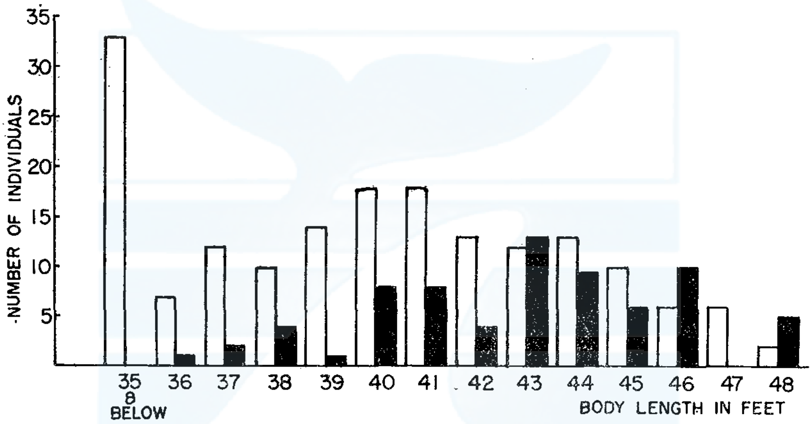

Fig. 7. Size Distribution of Female Humpbacks.
White: Antarctic 1938/39
Black: Antarctic 1950—52.

Sexual maturity

Table 5 was made classifying the male humpbacks taken to mature and immature whales according to the weight of testes, using 2 kilograms as the index of the sexual maturity. As shown in this table, the biggest immature male was 42 feet, which seems to be an exceptional one. The smallest mature male is 38 feet. Matthews (1937) describes that the male humpbacks reach sexual maturity at a body length of 12 meters

Table 5. Numbers of Immature and Mature Male Humpbacks in each Body Length Group.

Body Length in Feet	Immature	Mature	Total
38	2	1	3
39	2	5	7
40	1	3	4
41	0	3	3
42	1	5	6
43	0	5	5
44	0	9	9
45	0	3	3
46	0	2	2

(39 feet 4 inches). It seems that Table 5 confirms this, but owing to the scantiness of the whales examined, it is difficult to get the final conclusion. Female humpbacks are, as will be stated later, reach sexual maturity in average at a body length of 39–40 feet, which is smaller than figures stated by Matthews, it can be assumed that the male humpbacks also reach sexual maturity at a body length smaller than Matthews' figure, though there is no evidence to confirm this at present. According to Australian scientists (IWC. 1952), the minimum body length of the sexually mature male humpbacks examined was 35′9″, whilst a number were still immature at 38′0″ in the seas west of Australia.

Female whales with one or more corpora lutea in the ovaries were deemed as sexually mature and those without any corpus luteum sexually immature. In table 6 the results of examination were tabulated with the data gained by different authors for comparison. Fig. 8 was drawn based on these data.

In table 6 the body lengths in which the sexual maturity deemed to be attained in average were shown with thick numerals. The smallest body length is 37 feet in the Antarctic seasons 1940/41, the biggest is 40 feet in

Table 6. Numbers of Immature and Mature Female Humpbacks in each Body Length Group by different Authors.

Body Length in Feet	(1) Carnarvon 1951			(2) Antarctic 1938/39			(3) Antarctic 1940/41			(4) Antarctic 1950—52		
	Immature	Mature	Total	Immature	Mature	Total	Immature	Mature	Total	Immature	Mature	Total
32	1	0	1	33	0	33	0	0	0	0	0	0
33	1	0	1		0		1	0	1	0	0	0
34	2	0	2		0		1	0	1	0	0	0
35	3	0	3		0		9	1	10	0	0	0
36	1	0	1	6	1	7	5	1	6	1	0	1
37	3	3	6	11	1	12	**4**	**6**	10	2	0	2
38	**3**	**6**	9	7	3	10	3	9	12	3	1	4
39	1	11	12	8	6	14	1	14	15	1	0	1
40	1	11	12	**5**	**13**	18	1	18	19	**0**	**8**	8
41	0	7	7	1	17	18	0	24	24	0	7	7
42	0	13	13	0	13	13	1	24	25	0	4	4
43	0	11	11	0	12	12	0			0	13	13
44	0	7	7	0	13	13	0			0	9	9
45	0	5	5	0	10	10	0			0	6	6
46	0	0	0	0	6	6	0			0	10	10
47	0	1	1	0	6	6	0			0	0	0
48	0	0	0	0	2	2	0			0	5	5
49	0	1	1	0	0	0	0			0	0	0

(1) West Coast of Australia. (IWC 1952) (2) Antarctic Area IV. (Matsuura 1940)
(3) Antarctic Area V. (Omura 1944) (4) Antarctic Area V.

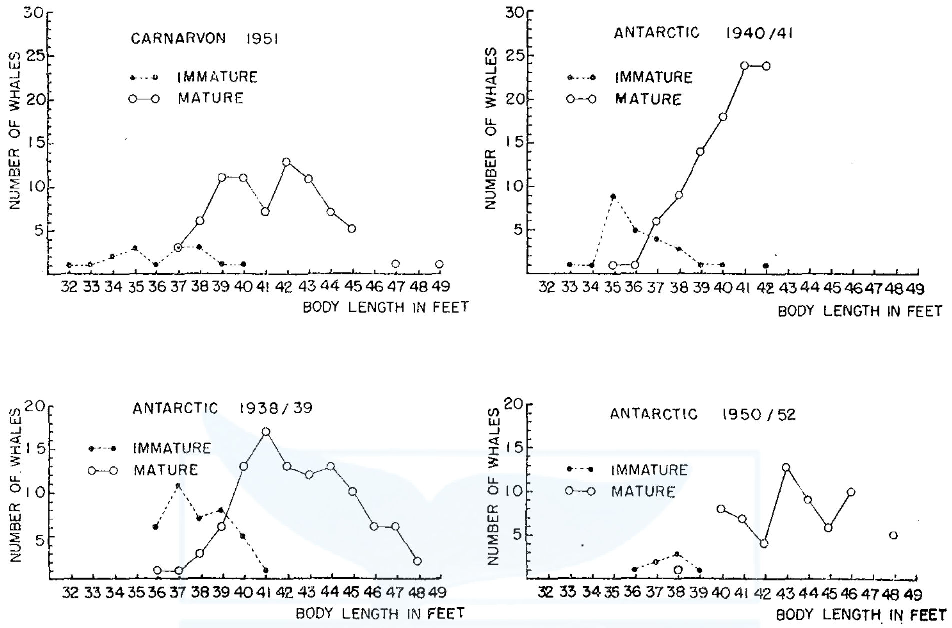

Fig. 8. Numbers of Immature and Mature Humpbacks in each Body Length Group.

the Antarctic seasons 1938/39 and 1950–52. Matthews (1937) states that the female humpbacks reach sexual maturity at a length of 12.5 meters (41 feet), but Australian scientists (IWC. 1952) describes that the mean length at which female humpback of the West Australian stock reach sexual maturity would appear to be less than the figure of 41 feet given by Matthews for the South Georgian and South African humpbacks and to be rather about 39 ft–40 ft. This latter statement is well supported by table 6. There seems no difference about this body length between whales in the areas IV and V.

Pregnancy

Female humpbacks observed may classified as Table 7 according to their sexual state.

Table 7. Biological State of female Humpbacks observed.

Seasons	Immature	Mature					Remarks
		Pregnant	Lactating	Resting	Pregnant or Ovulating	Total	
1950—52	7	54	0	8	1	63	
1938/39	71	73	13	14	3	103	Matsuura 1940

As shown clearly in this table the proportion of pregnancies against total mature females is very high, contrary to the data obtained by the Discovery staff as reported by Matthews (1937). About 86 per cent of the mature females are pregnant, and even in Matsuura's case the figure is about 70 percent. Though the figures in table 7 can not be said as representatives of the population, because it is forbidden to take or kill female whales which are accompanied by calves or suckling whales by the International Convention for the Regulation of Whaling, nevertheless we can not deny the high percentage of pregnancy in the Antarctic areas IV and V. According to the International Whaling Statistics XXVIII, 410 foetuses were reported in the Antarctic season 1950/51. As it includes one case of twin, 409 pregnant female were taken in the said season. If we assume a female below 39 feet as immature and others as mature, we can calculate the total 947 female humpbacks caught in that season should include 771 mature females, of which 409 whales were pregnant. That means about 53 per cent of pregnancy, which is deemed to be reasonable. There might be some cases of overlooking, if the whale were in a very early stage of pregnancy. Humpback whaling in that season, however, were conducted 1–7 February and on these dates the foetus is generally grown up big enough to be overlooked. So, such case of overlooking may be exceptional one, if any.

Regarding of the high percentage of pregnancy in the areas IV and V, one might imagine the case of two pregnancy in each three years or the case in which the pregnant whale are likely go down to the Antarctic, while the resting one would linger in the northern warm waters. Conclusions, however, should be drawn from more data in future combind with similar data in the northern migratory areas in the neighbourhood of tropics.

It should be born in mind when considering the problems of protection of the humpbacks the fact that in the Antarctic areas IV and V the females consist of very high percentage of the catch, and moreover, most females are pregnant.

54 foetuses were obtained in the three seasons of 1950–52, in which one was too small to distinguish the sex. Of other 53 foetuses, 28 were males and 25 were females. Mean length of these foetuses are calculated in table 8, separately those obtained in the period from the end of December to beginning of January and those obtained in the beginning of February.

Comparing the mean value in table 8 to the figures of Matthews (1937) and of Matsuura (1938), we can conclude that there are no marked difference among those figures.

Table 8. Mean Length of Humpback Foetuses.

Season	Number	Range (cm)	Mean Value (cm.)	Standard Deviation	Coefficient of Variation
1950 (22 Dec. '49—4 Jan. '50)	36	26.7—116.8	56.2	17.45	31.05
1951 (2 Feb. '51—7 Feb. '51)	17	48.3—152.4	100.6	30.23	30.05
1952 (1 Feb. '52—5 Feb. '52)					

Distribution

Japan Association of Whaling presents us a good data concerning the distribution of humpbacks in the areas IV and V. That is the "Whaling Ground in the Antarctic", in which the number of humpbacks taken in each square of two degrees of Longitude and one degree of Latitude by Japanese expeditions are shown separately by months for six seasons from 1935/36 to 1940/41. Unfortunately, the numbers of whales taken in each square are not given by actual number, but by discs of different diameters classifying into 7 classes, namely 1–5, 6–15, 16–25, 26–40, 40–60, 61–100 and over 100 whales. We do not have any way to know the actual number, which based these charts, bacause all such data were burned during the war.

Figs. 9–14 are drawn based on these charts, but assuming the actual numbers taken for each class were 3, 10, 20, 33, 50, 89 and 110, respectively. The actual numbers taken in post-war seasons were added to these figures. Consequently, the figures written in these charts are not to be relied on in detail. But, we can get, I believe, the general idea of distribution and concentration of the humpback whales in the Antarctic areas IV and V.

As shown in Fig. 9, the most abundant region in the area IV lying in the neighbourhood of 100 degree of East Longitude, having its center around Long. 102°–104°E., and Lat. 61°–62°S.. There are also good concentrations in Long. 82°–88°E., and Long. 110°–116°E.. In the area V big concentrations are seen in the North-West regions of Balleny Is., but there is also a good ground in Long. 172°–178°E. The boundary between the distribution of the two populations seems lying Long. 130°–142°E., but it is not so evident that we can say definitely there is no intermingling of the two populations. Figs. 10–14 show such distribution and concentration monthly, from November until March. We can see the movement of the concentrations by months from these charts, though numbers of whales taken are not so enough in February and in March to get any concreat ideas in these months.

In the area V and also in the area IV the centers of the concentrations move in December south-eastward as compared in November. In November the boundary between areas IV and V lying Long. 120°–130°E., but it seems to move in December also eastward to eastside of Long. 140°E., though the catch in Long. 120°–140°E. are rather few and we can not judge to which populations these whales belong. In January this boundary is very evident, lying Long. 120°–140°E., but we can not recognize the eastward movements of the concentrations, except those in area V and southward one. Such movements are, of course, in accordance with the ice conditions in the sea. Big herds in the north-west region of Balleny Is. approach to these islands with the melting of the pack ice, which hampered their course before.

In February, the boundary of the distribution of the two populations is again obscure, being the center of the concentrations seems located Long. 120°–130°E..

Conclusions

Data of the biological observations on the humpback whales taken by Japanese antarctic whaling expeditions in the areas IV and V were analysed, comparing with other data of different authors, and the following conclusions were reached.

1. Few black coloured group were seen compared with South Georgian and South African humpbacks as reported by Matthews. No definite conclusions could be reached regarding of body colour between the two populations in the areas IV and V, though there is some minute difference in the data analysed. No difference were seen between males and females regarding of colour.
2. Average body length at which female humpbacks reach sexual maturity is deemed 39–40 feet, which is smaller than the figure given by Matthews. No difference between the two populations in the areas IV and V were observed.
3. Most humpbacks taken in the areas IV and V are females, in which pregnant is most dominant.
4. Mean weight of testes increases according to body length until about 44 feet is attained.
5. Regarding of the distribution and concentration the centers in the areas IV and V are lying in the neighbourhood of Long. 100°E. and

North-West side of Balleny Is., respectively, with slight variations according to the month.

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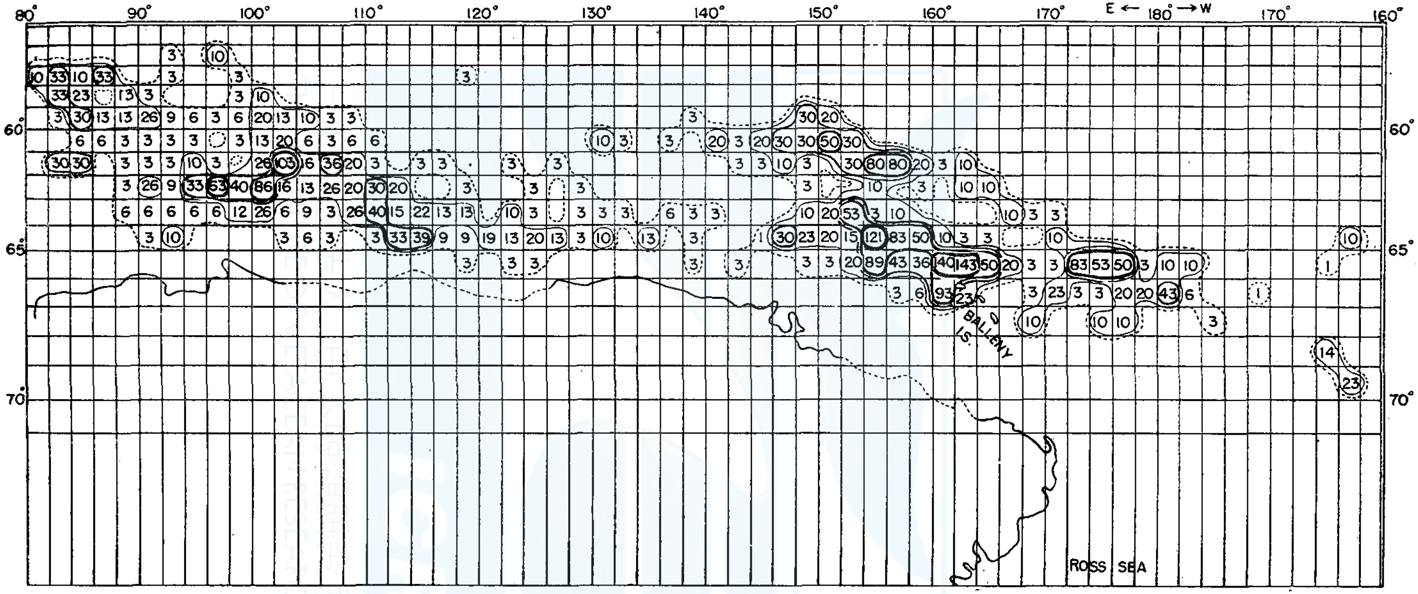

Fig. 9. Distribution and Concentration of Humpback Whales in the Antarctic areas IV and V. Grand Total. Each figure shows number of whales taken by Japanese expeditions in each square of two degrees of Longitude and one degree of Latitude during the seasons from 1935/36 to 1951/52. These figures are not to be relied on in detail.

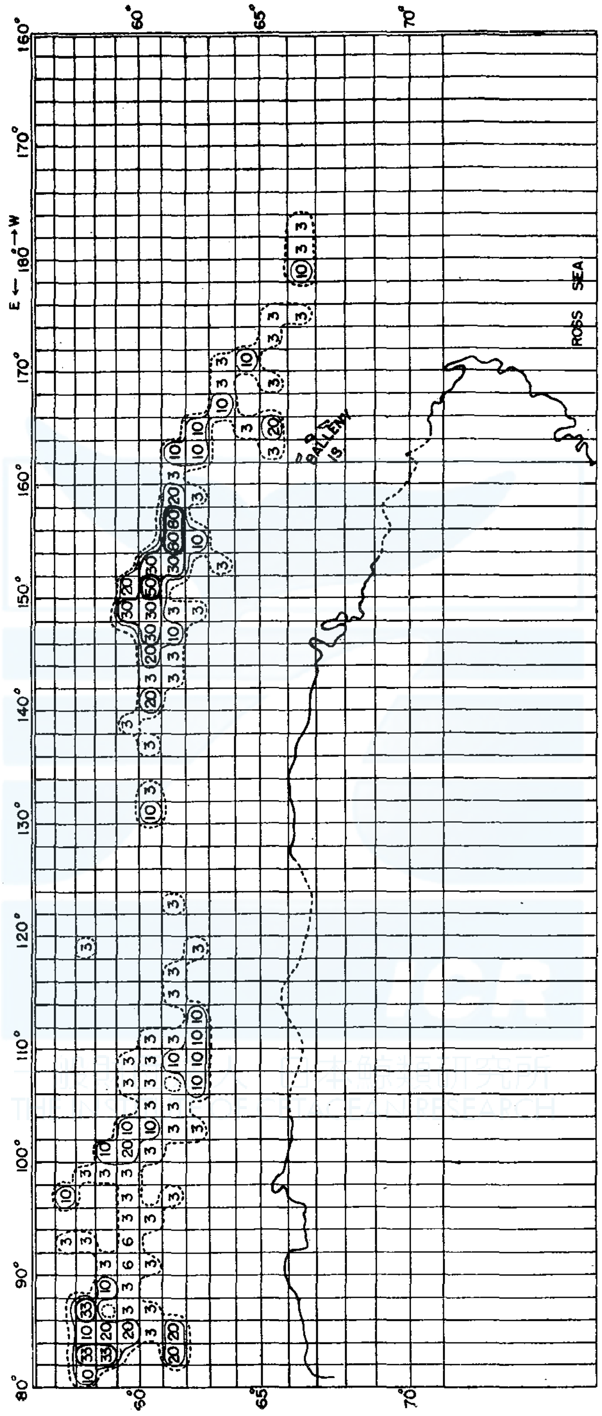

Fig. 10. Distribution and Concentration of Humpback whales in the Antarctic areas IV and V. November.

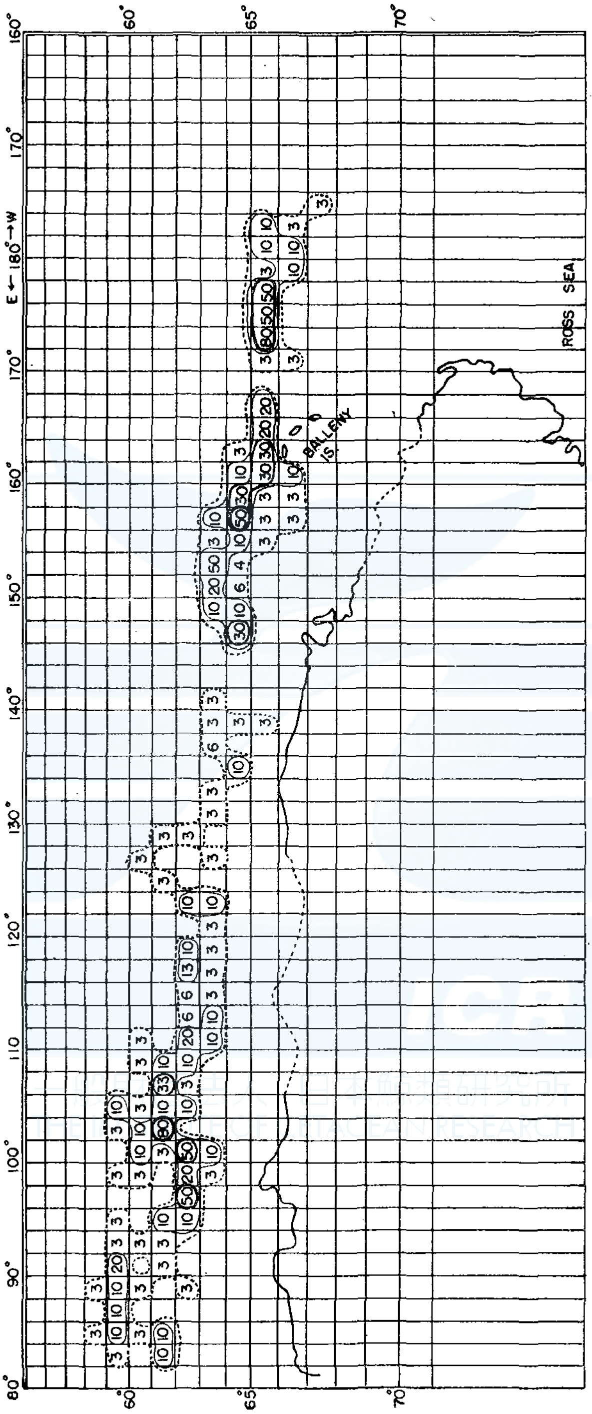

Fig. 11. Distribution and Concentration of Humpback Whales in the Antarctic Areas IV and V. December.

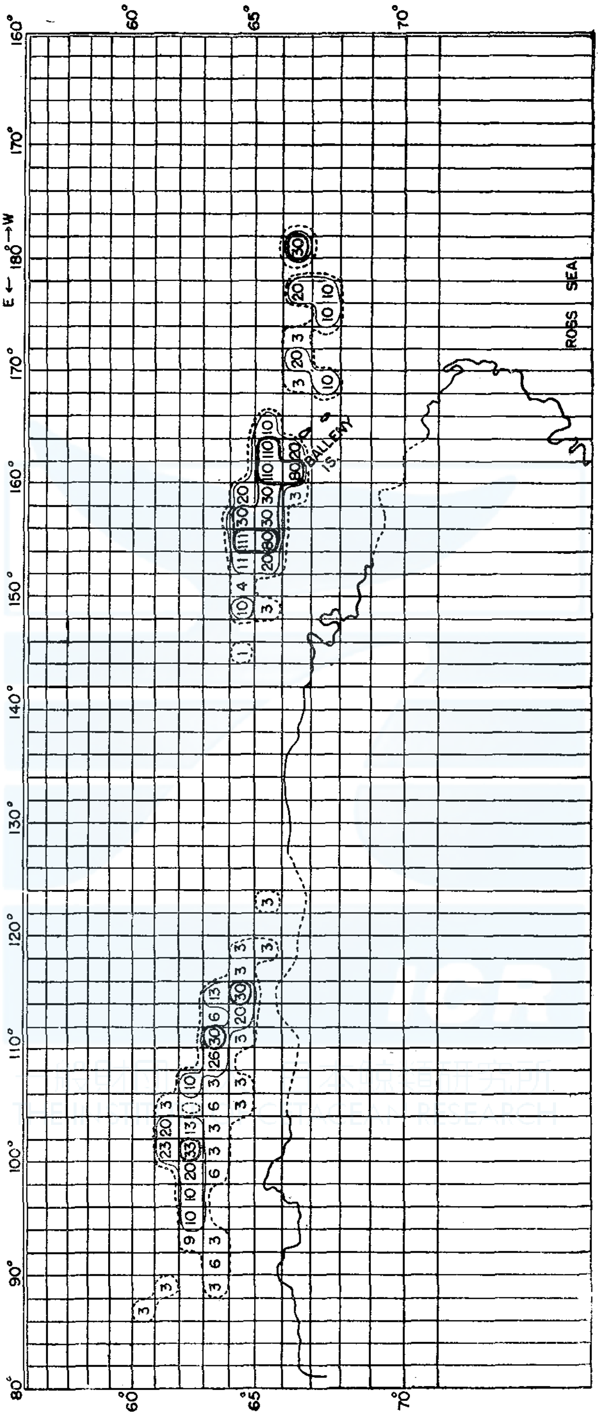

Fig. 12. Distribution and Concentration of Humpback whales in the Antarctic Areas V. January.

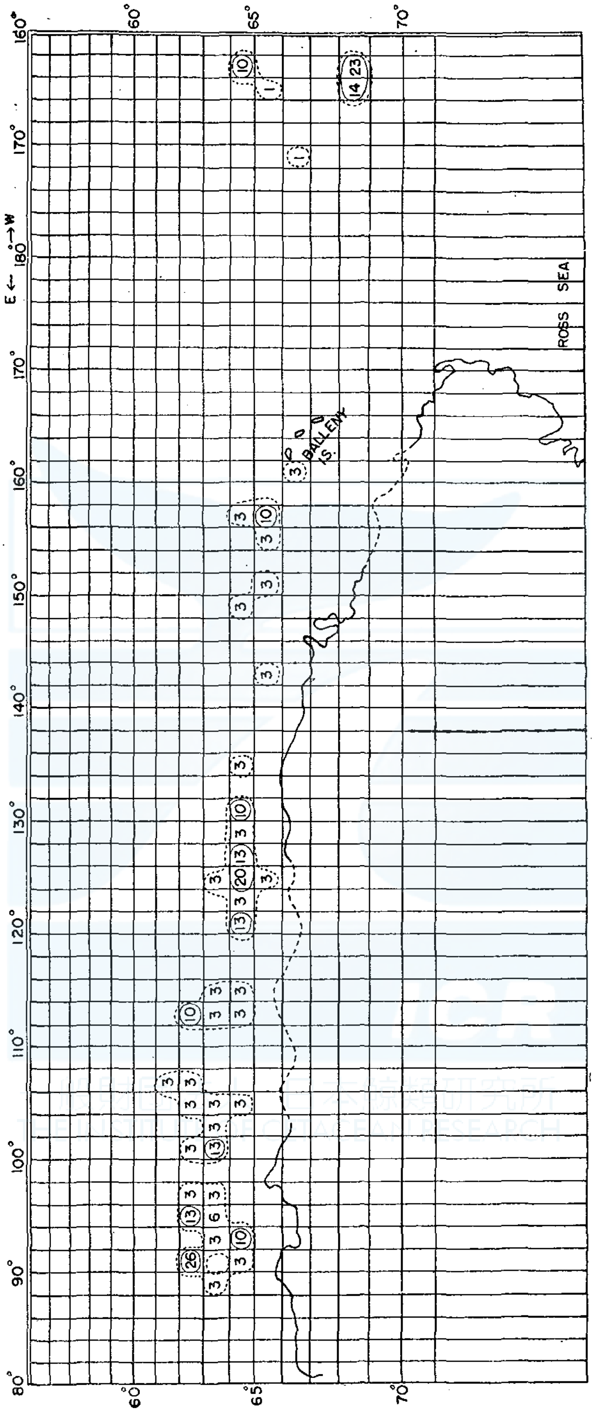

Fig. 13. Distribution and Concentration of Humpback whales in the Antarctic Areas IV and V. February.

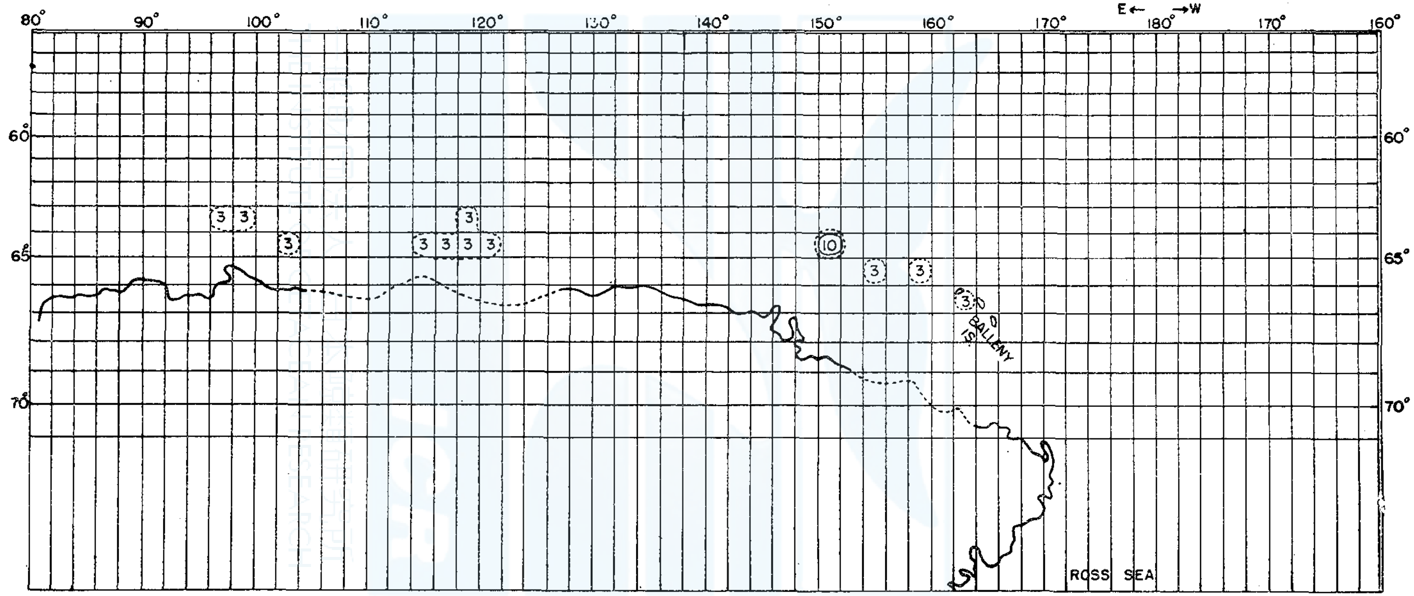

Fig. 14. Distribution and Concentration of Humpback Whales in the Antarctic Areas IV and V. March.

On the Serological Constitution of the Sei-, Fin-, Blue- and Humpback-Whales (I)

By

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Introduction

In 1901 Karl Landsteiner[1] classified the human blood groups by discovering the agglutinogens A and B in human erythrocytes according to the isohemagglutination. This blood grouping was named the "ABO System". In 1910–1911 von Dungern and Hirschfeld[2,3] confirmed that the blood group is a hereditary charactor. And then the trigemic theory was advanced by Bernstein[4] and Furuhata[5,6]. Thus the fundamental idea of blood groups was established. Furthermore, besides the classification by ABO system, such antigens as C[7,8], M, N[9,10,11,12,13,14,15,16], Q and Rh have come to be discovered. As for various mammals except human being the blood grouping by isohemagglutination, isohemolysis[17,18,19,20,21,22,23] and immune antibodies[24,25,26,27,28] have been worked out by many investigators. On the other hand by discussing on the distribution of the partial antigens[29,30,31,32,33,34,35,36,37] of each receptors in human erythrocytes, the problem of the systematic evolution of various animals was studied. Moreover the indexing of heterotype antigens[38,39,40] and the analysis of the structure of each type of receptors were worked out.

By these results the application scope of the blood groups covers on clinical medicine, medical jurisprudence[41,42,43,44,45], genetics[4,5,6,46,47,48,49,50] and anthropology[51,52,53,54].

The author, fixing attention on the said points, is working at the serological studies on whales. At first he tried to classify the antigens in each kind of whale erythrocytes, and he discovered the two antigens, namely Dc_1 and Dc_2, in the erythrocytes of the striped dolphin which belongs to the toothed whale. Consequently the dolphin bloods are classified into three kinds.[55] In the same manner as the above mentioned idea he immunized the rabbits with the erythrocytes of each kind of baleen whales, namely the sei-whale[56] caught near Bonin Islands, the fin-, blue- and humpback-whales of the northern Pacific Ocean. By thus obtained immune antibodies, he discovered the antigens Bb_1–Bb_2, Bp_1–Bp_2, Bm_1–Bm_2 and Mn_1–Mn_2 respectively. In consequence he was able to classify the whale bloods into the four kinds in each species respectively.

Most of this study was performed through various difficulties on the whaling factory ship "Baikal-maru", and owes very much to the comprehension and assistance by each member of the Division of northern Pacific Whaling Operation of the Kyokuyo-Hogei Co. Ltd., to whom the author express here his appreciation. The author also express his hearty thanks to Prof. Tanemoto Furuhata of the Institute of Legal Medicine, Tokyo Medical and Dental University for his kindness in guiding and in reading the original manuscript: to Emeritus Prof. Ikusaku Amemiya and Prof. Yoshio Hiyama, both of the Fisheries Department, Faculty of Agriculture, Tokyo University, who kindly read the original manuscript: to Prof. Teizo Ogawa of the Anatomical Institute, Faculty of Medicine, Tokyo University, for his valuable advice in naming the antigens: to Dr. Hideo Omura, chief of the first Biological Research Section, Fisheries Agency, and Dr. Tsutomu Maruyama, chief of the Whales Research Institute, for their usual encouragements, and to Dr. Katsumi Yamaguchi who has guided the author directly and given him a precious advice.

Material and Method

Erythrocytes and Serum of Whale: When a whale was pulled up to the working deck and its tail flukes were cut off, the blood which flowed out of the caudal artery was collected in a bottle. After coagulation, the erythrocytes were separated and cleaned with the physiological salt solution. These erythrocytes were used for immunization adsorption and reaction test. The separated serum was made inactive in the warm bath of 56°C for 30 minutes. And then the physiological salt solution with 5% carbolic acid was added, its quantity being 1/10 of that of the serum. After enough mixing it was preserved in the ice box.

Human Erythrocytes: The blood was taken from the elbow vein of a healthy person and was cleaned several times with the physiological salt solution and then centrifuged. The precipitated erythrocytes were used for adsorption, agglutination and hemolysis.

Immune Animal: The rabbit used for immunization must be healthy and 2.5 to 3.0 kg. in weight. Previous to immunization, its serum type and whether the rabbit is secretor or non-secretor concerning A receptor, namely A^+-type or A^--type was also examined.

Immunizing Method: At first the 10% suspension of the cleaned erythrocytes was made of the salt solution. Each other day 5 cc. of the suspension was injected into the ear vein of the rabbit, 7 time in all.

Collecting and Preserving Method of Antiserum: One week after the latest injection, the whole blood was collected from the carotid artery of the immunized rabbit. The separated serum was made inactive in the warm bath of 56°C for 30 minutes. And then the physiological salt solution with 5% carbolic acid was added to it, its quantity being 1/10 of that of the serum. After adequate mixing, it was preserved in the ice box. Food was withheld for 12 hours prior to the bleeding so as to prevent the turbidity of the serum.

Testing Method of Agglutination and Hemolysis: 30 minutes after mixing antigens and antibodies the agglutination was confirmed by the holeglass method in the room temperature. The hemolysis was judged by the test tube method, adding the guinea pig serum as complement, after 30 minutes warm bathing of 37°C.

Adsorption Test: Erythrocytes used for adsorption were to be the cleaned one, and to be regulated in quantity according to the dilution of the antiserum. After being left in the room temperature for a few hours the upper clear part was used for reaction. Meanwhile the mixture was shaken several times in order to make rapid the adsorption.

Isohemagglutination

(a) Sei-whale On rare occasions, the isohemagglutination was recognized in sei-whale, but its reaction was so weak that it was impossible to classify the antigens existing in the sei-whale erythrocytes. (See Table I)

Table I. Isohemagglutination of the sei whale.

		Erythrocytes of the sei whales															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Normal sera of the sei whales	1	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	2	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	3	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	4	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	5	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	6	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	7	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	8	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	9	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	10	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	11	−	−	−	−	−	+	−	−	−	−	−	−	+	−	−	−
	12	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	13	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	14	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−
	15	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	16	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−

(b) Fin-whale The isohemagglutination was generally weak, but sometimes it was comparatively strong. In the latter case, some one showed a relation with the reaction by the immune agglutinin which is to be stated afterward. (See Sera Nos. 9 and 13 of Table II) But it was difficult to classify clearly the antigens existing in the erythrocytes. On the other hand the agglutinins which have no relation to the immune antibodies were found rarely. (See Sera Nos. 2, 3, 8 & 10 of Table II)

Table II. Isohemagglutination of the fin whale.

		Erythrocytes of the fin whales																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	20
Normal sera of the fin whales	1	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	2	−	−	−	−	−	+	+	−	−	−	−	+	−	−	−	+	−	−
	3	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
	4	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	5	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	6	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	7	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	8	−	−	−	−	−	+	+	−	−	−	−	⧻	−	−	−	−	−	−
	9	−	⧺	−	−	−	+	+	−	−	−	+	⧺	−	−	−	−	−	−
	10	−	−	−	−	−	−	−	−	−	−	−	⧺	−	−	−	−	−	−
	11	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	12	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	13	−	⧺	−	−	−	+	+	−	−	−	⧺	⧻	−	−	−	−	−	−
	14	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	15	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	16	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	18	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	20	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

(c) Blue-whale Generally the isohemagglutination was comparatively strong, and showed a relation to the reaction with the immune agglutinin which is to be stated afterwards. It was possible to classify the antigens existing in the erythrocytes. (See Table III)

(d) Humpback-whale Generally the isohemagglutination was comparatively strong and showed a relation to the reaction with the immune agglutinin which will be described afterwards. The classification of the antigens which exist in the erythrocytes seems to be possible. (See Table IV)

As stated above, among the baleen whales the isohemagglutination was weak in the sei- and fin-whales, so it was impossible to classify the antigens existing in the erythrocytes by their reactions only. On the other hand isohemagglutination was found irregularly in the blue- and humpback-whales, but generally the reaction was strong, and it was possible to classify the antigens existing in the erythrocytes.

Table III. Isohemagglutination of the blue whale.

		Erythrocytes of the blue whales											
		117	129	140	141	146	155	156	157	159	160	164	174
Normal sera of the blue whales	117	−	⧺	−	−	−	−	−	−	−	−	−	−
	129	−	−	−	−	−	−	−	−	−	−	−	−
	140	−	+	−	−	−	−	−	−	−	−	−	−
	141	−	+	−	−	−	−	−	−	−	−	−	−
	146	−	+	−	−	−	−	−	−	−	−	−	−
	155	−	+	−	−	−	−	−	−	−	−	−	−
	156	⧺	⧻	−	−	−	−	−	−	−	⧻	−	−
	157	⧺	⧻	−	−	−	−	−	−	−	⧻	−	−
	159	⧺	⧻	−	−	−	−	−	−	−	⧺	−	−
	160	−	⧻	−	−	−	−	−	−	−	−	−	−
	164	−	⧺	−	−	−	−	−	−	−	−	−	−
	174	⧺	⧻	−	−	−	−	−	−	−	⧻	−	−

Table IV. Isohemagglutination of the humpback whale.

		Erythrocytes of the humpback whales									
		142	143	151	180	184	191	192	203	204	206
Normal sera of the humpback whales	142	−	−	−	−	−	−	−	⧺	−	−
	143	−	−	⧺	−	−	−	−	⧺	−	−
	151	−	−	−	−	−	−	−	⧺	−	−
	180	−	−	⧺	−	−	−	−	⧺	−	−
	184	−	−	−	−	−	−	−	−	−	−
	191	−	−	⧺	−	−	−	−	⧻	−	−
	192	−	−	⧺	−	−	−	−	⧻	−	−
	203	−	−	−	−	−	−	−	−	−	−
	204	−	−	⧺	−	−	−	−	⧻	−	−
	206	−	−	−	−	−	−	−	⧻	−	−

Serum-type

Whether the agglutinins against the receptors A and B of human erythrocytes exist or not in the normal sera of each whale species was examined by the agglutination to each type of human erythrocytes. The frequencies of these types were shown in Table V, in which it was known that o'- and α'-types are found in every whale species and the former has high frequency. The agglutinin titer of α'-type against human A erythrocytes was 2 to 4 times. On the other hand β'-type was found only in the two fin-whales (6.5%), namely Nos. 253 and 277. Their agglutinin titer against human B erythrocytes are 8 times. $\alpha'\beta'$-type was found in the fin- and blue-whales. As for the existence of anti-C agglutinin, the positive proof of the experiment of adsorption and dissociation by fresh human A and B type erythrocytes is not obtained yet.

Table V. Serum-type frequencies of the baleen whales.

(a) Sei whales

Serum-type	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
α'β'	0	0.0	0	0.0	0	0.0
α'	2	22.2	1	14.3	3	18.8
β'	0	0.0	0	0.0	0	0.0
o'	7	77.8	6	85.7	13	81.2
Total	9	100.0	7	100.0	16	100.0

(b) Fin whales

Serum-type	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
α'β'	3	18.8	0	0.0	3	9.6
α'	1	6.2	1	6.7	2	6.5
β'	0	0.0	2	13.3	2	6.5
o'	12	75.0	12	80.0	24	77.4
Total	16	100.0	15	100.0	31	100.0

(c) Blue whales

Serum-type	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
α'β'	5	21.8	2	14.2	7	8.9
α'	5	21.8	6	42.9	11	39.7
β'	0	0.0	0	0.0	0	0.0
o'	13	56.4	6	42.9	19	51.4
Total	23	100.0	14	100.0	37	100.0

(d) Humpback whales

Serum-type	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
α'β'	0	0.0	0	0.0	0	0.0
α'	2	25.0	4	57.2	6	40.0
β'	0	0.0	0	0.0	0	0.0
o'	6	75.0	3	42.8	9	60.0
Total	8	100.0	7	100.0	15	100.0

Antigens proved by immune antibodies

1. Immune antiserum against each antigen

(a) Anti-sei-whale Bb_1- and Bb_2-sera

When a rabbit was immunized with the sei-whale erythrocytes which belong to Bb_1, the anti-Bb_1 agglutinin and hemolysin were produced together with the species specific agglutinin and hemolysin to the sei-whale erythrocytes in the serum of the rabbit. When the species specific antibodies were adsorbed away with Bb_2 erythrocytes, the anti-Bb_1 immune agglutinin and hemolysin were obtained. The anti-Bb_2 immune agglutinin and hemolysin were obtained by the same operation. By these immune antibodies, it was proved that the existences of the both agglutinogens and hemolysinogens, namely Bb_1 and Bb_2 in both, were perfectly consistent with each other.

(b) Anti-fin-whale Bp_1- and Bp_2-sera

Anti-Bp_1 and anti-Bp_2 immune agglutinins and hemolysins were obtained by the same operation as stated in (a), using as antigens the fin-whale erythrocytes which belong to Bp_1 and Bp_2 respectively. By these immune antibodies it was proved that the existences of the both agglutinogens and hemolysinogens namely Bp_1 and Bp_2 in both, were perfectly consistent with each other.

(c) Anti-blue-whale Bm_1- and Bm_2-sera

Anti-Bm_1 and anti-Bm_2 immune agglutinins and hemolysins were obtained by the same operation as stated in (a), using as antigens the blue-whale erythrocytes which belong to Bm_1 and Bm_2 respectively. By these immune antibodies it was proved that the existences of the both agglutinogens and hemolysinogens, namely Bm_1 and Bm_2 in both, were perfectly consistent with each other.

(d) Anti-humpback-whale Mn_1- and Mn_2-sera

By the same method as stated in (a), the anti-Mn_1 and Mn_2 immune agglutinins and hemolysins against the humpback-whale erythrocytes were obtained. By these immune antibodies it was proved that the existences of the both agglutinogens and hemolysinogens, namely Mn_1 and Mn_2 in both, were perfectly consistent with each other.

As stated in (a) to (d), two kinds of antigens were found in each whale species, that is Bb_1-Bb_2, Bp_1-Bp_2, Bm_1-Bm_2 and Mn_1-Mn_2, in sei-, fin-, blue-and humpback-whales respectively. By the existences of these antigens the erythrocytes of the baleen whales were classified into each four kinds as follows, Bb_1Bb_2, Bb_1, Bb_2 and O; Bp_1Bp_2, Bp_1, Bp_2 and O; Bm_1Bm_2, Bm_1, Bm_2 and O and Mn_1Mn_2, Mn_1, Mn_2 and O in the sei-, fin-, blue- and hump-back-whales respectively.

2. Agglutinin titer and hemolysin titer

Each one example of the agglutinin titer and hemolysin titer of the immune sera obtained by the said method was to be shown in Table VI to IX.

Table VI. Agglutinin titer and hemolysin titer of the anti-Bb_1 and anti-Bb_2 immune sera against each type of the sei whale erythrocytes

Anti-Bb_1 Agglutinin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the sei whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
No. 8 Male	o′	A^+	No. 21 Bb_2	No. 13	Bb_1Bb_2	+++	+++	++	++	+	−	−	−
				No. 8	Bb_1	+++	++	++	+	+	−	−	−
				No. 21	Bb_2	−	−	−	−	−	−	−	−
				No. 6	O	−	−	−	−	−	−	−	−

Anti-Bb_2 Agglntinin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the sei whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
No. 9 Male	α'	A^+	No. 8 Bb_1	No. 13	Bb_1Bb_2	+++	+++	+++	+++	++	+	−	−
				No. 11	Bb_1	−	−	−	−	−	−	−	−
				No. 21	Bb_2	+++	+++	+++	++	++	+	−	−
				No. 5	O	−	−	−	−	−	−	−	−

Anti-Bb_1 Hemolysin titer

Immune rabbit No.	Serum-type	A^+ or A^-	Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the sei whale	Dilution of antiserum 1/20	1/40	1/80	1/160	1/320	1/640	1/1280	1/2560
No. 8 Male	o′	A^+	No. 21 Bb_2	No. 13	Bb_1Bb_2	+++	+++	++	+	−	−	−	−
				No. 8	Bb_1	−	−	−	−	−	−	−	−
				No. 21	Bb_2	+++	+++	++	+	−	−	−	−
				No. 6	O	−	−	−	−	−	−	−	−

Anti-Bb_2 Hemolysim titer

Immune rabbit No.	Serum-type	A^+ or A^-	Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the sei whale	Dilution of antiserum 1/20	1/40	1/80	1/160	1/320	1/640	1/1280	1/2560
No. 9 Male	α′	A^+	No. 8 Bb_1	No. 13	Bb_1Bb_2	+++	+++	++	++	+	−	−	−
				No. 11	Bb_1	−	−	−	−	−	−	−	−
				No. 21	Bb_2	+++	+++	++	+	+	−	−	−
				No. 5	O	−	−	−	−	−	−	−	−

Table VII. Agglutinin titer and hemolysin titer of the anti-Bp_1 and anti-Bp_2 immune sera against each type of the fin whale erythrocytes

Anti-Bp_1 Agglutinin titer

Immune rabbit No.	Serum-type	A^+ or A^-	Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the fin whale	Dilution of antiserum 1/20	1/40	1/80	1/160	1/320	1/640	1/1280	1/2560
No. 11 Male	o′	A^+	No. 316 Bp_2	No. 309	Bp_1Bp_2	+++	+++	+++	++	+	−	−	−
				No. 310	Bp_1	+++	+++	++	++	+	−	−	−
				No. 316	Bp_2	−	−	−	−	−	−	−	−
				No. 308	O	−	−	−	−	−	−	−	−

Anti-Bp_2 Agglutinin titer

Immune rabbit No.	Serum-type	A^+ or A^-	Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the fin whale	Dilution of antiserum 1/20	1/40	1/80	1/160	1/320	1/640	1/1280	1/2560
No. 12 Male	α′β′	A^+	No. 310 Bp_1	No. 309	Bp_1Bp_2	+++	+++	+++	+++	+++	++	+	−
				No. 310	Bp_1	−	−	−	−	−	−	−	−
				No. 316	Bp_2	+++	+++	+++	+++	++	++	+	−
				No. 308	O	−	−	−	−	−	−	−	−

Anti-Bp_1 Hemolysin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the fin whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
No. 11 Male	o′	A^+	No. 316 Bp_2	No. 309	Bp_1Bp_2	⧻	⧻	⧺	+	−	−	−	−
				No. 310	Bp_1	⧻	⧻	⧺	+	−	−	−	−
				No. 316	Bp_2	−	−	−	−	−	−	−	−
				No. 308	O	−	−	−	−	−	−	−	−

Anti-Bp_2 Hemolysin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the fin whale	Dilution of antiserum							
No.	Sorum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
No. 12 Male	α′β′	A^+	No. 310 Bp_1	No. 309	Bp_1Bp_2	⧻	⧻	⧻	⧻	⧺	+	−	−
				No. 310	Bp_1	−	−	−	−	−	−	−	−
				No. 316	Bp_2	⧻	⧻	⧻	⧺	⧺	+	−	−
				No. 308	O	−	−	−	−	−	−	−	−

Table VIII. Agglutinin titer and hemolysin titer of the anti-Bm_1 and anti-Bm_2 immune sera against each type of blue whale erythrocytes

Anti-Bm_1 Agglutinin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the blue whale	Dilution of antiserum							
No.	Serum-type	A^+ or A_-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
No. 13 Male	o′	A^+	No. 201 Bm_2	No. 297	Bm_1Bm_2	⧻	⧻	⧺	+	−	−	−	−
				No. 227	Bm_1	⧻	⧺	⧺	+	−	−	−	−
				No. 201	Bm_2	−	−	−	−	−	−	−	−
				No. 307	O	−	−	−	−	−	−	−	−

Anti-Bm_2 Agglutinin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the blue whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
No. 14 Female	α′	A^+	No. 227 Bm_1	No. 297	Bm_1Bm_2	⧻	⧻	⧻	⧻	⧻	⧺	+	−
				No. 227	Bm_1	−	−	−	−	−	−	−	−
				No. 201	Bm_2	⧻	⧻	⧻	⧺	⧺	+	−	−
				No. 307	O	−	−	−	−	−	−	−	−

Anti-Bm_1 Hemolysin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the blue whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
				No. 297	Bm_1Bm_2	⧻	⧺	⧺	+	−	−	−	−
No. 13	α'	A^+	No. 201	No. 227	Bm_1	⧻	⧺	⧺	+	−	−	−	−
Female			Bm_2	No. 201	Bm_2	−	−	−	−	−	−	−	−
				No. 307	O	−	−	−	−	−	−	−	−

Ants-Bm_2 Hemolysin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the blue whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
				No. 297	Bm_1Bm_2	⧻	⧻	⧻	⧻	⧺	+	−	−
No. 14	α'	A^+	No. 227	No. 227	Bm_1	−	−	−	−	−	−	−	−
Female			Bm_1	No. 201	Bm_2	⧻	⧻	⧻	⧺	⧺	+	−	−
				No. 307	O	−	−	−	−	−	−	−	−

Table IX. Agglutinin titer and hemolysin titer of the anti-Mn_1 and anti-Mn_2 immune sera against each type of the humpback whale erythrocytes

Anti-Mn_1 Agglutinin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the humpback whale	Dilution of antiserum							
No.	Serum. type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
				No. 203	Mn_1Mn_2	⧻	⧻	⧻	⧺	⧺	⧺	+	−
No. 15	α'	A^+	No. 211	No. 151	Mn_1	⧻	⧻	⧻	⧻	⧺	⧺	+	−
Female			Mn_2	No. 211	Mn_2	−	−	−	−	−	−	−	−
				No. 206	O	−	−	−	−	−	−	−	−

Anti-Mn_2 Agglutinin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for aggl.	Blood group of the humpback whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$	$\frac{1}{1280}$	$\frac{1}{2560}$
				No. 203	Mn_1Mn_2	⧻	⧻	⧻	⧻	⧺	+	−	−
No. 16	o'	A^-	No. 151	No. 151	Mn_1	−	−	−	−	−	−	−	−
Male			Mn_1	No. 211	Mn_2	⧻	⧻	⧻	⧺	⧺	+	−	−
				No. 206	O	−	−	−	−	−	−	−	−

Anti-$\mathrm{Mn_1}$ Hemolysin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the humpback whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^+				1/20	1/40	1/80	1/160	1/320	1/640	1/1280	1/2560
No. 15 Female	α′	A^+	No. 211 $\mathrm{Mn_2}$	No. 203	$\mathrm{Mn_1Mn_2}$	+++	+++	+++	+++	++	++	+	−
				No. 151	$\mathrm{Mn_1}$	+++	+++	+++	+++	+++	++	+	−
				No. 211	$\mathrm{Mn_2}$	−	−	−	−	−	−	−	−
				No. 206	O	−	−	−	−	−	−	−	−

Anti-$\mathrm{Mn_2}$ Hemolysin titer

Immune rabbit			Erythrocytes for adsorp.	Erythrocytes for hemoly.	Blood group of the humpback whale	Dilution of antiserum							
No.	Serum-type	A^+ or A^-				1/20	1/40	1/80	1/160	1/320	1/640	1/1280	1/2560
No. 16 Male	o′	A^-	No. 151 $\mathrm{Mn_1}$	No. 203	$\mathrm{Mn_1Mn_2}$	+++	+++	+++	+++	++	+	−	−
				No. 151	$\mathrm{Mn_1}$	−	−	−	−	−	−	−	−
				No. 211	$\mathrm{Mn_2}$	+++	+++	+++	++	++	+	−	−
				No. 206	O	−	−	−	−	−	−	−	−

3. Frequency of each type

As stated in the paragraph 1, the erythrocytes were classified into four kinds in each whale species. The frequencies of their groups were as follows. (see Table X) As shown in Table X (b), on fin whales were examined the 200 whales out of 213 which were caught in the northern Pacific Ocean in 1952. Consequently a remarkable seasonal variation was recognized in the frequency of each group. It seemed to the author that

Table X. Blood group frequencies of the baleen whales

(a) Sei whale

Blood group \ Sex	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
$\mathrm{Bb_1Bb_2}$	4	18.2	2	20.0	6	18.8
$\mathrm{Bb_1}$	4	18.2	3	30.0	7	21.9
$\mathrm{Bb_2}$	2	9.1	1	10.0	3	9.3
O	12	54.5	4	40.0	16	50.0
Total	22	100.0	10	100.0	32	100.0

(b) Fin whale

Catch, during from July 19 to August 10

Sex / Blood group	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
Bp_1Bp_2	1	2.5	2	5.0	3	3.8
Bp_1	14	35.0	4	10.0	18	22.5
Bp_2	1	2.5	3	7.5	4	5.0
O	24	60.0	31	77.5	55	68.7
Total	40	100.0	40	100.0	80	100.0

Catch, during from August 11 to August 31

Sex / Blood group	Male		Female		Total	
	Actual No.	%	Actual No-	%	Actual No.	%
Bp_1Bp_2	3	10.0	5	16.7	8	13.3
Bp_1	11	36.6	10	33.3	21	35.0
Bp_2	2	6.7	8	26.7	10	16.7
O	14	46.7	7	23.3	21	35.0
Total	30	100.0	30	100.0	60	100.0

Catch, during from Sept. 1 to Sept. 19

Sex / Blood group	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
Bp_1Bp_2	2	6.7	1	3.3	3	5.0
Bp_1	0	0.0	4	13.3	4	6.7
Bp_2	10	33.3	8	26.7	18	30.0
O	18	60.0	17	56.7	35	58.3
Total	30	100.0	30	100.0	60	100.0

Catch, during the whole season

Sex / Blood group	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
Bp_1Bp_2	6	6.0	8	8.0	14	7.0
Bp_1	25	25.0	18	18.0	43	21.5
Bp_2	13	13.0	19	19.0	32	16.0
O	56	56.0	55	55.0	111	55.5
Total	100	100.0	100	100.0	200	100.0

(c) Blue whale

Blood group \ Sex	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
Bm_1Bm_2	1	3.3	1	5.9	2	4.3
Bm_1	8	26.7	7	41.1	15	31.9
Bm_2	4	13.3	1	5.9	5	10.6
O	17	56.7	8	47.1	25	53.2
Total	30	100.0	17	100.0	47	100.0

(d) Humpback whale

Blood group \ Sex	Male		Female		Total	
	Actual No.	%	Actual No.	%	Actual No.	%
Mn_1Mn_2	2	11.1	2	11.8	4	11.4
Mn_1	5	27.8	4	23.5	9	25.7
Mn_2	1	5.6	2	11.8	3	8.6
O	10	55.5	9	52.9	19	52.3
Total	18	100.0	17	100.0	35	100.0

it has relations to the problem of migration and mixing of the different population among whale races, judging from the fact that the frequencies of human blood groups show the different values in the different races. However, the detailed discussion on this will be made in another occasion. As for other species, such as sei-, blue- and humpback-whales, no particular tendency was found in consequence of scantiness of thecatch.

Isohemagglutinin against each antigens

As already stated isohemagglutination was recognized in the whale normal sera. In sei-whales, however, the agglutination was so weak and none reacts specifically to the antigens Bb_1 and Bb_2 proved by the immune antibodies. In normal sera of the fin-, blue- and humpback-whales exist the isohemagglutinins which are able to be completely adsorbed away with each antigen proved with the immune antibodies. But they were found irregularly. Their agglutinin titers were generally low in the fin-whale. In comparatively higher case they were 32 times at most. In the blue-whale they were slightly stronger, that is 64 times at most, than in the fin-whale. In some humpback-whales their titers came up to 128 times.

Some examples of isohemagglutinins against the antigens Bp_1, Bp_2: Bm_1, Bm_2 and Mn_1, Mn_2 of the fin-, blue and humpback-whales were shown in Table XI to XIII.

Table XI. Anti-Bp_1 and anti-Bp_2 isohemagglutinins proved in the normal sera of the fin whales

(a) Anti-Bp_1 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Bp_1 agglutinin	216	188	Bp_1Bp_2	⧻	⧻	⧺	⧺	+	−	−	−
		193	Bp_1	⧻	⧺	+	−	−	−	−	−
		223	Bp_2	−	−	−	−	−	−	−	−
		221	O	−	−	−	−	−	−	−	−
	220	188	Bp_1Bp_2	⧻	⧺	+	+	−	−	−	−
		193	Bp_1	⧻	⧺	+	−	−	−	−	−
		223	Bp_2	−	−	−	−	−	−	−	−
		221	O	−	−	−	−	−	−	−	−
	221	188	Bp_1Bp_2	⧻	⧻	⧺	⧺	+	+	−	−
		193	Bp_1	⧻	⧺	+	+	−	−	−	−
		223	Bp_2	−	−	−	−	−	−	−	−
		221	O	−	−	−	−	−	−	−	−
	222	188	Bp_1Bp_2	⧻	⧻	⧺	+	−	−	−	−
		193	Bp_1	⧺	+	−	−	−	−	−	−
		223	Bp_2	−	−	−	−	−	−	−	−
		221	O	−	−	−	−	−	−	−	−
	223	188	Bp_1Bp_2	⧻	⧻	⧺	⧺	+	−	−	−
		193	Bp_1	⧻	⧺	+	−	−	−	−	−
		223	Bp_2	−	−	−	−	−	−	−	−
		221	O	−	−	−	−	−	−	−	−

(b) Anti-Bp_2 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Bp_2 agglutinin	187	188	Bp_1Bp_2	⧻	⧻	⧺	+	+	−	−	−
		165	Bp_1	−	−	−	−	−	−	−	−
		153	Bp_2	⧻	⧻	⧺	+	−	−	−	−
		161	O	−	−	−	−	−	−	−	−
	246	188	Bp_1Bp_2	⧻	⧺	⧺	+	−	−	−	−
		193	Bp_1	−	−	−	−	−	−	−	−
		223	Bp_2	⧻	⧺	+	+	−	−	−	−
		221	O	−	−	−	−	−	−	−	−
	247	188	Bp_1Bp_2	⧻	⧻	⧺	⧺	+	−	−	−
		193	Bp_1	−	−	−	−	−	−	−	−
		223	Bp_2	⧻	⧻	⧺	+	+	−	−	−
		221	O	−	−	−	−	−	−	−	−
	249	188	Bp_1Bp_2	⧻	⧺	+	+	−	−	−	−
		193	Bp_1	−	−	−	−	−	−	−	−
		230	Bp_2	⧻	⧺	+	−	−	−	−	−
		231	O	−	−	−	−	−	−	−	−
	251	188	Bp_1Bp_2	⧺	⧺	+	−	−	−	−	−
		193	Bp_1	−	−	−	−	−	−	−	−
		230	Bp_2	⧺	+	+	−	−	−	−	−
		231	O	−	−	−	−	−	−	−	−

(c) Anti-Bp_1Bp_2 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Bp_1Bp_2 agglutinin	248	188	Bp_1Bp_2	⧻	⧻	⧻	⧺	⧺	+	−	−
		193	Bp_1	⧻	⧻	⧻	⧺	+	+	−	−
		230	Bp_2	⧻	⧻	⧺	+	+	−	−	−
		231	O	−	−	−	−	−	−	−	−
	253	188	Bp_1Bp_2	⧻	⧻	⧺	+	−	−	−	−
		193	Bp_1	⧻	⧺	+	−	−	−	−	−
		230	Bp_2	⧻	⧻	⧺	+	−	−	−	−
		231	O	−	−	−	−	−	−	−	−

Table XII. Anti-Bm_1 and anti-Bm_2 isohemagglutinins proved in the normal sera of the blue whales

(a) Anti-Bm_1 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Bm_1 agglutinin	61	129	Bm_1Bm_2	⧻	⧻	⧺	⧺	+	−	−	−
		117	Bm_1	⧻	⧺	+	+	+	−	−	−
		160	Bm_2	−	−	−	−	−	−	−	−
		140	O	−	−	−	−	−	−	−	−
	155	129	Bm_1Bm_2	⧻	⧺	+	−	−	−	−	−
		117	Bm_1	⧺	⧺	+	−	−	−	−	−
		160	Bm_2	−	−	−	−	−	−	−	−
		140	O	−	−	−	−	−	−	−	−
	164	297	Bm_1Bm_2	⧻	⧻	⧻	⧺	⧺	+	+	−
		227	Bm_1	⧻	⧻	⧺	⧺	+	−	−	−
		160	Bm_2	−	−	−	−	−	−	−	−
		159	O	−	−	−	−	−	−	−	−

(b) Anti-Bm_2 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Bm_2 agglutinin	17	129	Bm_1Bm_1	⧻	⧻	⧻	⧺	+	−	−	−
		117	Bm_1	−	−	−	−	−	−	−	−
		160	Bm_2	⧻	⧻	⧺	⧺	+	−	−	−
		140	O	−	−	−	−	−	−	−	−
	157	129	Bm_1Bm_2	⧻	⧻	⧻	⧻	⧺	⧺	+	−
		117	Bm_1	−	−	−	−	−	−	−	−
		160	Bm_2	⧻	⧻	⧻	⧻	⧺	+	+	−
		140	O	−	−	−	−	−	−	−	−
	205	297	Bm_1Bm_2	⧻	⧻	⧺	+	−	−	−	−
		227	Bm_1	−	−	−	−	−	−	−	−
		199	Bm_2	⧻	⧻	⧺	+	−	−	−	−
		196	O	−	−	−	−	−	−	−	−

(c) Anti-Bm_1Bm_2 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Bm_1Bm_2 agglutinin	156	129	Bm_1Bm_2	+++	+++	+++	++	++	+	−	−
		117	Bm_1	++	++	+	+	+	−	−	−
		160	Bm_2	++	+	−	−	−	−	−	−
		140	O	−	−	−	−	−	−	−	−
	181	297	Bm_1Bm_2	+++	+++	+++	++	++	+	−	−
		227	Bm_1	+++	+++	+++	++	++	+	−	−
		160	Bm_2	+++	+++	++	++	+	−	−	−
		159	O	−	−	−	−	−	−	−	−

Table XIII. Anti-Mn_1 and anti-Mn_2 isohemagglutinins proved in the normal sera of the humpback whales

(a) Anti-Mn_1 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Mn_1 agglutinin	180	203	Mn_1Mn_2	+++	+++	+++	+++	+++	++	+	+
		151	Mn_1	+++	+++	+++	+++	++	+	−	−
		211	Mn_2	−	−	−	−	−	−	−	−
		192	O	−	−	−	−	−	−	−	−
	191	203	Mn_1Mn_2	+++	++	+	+	−	−	−	−
		151	Mn_1	++	+	−	−	−	−	−	−
		211	Mn_2	−	−	−	−	−	−	−	−
		192	O	−	−	−	−	−	−	−	−
	204	203	Mn_1Mn_2	+++	+++	+++	+++	+++	++	+	−
		151	Mn_1	+++	+++	+++	+++	++	++	+	−
		211	Mn_2	−	−	−	−	−	−	−	−
		192	O	−	−	−	−	−	−	−	−

(b) Anti-Mn_2 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Mn_2 agglutinin	142	203	Mn_1Mn_2	⧻	⧺	⧺	+	−	−	−	−
		151	Mn_1	−	−	−	−	−	−	−	−
		211	Mn_2	⧻	⧺	+	+	−	−	−	−
		192	O	−	−	−	−	−	−	−	−
	151	203	Mn_1Mn_2	⧻	⧺	+	−	−	−	−	−
		151	Mn_1	−	−	−	−	−	−	−	−
		211	Mn_2	⧻	⧺	+	−	−	−	−	−
		192	O	−	−	−	−	−	−	−	−
	206	203	Mn_1Mn_2	⧻	⧻	⧺	⧺	+	−	−	−
		151	Mn_1	−	−	−	−	−	−	−	−
		211	Mn_2	⧻	⧻	⧺	+	+	−	−	−
		192	O	−	−	−	−	−	−	−	−

(b) Anti-Mn_1Mn_2 agglutinin

Normal sera		Erythrocytes for agglutination		Dilution of the normal sera							
Anti-body	No.	No.	Blood group	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
Anti-Mn_1Mn_2 agglutinin	143	203	Mn_1Mn_2	⧻	⧻	⧻	⧺	+	−	−	−
		151	Mn_1	⧻	⧺	+	−	−	−	−	−
		211	Mn_2	⧻	⧻	⧺	⧺	+	−	−	−
		191	O	−	−	−	−	−	−	−	−
	192	203	Mn_1Mn_2	⧻	⧻	⧻	⧻	⧻	⧺	+	+
		151	Mn_1	⧻	⧻	⧻	⧻	⧺	+	−	−
		211	Mn_2	⧻	⧻	⧻	⧻	⧺	⧺	+	+
		191	O	−	−	−	−	−	−	−	−

Conclusion

(1) So far as just the author's survey goes, in the "serum type" of the four species of baleen whales, that is sei-, fin-, blue and humpback-whales, some

species have all of the four types, namely $\alpha'\beta'$, α', β' and o', while the other have only some part of the four. The frequencies of their types are as follows:

(a) Sei-whale $\alpha'\beta'$: 0.0%, α' : 18.8%, β' : 0.0%, o' : 81.2%
(b) Fin-whale $\alpha'\beta'$: 9.6%, α' : 6.5%, β' : 6.5%, o' : 77.4%
(c) Blue-whale $\alpha'\beta'$: 8.9%, α' : 39.7%, β' : 0.0%, o' : 51.4%
(d) Humpback-whale $\alpha'\beta'$: 0.0%, α' : 40.0%, β' : 0.0%, o' : 60.0%

(2) The existence of the two kinds of antigens, that is Bb_1-Bb_2, Bp_1-Bp_2, Bm_1-Bm_2 and Mn_1-Mn_2 in the erythrocytes of the sei-, fin-, blue- and humpback-whales respectively, were affirmed positively by the immune antibodies which were obtained by immunizing the rabbits with their erythrocytes. The erythrocytes of each species were able to be classified into four kinds as follows.

(a) Sei-whale Bb_1Bb_2: 18.8%, Bb_1: 21.9%, Bb_2: 9.3%, O: 50.0%
(b) Fin-whale Bp_1Bp_2: 7.0%, Bp_1: 21.5%, Bp_2: 16.0%, O: 55.5%
(c) Blue-whale Bm_1Bm_2: 4.3%, Bm_1: 31.9%, Bm_2: 10.6%, O: 53.2%
(d) Humpback-whale Mn_1Mn_2: 11.4%, Mn_1: 25.7%, Mn_2: 8.6%, O: 52.3%

(3) The frequency of each type of the fin-whales caught in the northern Pacific Ocean in 1952 showed a remarkable seasonal variation during the whaling season from July 19 to September 19.

(I) July 19 to August 10 (80 whales examined)
Bp_1Bp_2: 3.8%, Bp_1: 22.5%, Bp_2: 5.0%, O: 68.7%
(II) August 11 to August 31 (60 whales examined)
Bp_1Bp_2: 13.3%, Bp_1: 35.0%, Bp_2: 16.7%, O: 35.0%
(III) September 1 to September 19 (60 whales examined)
Bp_1Bp_2: 5.0%, Bp_1: 6.7%, Bp_2: 30.0%, O: 58.3%
Average through the whole season (200 whales examined)
Bp_1Bp_2: 7.0%, Bp_1: 21.5%, Bp_2: 16.0%, O: 55.5%

It seems that this fact can be taken for as the indicator of discriminating the local difference and mixing of different populations of whale races, judging from the meaning of biochemical racial index in human being. But detailed discussion must be looked for in future investigations. As for the other whale species no particular tendency was found because of the scantiness of the available number of whales.

(4) Isohemagglutinins was found in the normal sera on the four kinds of baleen whales. In the sei-whale it has no relation to Bb_1-Bb_2 system and the agglutinin titer was low. In the fin-, blue- and humpback-whales were found some agglutinins which react specifically to receptors of Bb_1-Bb_2, Bm_1-Bm_2 and Mn_1-Mn_2 systems respectively, and moreover their agglutinin titers were fairly high. But they were found irregularly.

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Errata for the Report: "On the Serological Constitution of Striped Dolphin (I)" inserted in the previous Bulletin No. 7

Page	Line	uncorrected	corrected
69	Contents 5	Existence	Detection
	〃 6	An Immune Antibody	The Immune Antibody
	〃 9	Appearance Rate	Frequency
	6-8	its range..in each charactor	its scope covers on partial antigens of A, B, C 8)9)10)11)12)13)14)15)16)17)18) O, M, N and other receptors in the blood corpuscles of various animals
	14	D1 and D2	Dc1 and Dc2
	〃	from	by
70	18	coagulating reaction	agglutination reaction
	27	floating liquid	suspension
	〃	made with	made of
	28	5 cc of the liquid	5 cc. of the suspension
71	1	Coagulating Reaction	Agglutination Reaction
72	6	connected	concerned
	8	Existence	Detection
	12	coagulating reaction	agglutination
	Table 2	Absorption test	Adsorption test
	15	Type O′	Type o′
73	1	until the dilution with..............in three times	until the 4 times dilution with the salt water
	9	the agglutinin and................dolphin's blood	the species specific agglutinin and hemolysin
	12-15	From thus obtained...by Dc2 blood corpuscle.	And then the former agglutinin and hemolysin were adsorbed away by Dc2 blood corpuscles from the antibodies. Consequently, the anti-Dc1 immune agglutinin and hemolysin were obtained.
	16	immune serum	immune antisera
	17	agglutinins	agglutinogens
	18	hemolysins	hemolysinogens
	Table 3	each type of serum	each type of blood corpuscles
74	Table 4	each type of serum	each type of blood corpuscles
	1	Appearance Rate	Frequency
75	3	coagulating reaction	agglutination
	Table 5	coagulating reaction	agglutination
76	10	Dc1Dc2-type	Dc1Dc2-system
	13	appears	are found
	16	connection with Dc1Dc2 blood type	relation with Dc1Dc2 system
	19	O′	o′
	29-30	no connection with.............appear irregularly	no relation with Dc1Dc2-system, and they were found irregularly.


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THE INSTITUTE OF CETACEAN RESEARCH

On the Presence and Disappearance of the Hind Limb in the Cetacean Embryos

By

TEIZO OGAWA

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I. A Historical Sketch

G. Guldberg of Norway reported for the first time the unquestionable existence of the hind limb protrusion in the fetal Cetacea. That is, he spoke on May 14, 1894, at the 8th meeting of the Anatomical Association of Germany opened at Strassburg upon a 7 mm long embryo of the harbor porpoise, Phocaena communis, which showed comparatively well developed hind limbs. At the same occasion *Guldberg* introduced two other embryos, 17 mm and 18 mm long of the same species, in which he could observe lateral to the genital tubercle very low eminences, representing to his mind the rest of the hind limbs.

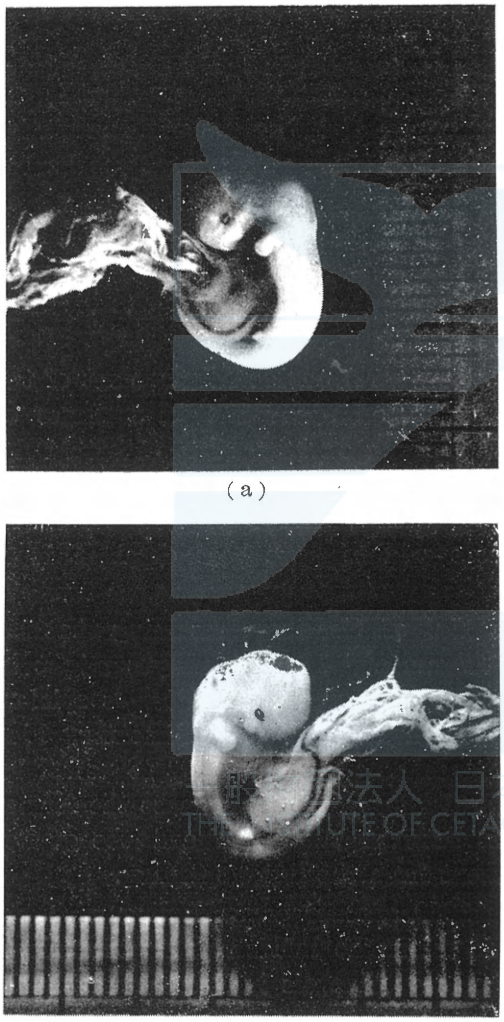
Soon afterwards a large monograph (1894) on the development of the dolphin was published from Bergen Museum under the joint names of *Guldberg* and *Fridtjof Nansen*, the famous explorer of the North Pole, and *Guldberg* reported then his findings in details on the hind limbs of the three Phocaena-embryos, together with a number of clear drawings. The 7 mm and 17 mm embryos were said to have been obtained from Greenland.

Shortly later (1895) *W. Kükenthal* of Germany, assuming that the low eminences seen by *Guldberg* in 17 mm and 18 mm embryos might be the anlage of the mammary glands, opposed partly to *Guldberg*'s opinion. He added that he had written already in 1893 on the rudimentary hind limb in a 25 mm long embryo of Phocaena. The originality requested by *Kükenthal* was not fully accepted by *Guldberg*, chiefly because the former mentioned the eminence in a height between the navel and the genital organ, namely, its position was different from the latter's finding.

Later *Guldberg* wrote again in 1899 another paper dealing with the same research materials as before, in which he laid stress on the microscopical proofs to indicate that the low eminences in 17 mm and 18 mm long embryos can never be the anlage of mammary glands, but nothing than the rest of the hind limbs. It is also to be noted in this paper, that *Guldberg* revised his earlier drawing on the external appearance of the 7 mm long Phocaena-embryo. Compare his pictures of 1894, Taf. IV,

Fig. 12 and of 1899, Taf. XX, Fig. 1.

The present author deems, the very interesting discussions between these two European authorities came to the end in 1899 with the victory of the Norwegian cetologist. Afterwards *Kükenthal* himself made in 1914 a great contribution to this problem, as he found in three embryos (32 mm, 28 mm, 30 mm "direkte Körperlänge") of Megaptera the existence of rudimentary hind limbs, that is, for the first time as to the baleen whales. The 32 mm embryo, which with relatively less marked curvature of the body-axis was estimated as the youngest of the three, showed on both sides of the genital tubercle the hind limb elevation, 1.2 mm in height and 0.9 mm wide at the base. It was conical but rounded at the tip, papilla-like, and flat laterally, and caudally directed. Also in two other embryos, 28 mm and 30 mm, the rest of the hind limb was recognized, though less remarkably. In the same paper *Kükenthal* added his observation on the hind limb of a 11 mm long embryo of Phocaenoides dalli (*True*).


(a)

(b)

Fig. 1. Fourteen millimeter embryo of Prodelphinus caeruleoalbus. (a) left side, (b) right side.

II. Personal Observations

Recently I could affirm in a 14 mm long embryo of Prodelphinus caeruleoalbus (*Meyen*) collected at Arari on the western coast of Izu Peninsula, the presence of the hind limb, as shown in the accompanying photographs (Fig. 1 a, b). The body-axis of the embryo is strongly bent, so the length (14 mm) was measured straight from the nucha to the caudal flexure. This way of measurement is appropriate so as not to spoil the delicate material after fixation in formalin, and besides to compare with *Guldberg*'s figures, as this author measured also the "Nacken-steiss-länge".

The form of the hind limb protrusion observed by me in this Prodelphinus-embryo is considerably different from *Guldberg*'s description. In my case it is more conical and pointed, the apex being directed caudally and laterad. Though the *Guldberg*'s pictures of the 7 mm long embryo are different as mentioned above between 1894 and 1899, one should take

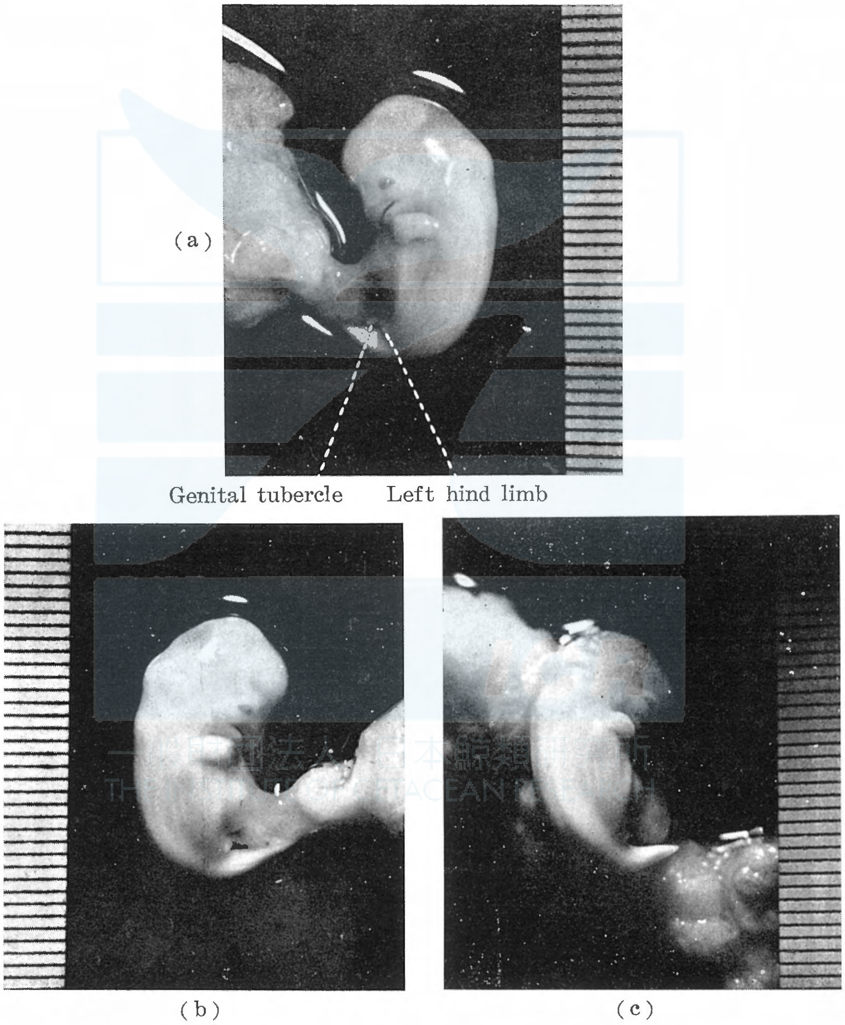


Fig. 2. Twenty millimeter embryo of Megaptera nodosa. (a) left side, (b) right side, (c) from right dorsal, the protrusion of the hind limb well noticable.

naturally the later published picture for more accurate. Anyway, in his specimen the limb in question must have been more rounded and relatively fan-like.

The difference of the form between *Guldberg*'s and mine is probably due to the ontogenetic stage of the embryos. It is very conceivable that in my specimen the retrogression of the hind limb has proceeded further. The difference according to the species of animals seems to be less plausible.

In two other more developed embryos of Prodelphinus caeruleoalbus collected recently by Dr. *M. Nishiwaki* at Arari, which are respectively 20 mm and 24 mm in body-length, I could recognize rudiments of the hind limb as a very low eminence on each side, exactly at the place, where *Guldberg* saw the rudimentary hind limb in the 17 mm and 18 mm embryos of Phocaena. But in my cases it appeared to the naked eye as a single eminence, though *Guldberg* found "on each side two small tubercles, which are connected at their origin". The body-length of these fetuses (20 mm and 24 mm) was measured not from the nucha, but from the head to the tail flexure, as the head is more erected and the neck flexure is less marked than in the 14 mm embryo. *Guldberg* also calculated the length of 17 mm and 18 mm from the head to the tail.

As the next, I wish to mention another finding of the hind limbs in a 20 mm long embryo of the Humpback, Megaptera nodosa. This embryo has been preserved for several years in formalin in the Whales Research Institute, Tsukishima, Tokyo, and its state of preservation is very good. On opening the fetal membranes the existence of the hind limb elevation is clearly visible (Fig. 2 a, b, c), though not so marked as in the 14 mm long Prodelphinus. To compare with *Kükenthal*'s description on the fetuses of Megaptera, the hind limb elevation in my case is a little lower in height but broader at the base. Fig. 9, Taf. 1 of his paper, showing a 28 mm long embryo, seems to resemble my own observation in a high grade, as to the hind limb.

III. Relation with the Caudal Flukes

My attention was further given to the chronological relation between the disappearance of the hind limb and the formation of the caudal flukes. For this purpose I examined several other fetuses of Prodelphinus, a little larger than the above mentioned, and reached the opinion that a certain synchronism exists between these two phenomena. In the 14 mm long embryo, which has the easily observable hind limb, no lateral widening of the flukes can be recognized, the tail tapering quite gradually to the tail-end (Fig. 3 a). Keeping pace with becoming smaller of the hind limb protrusion in the 24 mm and 25 mm long Prodelphinus, the elevation of the flukes makes appearance (Fig. 3 b, c), at first so faintly that one may fail to find it, if not with special care. In larger embryos, in which the flukes can be seen at ease, there remains no trace of the hind limb elevation at all (Fig. 3 d).

The same circumstance applies probably also to Megaptera, though I have examined till today only two embryos of this species small enough for this problem. We can recognize scarcely any elevation of the flukes in the 20 mm long embryo (Fig. 3 e), while the other embryo, 51 mm long (from the head to the tip of the tail, as the caudal flexure is here nearly absent), shows pretty well developed flukes, but no trace of the hind limb protrusion (Fig. 3 f).

This relation may be merely a matter of coincidence without any important significance. But if one considers the hind extremities of Pinnipedia, above all of Phocidae, being shifted far caudally and functioning in swimming rather as the main portion of the tail, the chronological agreement between the disappearance of the hind limb and the appearance of the caudal flukes deserves our special notice.

I won't discuss here the validity of *E. Häckel*'s famous thesis, that the ontogenesis recapitulates the phylogenesis, nor any phylogenetic relationship between Pinnipedia and Cetacea. But in my opinion the disappearance of the paired hind limbs in the Cetacea seems to have an intimate causal nexus with the appearance of the paired caudal flukes of them.

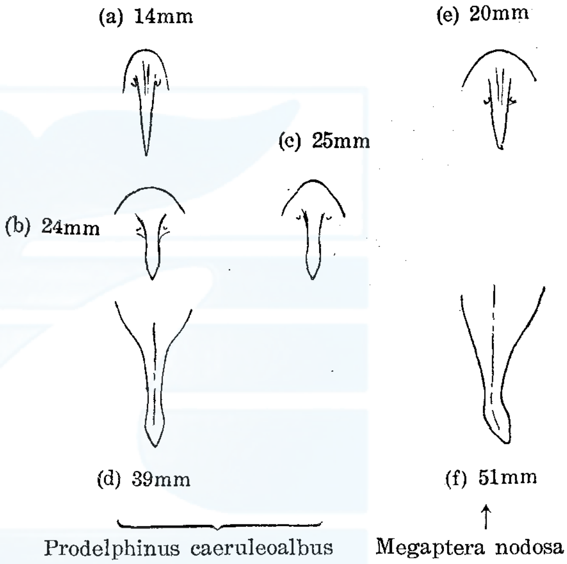


Fig. 3. Schema showing the tail and the hind limb in small embryos of the Cetacea (seen from caudal direction).

IV. Summary

In a 14 mm long embryo of the dolphin, Prodelphinus caeruleoalbus, and in a 20 mm long embryo of the Humpback, Megaptera nodosa, the paired elevations of the hind limb are pretty well developed. Photographs of them are shown. Further consideration was given to the simultaneousness of the disappearance of the hind limb elevation with the first appearance of the caudal flukes in the Cetacean embryos.

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On the Age and the Growth of Teeth in a Dolphin, (*Prodelphinus caeruleo-albus*). (I)

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Introduction

As age data are essential to the analysis of whale stocks, various methods of age determination have been tried to both whalebone and toothed whales. But a perfect one has not yet been developed, chiefly owing to the difficulty of measuring the growth of these animals in a known length of time. It is a rather old knowledge that there is seen a peculiar striation or "stripe-pattern", reminiscent of their possible relation to the age, both on the surface of the baleen plates of the whalebone whales and in the section of the teeth of the toothed whales. In the baleen plate, it is a series of those parallel grooves or "sculptures" which traverse the surface of the plate in the direction of its width; in the teeth of the toothed whales, it is those stripes found in the section of the dentine, which are arranged concentrically with the periphery of the dentine at roughly regular intervals.

It was J. T. Ruud of Norway who first proposed to utilize these "sculptures" for the age determination of whalebone whales. (1) The senior author of the present paper, who recently investigated into the rate of formation of these "sculptures" on the baleen plates, have found that the age of the whalebone whales is determinable from this structure, (2) and, applying this result, has shown that this group of whales attain sexual maturity at much older ages than hitherto believed. (3)

It is attempted in the present study to discover any relationship that may exist between the aforementioned stripes in the section of the dentine and the age of the toothed whales, in the hope that a method of age determination for these whales may be derived from the understanding of such relationship, so as to facilitate the analysis and conservation of their stocks.

Since its ultimate objective lies in contributing to the conservation of the resources of the toothed whales, this study ought to have dealt with the sperm whale, if conditions had permitted it; for this species far exceeds the other members of the group both in economic importance and in the need for an adequate conservation measure. But this species can hardly be reared, nor is the collection of its specimens covering a wide range of young age classes so easy, because its capture is limited by regulations. On account of these situations, it was decided to use a species of dolphin (*Prodelphinus caeruleo-albus*) as the material and to secure basic knowledges on the relation between the age and the growth of teeth in toothed whales. This dolphin, quite common in the Japanese and adjacent waters, is far smaller and much easier to handle than the sperm whale.

Part of the research fund of this study was supplied by the Ministry of Education as the Grant in Aid for fundamental Scientific Research. And the members of the research group on the "Growth of Hard Tissues" led by Prof. Masahiro Okada of the Tokyo Medico-Dental University gave us plentiful cooperation and guidance during the course of the study. We wish to aknowledge these aids most gratefully. Our sincere thanks are due also to the members of the Arari Fishermen's Cooperative, Shizuoka Pref. for their cooperation in catching and investigating material animals, and to the staffs of the Mito Aquarium, Shizuoka Pref. who kindly took the labour of rearing dolphins during the experiment.

Chapter I.

Observation of the Growth of Teeth by the *Intra vitam* Staining Method with Lead Acetate

With the view of determining the rate of formation of the aforementioned stripes in the dentine of toothed whales, teeth of captured dolphins were stained *intra vitam* with lead acetate by the method of Okada and Mimura (4, 5, 6).

On May 12, 1951, about 150 dolphins were caught by the traditional "driving-in" method in Arari Bay, Shizuoka Pref., of which four, measuring 162, 164, 169 and 220 cm. in body length, were used for the experiment. These were immediately taken on board live-fish boat and brought to the Mito Aquarium after a cruise of about two and a half hours. During the cruise, smaller three dolphins were being accommodated in the live-fish tank of the boat, but the largest one was being laid on the deck and covered with wet straw mats, over which sea water was being sprinkled.

While being on board, the paste containing lead acetate was injected by means of the ordinary lumbar puncture needle into the dorsal muscle of each dolphin about 6 cm. underneath that part of the skin about 10 cm. down from the center of the base of the dorsal fin. The paste was prepared by kneading the powdery crystals of lead acetate with the 35% solution of soluble starch which had been cooked and left to cool down and become tasty. The dose was 5 to 10 mg. of lead acetate per kg. of body weight of the dolphin, as indicated in Table 1.

Table 1. Dolphins used in the vital staining experiment with lead acetate.

No.	Body length	Date of injection	Date of death	Dose of lead acetate	Sex	Number of corpora lutea	Body weight soon after death	Remarks
P. 1	220 cm	1951. 5. 12 2.00 pm	1951. 5. 19 12.00 am	10 mg./kg.	Female	Old 1	89.8 kg	Lactating
P. 2	162	〃	1951. 5. 26 3.00 am	5 mg./kg.	Female	0	41.6 kg	Immature
P. 3	169	〃	1951. 5. 17 3.00 am	10 mg./kg.	Female	0	54.0 kg	Immature
P. 4	164	〃	1951. 5. 19 3.00 am	10 mg./kg.	Female	0	44.2 kg	Immature

Upon arrival to the Aquarium, the dolphins were released in a sea water rearing pool of about 1,000 square meters, which was the part of a small bay partitioned with net. In spite of the efforts to feed them with fresh or live squids, fresh sardine or other fresh fish, they were quite off their feed and died off within two weeks.

When they died, their teeth were fixed in a 10% formalin solution. Later, the portion containing the 20th tooth counted from the posterior end of the dental series and the adjacent alveolar bone was cut out, and decalcified by being immersed in the 0.2N hydrochloric acid saturated with hydrogen sulphide for about a week, and then cut into frozen sections. These were stained in a 0.1% solution of gold chloride, and examined under the microscope for the deposition of lead to be detected.

The line characteristic to the deposition of lead was not found in the sections from P 3, the dolphin which survived four days after 10 mg. per kg. of lead acetate was injected.

Two dolphins, P 1 and P 4, to which also 10 mg. per kg. of lead acetate was injected, survived seven days in the rearing pool. Though the deposition of lead was not detected in the sections from P 1, the line of deposited lead was found in the dentine and cement of the tooth of P 4.

P 2 survived 14 days after the injection of lead acetate. Though the dose only 5 mg. per kg., a distinct line of deposited lead was recognized in the section of its dentine close to the boundary-line between the dentine and the predentine (Fig. 1 and 2). If the dentine intervening between this line of deposited lead and the above-mentioned boundary-line is taken as

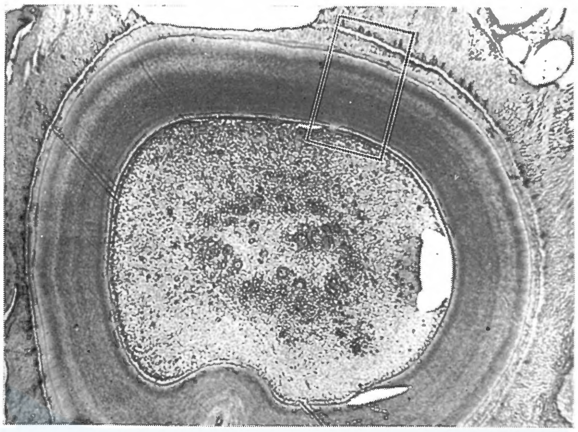

Fig. 1. Transverse section of a tooth of a dolphin (P. 1.) 14 days after the injection of lead acetate. ×20

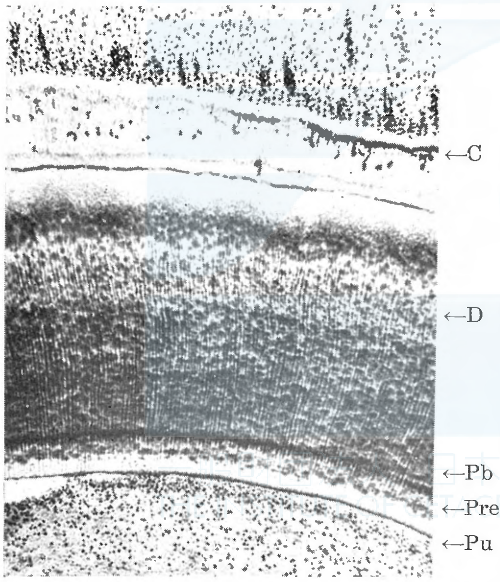

Fig. 2. Enlargement of the squarely marked part in Fig. 1. ×90
D, dentine; Pb, line of deposited lead; Per. d, predentine; Pu, pulp; C, cement.

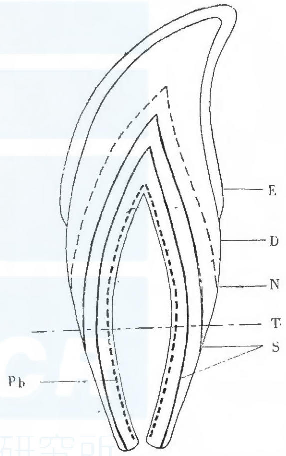

Fig. 3. Semi diagram of longitudinal section of a tooth of a dolphin.
E, enamel; D, dentine;
N, Neonatal line;
Pb, line of deposited;
T, Transverse cut;
S, Stripe.

being formed during 14 days, i. e. the period from injection to death, the whole thickness of the dentine, as measured in Fig. 2, corresponds to the formation during about 200 days. But it does not seem appropriate to draw any conclusion concerning the rate of dentine formation out of this single example, because not only this rate may vary from time to time and from one individual to another but the whole feature of the dentine is not represented adequately in the transverse section of the tooth, as is diagrammatically shown in Fig. 3. We are therefore looking forward for opportunities at which this sort of experiment can be repeated so as to reach any conclusive result.

Chapter II.

Physical Growth and the Morphological Characteristics of Teeth in this Dolphin

Along with the aforementioned experiment of the *intra vitam* staining of the teeth with lead acetate, inquiries were also made into the cause and the rate of the formation of the concentric stripes found in the section of the dentine of this dolphin. In the rooted teeth, as are possessed of by this species, the dentine formation does not proceed at constant rate throughout the life, but slows down with increasing age. Consequently, a linear relation does not hold between the thickness of the dentine and the age of its possessor, as such is the case between the body length and the age. In the dentine of this species, where the calcareous matter is deposited in the form of minute globules, there are not found in the section any growth line of short intervals, but there are recognized considerably distinct stripes being arranged concentrically with the periphery of the dentine, which are probably the relics of some changes in the physiological conditions of the respective dolpoin. Should light be thrown upon the cause and the time of the formation of these stripes, it will become possible to trace back the life history of each dolphin and thus to make a step forward toward the age determination.

General biological observations were made on the 90 dolphins (35 males and 55 females) caught by the "driving-in" method in Arari Bay, on May 13, 1951. Fifteen foetuses got in dissecting these females and another obtained in September of that year were also included in the material. Major lines of the results of this investigation are summarized below.

1. A mode was found between 120 and 150 cm. in the body length frequency (Table 2 and Fig. 4). The dolphins within this size range had

in their stomach milk only, or milk and a small amount of odontophores of squids. On the other hand, the largest foetus investigated was 103 cm. in body length. These facts suggest that the dolphins of the aforementioned size (120–150 cm.) consisted of the youngs of various stages, ranging from recently born sucklings up to the youngs in the very beginning of the weaning period.

Table. 2. Number of dolphins according to body length

Body length in cm	Male	Female	Total
120	1	0	1
130	0	1	1
140	0	2	2
150	1	1	2
160	0	0	0
170	0	0	0
180	5	1	1
190	1	2	3
200	1	4	5
210	6	5	11
220	4	16	20
230	2	12	14
240	5	10	15
250	10	1	11
260	4	0	4
270	0	0	0
Total number	35	55	90
Average length	228 cm	216 cm	221 cm
Sex ratio	38.9%	61.1%	100%

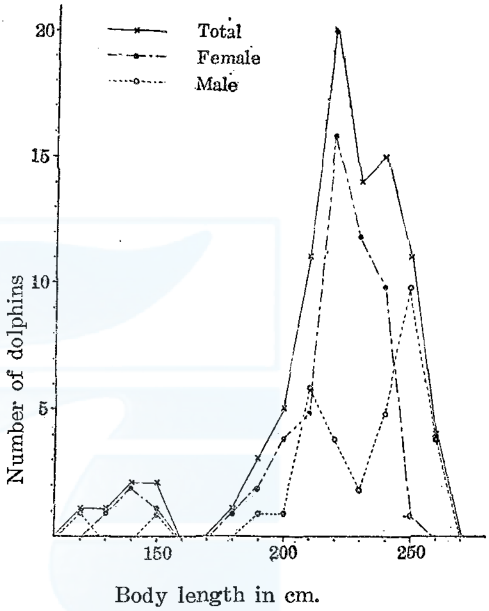

Fig. 4. Number of dolphins according to body length.

2. The number of corpora lutea in ovaries and the weight of both testes combined are plotted against the body length respectively in Fig. 5 and 6. The smallest female that had any corpus luteum in the ovary was 215 cm. in body length (Fig. 5), and the graphs suggest that in both sexes the generative organs are developed very rapidly at about this body length and upwards. It is inferred from these that the body length at the attainment of sexual maturity is about 215 cm. in this species, though the age at that time is not known. It is also suggested by the graphs that after the attainment of sexual maturity there is little increase in body length in either sex, especially in female.

3. By studying the foetal teeth of various stages of development and the teeth of postnatal individuals comparatively, it was ascertained that this species is monophyodont, i. e. with a single set of functional teeth that

is developed during the foetal period and persists all the life without being alternated. This finding confirms the proposition stated by Tomes: "No cetacean is known to develop more than one set of functional teeth." (7)-(p. 439)

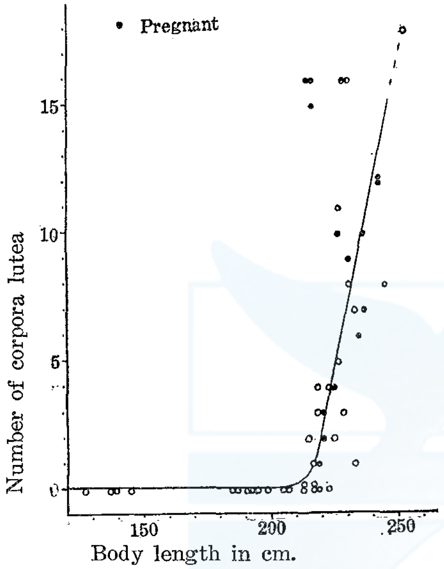

Fig. 5. Number of corpora lutea according to body length.

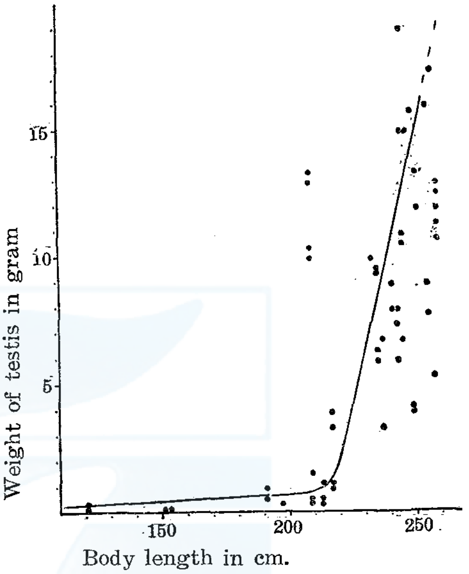

Fig. 6. Weight of testis according to body length.

The teeth of the dolphin are conical homodonts, about 50 of which are found in the dental series on each side of each jaw, though the number somewhat differs in different individuals. Their size varies slightly according to their position in the dental series. In every series, about the 20th tooth as counted from its posterior end is the largest, which is situated about the middle of the series. The tips of the teeth are exposed clear out of the gum near the posterior end of the dental series, but come to be buried in the gum towards the anterior end of the series. For this reason, the teeth are numbered more conveniently by counting them from the posterior end of the dental series.

The dentition is bilaterally symmetrical, and hardly differs in the upper and lower jaws. And all the teeth of an individual, except those implanted near the anterior end of the dental series, show the same striped pattern in the section of their dentine.

In the light of these morphological characteristics of the teeth of this species, one may reasonably designate in every individual a tooth in a fixed position of the dental series (e. g. the 20th tooth from the posterior end of the series) as the representative of all teeth of that individual, and compare only these teeth with one another, when the teeth of different individuals are to be compared.

Chapter III.

Formation of the Neonatal Line

As was mentioned in chapter II, 15 foetuses were obtained in May, 1951. Their body length composition was: 10 under 10 cm.; 2 between 10 and 15 cm.; and one each of 30, 85 and 103 cm. Five of them were selected so as to represent each size class (Table 3), and the observation was made on the development of their teeth. For the reason stated in the same chapter, the approximately 20th in the dental series as counted from its posterior end was investigated in every case.

Table 3. Dolphin foetuses, of which the development of their teeth was observed.

No.	Body length	Date when mother killed	Sex	No.	Body length	Date when mother killed	Sex
P. 5	103 cm	1951, 5, 13	Male	P. 8	11.5	1951, 5, 13	Male
P. 6	85	〃	Female	P. 9	4.5	〃	〃
P. 7	30	〃	〃				

The longitudinal sections of the aforementioned tooth or the corresponding part of the jaw were prepared by the freezing method after decalcification, double-stained with haematoxylin and eosin, and subjected to microscopic examination.

The primitive tooth-band (primitive dental lamina), which is the thickning of the epithelium of the mouth, was found in the smallest foetus of body length of 4.5 cm. (Fig. 7). The tooth-band (dental lamina) was recognized in the 11.5 cm. long foetus (Fig. 8).

The calcified dentine was first met with in the foetus of body length of 30 cm. (Fig. 9) The other two large foetuses had more developed teeth which were almost of the same form as those of postnatal individuals. And it is worth mentioning that the dentine of the largest three foetuses stained deeply with haematoxylin and was devoid of any striped pattern (Fig. 10).

For the comparison purpose, observation was also made on the teeth of 10 postnatal individuals. Four of these were P 1 to P 4 described in

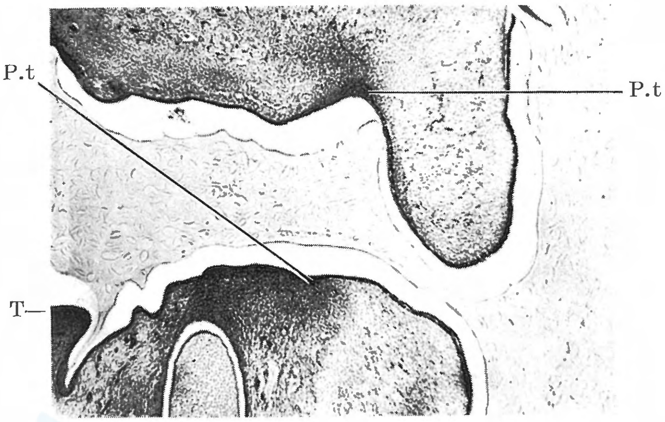

Fig. 7. Cross section of the upper and lower jaws of a 4.5 cm long foetus. Stained with haematoxylin and eosin. ×47
P.t, primitive tooth-band;
T, tongue

Fig. 8. Cross section of the upper jaw of a 11.5 cm long feotus, stained with haematoxylin and eosin. ×47
T.b, tooth-band

chapter I. The other six dolphins were selected out of those 1,050 dolphins caught at Kawana, Shizuoka Pref., on Sagami Bay on December 23, 1951, whose detailed description will be given in the next report. The approximately 20th tooth in the dental series as counted from its posterior end was taken from each dolphin, and its longitudinal sections were prepared by the freezing method after decalcification.

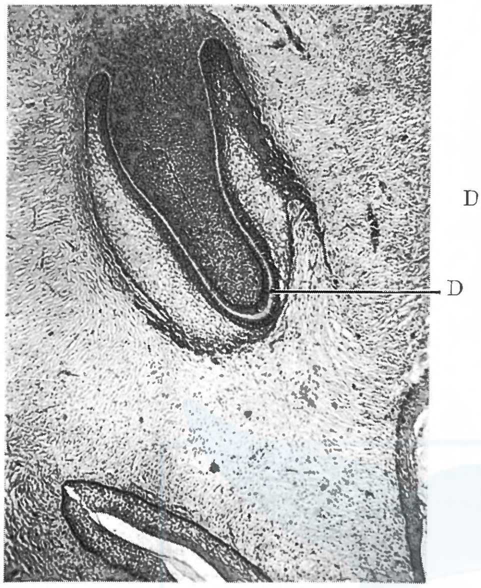

Fig. 9. Longitudinal section of a tooth in the upper jaw of a foetus of body Length of 30 cm, stained with haematoxylin and eosin. ×47 D, dentine.

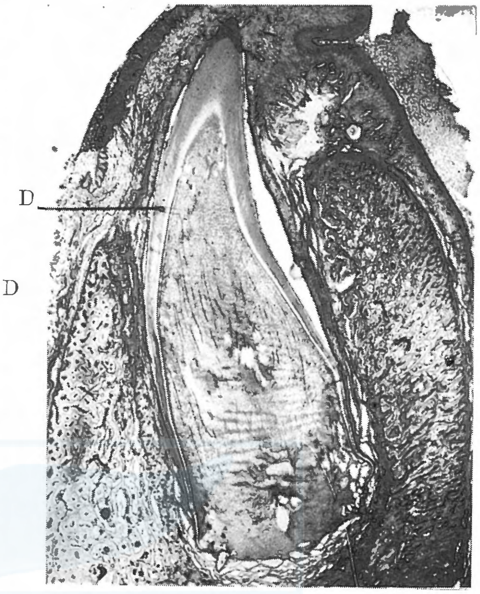

Fig. 10. Longitudinal section of a tooth in the lower jaw of a foetus (prenatal dolphin) of body length of 30 cm, stained with haematoxylin and eosin. D, dentine. ×10

In these sections, it was possible to distinguish the dentine in to three concentric parts of different structure. The innermost part is characterized by its striped appearance or "stripe-pattern", which is due to the alternate arrangement of stainable and unstainable zones, and 2 to 8 stripes (i. e. stainable zones) were seen in this part of the dentine of different individuals. The outside of this zone is bordered with a line unstainable with haematoxylin and, therefore, poorly calcified. The outermost part is characterized by its deep and homogeneous staining with haematoxylin (Fig. 11 and 12); this is the indication of sufficient and homogeneous calcification. It should be noted that this last part coincides, both in form and dimension, with the whole dentine of the 103 cm. long foetus which is regarded as being very close to birth.

If thin sections of the teeth of postnatal individuals are prepared by grinding, a peculiar line is recognized that very position in the dentine where the aforementioned line unstainable with heamatoxylin appears in decalcified sections (Fig. 13). Examination of such specimens under the polarizing microscope reveals that the arrangement of the crystals of calcareous salts differs on the two sides of this line (Fig. 14).

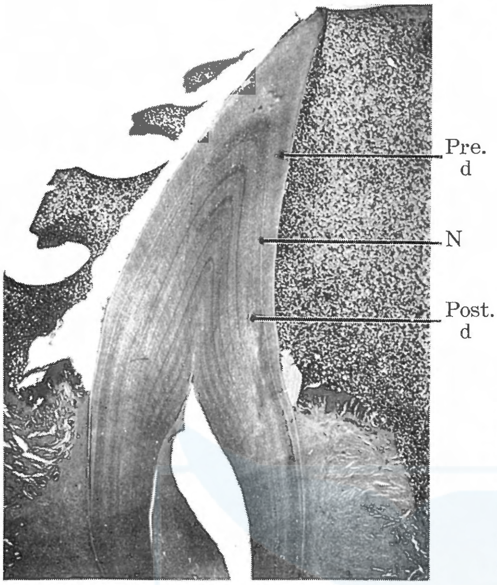

Fig. 11. Longitudinal section of a tooth in the upper jaw of a postnatal dolphin of body length of 220 cm. Stained with haematoxylin and eosin. ×10
Pre. d, prenatal dentine;
Post. d, postnatal dentine;
N, neonatal line.

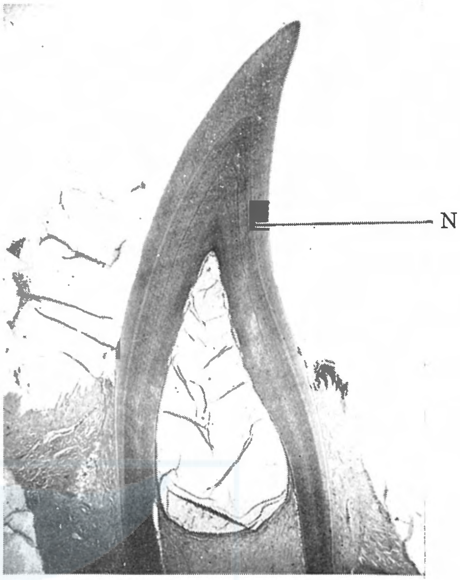

Fig. 12. Longitudinal section of a tooth in the upper jaw of a postnatal dolphin of body length of 162 cm. Stained With haematoxylin and eosin. ×10
N, neonatal line.

In the section of the root, this line is seen to extend downwards out of the dentine and terminate against the surface of the tooth. In this part the contour of the tooth is often marked with a distinct depression (Fig. 11 and 13), which is probably due to the hypoplasia (8) caused by the undernourishment.

These evidences indicate that the line in question, i. e. the line which is recognized in the longitudinal section of the dentine of the postnatal dolphin as a line unstainable with heamatoxylin and trimming the inner, striped part of the dentine, represents the thin layer of dentine which is formed during the period of undernouishment subsequent to birth. In other word, it is the neonatal line.

According to Schour (9), the neonatal line is more distinct in the enamel than in the dentine in human teeth. In the dolphin, however, it is not found in the enamel. This may be explained as that in this species the enamel formation is completed during the foetal stage,...as is indicated by the fact that the enamel of the foetal tooth is of the same dimension

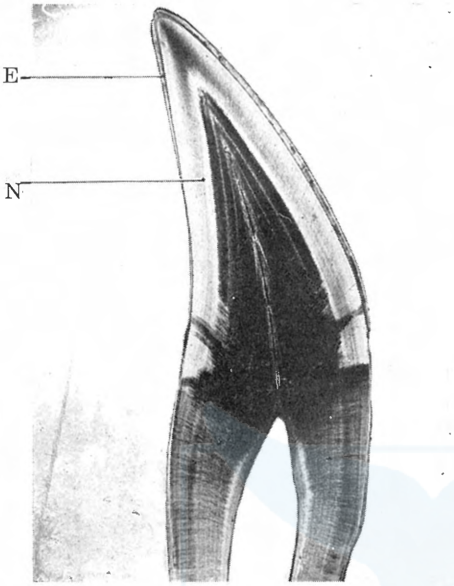

Fig. 13. Longitudinal section of a tooth in the upper jaw of a postnatal dolphin of body length of 220 cm, prepared by grinding, unstained. ×10
E, enamel; N, neonatal line

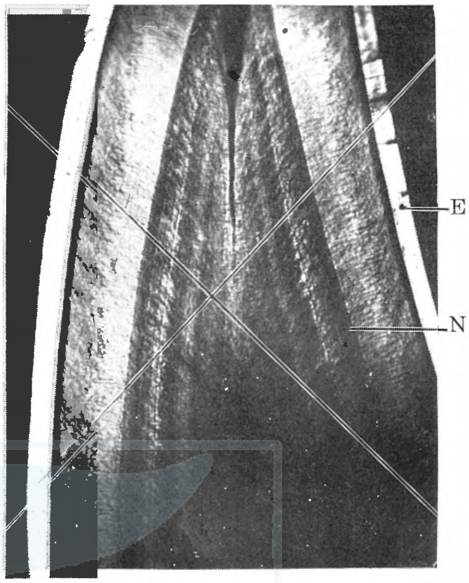

Fig. 14. Longitudinal section of a tooth in the lower jaw of a postnatal dolphin of body length of 195 cm, prepared by grinding, unstained. Observed by polarized light. ×27
E, enamel; N, neonatal line

as that of the tooth of the postnatal individual...and, therefore, is free from the influence of the birth.

Conclusions

1. By the *intra vitam* staining method consisting of the injection of lead acetate into the dorsal muscle, a layer containing the deposition of lead was produced in the dentine of the dolphin. The dose was 5 mg. of lead acetate per kg. of body weight. This layer was recognized as a distinct line in properly prepared sections of the tooth. As to the rate and cause of the formation of the striped pattern seen in the longitudinal section of the dentine, nothing more than preliminary informations were obtained, as successful observations could be made only on few individuals. This was chiefly due to the fact that the dolphins did not survived, after the injection, enough long for their teeth to grow to any considerable extent. Efforts will be made in future so that observation may be made on a considerable number of dolphins being reared for a sufficient length of time after injection.

2. So far as available data indicate, this species reach sexual maturity at the body length around 215 cm. But the data are so scarce that this must be considered as a preliminary conclusion.

3. This species is monophyodont. Its dentition is bilaterally symmetrical, and hardly differs in the upper and lower jaws. The dental series consists of the homodonts of very similar sizes. Except the very small teeth near the anterior end of the dental series, all teeth of an individual show the same striped pattern in the section of their dentine.

4. Such a striped pattern as is seen in that part of the dentine formed after the birth, does not appear in the dentine formed during the foetal period. In the longitudinal section of the teeth, the dentine is seen to be divided in these two parts by a line unstainable with haematoxylin. It was deduced that this line is the neonatal line, which is produced by the change in the nutritional conditions concurring with the transition from the foetal life to the suckling period.

5. We shall proceed further with this study by repeating the *intra vitam* staining experiments and by inquiring into the correlation between various age evidences and the striped pattern in the section of the dentine, so that an adequate age determination method may be derived.

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Errata for

“On the Age-Determination of Mystacoceti”

by M. Nishiwaki (July 1952)

p. 90, line 4. Delete “the” before “seasons.”
p. 90, chapter II, line 8, “deals” should be “dealt.”
p. 91, line 5, “July and August” should read “July or August.”
p. 92, line 26, “year” should be “years.”
p. 92, last sentence should read: Therefore, the majority of the females of the southern blue and fin Whales are considered to ovulate and conceive....
p. 94, line 2, “younger or older” should read “younger and older.”
p. 94, line 7. Change “Chapter V” to “Chapter IV.”
p. 95, line 2. Add “at these ages” after “the size limits.”
p. 95, the 2nd line from the bottom, “photocell-ammetertype” should be “photocell-ammeter-type.”
p. 101, Fig. 4-a and -b, along the abscissa, “Weight of testis in kg.” should read “Weight of testes in kg.”
p. 102, Table 2-b. The footnote should read: Note: (1) See the footnote (1) of Table 2-a.
p. 104, line 1. Delete “the approach of.”
p. 104, line 7. Delete “the” before “breeding.”
p. 107, line 18, “fastgrowing” should be “fast-growing.”
p. 109, line 22. A comma should be put before, instead of after, “partly.”
p. 110, line 23. Add “than” after “one” year earlier.”
p. 111, line 11, “Testis” should be “Testes.”
p. 111, the 7th line from the bottom, “Evalrdåets” should be “Hvalrådets.”

Biological Investigation on the Whales Caught by the Japanese Antarctic Whaling Fleets in the 1951-52 Season

By

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TAKEHIKO KAWAKAMI
and
KEN'ICHI IGUCHI

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Agency, Japanese Government

Introduction

In the 1951–52 season, Japan sent her sixth Antarctic whaling expedition since the cessation of the World War II. One of the features of this expedition was that it was the first one that Japan sent as a signatory to the International Whaling Convention. This report presents the summary of the results of that biological investigation on the whales taken by this expedition, of which the authors were in charge as the biologists on board the floating factories.

The expedition comprised three whaling fleets. The Tonan Maru fleet of the Nippon Suisan Co. Ltd. and the Nisshin Maru fleet of the Taiyo Gyogyo Co. Ltd. hunted primarily baleen whales. The Baikal Maru fleet of the Kyokuyo Hogei Co. Ltd. operated exclusively for sperm whales—a new type of operation which had never been attempted in the Antarctic waters. Either of the first two fleets was made up a newly built floating factory and new or newly outfitted catcher boats, and had considerably greater catching and processing capacities than its predecessor in the previous seasons.

All the fleets arrived on the whaling ground in November, 1951: Nisshin Maru on the 15th, Baikal Maru on the 16th, and Tonan Maru on the 23rd. Upon their arrival on the ground, they engaged in the catch of the sperm whales. While the Baikal Maru fleet continued this operation until February 20th, 1952, the other fleets turned to the baleen whaling when the season for baleen whales was opened on January 2nd, 1952. Fig. 1 shows the tracks of these fleets on the whaling grounds.

During the baleen whaling season lasting until March 5th, 1952, the Tonan Maru and the Nisshin Maru fleets hunted for blue and fin whales on the so-called "west Longitudes Ground," the waters bounded by latitudes 66° and 72°S and longitudes 160° and 180°W. According to the weather and migration of whales, the operations took place either along the pack ice line or in the open waters.

Humpback whales were hunted only by the Tonan Maru fleet, and 37 were caught during the season which lasted from February 2nd to 5th, 1952.

Japanese fleets took a total of 3,826 whales throughout the season (Table 1). The catch of blue whales was very small (231 whales), and the major part of the total catch was accounted for by fin whales. This was probably due to the fact that most of the successful operations were made in the offshore waters in this season.

Table 1. Nos. of catches by species and fleets

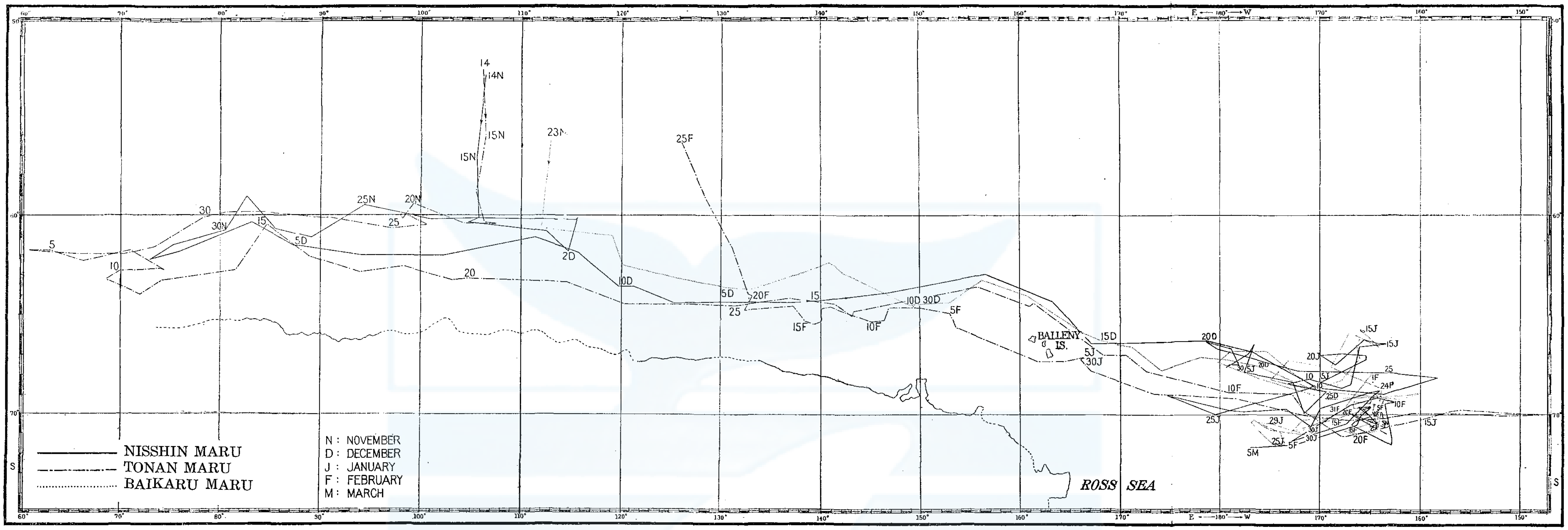
	Blue		Fin		Humpback		Total	Sperm	Total
	Nos.	%	Nos.	%	Nos.	%			
Tonan-Maru fleet	115	8.8	1,159	88.4	37	2.8	1,311	362	1,673
Nisshin-Maru fleet	116	7.5	1,438	92.5	—	—	1,554	377	1,931
Baikarl-Maru fleet	—	—	—	—	—	—	—	222	222
Total	231	8.1	2,597	90.6	37	1.3	2,865	961	3,826

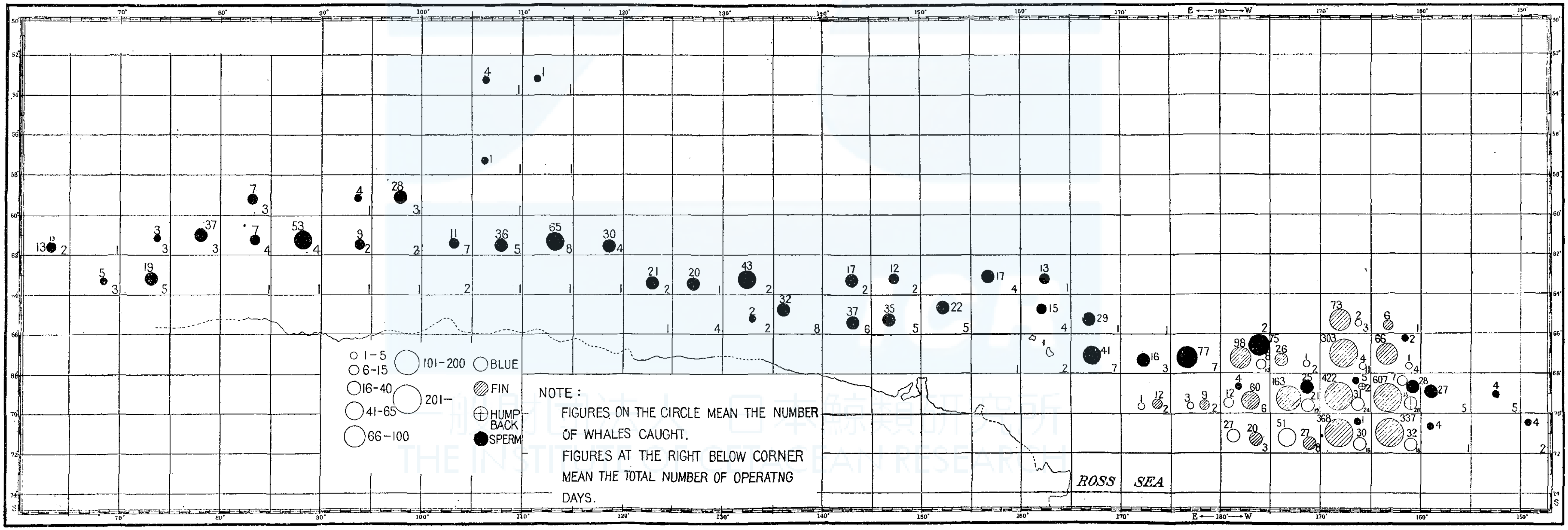
All the whales that were treated on board the floating factories were covered by the present investigation. The method of the investigation was the same as used in the preceding seasons. As the area of operation for baleen whales was very limited, no attempt was made to subdivide it in connection with the compilation of biological data of these species; the waters exploited in this season overlap Section III and a small eastern portion of Section II of last season (Ohno and Fujino: 1952).

Acknowledgement

The authors are profoundly indebted to the inspectors and the crew of the three fleets for their unsparing help to the present investigation. Inspectors for the Tonan Maru fleet were Messrs. Haruyuki Sakiura and Ryuzo Ohyama; for the Nisshin Maru fleet, Messrs. Yoshiro Teraoka and Heihachiro Kawamura; for the Baikal Maru fleet, Mr. Yasutake Nozawa.

Sincere thanks of the authors are also due to Dr. Hideo Omura and Dr. Hiroshi Kasahara, Investigation and Research Department, Fisheries Agency, for many kind suggestions concerning the preparation of this report, and to the Director of the whales Research Institute who favoured us with the opportunity to publish this work.





NOTE :
FIGURES ON THE CIRCLE MEAN THE NUMBER OF WHALES CAUGHT.
FIGURES AT THE RIGHT BELOW CORNER MEAN THE TOTAL NUMBER OF OPERATNG DAYS.

Chapter I

Composition of the Catch

1. Composition by Species.

In Table 2 is given the break-down into species of the catches by the Japanese Antarctic whaling expeditions in post war seasons. The table clearly indicates the sharp decrease of the blue whale catch and a rapid increase of the fin whale catch in recent two seasons. In 1950–51 the ratio of blue whale to fin whale recorded the first remarkable fall down to 11.6/88.4, and the ratio further dropped this season to a low of 8.2/91.8. In the whole Antarctic catch, ratio was rather sustained until last season (28.5/71.5 in 1950–51), but dropped markedly this season (20/80). The above ratio for the Japanese catch in 1951–52 is considerably lower than that for the whole catch in Area V (the Ross Sea Area) in the same season, 24.2/76.8. This is probably due to the fact that the Japanese fleets operated chiefly in the open waters this season.

Table 2. Nos. of catch by species and years

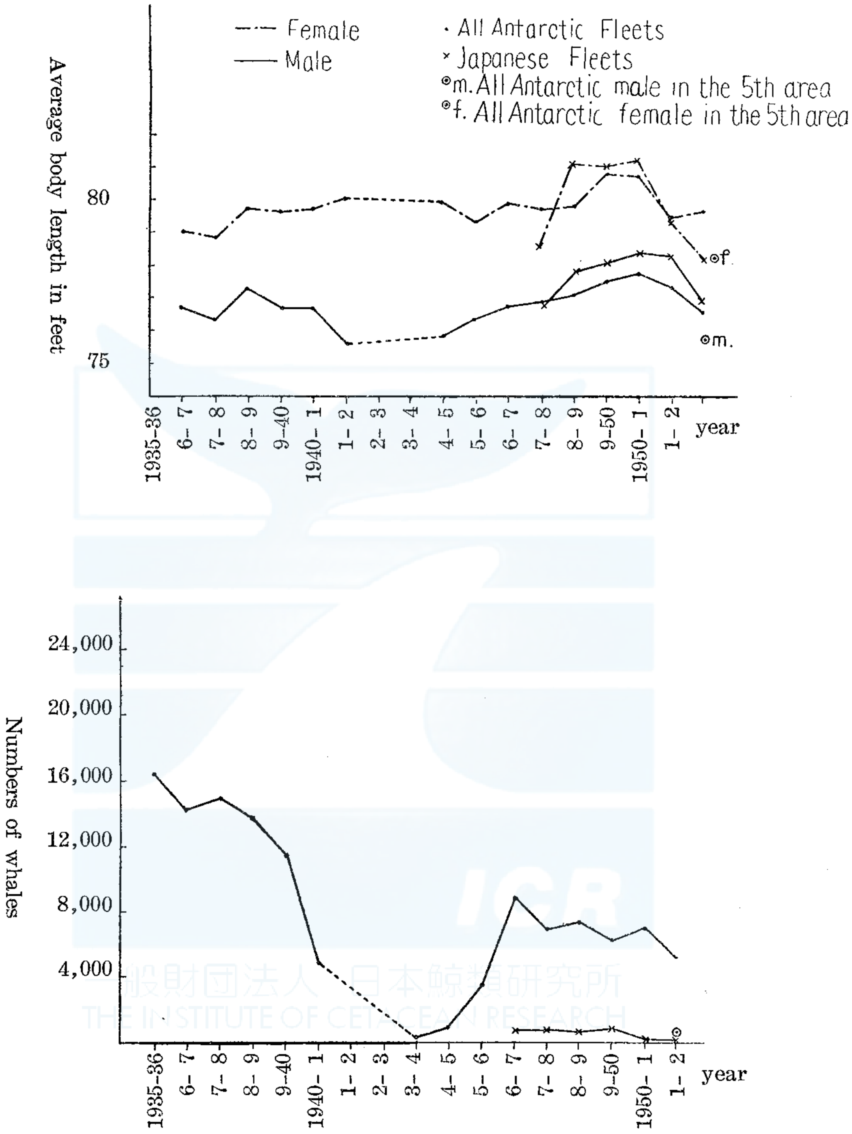
	Blue		Fin		Hump.		Total	Sperm	Total
	Nos.	%	Nos.	%	Nos.	%			
1946—47	690	59.2	474	40.6	0	0	1,164	1	1,165
1947—48	710	53.9	608	46.1	0	0	1,318	2	1,320
1948—49	631	38.4	1,012	61.6	0	0	1,643	0	1,643
1949—50	817	42.2	1,056	54.4	67	3.4	1,940	172	2,112
1950—51	271	11.6	2,050	88.0	9	0.4	2,330	409	2,739
1951—52	231	8.1	2,597	90.6	37	1.3	2,865	961	3,826

Humpback whales were hunted only by the Tonan Maru fleet this season, but the catch was greater than in last season.

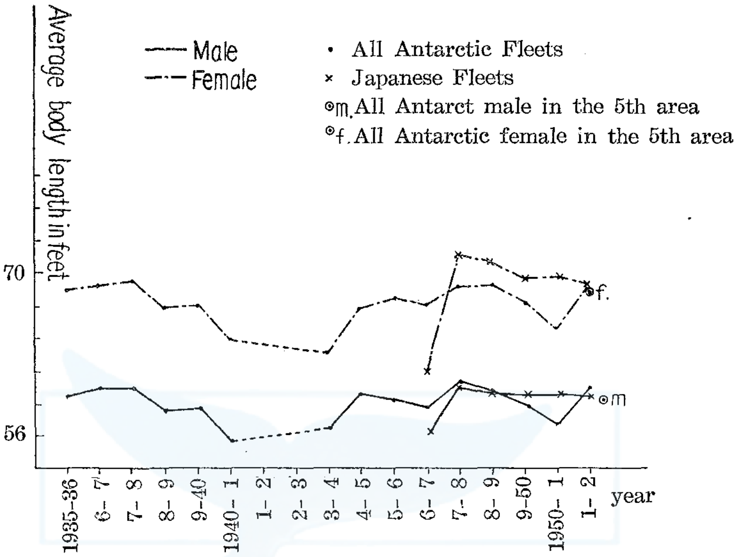
The catch of sperm whales was more than double that of the last season, owing to longer operation period and reinforced catching capacity. In recent seasons sperm whales have been caught in increasing numbers in the whole Antarctic waters.

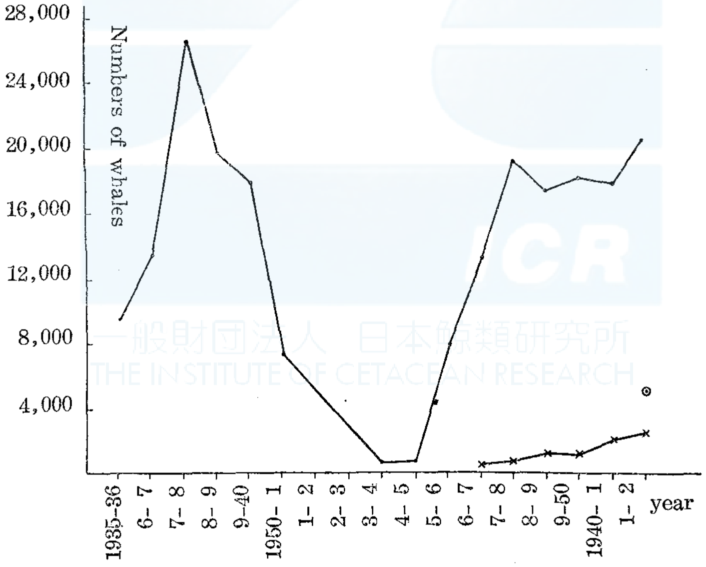
Fig. 2. Yearly variation of numbers of whales and the average body length.

2-1. Blue whale

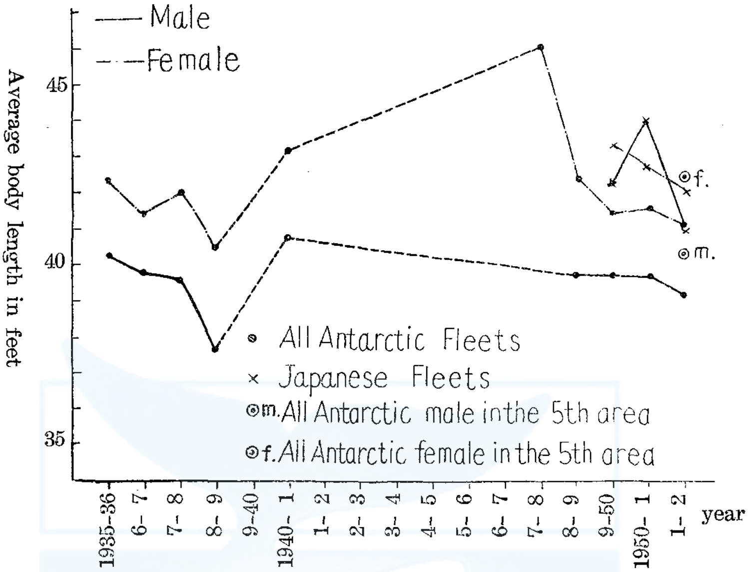


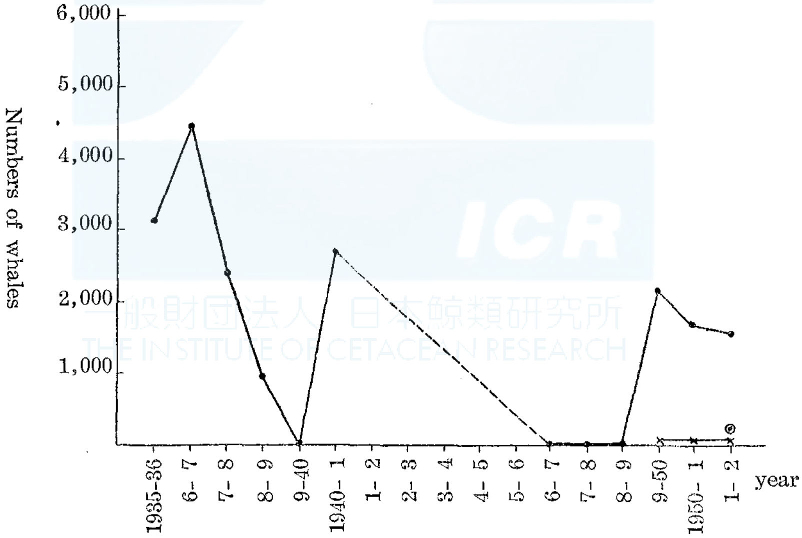
2-2. Fin whale


Average body length in feet
—— Male
—·— Female
• All Antarctic Fleets
× Japanese Fleets
⊙m. All Antarct male in the 5th area
⊙f. All Antarctic female in the 5th area
70
56
⊙f.
⊙m
1935-36
6-7
7-8
8-9
9-40
1940-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-50
1950-1
1-2
year

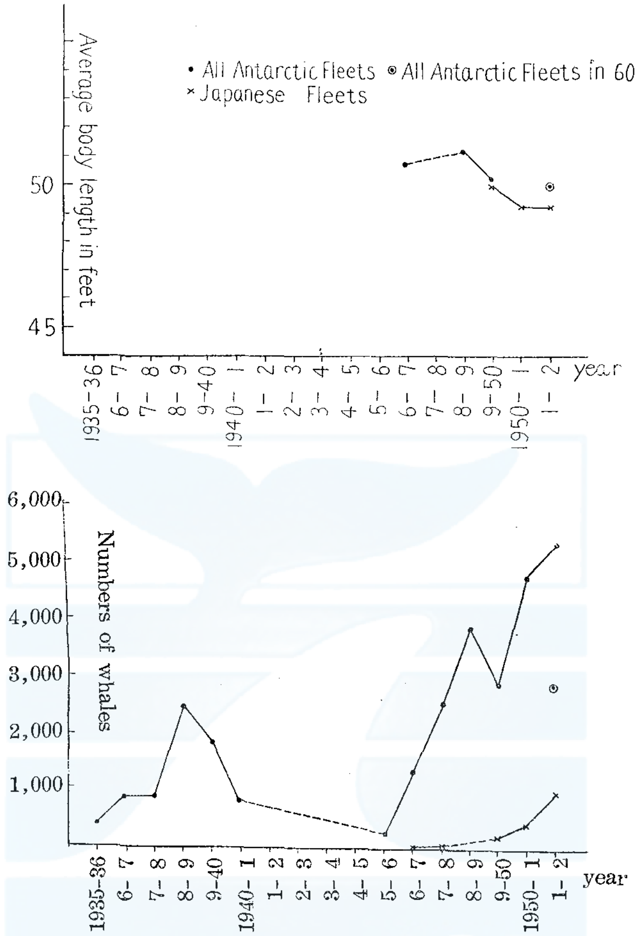

28,000
24,000
20,000
16,000
12,000
8,000
4,000
Numbers of whales
1935-36
6-7
7-8
8-9
9-40
1950-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-50
1940-1
1-2
year

2-3. Humpback Whale





2-4. Sperm Whale

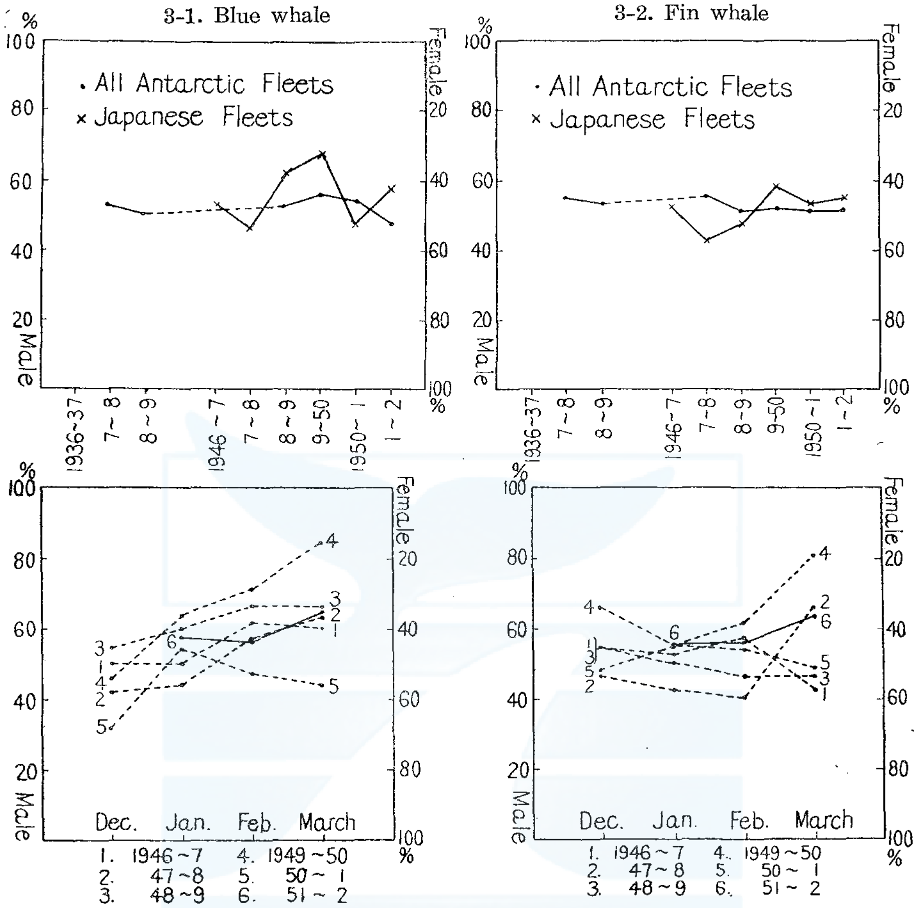


2. *Sex Ratio.*

This season's catches of blue, fin and humpback whales contained greater percentages of males than those of the last season (Fig. 3) or their parts made in Section III. (Table 3 and 4). This ground almost coincides with the waters exploited in the present season (Ohno and Fujino: 1952).

Catch statistics for preceding seasons indicate that the sex ratio was more changeable in Japanese catch than in the whole Antarctic catch. In 1951-52, Japanese blue and fin whale catch contained relatively more males than the whole Antarctic catch but as to humpback whales a lower percantage of males was associated with Japanese catch. (Fig. 3)

3-1. Blue whale 3-2. Fin whale



3-3. Humpback whale

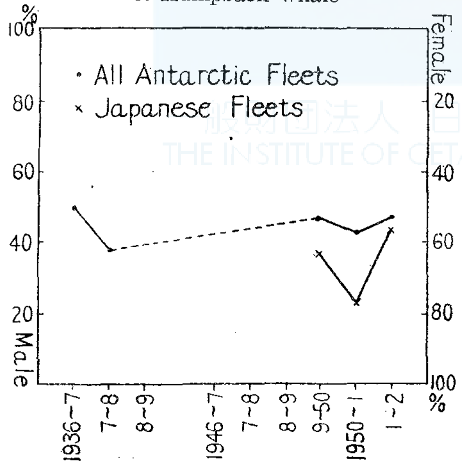


Fig. 3. Yearly variation of sex-ratio by month

Table 3. Nos. of catches and the sex ratio, monthly

		Male	Female	Total
Blue.	Jan.	76 (57.6)	56 (42.4)	132
	Feb.	46 (56.1)	36 (43.9)	82
	March	11 (64.7)	6 (35.3)	17
	Total	133 (57.6)	98 (42.4)	231
Fin.	Jan.	581 (54.8)	479 (45.2)	1,060
	Feb.	760 (55.5)	610 (44.5)	1,370
	March	106 (63.5)	61 (36.5)	167
	Total	1,447 (55.7)	1,150 (44.3)	2,597
Hump.	Feb.	16 (43.2)	21 (56.8)	37
Sperm	Nov.	220		220
	Dec.	600		600
	Jan.	45		45
	Feb.	96		96
	Total	961		961

Table 4. Nos. of catch and its sex ratio on the baleen whale in the 1950-51 season. (Ohno and Fujino, 1952)

	Male	Female	Total
Blue.	94 (51.9)	87 (48.1)	181
Fin.	580 (53.9)	496 (46.1)	1,076
Hump.	2 (22.2)	7 (77.8)	9

In every post-war seasons (except 1950–51), the proportion of males in Japanese blue whale catch remained almost unchanged during January and February and increased in March. In 1951–52, sex ratios followed this trend in both blue and fin whale catches (Table 3 and Fig. 3). The change of the sex ratio in the fin whale catch had not been so regular in past seasons as in the blue whale catch.

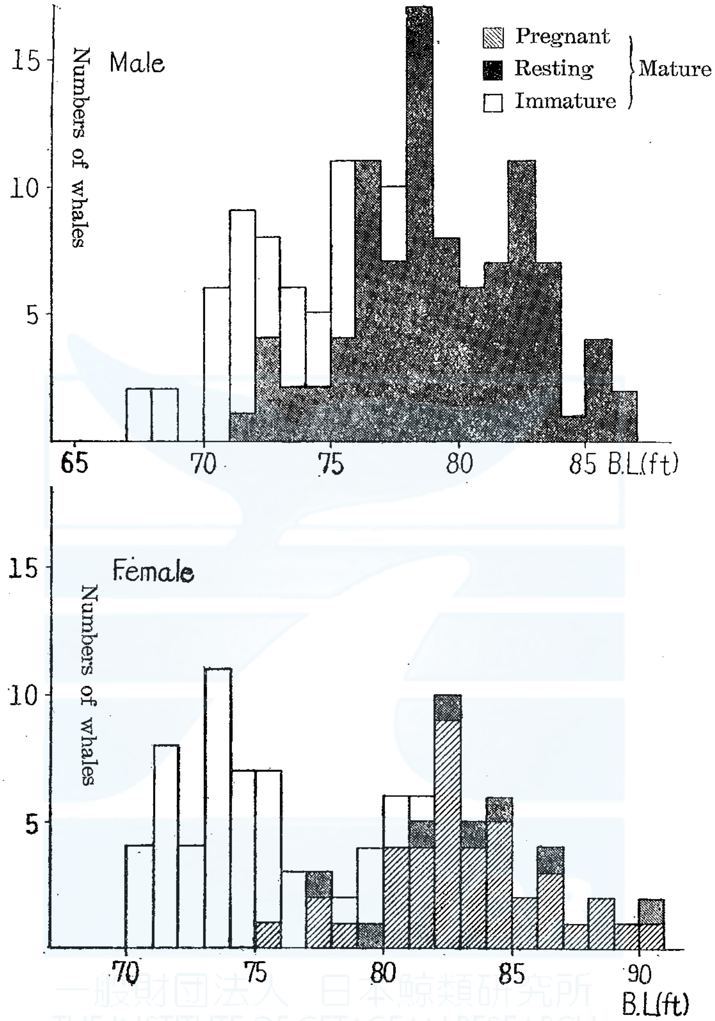
3. *Size Composition*

Figs. 4–1 to 4 show the length distribution of this season's catch by species and sexes, and Figs. 5–1 to 3 illustrate the percentage length distributions of the blue, fin and sperm whale catches in different months of this season. Percentage length distributions of the sperm whales caught in different whaling grounds are shown in Fig. 7.

Length compositions of the blue whales taken in this season and in last season hardly differ in either sexes, especially within the waters

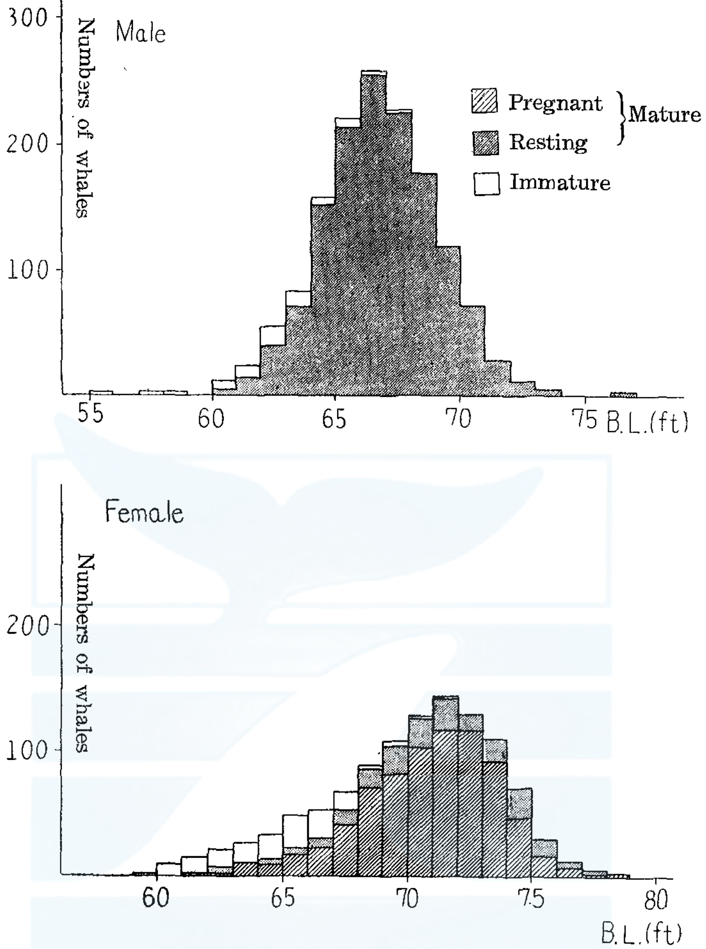
Fig. 4. Composition of body length.

4-1. Blue whale

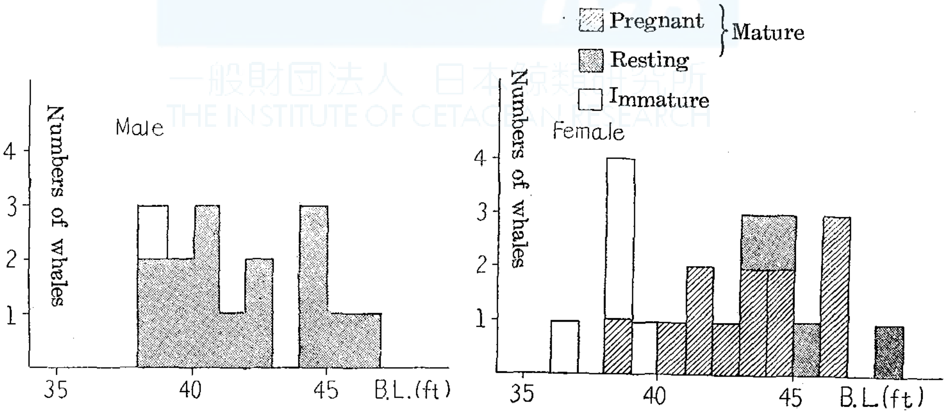


exploited during this season, as is clear from the comparison of Fig. 4-1. with Ohno & Fujino's Fig. 1 (1952). But the average length of this season's catch is smaller than that of last season's by 1.4 ft. and 1.1 ft. respectively in males and females. Compared with the catch in the season prior to 1950–51, this season's catch contained considerably more immature females.

In either sex of fin whales, the length composition of the catch was almost the same in this and last season.

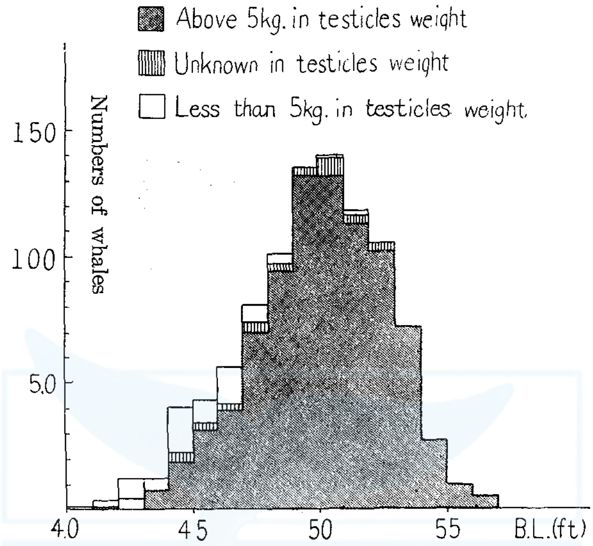


4-2. Fin whale



4-3. Humpback whale

4-4. Sperm whale



The catch of humpbacks has been too small to warrent the comparison of the length compositions of different season.

In sperm whales, there is fairly good agreement in length composition among the catches in post-war season, but there are indications that larger whales were caught in greater numbers in this season than in last season.

Average length of captured female blue whales increased steadily with the progress of the season (77.4 ft., 79.0 ft. and 80.5 ft. respectively for January, February and March), reflecting the increase in the proportion of larger females, while that of the males remained almost unchanged all through the season (76.9 ft. for January and February, and 76.7 ft. for March) (Table 5).

Length composition of the captured fin whales was almost the same in January and in February in either sex, but there occurred a slight increase in the proportion of smaller individuals in March (Fig. 5. 2 and Table 6). The average length, however, diminished gradually with the progress of the season.

Average length of the captured sperm whales varied considerably with months, partly due to the constant shift of the whaling ground for this species. The maximum was recorded in December, and the minimum in November and February (Table 8 and Fig. 5-3)

Table 5. The composition of catch on blue whale monthly

		Male			Female				Av. body length (feet)			Rate of mature			Rate of pregnance
		Imm.	Mat.	Total	Imm.	Pre.	Rest.	Total	Male	Fe-male	Total	Male	Fe-male	Total	
1951-52 season	January	22	54	76	31	20	5	56	76.9	77.4	77.2	71.0	44.6	59.8	80.0
	February	12	34	46	17	17	2	36	76.9	79.0	77.8	73.9	52.8	64.6	89.5
	March	4	7	11	2	3	1	6	76.7	80.5	78.1	63.6	66.7	64.7	75.0
	Total	38	95	133	50	40	8	98	76.9	78.2	77.5	71.4	49.0	61.5	83.3
1950-51 season	III area	11	83	94	34	24	29	87	78.5	80.2	79.3	88.3	60.9	75.1	45.3
	whole area	17	112	129	62	38	42	142	78.3	79.3	78.9	86.8	56.3	70.8	47.5

Table 6. The composition of catch on fin whale by the decade of month

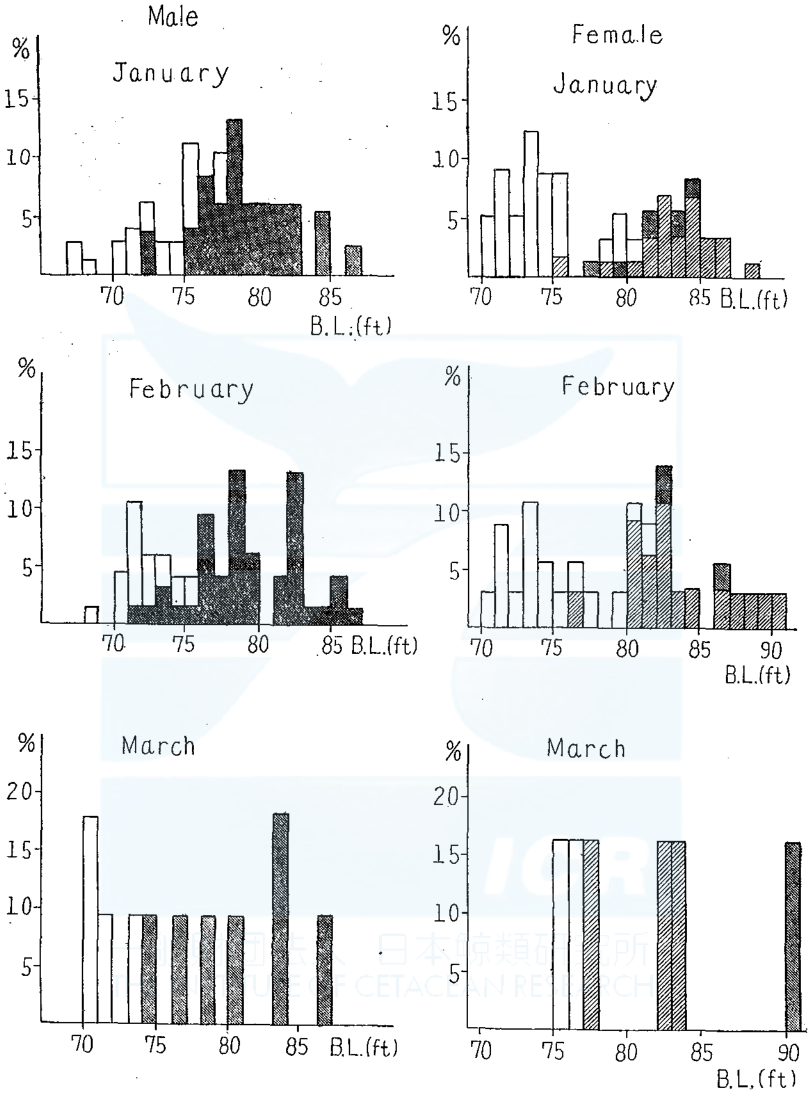
			Male				Female					Av. body length(feet)			Rate of mature			Rate of pregnancy
			Imm.	Mat.	uk.	Total	Imm.	Pre.	Rest.	uk.	Total	Male	Fe-male	Total	Male	Fe-male	Total	
1951-52 season	Jan.	1	9	130	1	140	18	117	18	1	154	66.4	69.9	68.2	93.5	88.2	90.8	87.4
		2	8	225	2	235	23	97	33	—	153	66.7	70.1	68.1	96.6	85.0	92.0	73.8
		3	10	195	1	206	19	125	28	—	172	66.4	69.9	68.0	95.1	89.0	92.3	81.7
		Total	27	550	4	581	60	339	79	1	479	66.5	70.0	68.1	95.3	87.4	91.8	81.1
	Feb.	1	13	213	2	228	30	133	34	1	198	65.9	69.6	67.6	94.2	84.8	89.8	78.7
		2	9	273	—	282	40	170	49	3	262	66.3	69.5	67.9	96.8	84.6	90.9	78.1
		3	12	238	—	250	36	89	25	—	150	65.6	68.7	66.8	95.2	76.0	88.0	77.2
		Total	34	724	2	760	106	392	108	4	610	66.0	69.3	68.3	95.5	82.5	89.7	78.4
	March		4	100	2	106	12	31	17	1	61	66.1	69.1	67.4	96.2	80.0	90.2	64.6
	Total		65	1,374	8	1,447	178	762	204	6	1,150	66.2	69.6	67.7	95.5	84.4	90.6	78.9
1950-51 season	III area		33	547	—	580	65	269	161	1	496	66.3	69.9	68.0	94.3	86.9	90.9	62.6
	whol areae		123	974	—	1,097	164	529	259	1	953	66.1	69.6	67.7	88.8	82.8	86.0	66.7

Table 7. The composition of catch on humpback whale

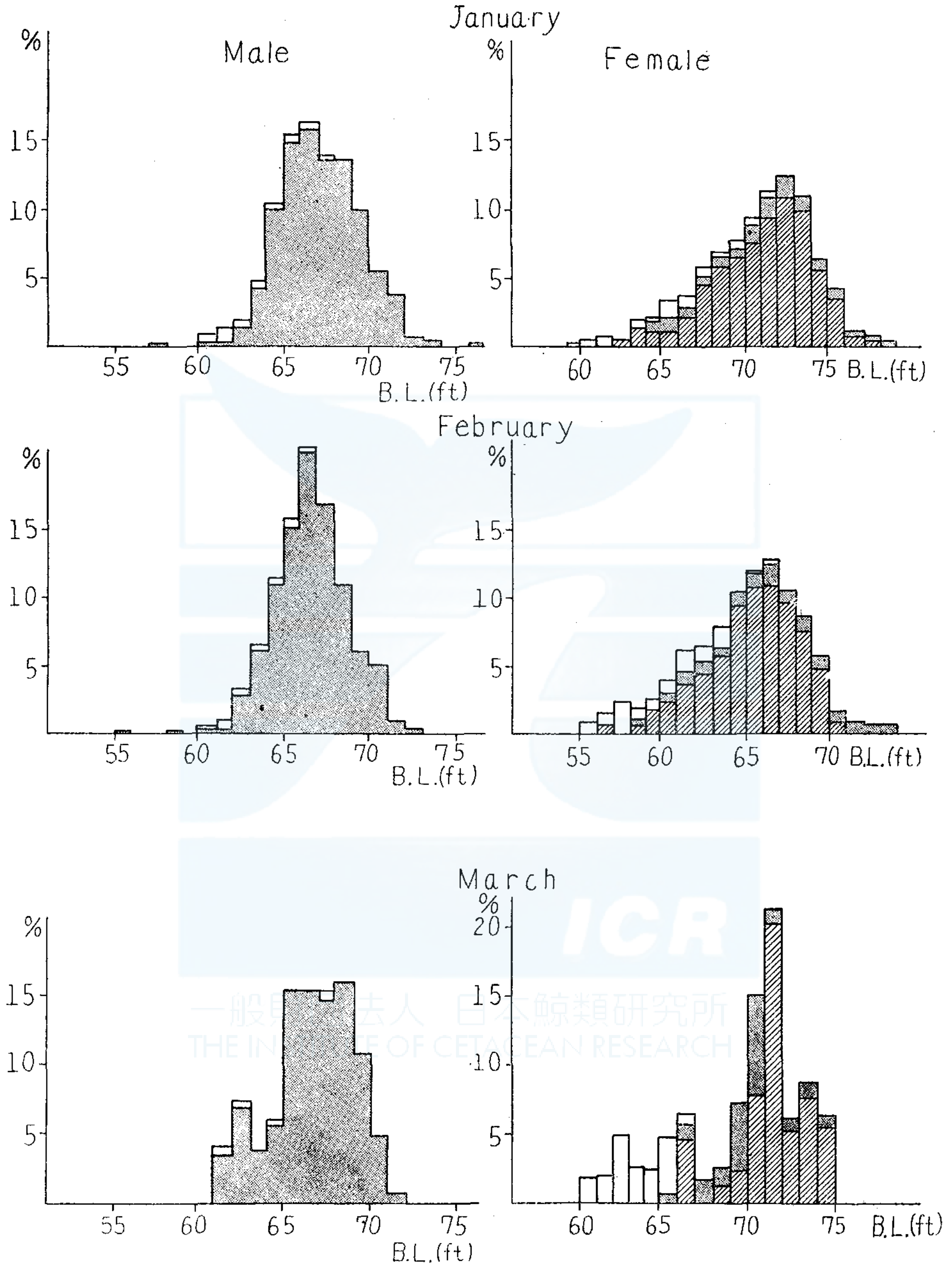
		Male			Female				Av. body length (feet)			Rate of mature			Rate of pregnancy
		Imm.	Mat.	Total	Imm.	Pre.	Rest.	Total	Male	Fe-male	Total	Male	Fe-male	Total	
1951-52	February	1	15	16	5	12	4	21	41.3	42.0	41.7	93.8	76.2	83.8	75.0
	1950-51 season	0	2	2	1	5	1	7	44.0	42.7	43.0	100.0	85.7	88.9	83.3

Fig. 5. Composition of body length by season.

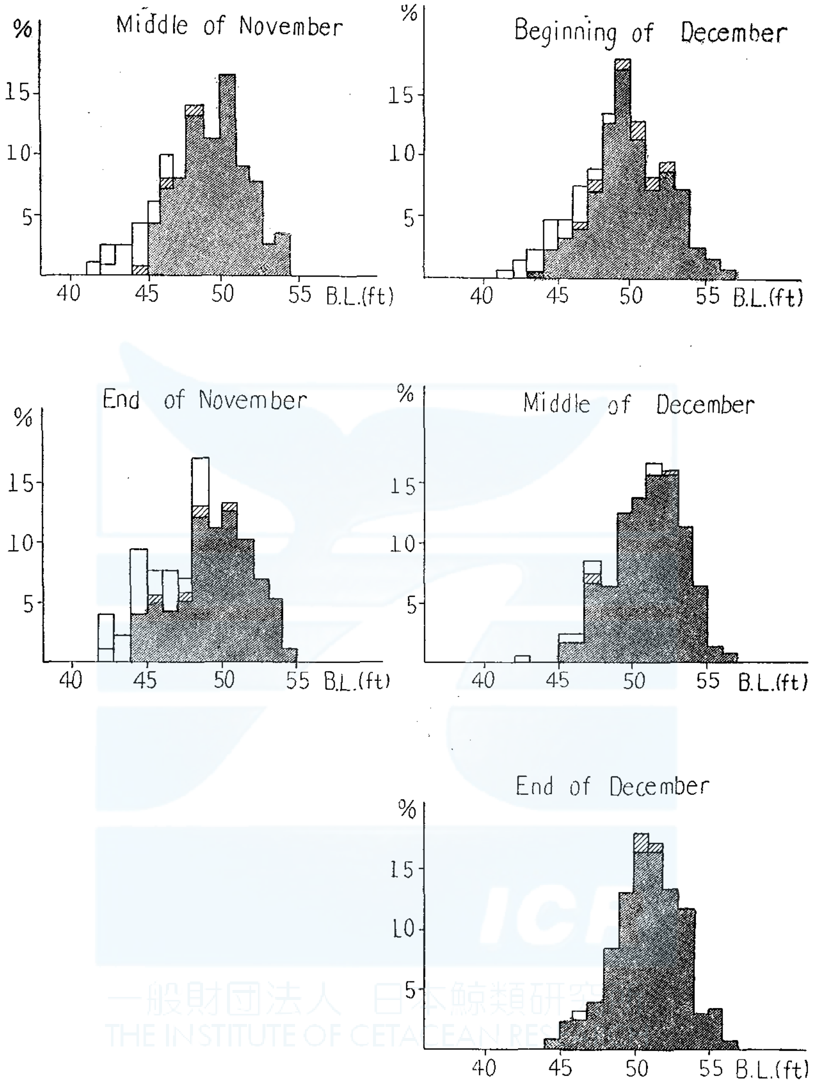
5-1. Blue whale



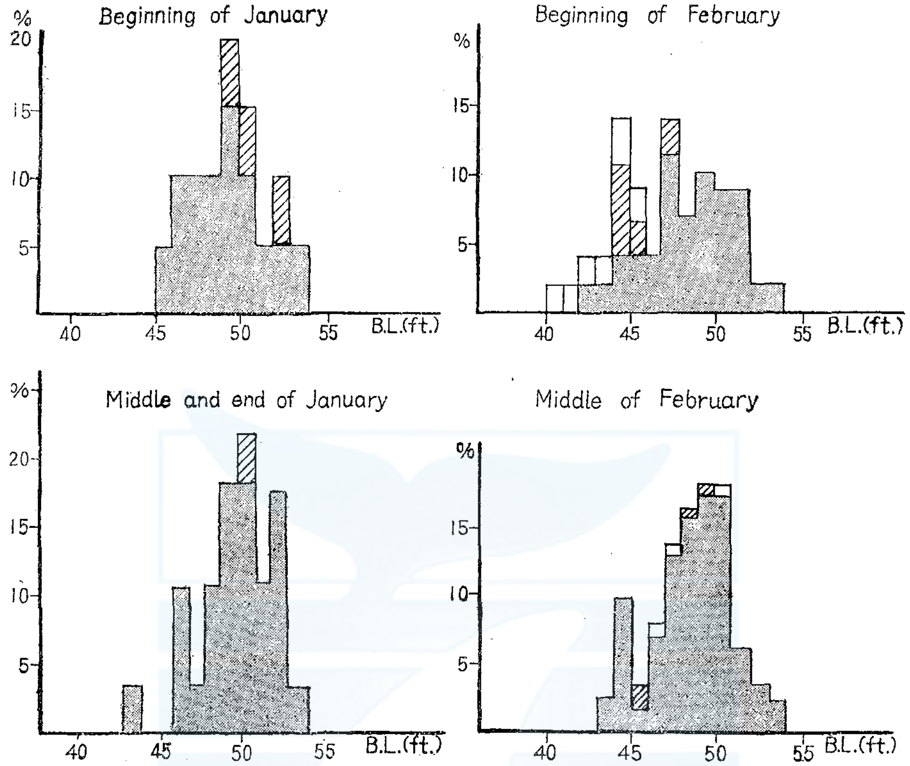
5-2. Fin whale


January
Male
Female
%
15
10
5
55
60
65
70
75
B.L.(ft)
February
March
20

5-3. Sperm whale

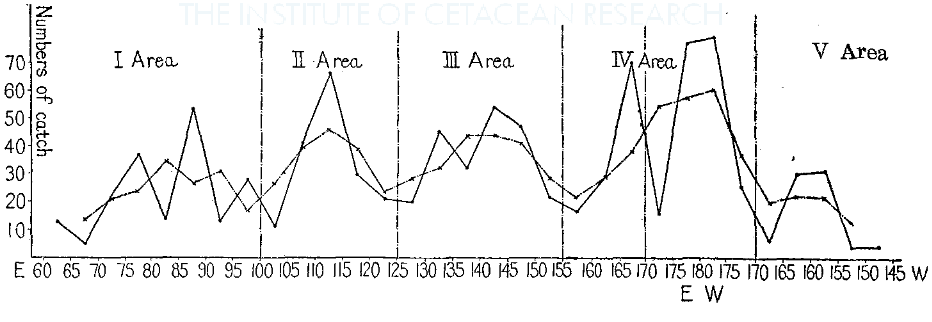


5-4. Sperm whale (Continued)



As sperm whales were hunted over a wide area from 60°E eastward to 145°W, it seems appropriate to analyse their catch in realtion to geographic positions. In Fig. 6 the catches made in each 50 (longitude) sector are plotted against the longitude. It is clear from this graph that there were five major grounds. Accordingly, the entire area is divided longitudinally into the following five parts, so that each part may include one major ground.

Fig. 6. Catch by area (Spern whale)



Region	Longitude				Period of operation
I	From	60°E	eastward to	100°E	Late November through early December
II	〃	100°E	〃	125°E	Middle November through early December
III	〃	125°E	〃	155°E	Early and late December, and February
IV-1	〃	155°E	〃	170°E	Middle December and early January
IV-2	〃	170°E	〃	170°W	Late December and early January
V	〃	170°W	〃	145°W	Late Decomber and middle January

The percentage distribution and the average length of the catch made in each of these regions are respectively shown in Fig. 7 and Table 8. Fig. 7 shows that the proportion of large whales increases and that of young whales with the testes weight less than 5 kg. decreases with the shift of the whaling ground from the west to the east. In the easternmost region V no such young whales were caught. Another remarkable feature is that within one region the average size of the sperm whales considerably varies with months: in Region II, the whales caught in late November, which are represented by the minor mode around 44 ft. in the length distribution (Fig. 7), were much smaller than those taken in other period; in Region III, small whales predominated in the catch in February as compared with December (Table 8); in Regions IV and V the average length of the catch was smaller in January than in December. It is suggested by these examples that the whales taken at different places and time did not come from a single population of sperm whales with uniform biological properties. This point will be touched upon in another part of this report.

In the following paragraphs the average lengths of the baleen whales caught by Japanese fleets in this season are compared with those for the whale Antarctic pelagic catch of this season, and with those for the catch

Table 8. Sperm whale, nos, and the av. body length by the area and monthly (Japanese fleets)

	I	II	III	IV		V	mean	
				1	2			I 60∼100°E II 100∼125°E
Nov.	47.8(99)	48.5(121)					48.2(220)	III 125∼155°E
Dec.	48.5(86)	49.1(48)	49.4(117) 49.7(7)	50.7(100)	50.4(192)	50.9(50)	49.9(600)	IV$_1$ 155∼170°E
Jan.				48.9(18)	50.0(2)	49.2(25)	49.2(45)	IV$_2$ 170°E∼170°W
Feb.			37.4(96)				47.4(96)	V 170∼145°W
Total	48.1(185)	48.7(169)	48.6(220)	50.4(118) 50.4(312)	50.4(194)	50.3(75)	49.2(961)	( ) : nos.

Fig. 7. Compositiion of body length by area.

Sperm whale

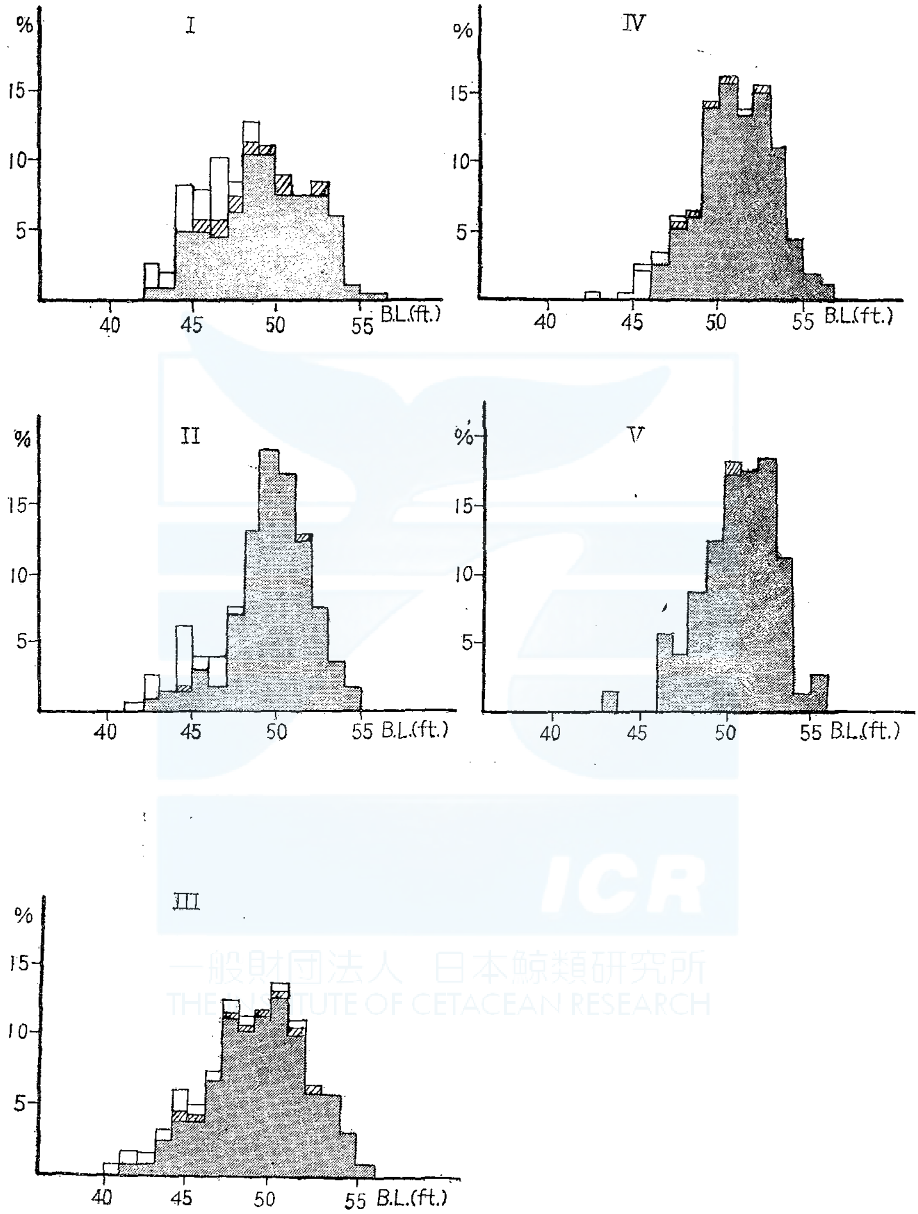


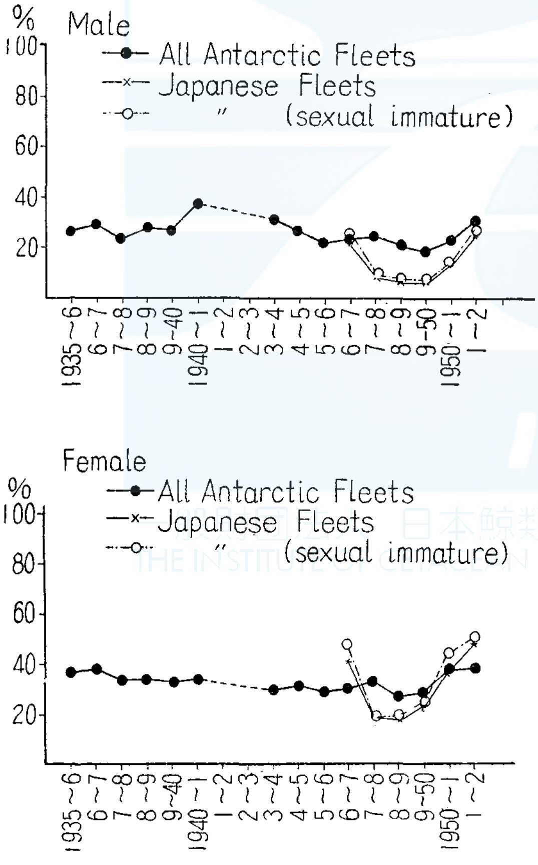
Table 9. Nos. of the observed whale and the av. body length in the V area and whole the Antarctic

	V Area						Whole Antarctic					
	Male		Female		Total		Male		Female		Total	
	Av. bl.	Nos.	Av. bl.	Nos.	Av. bl.	Nos.	Av. bl.	Nos.	Av. bl.	Nos.	Av. bl.	Nos.
Blue	75.7	825	78.2	792	76.9	1,617	76.5	2,367	79.6	2,542	78.1	4,909
Fin	66.2	2,584	69.5	2,488	67.8	5,072	66.4	9,579	69.6	8,601	68.0	18,380
Hump.	40.3	67	42.4	116	41.6	183	39.2	634	41.1	723	40.2	1,357
Sperm	55.3	1,296			50.3	1,296	49.9	5,187			49.9	5,187
Sperm	49.7	2,854			49.7	2,854						

1) 60°E~140W

Eig. 8. Rate of immature (classified by body length)

8-1. Blue whale



in Area V, where the Japanese operations took place.

Average length of the male blue whales taken by Japanese fleets exceeded the averages for the Antarctic pelagic catch and the catch in Area V by 0.4 ft. and 1.2 ft. respectively. As for female blue whales, the average length of the Japanese catch was exceeded by that of the Antarctic pelagic catch by 1.4 ft., and was the same with the average for the Area V catch.

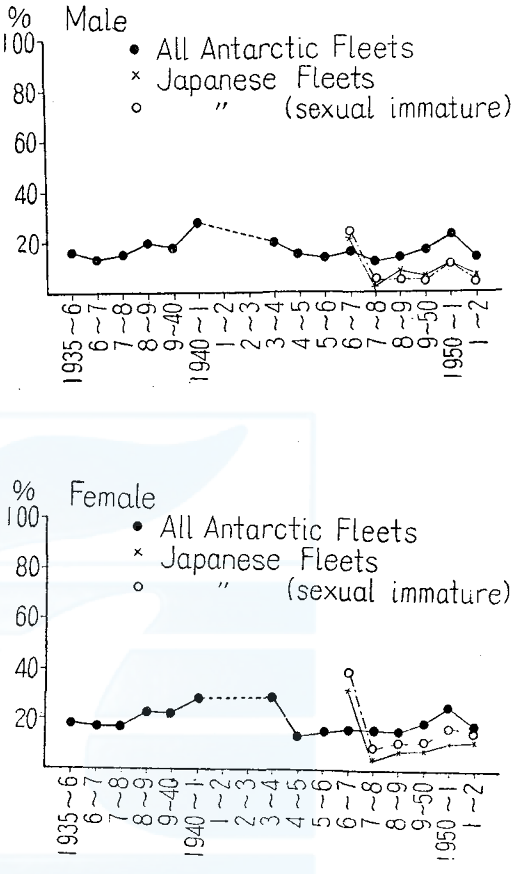
The average length of either sex of fin whales hardly differs in three kinds of the catch.

The catch of humpbacks was too small to justify any precise comparison. A tentative conclusion based on the available data is that the males caught by Japanese fleets were larger than those taken by the whole Antarctic pelagic operations and in Area V by about 2 and 1 ft.

in average respectively, and the females caught by Japanese fleets were, in average, about 1 ft. larger than those taken by the whole Antarctic pelagic whaling and a little smaller than those caught in Area V.

Average length of the sperm whales caught by the Japanese fleets in this season was 0.7 ft. smaller than the average of the Antarctic pelagic catch of the same season, and 0.5 ft. smaller than the average for the total catch in the waters 60°E eastward to 140°W, where the Japanese operations took place.

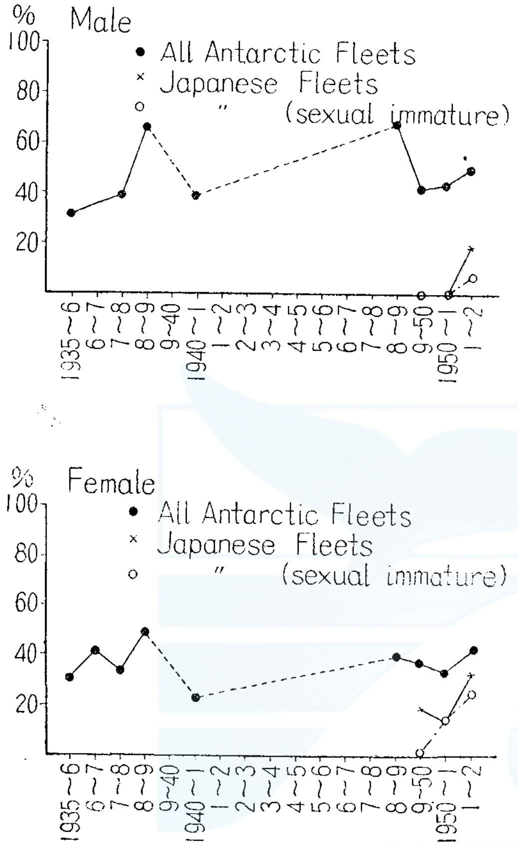
8-2. Fin whale



4. *Immature Whales*

According to Mackintosh & Wheeler's classification based on the body length, the percentage of sexually immature whales was calculated for the total Antarctic pelagic catches in seasons 1935/36 to 1951/52 and for the catches by the Japanese fleets in seasons 1946/47 to 1951/52, and illustrated in Fig. 8-1 to 3 respectively for blue, fin and humpback whales. As the data are available on the classification of the Japanese catches based on the examination of genital organs, these are also plotted in these graphs so as to be compared with the result of the former classification. In the latter method, females of any species lacking a corpus luteum on ovaries, and males of the blue, fin and humpback whales with a pair of testes weighing less than 10, 5, and 2 kg. respectively are considered sexually immature. The results of the two methods show fairly good agreement for both sexes of blue and fin whales, but the method based on body length usually results a slightly higher percentage of immature except for the males of fin whales (Figs. 8. 1 and 2), where the results of the two methods are in the reverse relation for certain seasons. When applied to humpback

8-3. Humpback whale



whales, two methods give considerably different results (Fig. 8–3).

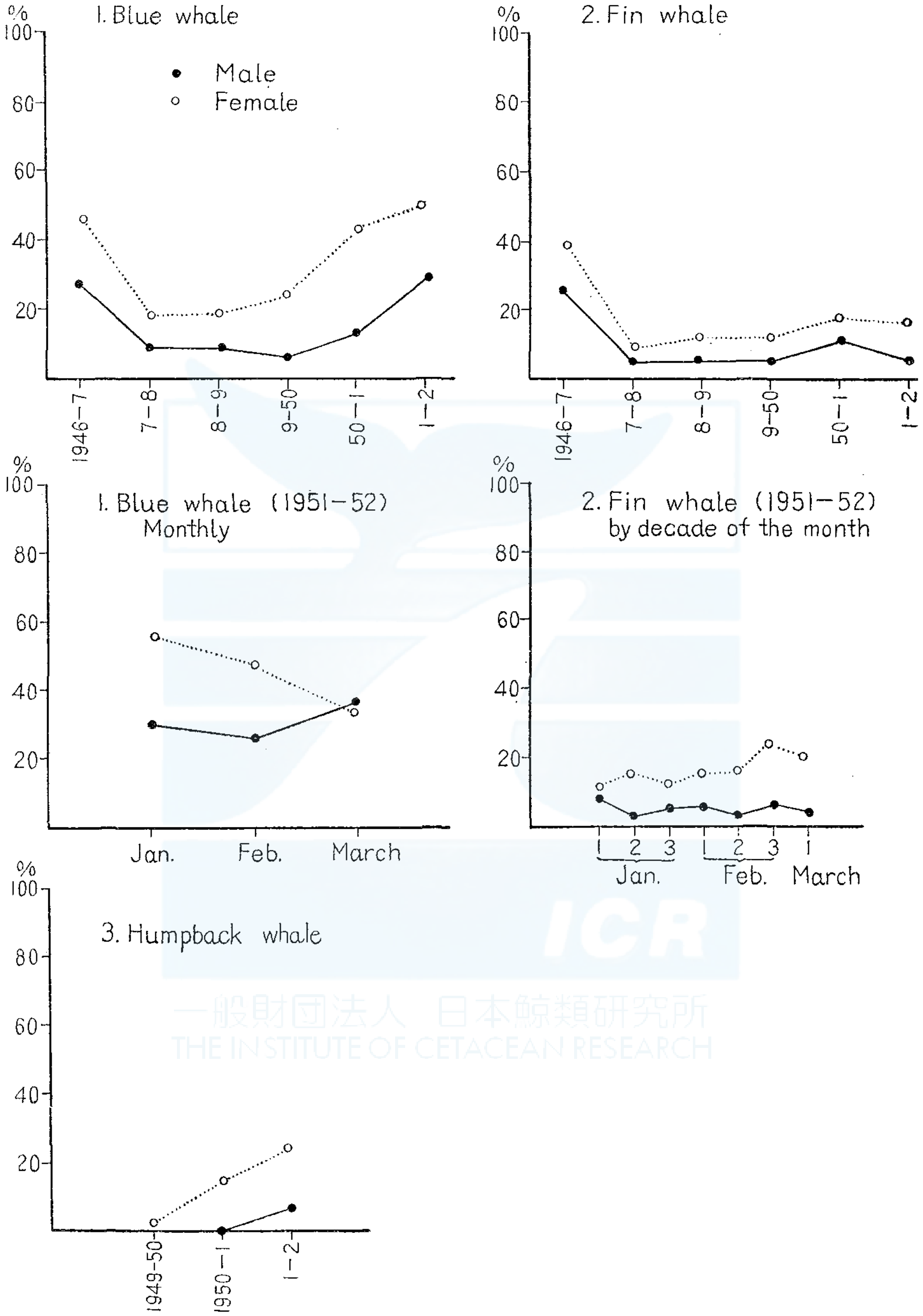
In 1946/47 the percentage of immature whales in the Japanese catch was as high as or higher than in the total Antarctic pelagic catch for either sex of blue and fin whales. Since the following season, however, the same percentage has been much lower in the Japanese catch than in the total Antarctic pelagic catch for these species, except the cases of female blue whales caught in 1950/51 and 1951/52 (Fig. 8–1 and 2).

As for humpback whales, the Japanese catch have contained immature whales in much smaller proportions than total Antarctic pelagic catch in the recent post-war seasons.

The fluctuation of the percentage of immature whales in the catch by Japanese fleets is illustrated in Fig. 9 by species and sexes for the period 1946/47 to 1951/52. Mature and immature whales are distinguished on the basis of the examination of genital organs. In the baleen whale species, the percentage of female immature was consistently higher than that of male immature, but the two percentages underwent similar changes during the period. Since the 1949/50 season the percentage of captured blue whale immature increased steadily, and in 1951/52 reached 29% and 51% respectively in males and females. On the contrary, a lower percentage of immaturity was recorded in 1951/52 for either sex of fin whales than in the previous season. The humpback catch of the 1951/52 season contained relatively more immature whales than in the previous season.

Within the 1951/52 season, the percentage of immaturity of male blue whales was lowest in February and highest in March, while that of female blue whales decreased steadily with months. In the males of fin whalse

Fig. 9. Rate of immature (sexual)

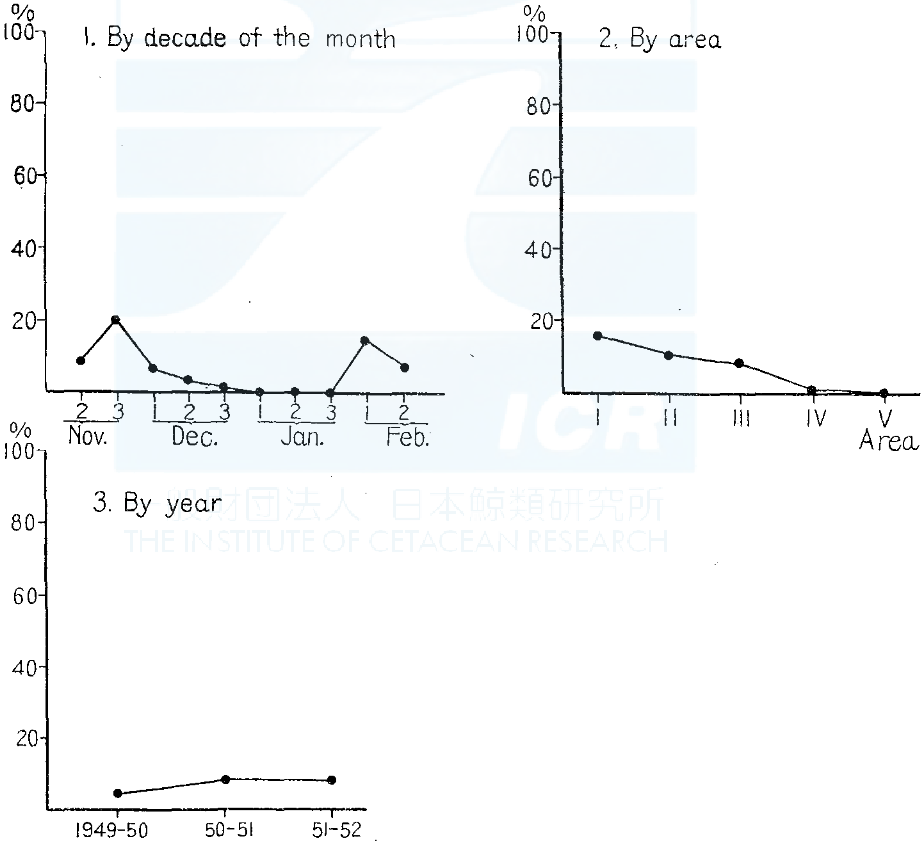


that percentage remained almost constant during the season, but in the females it followed a slightly upward trend.

No standard has yet been established to determine the sexual maturiy of male sperm whales. For temporary purposes, those males whose pair of testicles weighted less than 5 kg. are considered immature. According to this classificatian, 8.2% and 7.5% of the sperm whales taken by Japanese fleets in the 1950/51 and 1951/52 seasons respectively were sexually immature. In addition, some of the sperm whales were found to have very small testicles. These facts suggest the need to reexamine the conventional theory that sperm whales are all mature in the Antarctic waters.

The percentage of the captured sperm whale immature varied considerably with whaling grounds, months during the 1951/52 season (Fig. 10). While immature individuals constituted a considerable part of the catch in late November and early February, only one such individual

Fig. 10. Speam whale (under 5 kg in both testicle weight)



was caught during January. In Regions I, II, and III the catch contained a good number of immature whales, but their number markedly decreased in Region IV and none of them was caught in Region V.

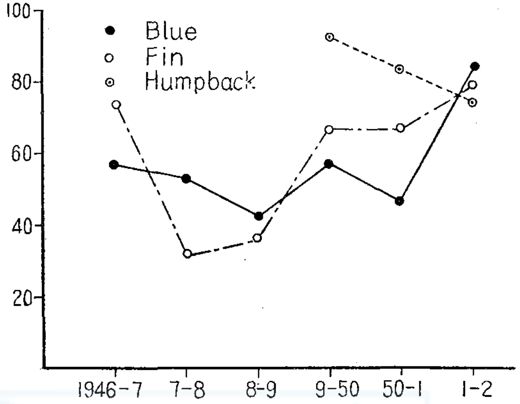
5. *Percentage of Pregnancy*

Pregnant whales constituted 83% and 79% respectively of the adult females of blue and fin whales caught by Japanese fleets in the 1951/52 season. These are the highest percentages ever recorded in post-war seasons (Fig. 11-1). Of 16 mature female humpbacks taken by these fleets, 14 or 75% were pregnant, a lower percentage of pregnancy than in the previous season.

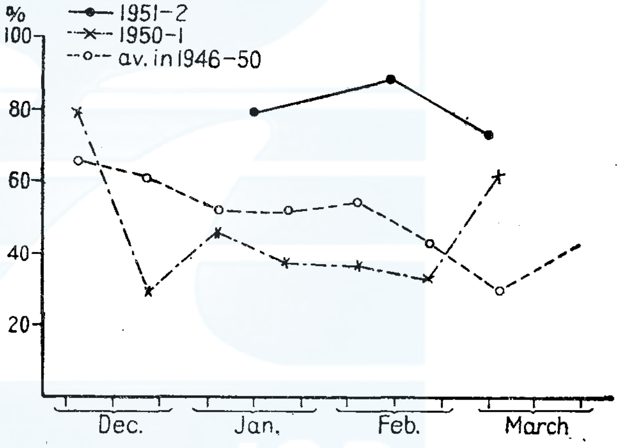
During the season the percentage of pregnancy of blue whales fluctuated in much the same manner as the average for seasons 1946/47 to 1949/50, and a maximum of 90% occurred in February (Fig. 11-2). The same percentage of fin whales

Fig. 11. Rate of pregnancy

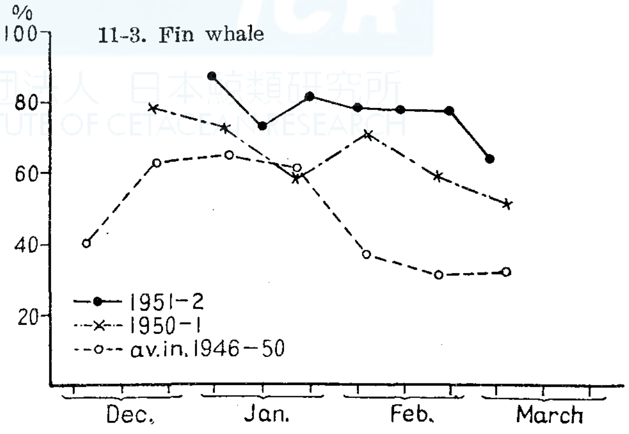
11-1. By year



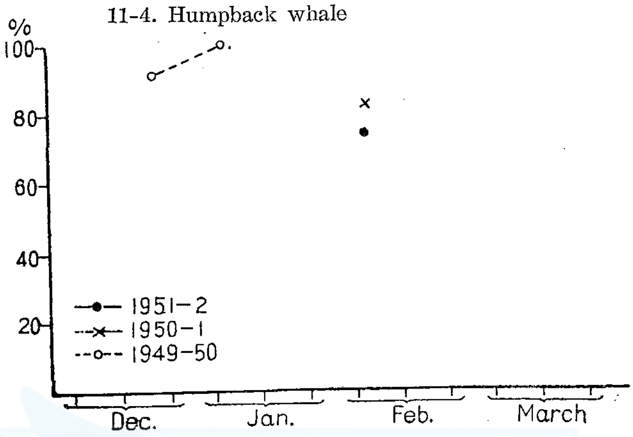
11-2· Blue whale



11-3. Fin whale



11-4. Humpback whale



decreased as the season advanced, as was the case in preceding seasons. The decline was gradual during January and February except a temporary drop in middle January, and became sharp in March (Fig. 11–3).

Ohno and Fujino (1952) deduced from the low percentages of pregnancy for the later part of the season a tendency that pregnant whales leave the Antarctic for the warmer waters suitable for breeding earlier than the other whales. This seems to be the case, because the decrease in the proportion of females in the catch in the course of the season also suggests such a tendency.

Chapter II

Thickness of Blubber, Stomach Contents and External Parasites

1. *Thickness of Blubber*

It is generally believed that the whales become well nourished and the thickness of their blubber increases while they are engaged in feeding migration in the Antarctic waters and, as a result, the whales caught in the later part of the whaling season have thicker blubber than those taken in the earlier part. In addition, the presence of a sex difference in the thickness of the blubber has been suggested by past reports. It seems also probable that such physiological factors as sexual maturity or pregnancy control the thickness of the blubber. The data for the present season, therefore, have been analysed so as to ascertain these points.

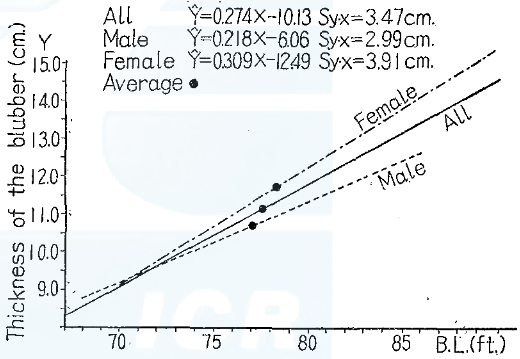
The thickness of the blubber was measured on all the whales that were dismembered at that part of the body side where the mid-lateral line intersects the vertical line passing the dorsal fin. These actual measurements, however, are not directly comparable, because the thickness of the blubber depends partly on the size of the whale, which varied greatly in the material under consideration. In view of this, a linear regression of the thickness of the blubber upon the length of the whale has been assumed, and the regression coefficient, the variance, and the adjusted mean thickness of the blubber are computed for each group of whales and used as the basis for comparison.

i) Blue whales

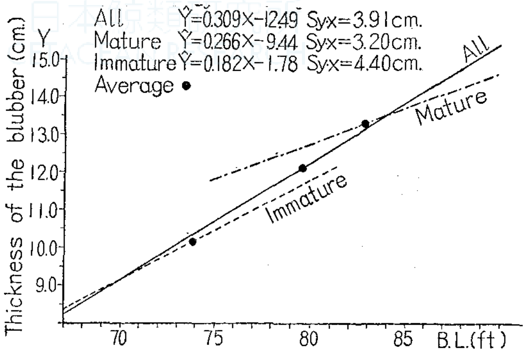
The results of the regression analysis are summarized in Table 10–1. Though the regression coefficient does not differ significantly in two sexes, significant sex difference exists in the variance and the adjusted mean, indicating that females had thicker blubber than the males of the same size (Fig 12–1). Between mature and immature females, too, significant difference is found in the variance and the adjusted mean and not in the regression coefficient, and the conclusion is that the mature females had thicker blubber for their lengths than the immature (Fig. 12–2). On the other hand, the regression coefficient, variance and adjusted mean computed separately for the males, immature females and mature females caught in January do not differ significantly from the same statistics for the respective group of whales taken during February and March (Fig. 12–3–5). (The whales caught in March are so small in number that they are combined with the catch in February.) This suggests that the increase in the thickness of the blubber was slight, if any, during the season. But in males and mature females the adjusted mean thickness of the blubber was greater, though

Fig. 12. Blue Whale, thickness of the blubber (regression estimating the thickness of the blubber contrusted with the body length)

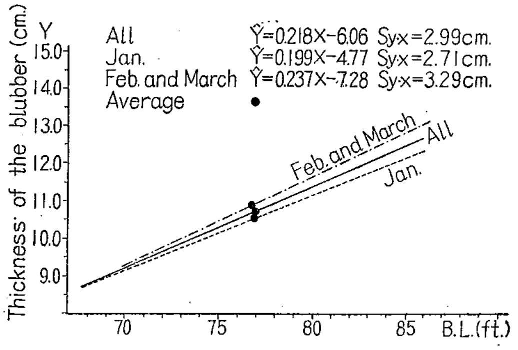
12-1. By sex



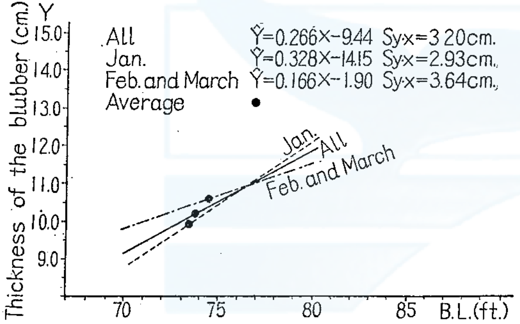
12-2. Female by maturity



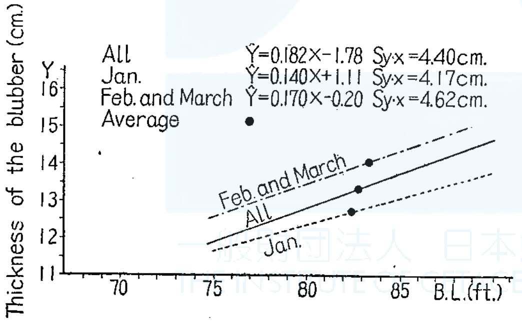
12-3. Male by month



12-4. Female immature by month



12-5. Female mature by month



not significantly, in February and March than in January, seemingly in favor of the conventional theory. In the immature females less than 77 ft. of length the blubber was thicker in February and March than in January, and the reverse was the case in the individuals of greater lengths. This result, however, can not be considered conclusive because it is based on the data of only 50 whales.

In a 84 ft. long mature female caught in January, the blubber was as thick as 21 cm. This whale was not included in the foregoing analysis, because it was statistically shown that its blubber was exceptionally thick.

ii) Fin whales.

Table 10–2. shows the summary of the results of the regression analysis for this species.

There is no doubt that females had thicker blubber than males, because the adjusted mean thickness of the blubber as well as the coefficient and variance of the regression differs highly significantly in the two sexes (Fig. 13–1).

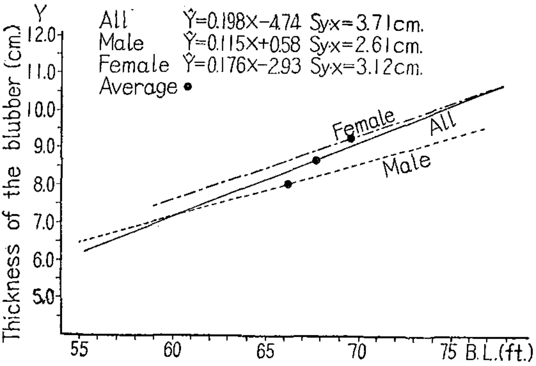
Within the females, the blubber was increasingly thicker in the immature, resting and pregnant groups (Fig. 13–2): the adjusted mean of the thickness of the blubber differs highly significantly in the three groups, and the variance, between immature and pregnant and between resting and pregnant, while there is no significant difference in the regression coefficient.

Comparison of the regressions for the males caught in different months indicates that statistically significant increase took place in the thickness of the blubber of the males in the course of the season (Fig. 13–3). In this case, the adjusted mean thickness differs highly significantly in the three month-groups, and the variance differs significantly between the January and the February group, while the differences are not significant between the coefficients of the three month-group regressions, and between the variances for the February and the March group.

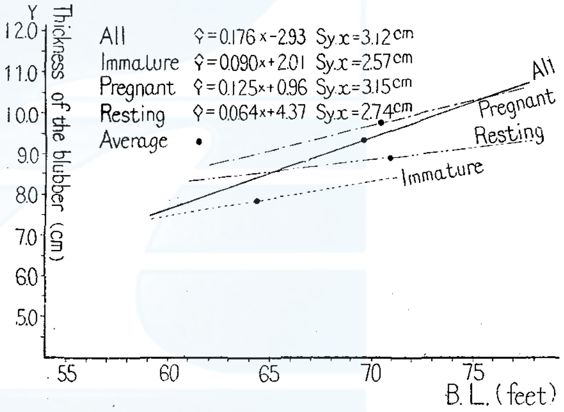
The data for the immature, pregnant, and resting females are also treated in the similar manner. With the immature females, highly significant difference in the regression coefficient and in the adjusted mean exists between the regressions for the January and the February groups, while only the regression coefficient differs in the February and the March group (Fig. 13–4). And the adjusted mean is greater in

Fig. 13. Fin whale, thickness of the blubber

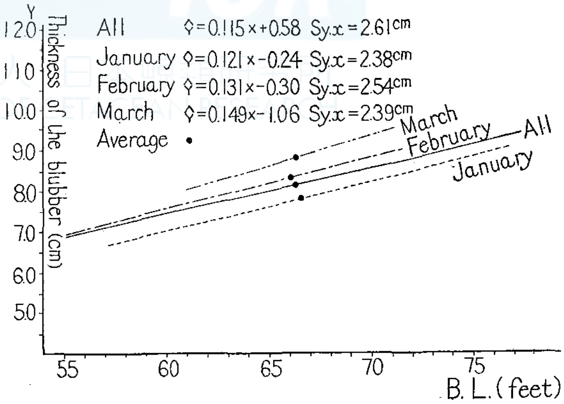
13-1. By sex



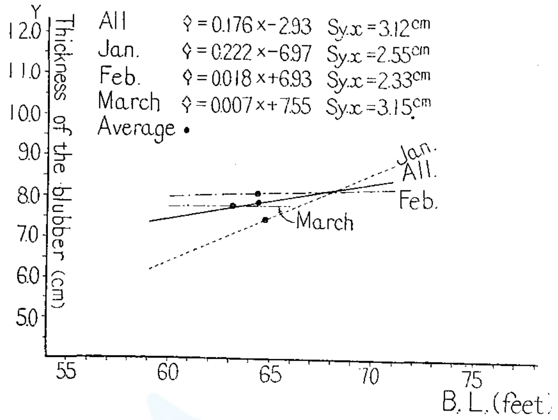
13-2. Female by maturity



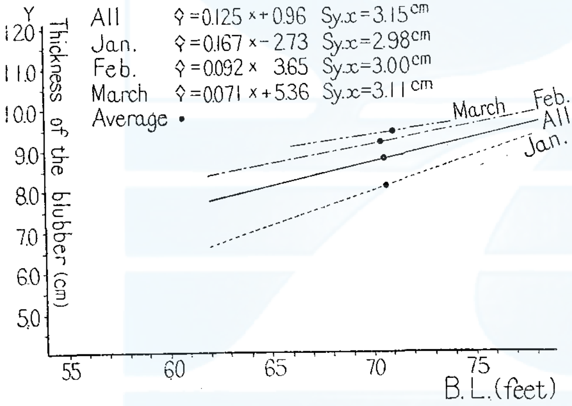
13-3. Male by month



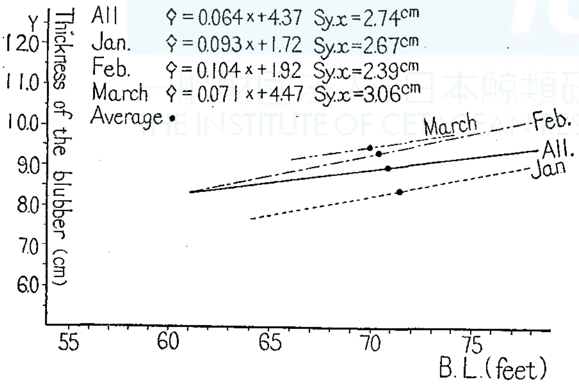
13. 4 Female immature by month



13. 5 Females pregnant by month



13. 6 Female, reating, monthly



the February group than in the January group. In both pregnant and resting whales, neither the regression coefficient nor the variance differs significantly in the three month-group regressions, and a significant difference in the adjusted mean occurs only between the January and the February group, a greater mean being associated with the latter month-group. (Figs. 13–5 and 6).

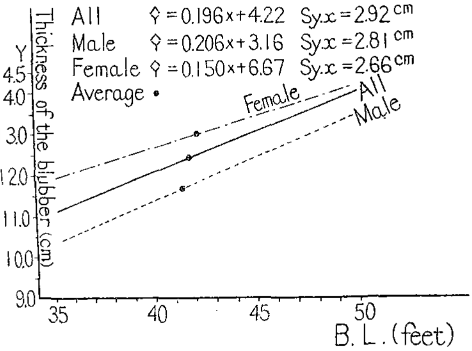
iii) Humpback whales

Neither the coefficient nor the variance of the regression of the blubber thickness upon the length of whale differs significantly in the two sexes of humpback whales, but the difference is significantly great in the adjusted mean of the blubber thickness; therefore, it may be said that females had thicker than the males of the similar size (Table 10–3 and Fig. 14).

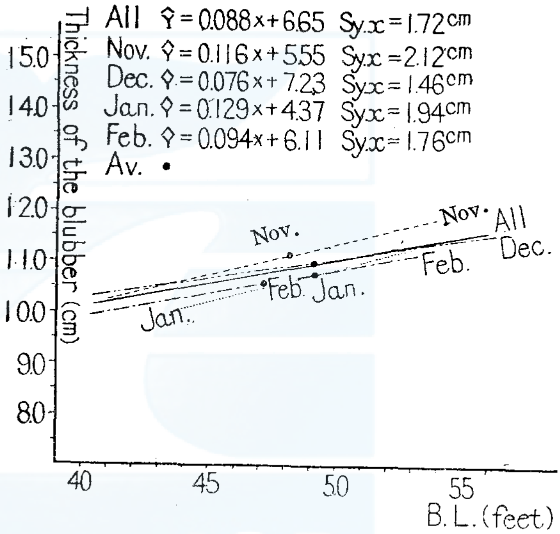
iv) Sprem whales.

As the catch of sperm whales consisted exclusively of males, comparison is made only between the catches in different months (Table 10–4 and Fig. 15). In the first three month groups, i. e., November to January, both the variance and the adjuted mean thickness of the blubber vary significantly or highly significantly, whereas the regression coefficient is not significantly different. And the trend of the adjusted mean thickness for these months is such that the thickness of the blubber decreased with months, contrary to the case in blue and fin whales. In the January and the February group, the variance and the adjusted mean do not differ significantly, while the regression coefficient differs highly significantly. Accordingly, there is little ground to discuss the change in the proportionate thickness of the blubber during these months.

Fig. 14. Humpback whale



Ffg. 15. Sperm whale, monthly



Possible explanations of the aforementioned trend of the proportionate thickness of the blubber during the season may be: (1) sperm whales grew thinner for want of suitable food during their

Table 10-1. Blue whale, the relation between the thickness of blubber and the body length

	Whole male and female	Female mature and imm.	Male Jan. and others	Imm. flemale Jan. and others	Mature female Jan. and other
Difference of regression coefficiency	○	○	○	○	○
Difference of variance	＊＊	＊	○	○	○
Difference of adjusted mean	＊＊	＊	○	○	○

[Note] ○ no significant difference.
* significant difference in 5% c.v. level.
** significant difference in 1% c.v. level.

Table 10-2. Fin whale

	Whole male and female	Female			Male		Imm. female		Pre. female		Rest. female	
		imm. and pre.	imm. and rest.	pre. and rest.	Jan. and Feb.	Feb. and March	Jan. and Feb.	Feb. and March	Jan. and Feb.	Feb. and March	Jan. and Feb.	Feb. and March
Difference of regression coefficiency	**	○	○	○	○	○	**	*	○	○	○	○
Difference of variance	**	**	○	**	*	○	○	○	○	○	○	○
Difference of adjusted mean	**	**	**	**	**	**	**	○	**	○	**	○

Table 10-3. Humpback

	Whole male and female
Difference of r.c.	○
Difference of v.	○
Difference of a.m.	*

Fig. 10-4. Sperm whale

	Male		
	Nov. and Dec.	Dec. and Jan.	Jan. and Feb.
Difference of r.c.	○	○	**
Difference of. v.	**	**	○
Difference of a.m.	**	*	○

stay in the Antarctic; (2) although the supply of food was sufficient, there was a constant recruitment of thin whales from the northern waters throughout the season; or (3) the fatness of the sperm whales differed in different whaling grounds, and the waters exploited early in the present season were inhabited by relatively fat whales. The first explanation is false, because the amount of the stomack content increased with the progress of the season (p. 183). The latter two hypotheses seem to be valid, for they are supported also by the study of external parasites (p. 189).

2. *Stomach Contents*

Observation was made of the quantity and composition of the stomach contents which issued from the first stomach at the dissection of the whale carcass. The quantity of the stomach contents was recorded in the usual manner with the following notation which represents the degree of impregnation of the first stomach: R (75—100%), rrr (50—75%), rr (25—50%), r (less than 25%), and O (empty).

The results of the observation on the baleen whales and the sperm whale are presented separately because of the difference in their feeding habits.

i) Baleen whales

Stomach contents consisted exclusively of the krill, *Euphausia superba*, in blue whales. They consisted also of the krill in the majority of fin whales, but in their minority the first stomach contained a few small fish besides the krill.

In Table 11-1 and 12-1 the blue and fin whales caught during each 10-day period are broken down according to the quantity of the stomach contents. Table 11-2 and 12-2 are the percentage expressions of the same break-downs.

As is clear from Table 11-2, the first stomach was empty in 54% of the blue whales caught during the present season, and was filled with food in 6% of them. And there was a steady decrease in the frequency from the "O" class toward the "R" class. Both the percentage of the whales with an empty first stomach and that of the whales with a filled first stomach varied during the season: the former was high as 67% at the beginning of the season, but decreased progressively, till the minimum of 35% was reached in March; the latter varied between O and 11%, and the maximum occurred in late January.

By comparison, the first stomach was empty in 57% of fin whales,

Table 11-1. Blue, nos. of whales by the degree of the quantity of stomach contents by the decade of month.

	January			February			March	Total
	1	2	3	1	2	3		
R	1	0	10	0	4	0	0	15
rrr	2	4	8	0	5	3	2	24
rr	3	3	10	0	7	1	6	30
r	1	4	13	7	8	2	3	38
o	14	9	50	9	32	4	6	124
Total	21	20	91	16	56	10	17	231

Table 11-2. Blue, the rate of nos. by the degree of the quantity of the stomach contents by the decade of month

	January			January			March	Total
	1	2	3	1	2	3		
R	4.76	0.00	10.99	0.00	7.14	0.00	0·00	6.49
rrr	9.52	20.00	8.79	0.00	8.93	30.00	11.76	10.39
rr	14.29	15.00	10.99	0.00	12.50	10.00	35.29	12.99
r	4.76	20.00	14.29	43.75	14.29	20.00	17.65	16.45
o	66.67	45.00	54.95	56.25	57.14	40.00	35.29	53.68
Total	100.0 %	100.00%	100.09%	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

and was filled in 8%; the frequency diminished from the "O" class towards the "R" class, as was the case in blue whales. The percentage of the whales with an empty first stomach showed a lower tendency throughout the season, though it never dropped below 51%. On the contrary, the percentage of the whales showing the filled first stomach generally increased with the progress of the season. Similar trends have been reported to have prevailed in the 1949/50 season.

Table 12-1. Fin, nos. of whales by the degree of the quantity of the stomach contents by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
R	3	23	26	33	52	33	25	195
rrr	19	26	29	29	56	52	25	236
rr	45	40	41	50	91	55	13	335
r	49	49	56	60	66	51	14	345
o	178	250	226	254	279	209	90	1486
Total	294	388	378	426	544	400	167	2597

Table 12-2. Fin, the rate of nos. by the degree of the stomach contents by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
R	1.02	5.93	6.88	7.75	9.56	8.25	14.97	7.51
rrr	6.46	6.70	7.67	6.81	10.29	13.00	14.97	9.09
rr	15.31	10.31	10.85	11.74	16.91	13.75	7.78	12.94
r	16.67	12.63	14.81	14.08	12.13	12.75	8.38	13.29
o	60.54	64.43	59.79	59.62	51.10	52.25	53.89	57.18
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

The krills contained in the first stomach were graded large (L), medium (M), or small (S), according as their majority measured over 5 cm., between 4 and 5 cm., or less than 4 cm. in size. Tables 13-1 and 14-1 show the actual frequencies of occurrence of L, M and S during each 10-day period in the blue and fin whales respectively. Table 13-2 and 14-2 show the corresponding percentage frequencies.

The krills from the first stomach of blue whales were small in 62% of the cases, medium-sized in 28%, and large in only 10% (Table 12-2). They were all small at the beginning of the season, and the medium-sized and large krills appeared for the first time respectively in late January and in early February. These larger krills became commoner with the progress of the season, and occurred much oftener than small krills in March.

Table 13-1. Blue, nos. of whales by the size of krill by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
L	0	0	0	2	2	0	7	11
M	0	0	14	1	10	2	3	30
S	7	11	27	4	12	4	1	66
Total	7	11	41	7	24	6	11	107

Table 13-2. Blue, the rate of nos. by the size of krill by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
L	0.00	0.00	0.00	28.57	8.33	0.00	63.64	10.28
M	0.00	0.00	34.15	14.29	41.66	33.33	27.27	28.04
S	100.00	100.00	65.85	57.14	50.00	66.67	9.1	61.68
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

The stomack contents of fin whales consisted of small, mediumsized and large krills respectively in 69, 30 and 1% of the cases. It is noteworthy that the occurrence of large krills was much rarer than in blue whales. The relative frequency of S diminished with time from early January through February, and then increased in March, while that of M increased steadily throughout January and February and decreased in March. large kills made their first appearance in middle January. It was probably because blue and fin whales were hunted on different whaling grounds that the behaviours of the relative frequencies of L, M and S differed in the two species.

The results for the humpbacks are shown in Table 15. The whales showing the empty first stomach accounted for 35% of the catch, and small krills predominated in the stomach contents.

ii) Sperm whales

Squids were by far the most important, and in many cases the only,

Table 14-1. Fin, nos. of whales by the size of krill by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
L	0	1	4	0	7	1	0	13
M	5	13	35	35	113	101	26	328
S	111	124	113	137	143	82	46	756
Total	116	138	152	172	263	184	72	1097

Table 14-2. Fin, the rate of nos. by the size of krill by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
L	0.00	0.72	2.63	0.00	2.66	0.54	0.00	1.19
M	4.31	9.42	23.03	20.35	42.97	54.89	36.11	29.90
S	95.69	89.86	74.34	79.65	54.37	44.57	63.89	68.92
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 15. Humpback, nos. and the rate of krill by the size and the quantity

	Quantity					Total	%
	o	r	rr	rrr	R		
S		2	6	6	8	22	59.4
M					2	2	5.4
O	13					13	35.2
Total	13	2	6	6	10	37	
%	35.2	5.4	16.2	16.2	27.0		100.0

constituent of the stomach contents of sperm whales, and there were indications that these squids belonged to the several distinct species including the well-known "king". The minor constituents were the fishes of several species, the results of whose taxonomic studies will appear as a separate work.

The quantity of the stomach contents was recorded with the same notation as was used in baleen whales. And the actual and percentage break-downs of the captured sperm whales according to the quantity of the stomach contents are shown in Tables 16–1 and 16–2 respectively. The first stomach was empty in 46% of the sperm whales, and the number of the whales steadily decreased from the "O" class toward the "R" class.

The percentage of the whales showing an empty first stomach was subject to the considerable variation throughout the season, which may be ascribable in part to the shift of the whaling ground. It was lowest in late November through early December, and highest in February.

Table 16-1. Sperm, nos. of whales by the degree of the quantity of stomach contents by the decade of month

	November		December			January	February	Total
	2	3	1	2	3			
R	0	1	4	5	9	2	5	26
rrr	3	13	17	17	10	5	7	72
rr	14	29	54	48	16	9	8	178
r	22	45	59	52	34	13	14	239
o	46	47	78	143	54	16	62	446
Total	85	135	212	265	123	45	96	961

Table 16-2. Sperm, the rate of nos. by the degree of the quartity of stomach contents by the decade of month

	November		December			January	February	Total
	2	3	1	2	3			
R	0.00	0.74	1.89	1.89	7.32	4.44	5.21	2.71
rrr	3.53	9.63	8.02	6.42	8.13	11.11	7.29	7.49
rr	16.47	21.48	25.47	18.11	13.01	20.00	8.33	18.52
r	25.88	33.33	27.83	19.62	27.64	28.89	14.58	24.87
o	54.12	34.81	36.79	61.51	43.90	35.56	64.58	46.41
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 16-3. Sperm, the rate of nos. by the degree of the quantity of stomach contents by the decade of month

	November		December			January	February	Total
	2	3	1	2	3			
R+rrr	3.53	10.37	9.91	8.31	15.45	15.55	12.50	10.20
rr+r	42.35	54.81	53.30	37.73	40.65	48.89	22.91	43.39
$\frac{R+rrr}{rr+r}$	0.08	0.18	0.18	0.22	0.38	0.32	0.55	0.24

Among the whales whose first stomach contained any food, there was a tendency for the proportion of those whose stomach was impregnated with food to higher degrees to increase with the time. This is demonstrated in Table 16–3 where "R+rrr" and "rr+r" refer to the sums of those percentage frequencies which are shown in Table 16–2. The steady increase in the value of the ratio (R+rrr)/(rr+r) represents the aforementioned tendency.

3. *External Parasites*

Observation was made, according to the usual method, of the skin of the whales for evidence of infection with external parasites, and the results are summarized in Table 17 for different species of whales.

Table 17. Blue, Fin, Sperm and Humphack, the rate of infection by sp. of parasites

	Blue			Fin		
	nos. of observed	nos. of infected	rate of infection	nos. of observed	nos. of infected	rate of infection
Cyamus sp.	231	5	2.16	2597	38	1.46
Coronula sp.	〃	1	0.43	〃	2	0.08
Conchoderma sp.	〃	0	0.00	〃	1	0.04
Pennella sp.	〃	3	1.30	〃	3	0.12
Diatom film	〃	45	19.45	〃	529	20.37
Not infected			23.34			22.07

	Sperm			Humpback		
	nos. of observed	nos. of infected	rate of infection	nos. of observed	nos. of infected	rate of infection
Cyamue sp.	961	187	19.15	37	25	67.57
Coronula sp.	〃	7	0.73	〃	37	100.00
Conehoderma sp.	〃	21	2.19	〃	37	100.00
Pennella sp.	〃	2	0.21	〃	0	0.00
Diatom film	〃	341	35.48	〃	0	0.00
Not infected			50.47			0.00

The percentage of the whales infected with external parasites was much the same in blue and fin whales, respectively 23.34% and 22.07%. The major part of the cases was accounted for by the diatom film, and the minor part, by *Cyamus*, *Pennella*, *Coronula*, and *Conchoderma* in the descending order of importance. Nearly one half of the captured sperm whales were infected by the external parasites, mostly by diatoms or *Cyamus*. All the humpback whales were infected by both *Coronula* and *Conchoderma*, and about two-thirds of them were infected also with *Cyamus*. But no humpbacks showed the infection with *Pennella* or with the diatom film. Compared with the last season, the percentage infected with the diatoms was lower in any whale species, but the percentages infected with other parasites were much the same as in the last season.

While the occurrence of *Coronula*, *Conchoderma* and *Pennella* on the blue and fin whales was limited to January, and that of *Cyamus* to January and February, the diatom film grew increasingly common on these whales with the progress of the season. This observation was in good agreement with the conventional theory that the diatom film is developed but the other parasites fall off while the whales are migrating over the Antarctic waters.

Further details of the occurrence of the diatom film on blue and fin whales are shown in Tables 18-1 to 19-2 and Fig. 16. As is clear from Fig. 16, the percentage of the blue infected with the diatom film, especially of those suffering from heavy infection, showed marked decrease both in early February and in March. Similar decrease in early February was reported in last season. In fin whales the percentage infection increased with the progress of the season, with a concurrent increase in the percentage suffering from relatively heavy infection.

It is generally believed that diatom spores attach to the whale skin after whales have entered the Antarctic waters, and that it takes these spores at least one month to grow to form a diatom film visible to the naked eye. In that case, the fact that a considerable part of blue and fin whales are found free from diatom film even at the end of the whaling season may indicate that the migration of these species from lower latitudes into the Antarctic continues for a considerable length of time after the season is opened.

Table 18-1. Blue whale, nos. of infected by sp. of parasites and the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
Cyamus sp.	0	1	0	0	3	1	0	5
Coronula sp.	0	0	0	0	0	0	0	0
Conchoderma sp.	0	0	1	0	0	0	0	1
Pennella sp.	1	1	1	0	0	0	0	3
Diatom film	0	4	16	1	20	3	1	45
nos. of observed	21	20	91	16	56	10	17	231

Table 18-2. Fin whale, nos. of infected by sp. of parasites and the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
Cyamus sp.	5	7	12	4	6	4	0	38
Coronula sp.	0	0	2	0	0	0	0	2
Conchoderma sp.	0	0	1	0	0	0	0	1
Pennella sp.	0	2	3	0	0	0	0	5
Diatom film	35	48	60	87	129	115	55	529
nos. of observed	294	388	378	426	544	400	167	2597

Table 19-1. Blue whale, nos. of infected by diatoms by the decade of month

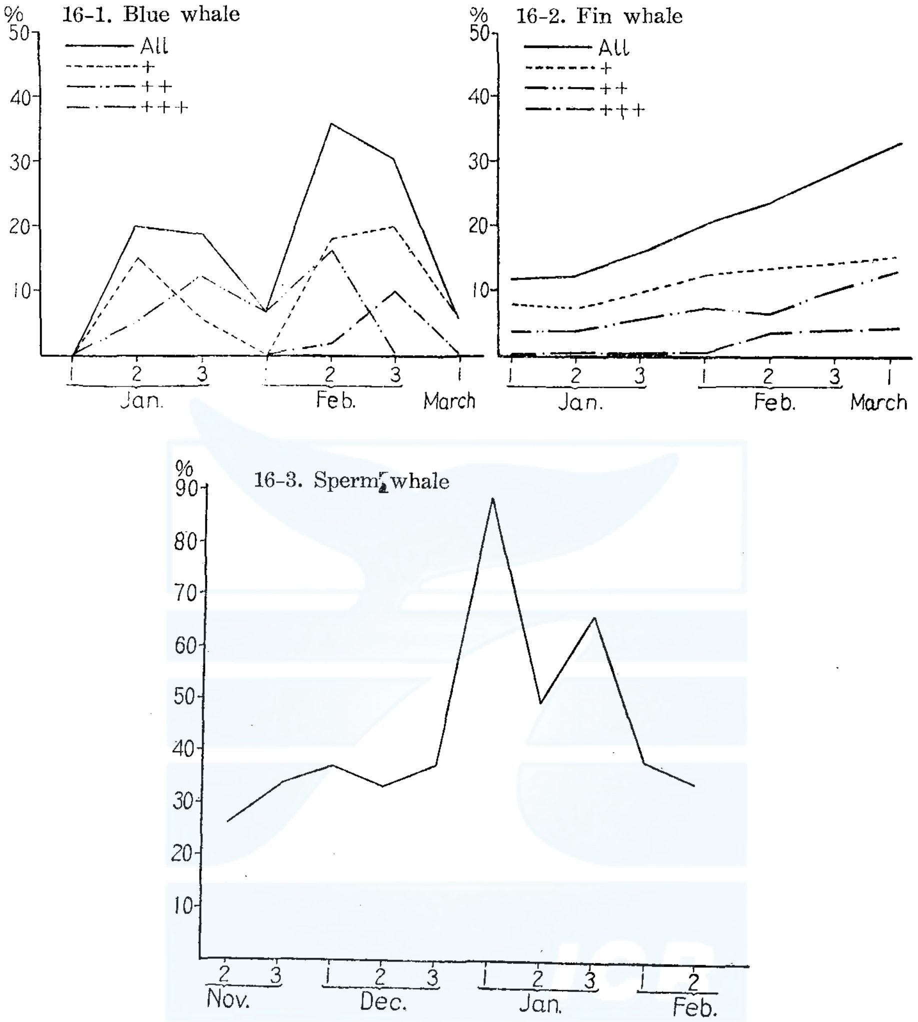
	January			February			March	Total
	1	2	3	1	2	3		
⧻	0	0	0	0	1	1	0	2
⧺	0	1	11	1	9	0	0	22
+	0	3	5	0	10	2	1	21
O	21	16	75	15	36	7	16	186
Total	21	20	91	16	56	10	17	231

Table 19-2. Blue whale, the rate of infection of diatoms by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
⧻	0.00	0.00	0.00	0.00	1.79	10.00	0.00	0.87
⧺	0.00	5.00	12.09	6.25	16.07	0.00	0.00	9.52
+	0.00	15.00	5.49	0.00	17.86	20.00	5.88	9.09
O	100.00	80.00	82.42	93.75	64.29	70.00	94.12	80.52
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The occurrence of varions external parasities on sperm whales is shown in Tables 20-1 and 21-1, and the corresponding percentage infection in Tables 20-2 and 21-2. The subdivision of the whaling ground used in Tables 20-1 and 20-2 is the same that has been described in connection with the analysis of size composition data (p. 163). Nearly one half of the sperm whales captured during the season was infected with external parasites. Diatom film was most important among the parasites, and was found in 36% of the whales, mostly on the anterior part of the head. *Cyamus* graded next in importance, occurring on 19% of the total

Fig. 16. The rate of infection of Diatoms by the decade of the month



16-1. Blue whale

16-2. Fin whale

16-3. Sperm whale

catch. Other parasites were far less important. The percentage infection with diatom film was high in regions I and V, and low in region II. The percentage infection with *Cyamus* ranged from 37% in region V to 17% in region IV (Table 21-2).

The percentage infection with *Cyamus* varied greatly with time, and the maximum occurred in both late December and middle January (Table 22-2). The percentages infected with *Coronula* and *Pennella* were low, and reached the maximum respectively in early January and late November. The latter parasite was not found from late December onwards.

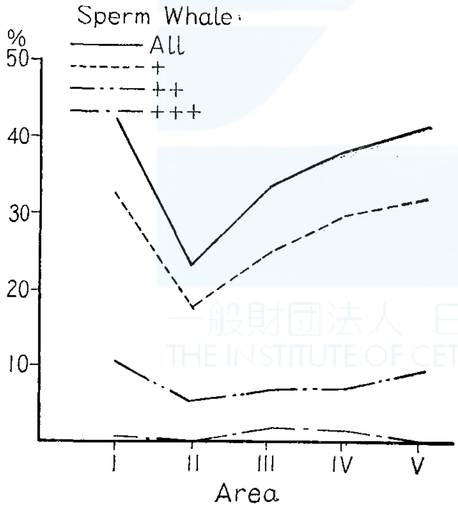
Table 20-1. Fin whale, nos. of infected by diatoms by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
+++	0	3	1	2	20	16	7	49
++	11	16	22	32	35	42	22	180
+	24	29	37	53	74	57	26	300
O	259	340	318	339	415	285	112	2068
T.	294	388	378	426	544	400	167	2597

Table 20-2. Fin whale, the rate of infection by diatoms by the decade of month

	January			February			March	Total
	1	2	3	1	2	3		
+++	0.00	0.77	0.26	0.47	3.68	4.00	4.19	1.89
++	3.74	4.12	5.82	7.51	6.43	10.50	13.17	6.93
+	8.16	7.47	9.79	12.44	13.60	14.25	15.57	11.55
O	88.10	87.63	84.13	79.58	76.29	71.25	67.07	79.63
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Fig. 17. The rate of infection of Diatoms by whaling area



The precentage showing diatom film also varied irregularly with time (Table 22-2 and Fig. 16-3). It was low in middle November as well as during February. In the former period the operation took place in region II, and during the latter, in region III where small whales of average length of 47.4 ft. were dominant. While percentage infection was very high in early January when the operation took place in the western half of region IV (around 160°E), it dropped considerably in the middle and late parts of the month, when the fleet shifted eastward and operated in the other half of region IV and in region V.

It may be concluded from the foregoing that the variation in the percentage infection with diatom film is associated not only with the time but also with the geographical position. This is a strong indication that sperm whales with different history were found in different whaling grounds, or that the sperm whales over these grounds did not come from a single population. Furthermore, the considerable variation with time in the percentage infection with diatom film and the consistent occurrence of *Cyamus* throughout the season suggest that there was a constant recruitment of sperm whales from lower latitudes all through the season (p. 178).

Table 21-1. Sperm whale, nos. of infected by sp. of parasites, degree of quantity and area

	I				II				III			
	+	⧺	⧻	Total	+	⧺	⧻	Total	+	⧺	⧻	Total
Cyamus sp.	27	4	2	33	14	13	3	30	33	9	3	45
Coronula sp.	0	0	0	0	2	0	0	2	3	0	0	3
Conchoderma sp.	4	1	1	6	2	3	0	5	3	0	0	3
Pennella sp.	1	0	0	1	0	0	0	0	0	0	0	0
Diatom film	59	18	1	78	30	9	0	39	54	15	4	73
nos. of not infected				83				97				117
nos. of observed				185				169				220

	IV				V				Total			
	+	⧺	⧻	Total	+	⧺	⧻	Total	+	⧺	⧻	Total
Cyamus sp.	32	17	4	53	14	9	0	23	120	52	12	184
Coronula sp.	2	0	0	2	0	0	0	0	7	0	0	7
Conchoderma sp.	4	2	0	6	1	0	0	1	14	6	1	21
Pennella sp.	1	0	0	1	0	0	0	0	2	0	0	2
Diatom film	93	22	4	120	24	7	0	31	260	71	9	340
nos. of not infected				154				34				485
nos. of observed				312				75				951

Table 21-2. Sperm whale, the rate of the infection by sp. of parasites, degree of quantity and area

	I				II				III			
	+	++	+++	Total	+	++	+++	Total	+	++	+++	Total
Cyamus sp.	15.14	2.70	1.62	18.38	8.28	7.69	1.78	17.75	15.00	4.09	1.36	20.45
Coronula sp.	0.00	0.00	0.00	0.00	1.18	0.00	0.00	1.18	1.36	0.00	0.00	1.36
Conchoderma sp.	2.70	0.54	0.54	3.78	1.18	1.78	0.00	2.96	1.36	0.00	0.00	1.36
Pennella sp.	0.54	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diatom film	32.43	10.27	0.54	42.16	17.75	5.33	0.00	23.08	24.55	6.81	1.82	33.18
rate of not infected				44.86				57.40				53.18
rate of observed				100.00				100.00				100.00

	IV				V				T.			
	+	++	+++	Total	+	++	+++	Total	+	++	+++	Total
Cyamus sp.	10.26	5.45	1.28	16.99	18.67	12.00	0.00	36.67	12.62	5.47	1.26	19.35
Coronula sp.	0.64	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.74
Conchoderma sp.	1.28	0.64	0.00	1.92	1.33	0.00	0.00	1.33	1.47	0.63	0.11	2.21
Pennella sp.	0.32	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.21
Diatom film	29.81	7.05	1.28	38.46	32.00	9.33	0.00	41.33	27.34	7.46	0.95	35.75
rate of not infected				49.36				45.33				51.00
rate of observed				100.00				100.00				100.00

Table 22-1. Sperm whale, nos. of infected by sp. of parasites and the decade of month

	November		December			January			February		Total
	2	3	1	2	3	1	2	3	1	2	
Cyamus sp.	14	24	40	50	29	2	9	0	7	9	184
Coronula sp.	2	0	1	1	0	2	0	0	0	1	7
Conchoderma sp.	5	0	6	6	0	1	1	0	1	1	21
Pennella sp.	0	1	0	1	0	0	0	0	0	0	2
Diatom film	22	45	75	88	46	16	12	2	17	18	341
nos. of not infected	46	71	104	139	63	1	8	1	23	29	485
nos. of observed	85	135	212	265	123	18	24	3	44	52	961

Table 22-2. Sperm whale, the rate of infection by sp. of parasites and the decade of month

	November		December			January			February		Total
	2	3	1	2	3	1	2	3	1	2	
Cyamus sp.	16.47	17.78	19.80	18.88	23.58	11.11	37.00	0.00	15.91	17.27	19.15
Coronula sp.	2.35	0.00	0.50	0.38	0.00	11.11	0.00	0.00	0.00	1.92	0.73
Conchoderma sp.	5.88	0.00	2.97	2.26	0.00	5.56	4.17	0.00	2.27	1.92	2.19
Pennella sp.	0.00	0.74	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.21
Diatom film	25.88	33.33	37.13	33.21	37.40	88.89	50.00	66.67	38.64	34.55	35.48
rate of not infected	54.12	52.59	51.49	52.45	51.22	5.56	33.33	33.33	52.27	55.66	50.47

Chapter III

Weight of Testicles and Number of Corpora Lutea

1. *Weight of Testicles in Relation to Length of Whale.*

Figs. 18–1 to 18–4 show the relation between the combined weight of the pair of testicles and the length of male whales in blue, fin, humpback and sperm whales respectively. In every species there is a general increase in the weight of testicles with increasing length of the whale.

The graphs for blue and fin whales, however, suggest more than this general relationship. Fig. 18–1 indicates that male blue whales with the testicles weighing between 7 and 12 kg. were rare. This may be taken to indicate that the weight of testicles from 7 to 12 kg. corresponds to the puberty of male blue whales when a rapid increase in the weight of testicles takes places. Since the pair of testicles weighed over 10 kg. in the minority of the males between 71 and 75 ft., but in almost all the males larger than 77 ft., it may be said that male blue whales attain sexual maturity at the lengths between about 71 and about 77 ft.

In fin whales (Fig. 18–2), the rapid growth of testicles concurrent with puberty is indicated by the scarcity of the males showing the testicles weight of 5 kg. As the weight of testicles less than 5 kg. was associated generally with the lengths under 67 ft. and that over 5 kg. with the lengths 60 ft. or more, it seems that male fin whales attain sexual maturity at the length between 60 and 67 ft.

The data for humpbacks are not plentifully enough to justify any detailed analysis (Fig. 18–3).

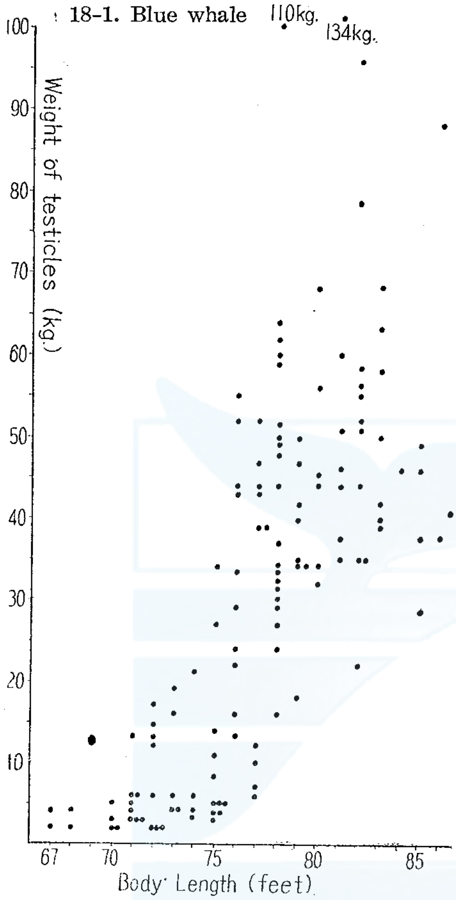


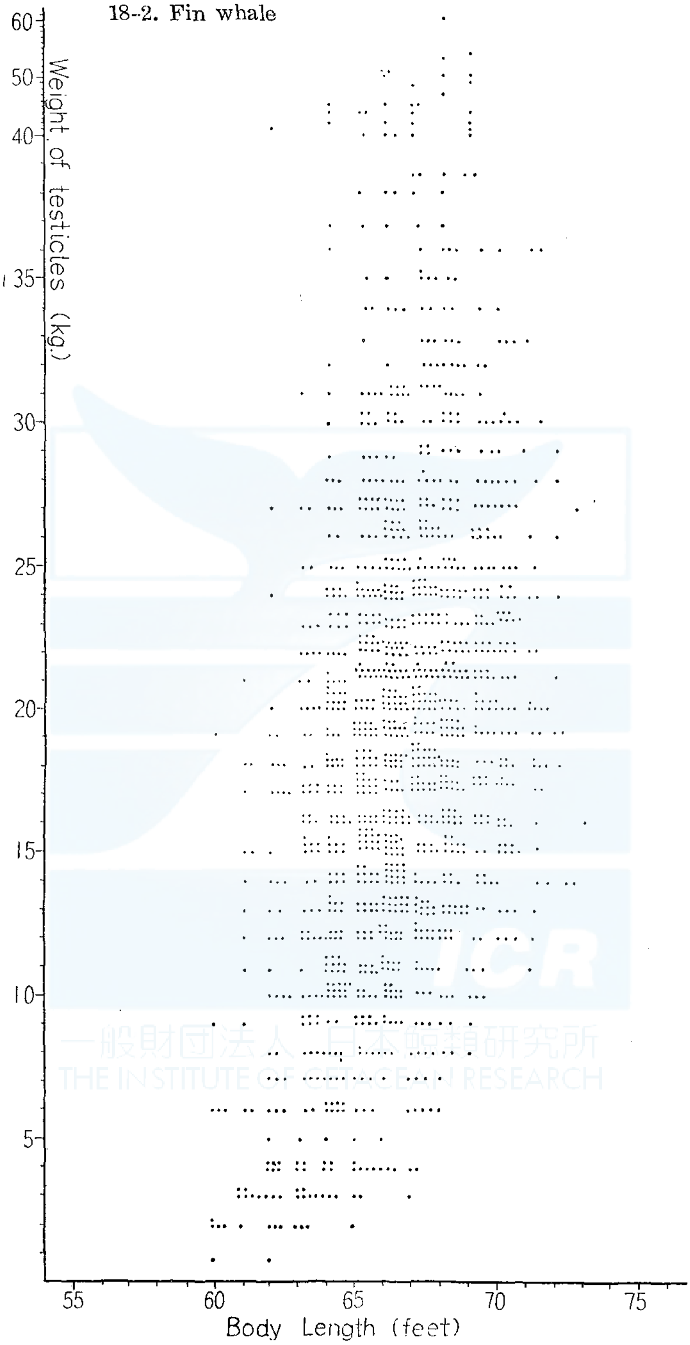
Fig. 18. The relations between body length and the testicles weight

The rapid growth of testicles during puberty is not clearly represented in the graph for sperm whales (Fig. 18-4). It is noteworthy, however, that a considerable percentage of the captured sperm whales had very small testicles. In Table 23 are classified the sperm whales whose pair of testicles weighed less than 6 kg. It is clear from this table that the pair of testicles weighed less than 5kg. In 27% of the catch, and less than 2 kg. in 1%. This fact strongly suggests that, contrary to conventional belief a considerable portion of the sperm whales found in the Antarctic waters are sexually immature. A similar tendency was also encountered in last season (Ohno and Fujino: 1952).

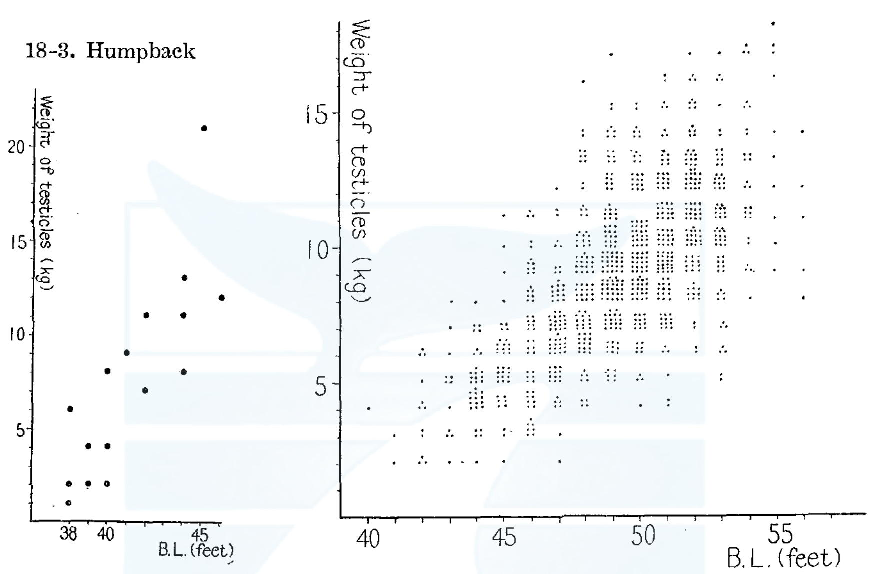
2. *Number of Corpora Lutea in Relation to Length of Whale.*

Fig. 19. 1 to 19. 3 show the relation between the number of corpora lutea and the length of female whales in different species.

18-2. Fin whale



In blue whales, the smallest female showing a corpus luteum meaured 75 ft. (Fig. 19–1), and the corpora lutea number generally increased with the length of whale. While this general relationship holds well in the length classes 75 to about 85 ft., there occurs an decreasing tendency of the corpora lutea number in the larger females—a strange feature which


18-3. Humpback

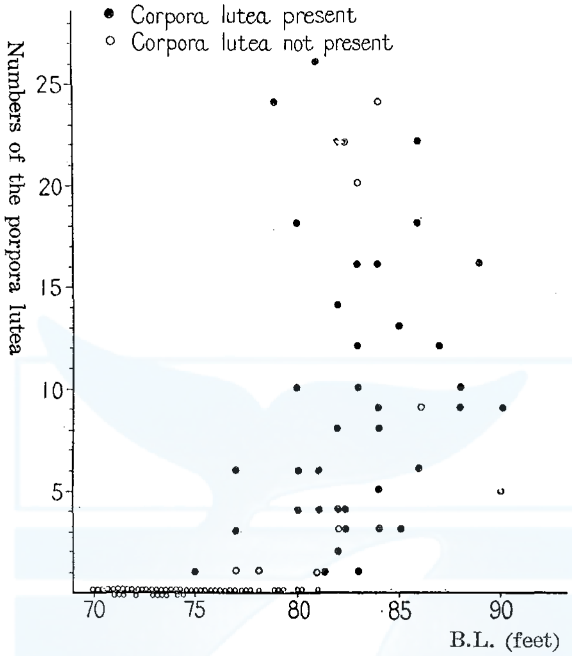
18-4. Sperm whale

Table 23. Sperm whale, nos. and the rate of whale with lighter testicles in weight by body length

	under 1 kg		under 2 kg		under 3 kg		under 4 kg		under 5 kg		under 6 kg		nos. of observed
	nos.	%	nos.	%	nos.	%	nos.	%	nos.	%	nos.	%	
40							1	100.0	1	100.0	1	100.0	1
41			1	33.3	2	66.7	2	66.7	2	66.7	3	100.0	3
42			3	25.0	5	41.7	8	66.7	9	75.0	12	100.0	12
43			1	8.3	4	33.3	5	41.7	9	75.0	10	83.3	12
44			1	2.8	5	13.9	18	50.0	28	77.8	31	86.1	36
45			1	2.5	3	7.5	9	22.5	21	52.5	32	80.0	40
46					7	13.0	15	27.8	21	38.9	27	50.0	54
47			1	1.3	2	2.6	7	9.1	19	24.7	36	46.8	77
48							4	4.1	9	9.2	24	24.5	98
49									6	4.5	15	11.4	132
50							1	0.8	4	3.0	10	7.5	133
51							2	1.7	3	2.6	6	5.2	115
52											2	2.0	102
53									2	2.8	5	6.9	72
Total			8	0.9	28	3.2	72	8.1	134	15.1	214	24.1	887

Fig. 19. The relations between body length and the nos. of corpora lutea

19-1. Blue whale

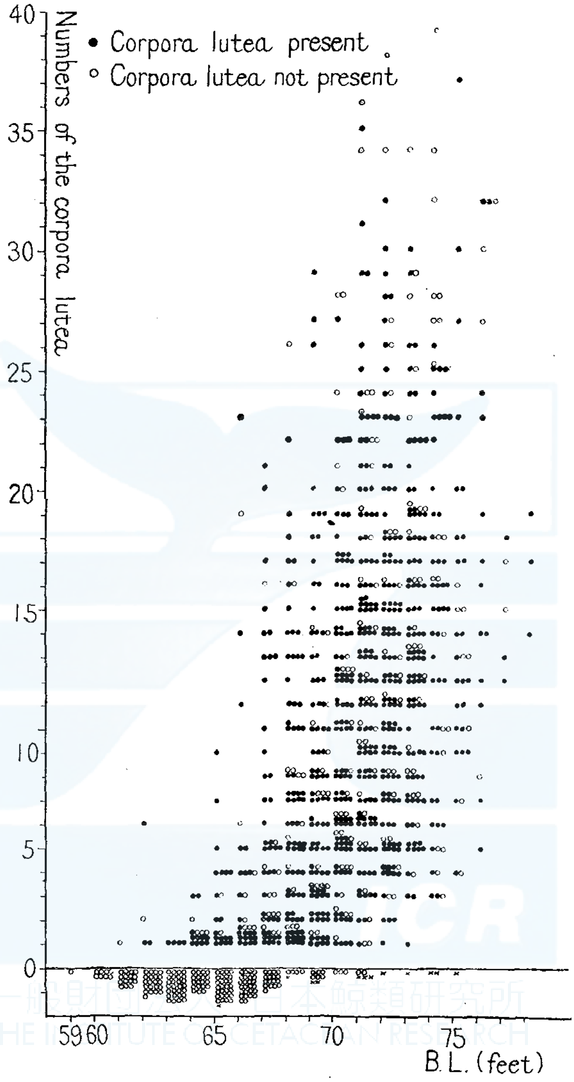


was not recognized in last season. As a result, corpora lutea number over 20 was confined to the females from 79 to 86 ft. in size. Since it is well established that corpora lutea persist all the life of blue whales, it may be that among very large females of this species the individuals having many corpora lutea suffer a higher rate of natural mortality or are less liable to be captured than those having relatively smaller number of corpora lutea.

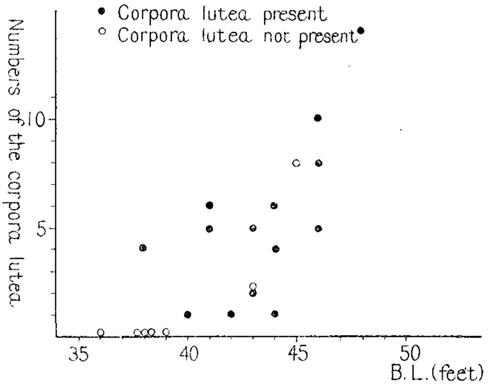
In fin whales, too, very high corpora lutea number, namely over 34 occurred in the length classes 68–74 ft, and the number never exceded 20 in very large females measuring 77 to 78 ft. in length, I although the general trend was that the larger the whales, the more corpora lutea on their ovaries (Fig. 9–2). A similar tendency was observed in last season. The lower tendency of the corpora lutea number in very large females may be explained in the same manner as in the case of blue whales.

In humpback whales, the number of corpora lutea increased with the length of whale. An exceptionally high corpora lutea number, namely 32, was shown by a female measuring 48 ft. in length.

19-2. Fin whale



19-3. Humpback whale



Chapter IV

Foetuses

1. Occurrence and Growth of Foetuses.

In Table 23 is summarized the occurrence of foetuses in the female whales captured during the present season.

Twin and triplet foetuses occurred only in fin whales. Eleven females of this species were found with twin foetuses, and one, two, and three corpora lutea were functional in 5, 5 and 1 of these mothers, respectively. In two mothers of the second group, the two functional corpora lutea were found on one ovary. In the mother showing three functional corpora lutea, the twin foetuses were of different sex. Triplet foetuses were met with in a single instance, where two larger foetuses were female and dead measuring 17 ft. 8 in. and 15 ft. in length and the smallest one, 5 ft. 2 in long, was male and alive.

A slight preponderance of male foetuses over female was observed in the three species of whales examined. This tendency had been recognized in blue and fin whale foetuses during last season (Table 24). The marked variation in the sex ratio of humpback foetuses may be ascribed to the scarcity of data.

As far as blue and fin whales are concerned, the preponderance of males over females is more considerable in the adults that are captured by pelagic whaling than in foetuses (Table 25). This fact may suggests that females of these species suffer a higher mortality rate after birth than males, or have an tendency to migrate over other waters than those covered by pelagic operations.

The length of foetus is plotted against the date of capture in Figs. 20-1 to 20-3 by species. The seasonal changes in the foetus size as shown by Figs. 20-1 and 20-2 are in good agreement with the growth curves proposed by Mackintosh and Wheeler as well as with the results obtained in last season.

Table 24. Nos. of foetuses

		January				February				March				Total				
		male	female	u.k.	Total	male	female	u.k.	Total	male	female	u.k.	Total	male	female	u.k.	Total	
Blue	nos.	9	11		20	9	7		16	2	1		3	20	19		39	
	sex ratio	45.0	55.0			56.25	43.75			66.7	33.3			51.3	48.7			
Fin.	nos.	167	160	1	328	197	193	1	391	14	15		29	37.8	368	2	748	twins 11 pairs
	sex ratio	51.1	48.9			50.5	49.5			48.3	51.7			50.7	4.93			triplets 1 pair
Hump.	nos.					7	5		12					7	5		12	
	sex ratio					58.3	41.7							58.3	41.7			

Table 25. Sex ratio of foetuses in 1950-51 (Ono and Fujino, 1951)

	male	female	nos.
Blue	52.6	47.4	38
Fin	51.0	48.9	533
Hump.	40.0	60.0	5

Table 26. Sex ratio of whales caught

	male	female	nos.
Blue	57.6	42.4	231
Fin	55.7	44.3	2597
Hump.	43.2	66.8	37

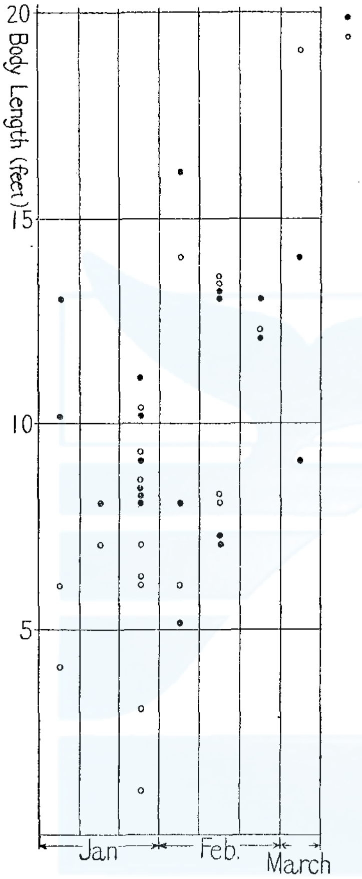
2. Relation between Foetus Size and the Diameter of Functional Corpus Luteum of the Mother.

The diameter of the functional corpus luteum of the mother whale is plotted against the length of the foetus in Figs. 21-1 to 21-4 by species. A tendency that the diameter of functional corpus luteum diminishes with the increase in foetues size is observed, though not clear, in fin and humpback whales.

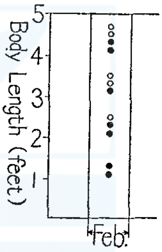
3. Relation between Foetus Size and the Thickness of Mammary Glands of the Mother.

Fig. 20. The length of the foetuses by season

20-1. Blue whale



20-3. Humpback whale



The said relation is depicted in Figs. 22. 1 to 22. 4 for different species. In every species there is a slight indication that the thickness of mammary grands deminishes as the foetus grows larger.

20-2. Fin whale

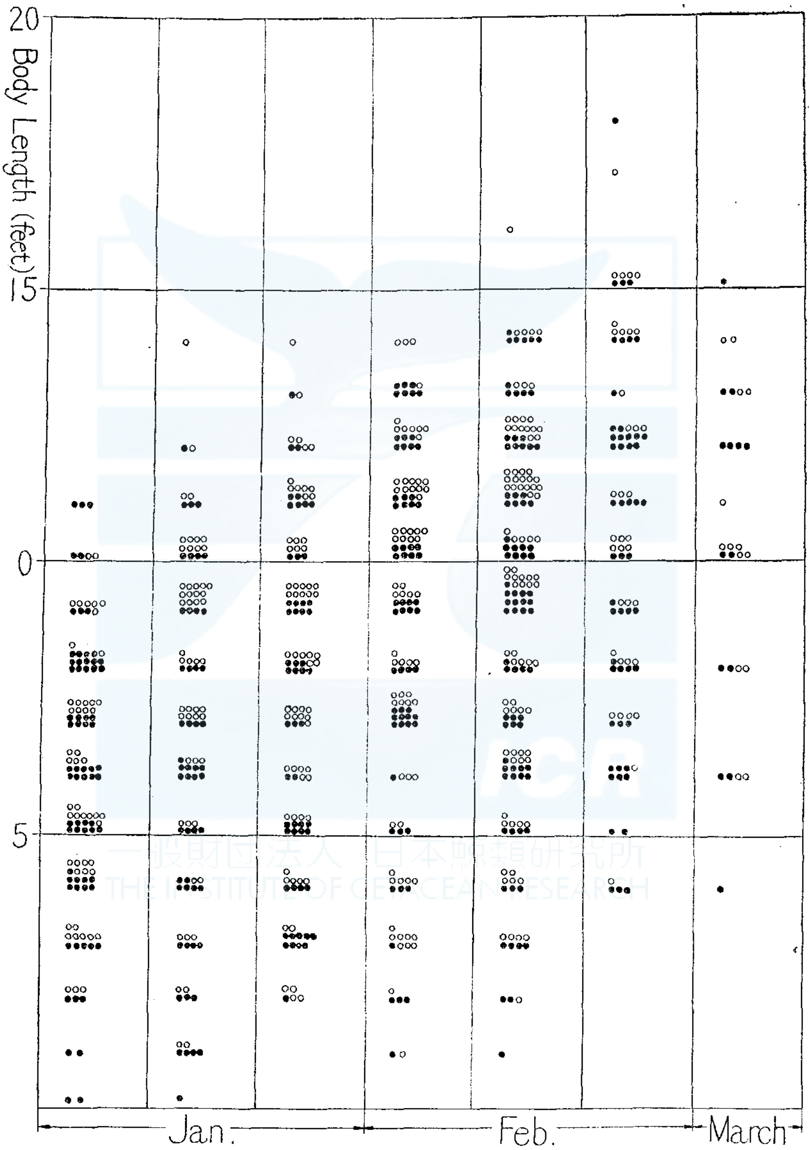


Fig. 21. The relations between the size of foetuses and the size of the functional corpora lutea of the mother whale.

21-1. Blue whale

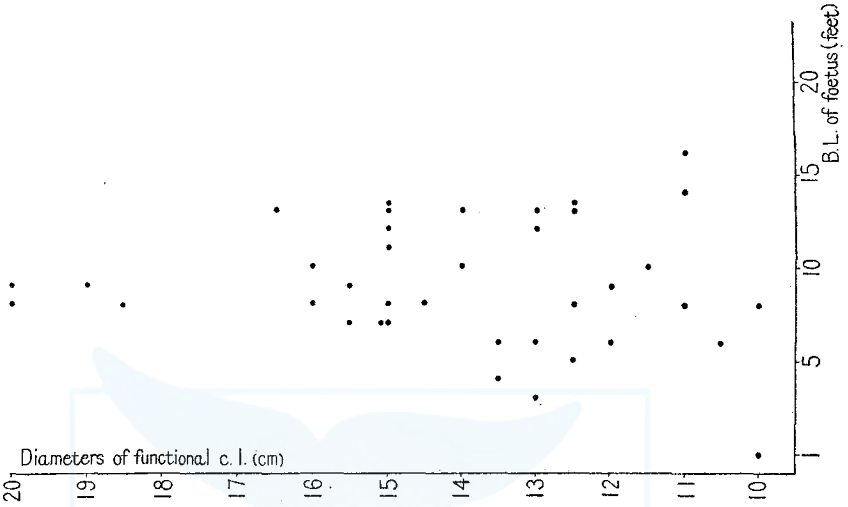
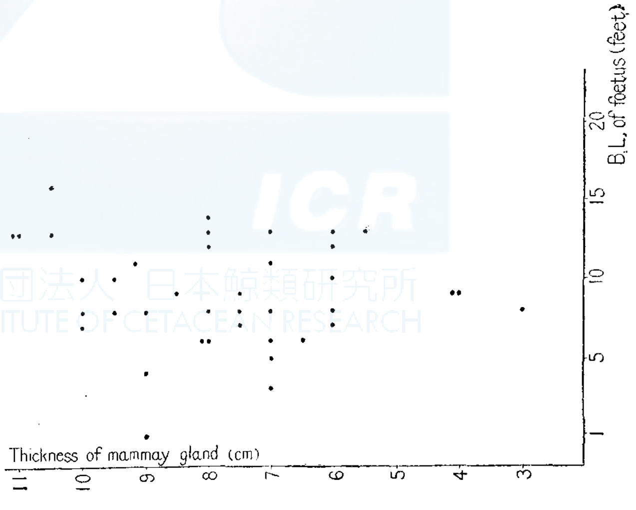
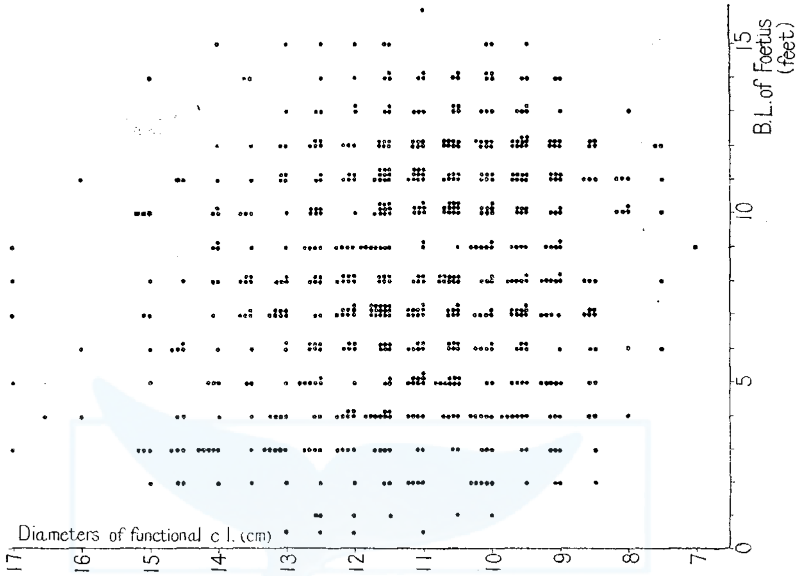


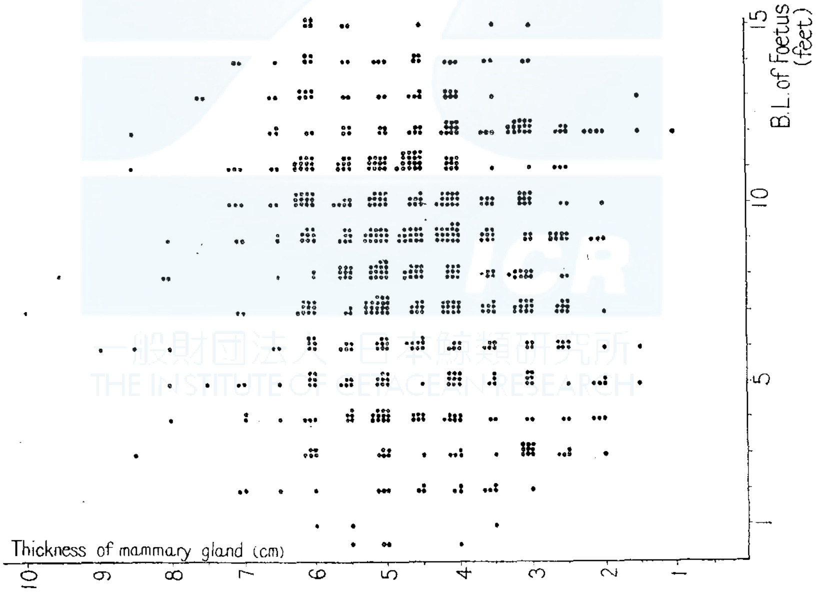
Fig. 22. The relations between the size of foetuses and the thickness of the mammary gland.

22-1. Blue whale

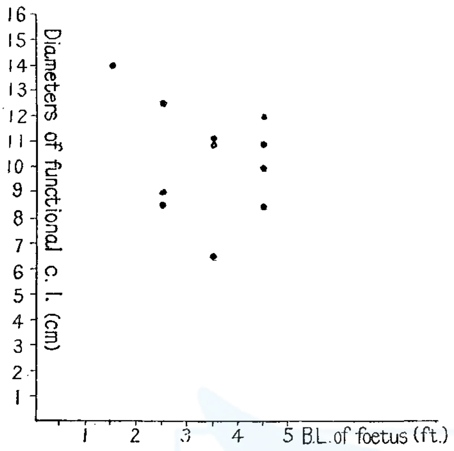




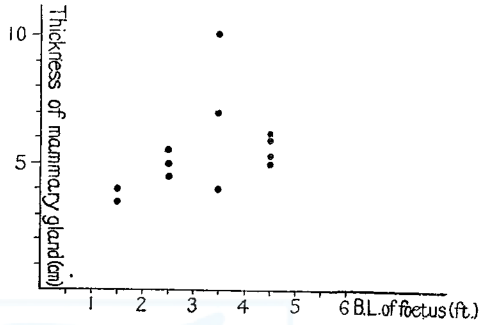
21-2. Fin whales



22-2. Fin whale



21-3. Humpback whale



22-3. Humpback whale

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Appendix

Table 1. The organization of fhe Japanese Antarctic whaling fleets

Tonan-maru fleets				Nisshin-maru fleet				Baikal-maru fleet			
Name of boat	Total tonnage	Engines		Name of boats	Total tonnage	Engines		Name of boats	Total tonnage	Engines	
		sp.	Hp.			sp.	Hp.			sp.	Hp.
Tonan-maru	19,320.38	turbin	8,000	Nisshin-maru	16,777.09	diesel	8,000	Baikal-maru	4,744.43	diesel	3,200
Koyo-maru	366.92	diesel	1,800	Seki-maru	365.02	,,	1,600	No. 1 Kyo-maru	285.30	,,	950
No. 2 Koyo-maru	367.88	,,	1,800	No. 7 Seki-maru	306.56	,,	1,600	No. 3 Kyo-maru	370.25	,,	1,800
No. 3 ,,	367.88	,,	1,800	No. 11 ,,	473.32	,,	2,000	No. 5 Kyo-maru	373.72	,,	1,800
Konan-maru	379.76	,,	1,600	No. 2 Fumi-maru	304.00	,,	1,600	No. 6 Kyo-maru	374.65	,,	1,800
No. 2 Konan-maru	378.33	diesel	1,600	No. 3 Fumi-maru	312.45	diesel	1,600	No. 15 Kyo-maru	334·07	recip.	1,400
No. 3 ,,	417.43	,,	1,800	No. 6 ,,	304.00	,,	1,600	Nichinan-maru	5,296.28	turbin	4,000
No. 5 ,,	434.29	,,	1,800	No. 7 ,,	451.35	,,	2,000				
No. 6 ,,	433.83	,,	1,800	No. 8 ,,	451.35	,,	2,000				
No. 8 Syonan-maru	355.79	recip.	1,000	No. 11 ,,	473.58	,,	2,000				
No. 11 Syonan-maru	354.25	recip.	1,000	No. 12 Fumi-maru	473.18	diesel	2,000				
No. 2 Takunan-maru	343.46	,,	990	Tenyo-maru	11,224.20	turbin	5,000				
No. 3 ,,	343.46	,,	990	No. 2 Tenyo-maru	10,619.69	diesel	5,400				
No. 6 ,,	345.96	,,	990	No. 3 ,,	3,689.31	,,	2,250				
Shinano-maru	538.59	diesel	750	Banshu-maru	983.35	,,	710				
No. 3 Kyo-maru	370.25	diesel	1,800	No. 32 Banshu-maru	782.21	diesel	630				
No. 5 ,,	373.72	,,	1,800	No. 35 ,,	991.81	,,	630				
Settsu-maru	9,329.06	,,	3,200	No. 36 ,,	998.71	,,	490				
Kaiko-maru	2,940.67	,,	1,440	Kinjo-maru	11,108.88	,,	3,400				
Chikuzen-maru	1,161.53	,,	880	No. 3 Seki-maru	307.02	,,	1,400				
Sagami-maru	999.72	diesel	880	No. 5 Fumi-maru	384.80	diesel	1,600				
Tone-maru	535.05	,,	550	No. 8 Seki-maru	308.18	,,	1,600				
Tatsuta-maru	543.90	,,	550	No. 38 Banshu-maru	998.71	,,	490				
Gyokuei-maru	10,419.42	,,	4,000			,,					

Table 2. Production, oil and others
(unit: metric tons, but kg in liver oil; raw material)

(i) Sperm whale

Production / Heet	Sperm oil	Frozen materia			Satted material							Total	Liver oil
		Meat	Blubber	Liver	Tail flukes	Blubber for leather	Main blubber	Spermaceti case	Gelatine	Fibrous head tissue	Others		
Tonan-maru fl.	3,620.0				89.0	29.5			36.5	9.5		3,784.5	7,390
Nisshin-maru fl.	3,483.0				85.0	166.0		120.0				3,854.0	5,100
Baikal-maru fl.	1,810.0	71.0	222.0	88.0	71.0	128.0	40	146.0			3	2,579.0	
Total	8,913.0	71.0	222.0	88.0	245.0	323.5	40	266.0	36.5	9.5	3	10,217.5	12,490

(ii) Whale-bone whale

Fleets		Tonnan-maru fl.				Nisshin-maru fl.				Total			
Sp. of whales		B	F	H	Total	B	F	H	Total	B	F	H	Total
Nos. of treated		115	1,159	37	1,311	116	1,438		1,554	231	2,597	37	2,865
B. W. U.		709.3				777.0				1,486.3			
Whale oil		16,248.0				18,950.0				35,198.0			
Frozen	Meat	7,198.7				12,577.5				19,776.2			
	Sunoko[1]					458.0				458.0			
	Others	55.9				74.5				130.4			
Salted	Meat	832.5				1,227.0				2,059.5			
	Sunoko	549.5				668.0				1,217.5			
	Unesu[2]					2,703.0				2,703.0			
	Une[3]	1,147.2				270.0				1,417.2			
	Oba	244.0				258.0				502.0			
	Others	7.6				47.5				55.1			
Total		26,283.4				37,233.5				63,516.9			
Liver oil		18,112				23,600				41,712			

Note: 1) Layer of connective tissues covering the meat of the ventral grooves
2) Ventral grooves with layer of connective tissues
3) Ventral grooves

Table 3. Catches and the production by fleets in 1951-52 Antarctic Whaling

Name of fleet by country	nos. of catch						Production (Barrel)			nos. of factory ships	nos. of catcher boats	nos. of. treated B.W.U.	whale oil productio per B.W.U.
	Blue	Fin.	Hump.	Sei	Sperm	Total	whale oil	sperm oil	Total				
Norway													
Antarctic	78	956	—	18	91	1,143	77,250	5,050	82,300	1	12	553.2	139.6
Kosmos III	422	1,031	5	—	234	1,692	129,250	11,550	140,800	1	15	933.0	138.5
Kosmos IV	123	1,901	31	—	375	2,430	140,900	18,244	159,144	1	15	1,074.4	131.1
Norhval	343	1,076	1	—	360	1,780	113,500	17,800	131,300	1	15	877.4	129.4
Pelagos	128	918	222	—	141	1,409	83,329	7,000	90,329	1	12	667.4	124.9
Sir J.C. Ross	58	1,245	2	1	116	1,422	97,500	6,240	103,740	1	14	677.5	143.9
Suderoy	304	492	—	—	121	917	68,500	6,020	74,520	1	9	551.0	124.3
Thorshammea	205	208	359	—	321	1,093	56,000	16,000	72,000	1	12	445.8	125.6
Thorshavet	329	521	48	—	398	1,296	82,648	21,721	104,369	1	14	607.7	136.0
Thorshovdi	101	1,343	—	2	135	1,581	118,124	7,245	125,369	1	14	766.3	154.1
United Kingdom													
Balaena	601	1,066	43	—	324	2,034	143,700	16,300	160,000	1	18	1,136.9	126.4
Southern Harvester	104	1,430	—	7	418	1,959	117,950	23,990	141,940	1	14	809.2	145.8
Southern Venturer	444	649	402	—	468	1,963	119,006	25,526	144,532	1	15	923.4	128.9
Union of South Africa													
Abraham Larsen	613	1,511	8	—	362	2,494	164,193	19,837	184,030	1	16	1,358.2	120.9
Netherlands													
Willem Barendsz	425	717	150	—	357	1,650	93,000	17,300	110,300	1	12	833.1	111.6
Panama													
Olympic Challenger	424	900	62	1	21	1,408	95,946	1,127	97,073	1	16	889.1	107.9
Japan													
Nisshin Maru	116	1,439	—	—	377	1,932	111,471	20,488	131,959	1	14	834.0	133.7
Tonan Maru	115	1,163	37	—	362	1,677	95,576	21,294	116,870	1	13	708.8	134.8
Baikal Maru	—	—	—	—	222	222	—	10,647	10,647	1	5	—	—
U.S.S.R.													
Slava	191	1,951	175	3	139	2,459	140,294	7,353	147,647	1	15	1,229.0	114.2
Total	5,124	20,518	1,545	32	5,342	32,561	2,048,137	280,730	2,328,869	20	270	15,875.3	129.0

Table 4. Composition of whales

1. Blue whale, whole season.

B.L. \ Sex	Male Imm.	Male Mat.	Male Total	Female Imm.	Female Mat. Pre.	Female Mat. Rest.	Female Total	Total
67	2		2					2
8	2		2					2
9	0		0					0
70	6		6	4			4	10
1	8	1	9	8			8	17
2	4	4	8	4			4	12
3	4	2	6	11			11	17
4	3	2	5	7			7	12
5	7	4	11	6	1		7	18
6	0	11	11	3	0		3	14
7	2	8	10	0	2	1	3	13
8		17	17	1	1	0	2	19
9		8	8	3	0	1	4	12
80		6	6	2	4	0	6	12
1		7	7	1	4	1	6	13
2		11	11		9	1	10	21
3		7	7		4	1	5	12
4		1	1		5	1	6	7
5		4	4		2	0	2	6
6		2	2		3	1	4	6
7					1	0	1	1
8					2	0	2	2
9					1	0	1	1
90					1	1	2	2
Total	38	95	133	50	40	8	98	231
a.v. B.L.			76.9				78.2	77.5
Sex ratio			57.6				42.4	100

Blue Whale, January.

B.L. \ Sex	Male Imm.	Male Mat.	Male Total	Female Imm.	Female Mat. Pre.	Female Mat. Rest.	Female Total	Total
67	2		2					2
8	1		1					1
9	0		0					0
70	2		2	3			3	5
1	3		3	5			5	8
2	2	3	5	3			3	8
3	2	0	2	7			7	9
4	2	0	2	5			5	7
5	6	3	9	4	1		5	14
6	0	6	6	0	0		0	6
7	2	6	8	0	0	1	1	9
8		0	10	1	1	0	2	12
9		5	5	2	0	1	3	8
80		5	5	1	1	0	2	7
1		5	5		2	1	3	8
2		5	5		4	0	4	9
3		4	4		2	1	3	7
4		0	0		4	1	5	5
5		2	2		2		2	4
6					2		2	2
7					0		0	0
8					1		1	1
9								
90								
Total	22	54	76	31	20	5	56	132
av. B. L.			76.9				77.4	77.2
Sex ratio			57.6				42.4	100

by the body length.

Blue Whale, February

B.L. \ Sex	Male			Female				
					Mat.			
	Imm.	Mat.	Total	Imm.	Pre.	Rest.	Total	Total
67								
8	1		1					1
9	0		0					0
70	2		2	1			1	3
1	4	1	5	3			3	8
2	2	1	3	1			1	4
3	1	2	3	4			4	7
4	1	1	2	2			2	4
5	1	1	2	1			1	3
6		4	4	2			2	6
7		2	2	0	1		1	3
8		6	6	0	0		0	6
9		3	3	1	0		1	4
80		0	0	1	3		4	4
1		2	2	1	2		3	5
2		6	6		4	1	5	11
3		1	1		1	0	1	2
4		1	1		1	0	1	2
5		2	2		0	0	0	2
6		1	1		1	1	2	3
7					1		1	1
8					1		1	1
9					1		1	1
90					1		1	1
Total	12	34	46	17	17	2	36	82
av. B. L.			76.9				79.0	77.8
Sex ratio			56.1				43.9	100

Blue Whale, March

B.L. \ Sex	Male			Female				
					Mat.			
	Imm.	Mat.	Total	Imm.	Pre.	Rest.	Total	Total
67								
8								
9								
70	2		2					2
1	1		1					1
2	0		0					0
3	1		1					1
4		1	1					1
5		0	0	1			1	1
6		1	1	1			1	2
7		0	0		1		1	1
8		1	1		0		0	1
9		0	0		0		0	0
80		1	1		0		0	1
1		0	0		0		0	0
2		0	0		1		1	1
3		2	2		1		1	3
4		0	0				0	0
5		0	0				0	0
6		1	1				0	1
7							0	0
8							0	0
9							0	0
90						1	1	1
Total	4	7	11	2	3	1	6	17
a.v. B.L.			76.7				80.5	78.1
Sex ratio			64.8				35.2	100

Table 4. (cont.)

2. Fin whale, whole season.

B.L. \ Sex	Male				Female						Total
						Mat.					
	Imm.	Mat.	u.k.	Total	Imm.	Pre.	Rest.	Lact.	u.k.	Total	Total
55	1			1							1
6	0			0							0
7	1			1							1
8	1			1							1
9	0			0	1					1	1
60	6	5		11	8					8	19
1	8	13		21	15		1			16	37
2	13	36		49	21	3	1			25	74
3	14	74		88	28	4	0			32	120
4	7	149	1	157	19	11	4			34	191
5	8	208	2	218	28	19	2		1	50	268
6	3	255	4	262	26	23	9		0	58	320
7	3	224	0	227	17	41	13		0	71	298
8		175	0	175	4	72	13		1	90	265
9		117	1	118	6	82	19	1	1	109	227
70		73		73	3	101	26	0	0	130	203
1		32		32	2	115	30	1	1	149	181
2		10		10		113	21		1	135	145
3		2		2		88	25		0	113	115
4		0		0		45	22		1	68	68
5		0		0		26	9			35	35
6		1		1		13	4			17	18
7						3	2			5	5
78						3	1			4	4
Total	65	1374	8	1447	178	762	202	2	6	1150	2597
a. v. B.L.				66.2						69.6	67.7
Sex ratio				55.7						44.3	100

Fin whale, January.

B.L. \ Sex	Male				Female						Total
						Mat.					
	Imm.	Mat.	u.k.	Total	Imm.	Pre.	Rest.	Lact.	u.k.	Total	Total
55											
6											
7	1			1							1
8	0			0							0
9	0			0	1					1	1
60	3	1		4	3					3	7
1	3	2		5	5					5	10
2	6	8		14	2	2				4	18
3	6	24		30	12	3				15	45
4	1	60		61	4	7	3			14	75
5	4	84	2	90	9	9	0			18	108
6	1	89	2	92	10	8	3			21	113
7	2	82		84	5	21	4			30	114
8		81		81	4	27	3			34	115
9		58		58	2	33	5		1	41	99
70		32		32	2	36	10			48	80
1		22		22	1	49	11			61	83
2		4		4		58	7			65	69
3		2		2		41	11			52	54
4		0		0		21	11			32	32
5		0		0		15	6			21	21
6		1		1		7	2			9	10
7						1	2			3	3
78						1	1			2	2
Total	27	550	4	581	60	339	79	0	1	479	1060
a. v. B.L.				66.5						70.0	68.1
Sex ratio				54,8						45.2	100

Table 4. (cont.)

Fin whale, February.

B.L. \ Sex.	Male				Female						
						Mat.					
	Imm.	Mat.	u.k.	Total	Imm.	Pre.	Rest.	Lact.	u.k.	Total	Total
55	1			1							1
6	0			0							0
7	0			0							0
8	1			1							1
9	0			0							0
60	3	4		7	4					4	11
1	4	7		11	9		1			10	21
2	6	21		27	16	1	1			18	45
3	8	46		54	14	1	0			15	69
4	5	85		90	13	4	1			18	108
5	4	108		112	17	10	1		1	29	141
6	2	150	2	154	15	13	5		0	33	187
7		127		127	12	20	8		0	40	167
8		77		77	0	44	9		1	54	131
9		48		48	4	47	11	1	0	63	111
70		36		36	1	59	13	0	0	73	109
1		9		9	1	56	16	1	0	74	83
2		6		6		52	13		1	66	72
3						42	13		0	55	55
4						22	9		1	32	32
5						11	3			14	14
6						6	2			8	8
7						2				2	2
8						2				2	2
Total	34	724	2	760	106	392	610	2	4	160	1370
a. v. B.L.				66.0						69.3	68.3
Sex ratio				55.5						44.5	100

Fin whale, March.

B.L. \ Sex.	male				Female						
						Mat.					
	Imm.	Mat.	u.k.	Total	Imm.	Pre.	Rest.	Lact.	u.k.	Total	Total
55											
6											
7											
8											
9											
60					1					1	1
1	1	4		5	1					1	6
2	1	7		8	3					3	11
3	0	4		4	2					2	6
4	1	4	1	6	2					2	8
5	0	16	0	16	2		1			3	19
6	0	16	0	16	1	2	1			4	20
7	1	15	0	16		0	1			1	17
8		17	0	17		1	1			2	19
9		11	1	12		2	3			5	17
70		5		5		6	3			9	14
1		1		1		10	3		1	14	15
2						3	1			4	4
3						5	1			6	6
4						2	2			4	4
5											
6											
7											
3											
Total	4	100	2	106	12	31	17	0	1	61	167
a. v. B.L.				66.1						69.1	67.4
Sex ratio				63.5						36.5	100

Table 4. (cont.)

3. Humpback whale.

B.L. \ Sex.	Male			Female				
					Mat.			
	Imm.	Mat.	Total	Imm.	Pre.	Rest.	Total	Total
36				1			1	1
7				0				0
8	1	2	3	3	1		4	7
9		2	2	1			1	3
40		3	3		1		1	4
1		1	1		2		2	3
2		2	2		1		1	3
3		0	0		2	1	3	3
4		3	3		2	1	3	6
5		1	1		0	1	1	2
6		1	1		3	0	3	4
7						0	0	0
48						1	1	1
Total	1	15	16	5	12	4	21	37
av. B.L.			41.3				42.0	41.7
Sex. ratio			43.2				56.8	100

4. Sperm whale, by season.

B.L. \ Sea.	Whole season
40	1
1	3
2	12
3	12
4	40
5	43
6	56
7	81
8	101
9	135
50	140
1	118
2	105
3	72
4	27
5	10
56	5
Total	961
av. B.L.	49.2

B.L. \ Sea.	Nov.	Dec.	Jan.	Feb.
40				1
1	1	1		2
2	7	3		4
3	4	3	1	12
4	17	11	0	6
5	17	19	1	6
6	20	25	5	14
7	16	48	3	11
8	31	54	5	14
9	24	88	9	13
50	32	86	9	7
1	23	84	4	3
2	15	81	6	2
3	9	59	2	
4	4	23		
5		10		
56		5		
Total	220	600	45	96
av. .BL.	48.2	49.9	49.2	47.4

5. Sperm whale, by area.

B.L. \ Area	I	II	III	IV	V
40			1		
1		1	2		
2	5	4	2	1	
3	4	2	5	0	1
4	15	11	13	1	0
5	16	7	11	9	0
6	19	7	16	10	4
7	18	12	27	21	3
8	25	23	26	21	6
9	21	33	27	45	9
50	18	29	31	48	14
1	14	20	25	46	13
2	15	12	15	49	14
3	11	5	12	36	8
4	2	3	6	15	1
5	1		1	6	12
6	1			4	
Total	185	169	220	312	75
av. B.L.	48.1	48.7	48.6	50.4	50.3

Table 5. Whales caught by species, sex and groups of size.

Blue whale

Nos. and the rate / Year / Group		Numbers						Ratio					
		1946 ~47	1947 ~48	1948 ~49	1949 ~50	1950 ~51	1951 ~52	1946 ~47	1947 ~48	1948 ~49	1949 ~50	1950 ~51	1951 ~52
Group	1 (und. 70 ft.)	23	9	5	1	6	14	3.3	1.3	0.8	0.1	2.2	6.0
,,	2 (71-85 ft.)	634	639	583	763	241	205	91.0	90.0	92.4	93.4	88.9	88.7
,,	3 (over 8 ft.)	33	62	43	53	24	12	4.8	8.7	6.8	6.5	8.9	5.3
Total		690	710	631	817	271	231	100.0	100.0	100.0	100.0	100.0	100.0
	imm. (und. 73 ft.)	85	28	30	40	13	33	23.0	8.7	7.7	7.2	10.1	24.8
Male	mat. (over 74 ft.)	284	310	361	517	116	100	77.0	91.3	92.3	92.8	89.9	75.2
	total	369	338	391	557	129	133	100.0	100.0	100.0	100.0	100.0	100.0
	imm. (und. 77 ft.)	131	71	44	57	51	47	40.8	19.1	18.3	21.9	35.9	48.0
Female	mat. (over 78 ft.)	190	301	196	203	91	51	59.2	80.9	81.7	78.1	64.1	52.0
	total	321	372	240	260	142	98	100.0	100.0	100.0	100.0	100.0	100.0

Fin whale

Nos. and the rate / Year / Group		Numbers						Ratio					
		1946 ~47	1947 ~48	1948 ~49	1949 ~50	1950 ~51	1951 ~52	1946 ~47	1947 ~48	1948 ~49	1949 ~50	1950 ~51	1951 ~52
Group	1 (und. 55 ft.)	2	0	0	0	2	1	0.4	0.0	0.0	0.0	0.1	0.0
,,	2 (56-65 ft.)	217	110	237	283	556	712	45.8	18.1	23.4	26.8	27.1	27.4
,,	3 (over 66 ft.)	255	498	775	773	1492	1884	53.8	81.9	76.6	73.2	72.8	72.6
Total		474	608	1012	1056	2050	2597	100.0	100.0	100.0	100.0	100.0	100.0
	imm. (und. 62 ft.)	54	6	43	36	117	84	21.6	2.3	8.8	5.8	10.7	5.8
Male	mat. (over 63 ft.)	194	257	445	583	980	1363	78.4	97.7	91.2	94.2	89.3	94.2
	total	250	263	488	619	1097	1447	100.0	100.0	100.0	100.0	100.0	100.0
	imm. (und. 64 ft,)	72	13	39	33	104	116	32.1	3.8	7.4	7.6	10.9	10.1
Female	mat. (over 65 ft.)	152	332	485	404	849	1034	67.9	96.2	92.6	92.4	89.1	89.9
	total	224	345	524	437	953	1150	100.0	100.0	100.0	100.0	100.0	100.0

Humpback whale

Nos. and the rate / Yera / Group		Numbers			Ratio		
		1949~50	1950~51	1951~52	1949~50	1950~51	1951~52
Group	1 (und. 35 ft.)	0	0	0	0.0	0.0	0.0
,,	2 (36-45 ft.)	57	7	32	85.1	77.8	86.3
,,	3 (over 46 ft.)	10	2	5	14.9	22.2	13.7
Total		67	9	37	100.0	100.0	100.0
	imm. (und. 38 ft.)	0	0	3	0.0	0.0	18.7
Male	mat. (over 39 ft.)	24	2	13	100.0	100.0	81.3
	total	24	2	16	100.0	100.0	100.0
	imm. (und. 40 ft.)	8	1	7	18.6	14.3	33.3
Female	mat. (over 41 ft.)	35	6	14	81.4	85.7	66.7
	total	43	7	21	100.0	100.0	100.0

Table 6. Rate of pregnancy, by the season.

1. Blue whale.

Year		December		January		February		March		Total
		Former half	Latter half	Former half	Latter half	Former half	Latter half	Former 1st D.	Latter half	
av. in 1946~50	(1) Mat. Famale (2) Preg. 〃 (3) Rate of pre.	53 35 66.0	195 120 61.5	150 79 52.7	158 82 51.9	117 64 54.7	118 52 44.1	46 14 30.4	9 4 44.4	846 450 53.2
1950~51	(1) (2) (3)		10 8 80.0	10 3 30.0	24 11 45.8	16 6 37.5	9 3 33.3	11 7 63.6		80 38 47.5
1951~52	(1) (2) (3)			25 20 80.0		19 17 89.5		4 3 75.0		48 40 83.3

2. Fin whale

Year		December			January			February			March			Total
		Form. half		Latter half	Form. half		Latter half	Form. half		Latter half	Form. half		Latter half	
		1st D.	2nd D.	3rd D.	1st D.	2nd D.	3rd D.	1st D.	2nd D.	3rd D.	1st D.	2nd D.	3rd D.	
av. in 1946~50	(1) (2) (3)	10 4 40.0		106 67 63.2	201 131 65.2		286 176 61.5	409 151 36.9		153 48 31.4	127 41 32.3			1292 618 47.8
1950~51	(1) (2) (3)			142 112 78.9	150 109 72.7		135 80 59.3	145 104 71.7		122 72 59.0	93 48 51.6			787 525 66.7
1951~52	(1) (2) (3)				135 118 87.4	130 96 73.8	153 125 81.7	167 133 78.7	219 171 78.1	114 88 77.2	48 31 64.5			966 762 78.9

3. Humpback whale.

		December		January		Feb.	Total
		Former half	Latter half	Former half	Latter half	Former half	
1949~50	(1) (2) (3)		34 31 91.2	6 6 100.0			40 37 92.5
1950~51	(1) (2) (3)					6 5 83.3	6 5 83.3
1951~52	(1) (2) (3)					16 12 75.0	16 12 75.0

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Hermaphroditism in a Dolphin (*Prodelphinus caeruleo-albus*)

By

MASAHARU NISHIWAKI

(Received Feb. 20, 1953)

Although there are many reports on the hermaphroditism in mammals, it does not seem that any case has ever been reported in whales, I suppose. I report here a case which was recently by chance.

As a part of my study on the stocks of various whale species, I have been seeking for a method of determining the age of toothed whales. It is wellknown that the tooth of these whales shows in its section a peculiar structure comparable to the grain of the wood. The idea occurred to me that this structure might be utilized as the age mark. For the purpose of varifying the varidity of this idea, I selected the dolphin (*Prodelphinus caeruleo-albus*) as the material, and have been collecting in the field the data on body length, development of gonads, condition of teeth, etc. from large numbers of individuals. This species is caught in a great number in the coastal waters of Japan.

In the course of this study, I examined about 1,200 individuals of this dolphin which were caught by the "driving-in" method at Kawana, Izu peninsula, Shizuoka Pref., on December 6, 1952. It was among this material that hermaphrodite, 231 cm. in body length, was found.

It is my rule in the field survey to measure body length and determine the sex of every individual, and examine the gonads and collect the teeth of only those individuals for which such data seem necessary: the body length is read to the nearest 5 or 10 cm. and the sex is determined from the appearance of the external genital organs. According to this procedure, the individual in question was first recorded as a female of 230 cm. As this body length was considerably great for a female of this species and well exceeded the average at sexual maturity, I thought to examine its corpora lutea. Through a median incision made on its belly, I inserted my hand into the abdominal cavity and felt for ovaries. But what I felt were the testes, not the ovaries.

Fig. 1 is the photograph of the urino-genital system of this individual. The external genital organs are perfectly those of the normal female of this species: neither the clitoris nor the vulva show anomaly in their shape, size, and relative position to the anus.

The upper part of the vagina terminates in the normal manner in the uterus, which gradually shrinks towards the upper part. Ligaments suspend the uterus from a pair of gonads, which are the testes instead of the ovaries.

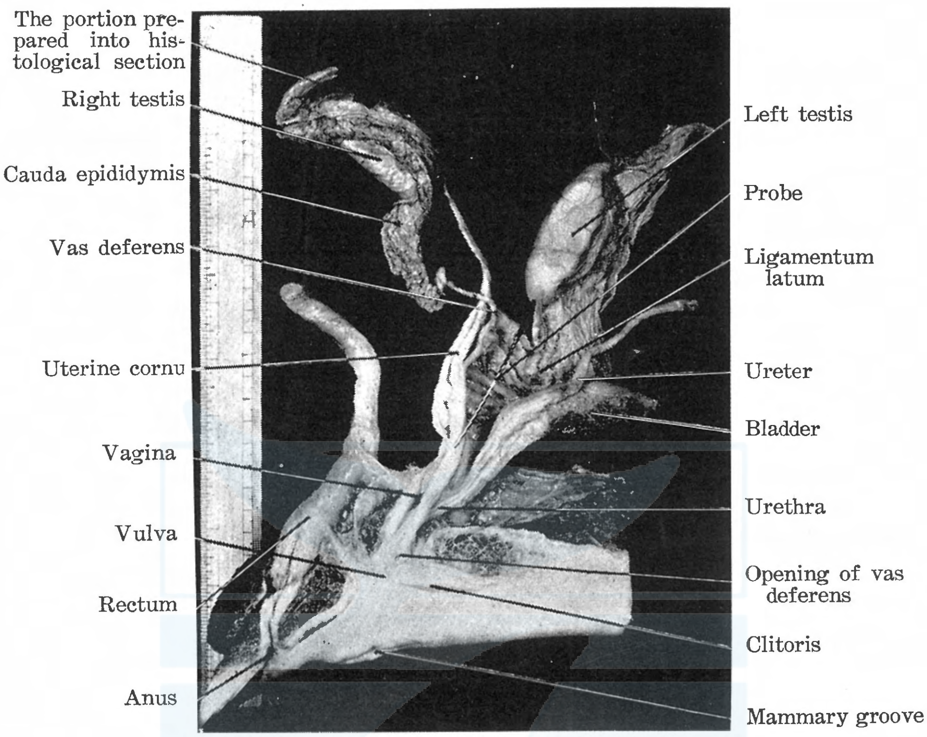

Fig. 1. Urino-genital system of a hermaphrodite of the dolphin.

The testes are more rounded in shape, having a somewhat longer minor axis and a much shorter major axis, compared with those of the sexually mature male of the similar body length. But they weighed almost as much as the testes of the normal male, i. e. about 50 g. each.

To either testis is attached the epididymis, which is longer like in the normal male, than the major axis of the testis. From this organ downward leads the vas deferens: via a course clearly apart from the passage of the oviduct in the normal female, it reaches the middle part of the vagina, to which it adheres for a short distance, then shifts anteriorly, adheres to the urethra, and finally discharges to the outside on either side of the opening of the urethra.

In order to determine the maturity of the testes, a small portion of the right testis was prepared into sections (Fig. 2). As is clear from this figurs, there were found many spermatozoa. This individual is, therefore, a male so far as the function of the gonad is concerned, while its external genital organs are those of the female.

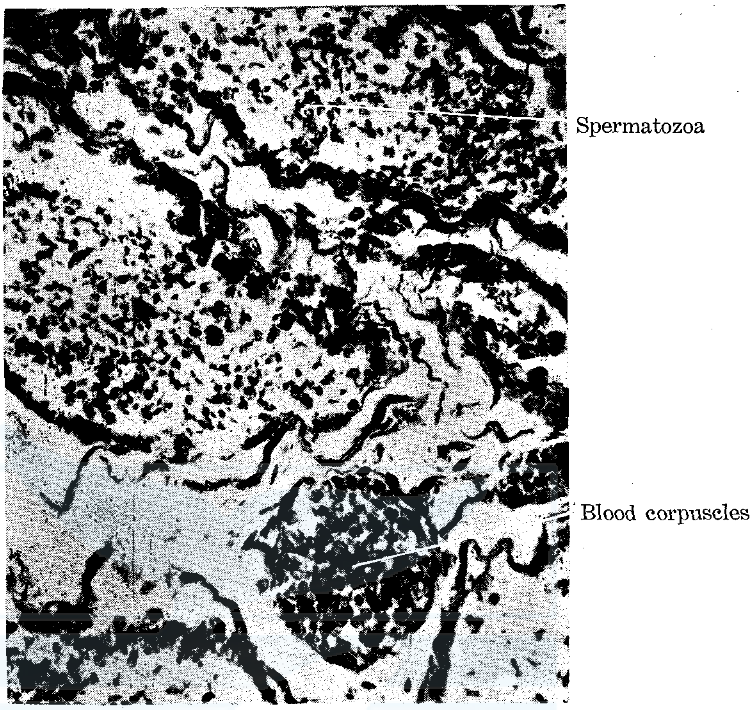

Fig. 2. A section of the right testis of a hermaphroditie of the dolphin; showing the presence of spermatozoa. (× 600)

The measurement of various external body parts of this hermaphrodite are shown in Fig. 3.

The body proportions derived from these data resemble the values of the normal male in the anterior part of the body (the head and thorax).

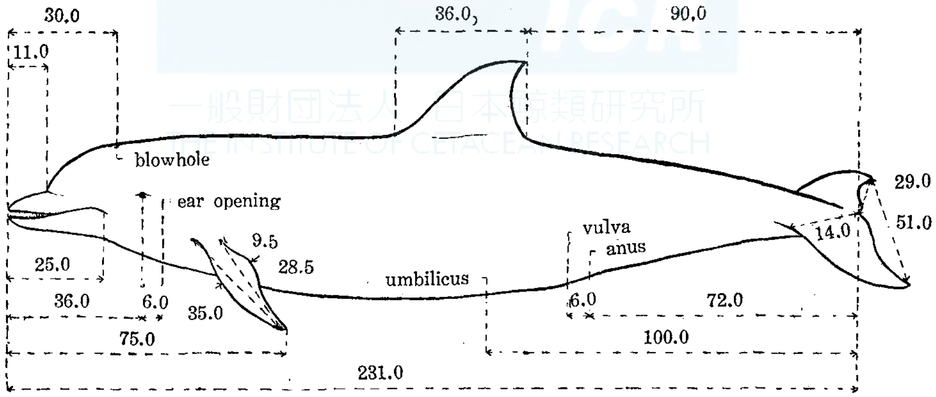

Fig. 3. Measurements of external body parts of a hermaphrodite of the dolphin (in cm.)

In the posterior part of the body (the abdomen and tail), however, they resemble the values of the normal female; this is particularly the case in the distances from the notch of tail-flukes to the anus and to the reproductive aperture. As body proportion data for normal individuals are still scanty, above statements may be subjected to correction when more data are accumulated.

It has been a common custum among the whalers of the world to distinguish the sexes of the whales they caught. But this is done usually by observing the external organs; the internal genital organs are examined only in those relatively few individuals which are handred in special biological investigations. Therefore, there is some possibility that the hermaphrodites of such a degree as the present case were captured but left unnoticed. Then, the hermaphroditism may not be very rare in whales, although no case has ever been reported until the present one.

In any case, the present finding has aroused my interest considerably, though it has little bearing upon the study of whale stocks. If any of the readers would kindly let me known of his observation on this sort of anomaly in whales, I should appreciate it very much.