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On the Cardiac Nerves of Some Cetacea, with Special Reference to Those of *Berardius Bairdii Stejneger*

BY

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The innervation of the mammalian hearts has very often become the subject of profound and extensive studies in the anatomy as well as in the physiology, and among a great many anatomists, who have devoted themselves to this problem, especially *His jr.* (1891), *Schumacher* (1902), *Perman* (1924), and *Worobiew* (1928) are noted for their very fruitful researches. The detailed works of the last mentioned author and his collaborators, *Anufriew, Belowa, Schurawlew, Wolhynski,* etc., seemed to have left nothing important in the gross anatomy of the cardiac nerves. Later, *Nonidez* (1939) made still a remarkable progress, as he reported the possibility of discerning stain-technically between sympathetic and parasympathetic fibers in the dog's heart, and quite recently *Nomura* by his microscopical works (1951, 1952) on the cardiac nerves of the mouse contributed much upon the problem. *Nomura* as well as *Glomset* (1940) insisted upon the abundance of nerve fibers in or near the so-called conduction system of *His jr.* and *Tawara.*

The aim of the present paper lies mainly in mentioning my own observations on the cardiac nerves in a fetus of the Pacific beaked whale, *Berardius bairdii Stejneger*, for they contain some very different points from the remarks of previous investigators, and though the materials here treated are yet scanty, the results have, I guess, a greater meaning than they at first look. Afterwards the cardiac nerves in two other sorts of the Cetacea, *Balaenoptera borealis Lesson* and *Prodelphinus caeruleoalbus Meyen*, will be described, comparing with *Berardius*, as the cardiac innervation of the Cetacea has attracted till today seemingly very few attention of the anatomists.

Material and Method

The cetologically very interesting species, *Berardius bairdii Stejneger* (Japanese name: *Tuchi-kujira*), haunts our sea near Awa, the southern province of Chiba Prefecture from June to September, mostly in summer. The adult whales attain usually the body length of 10 m. Two fishery companies are erected to perform works for catch and utilization of this beaked whale. The research materials were given us from these companies.

The Sei whale (Japanese name: *Iwashi-kujira*) treated in this paper was caught near the Bonin Islands, and so it may belong to the *Bryde*'s whale, *Balaenoptera brydei*, rather than to *Balaenoptera borealis* (*H. Omura* et al, 1952). But as this problem of identification is not yet fully settled, the more common nomination will be adopted here.

The dolphin, *Prodelphinus caeruleoalbus Meyen* (Japanese name: *Suji-iruka*), is very abundantly seen and caught at Izu Peninsula in winter (*Ogawa*, 1937). The villages Kawana and Arari are famous for the dolphin fishery, and we got the materials there.

In the present work nearly always fetal hearts of them were dissected with naked eye and without any staining. Only sometimes the adult hearts were examined and a few microscopical preparations stained with hematoxylin-eosin or by *van Gieson*'s method or by the *Bielschowsky*'s method were also employed.

The fetal hearts are very appropriate for the observation of the nerves, for these are relatively well developed, and clearly visible owing to scantiness of the adipose tissue and poor existence of the connective tissue. Besides, the size is fitted for our treatment, the adult hearts of *Balaenoptera* and *Berardius* being too bulky to handle for studying.

Observations

Berardius bairdii Stejneger (Figs. 1, 2, and 3)

One fetal heart, which is ca. 13,5 cm long measured straight from basis to apex cordis, and ca. 14,0 cm wide in the transverse direction at the height of the coronary sulcus, was examined. The heart had been taken out by another person from a fetus of *Berardius*, the body length of which was about 1.8 m, and consulting the size it must be in the later period of pregnancy.

Nearly the whole heart is undamaged, showing only a little wound limited to the base of the left pulmonary vein. The cut out material includes, besides the heart itself, the aortic arch, the *Botallo*'s duct, the pulmonary artery with its right and left rami, the lower portion of the trachea with bilateral bronchi, a portion of oesophagus with vagi attached to its wall, and some parts of thymus remaining near the heart. The stem of the pulmonary artery is ca. 3,5 cm wide, while the ascending aorta is ca. 5,5 cm in its greatest transverse diameter.

The left vagus, which is a large trunk of ca. 5 mm thickness, while descending on the ventral surface of the aortic arch, dispatches at the height a little above the upper end of the *Botallo*'s duct a remarkable branch (A) mediocaudally (figs. 1 and 2). This branch seems to consist mostly of vagal fibers, but partly to contain sympathetic ones, as the vagus trunk shows anastomosis with the left sympathetic near the origin of this branch and in addition the branch (A) itself receives a few twigs from the left sympathetic.

The further course and distribution of A are noteworthy, for it

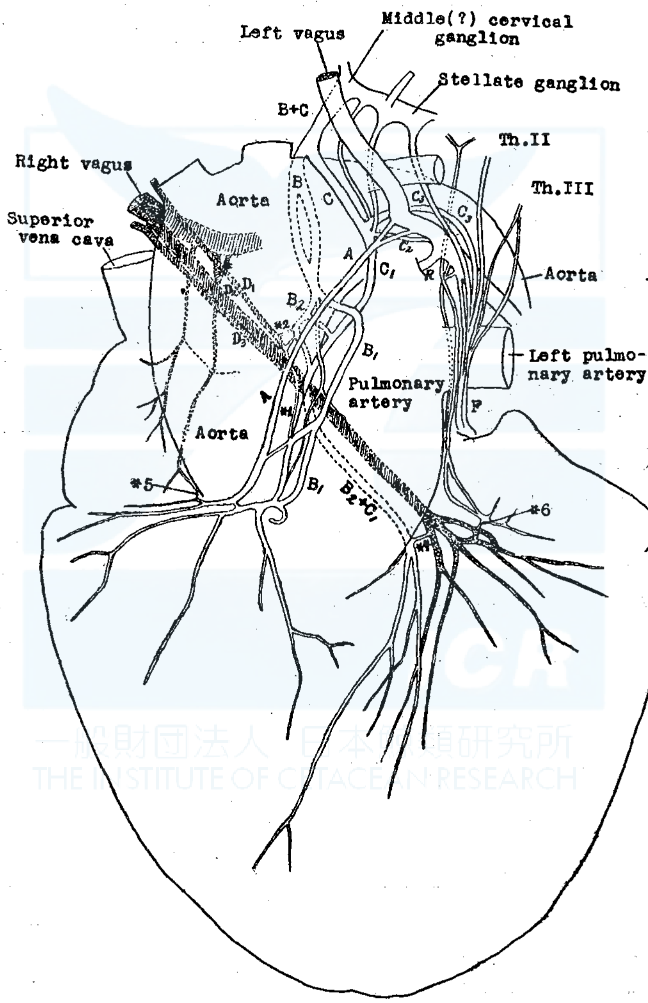

Fig. 1. Cardiac nerves of *Berardius bairdii* (anterior view)
Dark···Right vagosympathetic

runs down and to the right side always attached to the ventral surface of the ascending aorta, until it reaches above the beginning part of the right coronary artery. On the way it shows two small connections with sympathetic twigs coming from B, which will be related later. The branch (A) is distributed, after dividing into many small rami, to the upper lateral portion of the ventral wall of the right ventricle. Anastomosis occurs very few between this branch and the nerves existing on the ventral surface of the right atrium (fig. 1, *5). It is important, that this A, departing from the left vagus and receiving twigs from the left sympathetic nerve, undergoes during its whole course no large connection with the right nerves, definitely innervates a certain part of the right ventricle.

Next the stout sympathetic branches (B and C) will be described (figs. 1 and 2). Both start, at first being united in a common trunk, downwards from the middle cervical ganglion of the left side. This trunk bifurcates at the height of the upper margin of the aorta into two thick branches, anterior (C) and posterior (B).

The branch (B) descends behind the aorta in contact with the left ventrolateral surface of the trachea and reaches the right side of the *Botallo*'s duct, after passing in front of the right pulmonary artery. Behind the aorta it is divided temporarily into two portions, both of which unite together again. Then it ramifies into two branches, right (B_2) and left (B_1).

B_1 crosses over the later to be mentioned C_1, where very few fibers seem to be exchanged between B_1 and C_1 at the crossing, and then proceeds forwards and to the right side on the right upper surface of the pulmonary artery. Precisely persuing the rami and ramuli of B_1, we know that this nerve reaches solely the conus arteriosus of the right ventricle, running there subepicardially in downward direction. On the way it receives a small twig (*1) apparently coming from the right nerves. But as the right nerves show just at the origin of this twig two small anastomoses (*2, *3) with the left sympathetic nerve (B_2), it is not decided, whether the twig in question conveys fibers originating from the right or from the left nerve.

B_2 sends off at first a small ramus, which crosses over C_1 dextral to B_1, where no exchange of fibers is found between them, and then goes down and forwards on the right upper surface of the pulmonary artery. It then courses forwards under B_1 and disappears as fine ramuli from sight at the basis of the pulmonary artery.

The stem of B_2 is strongly bent to the right side, and after dispatching a branch forwards to unite with C_1, shows two small anastomoses with D_1 coming from the right side. These two anastomoses (*2, *3) are worthy of special attention, for in this fetal heart direct communication between the nerves of both sides reaching in front of the transverse sinus of the pericardium occurs only at these places, at any rate in a very small amount. The stem of B_2 goes then to the left caudal direction and makes with C_1 a large trunk (B_2+C_1), which

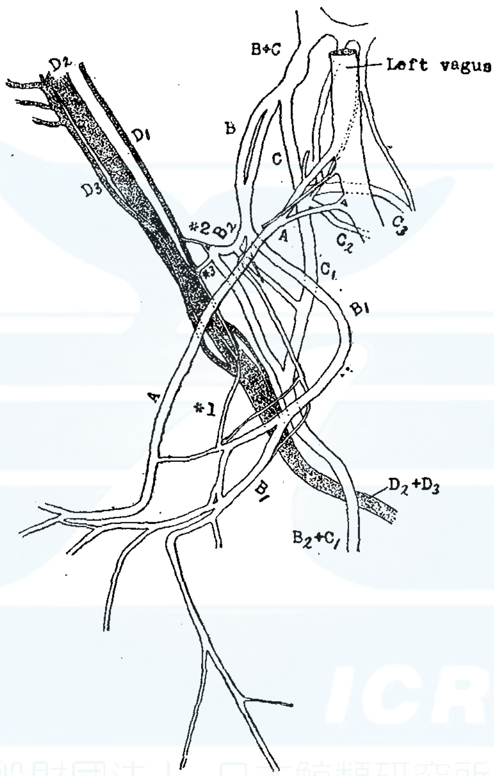

Fig. 2. Plexus cardiacus superficialis of *Berardius bairdii*
Dark···Right vagosympathetic

courses behind the pulmonary artery obliquely from right upper to left lower and reaches the uppermost portion of the interventricular groove. During its course posterior to the pulmonary artery no direct connection exists between this trunk (B_2+C_1) and the later to be mentioned D_2+D_3. Branches of the trunk (B_2+C_1) are followed to the medial part of the ventral wall of the right ventricle adjacent to the interventricular groove, in other words, to a part of the conus arteriosus, running in apical direction from the left upper region (fig. 1).

The other thick branch (C) descends anterior to the aortic arch and ramifies into three (C_1, C_2, C_3). One of them (C_2), comparatively the smallest, goes into the stem of the left vagus at a level between the origin of A and the recurrens (fig. 1, R). Another branch (C_3), larger than C_2, turns to sinistral and reaches together with other left sympathetic nerves and with a branch from the left vagus, after descending anterior to the left pulmonary artery, the wall of the left atrium to continue into F, which will be related afterwards.

The thickest branch (C_1) makes the stem of C, attains the right side of the *Botallo*'s duct and then the right upper surface of the pulmonary artery. Here it is crossed over at first by B_1, later by a branch of B_2, while it courses to the right lower direction. Then it is fused with the stem and a branch of B_2, building so a large trunk (B_2+C_1), the course and destination of which were mentioned already.

In short, the conus arteriosus of the right ventricle is innervated mostly, if not all, by rostrally originating sympathetic fibers of the left side. These fibers descend partly in front of, partly behind the aorta and reach the destination passing dextral, and partially sinistral to the basal portion of the pulmonary artery.

On the other hand, we see directly behind the aorta three nerves (D_1, D_2, D_3) of various sizes, all coming from the right side, at first almost parallel to each other, in an oblique direction on the right ventrolateral surface of the trachea (figs. 1 and 2···dark drawn). Though owing to incompleteness of the material, their origins from the vagus and from the sympathetic trunk are not definitely determined, the largest and middle placed D_2 contains quite certainly both vagal and sympathetic fibers, while the much smaller D_1 and D_3 consist nearly exclusively of sympathetic fibers.

D_1 lies a little upper than D_2 and shows at the level of the lower margin of the aortic arch two small anastomoses, proximal (*2) and distal (*3), with B_2, as these were already mentioned in relation to B_2. At the distal anastomosis D_1 unites with D_2 and just from the place of this fusion a thin nerve extends down and forwards, on the way receiving a small branch from D_2, and runs through the narrow space between the aorta and the pulmonary artery to reach further a branch of B_1. This thin nerve (*1) was accounted for already in the description of B_1. It is the only nerve, which apparently belongs to the right nerves (D_1, D_2), and is distributed further together with the left nerves (B_1). But it is difficult at present to decide, whether its fibers originally belong to the right or to the left nerves, when one considers the small anastomoses between B_2 and D_1.

D_2 is a stout, cylindrical nerve trunk and unites with the slightly lower running D_3 in front of the right pulmonary artery. The large trunk (D_2+D_3), to which D_1 also might be mixed ($D_2+D_3+D_1$?), proceeds behind the pulmonary artery obliquely downwards and to the left side and reaches above the left coronary artery, where it is divided into three. It is quite remarkable, as pointed out above, that behind the pulmonary artery no direct connection takes place between D_2+D_3 and B_2+C_1.

Branches of D_2+D_3, after repeated ramifications, go partly into the interventricular groove, partly proceed into the medial part of the left coronary sulcus, and innervate the ventral wall of the left ventricle. One can see many of them run subepicardially either from the interventricular groove or from the medial portion of the coronary sulcus, generally to the left caudal direction. They never follow the branchings of the coronary artery, as the independency between nerves and vessels is easily proven also in all other parts of the heart.

With enthusiasm I looked for anastomosis between D_2+D_3 and B_2+C_1 in this region, but found only a small one at the upper end of the interventricular groove (*4). Besides, a twig deviates from the main trunk of $D_2+D_3(+D_1?)$ to attain the lower part of the ventral surface of the left atrium, but it sinks for the most part into the depth of the coronary sulcus to be delivered with other branches of D_2+D_3 to the lateral marginal part of the left ventricle. Only a tiny anastomosis was seen between this portion and the nerves on the ventral surface of the left atrium (*6).

Observing as the next step the heart from behind (fig. 3), the right and left relations of the cardiac nerves are quite unlike to those of the anterior view. Along the superior vena cava there are two middle sized nerves coming from the right side and consisting probably for the most part of the sympathetic fibers (D_4 and D_5). One of them (D_4) descends behind this vein and after ramification partly unites with D_5, partly attain the terminal sulcus. The sinus node, if this be existent, must receive this branch, though I could not ascertain the presence of the sinus node in *Berardius*.

D_5 descends along the left side of the superior vena cava, and some of its branches reach the ventral surface of the right atrium, making here plexus with a portion of branches arisen from D_6. This plexus sends twigs to the right auricula and to the terminal sulcus. The sinus node may receive these twigs too.

On the dorsocranial surface of the right atrium, more sinistral than the orifice of the superior vena cava a remarkable nerve plexus (*7) exists directly ventrocaudally to the right pulmonary artery. It is made chiefly by branches of D_5 and D_6. One finds just in its neighbourhood a concentration area of the atrial musculature, corresponding probably to the septal raphe reported by *Papez* (1920). D_6 comes out

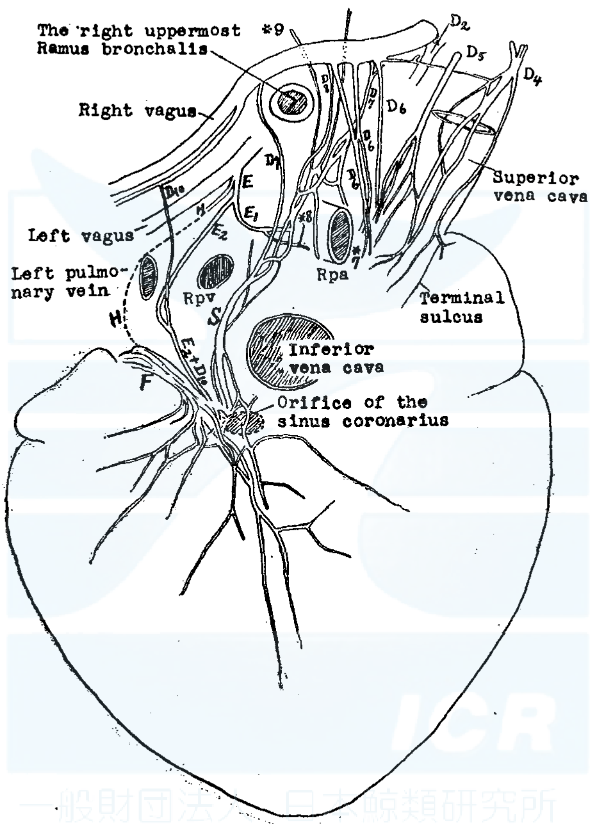

Fig. 3. Cardiac nerves of *Berardius bairdii* (posterior view)
Rpa···Right pulmonary artery
Rpv···Right pulmonary vein

more caudally than D_2 from the right vagus as three separated nerves, goes down partly to the ventral surface of the right atrium, partly to the plexus on the dorsocranial surface of the right atrium (*7).

Two other branches (D_7 and D_8) start also from the right vagus nearly at the same level as D_6, but more medially than this. D_7 shows at the origin an anastomosis with the sympathetic nerve. D_7 and D_8 descend posterior to the right pulmonary artery, except a small portion of D_7, which goes to the ventral surface of the atrium. They make behind this artery a remarkable nerve plexus (*8), to which besides them the left vagus and the left sympathetic send also branches very clearly. For the problem of the cardiac innervation this part surrounding the right pulmonary artery from before and behind, where the vagal and the sympathetic fibers coming from both sides meet together, seems to be the most important. The concentration area of the atrial musculature lies just beneath the plexus in question. One branch from the left sympathetic can be traced a long distance (*9) from the dorsal surface of the aorta to this plexus. Another branch belonging to the left vagus (E_1) is issued from E, which will be mentioned below. Within this plexus (*8) the nerve bundles look here and there ganglionated, and the plexus sends to the hinder and lower direction a well developed septal nerve (S), which descends through the interatrial septum to the fossula nervina of *Worobiew*.

D_9 is a branch from the right vagus, issued more caudally than D_8. It descends at first behind the uppermost ramus bronchalis and reaches further down the lower part of the remarkable nerve plexus, but it continues more distinctly to the septal nerve, apparently making its main constituent. Fibers of the septal nerve are distributed partly to the dorsal walls of the ventricles, but partly disappear from sight, sinking deeply at the left side of the orifice of the coronary sinus. In the heart of an adult *Berardius* I could prove the intimate connection of this deeply going nerve with the atrioventricular node of *Tawara*. The septal nerve shows also anastomosis with F, viz. branches from the left vagus and left sympathetic.

The left vagus sends off a fairly large branch (E) at the height a little below the recurrens. After it runs to the right lower direction for a short distance, it bifurcates, and the one branch (E_1) turning sharply to the right side enters the large plexus behind the right pulmonary artery, while the other (E_2) courses for a long distance on the surface of the left atrium, and descends to the fossula nervina a little sinistral to the septal nerve, nearly parallel to this. It anastomoses on the way with a small nerve (D_{10}) started very distally from the right vagus. At the fossula nervina the nerve (E_2+D_{10}) lies more superficially and more sinistral than the septal nerve, but further distribution of its fibers seems to be the same as that of the septal nerve.

On the dorsal surface of the left atrium a large assembly of nerve bundles (F) run obliquely along the *Marshall*'s vein. About one half of them comes down from the left stellate ganglion and from the second and third thoracic ganglia of the left side (fig. 1), while about the other half makes the continuation of C_3 and of a branch (H) of the left vagus, dispatched from this at the same level as E. All of the sympathetic and vagal nerves descend in front of the aorta, then of the left pulmonary artery, and reach the angle between the left auricula and the left pulmonary vein. Here they are contained in the plica nervina of *Worobiew*, and then proceed to the coronary sinus, on the way they give off small branches to the dorsal wall of the left atrium. From the coronary sinus branches of F after making anastomoses with the septal nerve and with E_2+D_{10} are delivered widely over the dorsal surfaces of the right and left ventricles. Some fibers seem to attain the *Tawara*'s node through the anastomosis with the septal nerve. Nerves on the ventral surface of the left atrium show also an intimate relation with the proximal part of F. Besides, a small nerve can be traced downwards from the sympathetic between the stellate and the second thoracic ganglia at first behind the aorta, then just before the left pulmonary artery to the ventral surface of the left atrium (fig. 1, not signed in the picture).

To summarize, the cardiac branches both of the vagus and the sympathetic going in front of the transverse sinus to the ventral walls of both ventricles are crossed, at least for the greatest part. They constitute the so-called superficial cardiac plexus, but in this plexus of *Berardius* anastomosis occurs in a very small amount between the nerves of both sides. On the other hand, the branches distributed to both atria and to the dorsal walls of the ventricles passing posterior to the transverse sinus, do not cross, or at least the crossing is never clearly seen. These belong to the so-called deep cardiac plexus, and in this plexus anastomosis takes place very frequently between the nerves coming from both sides. Moreover it is worthy of notice, that the conus arteriosus of the right ventricle receives chiefly sympathetic fibers coming from the left side.

In addition one can definitely say that the nerves going to the ventral walls of the ventricles depart from the stems of vagus and sympathetic at levels generally higher than those innervating the atria and the dorsal walls of the ventricles. The nervous supplies to the sinus node of *Keith* and *Flack* and to the atrioventricular node of *Tawara* will be discussed afterwards.

Balaenoptera borealis Lesson (Figs. 4 and 5)

The heart was taken out from a 120 cm long fetus of the Sei whale. It is 9,8 cm long from basis to apex cordis and 9,2 cm wide measured at the coronary sulcus. The left vagus, a 3,4 mm thick bundle descending down the neck, sends off, while it runs in front of the aortic arch a remarkable branch (A) mediocaudally. This branch makes its course to the right side always attached to the ventral surface of the aorta and reaches above the beginning part of the right coronary artery, where it communicates with a thick nerve (G) coming from the superficial cardiac plexus through the narrow space between the ascending aorta and the pulmonary artery. This plexus is built by the left sympathetic branches (B + C) and by the right vagosympathetic nerve (D). These nerves have reached here from both sides passing almost all behind the aorta. From the confluent nerve bundle (A + G) many branches are given to the ventral surface of the right ventricle inclusive of the conus arteriosus, all of them running downwards directly under the epicardium. From the complicated form of the plexus it is in this heart difficult to know, how much G conveys fibers from the right or from the left side.

The left sympathetic nerve, B and C, start from the trunk at a very high level, probably from the superior cervical ganglion and descend for the greatest part behind the aorta. Only a very small portion runs anterior to this vessel. Therefore, in comparison with *Berardius*, one might conceive almost all of them as belonging to B. B and C are divided into several branches in front of the right pulmonary artery dextral to the *Botallo*'s duct, some of them making ansae with each other, and most of them being united to the right nerves (D). One small branch of B and C shows a very noteworthy course (b). It passes at first in front of D to the right side, reaches the left concave surface of the ascending aorta and goes then further down passing behind D to the lower part of the anterior surface of the left atrium, where it unites with the most sinistral branch of D (fig. 4 a, b). It is probable that fibers of this small branch are distributed to the lateral marginal part of the left ventricle.

D lies behind the aorta as a very thick nerve arising from the right side. It is made by union of D_1 and D_2. D_1 comes out from the lower end of the right superior cervical ganglion, so is sympathetic in nature, while D_2, certainly vagosympathetic, is much larger and starts from the right vagus at the same level as the recurrens, but separately from this. Just after confluence of D_1 and D_2 a remarkable branch is given off from the dorsal part of D to the anterior surface of the right atrium (*1). This branch seems to bring the fibers corresponding to the anterior branches of D_5 and D_6 of *Berardius*, considering the destination of the fibers.

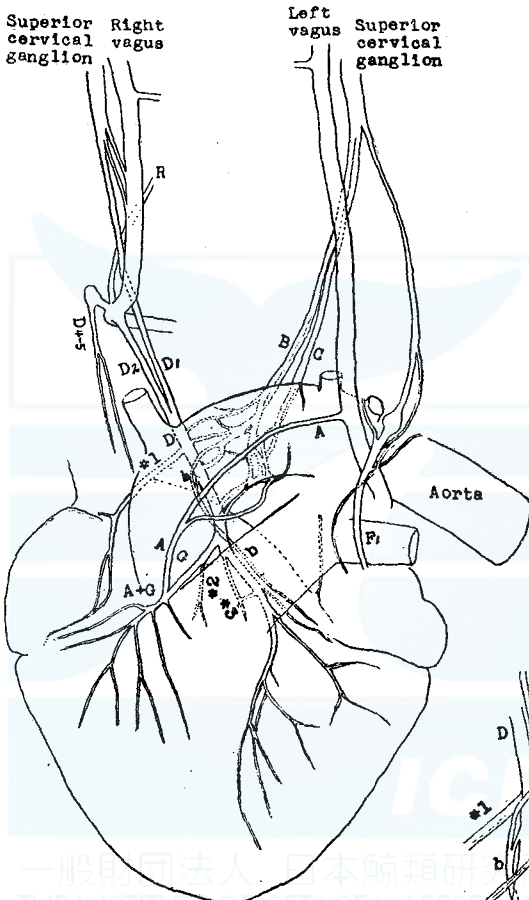

Fig. 4. Cardiac nerves of *Balaenoptera borealis* (anterior view)

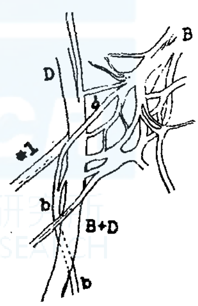

Fig. 4a. The nerve plexus just behind the aorta, in details

Behind the aorta the thick nerve D receives B and C from the left side, but as C is minimal in this case, one can call hereafter the resulted large trunk "B+D". From this B+D a thick branch (G) deviates to the right side, and connects with A, as already described.

It may be possible, though not fully proven, that G makes chiefly the continuance of B, as one can guess comparing the relation in this region between *Berardius* and *Balaenoptera*.

Small ramuli are given off from G and from B+D to the hinder circumference of the pulmonary ostium (fig. 4, *2, *3), to end probably in a part of the conus arteriosus. B and D, or simply D if the analogy with *Berardius* holds true, descend obliquely behind the stem of the pulmonary artery to the left side and reach after ramification partly the anterior interventricular groove and partly the coronary sulcus. The fibers are followed to the ventral wall of the left ventricle. It seems that none of them goes from here to the right ventricle, but many fine anastomoses are seen between nerves of the right and left ventricles on the ventral surface.

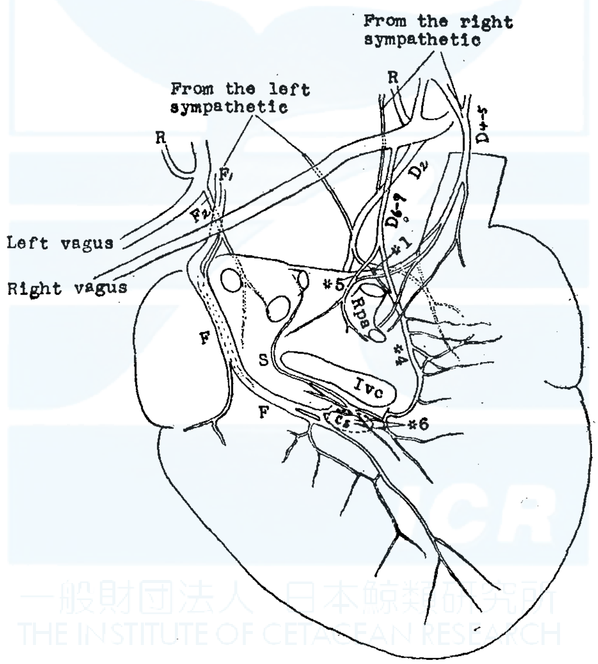

Fig. 5. Cardiac nerves of *Balaenoptera borealis* (posterior view)
Rpa···Right pulmonary artery
Ivc···Inferior vena cava
Cs····Sinus coronarius

Corresponding to D_4, D_5, D_6, D_7, D_8, D_9 of *Berardius*, the fetal heart of *Balaenoptera* has only two nerves, or better to say three, if one adds the branch of D going to the anterior surface of the right atrium. The two nerves might be called here D_{4-5} and D_{6-9}. D_{4-5}, sympathetic in nature, descends along the posterior and left surface of the superior vena cava, and is distributed mostly to the atrial wall sinistral to this vein, a few of its branches extending further into the right lung.

D_{6-9} arises from the right vagus a little below the recurrens and goes down the lateral surface of the right bronchus. Above the right pulmonary artery it is divided into two, one of which (fig. 5, *4) descends in front of this vessel, becomes attached to the surface of the atrial musculature, gives off many branches horizontally to this, and runs subepicardially on the right side of the inferior vena cava, reaching at last the medial part of the coronary sulcus, caudally to this vein. On the way it receives a small branch, which is issued from the branch of D going to the anterior surface of the right atrium (*1), and comes posteriorly after penetrating through the *Bachmann*'s bundle. The other branch (fig. 5, *5) of D_{6-9} descends behind the right pulmonary artery, undergoes an anastomosis with a branch of D_{4-5} and continues downwards in the atrial septum, partially reaching the left side of the inferior vena cava. The bundle, which corresponds topographically to the septal nerve of *Berardius,* is very poorly developed in *Balaenoptera* (S); also the nerve plexus is relatively better developed anterior than posterior to the right pulmonary artery. As to the septal nerve a great defference is perceived between *Berardius* and *Balaenoptera.*

The presence of a large assembly of nerve bundles (F) along the *Marshall*'s vein is common to both whales in question. These bundles come in *Balaenoptera* too from the left vagus and the left sympathetic. The sympathetic nerves (F_1) start from the stellate ganglion and from the 2. and 3. thoracic ganglia. They descend, making a large trunk, in front of the vagus stem and of the aorta, then anterior to the left pulmonary artery and reach the angle between the left pulmonary vein and the left auricula, giving rise here to the plica nervina of *Worobiew.*

One branch is sent off from the left vagus at the level of the recurrens, to take part in the formation of F after passing behind the pulmonary artery. The bundles of F reach mostly the coronary sinus, after giving some ramuli to the dorsal wall of the left atrium and to the marginal part of the left ventricle, and then innervate after repeated ramifications the greater part of the dorsal walls of the right and left ventricles. A portion of them sinks deeply at the left side of the orifice of the coronary sinus, to enter probably into connection with the atrioventricular node. The septal nerve (S), lying sinistral to the inferior vena cava, is small and seems to come mostly from the left vagus. It shows anastomosis with the long branch of D_{6-9} (*4), which attains here dextral to the inferior vena cava. The connection between the nerves originating from the right side and the atrioventricular node is less marked than in *Berardius*, though two small twigs (fig. 5, *6) from the long branch of D_{6-9} are tracable, sinking deeply at the right side of the coronary sinus, to the direction of the *Tawara*'s node.

Prodelphinus caeruleoalbus Meyen (Figs. 6 and 7)

The left vagus sends off mediocaudally a remarkable branch (A) at a level slightly above the aortic arch. It descends along the ventral surface of the aorta and then unites with the left sympathetic nerves (B), which have reached here behind the aorta. These sympathetic nerves are grouped into two (B_1 and B_2), both starting from the middle cervical ganglion of the left side. A joins at first with the more lateral coursing B_1, and then with the more medial running B_2.

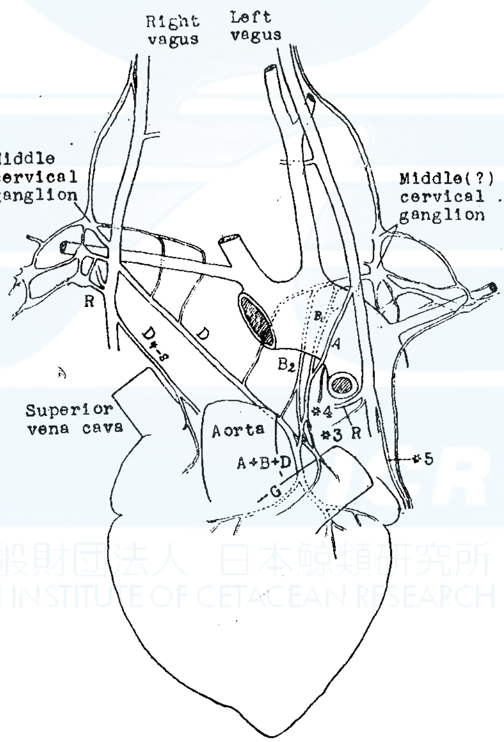

Fig. 6. Cardiac nerves of *Prodelphinus caeruleoalbus* (anterior view)

The thus formed nerve (A+B) unites then with a large trunk (D) coming posterior to the aorta from the right side. D starts from the right vagus a little above the recurrens. It must contain both vagal and sympathetic components. On its way D receives small sympathetic ramuli not only from the right but also from the left side.

The large trunk (A+B+D) gives off a branch (G), which goes through the narrow space between the ascending aorta and the pulmonary artery to the base of the right coronary artery. The larger remaining portion of A+B+D descends obliquely behind the pulmonary artery to reach partly the interventricular groove and partly the coronary sulcus, and the fibers are distributed chiefly to the ventral surface of the left ventricle. Only a very small portion attains the lower part of the ventral surface of the left atrium.

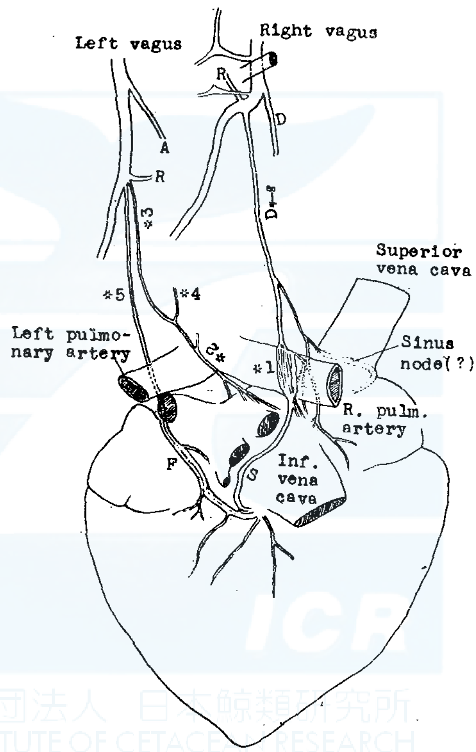

Fig. 7. Cardiac nerves of *Prodelphinus caeruleoalbus* (posterior view)

At the space between the aorta and the pulmonary artery each of B_1, B_2, and D dispatches a thin branch, in all three rami, which unite together into a single trunk, proceeding forwards on the right side of the *Botallo*'s duct to the dextrocranial surface of the pulmonary artery. This innervates probably the conus arteriosus of the right ventricle. Some small branches issued forth from the left sympathetic descend behind the aorta and innervate the ventral surface of the left atrium.

From the right vagus another remarkable branch, corresponding to D_{4-8} of *Berardius*, starts a little below the recurrens. It is about half so thick as D, and is divided while descending into two, anterior and posterior. They go partly to the ventral surface of the right atrium, partly behind the *Bachmann*'s bundle just in front of the right pulmonary artery to the septal raphe of *Papez*, but for the greater part behind the right pulmonary artery, making here a thin but broad sheet of nerve fibers closely attached to the dorsal surface of this vessel (fig. 7, *1); thence the fibers reach partly the septal raphe, partly the atrial septum to continue further down into a remarkable septal nerve (S). Just above the septal raphe, where many of the atrial musculature show the tendency to concentrate, we see well developed nerve plexuses. To these the right vagal and sympathetic fibers are brought in by D_{4-8}, while the left vagal and sympathetic fibers are conveyed by a nerve bundle (*2), which descends obliquely from upper left to lower right directly behind the bifurcatio of the right and left pulmonary arteries, and whose origins each from the left vagus and from the left sympathetic are determined clearly. The vagal component (*3) comes from the base of the recurrens; the sympathetic one (*4) belongs to the most sinistral bundles of B.

F is a large group of nerve bundles, running along the *Marshall*'s vein. It consists of the vagal and sympathetic fibers coming from the left side. The vagal branch (*5) begins nearly at the same level as the recurrens. Fibers of F are distributed partly to the dorsal wall of the left atrium, but for the greater part to the dorsal walls of the right and left ventricles. At the fossula nervina of *Worobiew* a part of F together with a portion of the septal nerve sinks deeply to the direction of the *Tawara*'s node.

Speaking in short, the cardiac nerves of *Balaenoptera* and *Prodelphinus* are considerably different from those in *Berardius*. In them the crossing of the nerves going to the ventral walls of the ventricles is not so clearly seen, except as to the branch A in *Balaenoptera*, which starts from the left vagus and innervates definitely a portion of the ventral wall of the right ventricle. In *Prodelphinus* even the vagal branch corresponding to A is lost in the superficial cardiac plexus, so its further course, whether to the right or to the left ventricle, is very difficult to ascertain. But the possibility, that also here the same relation as in *Berardius* exists, should not soon be excluded. No definite proof could be obtained against this assumption. I thought at first to have met such a proof in a small branch (b) of *Balaenoptera*, which belongs to the left sympathetic nerve and goes after a complicated detour to the left ventricle. But as its destination is certainly the transitional part between the ventral and dorsal walls of the left ventricle, this observation too never disproves the thesis.

The second problem, that the nerves ending in the atria and the dorsal walls of the ventricles start from the stems generally more caudally than the nerves going to the ventral walls of the ventricles, and moreover they are probably not crossing, holds also in *Balaenoptera* and *Prodelphinus*, though in these Cetacea the cardiac nerves especially on the right side, which descend posterior to the transverse sinus, are gathered into a small number of trunks, 2 or 3, while in *Berardius* the corresponding number is so large amounting to 10, that one can in this whale more easily determine the height of origin for each branch innervating various parts of the heart.

The third problem is relative to the nerve plexus lying near the right pulmonary artery just above the concentration area of the atrial musculature and to the septal nerve descending through the atrial septum. Concerning them there is a great difference between the toothed whales, *Berardius* and *Prodelphinus*, and the baleen whale, *Balaenoptera*. In the former the nerve plexus in question is very well developed and branches from the vagus and sympathetic of both sides are clearly traced to this plexus and an imposing septal nerve descends passing sinistral to the inferior vena cava toward the fossula nervina. Contrarily, the nerve plexus surrounding the right pulmonary artery as well as the septal nerve is meagre in *Balaenoptera*. Instead of the septal nerve, the Sei whale has a large nerve, which departs from the right vagus and descends on the dorsal surface of the right atrium passing dextral to the inferior vena cava.

To the *Tawara*'s node the left nerves go mostly through the nerve bundles running along the *Marshall*'s vein and the right nerves chiefly through the septal nerve. These relations are seen well in the toothed Cetacea, while in the Sei whale the nerve descending right to the inferior vena cava seems to substitute for the septal nerve, as to the innervation of the atrioventricular node.

Comment

It was a much impressive observation in the fetal heart of *Berardius*, that the cardiac nerves leaving the vagus and the sympathetic at relatively high levels to innervate the ventral walls of the ventricles decussate for the greatest part, and the present author does not take this fact for a mere variation or a characteristic feature restricted only to this species. It seems to have more important significance.

Up to the present time the crossing of the cardiac nerves has been very few spoken of. *Kazem-Beck* saw in 1888 in the rabbit branches of the superficial cardiac plexus, especially those coming from the left cardiac ramus, go between the aorta and the pulmonary artery to the surface of the right ventricle. Moreover, in some rabbits *Kazem-Beck* found that the left cardiac ramus, before it undergoes connection with the right nerves, sends off a twig, which goes along the pulmonary artery to the surface of the ventricle. By this "ventricle" he must have meant the right one, as we can estimate from his figure and explanation (fig. 1 d of his paper). Also in the dog's heart *Kazem-Beck* traced a portion of fibers, which belong mostly to the right cardiac rami, from the plexus to the surface of the left ventricle. Perhaps he was of the opinion, that not a small amount of the cardiac nerves are crossed in these animals, though he did not emphasize at all upon the decussation.

On the contrary, *Schumacher* (1902) concluded in his extensive studies on many mammalian hearts, that the right nerves innervate in general the right atrium and the right ventricle, including a part of the left ventricle adjacent to the anterior interventricular groove, while the left nerves are distributed solely to the left ventricle and the left atrium. The remarks of *Schumacher* seem to have found relatively much agreement in the successors. Meanwhile *Perman* (1924) proposed partial correction of *Schumacher*'s conclusion, though he acknowledged also the ipsilateral relation for the most of the cardiac nerves. In several mammals *Perman* could trace one or two nerves coming from the left side and passing anterior to the aortic arch, to the right ventricle.

My own acquisition in *Berardius* looks quite extraordinary in this respect. But to my mind the more general occurrence of the contralateral relation for the cardiac nerves is never inconceivable, if one considers that in most mammals through the inextricable maze of the superficial cardiac plexus each nerve bundle can never be persued with confidence. The difficulty of tracing them confidently through the plexus was great also in *Balaenoptera* and *Prodelphinus*, and thereupon the unique finding in *Berardius*, in which only minimal anastomosis takes place between the nerves of both sides, seems to mean much.

The decussation of the cardiac nerves above referred to was caused in my opinion by the torsion of this part of the ventricular canal, which must have occurred in the early embryo in the region of the porta arteriosa. *Braus* wrote in his famous textbook, "eine Torsion des Herzschlauches in der Nähe der Porta arteriosa mit dem Uhrzeiger (von der Arterie stromaufwärts gesehen)—auch an Einrichtungen des menschlichen Herzens erkennbar." (*H. Braus:* Anatomie des Menschen. Bd. 2, 1924, S. 626) Our finding tells probably, that the musculature of the ventral wall of the right ventricle was given rise at first on the left side, and that of the ventral wall of the left ventricle on the right side, the nerves retaining their original relation honestly till the adult stage.

A natural deduction from this is my rather bold assumption, that the neuromuscular connection must have begun in the heart very early, though since *His jr.* (1891) the late innervation of the heart has often been reported. In the fowls' heart *His jr.* saw the first nerves appear on the 6. day of incubation, and *Perman* (1924) observed them in the embryo of 4 days and 2 hours. As to mammals, *Hall* (1951) met with nerve fibers in the sinus venosus and atria only of the rat embryos older than 14,5 day stage, a remark which sounds not a little contradictory to the earlier work of *Shaner* (1930), who proved the presence of all nerves going to the heart of a 20 mm long calf embryo already. Anyway, the relatively late development of the cardiac nerves has furnished, as well known, the most powerful basis for the myogenic theory of the conduction or automatism in the cardiac function.

My hypothesis upon the early innervation of the heart finds, however, another support in the fact, that the nerves entering the superficial cardiac plexus, which corresponds undoubtedly to the "Bulbusgeflecht" of *His jr.*, start from the vagus and sympathetic at levels generally higher than the nerves descending posterior to the transverse sinus to both atria and to the dorsal walls of both ventricles. The nervous connection of the heart seems to have been established in a very young embryo, when the porta arteriosa was situated more rostrally than the porta venosa. Otherwise, the above mentioned difference of the levels, where the cardiac nerves leave the vagus and sympathetic trunk, might be difficult to explain.

Another finding, that in *Berardius* the conus arteriosus of the right ventricle receives a special innervation, viz. chiefly the most rostral sympathetic fibers coming from the left side, deserves also much attention from the embryological viewpoint, as this part is generally looked upon as nothing than the bulbus arteriosus of the early embryo.

As to the problem of the cardiac nerves the sinus node discovered by *Keith* and *Flack* seems to be in the Cetacea no special locality, as only a few small branches of the right nerves reach there. Contrarily a remarkable nerve plexus, especially well developed in the toothed whales, is attached to the atrial wall just dextral to the interatrial septum and directly under the right pulmonary artery. *Papez* named this portion "septal raphe" and called attention to the richness of nerves coming there from the right vagosympathetic. I myself could observe in addition branches from the left vagus and from the left sympathetic reaching distinctly the nerve plexus in question.

Summary

The cardiac nerves were studied with naked eye in the fetuses of *Berardius bairdii, Balaenoptera borealis* and *Prodelphinus caeruleoalbus*. In *Berardius* the vagal and sympathetic nerves originating from the right and left side and attaining the ventral walls of the ventricles decussate at least for the most part, the left nerves going to the right, the right ones to the left ventricle. In *Balaenoptera* and *Prodelphinus* the decussation of these nerves is not definitely determined, though its possibility can also never be denied. They start from the vagus and sympathetic trunk always more rostrally than the other nerves, which descend posterior to the transverse sinus to both atria and to the dorsal walls of the ventricles. For the latter the ipsilateral innervation, the right to right and the left to left, probably prevails.

We may explain these findings the most easily from the complicated morphogenesis of the mammalian heart, but at the same time we have to assume the very early innervation of the heart musculature, a fact, which does not coincide well with the data reported by previous authors.

Innervations of the sinus node, of the *Tawara*'s node and of the septal raphe of *Papez* were also studied, special attention being paid to the septal nerve, which descends through the atrial septum, and to the thick nerve bundles, which run together with the *Marshall*'s vein. A great difference was recognized as to the development of the septal nerve between the toothed whales and the Sei whale.

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On an Attempt to Preserve Whale Meat Freshness with 5-Nitrofurfuriden Aminoguanidine from Decay

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(Receiver June 15, 1952)

With latest improvement of food situation the demand for whale meat is decreasing in Japan. It seems chiefly due to the easy decay of freshness of whale meat that this tend is seen, in spite of high nutritive value of it which is practically equal to that of general edible meats.

Freshness decay is inevitable in coastal whaling, particularly in summer, for the reasons of air injection into whale body to float it after death and of tugging whales to land stations for a considerably long time. The purpose of our present study is to preserve whale meat freshness from decay by injection and circulation of a germicide which is attached at the head of the harpoon. As a germicide, 5-nitrofurfuriden aminoguanidine hydrochloride (Guanofracin in commercial name, abbreviated G.F. in this report), one of nitrofuran group, which was lately discovered, was adopted for our experiment, from the following view points: 1. mighty sterilizing power 2. harmless as food and 3. very soluble in water etc. This is yellow powder, soluble in about 100 parts of cold water and in about 30 parts of warm water (60°C). Although sterilizing power depends upon species of bacteria, G.F. is thought sufficiently effective at the concentration of 1/10,000–100,000 for our purpose. If whales caught in the adjacent waters to Japan are assumed to be 20 tons in average body weight and quantity of their blood is assumed to be 1/13 of body weight, viz., 1.5 tons, about 15 gr. of G.F. would be necessary for keeping G.F. at a concentration of 1/100,000 in such a quantity of blood. On the basis of this assumption 10–20 gr. of G.F. per whale was used in the present experiments. The experiments were carried on at Akkeshi, Hokkaido in September 1950 and in August 1951 and at Ayukawa, Miyagi prefecture, in November 1950. Successful injection on sei whales and sperm whales could be at Akkeshi but no successful results could be obtained at Ayukawa due to bad weather and end of the whaling season.

In order to compare the freshness change between G.F. injected whales and a control whale, pH of aqueous extract of their meat and G.F. concentration in their blood were measured. In 1951, a glass

Table 1. Results of Experiments in 1950.

No.	Sp.	Sex	Body length in feet	Lapse of time between capture and flensing	G.F. quantity used	G.F. attached harpoon	Estimated concentration of G.F. in blood
No. 1	Sperm	Female	40	23.00 hrs.	13 g/340 cc physiological salt solution	hit	0.5 mg%
No. 2	〃	Male	37	22.00 〃	5 g/300 cc* water	〃	trace
No. 3	〃	〃	38	22.00 〃	—	—	—
No. 4	Sei	〃	44	24.00 〃	15 g/300 cc water	pierced	—
No. 5	〃	〃	43	24.00 〃	20 g/300 cc water	〃	—

* 2/3 of G.F. quantity was lost due to the shock of the failed first harpooning.

Table 2. Results of

No.	Sp.	Sex	Body length in feet	Date of captured		Date of treatment		Lapse of time between capture and flensing	Water temperature °C	Weather	Locality of capture	G.F. attached harpoon
				Day	Time	Day	Time					
No. 6	Sei	Male	44	Aug. 7	6.30	Aug. 8	14.00	31.30 hrs.	20.3	B	SSE135° Akkeshi	not used
No. 7	〃	〃	44	10	12.00	10	9.30	21.30 〃	22.0	C	SE/S 118°	used
No. 8	〃	〃	48	〃	18.00	〃	10.00	16.00 〃	22.0	C	SSE 107°	〃
No. 9	〃	Female	47	15	10.00	16	0.30	14.30 〃	21.0	F	SSE 85°	〃
No. 10	〃	Male	44	〃	11.00	〃	1.00	14.00 〃	21.0	F	SSE 85°	〃
No. 11	Sperm	Female	37	19	16.00	20	15.00	23.00 〃	23.5	B	SE 1/2 E 110°	〃
No. 12	〃	〃	37	〃	14.00	〃	16.00	26.00 〃	24.0	B	SE 1/2 E 105°	〃

** The 2nd harpoon which had seemed misfired, was found fired when the whale electrode pH meter which was carried as far as to Akkeshi was used, as well as pH test paper.

By the results of qualitative and quantitative analysis applied to fracin group, it was found that G.F. turns reddish orange with caustic alkali like some of 5-nitrofran derivatives. On the basis of the result of the preliminary test, therefore, colorimetric determination of G.F. in whale blood was made. In the same concentration, colorimetric value of G.F. in blood was considerably smaller than that of G.F. in water. This may be due to the loss in the treatment to remove protein from blood. Injected G.F. presented in blood at an extremely small concentration, so sample had to be concentrated if necessary.

Table 1 shows the results of the five cases at Akkeshi in 1950 (2 sei whales and 3 sperm whales). Among them, one was for control and the successful G.F. injection was seen only in 2 cases (on sperm whales)

Experiments in 1951.

1st harpoon	G.F. amount	2nd harpoon	G.F. amount	3rd harpoon	G.F. amount	Amount of G.F. injected to whale	Estimated concentration of G.F. in whale blood	Note
hit	0	hit	20 gr	hit	20 gr	40 gr	1.2 mg%	G.F. sufficiently circulated during 10 or so minutes between 3rd harpooning and death of the whale.
〃	0	misfired	20 〃	pierced	15 〃	0	0	
〃	0	pierced	20 〃			0	0	
〃	0	hit	20 〃			20 gr	0.4 mg%	G.F. did not circulated so well due to a short interval between 2nd harpooning and death of the whale.
〃	20					20 〃	trace	G.F. concentration in blood was very small due to instant death of the whale.
pierced	20					0	0	

was flensed.

and the rest were failed due to misfire or piercing of harpoon and instant death of whale.

Table 2 shows the results of the seven cases at Akkeshi in 1951 (5 sei whales and 2 sperm whales). Among them, one was for control and successful G.F. injection was seen in 2 cases (sei whales) and the rest was not successful. pH curves for each experiment in Tables 1 and 2 are shown in Figs. 1–4. Fig. 1 indicates pH values which were measured with pH test paper (Toyo Filter Paper Co. Ltd., made) on a control whale and two G.F. injected whales in 1950. Figs. 2–4 indicate those which were measured with a glass electrode pH meter on a control whale and two G.F. injected whales in 1951. Time when the whale was completely caught is shown by 0 and the oblique lined part covers time when the whale was being flensed on the land stations. After flensing was finished, the sample meat was kept at 30°C in the thermostat.

In 1950, both of the two successfully injected whales were sperm whales. The whale No. 1 was injected 13 gr. of G.F., which was acknowledged to preserve freshness a little from decay on the basis of pH curve and odor and appearance of meat. The concentration of G.F. in blood was at a level of 1/200,000. The remarkable difference in pH curve was not seen between the whale No. 2 and the control whale, because 2/3 parts of G.F. prepared were lost due to the shock of the failed first harpooning and the rest was injected with the second harpoon. In this case, a trace of G.F. was only seen in blood.

In 1951 successfully injected whales were both sei whales and the whale No. 7 was injected twice 20 gr. of G.F. each, 40 gr. in total,

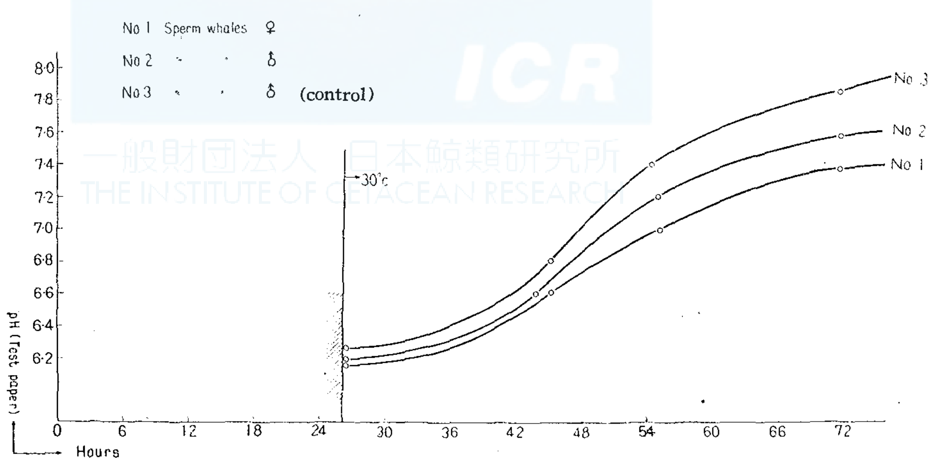

Fig. 1.

which indicated the concentration of G.F. in blood enough to restrain the growth of bacteria. pH curve in this case showed that G.F. injection could preserve freshness of meat from decay. The whale No. 10 was injected 20 gr. of G.F. but died immediately after hit, so the concentration of G.F. in blood was less than 1/200,000, which seemed to preserve freshness from decay to some extent.

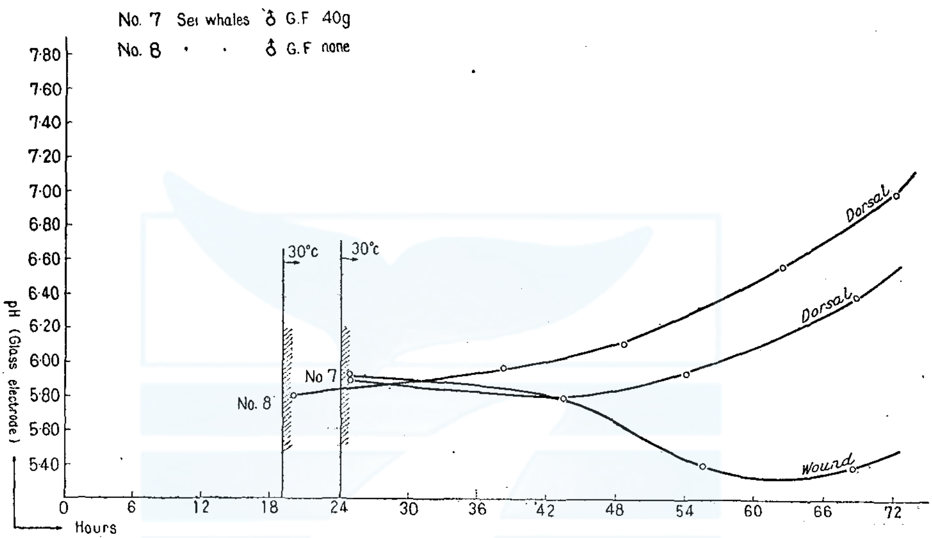

Fig. 2.

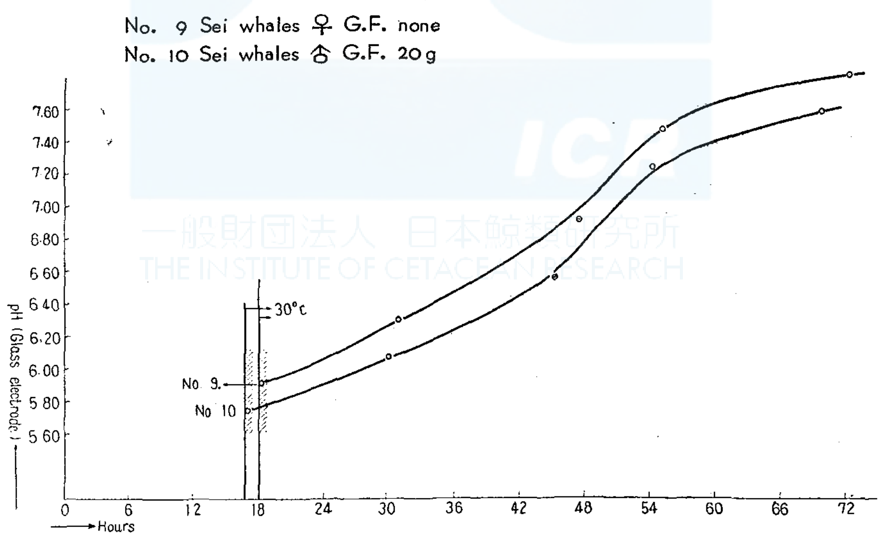

Fig. 3.

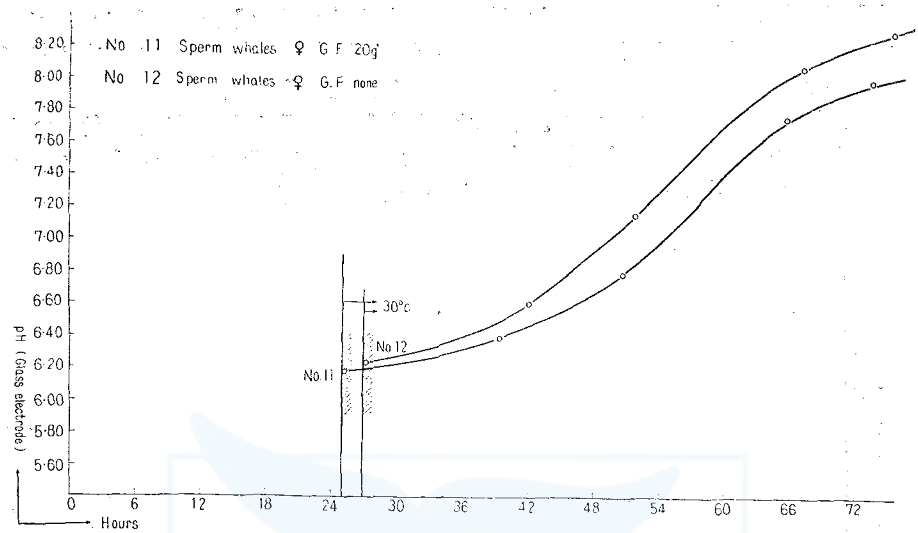

Fig. 4.

As these experiments depend much upon the external conditions, such as sea condition and whaling technique etc., we could not obtain only a few successful results. Nevertheless G.F. injected whale showed slow spoilage and injected G.F. was completely circulated although it was diluted to less than calculated value in concentration with permeated sea water and oozed humours in the course of tugging.

The conclusion might be therefore that G.F. can presserve freshness of whale meat from decay to some extent, if more than 20–40 gr. of G.F. are injected to a suitable point and G.F. is absorbed over 1/5–100,000 in concentration in blood.

We wish to express our sincere thanks to Mr. T. Nakai, Whales Research Institute for kind advice, to Toyama Chemical Co. Ltd., for supply of reagent, to Taiyo Fishing Co. Ltd., for various facilities in experiments and to Mr. T. Niwaguchi for cooperation. We owed a part of expenses to the Experimental Research Fund of the Ministry of Education, for which we wish to express our gratitude.

Experimental part

1. Attachment of G.F.

A grenade of the whaling harpoon is cylindrical and has a space of about 900 cc in it. An explosive compound and a fuse occupy most of the space, leaving about 300 cc for G.F. attachment. So, a tin or a gum made ice bag, in which 15–20 gr of G. F. and about 300 cc of water or physiological salt solution were mixed, was prepared.

In the beginning, the ice bag was used as a container, which was broken due to the shock of discharge and wet powder led often to misfire. In the later stage of the experiments, therefore, the tin was used instead of it. As any of the authors did not get aboard the catcher boat in 1950, detailed information on harpoon hitting was regretably not obtained. In 1951, they could get a chance to observe hitting of the harpoon on whales by aboarding the catcher boat.

2. Measurement of pH[1)]

Some 5 gr. blocks of meat taken from dorsal part of the whale by possible germ free operation were left at 30°C in the sterilized Petri's scale in the thermostat.

At intervals of a certain hours they were ground well with qualtz sand in the mortar. To those which were placed in a 150–200 cc flask, 100 cc of distilled water was added and stirred well for ten minutes. After standing, pH of the supernatant was measured with pH test paper (Toyo Filter Paper Co. Ltd. made) and with the glass electrode pH meter.

3. Measurement of G. F. concentration in blood

As the blood of the whale was diluted with sea water and humours, a certain quantity of comparatively dense blood was prefered, and after acidifying it with acetic acid, protein in it was coagulated by boiling. The filtrate was condensed again if necessary and cooled and filtered to remove the precipitate. G. F. concentration of this filtrate after alkalizing it with caustic alkali, were determined (Presence of G. F. turns the color to yellowish orange) with Duboscq colorimeter in 1950 and with Beckmann's spectrophotometer at 400–410 mμ in 1951 (cf. Akiya and Sawamura: reported separately).

For control a fundamental experiment was preliminary made with G. F. aqueous solution.

Summary

An attempt to preserve the whale meat freshness from decay by circulation of G.F. in whale blood which was attached in the head of the whaling harpoon, before its death, was tried in 1950 and 1951 at Akkeshi, Hokkaido. Successful injection was made on 2 sperm whales and 2 sei whales. The results of the measurement of pH of the meat

extract from them and concentration of G. F. in their blood showed that G. F. injected whales could preserve their freshness from decay, when compared with a control whale.

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Colorimetric Determinationof 5-Nitro-2-furfuridene Aminoguanidine

BY
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It has been often reported on the color reaction of 5-nitro-2-furfural derivatives. In this paper, the following two methods are applied to find whether they are useful for the detection and the colorimetric determination of its aminoguanidine derivative: one[1] is to detect nitrosoradical which is obtained by reduction of nitroradical and the other[2] is the same method as 5-nitro-2-furfural and its semicarbazone derivative whose color is changed into red with caustic alkali.

(*I*) *Coloration by sodium nitroprusside after reduction in neutrality.*

Aqueous solution of 5-nitro-2-furfuridene aminoguanidine (Guanofracin, the commercial name, G. F. is abbreviated in this paper) is filtered after reduction with zinc dust. To the filtrate are added sodium nitroprusside solution and KOH solution, and it turns reddish brown color. Its detectability is so weak that the limit is in 10 mg% (1/10,000) solution, and the distilled water which does not contain G.F. turns deep yellow by the same treatment as mentioned above. It is therefore difficult to apply this color reaction to the colorimetric determination for our purpose.

(*II*) *Coloration with caustic alkali.*

By the addition of caustic alkali, G.F. aqueous solution turns orange or red or makes fine red crystal in strong alkalinity, corresponding to G.F. concentration. To the reaction mixture are added dioxane, carbowax, aceton or other various solvents, respectively, in order to increase the stability and intensity of this coloration, and, as the result, aceton is the best one for this purpose. Using Beckmann's spectrophotometer, it is found that no strictness is required in the quantity of alkali to be added, 1 cc of N–NaOH solution being enough for 10 cc of test solution, and that the absorption maximum is observed approximately at 410 mμ. Further studies clarified that the following method is the most suitable one for the determination: the test solution is prepared in a proportion of 8 cc of G.F. solution, 2 cc of aceton and 0.1 cc of 10N–NaOH, and then the absorption spectrum is measured at 410 mμ after kept standing for 1.5 hours.

So the optical density of 0.1–2 mg G.F. aqueous solution is measured by Beckmann's spectrophotometer. The result (Fig. 1) shows that the optical density is measurable at this range of concentration and there is a proportional relationship between the concentration of G.F. and the optical density at 410 mμ. (In Fig. 1 the lines show the optical density of G.F. solution of various concentrations at 410 mμ and the dotted lines show the relationship between the wave length and the optical density.) The result of the measurement of 0.1–100 mg% G.F. aqueous solution by the Duboscq colorimeter (Fig. 2) shows an approximately proportional relation. (In Fig. 2 the dotted line indicates the values of the same test solution which are measured by Beckmann's spectrophotometer.

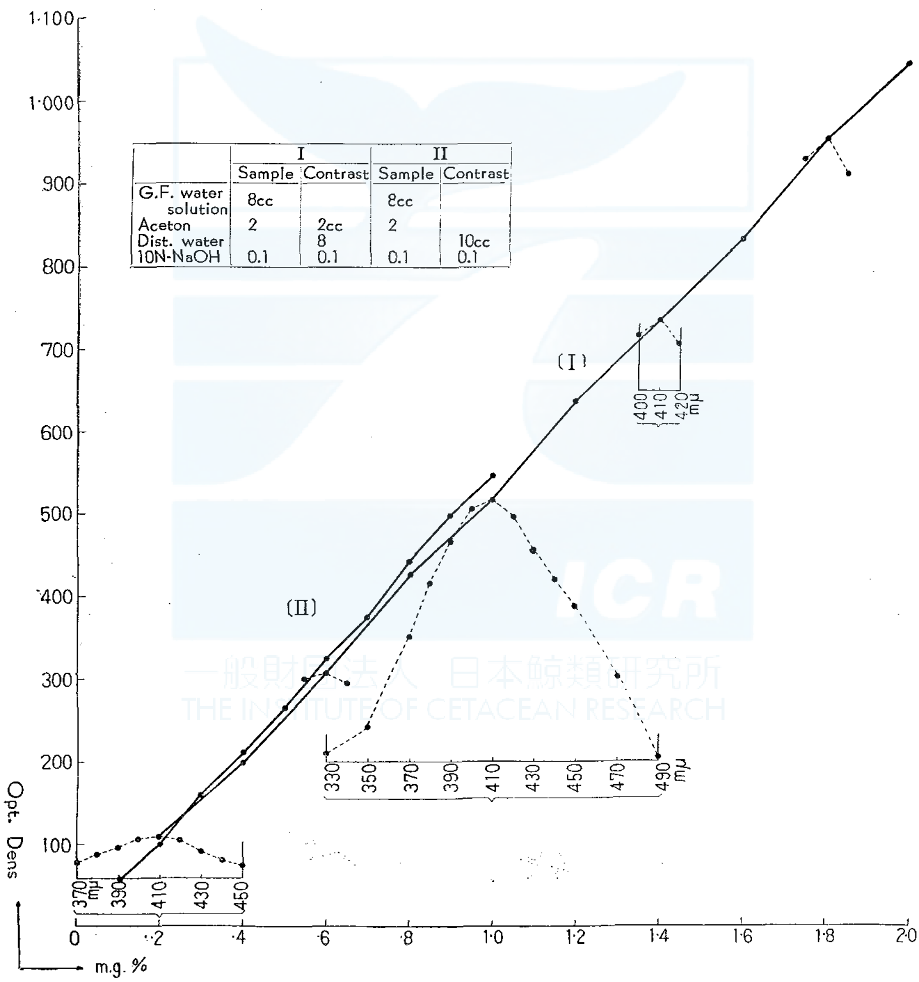

Fig. 1.

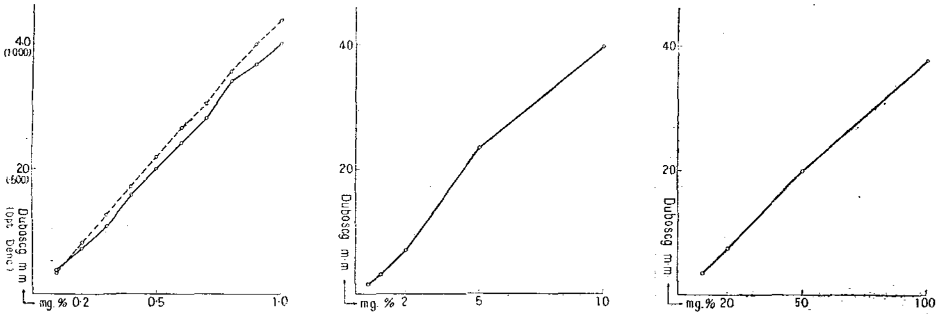

Fig. 2a.

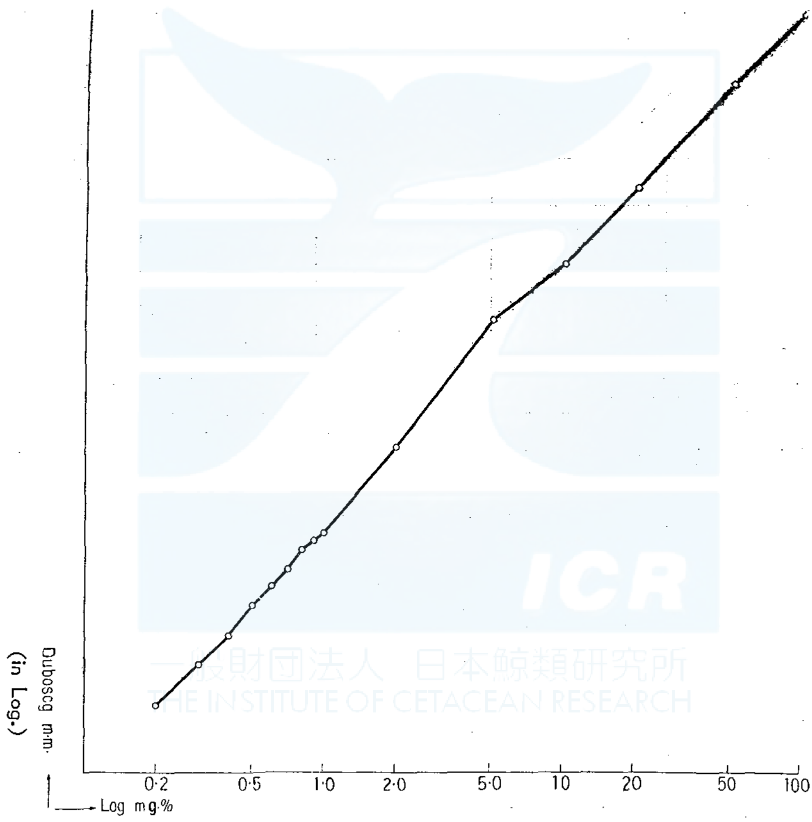

Fig. 2b.

(b) is summarized from (a).

In case of color reaction using caustic alkali, the above described range of concentration (0.1–2 mg%, viz. 1/1,000,000–1/50,000) gives a very suitable condition for the determination by spectrophotometer, and using the Duboscq colorimeter, colorimetric determination can be made easily at a wide range of concentration (0.1–100 mg%, viz. 1/1,000,000–1/1,000).

Table 1.

Wave length	15 min.	45 min.	1 hr.	1.5 hr.	2 hr.	3 hr.
360 mμ	—	—	0.232	0.243	—	—
380	0.327	0.360	0.373	0.380	—	—
400	0.470	0.490	0.498	0.502	0.500	0.502
410	**0.502**	**0.515**	**0.522**	**0.515**	**0.515**	**0.515**
420	—	—	0.505	0.502	0.495	0.488
430	—	0.475	0.468	0.461	—	—
460	—	0.330	0.360	0.366	—	0.360

Table 2.

Wave length	I	II	III	IV
390 mμ	0.465	**0.470**	0.465	0.448
400	0.522	**0.525**	0.512	0.495
410	0.528	**0.531**	0.530	0.518
420	0.510	**0.510**	0.510	0.495

The authors wish their thanks to Toyama Chemical Co. Ltd., for the supply of reagents and also to Messrs. S. Fukai and Y. Nakaji for their assistance in experiments. A part of the expenses of this study owes to the Experimental Research Fund of the Ministry of Education, to which also they are much obliged.

Experimental Part

(*I*) *Coloration by sodium nitroprusside after reduction in neutrality.*

1. Procedure

To 3 cc of G.F. aqueous solution in a test tube are added 6–7 drops of 10% $CaCl_2$ and about an spatuful of zinc dust. The reaction mixture is heated for a few minutes in a boiling water bath and then filtered through filter paper. After the filtrate is cooled, to it are added 6–7 drops of newly prepared 2.5% sodium nitroprusside solution. The mixture is vigorously shaken and then to it are also added 3 drops of 8% KOH solution, and the precipitate therein is removed by filtration. The filtrate turns reddish brown color in a few minutes.

2. Discussion

(1) The deep yellow, transparent filtrate is obtained by the above mentioned treatment from both whale blood and distilled water which do not contain G.F.

(2) This coloration is conspicuously observed in 100 mg% G.F. solution but not so in 10 mg% solution.

(II) Coloration by caustic alkali.

1. Procedure

To 8 cc of G.F. solution are added 2 cc of aceton and the mixture is vigorously shaken. And then to it is added 0.1 cc of 10N–NaOH and shaken vigously again. 1.5 hours later, absorption is measured with a colorimeter. In case of using Beckmann's spectrophotometer, a mixture of 8 cc of water, 2 cc of aceton and 0.1 cc of 10N–NaOH or a mixture of 10 cc of water and 0.1 cc of 10N–NaOH is used as a control and the absorption at 410 mμ is measured.

2. Discussion

(1) Absorption spectra of aceton-alkali-aqueous solution

Absorption spectrum of various concentrations in aceton aqueous solution, to which alkali is added is measured with Beckmann's spectrophotometer between 330 mμ and 450 mμ, and then the values obtained are almost constant, showing about 0.020 of optical density. The fluctuation of absorption by various quantities of aceton added is negligible.

(2) Effect of the reaction time

The results of the measurement for 15 minutes to 3 hours after preparation of test solution are shown in Table 1. The values are constant for 45 minutes to 3 hours after preparation of test solution (The value which is obtained for 1 hour after preparation is a little larger but the difference is only 1.3% from other values).

(3) Effect of various proportions of quantity between aceton and G.F. aqueous solution

	I	II	III	IV	Control
G. F. solution (in cc)	8.5	8	7.5	7	—
Aceton (〃)	1.5	2	2.5	3	—
10N-NaOH (〃)	0.1	0.1	0.1	0.1	0.1
Water (〃)	—	—	—	—	10.0

The result (Table 2.) shows that the mixture of proportion II gives the largest value in optical density. As the values for mixtures of proportion I and II fluctuate only 0.3–0.6% of the value of II, there is no necessity to change proportion more closely.

(4) In case of 100 mg% G.F. solution, there is no appearance of red precipitate even after the test solution is kept standing for several hours.

Summary

For the purpose of the colorimetric determination of aqueous solution of 5-nitro-2-furfuridene aminoguanidine, the two methods of coloration with sodium nitroprusside after reduction in neutrality and by caustic alkali were tried. The former was not suitable because of its dull sensitivity (10 mg% is the limit of detection). The latter was, on the contrary, applicable between in 0.1 and 100 mg% of G.F. concentration.

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Studies on Utilization of Higher Fatty Alcohol from Sperm Whale Oil

BY

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(Received June 00. 1952)

CONTENTS

Introduction

Sperm whale oil has been used in Japan for limited purposes such as wax, textile oil agent and detergent etc. So we studied utilization of higher fatty alcohol from sperm whale oil. Alcohol fraction from sperm whale oil was condensed with aromatic hydrocarbon to get alkyl aryl hydrocarbon, from which superior lubricating oil, hydraulic oil vacuum pump oil, cutting oil, detergent and fat splitting agent were made on an industrial scale.

Process for them and their properties are described in the following paragraphs.

1. New synthetic method of alkyl aryl hydrocarbon.

a. Condensation between saturated alcohol from hydrogenated sperm whale oil and naphthalene.

Hydrogenated sperm whale oil was used as sample, which was saponified and distilled into saturated alcohol (A.V. 0.2, S.V. 2.8, Ac. V. 190.6 and I. V. 4.7). The reaction between this alcohol and refined naphthalene using active clay as catalyst, with incessant stirring, at normal pressure let to dehydration at 160°C. There was a violent dehydration at 180° to 190°C. Then alkylation at 200°C and came up to its maximum in 30–90 minutes. The results of experiments showed that this new reaction for industrial synthesis of alkylnaphthalene was superior in the following points to previous methods using sulphric acid[2], metals haloide[3] or boron trifluoride[4] as catalyst.

1. More yield and easier operation in reaction process.

2. No need of after-treatment except removal of clay.
3. Simple equipment without special material.

By the result of the experiments on various temperatures, reaction hours, and amounts of active clay and naphthalene, the best condition to get a condensed oil principally consisting of monoalkyl naphthalene which is suitable for the diffusion pump oil, cutting oil and surface active agent as described later, was: 100 parts of higher fatty alcohol (1 mol), 103 parts of naphthalene (2 mols) and 20–25 parts of active clay, 180–200°C in reaction temperature, and 30–60 minutes in reaction hours. In this case, the yield of monoalkyl naphthalene was 57–59% of theoretical value. After various experiments, was found the best condition to obtain a condensed oil principally consisting of dialkylnaphthalene and polyalkylnaphthalene, which is used for high grade lubricating oil. That is, 100 parts of higher fatty alcohol (1 mol), 30 parts of naphthalene (0.6 mol) and 30 part of active clay, 200–210°C in reaction temperature and 90–120 minutes in reaction time. On this condition, the yield of dialkylnaphthalene and polyalkylnaphthalene was 45% of alcohol and that of monoalkylnaphthalene was 35% and the small amount of olefine dimer was obtained as by product. The above mentioned monoalkylnaphthalene is considered to consist of β alkylnaphthalene, for in the ultraviolet ray absorption spectrum photograph the maximum absorption of monoalkylnaphthalene did not coincide with that of α methyl naphthalene but with that of β methyl naphthalene. Furthermore, judging from the significantly lower solidifying point and the smaller viscosity index of monooctadecylnaphthalene than those of n-β monooctadecylnaphthalene, the alkyl in question should be not of normal chain but of isoparaffine base.

b. Condensation between olefine from saturated sperm alcohol and naphthalene and benzol.

For the synthesis of alkylaryl hydrocarbon by condensation of olefine and aromatic hydrocarbon, sulphric acid[6)], metal haloide[7)], phosphoric acid or boron trifluoride[8)] have been hitherto used. A condensation method to use active clay as catalyst has been already patented also[9)]. The following experiments were carried out to find the best condition of the reaction, for of which details have never been reported yet.

The above mentioned higher fatty alcohol from sperm whale oil was normally dehydrated with active almina at 300–350°C and distilled into olefine fraction (260–310° in distilling temperature, N_D^{20} 1.4425, I.V. 103.0 Mol. wt. 226) with a yield of 87% of alcohol.

Olefine content in this distillate was calculated 92% from molecular weight and iodine value. In the process of condensing this olefine and naphthalene in the presence of active clay, alkylation commenced at 140°C and came up to its maximum at 180–190°C. Olefine, even with half amount of active clay, led reaction easier and more sufficiently than alcohol did. The best condition was: 100 parts of olefine (1 mol) 104 parts of naphthalene (2 mols) and 11.8 parts of active clay 180–190°C in reaction temperature, 60 minutes in reaction time. In this case, the yield of monoalkylnaphthalene was 66.2% of thoretical value, showing better result than experiment (a), using alcohol.

It was also found that alkylbenzol could be more easily obtained by the condensation of the above mentioned olefine and benzol than in case of experiment using naphthalene. Namely, in a rotative autoclave, olefine and benzol began to alkylate at 120°C in the presence of active clay. The reaction advanced with the ascent of temperature, amounting to 60–70% at 150–160°C, and to the maximum, over 90% at 210°C. At higher temperature, decomposition was seen with the lapse of time, the yield of alkylbenzol decreasing. The best condition for monoalkylbenzol synthesis was: 100 parts of olefine (1 mol), 321 parts of benzol (10 mol) and 10 parts of active clay, at 200–210°C, 30 minutes in reaction time, at the pressure of 10–12 kgs/cm^2. In this case, the yield of monoalkyl benzol was 81.2% of theoretical value and that of dialkylbenzol was 8.8% viz. 90% of olefine was alkylated.

2. Utilization as lubricating oil and hydraulic oil and their properties.

Tomiyama demonstrated by his patent[10] that high grade lubricating oil can be synthesized from higher alcohol and naphthalene. Among many experimental manufacturing of lubricating oil from higher fatty alcohol of sperm whale oil and naphthalene with use of active clay as catalyst, the representative result is as follows. Condensation is made on the following condition: 96 kg of alcohol, 29 kg of naphthalene and 29 kg of active clay to 205–210°C for 90 minutes in reaction time, in the 200 L condensation kettle. Average yield of crude condensed oil was 86.4 kg. The result of topping 100 kg of the above mentioned condensed oil to 300°C in the oil temperature under the vacuum of 20 mg Hg in the vacuum super steam kettle, is as shown in the following table 1.

The followlng table 2 shows the comparison of properties among lubricating oil from natural mineral oil and the other synthetic lubricating oil.

Table 1. Results of fractional distillation of crude condensed oil.

	Distillates				
	Naphthalene fraction	1st fract.	2nd fract. N.F. No. 2	3rd fract. N.F. No. 63	Residum
Boiling point C/mmHg	84-120/760	120-180/20	180-203/20	203-210/20	—
Condenced water /distilled oil	5.2	0.9	2.9	6.2	—
Yield for condensed oil in percentage	5.5	14.2	21.0	14.6	43.5
Appearance	white solid	faint yellow liquid	light yellow liquid	light brown oily	reddish yellow oily
Viscosity at 100°F U.S.S.	—	57.0	169.5	294.0	1350

Table 2. Properties of some lubricating oil.

	Japanese Navy standard	Texaco No. 120	Philip	Lubricating oil polymerized from paraffin	Lubricating oil polymerized from fatty acid	Lubricating oil condensed by our method
Acid value	under 0.1	0.08	0.06	0.02	0.02	0.03
Saponification value	under 1.5	0.10	0.12	1.41	0.38	0.28
Specific gravity D_4^{25}	under 0.9	D_4^{30} 0.8806	D_4^{30} 0.8972	D_4^{30} 0.869	D_4^{30} 0.8504	D_4^{30} 0.8785
Flash point °C	over 200	251	246	245	261	248
Solidifying point 0°C	under −5	−14	−7.6	−13	−27	−5.6
Viscosity at 210°F U.S.S.	115–125	120.0	122.0	121	123	120.0
Viscosity index	over 90	95	77	107	117	111
Conradson test carbone %	under 1.5	0.56	1.13	0.70	0.97	0.980
Stability						
Viscosity ratio	under 2.0	1.06	1.37	1.90	1.45	1.15
Conradson test (%)	under 2.5	1.64	2.22	1.71	1.59	1.49

Engine test: The result of an engine test for 2180 kg of the above mentioned lubricating oil with use of (*EI*) 1450 H.P. engine, was as follows. After eighty hour running test it was judged that this oil could be used sufficiently for the practical purpose. Thus, our lubricating oil has some properties superior to common mineral oils and polymerized lubricating oils. It is not poorer in stability than higher grade mineral oils.

The second fraction (B.P. 180–203°C under the vacuum of 20 mm) and the third one (B.P. 203–210°C in the same vacuum) were dehydrated and refined with clay into a refined oil with the following properties, which was suitable for hydraulic oil for machine tool.

Table 3. General properties of NF 20 and NF 63

	Sample NF No. 2	NF No. 63
Specific gravity D_4^{20}	0.8883	0.8805
Index of refraction n_D^{20}	1.5092	1.5030
Flash point °C	152	
Solidifying point °C	−22	−16
Viscosity at 100°F U.S.S.	169.5	294.0
Viscosity at 210°F	45.1	54.0
Viscosity index	107.8	115.0
Molecular weight (by freezing point method)	420	590
Acid value	0.03	0.04
Saponification value	0.15	0.21
Iodine value	4.69	4.69
Oxidation test: at 100°C, for 12 hrs. air blown 6 L/min/40 gr		
Viscosity at 100°F	171.8	300.5
Viscosity ratio	1.01	1.02
Acid value	0.37	0.41
Increases in acid value	0.34	0.37

The comparative test between previously used Tycol Heavy Medium and the oil NF No. 2 was made about the effect on the velocity of reciprocating table of T 81 automatic internal grinder No. 502, made by the Toyo Kogyo Co. Ltd. During it, the pressure was 10 kg/cm^2 and the temperature was kept at 40°, 60° and 80°C by electric heater. The result is shown in the Tables 4 and 5.

Table 4.

	Tycol Heavy Medium	NF. No. 2
Flash point °C	221	152
Solidifying point °C	−12	−22
Viscosity at 30°C Red sec	380	192
〃 50°C	140	96.7
〃 80°C	61	50.8
〃 m	3.85	3.50

This result showed that the oil NF No. 2 had a smaller velocity change by temperature change than Tycol Heavy Medium, which was previously of the highest grade. As shown by the result of the

Table 5.

	Tycol Heavy Medium			NF No. 2		
	40°C mm/min	60°C mm/min	80°C mm/min	40°C mm/min	60°C mm/min	80°C mm/min
1/8	1,708,188	1,746,708	1,531,915	533,333	620,690	562,500
2/8	4,376,898	4,298,508	4,298,507	2,796,117	2,868,526	2,818,500
3/8	7,024,392	6,889,950	5,760,000	5,647,059	5,559,846	5,517,241
4/8	8,674,698	8,275,860	7,600,002	8,228,572	7,912,088	8,044,693
5/8	9,473,682	9,056,604	7,756,908	9,290,323	9,330,769	9,056,104
6/8	9,863,016	9,350,652	8,056,908	10,000,000	9,664,430	9,600,000
7/8	10,069,932	9,473,682	8,000,016	10,359,703	10,000,000	9,795,918
8/8	10,140,846	9,536,424	8,111,730	10,866,668	10,434,783	9,931,034

experiments, our condensation method made out a new lubricating oil with a large yield from higher fatty alcohol from sperm whale oil. This oil showing high viscosity index and a good stability for oxydation is superior to previously used synthetic lubricating oils and is equal to natural lubricating oils.

In addition, hydraulic oil for machine tool which is better than hydraulic oil from natural mineral oils hitherto used, was obtained from lower temperature fraction.

3. Utilization as vacuum pump oil and its property.

The authors have already reported that alkylnaphthalene has a good adaptability for a diffusion pump oil. Experiments were carried on by the various kinds of distilling methods for the purpose of obtaining a diffusion pump oil from the forementioned condensed oil. The result showed that method to obtain monoalkylnaphthalene fraction by the fractional distillation under the vacuum of 1.0–0.01 mm Hg with use of a rectifier, was the best one. After a distillation, the yield of the diffusion pump oil for the vacuum of 4×10^{-6} mm Hg was 54.2% of alcohol. After triplicate distillation, the yield of the diffusion pump oil for the vacuum of 6×10^{-7} mm Hg was 35.3%.

On the basis of these experiments, refined condensed oil was obtained in the average yield of 55 kg, from 50 kg saturated sperm whale alcohol and 51.5 kg of naphthalene. These materials condensed with 12.5 kg of active clay at 180–190°C, for 60 minutes in a 200 L iron-made condensation kettle. By steam distillation of this condensed oil, excess naphthalene was distilled out. The average yield of the dehydrated and refined condensed oil was 55 kg for these materials.

25 kg of this refined condensed oil was rectified again in a 50 L iron-made rectifier, 20 cm in diameter and 100 cm in height, which was pached with rectifying tower full of porcelain berl saddle in it. The condition was as follows: vacuum was 0.2–0.4 mm Hg, reflex ratio was 2 and distillating velocity was 1.5–20 L/hr. After rectification, the yield of the diffusion pump oil for $2-4\times10^{-6}$ mm Hg was 51–53% of the alcohol. After double rectification, superior diffusion pump oil was obtained with the yield of 38–40% of the alcohol. Properties of this oil was as follows.

Specific gravity D_4^{30}		0.9038
Index of refranction n_D^{30}		1.5224
Viscosity	80°F U.S.S.	224
	100° 〃	130
	130° 〃	74
Solidifying point		−45°C
Molecular weight		345
Maximum vacuum		6×10^{-7} mmHg

The results show there is a possibility that the excellent diffusion pump oil is produced on the industrial scale from the saturated alcohol of sperm whale oil.

4. Utilization as cutting oil and its property.

By distilling out naphthalene, 113 parts of refined condensed oil was obtained from the above mentioned condenced oil which had been made of 100 parts of saturated alcohol from sperm whale oil. For this oil, friction coefficient between steel and steel with a load of 10 kg/mm² at room temperature were measured with the pendulum oiliness tester. The result is shown in the following table:

	Crude condensed oil	Soya bean oil	Spindle oil
Specific gravity D_4^{30}	0.8978	0.9197	0.8940
Index of refraction n_D^{30}	1.5138	1.4733	—
Viscosity 50°C centistokes	26.3	24.6	8.19
Acid value	0.04	0.9	0.08
Friction coeffieient	0.078	0.100	0.305

Thus the refined condensed oil, of which the principal ingredient is monoalkylnaphthalene, has an excellent oiliness. The following tables show the results of adaptability test of this condensed oil which is blended in turbine oil as oiliness accelerator, and the results of comparative test of utility among turbine oil, soya bean oil and this condensed oil.

No. of cutting oil	No. 3	No. 4	No. 8
Constituent of samples			
Turbine oil	100	80	80
Soya bean oil	—	20	—
Condensed oil	—	—	20
Viscosity 30°C Redwood sec.	425	294	333
50°C 〃	146	114	122
Acid valte	0.2	0.7	0.1
Saponification value	—	39.2	—
Friction Coefficient (μ)	0.167	0.131	0.136

Conditions in cutting

Machine used	Hobbing machine
Cutting material	Hard steel (0.55 C)
Hardness of cutting material	39-41° (shore's)
Cutting speed	17 m/min.
Cutting depth	Rough cutting 10.75 mm finish 0.4 mm
Cutting feed.	0.56 mm/rev.
Hobb	All ground hobb
Oiling capacity	6 l/min.

The result is shown in the following figure. The amount of friction, when No. 8 oil was used, of hobb at two gear cutting, was 1/4 of that when No. 3 oil was used and was 1/3 of that when No. 4 oil was used. In case of No. 3 oil, hobb had to be repolished after only two gear cutting. In case of No. 8, it was not so, even after 4 gear cutting. It was thus found that our condensed oil shows a very good oiliness exactly suitable for gear cutting oil.

5. Utilization as detergents and fat splitting agent and their properties.

Monoalkyl benzol was made of the above mentioned olefine which was obtained from sperm whale oil. To 1 mol of this monoalkyl benzol, 3 mols of 20% fuming sulphric acid was dropped at 30°C. This sulfonic acid was dissolved into alcohol and neutralized with caustic soda, then produced sodium sulfate was removed by filteration. To this alcoholic solution, petroleum ether was added so as to extract out the oil which remained not reacted. By further distillation of alcohol, alkyl benzol sodium sulfonate was obtained. Its yield and surface activity in 0.5% water solution are compared as follows, with those of sulphric ester soda salt which is normally made from saturated alcohol from sperm whale oil.

Yield for higher fatty alcohol		Monoalkylbenzol sulphonic acid soda salt	Alcoholic sulfuric acid ester-soda salt
From sperm whale oil in percentage		128	105
Sulphonation ratio in percentage		95	75
Forming (at 40°C)	1 min.	1655	1275
Loss & Milrs methods	10 min.	1620	1205
Surface tension dyn/cm²		31.05	35.81
Interfacial tension 〃		4.21	7.05

The above results show that monoalkyl benzol-sodium sulfonate obtained by the method of condensing olefine and benzene, have the better foaming and better interfacial tension than those of sulfuric acid soda salt of alcohol. In addition, to 100 parts of the above mentioned refined condensed oil, 100 parts of 20% fuming sulpfric acid was dropped at 30°C and then a little water was added. After standing to remove the waste acid, fat splitting agent of which 80% was alkylnaphthalene sulphonic acid was obtained with a yield of 156% for alcohol, raw material.

The comparative splitting test against palm oil was made between this splitting agent and the previous one mainly consisting of dibutylnaphthalene sulphonic acid. A mixture of 100 parts of palm oil, 50 parts of water and 1.5 parts of fat splitting agent was splitted with stirring for 4 hours at 95°C. Neutralization value of fatty acid produced by our fat splitting agent was 186.0 and that of fatty acid by the previous one was 156.9. For the industrial products by this method the fat splitting test with use of the above mentioned palm oil showed that they had so good a splitting power as 96–98%.

As the result of the above experiments showed, from saturated alcohol from sperm whale we could produce with a large yield a powerful agent, which mainly consists of alkylnaphthalene sulphonic acid and has better splitting power than the previously used dibutylnaphtalene sulphonic acid.

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(These studies were made at Ressearch Dept., Lion Fat and Oil Co. Ltd.)

A Rapid Method for the Separate Determination of Vitamin A and Kitol in the Whale-liver Oil

By
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Spectrophotometric determination of vitamin A in the whale-liver oil is usually interfered by the existence of kitol.[1] The method to determine vitamin A by the color reaction with glyceroldichlorohydrine has been proposed to reject the interference of kitol,[2] but there remained unknown how to determine kitol in the co-existence of vitamin A.

The author has found that the simple method of semimicro molecular distillation is useful to separate vitamin A from kitol. The method was used to separate quantitatively the free cholesterol from the ester one in the blood plasm,[3] but no example has been applied to liver oil constituents. It can be naturally assumed that both vitamin A and kitol exist in the liver oil in state of ester form, then the distilling temperature differs each other so much that each compound can be separated by molecular distillation. The paper describes the fundamental experiment in detail to perform the newly found method.

Experimental Part

1. Distillation at 200° and Recovery of Vitamin A.—Semimicro molecular distillation apparatus[4] consisting of semimicro molecular still and Hickman's oil diffusion pump was used. The evaporation surface was 2.5 cm. diameter, and the distance between evaporator and condenser was 0.8 cm., the condensing surface being cooled by water current. Samples were liver oils of pollack, salmon shark, hammerhead shark, mixed shark (mixture of several kinds of shark-liver), and whales A and B, all being commercially prepared.

Just 0.120 cc. of the sample was micropipetted, from which the film thickness, one of the important factors in molecular distillation, was calculated as 0.25 mm. At first, the temperature of oil bath was kept constant at 200° and the distillation time was changed from 2 min. to 40 min. After each distillation, the condensing surface was taken out and washed with chloroform to recover the condensed vitamin A into an aliquot, which was treated by antimony trichloride reagent to measure the recovered vitamin A, the cod-liver oil unit being conveniently calculated for the weight of original sample 111.7 mg.

(calculated from mean specific gravity multiplied by 0.120) (Table 1).

Table 1. Recovery of Vitamin A in Distillation at 200° (C.L.O.U.)

Distillation time min.	Liver oil of:					
	Pollack	Salmon shark	Shark, mixed	Hammerhead shark	Whale A	Whale B
2	4.04	—	—	23.0	99.0	—
5	6.10	9.0	6.30	33.7	140	80.0
12	7.10	11.0	8.10	42.7	191	105
22	7.10	11.0	8.13	44.2	215	130
40	—	—	—	45.2	240	—
Original	7.25	11.2	9.04	45.7	206	108
Ratio*	100	100	100	104	113	124

* Ratio ≡ R 200° (22/12): that is, % of recovered vitamin A after 22 min. for that after 12 min.

Color reaction of the original liver oil of mixed shark, hammerhead shark and whale considerably differed from the standard color, so that the ratio of recovered vitamin A after 22 min. for that after 12 min. expressed in percentage was tentatively introduced, which divided liver oils into two groups. To one group with the ratio of 100% belonged the liver oil of pollack, salmon shark, and mixed shark, and to the other group with the ratio more than 100% belonged the liver oil of hammerhead shark, mixed shark, and whale, the former containing vitamin A ester, while the latter containing kitol ester in addition to vitamin A ester. Also Table 1 shows that about 15 minutes' heating is necessary to recover vitamin A completely by molecular distillation at 200°.

2. Distillation for 15 minutes and Recovery of Vitamin A.— Secondly, the distilling time was kept constant for 15 min. and the temperature was changed from 150° to 250° (Table 2).

In order to discriminate the liver oil containing kitol from that free from kitol the ratio of the recovered vitamin A at 230° for that at 200° during distillation for 15 min., expressed in percentage, was introduced. The ratio in case of the whale-liver oil is about 130%, while those of pollack and salmon shark-liver oils are about 100%. The difference 30% is attributed to that the former contains much amount of kitol. Moreover, the color test of the residual oil was fonnd to be useful to check the presence of kitol, blue color representing vitamin A, and red color representing kitol. The recovery of vitamin A at

Table 2. Recovery of Vitamin A in Distillation for 15 min. (C.L.O.U.)

Distillation temperature °C	Liver oil of :					
	Pollack	Salmon shark	Shark, mixed	Hammerhead shark	Whale A	Whale B
150	—	—	1.27	—	55.1	—
180	—	8.0	4.71	28.3	141	84.6
200	7.30	11.2	8.14	44.8	206	114
230	7.21	11.4	9.67	53.3	269	147
250	—	—	9.19	53.9	240	157
Color reaction of the residue with antimony trichloride reagent						
150	—	—	blue	—	bluish violet	—
180	—	blue	blue	blue	bluish violet	bluish violet
200	pale blue	pale bluish violet	pale reddish violet	red	red	red
230	colorless	colorless	pale red	pale red	red	red
250	—	—	pale red	pale red	blue	blue
Ratio*	99	102	119	119	131	129

* Ratio ≡ R 15 min. (230/200): that is, % of recovered vitamin A at 230° for that at 200°.

250° of whale-liver oil was less than that at 230° because a portion of the condensed vitamin A oil dropped to the residue, which was clearly proved by that the color test of the residual oil was blue.

3. **Change of Absorption Spectrum during Distillation.**— In the separation method before mentioned the distilled vitamin A was stable at condensing surface cooled with water, but the stability of remaining kitol was unknown. It was proved by absorption spectrum that kitol

Table 3. Extinction Coefficient of the Whale-liver Oil before and after Distillation, E (1%, 1 cm.)

Wave length, mμ	Original liver oil	Distillation, 200°, 15 min.			Distillation, 250°, 15 min.		
		Distillate	Residue	Total	Distillate	Residue	Total
310	53.2	30.4	25.40	55.8	46.6	12.80	59.4
320	52.4	34.5	19.02	53.5	53.1	9.14	62.2
325	50.8	35.85	15.55	51.4	55.0	7.05	62.1
328	49.0	35.85	13.85	49.7	54.9	6.10	61.0
330	47.5	35.25	12.75	48.0	54.1	5.52	59.6
334	43.5	32.9	10.65	43.6	50.5	4.44	54.9
340	35.85	28.65	7.38	36.0	43.6	2.74	46.3
350	22.9	19.52	3.96	23.5	29.45	1.14	30.6

did not decompose during distillation at 200° for 15 min. Precisely weighed sample of the whale-liver oil was placed in a small dish on the evaporating surface and was distilled for 15 min. at 200° and 250°. After distillation, the absorption spectra of distillate and residue were measured in isopropanol by Beckman spectrophotometer, while the absorption spectrum of the original sample was independently measured. Each extinction coefficient was calculated from the total weight of the sample.

As shown in Table 3, in case of the distillation at 200° and for 15 min., the total extinction coefficient of the distillate and residue at each wave length after distillation was almost equal to that of the original sample, on the other hand the difference clearly appeared in case of the distillation at 250° and for 15 min. Consequently, it was proved that both vitamin A and kitol did not change during the separation process by molecular distillation at 200° and for 15 min. Separated vitamin A and kitol can be determined by colorimetric or spectrophotometric method as usual. Simple colorimetric method to determine kitol will be reported by the author in future.

Summary

It was found that when the whale-liver oil or other fish-liver oils containing kitol in addition to vitamin A was distilled in a semimicro molecular still at 200°, for 15 min., and with the film-thickness of 0.25 mm., all vitamin A ester distilled on the condenser and kitol ester remained in the residue without decomposition.

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Whale Meat in Nutrition

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1. Introduction

It is a matter of common knowledge that protein is one of the most important substances in nutrition, and it is also well known to all that protein, especially animal protein, in our Japanese food is inclined to the deficiency. They say repeatedly that protein, vitamin and calcium are the three big shortages in Japanese food. It is, therefore, most necessary to supply our daily diet with protein.

Protein food materials in agricultural, stock-raising and marine products, however, are in general insufficient and they are, therefore, high in price. In the commercial condition alone, we can never take the sufficient amount of protein daily, if we want to live within our present income. There are, hence, many difficulties in suppling this nutriment in sufficient amount under unavoidable productive and economical bad circumstances.

In the midst of such circumstances, over 3500 whales are caught yearly in the Antarctic Ocean and in the adjacent waters of Japan. And so we thought that it may be wise to make the most use of various organs of the whale body to improve our bad nutritive conditions.

That is why we have attempted this sitological study on whale meat.

In the first place we have done the nutritive chemical analysis of muscles and other organs of whales and compared the results with that of other animal foodstuffs.

In the second place we have investigated and studied the price, the taste and the art of cooking etc. of the whale meat.

2. The nutriments of various organs of whales

The nutritive chemical analysis of skin parts, muscles and internal organs etc. has been done on 4 species of whales: blue, fin, sei and sperm whale.

Moreover we have carried out the analysis of some canned whale meat for reference of our study.

The results are shown in Table 1.

Table 1. Nutrients of various organs (4 species of whales).

Organs	Species of Whales	Water %	Protein %	Fat %	Ash %	Fuel value Calories	Calcium (Ca) mg%	Phosphorus (P) mg%	Iron (Fe) mg%	NaCl mg%
Common meat (tinged with red) (A)	Sperm	74.49	20.83	3.56	1.12	115	16	71	—	—
〃 (B)	〃	74.00	23.77	1.09	1.14	105	9	82	5	—
〃 (rapid freezing)	〃	72.27	17.89	8.92	0.92	152	11	157	—	—
〃 (slow freezing)	〃	67.74	18.49	12.84	0.93	190	17	120	—	—
Common meat (tinged with red)	〃	67.88	23.90	7.15	1.07	160	7	205	20	145
〃	〃	70.46	24.49	4.10	0.97	135	8	135	9	7
〃	Fin	72.71	23.27	2.95	1.07	120	11	193	5	65
〃	〃	68.61	18.49	12.09	0.81	183	8	122	6	29
〃	〃 ♂	83.93	22.87	12.35	0.81	203	4	112	6	51
〃	〃	77.80	19.57	1.65	0.98	93	22	83	—	—
〃	〃	75.88	20.16	3.15	0.81	109	—	—	—	—
〃	〃	49.76	14.88	34.68	0.68	372	25	90	1	—
〃	〃	73.93	21.90	3.21	0.96	117	—	—	—	—
〃	Blue	62.88	22.04	14.09	0.99	215	32	412	—	—
〃	Sei	73.79	24.70	0.67	0.84	104	7	183	2	84
〃 (salted)	Fin	59.10	24.37	6.21	10.22	154	49	1125	4	—
Meat around ribs	Fin ♂	62.35	18.84	18.18	0.65	238	5	70	6	38
〃	〃	69.52	22.35	7.20	0.93	154	14	117	3	—
〃	Sei ♂	77.48	21.60	0.33	0.58	89	6	69	3	26
Dorsal meat	Sperm	72.78	24.05	2.22	0.95	116	16	206	20	90
Tail meat	Fin	45.77	12.70	41.04	0.49	420	10	82	4	12
〃	〃	62.88	22.04	14.09	0.99	215	32	414	—	—
〃	〃 ♂	54.75	22.57	22.04	0.60	288	5	90	4	31
〃	Sei	74.15	13.68	11.60	0.61	158	13	110	2	36
Tail flukes	Fin ♂	53.20	28.59	17.95	0.26	276	8	45	2	9
〃	Sperm	55.86	28.17	15.25	0.72	250	11	26	2	340
Ventral meat	Fin ♂	64.06	19.15	15.43	0.76	218	5	141	3	68
〃	〃 ♂	73.62	21.48	4.06	0.84	123	14	87	6	256
〃	〃 ♂	75.05	22.00	2.02	0.93	106	6	161	3	106
〃	〃	68.51	24.06	6.60	0.83	156	10	85	4	71
〃	Blue ♂	71.10	21.77	6.24	0.89	143	6	137	3	145
〃	Sei	72.67	21.80	4.75	0.72	130	6	96	3	52
Blubber of ventral grooves	Fin	54.07	22.21	22.55	0.54	291	8	21	2	310
〃	〃 ♂	61.05	22.48	15.80	0.68	232	8	42	3	268
〃	Blue ♂	60.48	20.24	18.72	0.56	249	8	29	2	244
Epidermis of head and back	Fin ♂	65.87	30.31	2.62	1.20	145	36	111	11	101
Epidermis & Cutis of head	〃	35.56	10.72	53.70	0.22	526	6	31	1	10
〃	〃 ♂	32.80	13.92	52.89	0.35	532	6	28	3	47
Epidermis & Cutis of back	〃	24.63	10.08	65.05	0.24	626	4	21	2	86
Epidermis & Cutis	〃	30.57	8.38	60.91	0.14	582	5	37	1	10,028
Jaw ligament	Sperm	72.73	18.30	7.87	1.10	144	23	63	21	389

Organs	Species of Whales	Water %	Protein %	Fat %	Ash %	Fuel value Calories	Calcium (Ca) mg%	Phosphorus(P) mg%	Iron (Fe) mg%	NaCl mg%
Nasal cartilage	Fin	85.47	13.13	0.13	1.27	54	62	10	2	142
〃	Sei	86.65	11.50	0.21	1.64	48	48	18	1	101
Tongue	Fin ♂	18.27	9.20	7.62	0.91	681	27	28	1	481
〃	Sei	41.10	7.48	50.71	0.71	486	8	21	1	520
〃	Sperm	49.57	45.23	3.53	1.67	213	50	373	36	452
Oesophagus	Sperm	74.21	24.89	0.47	0.43	104	14	206	8	609
Stomach	Fin ♂	77.08	17.98	3.30	1.64	102	28	230	8	385
〃	Sei	76.81	17.29	4.39	1.51	109	31	202	9	314
The first Stomach	Sperm	71.20	27.20	0.70	0.90	115	17	319	21	392
The second 〃	〃	78.20	20.05	0.84	0.91	88	12	247	5	986
The third 〃	〃	26.77	6.04	66.75	0.44	925	9	80	11	405
Small gut	Fin	80.78	14.07	4.04	1.13	93	11	103	3	256
〃	〃 ♂	81.15	13.70	3.46	1.69	86	32	65	3	1,010
〃	Blue	79.31	16.58	2.62	1.49	90	35	349	3	—
Large gut	Blue	73.66	14.12	11.44	0.78	160	29	498	15	—
〃	Sperm	65.53	15.68	17.51	1.28	220	—	95	14	202
Lung	Fin ♂	77.92	19.92	0.55	1.61	85	49	134	10	729
〃	Sei	76.65	20.03	1.50	1.82	94	38	161	16	825
〃	Sperm	74.85	21.22	2.63	1.30	109	42	184	27	628
〃	〃	80.94	16.34	0.98	1.74	74	27	64	25	902
Heart	Fin ♂	79.16	18.68	1.20	0.95	86	9	231	9	115
〃	Sei	72.26	17.22	5.51	1.01	118	8	160	8	175
Liver	Fin ♂	68.40	23.60	4.29	1.41	142	8	166	117	24
〃	Sei	73.06	21.57	2.57	1.25	116	13	275	34	58
〃	Sperm	73.83	20.75	4.47	0.95	123	13	154	45	108
Kidney	Fin	79.56	15.97	3.34	1.13	94	14	162	6	278
〃	〃	76.45	18.97	3.46	1.12	107	21	80	7	530
〃	Sei	79.80	16.09	2.70	1.41	89	19	174	6	204
〃	Sperm	66.47	15.04	17.25	1.24	215	36	107	11	631
Pancreas	Fin	77.51	16.38	4.45	1.66	106	31	446	11	342
〃	Sei	75.45	17.90	4.79	1.86	115	14	386	4	460
〃	Sperm	40.69	2.84	56.19	0.28	517	9	35	24	0
Spleen	Sperm	52.49	19.88	26.71	0.92	320	14	245	14	222
Testicle	Fin	83.97	12.18	2.68	1.17	72	14	112	5	370
〃	Sei	82.54	14.40	1.84	1.22	74	10	249	4	263
〃	Sperm	85.26	11.02	2.87	0.85	70	12	149	4	243
Ovary	Sei	81.61	16.80	0.47	1.12	71	17	107	5	604
Fat tissue of the intestine	Sperm	55.98	24.66	18.87	0.49	268	4	85	4	27
〃	〃	15.19	1.70	82.86	0.25	753	2	23	9	170

The facts which we have known from this analysis are as follows:

1) Protein

The content of protein of the epidermal part of the head and back (Fin wh.) was the most (30.31%) and that of pancreas and 3. stomach (sperm wh.) were the least (2.84 and 6.04% respectively). The content of it of muscles, so-called "red meat", was as shown under.

Blue wh.	22.40%
Fin wh.	23.27–18.49%
Sei wh.	24.70%
Sperm wh.	24.49–20.83%

2) Fat

The content of fat of the cutis and subcutaneous part (fin wh.) was the most (65.05%) and that of the nasal cartilage (fin wh.) was the least (0.13). The muscles show the content of fat from 0.13 to 34.68 in per cent. Many internal organs, except the tongue, show the content of 0.5–5.0 in per cent.

3) Calories

Calories culculated from the content of nutrients of various organs are between 604 (cutis and subcutaneous part of the back, the highest) and 51 (nasal cartilage, the lowest). The cutis and subcutaneous part and the tongue are especially rich in calories and it is clear that the calories generally become higher in proportion to the content of fat. The muscles show 48–420 cal.. The internal organs, except the special ones like the tongue, show the calories of 70–220. The stomach, pancreas and spleen are sometimes considerably rich in calories.

4) Calcium

The most content of calcium was found in the nasal cartilage of the fin whale (62 mg%) and the least in the cutis and subcutaneous parts of itself (4 mg%). In general the epidermal part and muscles are rich in calcium compared with the internal organs. Especially the nasal cartilage, the lung and the epidermal part contain a large amount of calcium. The content of it of the muscles lies between 5 and 36 mg per cent.

5) Phosphorus

The content of phosphorus of the pancreas (fin wh.) was the most (446 mg%) and that of the nasal cartilage (fin wh.) was the least. The fatty parts of whales, such as the tongue and subcutaneous part, are in general low in phosphorus. The content of phosphorus of the muscles lies between 10 and 534 mg per cent.

6) Iron

The liver (fin wh. ♂) contained the most iron (117 mg%) and the tongue and the nasal cartilage etc. the least (1 mg%). The fatty parts of whales, such as the tongue and the cutis and suncutaneous part etc. are poor in iron. The content of iron of the muscles shows 2 to 20 mg per cent.

7) NaCl

The lung (sei wh.) contained the most NaCl (825 mg%) and the tail flukes (fin wh. ♂) the least (9 mg%). In general the lung, ovarium, tongue and pancreas etc. indicate the large content of this salt. However, the skin parts and muscles, with the exception of the blubber of ventral grooves, are low in the salt.

It is evident that according to the tested materials, though they are samples of the same name, show extraordinary different contents of the salt. And we suppose that this fact might be caused by the samples which were accidentally mixed with salt when they were artificially frozen or stored or transported.

From the results above mentioned we summarize as follows:

a) The content of nutriments of organs of the whale does not indicate much difference depending on the species, sex, age or the area where the whale was caught.

b) Protein abounds in muscles, internal organs etc. and fatty parts of the body are low in this nutriment.

c) Fat abounds in skin parts.

d) Calories are as a rule in proportion with the content of fat of organs. Accordingly the skin parts are rich in them.

e) Minerals are abounded in internal organs.

f) When we compared whale meat with beef and pork etc. we found that they did not much differ in the content of nutriments.

3. Nutrients of canned whale meat

Table 2 shows the results of the measurement of nutrients of the canned whale meat which was made of the meat brought back frozen from the Antarctic Ocean.

Protein content of these products lies between 22.71% and 26.81%, on the whole 25%. Fat between 3.42% and 7.61%, on the whole 4%. Minerals between 3.16% and 7.77%, on the whole 3.5%.

Some of these are seasoned with carbohydrate, NaCl and soy etc. and the sugar content of "yamatoni", which is a flavoured canned meat and is very popular one in Japan, was, calculated as cane sugar, 3.33 to 7.44%. It was hard to prove the existence of artificial sweet matter, like saccharine and dulcine. The amount of them has to be minimum, if any. "Yamatoni" of sperm whale meat and fin whale ventral meat, and merely boiled meat made of meat preserved with salt, contained 0.008, 0.011 and 0.009% nitre respectively which is used to bring out the colour of meat.

Table 2. Nutrients of whale meat canned.

Nutrients / Canned meat	NaCl %	Protein %	Fat %	Ash %	Water %	Fuel value calories	Carbo-hydrate %
Yamatoni (Sperm)	—	26.45	4.21	3.64	61.38	161	4.32
〃 (Fin)	—	25.67	4.71	3.68	62.09	161	3.85
Meat (tinged with red, salted) boild plain (Fin)	0.66	25.17	3.42	3.44	67.97	132	
Yamatoni of ventral blubber	Sugar % (as cane sugar) 3.33	26.34	5.90	3.77	60.66	172	
Yamatoni of ventral meat (Fin and Sei)	3.92	24.89	4.32	3.54	63.33	155	
Yamatoni of common meat (Fin)	7.38	26.81	3.71	3.75	58.35	170	
Yamatoni of ventral meat salted	7.44	22.71	4.66	3.16	62.03	163	
Yamatoni of heart (Fin)	6.82	26.26	7.61	3.68	55.63	201	

4. Price of whale meat

Since we acknowledged from results of our study that whale meat is in the nutritive value almost equal to other meat, especially beaf and pork, we intended to make the best use of it. Therefore we first investigated the price of it and compared it with other protein food stuffs.

Those inserted in Table 3 were the retail prices of them on September 12, 1951 in the city of Tōkyō.

The non eatable parts of those food stuffs were put away, and the protein content of the rest was calculated from the analytical data of the nutrients of the foodstuffs by grams.

Dividing the prices by the number of obtained grams, we were able to know the prices of each food stuffs per 1 gram protein. Thus we compared the prices with one another.

Through the investigation it became clear that whale meat was remarkably cheap and dearer a bit than the cuttle fisches which were caught in large quantities in the best season for the haul. Regarding the protein content and the price of whale meat, to say the least of it, we really believe that it is to be used with much effect on the daily diet.

Table 3. Prices of various protein foodstuffs (November 12, 1951).

Foodstuff	Retail price	yen	Protein in 100 g of foodstuffs g	Price per 1 g protein yen
Whale meat (tinged with red)	100 momme	40.00	23.23	0.45
Tail flukes of whales	〃	100.00	28.59	0.93
Beef (good)	〃	150.00	20.10	1.99
〃 (common)	〃	130.00	19.20	1.81
Pork (good)	〃	180.00	21.40	2.24
〃 (common)	〃	150.00	14.10	2.84
Sardine	〃	33.00	17.00	0.52
Mackerel	〃	67.00	18.00	1.00
Tunny	20 momme	15.00	23.00	0.87
Cuttle fish	100 〃	22.55	17.00	0.35
Hen's egg	one (47 g)	15.00	16.10	1.98
Satsumaage (fried hashed fish in oil)	100 momme	50.00	14.10	0.85

The price is calculated from 100 momme = 375 g.

5. Survey on school-children's taste to whale meat

Each man has own likes and dislikes, and some people like whale meat and others dislike.

It is also the truth that the popularity of whale meat differs, according to districts, for instance, it is relatively popular with the people who live in Kwansai and Kyūshū districts, and is unpopular with them in Kwantō and Tōhoku districts. That is how the people have been

Table 4. Survey on taste (animal foodstuffs). Percentage of dislike.

Foodstuffs \ Classes	I. Class			II. Class			III. Class			IV. Class			V. Class			VI. Class			Averages in total		
	male	female	total	male	female	total	male	female	total	male	female	total	male	female	total	male	female	total	male	female	total
Whale meat	8.9	10.8	19.8	7.6	11.3	18.9	8.8	11.3	20.1	8.6	15.0	23.6	10.6	18.1	28.7	10.5	15.0	25.5	9.2	13.6	22.8
Beef	6.1	7.0	13.1	6.9	10.1	16.9	5.8	9.3	15.1	4.5	9.4	13·9	3.1	9.8	12.9	2.8	6.4	9.2	4.9	8.7	13.6
Pork	7.4	7.7	15.1	7.1	10.7	17.7	6.7	10.1	16.8	5.6	10.5	16.1	4.7	10.4	15.1	3.2	6.9	10.1	5.8	9.4	15.2
Sardine	6.9	5.6	12.5	6.6	7.5	14.1	5.8	6.4	12.2	4.9	6.9	11.8	5.3	6.7	12.0	3.4	5.5	8.9	5.5	6.4	11.9
Scad	6.2	6.1	12.3	6.9	9.3	16.2	5.7	8.2	13.9	5.4	7.3	12.7	5.2	8.1	13.3	4.0	5.8	9.8	5.6	7.4	13.0
Tunny	5.0	4.4	9.4	3.8	5.9	9.7	4.3	5.1	9.4	2.8	5.1	7.9	3.2	5.2	8.4	2.1	4.0	6.1	3.5	5.0	8.5
Turbot	5.8	5.2	11.0	5.9	7.0	13.0	5.6	6.3	11.9	5.8	7.1	12.9	7.8	7.9	15.9	7.2	6.9	14.1	6.4	6.8	13.2
Saury	4.7	3.3	8.0	3.7	4.1	7.8	3.9	3.5	7.4	3.5	4.6	8.1	4.1	4.3	8.4	2.6	4.8	7.4	3.8	4.1	7.9
Muckerel	5.4	5.9	11.3	4.6	4.5	9.1	5.1	5.1	10.2	4.5	5.7	10.2	4.8	6.9	11.7	3.7	5.4	9.1	4.7	5.6	10.3
Cuttle fish	5.1	4.3	9.4	5.6	6.7	12.3	4.9	5.2	10.1	4.7	5.0	9.7	4.7	5.6	10.3	4.0	4.4	8.4	4.8	5.2	10.0
Eel	10.8	12.9	23.7	11.9	21.2	33.1	12.3	19.6	31.9	9.6	21.5	31.1	11.1	20.8	31.9	6.4	16.1	22.5	10.4	18.2	29.1
Salmon	5.4	5.8	11.2	5.0	6.1	11.1	3.6	4.9	8.5	3.8	3.8	7.6	1.7	2.6	4.3	1.4	1.6	3.0	3.5	4.1	7.6
Small fishes dried (for flavouring)	12.6	12.7	25.3	14.1	16.1	30.2	15.5	17.3	32.8	16.4	20.2	36.6	20.4	23.6	44.0	17.5	20.3	37.8	16.1	18.4	34.5
Carpet of the Philippines	6.1	5.8	11.9	4.9	6.3	11.3	4.8	6.0	10.8	4.8	6.7	11.5	5.8	7.3	13.1	2.6	6.0	8.6	4.8	6.4	11.2
Corbicula	6.4	6.0	12.4	5.9	7.4	13.3	5.6	7.1	12.7	5.0	8.1	13.1	6.4	8.8	15.2	4.2	7.0	11.2	5.6	7.4	13.0
Chikuwa	4.6	3.7	8.3	3.8	3.9	7.7	3.1	3.4	6.5	2.3	2.7	5.0	2.8	3.9	6.7	2.0	2.1	4.1	3.1	3.3	6.4
Hampen (fish)	6.0	5.2	11.2	5.6	7.4	13.0	4.8	5.9	10.7	4.4	6.8	11.2	5.1	7.2	12.3	4.0	4.2	8.2	5.0	6.1	11.1
Satumaage	3.3	3.2	6.5	2.9	3.9	6.8	2.5	3.2	5.7	2.9	3.3	6.2	3.1	4.2	7.2	2.2	3.1	5.3	2.8	3.5	6.3
Dried skim	8.9	11.0	19.9	12.1	16.9	29.0	14.7	18.9	33.6	15.3	22.1	37.4	17.7	25.4	43.1	14.2	20.0	34.2	13.8	19.1	32.9
Butter	4.7	4.6	9.3	6.4	7.1	13.5	4.6	6.1	10.7	4.3	6.6	10.9	3.3	6.2	9.5	2.6	4.3	6.9	4.3	5.8	10.1
Hen's egg	2.5	1.5	4.0	1.9	2.2	4.1	1.5	2.1	3.6	1.1	2.1	3.2	1.0	1.3	2.3	0.9	1.1	2.0	1.5	1.7	3.2
Tofu (Bean curds)	3.5	3.2	6.7	3.0	2.5	5.5	1.9	2.3	4.2	1.8	1.1	2.9	1.4	1.7	3.1	0.8	0.9	1.7	2.1	2.0	4.1
Natto (Fermented soy-beans)	6.3	6.9	13.2	6.3	7.7	14.0	5.3	6.4	11.7	5.8	8.1	13.9	4.2	8.1	12.3	3.2	6.0	9.2	5.2	7.2	12.4
Fried bean-curd	3.4	3.0	6.4	2.9	3.9	6.8	2.1	3.1	5.2	1.7	2.9	4.6	1.7	2.7	4.4	0.7	1.5	2.2	2.1	2.9	5.0
Miso (Bean paste)	7.6	6.9	14.5	9.0	9.0	18.0	8.1	6.9	15.0	6.9	9.8	16.7	6.3	7.4	13.7	4.4	5.5	9.9	7.1	7.6	14.7
Number of children inquired	1233	1248	2481	1238	1230	2468	1584	1431	3015	1327	1332	2659	1199	1155	2354	997	983	1980	male in total 7578	female in total 7379	total 14957

concerned with the whale meat under the influence of the surroundings for a long time. This fact suggests us that the people who dislike whale meat may become fond of it, if they will be accustomed to eating of it. Hence we have endeavoured to know taste of the school-children to many common foodstuffs.

a) Survey on school-children's taste to common animal foodstuffs.

This survey was performed in 14957 primary school-children. We requested the children to record on the inquiry papers whether they like or dislike each foodstuffs whose names were printed on it, under the guidance of the teachers.

The results are as shown in Table 4.

Generally speaking Table 4 indicates as follows:

The children in 4. or 5. class show a tendeney to the high percentage of disliking to a large majority of foodstuffs with some exception, children in 6. class, on the contrary, show lower percentage. Taken altogether, the percentage of disliking has a tendency to going down with the progress of the class. The percentage of disliking in female is commonly larger than in male, both in each class and in all the classes through. On an average, there are some foodstuffs which show significant high percentage of disliking, for instance, Niboshi (dried small fisches for flavouring) (34.5%), dried skim (32.9%), eel (29.1%) and whale meat (22.8%) etc..

In these four foodstuffs above mentioned, however, whale meat shows the lowest percentage.

b) Survey on school-chileren's taste to common vegetable foodstuffs.

The children of the primary school age have a tendency to dislike also some of the vegetable foodstuffs. We have accomplished this survey in 14060 primary school-children (see Table 5).

The results of this survey indicate that carrots, radishes, Welsh onions, Swedish turnips, edible burdocks are the vegetable foodstuffs for which a large number of the schoolchildren loose their taste. The percentage of disliking to edible burdocks is 22.2% and that to carrots is 53.4%. The percentages of disliking to onions, radishes, Welsh onions and Swedish turuips are situated between the two above mentioned, moreover the percentages for all these four are 27 and upwards.

c) Survey on school-children's taste to common vegetable foodstuffs cooked.

The grade of disliking to vegetable foodstuffs is different according to the variety of cooking, however carrots and onions etc. are on the whole hated by the school-children. We have investigated also this

Table 5. **Survey on taste (vegetable foodstuffs). Percentage of dislike in 14957 schoolchildren.**

	Sex etc. / Vegetables	Male		Female		Total	
		number	%	number	%	number	%
Vegetables	Carrots	3769	25.2	4224	28.2	7993	53.4
	Radishes	3437	23.0	3543	23.7	6980	46.7
	Turnips	1925	12.9	2200	14.7	4125	27.6
	Edible Burdock	1681	11.2	1640	11.0	3321	22.2
	Indian Lotus	1079	7.2	1109	7.4	2188	14.6
	Potatoes	716	4.9	712	4.8	1428	9.8
	Sweet Potatoes	482	3.2	409	2.8	901	6.0
	Dasheen, Taro	600	4.0	565	3.8	1165	7.8
	Egg Plants	1272	8.5	1128	7.5	2400	16.0
	Cucumbers	467	3.2	351	2.3	818	5.5
	Pumpkins	811	5.4	700	4.7	1511	10.1
	Cabbage	796	5.4	859	5.7	1655	11.1
	Spinach	769	5.1	809	5.4	1578	10.5
	Sprouted Beans	1424	9.5	1476	9.9	2900	19.4
	Welsh Onions	2486	16.6	2893	19.3	5379	35.9
	Onions	3603	24.0	4140	27.8	7743	51.8
Fruits	Pears	153	1.0	178	1.2	331	2.2
	Apples	231	1.5	237	1.6	468	3.1
	Oranges	166	1.1	114	0.8	280	1.9
	Tomatoes	760	5.1	702	4.7	1460	9.8
Sea weeds	Laminaria	938	6.7	1000	7.1	1938	13.8
	Undaria	983	7.0	963	6.8	1946	13.8
Grain Products	Bread	428	2.8	537	3.6	965	6.4
	Rice-cake	258	1.7	308	2.1	566	3.8
	Buckwheat Vermicelli	686	4.6	900	6.0	1586	10.6
	Wheat Vermicelli	1038	6.9	1208	8.1	2246	15.0
	Suiton (stock with back-wheat-cake)	2065	17.4	3033	20.3	5638	37.7

subject and the results are as shown in Table 6. In this table, concerning vegetables, the number of disliking children to all the children inquired and the number of disliking children of each cooked vegetable to the number of children who explains that they have a dislike for the original uncooked vegetable itself, are indicated in per cent.

Table 6. Survey on taste (Vegetables cooked). Percentage of dislike in 14060 schoolchildren (7140 male, 6920 female).

Vegetables and dishes \ Sex, number, %	Number and Percentage of disliking children to all the children inquired			Number of disliking children accordingly dishes to all the no. of children who dislike the very uncooked vegetables		
	Male	Female	Total	Male	Female	Total
Carrots	(3769) 25.2	(4224) 28.2	(7993) 53.4			
Fried	(1889) 13.4	(2207) 15.7	(4095) 29.1	23.6	27.6	51.2
Prepared with oil	(1781) 12.7	(2126) 15.1	(3907) 27.8	22.3	26.5	48.9
Gomokumeshi (boiled rice with vegetables)	(1430) 10.2	(1482) 10.5	(2912) 20.7	17.9	18.5	36.4
Boild	(2686) 19.1	(2767) 19.7	(5453) 38.9	33.6	34.6	68.2
Onions	(3603) 24.0	(4140) 27.8	(7743) 51.8			
Prepared with oil	(1751) 12.4	(2007) 14.3	(3758) 26.7	22.6	25.9	48.5
Stock of soy paste	(1894) 13.5	(2109) 15.0	(4003) 28.5	24.5	27.2	51.7
Boiled	(1833) 13.0	(2005) 14.3	(3838) 27.3	23.7	25.9	49.6
Curried Stock	(1178) 8.4	(1486) 10.6	(2664) 18.9	15.2	19.2	34.4
Stew	(1430) 10.2	(1799) 12.8	(3229) 23.0	18.5	23.2	41.7
Radishes	(3437) 23.0	(3543) 23.7	(6980) 46.7			
Boiled	(2475) 17.6	(2382) 16.9	(4857) 34.5	35.5	34.1	69.6
Stock of soy paste	(1495) 10.6	(1550) 11.0	(3045) 21.7	21.4	22.2	43.6
Grated	(1406) 10.0	(1445) 10.3	(2851) 20.3	20.1	20.7	40.8
Edible Burdock	(1681) 11.2	(1640) 11.0	(3321) 22.2			
Kimpira (chopped burdock fixed in oil	(713) 5.1	(621) 4.4	(1334) 9.5	21.5	18.7	40.2
Boiled	(1316) 9.3	(1369) 9.7	(2685) 19.0	39.6	41.2	80.8

Parenthesized are the number of children inquired.

From the surveys (a, b, c), we can recognize that many food stuffs, both animal and vegetable, are hated by school-children, and not a few of them are more hated than whale meat is. When we knew, however, that the disliking to whale meat is attributed to its particular odour, we must have views upon the importance of freshness, storage, transportation and cooking etc. of it. According to our opinion the disliking of school-children to whale meat will surely decrease in per cent and will approach the dislike level of beef and pork. In addition, we imagined that the number of disliking children includes the children of such kind who have a prejudice against whale meat. It can be easily thought that these children might have been affected by their daily home life.

This is why we have arranged the results of our survey according to the schools.

d) Survey on school-children's taste to foodstuffs according to the schools.

We have calculated numerically the number of children who like or dislike whale meat according to schools. The following statistics (Table 7.) are furnished by us.

As shown in Table 7, eighteen primary schools were concerned in this statistics. In every school the number of children who dislike meat is larger in percent in female than in male.

On the whole the percentage of disliking to whale meat is larger than to beef. The percentages of dislike to beef, pork and whale meat which are found in the children of the primary schools named Masago, Toyokawa, Hōkei, Toyotama and Haneda are almost alike. The percentages of dislike to whale meat in Morimura (in residential quater), Hisamatsu (in the place where the government office center and commercial district lie), Yakumo in residential quater) and Seikwa (in commercial district) are markedly large and those in Otsuka school for the deaf, Shakujii (in agricultural district) and Kurihara (in agricultural and factory district) are relatively small. This difference may be caused by the standard of living of the children. Generally speaking the children attending to the former live in luxury and those attending to the latter live economically. For instance the Morimura primary school is well-known as one of the luxurious schools.

And the children in such a school as the Shakujii which is in agricultural district can not but to lead a indigent life.

If it is really so, the decrease of the grade and percentage of disliking of children to whale meat will become possible owing to the future study of cooking and getting the children accustomed to whale meat.

We lay emphasis on our opinion that all these matters are entirely

Table 7. Survey on taste (according to schools). Percentage of dislike.

Location of school	Sex	Number of children		Pork		Beef		Whale Meat	
				%	%	%	Total	%	Total
1. Showa School (Chūō)	♂ ♀	202 224	426	7.77 13.62	21.36	7.27 12.68	19.95	9.13 17.06	26.19
2. Hisamatsu Sch. (Chūō)	♂ ♀	576 582	1158	7.51 13.56	21.07	5.61 10.27	15.88	13.73 22.28	36.01
3. Seikwa Sch. (Daitō)	♂ ♀	397 367	764	6.67 11.25	17.93	6.02 11.26	17.28	11.39 17.01	28.40
4. Masago Sch. (Bunkyō)	♂ ♀	516 503	1019	6.19 8.63	14.82	4.61 8.44	13.28	5.99 8.63	14.62
5. Toyokawa Sch. (Kita)	♂ ♀	468 460	928	5.50 10.24	15.74	5.50 11.52	17.02	6.36 11.85	18.21
6. Ōshima Sch. (Kōtō)	♂ ♀	669 680	1349	5.27 10.00	15.27	1.04 9.19	10.23	6.97 13.49	20.46
7. Toyama Sch. (Shinjuku)	♂ ♀	438 459	897	5.91 12.26	18.17	4.57 11.26	15.83	12.04 19.96	32.00
8. Yakumo Sch. (Meguro)	♂ ♀	745 692	1437	5.15 10.02	15.17	3.65 7.79	11.44	10.92 18.72	29.64
9. IV. Suginami Sch. (Suginami)	♂ ♀	526 505	1031	5.24 9.21	14.45	4.08 8.43	12.51	6.79 12.12	18.91
10. Kurihara Sch. (Adachi)	♂ ♀	268 319	587	6.64 3.07	9.71	6.64 5.11	11.75	6.30 10.22	16.52
11. Ōizumi Sch. (Nerima)	♂ ♀	129 104	233	8.16 9.26	15.45	11.16 15.02	26.18	14.16 9.01	23.17
12. Shakujii Sch. (Nerima)	♂ ♀	621 506	1127	4.95 5.03	9.98	5.74 6.26	12.00	6.26 6.89	13.15
13. Hōkei Sch. (Nerima)	♂ ♀	212 243	455	8.36 14.05	22.41	8.34 16.04	24.40	4.06 16.05	20.11
14. Toyotama Sch. (Nerima)	♂ ♀	278 274	552	7.46 10.45	18.00	5.64 12.72	18.36	7.09 11.09	18.18
15. Haneda Sch. (Ōta)	♂ ♀	888 904	1792	6.14 8.59	14.73	5.36 6.75	12.11	6.14 7.87	14.01
16. Morimura Sch. (Minato)	♂ ♀	169 206	375	4.80 10.67	15.47	4.47 8.80	12.27	17.86 38.14	56.00
17. Ōtsuka Sch. for deaf (Toshima)	♂ ♀	64 55	119	4.20 4.20	8.40	1.68 2.52	4.20	2.51 8.41	10.92
18. Attached Sch. to Educatinal Univ. (Bunkyō)	♂ ♀	412 296	708	6.47 7.01	13.48	4.62 5.19	9.81	15.42 9.96	25.38
Averages				6.24 9.39	15.63	5.33 9.35	14.68	9.06 14.38	23.44

Names of wards are parenthesized.

applicable not only to children but also to adults.

From our point of view, it is of deep significance to inquire into the dressing of whale meat which may be one of the valuable sources of animal proteins of our diets.

6. Cooking of whale meat

In order to supply Japanese diet with protein, we have engaged both in the study on cooking of whale meat and in the nutritive utilization of various organs of whales. At first, Arai, one of the authors tried to eat almost all the organs which are denoted in Table 1.

From this trial we knew that nearly all the organs can be made use of, though they differ on taste.

Among the organs concerned lungs and penes are so much tough that we can not chew them off, so far as they are commonly cooked.

The kidney, liver and heart etc. are, however, eatable with some relish. Intestines of the blue and fin whale are considerably delicious, though they are a little stiff. When they are steamed or boiled or roasted, they give out the perfume which has a remarkable resemblance to an ear-shell boiled or steamed. Some people are very fond of these boiled intestines notwithstanding slightly rough taste compared with pigs' entestines which are eaten to some extent by way of roasting (roasted pigs' intestines are sold under the name of "Yakitori" which is meant by roast fowl).

The people in Nagasaki district have for a long time used to eat the intestines of whales: intestines boiled and sliced are eaten as vinegard dishes. The intestines of animals are in general long, so they are called "Hyakuhiro" in Japanese which is meant by a hundred fathoms. Especially the intestines of whales are long and big, and they are welcomed as a sign of enlarging. This is why the Nagasaki people have used to eat the whale intestines in honour of the New Year.

The whale meat, which is brought back frozen from the Antarctic Ocean, is nice, even if it is eaten raw. "Sashimi" of whale meat is well-known among men of the world (the literal meaning of Japanese "Sashimi" is sliced raw fish meat). The fresh whale meat has no disagreeable odour.

We have found a new method of cooking to serve nice dishes of whale meat.

Whale meat (frozen meat is the best) is thrown in a pan or a pot, added a small amount of salt and water, heated and boiled till the last drop of water volatilizes and the meat is a little burnt. Then we can obtain a lump of meat whose surface is rather brown or black. When we deal with the meat in such procedure, it increases it's delicacies very much, and no bad odour is smellt by us. It is true that the procedure gives rise to a special kind of nice sweet taste of the meat, although the mechanism of it is not yet clear.

Such a whale meat can be palatably used for many kinds of dishes in European, Chinese and Japanese styles.

If this meat is sliced and seasoned with bitter orange juice, or ginger soy, or grated radish and soy etc., it tastes very nice.

Furthermore, this meat can, for some time, be preserved without putrefaction and be used cutting at one's request.

The refrigerated meat sliced is a dainty if it is eaten as one grills on a iron plate after the roasting of the duck meat in a hunting ground. Such a method of cooking is called "Karibayaki" in Jananese; "Kariba" is meant by hunting ground and "Yaki" by roasting.

A bun, stuffed with minced intestine or liver which are flavoured with suitable spices, is also good.

We know still more cookings of whale meat, but we have to abbreviate detailed descriptions for further particulars of cooking of it so as this paper not to be lengthened. And we will mention the results of the survey concerning the taste of the school-children for whale meat cooked.

We have been interested in knowing how much do the schoolchilden really eat the whale meat cooked. In July and September 1951 we picked up 5 primary schools and selected 20 children (male and female 10 respectively) of each class (1.–6. class). Then we offered these children several test dishes of whale meat and had the returns, whether they ate the dishes with relish or not, written on inquiry papers. Selected primary schools are as follows:

The Second Takinogawa school (Kita), Akabane school (Minato), the Second Nerima school (Nerima), the Fifth Suginami school (Suginami), Haneda school (Ota).

(Parenthesized are names of wards)

Bills of fare for the test dishes, as the first attempt, are 8 in all as shown in Table 8.

Any two or three of them are adopted in each school.

From Table 8 and 9 we knew that the percentages of like or dislike are much influenced by cookery of foodstuffs. For instance, the stew made direct from raw whale meat was received unfavourably by the school children, while those from boiled whale meat caught the fancy of themselves. Whale bacon with cabbage, whale meat with mashed

Table 8. Menu of dishes (whale meat was used as a principal foodstuff).

Name of dishes	Name of food-materials	Quantity g
Stew	Whale meat boiled plain	30
	Potato	80
	Carrot	30
	Onion	50
	Dried skim	7
	Wheat flour	5
	Oil	3
Gomokuni (boiled meat and other foodstuffs)	Sumitazuke (whale meat boiled)	25
	Potato	100
	Carrot	50
	Onion	50
	Oil	3
Whale meat with mashed potato	Whale meat minced	20
	Potato	100
	Carrot	30
	Onion	30
	Dried skim	15
	Oil	4
Stew with vegetables and whale meat boiled	Whale meat (tinged with red)	15
	Sugar	5
	Soy	—
	Radish	30
	Potato	20
	Carrot	20
	Cabbage	30
	Wheat flour	10
	Dried skim	22
	Oil	3
Whale Bacon with Saled	Whale bacon	20
	Potato	100
	Carrot	30
	Cucumber	30
	Wheat flour	10
	Dried skim	5
	Onion	a little
	Oil	4
Whale Bacon with Cabbage	Whale bacon	20
	Cabbage	30
	Potato	50
	Onion	50
	Wheat flour	10
	Dried skim	5
	Carrot	50
Curried Stock with Whale Meat	Whale meat (tinged with red)	16
	Potato	80
	Carrot	20
	Cabbage	20
	Onion	30
	Wheat flour	10
	Oil	3
Whale Meat boiled in Chinese style	Whale meat (tinged with red)	16
	Minced pork	5
	Potato	50
	Carrot	20
	Welsh Onion	15
	Wheat flour	5
	Sugar	3
	Oil	3

Table 9. Survey on taste (according to dishes in which whale meat was used as a principal foodstuffs). Percentage of dislike.

Names of dishes	Whale meat used	Like %	Dislike %	Number of children inquired	Name of schools
Stew	Boiled plain	87	13	568	II. Takinogawa Sch.
〃	〃	79	21	1408	Akabane Sch.
〃	〃	63	37	541	II. Nerima Sch.
〃	Raw	36	64	1300	V. Suginami Sch.
Gomokuni (boiled meat and other foodstuffs)	Sumitazuke (boiled)	67	33	568	II. Takinogawa Sch.
〃	〃	74	26	1408	Akabane Sch.
〃	〃	85	15	541	II. Nerima Sch.

Names of dishes	Whale meat used	Like %	Dislike %	Number of children inquired	Name of schools
Salad	Whale bacon	80	20	568	II. Takinogawa Sch.
〃	Raw	75	25	1954	Haneda Sch.
Mashed potato	Minced	87	13	568	II. Takinogawa Sch.
Whale bacon with cabbage	Whale bacon	87	13	568	II. Takinogawa Sch.
Curried stock	Raw	88	12	1954	Haneda Sch.
Boiled in Chinese style	Raw	87	13	1300	V. Suginami Sch.

potato, curried stock with whale meat, whale meat boiled in Chinese style were rather more popular than beef and pork.

These facts suggest us that if we elaborate how to dress whale meat we may be able to obtain delicious dishes which are eaten by almost all the school children. And if so, there will be nothing to choose between the dishes of whale meat and beef or pork.

7. Conclusion

If whale meat is maintained fresh, dressed palatably and accustomed to be eaten, it will be good to eat even for the school children.

In such a case, whale meat will be not less delicious than beef or pork. Adults will easier be familiar to the taste of whale meat than the school children will be.

Concerning the content of nutriments whale meat never falls behind beef or pork.

Whale meat is therefore one of the very good animal protein foodstuffs for Japanese.

Many thanks to "Nihon Suisan Fishery Co. Ltd." and "Taiyō Fishery Co. Ltd." for their kindness in Supplying the materials, and also to the primary schools concerned for their enthusiastic cooperations with us in our survey.

(The Tôkyô-to Laboratories for Medical Sciences, Tôkyô)

On the Serological Constitution of Striped Dolphin (*Prodelphinus caeruleo-albus* (Meyen)) (I)

BY

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Chapter 1. Introduction

Since Karl Landsteiner classified the human blood type according to isohaemagglutination at the beginning of the 20th century, the classification of blood type in various animals has been made according to isohaemagglutination,[1)2)3)4)5)] isohaemolysis and immune antibody.[6)7)] On the other hand, the advancement of serology has been so remarkable during the latest half century that its range covers the A, B, C,[8)9)] O, M, N of blood corpuscles in various animals and the distributive state of partial antigens[10)11)12)] in each character, up to the systematic evolution of animals and the indexing of heterotype antigens, and even to the analysis of the structure of each formal substance.

Serological study on whales which belong to the aquatic Mammalia has been hardly done up to the present. The authors, following the above stated results brought by the forerun researchers, have discovered the two antigens, namely D_1 and D_2, from the immune agglutinin and haemolysine produced by immunizing rabbits with the blood corpuscles of the striped dolphin, one of the aquatic mammals, and, by it, have been able to classify the blood corpuscle of striped dolphin into three kinds. So it is a great honor for them to report on it so as to receive a lot of precious critics from various worlds.

Chapter 2. Materials and Methods of the Experiment

Materials and methods of the experiment are to be summerized in the following. Details will be given in each clause.

Blood Corpuscle and Serum of Striped Dolphin

The spouting blood was taken into a pot when a dolphin had been pulled up to the operating place and his heart was stabbed with a knife. Blood corpuscles were separated from the blood clot on the absorbent cotton after coagulation by using physiological saline solution. After several times of centrifugal washing, the obtained blood corpuscles 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 saline solution with 5% carbolic acid was added to it. (Its quantity was 1/10 of that of the serum). After enough mixing, it has been preserved in the ice room.

Human Blood Corpuscle

A part of the blood taken, for the test of Wassermann's reaction, from the elbow veine of a healthy person was washed several times with physiological saline solution and was centrifuged. The precipitated blood corpuscles obtained thus were used for adsorption and coagulating reaction test.

Immune Animal

Serum type in the normal sera and whether the A character in the saliva was discharging type or non-discharging type, namely A+ type or A−type, were examined in a healthy rabbit, 2.5 to 3.0 kg in weight.

Immunizing Method

The blood corpuscles were washed several times with physiological saline water, and then the 10% floating liquid was made with saline water. Each 5 cc of the liquid was injected into the ear veine of a rabbit each other day. The total number of injection was 7.

Collecting and Preserving Method of Antiserum

One week after the last injection the whole blood was collected. The separated serum was made inactive in the warm bath of 56°C for 30 minutes. And then the physiological saline solution with 5% carbolic acid was added to it. (Its quantity was 1/10 of that of the serum). After adequate mixing, it has been preserved in the ice room. Any food had been given to the immune animal for about 12 hours before the blood collecting so as to prevent the turbidity of serum.

Testing Method of Coagulating Reaction and Hemolysis Reaction

30 minutes after, the coagulating reaction was judged by the holeglass method in the room temperature. The hemolysis reaction was judged by the test tube method, adding marmot serum as complement, after 30 minutes warm bathing of 37°C.

Adsorption Test

For adsorption, appropriate amount of the washed precipitated blood corpuscles had been mixed according to the dilution of antiserum. After being left in the room temperature for a few hours, the upper clear part was used for reaction.

Chapter 3. Isohaemagglutination

Isohaemagglutination in striped dolphin is generally weak. On rare occasions, however, it is comparatively strong, but not enough to

Table 1. Isohaemagglutination in *Prodelphinus caeruleo-albus* Meyen

	Blood corpuscle / Serum	Blood corpuscle of striped dolphin																																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Normal serum of striped dolphin	1	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	2	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	3	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	4	−	−	−	−	+++	−	−	−	++	−	++	+++	−	−	−	+++	−	−	−	−	+++	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	5	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	6	−	−	−	−	−	−	+	−	+	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	+	−	−	−	−	+	−	−	−	−	−	−
	7	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	8	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	9	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	10	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	11	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	12	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	13	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	14	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	15	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	16	−	−	−	−	−	−	−	+++	−	++	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	++	−	−	−	−	−	−	++
	17	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	18	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	19	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	20	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	21	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	22	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	23	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	24	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	25	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	26	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	27	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	28	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	29	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	30	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	31	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	32	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	33	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	34	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	35	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	36	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

classify easily the blood type with it. As shown in the Table 1, the reaction to the Sera No. 4 and No. 16 is comparatively strong, and moreover each agglutinin is adsorbed completely by each blood corpuscle which reacts positively to it so that the relation to the immune agglutinin which is to be stated after is noticed. On the other hand, the Serum No. 6 reacts weakly, but it seems not to be connected with what is to be stated after.

Chapter 4. Serum-type and the Existence of Anti C Agglutinin in Serum

Whether the agglutinins to the Human A, B and C characters exist or not in the normal serum of striped dolphin was examined by the coagulating reaction to each type of human blood. Some results of the reaction are given in the Table 2.

Table 2. Absorption test of striped dolphin's normal serum by Human Blood Corpuscles A, B and O

** \ Serum *		Serum of striped dolphin																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Before absorption	A	+++	−	++	−	+++	−	−	−	−	++	−	+	+++	−	−	−	+++	−	++	−	−	−	−	−	−
	B	−	+	−	−	+	−	−	−	−	++	−	−	−	−	−	−	++	−	−	−	−	−	−	−	−
	O	−	−	+	−	++	++	−	−	−	++	−	−	+++	−	−	−	+++	−	−	−	−	−	+	−	−
O	A	+++	−	−	−	++	−	−	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	−
	B	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
A	A	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	B	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
B	A	+++	−	−	−	++	−	−	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	−
	B	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

* Work human blood corpuscle
** Absorption human blood corpuscle

As clarified in the above table, the Type α' is seen in the four dolphins (16%), namely Nos. 1, 5, 14 and 20, while the Type O' in all the rest, that is 21 dolphins (84%). The Types β' and $\alpha'\beta'$ did not appear in any of the 25 dolphins. In the Type α', Nos. 1 and 5 react positively until the dilution with the water whose quantity is three times as much as the original liquid, and Nos. 13 and 19 react positively only in the state of the original liquid. The existence of the normal anti C agglutinin was not testified in any serum.

Chapter 5. Antigens Dc_1 and Dc_2 Proved by An Immune Antibody

Paragraph 1. Anti Dc_1 Serum and Anti Dc_2 Serum

When a rabbit is immunized using as antigen the striped dolphin's blood corpuscle which belongs to Dc_1, the agglutinin and haemolysin, particular in each species, to the striped dolphin's blood corpuscle are produced in the serum of the rabbit. Simultaneously anti Dc_1 agglutinin and haemolysin are also produced. From thus obtained antibodies the anti Dc_1 immune agglutinin and haemolysin are obtained if the agglutinin and haemolysin, particular in each species, are adsorbed away by Dc_2 blood corpuscle. Anti Dc_2 immune agglutinin and haemolysin are obtained by the same operation. By the immune serum obtained by the above method, it was proved that the existences of both agglutinins and the both haemolysins, namely Dc_1 and Dc_2 were perfectly consistent each other.

Paragraph 2. Agglutinin Value and Haemolysin Value

Examples of the agglutinin value and haemolysine value of the anti Dc_1 and Dc_2 immune sera obtained by the method given in the previous Paragraph are shown in the Tables 3 and 4 respectively.

Table 3. Agglutinin value of anti Dc_1 and Dc_2 immune sera to each type of serum of striped dolphin

Anti Dc_1 agglutinin value

Immune rabbit			Absorption blood corpuscle	Work blood corpuscle	Blood type of striped dolphin	Dilution of antiserum					
Serum No.	Serum type	Existence or non-existence of Character A in saliva				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$
No. 7 ♀	β′	O′	No. 8 Dc_2	No. 3	Dc_1 Dc_2	+++	+++	+++	++	+	−
				No. 1	Dc_1	+++	+++	+++	++	+	−
				No. 4	Dc_2	−	−	−	−	−	−

Anti Dc_2 agglutinin value											
Immune rabbit			Absorption blood corpuscle	Work blood corpuscle	Blood type of striped dolphin	Dilution of antiserum					
Serum No.	Serum type	Existence or non-existence of Character A in saliva				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$
No. 6 ♂	o′	O′	No. 16 Dc_1	No. 3	Dc_1 Dc_2	+++	+++	+++	++	+	−
				No. 1	Dc_1	−	−	−	−	−	−
				No. 4	Dc_2	+++	+++	++	++	+	−

Table 4. Haemolysine value of anti Dc_1 and Dc_2 immune sera to each type of serum of striped dolphin

Anti Dc_1 haemolysine value											
Immune rabbit			Absorption blood corpuscle	Work blood corpuscle	Blood type of striped dolphin	Dilution of antiserum					
Serum No.	Serum type	Existence or non-existence of Character A in saliva				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$
No. 7 ♀	β′	O′	No. 8 Dc_2	No. 3	Dc_1 Dc_2	+++	+++	+++	++	+	−
				No. 1	Dc_1	+++	+++	++	++	+	−
				No. 4	Dc_2	−	−	−	−	−	−

Anti Dc_2 haemolysine value											
Immune rabbit			Absorption blood corpuscle	Work blood corpuscle	Blood type of striped dolphin	Dilution of antiserum					
Serum No.	Serum type	Existence or non-existence of Character A in saliva				$\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{80}$	$\frac{1}{160}$	$\frac{1}{320}$	$\frac{1}{640}$
No. 6 ♂	o′	O′	No. 16 Dc_1	No. 3	Dc_1 Dc_2	+++	+++	+++	++	+	−
				No. 1	Dc_1	−	−	−	−	−	−
				No. 4	Dc_2	+++	++	++	++	+	−

Paragraph 3. Appearance Rate of Each Type

By the above stated method it has become clear that the two kinds, that is to say Dc_1 and Dc_2, of agglutinogen and haemolysinogen exist in the blood corpuscles of striped dolphin. The blood corpuscles of the 36 striped dolphins are classified by this into the following three kinds.

Blood type	Male	Female	Total
Dc_1 Dc_2	10 (50.0)	11 (68.8)	21 (58.3)
Dc_1	4 (20.0)	3 (18.7)	7 (19.4)
Dc_2	6 (30.0)	2 (12.5)	8 (22.3)
Total	20	16	36

(Parenthesized figure shows percentage.)

Chapter 6. Anti Dc_1 and Anti Dc_2 Isohaemagglutinin Seen in Normal Sera of Striped Dolphin

The Table 5 shows the respective comparison between the coagulating reaction of each type of the striped dolphin's blood corpuscles to

Table 5. Comparison between the coagulating reaction of each type of the striped dolphin's blood corpuscles to the anti Dc_1 and Dc_2 immune sera and the coagulating reaction to the normal sera Nos. 4, 16 and 6 of the striped dolphin which has the isohaemagglutinin.

		Abs. blood corpuscle \ Work blood corpuscle	Blood corpuscles of striped dolphin													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Immune serum	Anti Dc_1	No. 4 (Dc_2)	+++	++	++	-	++	++	-	-	++	-	++	++	-	+++
	Anti Dc_1	No. 16 (Dc_2)	-	+++	+++	++	-	+++	+++	+++	-	+++	-	+++	+++	+++
	Blood type		Dc_1	Dc_1 Dc_2	Dc_1 Dc_2	Dc_2	Dc_1	Dc_1 Dc_2	Dc_2	Dc_2	Dc_1	Dc_2	Dc_1	Dc_1 Dc_2	Dc_2	Dc_1 Dc_2
Normal serum	Serum No. 4		-	-	-	-	+++	-	-	-	++	-	++	+++	-	-
	Serum No. 16		-	-	-	-	-	-	-	+++	-	+++	-	-	-	-
	Serum No. 6		-	-	-	-	-	-	+	-	+	-	-	-	-	-

	Blood corpuscles of striped dolphin																					
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Anti Dc_1 No. 4 (Dc_2)	++	++	+++	+++	++	-	++	+++	+++	+++	+++	+++	++	+++	-	+++	++	+++	+++	+++	++	-
Anti Dc_1 No. 16 (Dc_2)	+++	-	+++	+++	++	++	-	+++	+++	+++	+++	+++	++	++	++	+++	++	++	++	++	-	++
Blood type	Dc_1 Dc_2	Dc_1	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_2	Dc_1	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1 Dc_2	Dc_1	Dc_2
Serum No. 4	-	+++	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-
Serum No. 16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	++
Serum No. 6	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-

the anti Dc_1 and Dc_2 immune sera and the coagulating reaction to the normal sera Nos. 4, 16 and 6 of the striped dolphin which has the isohaemagglutinin.

According to this Table, the Serum No. 4 seems to react positively to all other Dc_1-type blood corpuscles than No. 1 and to have the anti Dc_1 normal agglutinin, but it reacts positively only to No. 13 and negatively to all others so far as Dc_1-Dc_2-type is concerned.

While the Serum No. 16 reacts positively only to the Blood corpuscles Nos. 8 and 10 of the Dc_2-type. The Serum No. 6 reacts so weakly that it has no relation to Dc_1-Dc_2-type at all.

That is to say that some normal isohaemagglutinins in the serum of striped dolphin show the similar reaction to the agglutinin obtained by immunization, but that their reaction is so weak and appears so irregularly that the blood type can not be classified clearly by this. On the other hand, there exist some other isohaemagglutinins whose reaction has no connection with Dc_1-Dc_2 blood type.

Chapter 7. Conclusion

1) So far as just our survey is concerned, the type α' and type O' were found, but the type β' and type $\alpha'\beta''$ were not found in the serum of striped dolphin. The existence of anti C agglutinin was not testified in that serum.

2) The existence of the two kinds (Dc_1 and Dc_2) of antigen in the blood corpuscle of striped dolphin was testified by the anti Dc_1 and Dc_2 agglutinins and haemolysins obtained by immunizing the rabbit with the striped dolphin's blood corpuscle. The blood corpuscles of striped dolphin can be classified by this into the three kinds, namely Dc_1-Dc_2-type, Dc_1-type and D_2-type.

3) Some isohaemagglutinins of striped dolphin react particularly to Dc_1-type or Dc_2-type and some others react having no connection with Dc_1-D_2-type. It was found, but they appear irregularly.

At last it is a pleasure for the authors to record here a debt of gratitude to Professor Furuhata of the Institute of Legal Medicine, Tokyo Medico-Dental University, for his kindness in guiding their work and reading the original manuscript, and also to Professors Hiyama and Suehiro of the Fisheries Department, Faculty of Agriculture, Tokyo University, for their kindness in reading the original manuscript. Further the authors desire to acknowledge the valuable advice, rendered by Professor Ogawa of the Anatomy Department of Faculty of Medicine, Tokyo University, in naming the Dc_1 and Dc_2 antigens. They also wish to thank Dr. Oumura, chief of the First Biological Research Section, Fisheries Agency, and Dr. Maruyama, chief of the Whales Research Institute, for their usual encouragement.

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Food of Sei Whales (*Balaenoptera borealis*) caught in the Bonin Island Waters

By

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(Received June 20, 1952)

I. Introduction

The factory whaling was conducted from February to June every year after the World War II, and the biological investigations were put in practice when the carcases were treated on board the factory ship, but the stomach contents of sei whales had never been completely studied. The stomach contents of whales in these warm waters, far from Japan, seemed different from those in the adjacent waters of Japan, so we gathered every kinds of stomach contents when the carcases were treated on board the "Baikal-maru" in 1951.

On returning home, we requested the classification of them to the zoologists of the research institutes. Now we have got the answer of them, and wish to report on them in brief along with other description of research about the food of whales.

In the previous reports on the stomach contents of sei whales caught in these waters, including that in 1951, the species of them are found to be incorrect and must be corrected as follows.

Previous reports	Be corrected
Euphausia sp. or Eu.	*Thysanoessa gregaria* G.O. Sars.
Lantern fish or sardine	*Yarrella* sp.

In the following descriptions, we are indebted to Dr. Shigeru Motoda of the Hokkaido University on *Thysanoessa gregaria* and Dr. Tokiharu Abe of the Tokai Regional Fisheries Research Laboratory and Mr. Masao Watanabe of the Research Institute for Natural Resources on fishes, and moreover the crew of the factory ship "Baikal-maru". To all, we extend our sincere thanks.

II. Kind of Food

1. Thysanoessa gregaria G.O. Sars. Fig. 1.

These were found in large quantity in the stomachs of the sei whales caught in these waters. Total length is about 20–25 mm. It is an approximate genus of *Euphausia* and is known from the Pacific, the Atlantic and the Mediterranean Sea. It has luminous organs and their luminating were seen even if it were got from the stomach when it was very fresh.

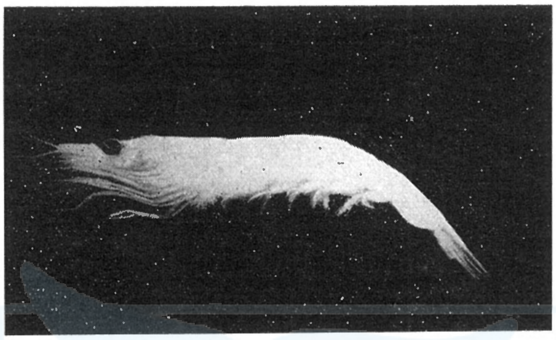

Fig. 1. *Thysanoessa gregaria* G.O. Sars. (×3)

2. *Yarrella* sp. (Gonostomidae) Fig. 2.

The body length of this species got from the stomachs of the sei whales caught in these waters was not more than 60 mm. Dorsal side of body is dark and ventral side silver. Luminous organs are around eyes and on the lower jaw and ventral side, 3 around eye, 2 lines on the lower jaw and ventral side before the anal fin, upper about 30 and

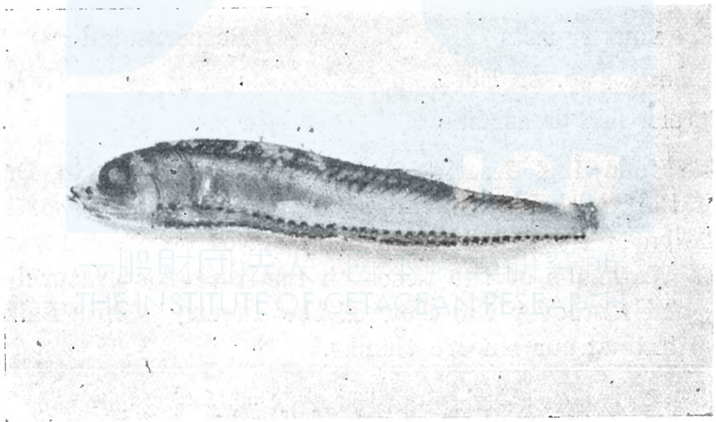

Fig. 2. *Yarrella* sp. (×1.5)

lower about 33–34 (10 of them on the back of opercle) and backward 1 line of 12–14. Dorsal fin: 12 soft rays, Pectoral fin: 8 soft rays, and about 40 scales in the lateral line. It resembles *Yarrella corythaela*

(Alcock) and is known from off Kochi, Kumanonada, Natal, Andamans, southern waters off Australia, etc.

In these waters, these fishes were sometimes found in full in the stomachs of the sei whales and sometimes in a small quantity mixed with *Thysanoessa*.

The data of founding of this species were as follows.

Date when the whales were caught	Whale	Location	Other food
15-30, 5 May	Sei, female 41 ft.	26-04 N 143-31 E	none
14-25, 〃	〃 male 40 ft.	26-16 N 143-35 E	〃
15-00, 10 May	〃 male 44 ft.	25-43 N 143-46 E	*Thysanoessa*
14-00, 14 May	〃 male 42 ft.	24-58 N 143-40 E	〃
16-55, 21 May	〃 male 42 ft.	25-41 N 143-55 E	none
12-15, 26 May	〃 female 44 ft.	25-50 N 143-36 E	*Thysanoessa*
11-05, 9 June	〃 male 41 ft.	25-41 N 144-02 E	none

3. Myctophum (Myctophum) asperum Richardson (Myctophidae) Fig. 3.

A line of luminous organs (about 25) are on the ventral surface, and 9 on the side scattered irregularly. Dorsal fin: about 12 soft rays. Pectoral fin: about 13 soft rays. Ventral fin: about 8 soft rays. Anal fin: about 22 soft rays. 39 scales in the lateral line. This species

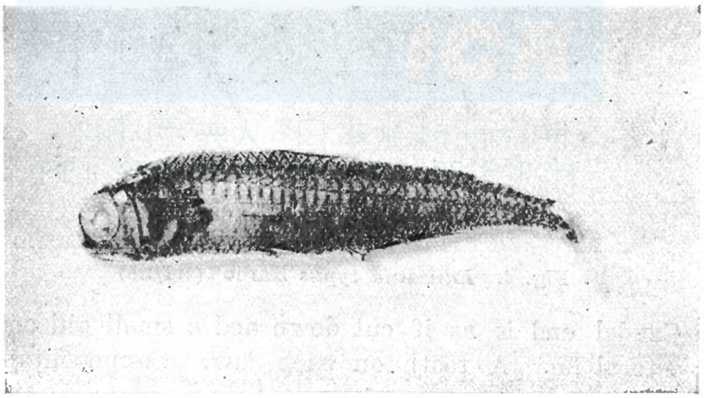

Fig. 3. *Myctophum (Myctophum) asperum* Richardson (×1/1.1)

is scattered widely in the Pacific and the Atlantic, and had been considered as "*Dascicopelus asper*", but recently the species above mentioned has come to be used.

In these waters, this species was not found alone in the stomachs of sei whales, but several mixed in *Thysanoessa*.

The data of founding of this species were as follows.

Date when the whales were caught	Whale	Location	Other food
07-15, 10 May	Sei. male 43 ft.	25-51 N 143-47 E	*Thysanoessa*
11-10, 〃	〃 male 42 ft.	25-34 N 143-50 E	*Thysanessa*, (in the 2nd stomach)
07-45, 20 May	〃 male 45 ft.	25-37 N 143-40 E	*Thysanoessa*
07-30, 〃	〃 female 44 ft.	25-43 N 143-50 E	〃

4. *Ranzania typus* Nardo (Molidae) Fig. 4.

This species was found once in the season. Total length about 14 cm., height about 3.5 cm., width about 2 cm. The body is com-

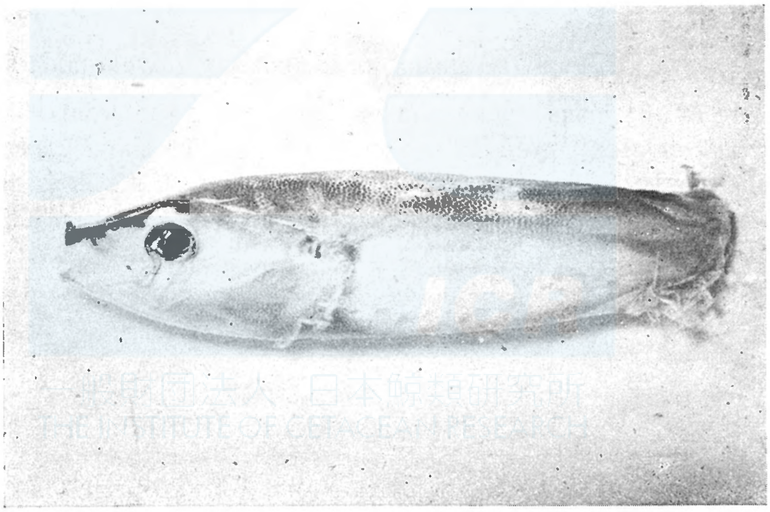

Fig. 4. *Ranzania typus* Nardo (×1/1.5)

pressed. Caudal end is as if cut down and a small gill opening is in front of pectoral fin. A tooth on each jaw. Cosmopolitan in warm seas.

The datum of founding of this species was as follows.

Date when the whale was caught	Whale	Location	Other food
06-40, 19 May	Sei, male 42 ft.	25-27 N 143-42 E	none

5. (a) *Argyropelecus* sp. (Sternoptychidae)

(b) *Polyipnus* sp. (Sternoptychidae)

Both of (a) and (b) were found only once in this season. They were so damaged that their species were unknown.

III. The State of Taking Food

Concerning the stomach contents, the first stomachs of all whales caught were investigated. The degree of quantity is classified into four classes; full (R), rich (rrr), moderate (rr), few (r) and empty (0).

The following table shows the quantity of food by month and by species in this whaling season, but fishes except *Yarrella* sp. are omitted as their numbers were very small.

	May				June				Total			
	T.sp.	Y.sp.	Total	(%)	T.sp.	Y.sp.	Total	(%)	T.sp.	Y.sp.	Total	(%)
R	12	—	12	9.8#	5	—	5	9.4#	17	—	17	9.7#
rrr	16	—	16	13.1#	6	—	6	11.3#	22	—	22	12.6#
rr	41	(2)*	41	33.6#	14	—	14	26.4#	55	— (2)*	55	31.4#
r	50	3 (1)*	53	43.4#	27	1	28	52.8#	77	4 (1)*	81	46.3#
No. of whales eating food	119	3 (3)*	122	59.8	52	1	53	69.7	171	4 (3)*	175	62.5
%	97.5	2.5 (2.5)*			98.1	1.9			97.7	2.3 (1.7)*		
Empty			82	40.2			23	30.3			105	37.5
Total			204	100.0			76	100.0			280	100.0

Note. R..........full rrr........rich rr.........moderate r.........few
T.sp........*Thysanoessa gregaria* Y.sp.......*Yarrella* sp.
*...........Figures in parentheses show the number or % of whales eating *Yarrella* sp. mixed with *Thysanoessa gregaria*.
#...........% to number of whales eating food.

Thus the main food was *Thysanoessa gregaria*, Schizopoda. 98% of whales having food in their stomachs had eaten *Thysanoessa gregaria* and whales eating *Yarrella* sp. only were 2% and those eating both *Thysanoessa gregaria* and *Yarrella* sp. were 4%.

Number of whales eating food was superior to that of whales whose stomachs were empty, 62.5% of all through the whaling season.

The following table shows the number of whales eating food and its percentage to all whales caught by ten days.

	1-10 May	11-20 May	21-31 May	1-10 June	Total
Number of whales investigated	50	72	82	76	280
Number of whales eating food	31	35	56	53	175
%	62.0	48.6	68.3	69.7	62.5

From this table it is found that the percentage was smallest in the period of 11-20 May, below 50%, and afterward it increased to near 70%. Regarding of the quantity, rather few food were found in the stomachs in most cases as shown in the previous table. Full stomsachs were only under 10% in each month.

IV. Weight of Food in Stomach

As mentioned before, the quantity of food in the 1st stomach was observed, but it had not been weighed in these waters yet. So this time it was weighed on 8 sei whales.

The method: the food out of the 1st stomach was put in an empty tin of kerosene, weighed and summed up.

No.	Whale			Time and Date of capture		Contents of the 1st stomach			
	Species	Sex	Body length			Kind	Weight	Mark used Quantity	Freshness
1	Sei.	female	40 ft.	06-00.	7 June	T.sp.	203.9 kg	R	fff
2	〃	〃	42	10-10.	〃	〃	156.0	〃	〃
3	〃	〃	42	11-00.	20 May	〃	155.0	〃	〃
4	〃	〃	43	12-30.	7 June	〃	129.0	〃	〃
5	〃	〃	40	07-50.	2 June	〃	121.0	〃	F
6	〃	male	40	14-10.	6 June	〃	95.9	rrr	ff
7	〃	〃	40	09-50.	4 June	〃	80.5	〃	〃
8	〃	〃	41	11-55.	20 May	〃	66.0	rr	fff

Note. T.sp.....*Thysanoessa gregaria* R.....full rrr....rich
rr.......moderate r.....few F.....very fresh fff....fresh
ff.......a little digested f.....nearly digested

In the upper table, the marks of quantity such as R, rrr, rr and r were determined by observation before weighed. This fact shows that the quantity was marked as R when the contents of the first stomachs of the sei whales in these waters were more than 100–120 kgs.

And the stomach content of No. 1 whale in the upper table seemed to be the fullest condition.

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(Fisheries Agency of Japanese Government)

On the Age-Determination of Mystacoceti, Chiefly Blue and Fin Whales

BY
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(Received October 9, 1951)

CONTENTS

Introduction

Because of its bearing on the conservation of whale resources, the problem of age and growth of Mystacoceti (whalebone whales) has been studied by many workers, and the results applied to clarification of the life history and analysis of the stock of these whales. Until very recently, however, studies of this sort had a fundamental limitation, i.e. the lack of an adequate method to determine the age of an individual whale exactly.

Seeking for such a method, both A. G. Tomilin of USSR and a group of Norwegian scientists led by J. T. Ruud (1940) came around 1940 independently to the same preliminary result that it might be possible to estimate the age of an individual whalebone whale on the basis of the surface structure of its baleen plates. Through further investigations with the material from the Norwegian and Antarctic waters, Ruud and his collaborators have nearly established a new method of age determination of whalebone whales (Ruud, 1945), and particularly of blue whales (Ruud, 1950 & Ruud et al, 1950). This method is based on the theory that the main sculptures (or the "transverse stripings") found on the surface of a baleen plate demarcate the annual growths of the plate. Though a variety of indirect evidences were accumulated in support of this theory, a direct proof had not been given prior to my work (Nishiwaki, 1950 c) which was submitted for publication in December 1950. In fact, Ruud (1950) called this theory a "working hypothesis" in an article published in June 1950 and stated as follows: "There can hardly remain any doubt therefore that the number of growth periods in the baleens depends on the age of the animals, but it is not proved thereby that the periods are annual." (Op. cit., p. 3)

Since Japan resumed her participation in the Antarctic pelagic whaling in the 1946–47 season after an interruption due to the World War II, I have been studying the life history of southern blue and fin whales with special references to age and sexual maturity, the factors most intimately connected with the conservation of whale stocks. In the age studies I have followed two different approaches, namely measurement of the colouration of the crystalline lens and examination of the surface structure of baleen plates.

In the first approach I (Nishiwaki, 1950 a) have shown that the degree of colouration of the crystalline lens is very closely correlated to the length of the whale as well as to other age data such as the number of corpora lutea, the weight of testes, and sexual and physical maturity. It was therefore concluded that this factor can be utilized as a measure of the age, provided that its relation to the true age of whale be successfully formulated.

I began my study of baleen plates being stimulated by Ruud's work (1940), in which the author reported a new apparatus to record on a sheet of paper an amplified image of the system of the transversal ridges and hollows in the cortical layer of baleen plates, and termed the recorded image the "baleen record". With a similar apparatus I also prepared baleen records, and the results of my observation on them have generally agreed with Ruud's findings.

Furthermore, I (Ibid., 1950 c) have proved with a considerable success that the part[1] of a baleen plate demarcated by two successive main sculptures corresponds to the annual growth of the plate, and thus justified the theory underlying the new method of age determination by means of the baleen record reading. Other possible approach to the proof of this theory may lie either in marking suckling calves,

1) The terminology for this item was not consistent in my previous studies: in the first report (Nishiwaki, 1949 c) it was termed the "period", "periodic cycle" or "cycle" on the baleen plates, and the "periodic cycle of the sculptures" or the "interval zone between the two successive main sculptures" in the second report (Ibid., 1950 c). Ruud (1940 & 1945) have termed it the "growth level" in the case of the baleen plates of fin whales and the "growth period" for both blue and fin whales. In following discussions I shall consistently use the "growth period" after Ruud because of the relevancy of the term and for the purpose of preventing a confusion due to arbitrary terminologies.

as suggested by Ruud (1950, p. 2), or in rearing, if possible at all, and observing a whale for a certain length of time.

In the present study I attempt to synthesize the results of my previous studies on the age and growth of Mystacoceti and to develop such overall and thorough-going discussions on the life history of these whales as were not possible in my earlier works partly because of the limited scope of these studies and partly for the lack of reliable method of age determination.

After the first manuscript of this paper was written up in December 1950, Dr. N. A. Mackintosh and Dr. J. T. Ruud kindly granted me current bibliographies and informed me of their recent progresses in this field. With these informations I made minor revisions of the manuscript. But the principal parts of the present work have been kept as it was first prepared.

I would like to acknowledge most gratefully the kindness shown by Dr. N. A. Mackintosh and Dr. J. T. Ruud. My sincere thanks are also due to the Japan Whaling Association for supplying a part of the research fund for this study, and to the Taiyo Fishing Co., Ltd., the Japan Marine Products Co., Ltd., and the government inspectors of the Fisheries Agency, Ministry of Agriculture and Forestry for cooperation in the collection of the material. Finally, I wish to acknowledge my indebtness to Dr. Ikusaku Amemiya, Dr. Hideo Omura and Dr. Yoshio Hiyama for their invaluable advice on the preparation of the manuscript.

Chapter I

Material

The data serving as the material for this study are all taken from my previous papers (cf. References), with the exception of a few unpublished data concerning the colouration of crystalline lenses of foetuses. They include the results of general surveys and special studies on the southern blue and fin whales caught by the Japanese Antarctic whaling expeditions in the four seasons 1946–47 through 1949–50. Though my original studies mentioned above covered also the southern humpback whale and the fin, sei and humpback whales from Japanese waters, they are not included in this study, because the data on southern humpbacks are too scanty and those on the whales from Japanese waters are to be analyzed in a separate work.

In each of the four seasons, with which the material of this study is concerned, Japan sent two whaling fleets which nearly matched each other in strength as well as in amount of actual catch. And the data to be analyzed in this study cover at least the whole catch by one fleet, they may well be regarded as a representative sample of the Japanese catch in respective the seasons.

The question whether the present material can be considered as a representative sample of total Antarctic pelagic catch in the respective seasons must be answered on the basis of a statistical comparison between the size compositions of the two groups. For reference purposes, the length frequencies of the blue and fin whales taken in seasons 1946–47 to 1949–50 by Japanese fleets and all Antarctic pelagic expeditions are given in the Appendix. The figures concerning the total Antarctic pelagic catch are based on the International Whaling Statistics.

Chapter II

The Age of the Female Whale at Sexual Maturity as Determined by the Number of Growth Periods in its Baleen Plates

In my first study on the age determination of whales by means of baleen record reading (Nishiwaki, 1949c, p. 169), I pointed out that the data strongly suggested that the females of the southern blue whale should attain sexual maturity at the age between 5 and 6 years and those of the southern fin whale at the age of 4 years. But I was prevented from advancing any decisive conclusion in this respect by the lack of a proof that each growth period in a baleen plate represents the annual growth of the plate. This study deals with the major part of the blue and fin whales caught by the Hashidate-maru fleet in the 1948–49 season.

In my second study on the same topic (Nishiwaki, 1950c) I proved successfully that each growth period in the baleen plates of the southern blue and fin whales is completed annually. The material for this study consists of the baleen plates of the blue and fin whales taken by the same fleet in the 1949–50 season. Now that this proof has been given, it seems appropriate to discuss again on the age at which these whales reach their sexual maturity.

All female blue and fin whales investigated in the previous two studies again serve as the material for the analysis. In Fig. 1-a and -b is plotted the number of corpora lutea of each of these whales against the age of the whale as determined on the basis of the number of growth periods found in the baleen plates, for blue and fin whales separately.

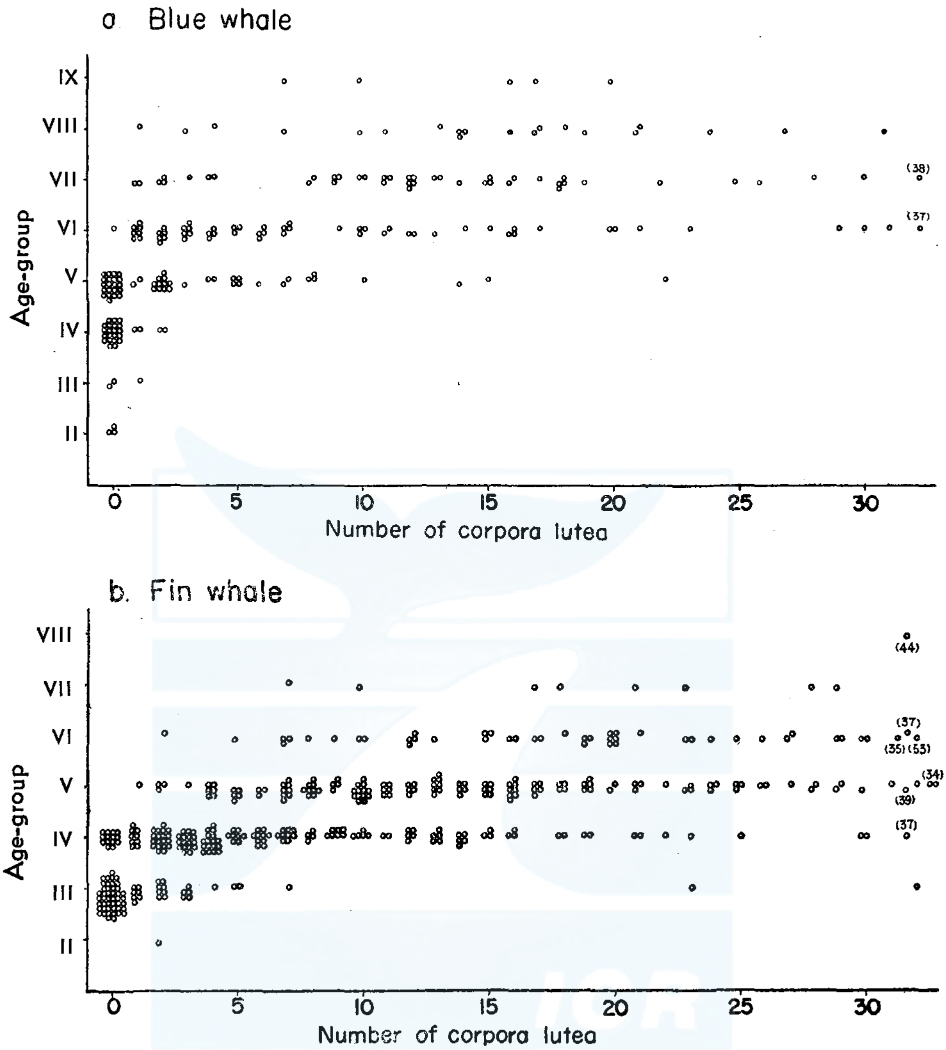


Fig. 1. Number of Corpera lutea and Age-group.

Before proceeding further, mention should be made of the definition of the "age of a whale" as employed in following discussions. According to my last study (Op. cit.) a main sculpture is formed on the baleen plates of a southern blue or fin whale annually, and emerges out of the gum about July and August to be recognized in baleen records. It is therefore at this time of the year that a new growth period is completed in the baleen record. It has been generally accepted, on the other hand, that the calves of these whales are born mostly during the season of the year centering in June. It then follows that the baleen records of the southern blue and fin whales, if taken in August, should usually consist of as many complete growth periods as the approximate age of the whale expressed in years. During the Antarctic whaling season extending from December to next March the whales must be some years plus 6 to 9 months old, and, provided that the tips of the baleen plates are not worn significantly, their baleen records must consist of as many complete growth periods as the number of full years in their age and another growth period that is still forming. Alternatively, if a whale caught during an Antarctic season gives a baleen record comprising n growth periods including one forming period, it may be correctly inferred that its age should be (n-1) years plus 6 to 9 months, provided that its baleen plates are not worn significantly at the tip. In case that this wear is heavy, however, the whale may be older than that above inferred. Therefore, (n-1) years and 6 to 9 months is the minimum probable age for a whale showing a total of n growth periods in the baleen record.

When the baleen records were read in my previous studies, merely the number of actually existing growth periods was counted without trying to determine the extent of the wear at the tip of the plates, because it was not feasible to carry out such a determination on every examined baleen plate. The minimum probable age of the whale estimated from these data according to the formula described in last paragraph is termed the age of the whale in this study. For example, if 6 growth periods are found in the baleen record of a female whale including one forming period, the whale is regarded as being $5^1/_2$ to $5^3/_4$ year old when hunted regardless of the extent of the wear of the baleen plate, and is assigned to the age group V in Table 1. The age group V refers to animals of ages between 5 and 6 years.

The data presented in Fig. 1-a and -b are respectively summarized in Table 1-a and -b so as to show the number and percentage of sexaully mature females in different age groups. The same percentage for the 1948–49 and 1949–50 seasons combined, which appears in the last column of the tables, is plotted in Fig. 2-a and -b respectively for the blue and fin whales.

Table 1 and Fig. 2 indicate that 75% of the females of the southern blue whale has reached sexual maturity in the sixth year (age group V) of their life, and the same percentage of the females of the southern fin whale in their fifth year (age group IV) of life. Therefore, are considered the majority of the females of the southern blue and fin whales to ovulate and conceive for the first time respectively in their sixth and fifth year of life.

Table 1-a Number and Percentage of Sexually Mature Animals in the Catch of Female Blue Whales

Age group(1)	Number of growth periods in the baleen-record	Season				Total	
		1948-49		1949-50			
		Number	Percent	Number	Percent	Number	Percent
III	4	0	0.0	1	50.0(2)	1	33.3(2)
IV	5	1	9.1	4	26.7	5	20.0
V	6	15	53.5	15	65.2	30	58.8
VI	7	27	100.0	30	96.8	57	98.3
VII	8	21	100.0	32	100.0	43	100.0

Note: (1) Whales have been assigned to the minimum probable age. Since southern blue and fin whales are born mostly around June and caught between December and March, and each growth period in their baleenplates represents one year in their life, the animals showing 5 growth periods in their baleen-records, for example, must have been about $4\frac{1}{2}$ to $4\frac{3}{4}$ year old when hunted, provided that the wear of the tips of the baleen plates was not significant. Accordingly, these whales have been assigned to age group IV, though they may prove to have been older if the wear of baleen plates is taken into account.

(2) These figures seem too high to be accepted as an estimate of the value for the stock. Probably, the lengths of female blue whales seldom exceed the size limit of 70 ft., and this causes a tendency that only a few fast-growing individuals are caught and a high percentage of sexual maturity results.

Table 1-b Number and Percentage of Sexually Mature Animals in the Catch of Female Fin Whales

Age group(1)	Number of growth periods in the baleen-record	Season				Total	
		1948-49		1949-50			
		Number	Percent	Number	Percent	Number	Percent
II	3	1(2)	100.0(3)	0	0.0	1	100.0(3)
III	4	13	32.5	13	50.0	26	39.4
IV	5	51	87.7	89	91.8	140	90.9
V	6	74	100.0	41	97.6	115	99.1
VI	7	36	100.0	10	100.0	46	100.0
VII	8	7	100.0	1	100.0	8	100.0

Note: (1) Whales have been assigned to the minimum age without considering the wear of the tips of the baleen plates. See the footnote (1) of Table 1-a for details.

(2) This specimen, in its third year after birth, already had two corpora lutea in the ovaries.

(3) These figures are too high to be accepted as an estimate of the value for the stock, and it is inferred, as in the case of female blue whales, that females of southern fin whales seldom exceed the size limit of 55 ft. at this age.

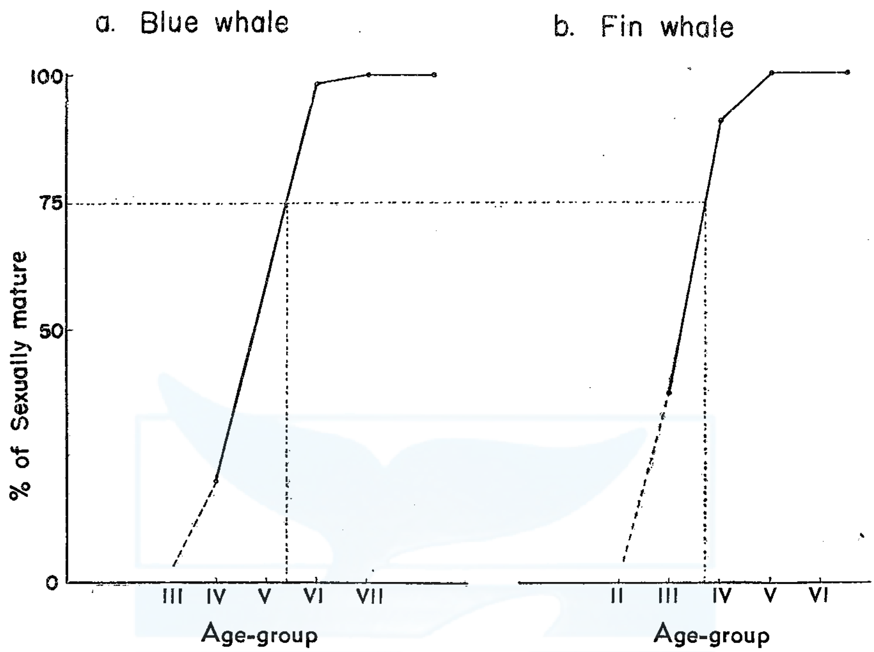


Fig. 2. Percentage of Sexual Maturity in Female Whale according to Age-group.

But the data also indicate that the minor part of the whales attain sexual maturity at younger or older ages than stated above. Of the three female blue whales belonging to the age group III in Table 1-a, one was found to be sexually mature with one corpus luteum in the ovary. And the single female fin whale belonging to the age group II in Table 1-b was sexually mature with two corpora lutea. The latter example will be cited again in Chapter V.

One would notice that Table 1 gives very high values of percentage of sexually mature females for the foregoing two age groups. And it does not seem that these values can be accepted as the estimates for the true values in the stocks of southern blue and fin whales. Perhaps, such unduly high values of percentage of sexual maturity are due partly to the variation inherent in small samples and partly to the tendency on the part of gunners to hunt larger whales. As is indicated by the scarce catch of female blue whales of the age group III and female fin whales of the age group II, the majority of the females of the southern blue and fin whales are probably below or not much above the size limits. Such being the case, the gunners' efforts to prevent violating the size regulations must result in a tendency that only the exceedingly fast-growing individuals are caught at these age levels. It is very probable that in such individuals the sexual development, as well as the physical growth, is accomplished much earlier than in the average individuals, for a number of such examples are known in terrestrial mammals.

Table 1 and Fig. 2 indicate also that a minor part of the females of the southern blue and fin whales are still immature respectively in their seventh and sixth year, though the majority of them attain sexual maturity respectively in the sixth and fifth year of their life.

It is noteworthy that the foregoing analysis shows that the majority of the females of the southern blue and fin whales respectively attain sexual maturity in the sixth and fifth year of their life, instead of in the third year as has been generally accepted. Ruud and his colleagues (Ruud et al, 1950), however, have already reached the same result regarding the age at which females of the southern blue whale attain sexual maturity with the catch by Norwegian fleets in the 1945–46 to 1947–48 seasons as the material. It is particularly interesting that the percentages of sexually mature females in different age group obtained by Ruud et al (Op. cit., Table 7) agree quite well with the corresponding figures in Table 1-a of this work.

Chapter III

The Colouration of the Crystalline Lens of the Sexually Immature Female

Crystalline lenses of blue and fin whales are usually coloured more or less in yellow, though some of them are colourless. And it is believed that this colour, ranging from slight yellow to deep yellow, is due to the pigment which is incessantly deposited in the lens during the life of the whale.

In the 1948–49 season I (Nishiwaki, 1950 a) measured the degree of colouration upon the crystalline lenses from 288 blue and 419 fin whales taken by the Hashidate-maru fleet. The measurement was made on board the floating factory by means of a photocell-ammetertype photometer expressly designed for this purpose. The percentage of the incident light absorbed by a crystalline lens was read on the ammeter. This, after being adjusted in respect to various errors, was termed the degree of colouration of the crystalline lens. Accordingly, the stronger was a lens coloured, the larger value of the degree of colouration resulted.

The analysis of the results of the measurement showed that the degree of colouration of the crystalline lens was closely correlated to the length of the whale, the number of corpora lutea and the weight of testes. This suggests that the colouration of the crystalline lens progresses at an approximately constant rate throughout the life of a whale, and that the degree of the colouration can be utilized as a measure of the age of whales.

In the same study females of the blue and fin whales were classified according to the degree of the colouration of the crystalline lens. In each class the percentage of sexually mature females was computed. By plotting this percentage against the degree of colouration of the crystalline lens, curves analogous to those in Fig. 2-a and -b were obtained for the blue and fin whales separately (Op. cit., Fig. 22). These curves indicate that 75% of the female blue and fin whales are sexually mature when the degree of colouration of their crystalline lens respectively reaches 9.5% and 8.7%.

The next problem is how to estimate the degree of colouration of the crystalline lens immediately after the birth of the whale. Though it is most desirable to have fresh samples of crystalline lenses of very young calves soon after birth, such calves are not caught under existing conditions of the whaling operations. Large foetuses may serve as the substitute to a certain extent. During the 1948–49 season I had opportunities of measuring the colouration of crystalline lenses of two large blue whale foetuses. These foetuses were 21 ft. 6 in. and 18 ft. 10 in. long, and their crystalline lens gave the degree of coloration of 4.7% and 4.4%.

The crystalline lens of a foetus differs from that of a young calf particularly in that blood vessels are distributed over its surface as well as through its center. As these blood vessels will have been lost before the calf acquires sight, a crystalline lens of a foetus is likely to absorb more light and consequently give a larger value of degree of colouration than that of a young calf. In addition, the degree of colouration of the crystalline lens of a young blue whale calf may differ from that of a young fin whale calf. Yet I propose to adopt 4.5%, the average for the two blue whale foetuses, as an approximate estimate for the degree of colouration of the crystalline lens in very young calves of the blue and fin whales.

Then it can be concluded that the degree of colouration of the crystalline lens of a sexually immature female blue whale increases from about 4.5% at the birth to about 9.5% at the attainment of sexual maturity and the same of a sexually immature female fin whale from about 4.5% at the birth upto about 8.7% at sexual maturity.

Chapter IV

The Frequency of Ovulation

Though the frequency of ovulation in southern blue and fin whales has been investigated by several authors, their results do not agree perfectly with each other. According to Laurie (1937) the average number of ova discharged by a female of the southern blue whale is 1.91 for the first year of sexual maturity and 1.13 for every following year. Peters (1939) considered a female of the southern blue and fin whales to shed not more than two ova during every two year period following the attainment of sexual maturity, while Wheeler (1930) estimated that a female of the sourthern fin whale will discharge 4 to 5 ova during the same period.

In this chapter I intend to describe a new method of estimating the frequency of ovulation in the southern blue and fin whales in which the result of my study on the colouration of crystalline lenses is incorporated. As has been shown in Chapter II of the present paper, it may be correctly deduced that the majority of the females of the southern blue whale attain sexual maturity in their sixth year of life and those of the southern fin whale in their fifth year, assuming that the investigated baleen plates are not worn significantly. In Chapter III it has been shown that the increase in the degree of colouration of the crystalline lens during the period from the birth to the attainment of sexual maturity is about 5.0% and 4.2% respectively in the females of the southern blue and fin whales. If we postulate an approximately constant increase of the degree of colouration of the crystalline lens during this period of whale's life, the average annual increment is given by the simple division:

$5.0\% \div 5.75 = 0.87\%$ per year for sexually immature blue whales,

and $4.2\% \div 4.75 = 0.88\%$ per year for sexually immature fin whales.

In my study on the 1948–49 catch (Nishiwaki, 1950a) I showed that the increase in the degree of colouration of the crystalline lens during the period between the attainments of sexual and physical maturity was about 5.3% in female blue whales and about 5.5% in female fin whales, and that the average increase in the number of corpora lutea during the same period was 10.0 and 9.5 respectively in the females of the blue and fin whale. If it is assumed that the degree of colouration of the crystalline lens continues to increase at the same constant rate during this period as prior to the attainment of sexual maturity, the approximate length of this period is 6 years for either species,

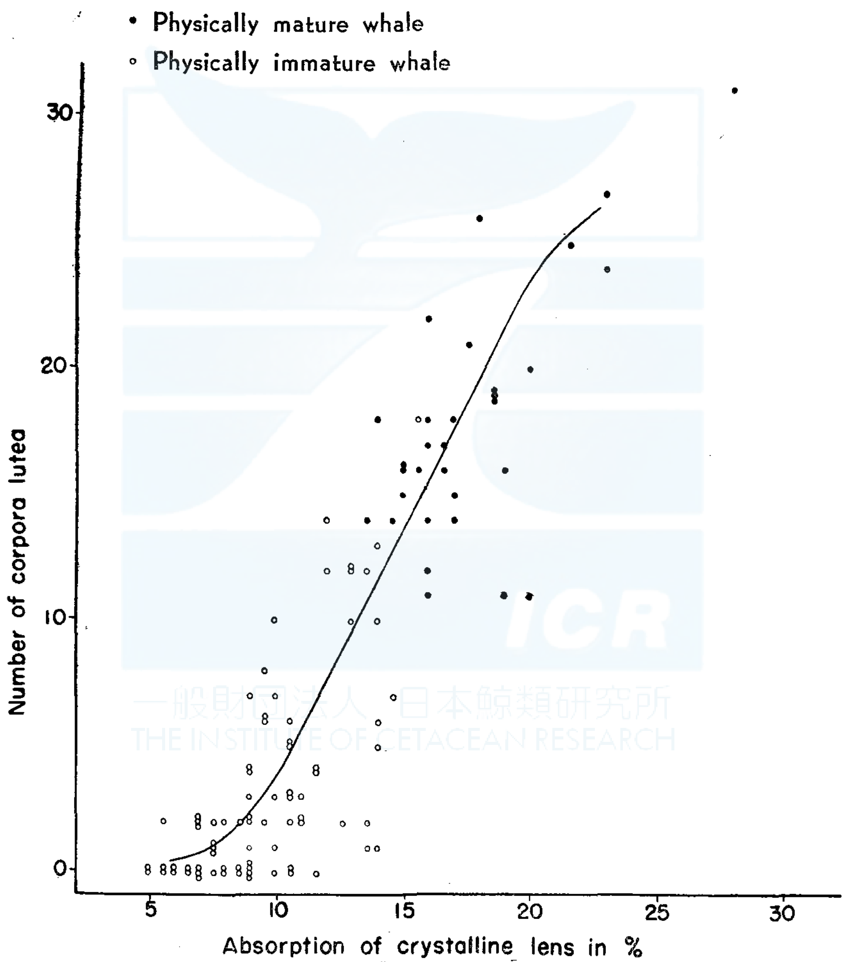


Fig. 3a. Number of Corpora Lutea and the Degree of Lenticular Colouration. (Blue whale female)

by dividing the increase in the degree of colouration during this period by the annual average increment determined in the foregoing paragraph.

By dividing the average increase in the number of corpora lutea during the period between the attainments of sexual and physical

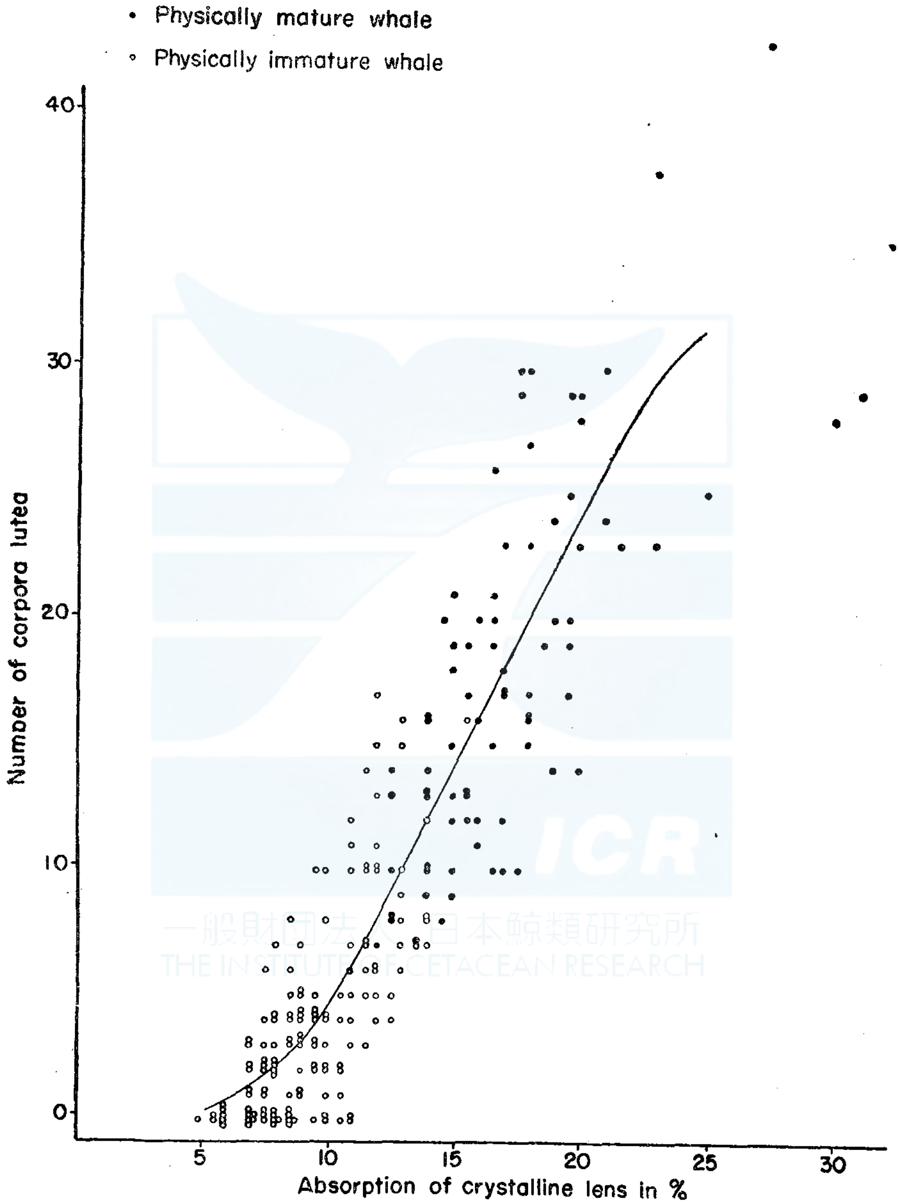


Fig. 3 b. Number of Corpora Lutea and the Degree of Lenticular Colouration. (Fin whale female)

maturity, 10.0 for the blue whale and 9.5 for the fin whale, by the length of the period, 6 years, we obtain 1.64 for the blue whale and 1.52 for the fin whale as the average number of ova discharged by a female whale per year.

If the foregoing estimates for the frequency for ovulation in the southern blue and fin whales are correct, it is inferred that a large part of the females of these whales should discharge two ova in the first year of sexual maturity. Such being the case, it does not seem unreasonable that one of the female fin whales listed in Table 1-b should have had two corpora lutea at the age of approximately $2^{3}/_{4}$ years and probably in the first year of sexual maturity.

Futher details basic to the foregoing discussions, e.g. the method to determine the physical maturity, appear in my original study (Op. cit.), of which the graphs showing the correlation between the colouration of the crystalline lens and the number of corpora lutea (Op. cit., Fig. 13 and 14) are reproduced in Figs. 3-a and -b because of their importance.

Chapter V

The Age of the Male Whale at Sexual and Physical Maturity

It is easy to determine whether a female whale is sexually mature or not, for this is accomplished by merely examining its ovaries for the presence of any corpora lutea. But there is much difficulty in the case of the male. The direct and probably most reliable method to determine the sexual maturity in the male whale consists in examining the testes histologically for the presence of spermatozoa or other evidences related to spermatogenesis. As this method is laborious, those indirect but easier methods are usually used, in which whales are classified into sexually mature and immature groups on the basis of the size of testes, the length of the whale or the like.

In recent years I have been using the weight of both testes combined as a criterion in determining the sexual maturity in the males of southern blue and fin whales. According to this method a blue whale showing the testes-weight of 10.0 kg. or more and a fin whale with the testes weighing 5.0 kg. or more are regarded as sexually mature. The usefulness of this criterion for southern blue whales has lately been confirmed by Norwegian scientists (Ruud et al, 1950, p. 33), though it was also pointed out at the same time that the weight of testes varies considerably in the male blue whales at attainment of sexual maturity.

Data on both the age and the sexual maturity are available for the major part of the male blue and fin whales caught by the Hashidate-maru fleet in the 1948–49 and 1949–50 seasons (Nishiwaki, 1949c & 1950c). In these data the age has been estimated from baleen records according to the formula described in Chapter II and the sexual maturity determined by the testes-weight method described above. The data are broken down into age groups, for each of which the number and percentage of sexually mature males are computed (Fig. 4-a, -b and Table 2-a, -b). The percentages of mature males for the two combined seasons are plotted in Fig. 5-a and -b respectively for blue and fin whales. In both figures plots are connected by strait lines to yield curves.

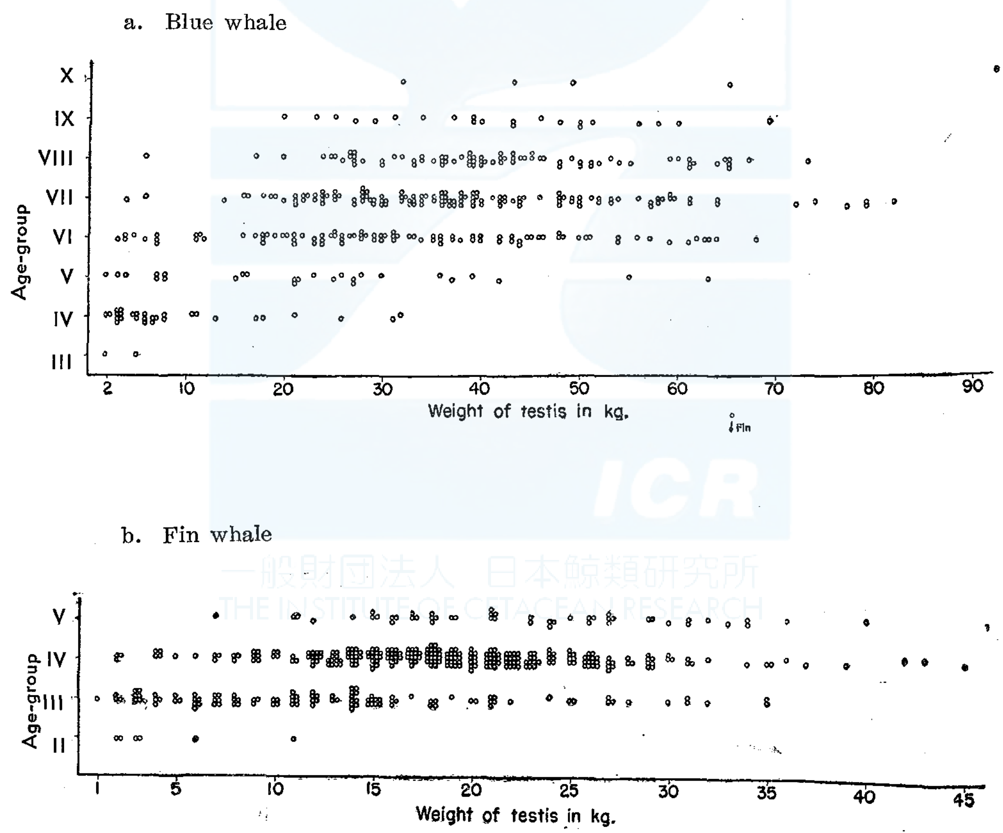


Fig. 4. Weight of Testes and Age-group.

Table 2-a Number and Percentage of Sexually Mature Animals in the Catch of Male Blue Whales

Age group(1)	Number of growth periods in the baleen record	Season				Total	
		1948-49		1949-50			
		Number	Percent	Number	Percent	Number	Percent
III	4	0	0.0	0	0.0	0	0.0
IV	5	5	33.3	4	28.6	9	31.0
V	6	9	81.8	10	33.3	19	73.1
VI	7	31	88.6	54	94.7	85	92.4
VII	8	64	100.0	65	98.5	129	99.2
VIII	9	43	100.0	39	97.5	82	98.8
IX	10	13	100.0	9	100.0	22	100.0

Note: (1) Whales have been assigned to the minimum probable age without considering the wear of the tips of baleen plates. See the footnote (1) of Table 1-a for details.

Table 2-b Number and Percentage of Sexually Mature Animals in the Catch of Male Fin Whales

Age group(1)	Number of growth periods in the baleen record	Season				Total	
		1948-49		1949-50			
		Number	Percent	Number	Percent	Number	Percent
II	3	2	33.3	0	0.0	2	33.3
III	4	63	86.3	27	79.4	90	84.1
IV	5	104	99.0	148	95.5	252	96.9
V	6	14	100.0	36	100.0	50	100.0

Note: See the footnote (1) of Table 2-a and 1-a.

Table 2-a and Fig. 5-a shows that more than 75% of male blue whales are already sexually mature in the sixth year of life, i.e. at the same age as the females, though there is a slight indication that males of this species attain sexual maturity at a little younger age than the females, when these table and figure are compared with Table 1-a and Fig. 2-a. Table 2-b and Fig. 5-b indicate that more than 75% of male fin whales are sexually mature in the fourth year of life, i.e. one year earlier than the females of the species. Consequently, we may consider the majority of male blue whales to be sexually mature at the age of about $5^3/_4$ years and the majority of male fin whales at the age of about $3^3/_4$ years.

In my previous study I (Nishiwaki, 1950a) showed that the degree

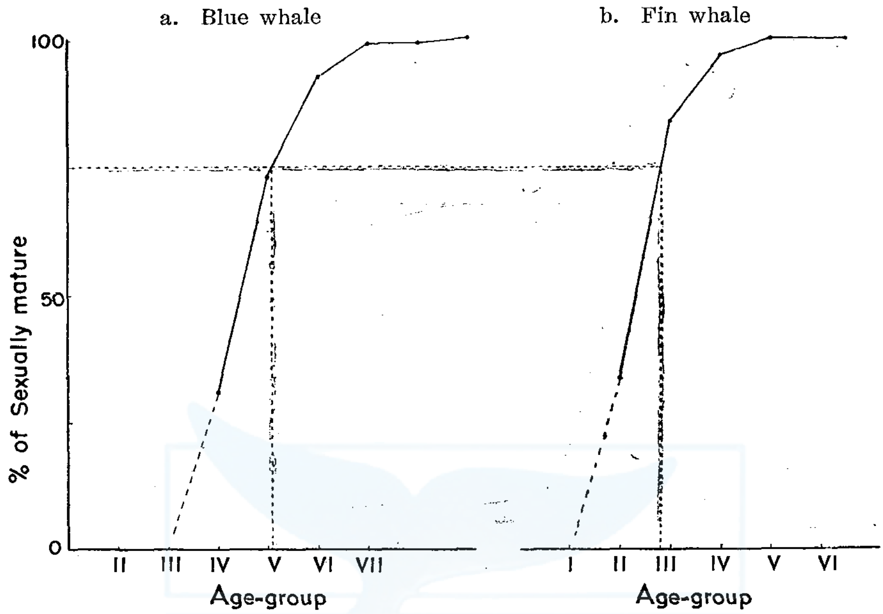


Fig. 5. Percentage of Sexual Maturity in Male Whale according to Age-group.

of colouration of the crystalline lens averages about 8.8% in male blue whales and about 8.2% in male fin whales at the attainment of sexual maturity. Assuming that the value of this factor is 4.5% at birth in both species as in the case of females in Chapter III, the increase during the period from birth to the attainment of sexual maturity is 4.3% in male blue whales and 3.7% in male fin whales. If it is assumed that this increase has taken place at an approximately constant rate throughout the period, the average annual increment is:

$4.3\% \div 5.75 = 0.75\%$ per year for sexually immature male blue whales,

and $3.7\% \div 3.75 = 0.98\%$ per year for sexually immature male fin whales.

These values differ from the corresponding values for females obtained in Chapter IV by about 0.1%. Then, it may be that the rate of increase of the degree of colouration of the crystalline lens differs according to sexes and species. But it is also likely that the difference of this magnitude can not be considered as significantly great, because a variation of this magnitude will easily result from a slight change in the value of the basic data to be involved in the foregoing equations.

In this connection we must consider the difference between the methods of determining sexual maturity in the two sexes of these whales.

In the case of females, with the approach of the sexual maturity approaching, ova are formed and gradually grow in the ovary. But the animal is not regarded as sexually mature until the ovum is shed in the first ovulation and the corpus luteum formed. It is well established that in southern blue and fin whales the ovulation takes place, with minor exceptions, during a limited season of the year, namely the pairing or the breeding season extending from June through August. As shown in Chapter II, the first ovulation generally takes place during the pairing season following the fifth birthday in female blue whales, and in the pairing season following the fourth birthday in female fin whales.

As the sexual maturity approaches in males, spermatozoa are formed and grow through metamorphosis in the testes, perhaps as gradually as the ova in ovaries of females. But, such a seasonal phenomenon as the ovulation is not known in the genital physiology of the male whale. And so, a male whale is usually regarded as sexually mature so long as spermatozoa are found in its testis, regardless of the extent of their development and whether coition or ejaculation has taken place or not. It is in this point that the method of determining sexual maturity in male whales primarily differs from the method for the females. Hence, it is to be expected that in male whales sexual maturity can be determined only less exactly than in females even by the direct method, i.e. the histological examination of testes, and also that the result of the determination will be such that suggests as if males attained sexual maturity earlier than females, even when both sexes really reach sexual maturity (i.e. the ovulation in females and, in males, the development of spermatozoa to a stage corresponding to the ovum at ovulation) at the same average age.

Moreover it is inevitable that additional disturbing factors will come into effect to reduce the exactness and reliability of the estimate of sexual maturity in males if the determination is made by such indirect methods as to employ testes-size or testes-weight as the criterion. Therefore, there is hardly any doubt that the estimated age at which male whales attain sexual maturity is less reliable than the similar estimate for females. Accordingly the data in Table 2 and the estimates of annual increment of the degree of colouration of the crystalline lens for males which are partly based on these data are less reliable than the data in Table 1 and the corresponding estimates for females.

Such being the case, I propose to use the estimates of the annual increment in the degree of colouration of the crystalline lens for females instead of the same estimates for males in estimating the age of males at sexual maturity. Then, this age in question is given as follows:

$4.3\% \div 0.87\% = 4.94$ years for male blue whales,

and $3.7\% \div 0.88\% = 4.2$ years for male fin whales.

This result, indicating that males attain sexual maturity about half a year earlier than females, coincides with the foregoing expectation that the estimated age of males at sexual maturity should be smaller than that for females. Following facts also suggests that one may accept this result. As sexual maturity has been determined with a high degree of reliability in female whales, the estimated annual increments of the degree of colouration of the crystalline lens for this sex (p. 97) are considerably reliable. These estimates, however, differ from the corresponding estimates for males by about 0.1%. This difference is not to be considered as significantly great, because a variation of this magnitude will be easily brought about by a slight shift in the boundary level of the testes-weight separating sexually mature males from immature. Therefore, one may consider that males of the southern blue and fin whales respectively attain sexual maturity at the average ages of about 5 and 4 years.

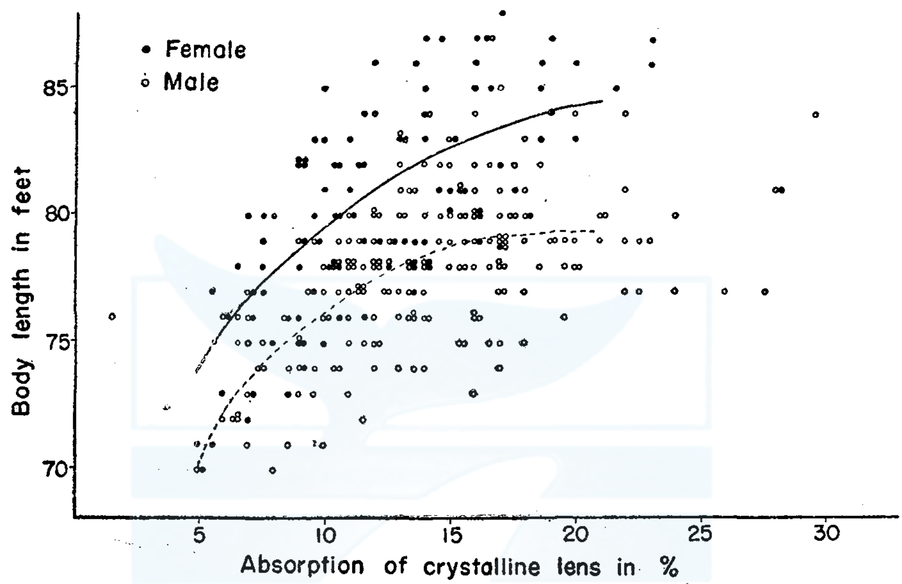
It was also shown in my previous study (Op. cit.) that the increase in the degree of colouration of the crystalline lens during the period from sexual maturity to physical maturity is 5.2% in male blue whales and 5.3% in male fin whales. Dividing these by the estimated annual increment of this factor in females, the length of this period is estimated at about 6 years for the males of both species, which is a little shorter than in the case of females.

Chapter VI

Average Length of the Whale at Different Ages

In my previous study (Nishiwaki, 1950a) it was shown that the degree of colouration of the crystalline lens was very closely correlated to the length of the whale as well as to such other age evidences as the number of corpora lutea, the weight of testes, and sexual and physical maturity in the southern blue and fin whales caught in the 1948–49 season, and the conclusion was advanced that this factor is most likely to increase exactly with the age in these whales and can be utilized as a measure of the age. In the foregoing two chapters the annual increment of this factor has been estimated at about 0.8% for both sexes of these whales. Therefore, it is now possible to determine the average lengths of these whales at various ages on the basis of those curves showing the average lengths of the whale at various levels of the degree of colouration of the crystalline lens which were presented in Figs. 5 and 6 of the aforementioned study (Nishiwaki, 1950a). These figures are reproduced in Figs. 6-a and -b.

a. Blue whale



b. Fin whale

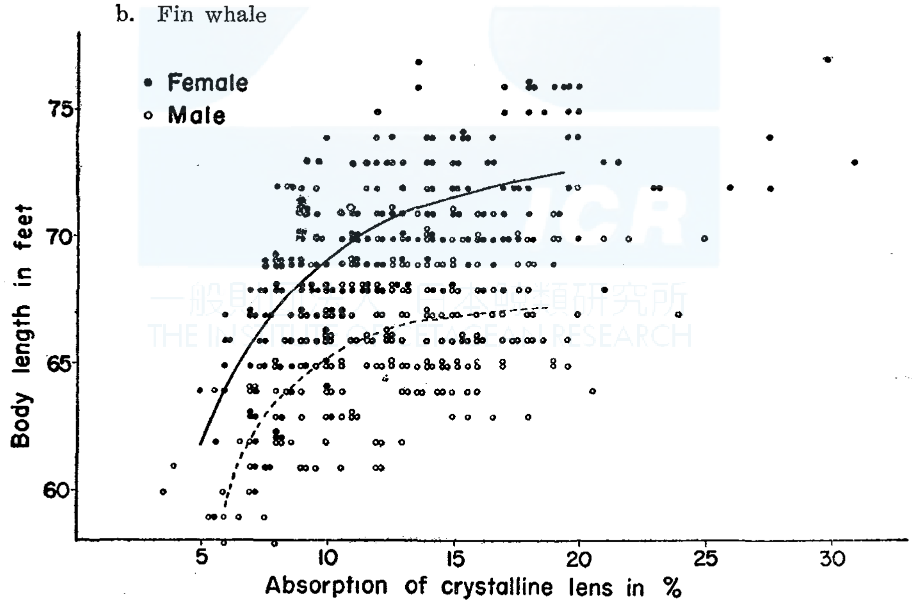


Fig. 6. Body Length and the Degree of Lenticular Colouration.

In the material upon which these curves are based, the average length of the whale at sexual maturity was determined as follows (Op. cit., p. 160):

Blue whale, male: 74.9 Eng. ft., female: 79.1 Eng. ft.

Fin whale, male: 63.5 Eng. ft., female: 67.8 Eng. ft.

From Chapter II and V of the present paper, blue and fin whales attain sexual maturity in the sixth and fifth year of life respectively. Hence, it is possible to express the scale of the abscissa of Figs. 6-a and -b in terms of the age of the whale instead of the degree of colouration of the crystalline lens. By doing so, the average lengths of the whale at different ages are read from the curves and tabulated in Table 3.

Table 3. Average Length of the Whale at Different Ages (Expressed in English feet)

Age group	III	IV	V	VI	VII	VIII	IX	X	XI
Approximate age (in years)	$3^3/_4$	$4^3/_4$	$5^3/_4$	$6^3/_4$	$7^3/_4$	$8^3/_4$	$9^3/_4$	$10^3/_4$	$11^3/_4$
Blue whale male	73.2	74.2	74.9	75.6	76.2	76.8	77.4	78.0	78.5
Blue whale female	77.0	78.1	79.1	79.9	80.6	81.3	81.8	82.2	82.6
Fin whale male	62.2	63.5	64.4	65.2	65.7	66.1	66.4	66.6	66.8
Fin whale female	67.0	67.8	68.7	69.5	70.1	70.6	71.0	71.3	71.5

It should be mentioned that this table gives unduly large average lengths for younger age groups. This is explained as the influence of the size limit. In other words, whales are not much larger at these ages than the size limits set forth by the International Whaling Conventions, and the catch of these age groups consisted of a small number of those fastgrowing individuals which were relatively large at respective ages.

It is well established that weaning blue whale calves measure about 53 Eng. ft. in length. Therefore, the increase in length from weaning to attainment of sexual maturity is 22 to 25 Eng. ft. in this species. Table 3 indicates that this increase takes place during about 4 years, i.e. an average increase of 5 to 6 Eng. ft. per year. This seems more reasonable than to consider the whole increase to take place during one and a half years as suggested in the conventional theory.

Chapter VII

Conclusions

The conclusions reached in the foregoing chapters are summarized as follows.

From the evidences derived from the study of the surface structure of baleen plates the age at attainment of sexual maturity has been estimated. Females of the blue whale reach sexual maturity in the pairing season following the fifth birthday, and the males at the age of about four and a half years, or somewhat earlier than the females. In the case of the fin whale, females attain sexual maturity in the pairing season following the fourth birthday and males at the age of about three and a half years.

This result entirely differ from the conventional theories proposed by Mackintosh & Wheeler (1929), Laurie (1937) or Peters (1939). But Ruud (1950) and his collaborators (Ruud et al, 1950) have already reached the same result upon the hypothesis that each growth period appearing in the baleen record represents the annual growth of the baleen plate. I proved in my previous study (Nishiwaki, 1950c) that this hypothesis is true to the fact, and have reached the foregoing result by analyzing the material for that and the preceding study (Nishiwaki, 1949c).

It is very difficult, however, to determine the frequency of ovulation simply from the investigation of baleen plates. This is because baleen plates gradually wear at the tip after when once a whale reach a certain age or a certain stage of physical growth. In the consequence of this tendency, exact age-determinations become nearly impossible by the baleen record method after blue whales are 7 to 9 year old and fin whales 6 to 8 year old, i.e. a few years after the sexual maturity is attained. Therefore, I have made use of the evidences concerning the colouration of the crystalline lens reported in my previous study (Nishiwaki, 1950a) together with the results of the baleen record reading in order to determine the frequency of ovulation.

By this method it has been found that the average number of ova shed by a female blue whale is 2 during the first year of sexual maturity and 1.64 per year during the following period, and in the case of a female fin whale 2 during the first year of sexual maturity and 1.52 per year during the succeeding period.

This result, though reached through an entirely different approach, agrees with the findings made by precedent authors.

Mackintosh (1946, p. 254) reported a case in which a female fin whale caught 6 years after marking had a total of 8 corpora lutea in ovaries. There is no means of determining in what period of life history this whale was marked. But if it was marked in the first year of sexual maturity, ova must have been shed at the rate of 1.33 per year during the period between marking and capture. If it was marked in the year preceding the attainment of sexual maturity, the ovulation took place at the rate of 1.6 ova per year. This example as well as the result of the present study suggests in blue and fin whales that an average of 2 to 3 ova are discharged every breeding season that lasts two years.

The length of the period from attainment of sexual maturity to that of physical maturity has been also estimated by a similar method. In both sexes of blue and fin whales the length of this period has been estimated at about 6 years. A whale is regarded as physically mature if epiphyses are ankylosed to the centrum in the middle vertebrae of both thoracic and the lumbar series.

In the present study I have employed, as far as possible, the material already dealt with in my previous works, though a few new data have been introduced when they are necessary to develop sound conclusions partly, because this material, having been collected prior to the formulation of the theory presented in this study, is entirely free from its influence and partly because I wished to proceed with the auguments which were not concluded in my earlier studies.

In short, the results of the present study differ from conventional theories most significantly in that they indicate that southern blue and fin whales attain sexual maturity at much older ages than suggested before. According to conventional theories it takes a weaning blue whale calf about one and a half years to reach sexual maturity, during which period the whale grows by 22 to 25 Eng. ft. in length, and thereafter the growth slows down to a rate of about 3 Eng. ft. per year.

In comparison, the present result indicates that the increase in length of 22 to 25 Eng. ft. takes place during about four and a half years, i.e. an average annual increase of 5.5 Eng. ft. But this average increase will not be maintained throughout the period from birth to the attainment of sexual maturity, for the growth must slow down with the age. Now let us assume that the blue whale attains sexual maturity at 5 years after birth and approximates its growth curve for this period with a logarithmic curve. Then the annual increase in length is 28 Eng. ft. for the first year following birth (including the suckling period), and 7.4, 5.9, 4.8 and 3.9 Eng. ft. for the subsequent years.

By extrapolating the same curve, annual increments in length in the years following the attainment of sexual maturity are 3.3, 2.9, 2.5, 2.1, 1.8 and 1.5 Eng. ft. These figures almost coincide with those obtained by previous workers. Then, can this fact not be taken as an indication that this logarithmic curve adequately depicts the growth of the blue whale and that the whale grows at the abovementioned rate to reach sexual maturity at the age of about 5 years?

From the results of the present study the life history of the southern blue and fin whales appears as follows. In the blue whale, males reach sexual maturity about four and a half years after birth and females about five years after birth. Both sexes experience the first coition between June and August following the fifth birthday. Thereafter, the breeding period of two years recurs in females, during which a series of gestation, parturition and lactation takes place. Physical maturity is reached about 6 years after the attainment of sexual maturity, i.e. about 11 years after birth. The average life of this species would be 25 to 30 years under natural conditions.

It does not seem that the life history of the fin whale much differ from that of the blue whale except that the sexual, and consequently the physical, maturity is attained about one year earlier in the former species.

It seems necessary to reexamine the age composition of the catch and analyze the situation of the stocks of blue and fin whales in the light of the result of the present study and to contrive an adequate system of regulating the whaling operations, if the whaling industry is to enjoy permanent prosperity and the whale resources to be conserved for the benefit of mankind. This problem will be dealt with in a separate work.

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APPENDIX

Blue and Fin Whales Caught in the Antractic in the Season 1946-47 to 1949-50, by Species, Sex and Body Length

a. Blue Whale

Body Length of Whale (ft) \ Season / No. of	1946 ~ 47											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
55												
56												
57												
58												
59	2		2									
60	2	3	5									
61	2	5	7									
62	4	2	6									
63	3	10	13	1		1				1		1
64	12	9	21									
65	15	15	30									
66	31	18	49									
67	26	24	50	1	1	2				1	1	2
68	22	15	37	1		1	1		1			
69	4	4	8									
70	231	186	417	9	10	19	6	2	8	3	8	11
71	216	161	377	23	18	41	13	12	25	10	6	16
72	210	124	334	21	13	34	8	6	14	13	7	20
73	234	146	380	29	10	39	16	5	21	13	5	18
74	260	183	443	34	17	51	19	6	25	15	11	26
75	342	216	558	27	15	42	11	9	20	16	6	22
76	389	216	605	35	21	56	15	9	24	20	12	32
77	324	197	521	31	26	57	13	14	27	18	12	30
78	419	256	675	34	29	63	13	11	24	21	18	39
79	366	252	618	33	25	58	10	12	22	23	13	36
80	407	346	753	28	26	54	10	9	19	18	17	35
81	261	227	538	19	25	44	10	5	15	9	20	29
82	219	269	488	15	10	25	5	6	11	10	4	14
83	154	282	436	9	19	28	4	6	10	5	13	18
84	100	258	358	5	14	19		9	9	5	5	10
85	75	264	339	9	14	23	3	7	10	6	7	13
86	36	196	232	3	11	14		3	3	3	8	11
87	17	144	161	1	4	5		1	1	1	3	4
88	9	121	130		7	7		2	2		5	5
89	3	93	96	1	5	6	1	2	3		3	3
90	3	82	85		1	1					1	1
91		39	39									
92		17	17									
93		19	19									
94		7	7									
95		5	5									
96		1	1									
97		1	1									
98		1	1									
99												
100		1	1									
101		1	1									
102												
103												
104												
Sum	4398	4466	8864	369	321	690	158	136	294	211	185	396
Average length (ft)	76.84	79.72	78.29	76.64	78.61	77.54	76.12	78.24	77.09	77.03	78.99	77.89
Sex ratio	49.62	50.38		53.48	46.52		53.74	46.26		53.28	46.72	

Body Length of Whale (ft) \ No. of \ Season	1947 ～ 48											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
55	1		1									
56												
57		2	2									
58	1		1									
59		1	1									
60	2	3	5									
61	3	3	6									
62	4	2	6									
63	3	6	9									
64	14	16	30		1	1		1	1			
65	20	13	33									
66	25	22	47									
67	33	20	53	1		1	1		1			
68	22	17	39									
69	6	5	11	2		2	1		1	1		1
70	219	222	441	1	4	5		3	3	1	1	2
71	194	135	329	6	1	7	3		3	3	1	4
72	150	118	268	10	6	16	4	3	7	6	3	9
73	146	118	264	8	6	14	3	3	6	5	3	8
74	153	102	255	15	12	27	9	5	14	6	7	13
75	222	114	336	27	12	39	16	4	20	11	8	19
76	236	131	367	44(1)	19	63(1)	18	9	27	26(1)	10	36(1)
77	246	98	344	36	10	46	12	1	13	24	9	33
78	287	148	435	48	24	72	20	12	32	28	12	40
79	276	113	389	43	24	67	16	8	24	27	16	43
80	313	219	532	29	30	59	8	11	19	21	19	40
81	220	171	391	22	42	64	9	15	24	13	27	40
82	200	187	387	27	38	65	13	15	28	14	23	37
83	136	182	318	7	35	42		13	13	7	22	29
84	115	191	306	5	25	30	3	4	7	2	21	23
85	69	197	266	3	25	28		11	11	3	14	17
86	45	155	200	2	22	24	1	10	11	1	12	13
87	28	113	141	2	18	20	1	1	2	1	17	18
88	21	97	118		7	7		4	4		3	3
89	4	60	64		6	6		2	2		4	4
90	9	84	93		1	1					1	1
91	7	47	54		3	3		1	1		2	2
92	2	41	43		1	1					1	1
93		26	26									
94		20	20									
95		9	9									
96		12	12									
97		3	3									
98		3	3									
99												
100												
101		1	1									
102		1	1									
103												
104												
Sum	3432	3228	6660	338(1)	372	710(1)	138	136	274	200(1)	236	436
Average Length (ft)	77.11	79.87	78.45	77.86	81.09	79.55	77.52	80.52	79.01	78.09	81.42	79.89
Percent	51.53	48.47		47.58	52.42		50.37	49.63		45.87	54.13	

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Season / Body Length of Whale (ft) / No. of	1948 ~ 49											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
55												
56												
57												
58												
59	1		1									
60	1	3	4									
61	2		2									
62	4	3	7									
63	7	1	8									
64	12	7	19									
65	21	22	43									
66	20	15	35									
67	18	16	34									
68	16	22	38									
69	6	7	13									
70	180	111	291	3	2	5	2	1	3	1	1	2
71	147	111	258	4	2	6	3	2	5	1		1
72	154	120	274	9	2	11	5	1	6	4	1	5
73	165	97	262	14	4	18	5	3	8	9	1	10
74	164	100	264	22	6	28	12	1	13	10	5	15
75	248	138	386	21	9	30	13	5	18	8	4	12
76	270	119	389	33	10	43	20	6	26	13	4	17
77	267	110	377	51	9	60	22	5	27	29	4	33
78	363	137	500	54	18	72	27	12	39	27	6	33
79	287	126	413	62	22	84	28	11	39	34	11	45
80	363	199	562	34	23	57	20	11	31	14	12	26
81	281	184	465	27	23	50	9	8	17	18	15	33
82	280	203	483	31	20	51	8	10	18	23	10	33
83	166	239	405	11	23	34	3	9	12	8	14	22
84	115	217	332	11	11	22	4	4	8	7	7	14
85	88	245	333	2	15	17	1	6	7	1	9	10
86	35	221	256	1	19	20		6	6	1	13	14
87	37	187	224	1	13	14	1	6	7		7	7
88	18	139	157		4	4		1	1		3	3
89	9	75	84									
90	7	100	107		3	3					3	3
91	3	43	46		2	2					2	2
92		39	39									
93		19	19									
94		10	10									
95		9	9									
96		3	3									
97		1	1									
98												
99		1	1									
100		1	1									
101		1	1									
102												
103												
104												
Sum	3755	3401	7156	391	240	631	183	108	291	208	132	340
Average length (ft)	77.57	80.83	79.12	77.98	81.04	79.15	77.68	80.23	78.63	78.49	81.71	79.74
Sex ratio	52.47	47.53		61.95	38.05		62.89	37.11		61.18	38.82	

Body Length of Whale (ft) \ Season / No. of	1949 ~ 50											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Fe-male	Total	Male	Fe-male	Total	Male	Fe-male	Total	Male	Fe-male	Total
55												
56												
57												
58	1		1									
59												
60	4	1	5	1		1	1		1			
61	2	1	3									
62	3	2	5									
63	6	4	10									
64	12	17	29									
65	17	23	40									
66	21	13	34									
67	31	26	57									
68	27	14	41									
69	4	6	10									
70	142	101	243									
71	131	103	234	7	4	11	4		4	3	4	7
72	115	105	220	11	8	19	7	5	12	4	3	7
73	132	73	205	21	7	28	16	6	22	5	1	6
74	146	77	223	24	8	32	13	3	16	11	5	16
75	206	102	308	38	9	47	19	4	23	19	5	24
76	205	89	294	58	12	70	29	7	36	29	5	34
77	227	80	307	45	9	54	23	3	26	22	6	28
78	293	81	374	77	17	94	44	9	53	33	8	41
79	268	88	356	62	14	76	31	7	38	31	7	38
80	416	132	548	73	15	88	25	5	30	48	10	58
81	297	119	416	50	18	68	21	9	30	29	9	38
82	269	157	426	41	28	69	18	12	30	23	16	39
83	179	183	362	26	26	52	9	11	20	17	15	32
84	124	217	341	15	21	36	7	7	14	8	14	22
85	74	183	257	3	16	19		8	8	3	8	11
86	28	178	206	4	19	23	2	5	7	2	14	16
87	19	175	194	1	12	13	1	7	8		5	5
88	7	120	127		6	6		2	2		4	4
89	4	80	84		5	5		1	1		4	4
90	1	81	82		4	4		2	2		2	2
91	1	38	39		1	1		1	1			
92		19	19		1	1					1	1
93		12	12									
94		7	7									
95		4	4									
96		2	2									
97												
98												
99												
100												
101												
102												
103												
104												
Sum	3412	2713	6125	557	260	817	270	114	384	287	146	433
Average length (ft)	77.70	80.71	79.03	78.4	81.2	79.2	77.9	80.8	78.7	78.9	81.5	79.8
Sex raito	55.71	44.29		68.18	31.82		70.31	29.69		66.28	33.72	

b. Fin whale

Body Length of Whale (ft) \ No. of \ Season	1946 ~ 47											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
45												
46												
47												
48	1		1									
49												
50	2	1	3									
51	2	1	3									
52	2	1	3									
53	4	1	5									
54	3		3									
55	51	38	89	1	1	2	1		1		1	1
56	72	44	116	3	2	5		1	1	3	1	4
57	62	59	121	6	4	10	3	3	6	3	1	4
58	78	56	134	2	10	12	1	6	7	1	4	5
59	90	71	161	4	3	7	3	1	4	1	2	3
60	188	134	322	7	6	13	2	2	4	5	4	9
61	225	122	347	19	11	30	8	4	12	11	7	18
62	237	144	381	12	12	24	5	1	6	7	11	18
63	348	184	532	23	9	32	12	3	15	11	6	17
64	572	261	833	28	14	42	6	7	13	22	7	29
65	771	328	1099	26	16	42	13	7	20	13	9	22
66	752	341	1093	22	11	33	5	4	9	17	7	24
67	782	380	1162	27	16	43	12	4	16	15	12	27
68	696	447	1143	29	19	48	13	7	20	16	12	28
69	531	512	1043	20	16	36	8	6	14	12	10	22
70	485	671	1156	13	13	26	6	3	9	7	10	17
71	220	553	773	5	14	19	1	5	6	4	9	13
72	101	498	599	3	17	20	1	9	10	2	8	10
73	66	489	555		10	10		4	4		6	6
74	29	422	451		12	12		5	5		7	7
75	15	337	352		5	5		2	2		3	3
76	3	188	191		2	2					2	2
77	2	106	108		1	1		1	1			
78	4	48	52									
79		25	25									
80		11	11									
81		2	2									
82												
83												
84												
85												
86												
87		1	1									
88												
89												
90												
Sum	6394	6476	12870	250	224	474	100	85	185	150	139	289
Average length (ft)	65.83	69.00	67.43	65.07	66.83	65.90	64.97	66.78	65.26	65.14	66.86	65.96
Sex ratio	49.68	50.32		52.74	47.26		54.05	45.95		51.90	48.10	

Body Length of Whale (ft) \ Season / No. of	1947 ～ 48											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
45												
46												
47	1	1	2									
48												
49												
50	1	1	2									
51	3	5	8									
52	8	4	12									
53	11	3	14									
54	5	2	7									
55	45	34	79									
56	81	66	147		1	1					1	1
57	84	65	149									
58	99	77	176									
59	116	93	209									
60	231	147	378	1		1	1		1			
61	220	125	345	1		1	1		1			
62	305	168	473	4	3	7	1		1	3	3	6
63	474	251	725	12	3	15	8	1	9	4	2	6
64	651	288	939	33	6	39	13	1	14	20	5	25
65	1002	365	1367	35	11	46	10	3	13	25	8	33
66	1095	396	1491	46	17	63	15	5	20	31	12	43
67	1315	438	1753	49	12	61	12	6	18	37	6	43
68	1238	506	1744	33	22	55	12	8	20	21	14	35
69	1032	545	1577	27	36	63	7	12	19	20	24	44
70	958	724	1682	10	43	53	3	16	19	7	27	34
71	479	669	1148	8	54	62	3	23	26	5	31	36
72	292	696	988	2	46	48	1	15	16	1	31	32
73	179	614	793	2	34	36		14	14	2	20	22
74	119	603	722		35	35		14	14		21	21
75	62	470	532		9	9		4	4		5	5
76	21	293	314		10	10		1	1		9	9
77	6	196	202		2	2		1	1		1	1
78	9	128	137		1	1					1	1
79	1	53	54									
80	5	67	72									
81		11	11									
82		10	10									
83		3	3									
84		4	4									
85		2	2									
86												
87												
88												
89												
90												
Sum	10148	8123	18271	263	345	608	87	124	211	176	221	397
Average length (ft)	66.65	69.52	67.93	66.52	70.53	68.79	66.17	70.73	68.85	66.70	70.41	68.77
Sex ratio	55.54	44.46		43.27	56.73		41.23	58.77		44.33	55.67	

Season / Body Length of Whale (ft) / No. of	1948 ~ 49											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Fe-male	Total	Male	Fe-male	Total	Male	Fe-male	Total	Male	Fe-male	Total
45												
46												
47												
48	1		1									
49	1	4	5									
50	1	2	3									
51	3	2	5									
52	6	6	12									
53	6	7	13									
54	7	1	8									
55	40	52	92									
56	56	59	115									
57	103	68	171									
58	88	60	148	2		2	2		2			
59	97	77	174	5	2	7	3	1	4	2	1	3
60	201	126	327	4	1	5	2	1	3	2		2
61	225	128	353	12	4	16	8	3	11	4	1	5
62	303	158	461	20	8	28	9	5	14	11	3	14
63	426	222	648	24	12	36	10	6	16	14	6	20
64	516	223	739	48	12	60	22	5	27	26	7	33
65	865	296	1161	69	14	83	34	6	40	35	8	43
66	916	300	1216	85	23	108	33	8	41	52	15	67
67	1101	427	1528	58	22	80	23	12	35	35	10	45
68	1116	479	1595	54	47	101	17	28	45	37	19	56
69	860	460	1320	59	50	109	18	26	44	41	24	65
70	758	837	1595	31	68	99	14	29	43	17	39	56
71	355	703	1058	11	66	77	7	21	28	4	45	49
72	224	795	1019	6	64	70	1	22	23	5	42	47
73	115	716	831		50	50		18	18		32	32
74	53	511	564		32	32		14	14		18	18
75	16	467	483		20	20		6	6		14	14
76	12	341	353		21	21		9	9		12	12
77	7	149	156		5	5		2	2		3	3
78	3	111	114		1	1					1	1
79	4	36	40									
80	1	38	39		2	2					2	2
81		11	11									
82		3	3									
83		2	2									
84												
85												
86												
87												
88												
89												
80												
Sum	8486	7877	16363	488	524	1012	203	222	425	285	302	587
Average length (ft)	66.40	69.65	67.96	66.2	70.2	68.3	65.88	69.70	67.87	66.5	70.6	68.7
Sex raito	51.86	48.14		48.21	51.79		47.78	52.22		48.55	51.45	

Season / Body Length of Whale (ft) / No. of	1949 ～ 50											
	Total Antarctic, Pelagic whaling			Japanese Expedition								
				Total			Hashidate Maru			Nisshin Maru		
	Male	Fe-male	Total	Male	Fe-male	Total	Male	Fe-male	Total	Male	Fe-male	Total
45												
46												
47												
48		1	1									
49	1	1	2									
50	2	7	9									
51	10	10	20									
52	14	5	19									
53	15	18	33									
54	17	12	29									
55	94	68	162									
56	119	113	232									
57	120	115	235									
58	159	140	299	1		1	1		1			
59	141	119	260	3	2	5	3	1	4	·	1	1
60	239	187	426	3	6	9		3	3	3	3	6
61	274	180	454	13	2	15	8	1	9	5	1	6
62	352	185	537	16	8	24	6	4	10	10	4	14
63	452	210	662	39	6	45	17	3	20	22	3	25
64	529	276	868	65	9	74	18	6	24	47	3	50
65	895	345	1240	95	15	110	41	4	45	54	11	65
66	1005	354	1359	106	19	125	46	8	54	60	11	71
67	1160	439	1599	89	31	120	35	14	49	54	17	71
68	1149	489	1638	87	33	120	35	20	55	52	13	65
69	972	546	1518	62	48	110	25	27	52	37	21	58
70	759	789	1548	24	58	82	8	25	33	16	33	49
71	365	729	1094	9	57	66	3	32	35	6	25	31
72	185	781	966	5	55	60	1	23	24	4	32	36
73	95	684	779	1	39	40	1	18	19	0	21	21
74	62	606	668	1	32	33		15	15	1	17	18
75	18	493	511		9	9		3	3		6	6
76	5	318	323		4	4		1	1		3	3
77	1	188	189		3	3		2	2		1	1
78	1	101	102		1	1		1	1			
79	1	44	45									
80	2	27	29									
81		8	8									
82		4	4									
83		3	3									
84		1	1									
85												
86												
87												
88												
89												
90												
Sum	9276	8596	17872	619	437	1056	248	211	459	371	226	597
Average length (ft)	65.98	69.07	67.46	66.2	69.8	67.7	66.1	69.7	67.7	66.3	69.9	67.7
Sex raito	51.90	48.10		58.62	41.38		54.03	45.97		62.14	37.86	

On the Sexual Maturity of the Sperm Whale (*Physeter catodon*) found in the Adjacent Waters of Japan (II)

BY

MASAHARU NISHIWAKI and TAKASHI HIBIYA

(Received Dec, 5, 1951)

Material and Method

The material which serves as the basis for this study covers all the sperm whales caught by the Baikal Maru fleet of the Kyokuyo Whaling Co., Ltd. in the waters east of the Bonin Is., 25°19′N–26°50′N and 142°17′E–145°10′E (Fig. 1), during the period March 17–June 10, 1951. They consist of fifty five males of the body lengths between 38 and 53 Eng. ft. and one female of 38 Eng. ft. long.

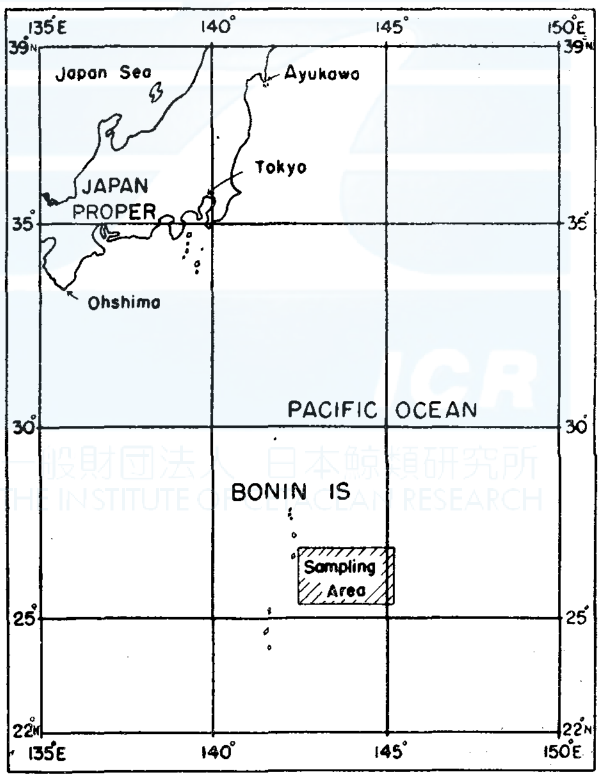

Fig. 1. Location of sampling area.

The method for the present study is the same as was used in the previous work (Nishiwaki & Hibiya: 1951).

We express our hearty thanks to the Kyokuyo Whaling Co., Ltd. for their immense cooperation in collecting the material and data for this study. We are grateful also to Messrs. Setsuo Mishimoto and Takehiko Kawakami, government inspectors of the Fisheries Agency, Ministery of Agriculture and Forestry, who directed the collection of the material on board. Our thanks are also due to Miss Hisako Jimbo who rendered much assistance in preparing the preparats for the histological study.

Result and Discussion

The result of the histological examination is presented in Fig. 2, where the right and the left testis of each whale are counted individually and those testes from which no spermatozoa were detected are classified into the "minus" or immature group irrespective of the feature of development of the testis tissue, as was done in the previous study.

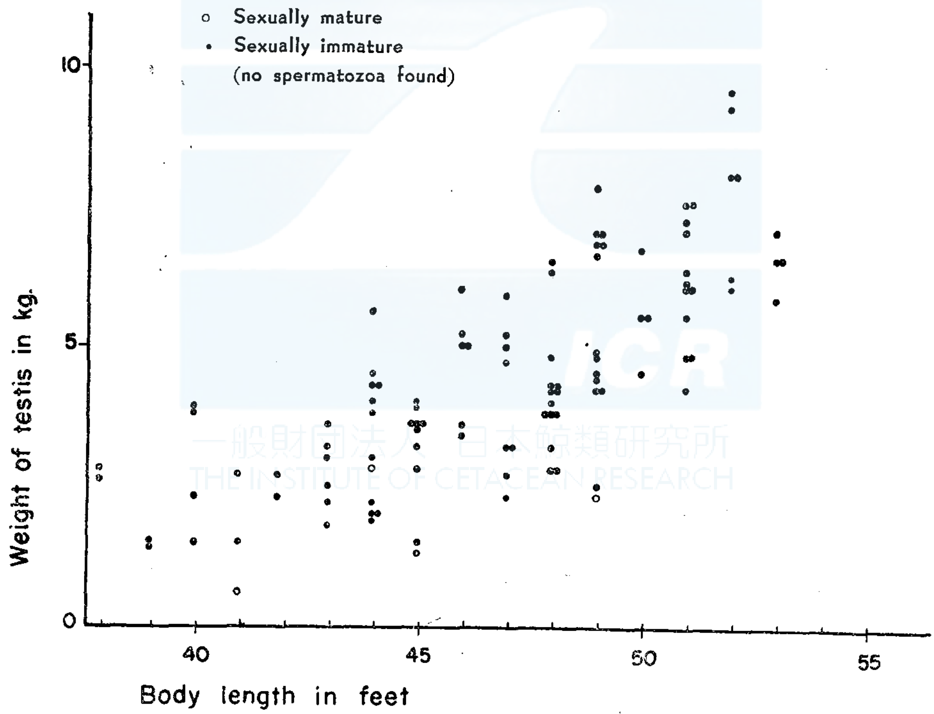

Fig. 2. Weight of testis and body length in the sperm whale caught in Bonin area, March-June 1951.

As is clear from Fig. 2, spermatozoa were found in all the examined testes except three, which respectively belonged to the males of 41, 44 and 49 Eng. ft. These males, however, were undoubtedly sexually mature, for spermatozoa were certainly found in their other testes.

In two of these males the weights of the right and the left testis differed markedly: the two testes weighed 0.6 and 2.7 kg. in the male of 41 Eng. ft. and 2.8 and 5.6 kg. in the one 44 Eng. ft. long. As it is usually the case that the weights of the two testes of a whale are very close, though they are not always exactly equal, it may be said that in these two males one of their testes represented unusually poorer development than the other. And it was in these smaller or poorly developed testes that the spermatozoa were not found. In the third male, of the length 49 Eng. ft., weights of the two testes were very close, measuring 2.3 and 2.5 kg. Though the detection of spermatozoa, which was made with the sample piece of the size of 1 cc., gave a negative result for one of the testes of this male, its two testes were hardly distinguishable from each other in point of the feature of the spermatids.

It seems that the foregoing evidences collectively lead to a conclusion that the male sperm whales in the adjacent waters of Japan reach sexual maturity at body lengths less than 38 Eng. ft., confirming the theory proposed in the previous study (Op. cit.).

In the course of the histological examination of testis samples, we came to notice that in the present study more spermatozoa could be found with less efforts than in the previous study. Such difference in the case with which spermatozoa are detected may closely be related to a periodicity in the activity of testis. This problem will be discussed when data covering different seasons and whaling grounds become available.

The only female sperm whale caught during the expedition with which this study is concerned measured 38 Eng. ft. in length. Her twelve corpora lutea, five to the right and seven to the left, were all old: as a matter of course, she was not pregnant.

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(The Whales Research Institute and the Laboratory of Fishery Zoology, Faculty of Agriculture, Tokyo University)

Biological Investigation on the Whales Caught by the Japanese Antarctic Whaling Fleets, Season 1950/51

BY

MIZUHO OHNO and KAZUO FUJINO

CONTENTS

Introduction

This report is a compilation of the results of the biological investigation on whales caught by the Japanese two whaling fleets during 1950/51 Antarctic season.

The Hashidatemaru fleet left Japan for the Antarctic on 29th October and the Nisshinmaru fleet left on 1st November to participate in sperm whaling prior to the commencement of the baleen whaling season. During 26th November to 21st December they caught respectively

243 and 166 sperm whales between 95° and 150°E., Long. Both fleets bagan baleen whaling on 22nd December 1950, the first day of the season authorized by International Agreement, and operated in the sector south of Latitude 63°S., between Longitude 96°E. and 162°W. They ceased operations on 9th March 1951. The catch during this season is shown as in the appended table. In the "Ross Area", more than 10 fleets gathered and their whaling ground also extended wide longitudinally. For convenience of comparison, the whaling ground is classified into the following three sections, section I (west of 135°E.), section II (135°–175°W.), and section III (east of 175°W.) in this report. Data on products are also appended at the end of this report.

The authors wish to express their sincere thanks to Messrs. K. Maeda, H. Sakiura, K. Ozaki and Y. Nozawa, Japanese Inspectors, for their kind cooperation and to the staff of whaling fleets of the Japan Marine Products Co. Ltd. and the Ocean Fishing Co. Ltd., for affording facilities in the course of this investigation.

I. Biological composition of catch

1. *Number of whales by species*

The catch composition during this season differs notably from those of preceding seasons in a point that both fleets caught very small number of blue whales and on the contrary many fin whales. (Cf. Table 1, Fig. 1 and Fig. 2) This trend was remarkably seen especially in section I. (Cf. Fig. 5) Comparing this with catch by foreign fleets during this season, however, it is safely said that Japanese catch was quite exceptional. Catch of humpback whales was also very small; the Hashidatemaru fleet only caught 9 whales, between 1st Feb. and 9th Feb., 1951. (Cf. Fig. 6) As seen in Fig. 6, catch of sperm whales in the Antarctic has been gradually increased since 1935/36 season. The Japanese catch of sperm whales during 1950/51 season was also larger than that of last season.

2. *Sex ratio*

In Fig. 7, sex ratio of blue, fin and humback whales caught by Japanese fleets after the War is compared with that by foreign fleets. This figure shows wider fluctuation of the former than the latter. This would be caused by difference of the whaling grounds and time lag of seasonal migration between male and female through these three species.

In blue and fin whales male decreased its percentage in sex ratio. In Fig. 7 is shown post-war monthly change of sex ratio. According to this, blue male whales during the preceding four seasons occupied larger percentage than female as season advanced. On the contrary, in this season, blue male decreased its percentage with the maximum of 54.3% in January. In fin whales seasonal migration would be rather complicated. Different from the result of the preceding four seasons, percentage of male whales increased in January in this season. This problem is so much related to migration that it is mentioned later again.

3. *Body length*

Length frequency of whales caught is shown in Fig. 1 (blue whales), Fig. 2 (fin whales), Fig. 3 (humpback whales), and Fig. 4 (sperm whales) in comparison between this season and post-war four seasons. According to these figures, there is not so large difference in size distribution among these seasons, excepting female of blue whales and male and female of humpback whales, which were so small in number of catch. Average body length is shown in Fig. 6. Blue male whales retained barely the top of last season. Average length of blue female whales went down remarkably from that of last season. Small number of catch in blue whales may not represent the real trend. In fin whales, both male and female decreased their average body length. As for size distribution in each section of whaling ground, smaller fin whales were seen more often in Section I than in other two sections. (See Table 4)

4. *Maturity*

Seasonal catch ratio of immature whales is shown in Figs. 10, 11 and 12. (Cf. Table 13) This classification is based solely on the body length by Mackintosh and Wheeler. The catch of immature whales both in blue and fin whales, has gradually increased since 1947/48 season, with the minimum catch in it. Both in blue and fin whales, male and female, the catch ratio of immature whales was the largest in Section I: 20.8% in blue male and 53.5% in blue female, (See Table 5), 18.3% in Section I, 11.6% in Section II in fin male whales: 20.6% in Section I, twice as large as in Section II and III in fin female whales. These figures indicate that catch of immature whales, both in blue and fin whales, got smaller as whaling fleets moved eastward, namely whaling season advanced.

There were very few immature humpback whales in Japanese catch. For the present, the standard of maturity determination on sperm whales is not so decisive as on baleen whales, and mention thereupon is omitted.

5. Pregnant ratio

In Fig. 9 is shown the pregnant ratio of whales caught by Japanese fleets during the post-war five seasons. Pregnant ratio for 1950/51 season was 67.0% in fin whales, and 83.3% in humpback whales, both of which were nearly same as that of 1949/50 season. In blue whales, pregnant ratio for this season was 47.5%; smaller by 10% than that of last season. Fig. 8 indicates semi-monthly fluctuation of pregnant ratio. The general trend is that pregnant ratio decreases as season advances. In blue whales it is rather complicate through the course of the season. For this fact there is a probable explanation that pregnant ratio lags behind the birth ratio.[1] From Fig. 13 (cited from Discovery Reports, Mackintosh & Wheeler) showing that birth season of both blue and fin whales covers about 4-5 months, it is thought that among pregnant whales migrating to the Antarctic there are some whales which leave the Antarctic comparatively earlier for warm water suitable to breeding. Namely, it seems probable that the decrease of pregnant ratio is caused by earlier departure of some whales for warm waters.

II. Some items related to migration

1. Blubber thickness

The trend is that blubber increases its thickness gradually after whales have migrated to the Antarctic, which is rich in their food. In Fig. 14 also, showing weekly fluctuation of average blubber thickness of baleen whales caught by Japanese fleets during post-war five seasons, it is seen. That of sperm whales for 1950/51 season only is shown in Fig. 17. Very few blue whales were caught this season, showing large fluctuation of blubber thickness. In addition, there was a sudden decrease of blubber thickness in the course of season. Probable explanation is that this may be caused by arrival of some whales from warm waters. Details on this question are mentioned in the following paragraph.

Fig. 15 indicates comparison of blubber thickness among male, female and pregnant whales. The result is same as in the preceding seasons:

1) Biological Investigation of whales caught by Japanese Antarctic whaling fleets seasons 1946/50 (in Japanese)

blubber of female is thicker than that of male and that of female in resting stage is thicker than that of pregnant female whales.

2. Parasites

By the same method as during the previous seasons, Cyamus, Coronula, Conchoderma, Pennella and Diatom film were investigated on their infection density and position. Table 7 indicates the result of the investigation during the post-war five seasons.

Infection rate of Cyamus and Diatom film for this season, fluctuates as wide as in the previous seasons. Other than the above two species, however, were very rare and varied little. So, as an index to migration of whales, here are taken Cyamus and Diatom film. Fig. 16 shows the weekly fluctuation of infection rate of them on male and female of blue and fin whales.

In the early stage of the season, female fin whales show lower infection rate of Diatom film than male. As the season advances, the former comes close to the latter in infection rate. This fact may endorse safely the conception that male whales arrive at the Antarctic earlier than female. This trend can be seen in blue whales also, which were so small in number of catch.

Between Cyamus and Diatom film, there is a relation that as the season advances, the former decreases its infection rate and the latter increases its rate. This corresponds to the results of investigation during the previous seasons.

Seasonal change of infection rate and blubber thickness might have a relation with migration of whales. In sperm whales (Fig. 17) Diatom film decreased its infection rate with the top in the second week and rather turned upward in the fourth week. On the contrary, Cyamus increased its upward trend of infection rate and turned downward in the fourth week. From these facts, it might be deduced that more sperm whales migrate newly to the whaling ground in the third week to fourth week. Change of blubber thickness is also helpful to understand this conjecture. While, in fin whales, for this season it is rather difficult to see the clear relation among these factors. It is too small in number of blue whales to get any conclusion upon blue whales.

3. White scars

Number and curing stage of white scars, which are likely to be caused by some kinds of protozoa, were investigated. The number is thought to have some relation with ages. Still more important is the curing stage of them and this is one of the items to be taken into consideration to learn the migrating season of whales to the Antarctic, as well as Diatom film infection rate and change of blubber thickness. In this season curing stage of white scars was investigated for the first time. The result showed that most of white scars had been already cured or nearly cured.

III. Some items related to age of whales

1. Number of corpora lutea

In order to learn the relation between body length and age of whales, it is more desirable to use total number of corpora lutea of right and left ovaries than to use total weight of both ovaries. Figs. 18, 19 and 20 indicate the relation between body length and number of corpera lutea of blue, fin and humpback whales. (A) in Fig. 18 is for the entire ground and nearly same trend is seen between the average of four seasons, 1946/50 and this season. (B), (C) and (D) in Fig. 18 indicate the relation by sections in blue whales. It is to be regretted that blue whale caught was too small in number. (C), (D) and (E) in Fig. 19 show the relation in fin whales in each section and (E) is for comparison among them. According to them, number of corpora lutea in each body length seems a little larger in Section I than in Section III. From Fig. 24, which shows the maturity rate of fin whales in each body length, it is seen that maturity rate is lower in Section III than in Section 1, in body length of 65 feet or there about, body length at which fin whales are said to get maturity. It is presumed that this is because of larger body length at which fin whales get maturity in Section III than Section I.

For the present, there are no other items to endorse this fact in fin female whales. Similar trend in male whales is, however, seen from weight of testes as mentioned later. As the average of number of corpora lutea in these cases, arithmetical mean was adopted. Since a definite standard to discriminate genuine corpora lutea from so-called pseudo-corpora lutea, is not yet available, number of corpora lutea in this report may include number of pseudo-corpora lutea also. It might be, therefore, danger for the present, to determine age of whales with body length and number of corpora lutea.

2. Weight of testes

It has been previously mentioned[1] that both volume and weight of

1) See footnote page 128.

testes increase in the similar trend with body length. So in this season, volume measurement was omitted. Weight of testes cannot be combined with age so directly as number of corpora lutea in female, and yet don't lose importance on determination of body length of whales, at which maturity is gained. Figs. 21, 22 and 23 indicate the relation between body length and total weight of right and left testes of blue fin and sperm whales respectively. As the average of weight of testes, geometrical mean was used herein. In fin whales there is a considerably large difference of weight of testes between for this season and for average of preceding four seasons (Fig. 22, A). It is most likely that body length at which fin whales get maturity, is larger by two feet in Section I than in Section III.

During the post-war four seasons, the principal whaling ground was the so-called "Ross Area", Section III in our classification. It is quite natural, therefore, that curve of the average weight of testes for four seasons and curve for this season in Section III are very similar. Although in Section II, catch was so small and weight of testes deviates so much, it shows the value between Section I and III. As mentioned above, body length at which fin whales get maturity in both male and female, shows difference between in Section I and in Section III. This might suggest fin whales which migrate to "Area IV" are of different group from those which migrate to "Area V". As for blue whale, small catch of them cannot lead the definite result.. Table 8 indicates number and percentage of sperm whales in each body length, of which testes were under 3, 4, 5 and 6 kgs in weight. The standard weight of testes enough to determine the sexual maturity of sperm whales is not yet found. In the above table there are considerable number of sperm whales of which testes are very light. This means that an opinion that sexually mature male sperm whales only migrate to the Antarctic is open to discussion. There is a difference of average curve of weight of testes between baleen whales and sperm whales in the adjacent waters of Japan, according to Mr. Ohmura. The same may hold for whales in the Antarctic. Histological study would be helpful largely to this question.

IV. Seasonal change of length of foetuses and Malformed foetuses

Foetuses we got during this season are tabulated as follows.

Species		Male	Female	Unknown	Total	Multiformed
Blue	number	20	18	—	38	0
	%	52.6	47.4	—	100	0
Fin	number	271	259	3	533	5 twins and 1 quadruplet
	%	51.0	48.9	0.1	100	
Humpback	number	2	3	0	5	0
	%	40.0	60.0	0	100	0

Among five fin whales with twin, four whales had 1 functional corpus luteum, viz. these foetuses were monooviparous, two groups of males and two groups of females, and the rest had two functional corpora lutea: this was dioviparous, one was male and the other female. One quadruplet was of one male, two females and 1 sex unknown foetus, all of which were malformed and found rotten on the way of development.

Fig. 25 indicates the seasonal change of length of foetus. As the average of lengths, arithmetical mean was adopted. The growth curve of both male and female foetus corresponds well to that of Discovery Reports Vol. 1 and to that of last season by Japanese fleets.

In Fig. 25, fin whales, mean curve of growth of fin whale foetuses which would be conceived in Dec.–Nov. was cited from Discovery Reports Vol. 1, page 425. Foetuses A and B which were gained during this season are dotted under this curve. Foetus A was found in the mother whale of 70 feet long caught at 64°25′S. Lat., 119°20′E. Long., on January 6th. Foetus B was found in the mother of same length caught at 64°35′S. Lat., 130°44′E. Long., on January 10th, 1951. Both of these foetuses were so small under 1 inch in length that their sex could not be determined. These seem to have been conceived in the latter half of December, taking from the above curve of growth of foetus cited from Discovery Reports. By reference to curve of frequency of pairing of fin whales, Discovery Reports Vol. 1, p. 426, there are some whales pairing in the latter half of December and foetuses A and B are not exceptional. It is, however, noteworthy that these were found in waters of so high latitude as 64° South Latitude.

For the reference, data of mother whales of foetuses A and B are as follows: they were both 70 feet long and not infected with external parasites. Respectively, 0.40% and 0.45% in percentage of blubber thickness to body length, are larger than 0.39% these of pregnant whales for 3–4th weeks. It will be inconclusive from these data only that it was not long before they got to the Antarctic.

V. Others

1. Body colour

Body colour of sperm whales and humpback whales was investigated by the same method as in the previous seasons. Fig. 27 indicates comparison of frequency of body colour between sperm whales caught in the adjacent waters of Japan[1] and those which were caught in the Antarctic. Classification and degree of body colour are as follows:

I. Body colour.
- A. uniform dark grey all over the body.
- B. lighter on the under surface of the head and lower jaw.
- C. light whitish all over the body.
- D. light whitish all over the body.

II. Slight coloured spiral marking on the head.
- a. very clear
- b. clear
- c. not clear
- d. none

III. Light grey flecking.
- 0. none
- 1. few
- 2. moderate
- 3. many
- 4. very numerous

IV. White splash.
- 0. none
- 1. normal
- 2. remarkable

Such a classification of colouration often depends upon the subject of observers, so that detailed comparative study would not have much significance. . It corresponds approximately to the results of Matthews and Ohmura that in item I, uniform dark grey whales over the body occupied 65.5% of total whales. It may be noteworthy that rather high percentage of whales with white splash in the Antarctic is seen in contrast with high percentage of normal whales in item IV, in the adjacent waters of Japan. Four items on colouration of humpback whales are not inconclusive, because of small catch of them.

Fin whales were investigated only in the following point: persence or absence of tongue of pigmentation behind anus. The result is as follows:

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1) Whales in the adjacent waters of Japan by H. Ohmura, Scientific Reports of the Whales Research Inst. No. 4, 1950

Sex	Number of whales investigated	Number of whales presence	absence	In percentage presence	absence
Male	1087	784	303	72.1%	27.9%
Female	941	661	280	70.2%	29.8%

2. Mammary gland

3. Ossification of vertebrae

4. Teeth of sperm whales

Colour and thickness of mammary gland, ossification of vertebrae in four classes at two points, thoracic and lumbar, and number of rudimentary exposed teeth of sperm whales were also investigated but no special results enough to show herein were gained.

5. Foods

Size, quantity and freshness of squid in the stomach of sperm whales and of *Euphausia superba* in the stomach of baleen whales were investigated. Sometimes fish were found in the mass of *Euphausia*. The comparison of size of *Euphausia superba* among sections is shown in Table 9. It is seen from this table that % of M which occupied the largest part in Section I, decreased gradually as whaling ground moved to II and III. S shows the largest percentage in Section III, this figure being larger than in last season. Something peculiar on the food seems to be seen in the "Ross Area" this season.

6. Lactating whales

In the Japanese catch there were two lactating whales found.

Date and time of catch	11 : 40, Jan. 10, 1951	10 : 45, Feb. 13, 1951
Date and time of treatment	13 : 50, Jan. 10, 1951	12 : 40, Feb. 13, 1951
Locality of catch	64°32′S, 129°45′E	65°05′S, 164°08′W
Species	Blue whale	Blue whale
Sex	Female	Female
Body length	79 ft.	86 ft.
Thickness of blubber	8.5 cm	10.0 cm
Stomach content	None	Small krill, half
Foetus	None	None
Amount of milk	under 1 L flowed	3-4 L flowed
Thickness of right mammary gland	14.5 cm	21.0 cm
Color of right mammary gland	Yellow	Pink
Greatest width of right uterus	21 cm	14 cm
Greatest width of left uterus	18 cm	17 cm
Color of inside of uterus	Normal	Yellowish grey

Weight of right ovary	1.3 kg	1.2 kg
Weight of left ovary	1.0 kg	1.8 kg
Number of functional corpora lutea	0	0
Number of old corpora lutea	2 in right and 1 in left ovary	4 in right and 6 in left ovary
Diameter of the largest corpora lutea	6.5 cm in right and 6.0 cm in left one	6.0 cm in right and 6.2 cm in left one

7. Dimensions and weight of whales

During this season also, measurement of bodily proportion and weight of whales, which have been made since 1947/48 season was continued. Data on dimensions and weight were collected on 5 fin, 2 blue, 1 humpback and 16 sperm whales. In addition to them, data on dimension only were collected on other 34 sperm whales. These data are appended at the end of this report. The method described in Discovery Reports vol. I and XVII was followed for the measurement of linear dimensions. These measurement were made with a taut steel tape while the whales lay on deck, prior to flensing.

The component parts of the body of each of these whales were weighed during flensing. Blubber, bone, meat and internal organs were removed from the carcass, cut into small pieces to weigh separately on platform scales of one half metric ton capacity. Weights were determined to one kilogram and added to give the total weight of the component parts. It is therefore probable that inaccuracies exist in the figures, and that the relative error is high for small organs and organs covered with a thick layer of fat or connective tissues.

Inconsistencies also result from the fact that flensing methods on two factories differ slightly, and sometimes vary on one vessel. For this reason, figures given for such items as ventral grooves, ventral meat, gums, head blubber, and dorsal fin are not always comparable. But figures given for the aggregate weight of blubber, meat, and bones and for the total weight of each whale are considered reliable.

All weights are expressed in kilograms; accuracy does not exceed three significant figures for the larger component parts (more than 1,000 kgs.) and two figures for the small organs.

The organs not listed in the tables and those for which no figure is given were not separated, and the weight is included in that of blubber, meat and bone. Blood and other body fluids were not weighed, and no attempt was made to estimate their weights.

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(The Whales Research Institute)

Appendix

Table 1. Catch by Japanese fleets, post-war five seasons

Season	Blue whale		Fin whale		Humpback whale		Baleen total	Sperm	Grand total
	No.	%	No.	%	No.	%	No.	No.	
1946/47	690	59.2	474	40.6	0	0	1164	1	1165
1947/48	710	53.9	608	46.1	0	0	1318	2	1320
1948/49	631	38.4	1012	61.6	0	0	1643	0	1643
1949/50	817	42.2	1056	54.4	67	3.4	1940	172	2112
1950/51	271	11.6	2050	88.0	9	0.4	2330	409	2739

Table 2. Comparison of catch, fin whales, by sections

	Operating days			Number of whales caught			Number of whales caught per day	Average body length (ft.)			Maturity ratio (%)			Pregnant ratio (%)
	Nisshin	Hashi-date	Total	Male	Female	Total		Male	Female	Total	Male	Female	Total	
Section I	26	26	52	448	396	844	16.2	65.8	68.9	67.3	81.7	76.8	79.3	75.7
Section II	8	12	20	69	61	130	6.5	65.6	70.5	67.9	88.4	88.5	88.5	55.6
Section III	44	40	84	580	496	1076	12.8	66.3	69.9	68.0	94.3	86.9	90.9	62.4
Entire ground	78	78	156	1097	953	2050	13.1	66.1	69.6	67.7	88.8	82.8	86.0	67.0

Table 3. Comparison of catch, blue whales, by sections

	Operating days			Number of whales caught			Number of whales caught per day	Average body length (ft.)			Maturity ratio (%)			Pregnant ratio (%)
	Nisshin	Hashi-date	Total	Male	Female	Total		Male	Female	Total	Male	Female	Total	
Section I	26	26	52	24	43	67	1.3	78.1	77.9	78.0	79.2	46.5	58.2	50.0
Section II	8	12	20	11	12	23	1.2	77.3	78.4	77.9	90.9	58.3	73.9	57.1
Section III	44	40	84	94	87	181	2.2	78.5	80.2	79.3	88.3	60.9	75.1	45.3
Entire ground	78	78	156	129	142	271	1.6	78.3	79.3	78.9	86.8	56.3	70.8	47.5

Table 4. Classification of fin whales by length in each section

Body length group (in ft.)	Whaling ground Section I						Section II					
	Number			%			Number			%		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
～55	0	2	2	0.0	0.5	0.2	0	0	0	0.0	0.0	0.0
56～60	27	22	49	6.0	5.6	5.8	3	0	3	4.4	0.0	2.3
61～65	153	59	212	34.2	14.9	25.2	27	6	33	39.1	9.8	25.4
66～70	254	136	390	56.7	34.3	46.2	38	20	58	55.1	32.8	44.6
71～75	14	170	184	3.1	42.9	21.8	1	33	34	1.4	54.1	26.2
76～	0	7	7	0.0	1.8	0.8	0	2	2	0.0	3.3	1.5
Total	448	396	844	100.0	100.0	100.0	69	61	130	100.0	100.0	100.0

Section III						Total					
Number			%			Number			%		
Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
0	0	0	0.0	0.0	0.0	0	2	2	0.0	0.2	0.1
13	5	18	2.2	1.0	1.7	43	27	70	3.9	2.8	3.4
193	48	241	33.3	9.7	22.4	373	113	486	34.0	11.9	23.7
345	204	549	59.5	41.1	51.0	637	360	997	58.1	37.8	48.6
29	224	253	5.0	45.2	23.5	44	427	471	4.0	44.8	23.0
0	15	15	0.0	3.0	1.4	0	24	24	0.0	2.5	1.2
580	496	1076	100.0	100.0	100.0	1097	953	2050	100.0	100.0	100.0

Table 5. Catch ratio of immature blue whales in each section

Whaling ground / Sex	I	II	III	Total
Male	20.8	9.1	11.7	13.2
Female	53.5	41.7	39.1	43.7
Total	41.8	26.1	24.9	29.2

(Total blue whale catch : 100)

Table 6. Catch ratio of immature fin whales in each section

Whaling ground / Sex	I	II	III	Total
Male	18.3	11.6	5.7	11.2
Female	23.2	11.5	13.1	17.2
Total	20.6	11.5	9.1	14.0

(Total fin whale catch : 100)

Table 7. Infection rate, external parasites, 1946/1951

Season	Whale sp. / Parasites sp.	Blue: No. of whales infected	Blue: No. of whales investigated	Blue: Infection rate (%)	Fin: No. of whales infected	Fin: No. of whales investigated	Fin: Infection rate (%)	Humpback: No. of whales infected	Humpback: No. of whales investigated	Humpback: Infection rate (%)	Sperm: No. of whales infected	Sperm: No. of whales investigated	Sperm: Infection rate (%)
1946~47	Cyamus sp.	66	690	10.6	84	474	17.7						
	Coronula sp.	6	〃	0.9	37	〃	7.8						
	Conchoderma sp.	0	〃	0.0	4	〃	0.8						
	Pennella sp.	21	〃	3.0	6	〃	1.3						
	Diatom film	352	〃	51.0	303	〃	63.9						
1947~48	Cyamus sp.	49	703	7.5	43	605	7.7						
	Coronula sp.	24	〃	3.5	54	〃	9.8						
	Conchoderma sp.	5	〃	0.7	5	〃	0.1						
	Pennella sp.	10	〃	1.6	5	〃	0.1						
	Diatom film	181	〃	34.8	208	〃	52.4						
1948~49	Cyamus sp.	18	631	2.9	46	1012	4.8						
	Coronula sp.	3	〃	0·5	14	〃	1.4						
	Conchoderma sp.	0	〃	0.0	1	〃	0.1						
	Pennella sp.	2	〃	0.3	3	〃	0.3						
	Diatom film	77	〃	13.9	281	〃	38.4						
1949~50	Cyamus sp.	20	817	2.4	52	1056	4.9	56	67	83.6	47	172	27.3
	Coronula sp.	3	〃	0.4	15	〃	1.4	67	〃	100.0	0	〃	0.0
	Conchoderma sp.	1	〃	0.1	4	〃	0.4	67	〃	100.0	4	〃	2.3
	Pennella sp.	5	〃	0.6	6	〃	0.6	0	〃	0.0	3	〃	1.7
	Diatom film	382	〃	46.8	528	〃	50.0	1	〃	1.5	129	〃	75.0
1950~51	Cyamus sp.	3	271	1.1	46	2050	2.2	2	9	22.2	69	409	16.9
	Coronula sp.	9	〃	3.3	68	〃	3.3	9	〃	100.0	2	〃	0.5
	Conchoderma sp.	1	〃	0.4	5	〃	0.2	9	〃	100.0	7	〃	1.7
	Pennella sp.	0	〃	0.0	11	〃	0.5	0	〃	0.0	1	〃	0.2
	Diatom film	45	〃	16.6	815	〃	39.8	0	〃	0.0	99	〃	24.2

Table 8. Sperm whales with light testes (under 52 ft. in length)

Body length (in ft.)	Under 3 kg		Under 4 kg		Under 5 kg		Under 6 kg		Total catch
	Number	%	Number	%	Number	%	Number	%	
42					1	50.0	1	50.0	2
43	1	14.3	1	14.3	1	14.3	4	57.1	7
44					2	20.0	8	80.0	10
45			2	11.8	5	29.4	6	35.3	17
46	1	3.0	1	3.0	7	21.2	13	39.4	33
47					3	8.3	13	36.1	36
48			4	7.4	6	11.1	10	18.5	54
49					1	1.5	4	6.2	65
50					1	1.9	3	5.6	54
51							2	3.9	52
Total	2	0.6	8	2.4	27	8.2	64	19.4	330

Table 9. Frequency of size of Euphausia in Sections I, II and III

Size	Section I	Section II	Section III
L	10.1%	3.1%	0.4%
M	58.7%	20.3%	3.4%
S	22.5%	68.8%	93.2%
X	6.2%	7.8%	2.8%
?	2.5%	0	0.2%
Total	100	100	100

Note: L: over 5 cm from a head of rostrum to end of telson
M: 4-5 cm 〃 〃
S: less than 4 cm 〃
X: all of L, M and S mixed
?: size unknown in digested condition

Table 10. Products by Japanese fleets

Sperm whale products

Fleet	Sperm whale oil	Frozen	Salted				Total	Liver oil
		red meat	Tail flukes	leather	gelatinous material	fibrous head tissue		
	ton	ton	ton	ton	ton	ton	ton	kg
Hashidate	2187.0	41.0	71.0	94.0	103.0	22.5	2,518.5	3,526.0
Nisshin	1612.0	432.0	33.0	95.0	69.0	2.0	2,243.0	2,000.0
Total	3799.0	473.0	104.0	189.0	172.0	24.5	4,761.5	5,526.0

Baleen whale products

Fleet		Hashidate				Nisshin				Total			
Sp.		B	F	H	Total	B	F	H	Total	B	F	H	Total
No of whales treated		134	824	9	967	137	1226	0	1363	271	2050	9	2330
B.W.U.		550.1				750.0				1300.1			
Whale oil		10,100 tons				14,960 tons				25,060 tons			
Frozen	Red meat	8,814.2 tons				11,972.0 tons				20,786.2 tons			
	Ventral grooves	—				716.0				716.0			
	Others	469.2				22.0				491.2			
Salted	Red meat	2,311.0 tons				1,821.0 tons				4,132.0 tons			
	Ventral meat	689.0				1,016.0				1,705.0			
	Blubber of ventral grooves	—				686.0				686.0			
	Ventral grooves	1,630.4				1,402.0				3,032.4			
	Tail flukes	248.5				309.0				557.5			
	Jaw ligaments	—				15.0				15.0			
Baleen		24.0 tons				14.0 tons				38.0 tons			
Total		24,286.3 tons				32,933.0 tons				57,219.3 tons			
Liver oil		14,546.0kg				14,300.0kg				28,846.0kg			

Post-war 5 seasons catch & products (in Tons)

Season	No of whales treated				B.W.U.	Whale oil	Frozen	Salted	Others	Total
	B	F	H	Total						
1950～51	271	2050	9	2330	1300.1	25.060	21,993.4	10,127.9	66.8	57,248.1
1949～50	617	1056	67	1940	1371.8	27.010	24,351.5	13,889.4	365.0	65,515.9
1948～49	631	1012		1643	1137.0	20.350	17,620.1	16,535.0	522.7	55,027.8
1947～48	710	608		1318	1014.0	17.830	18,205.3	9,048.1	301.3	45,384.7
1946～47	690	474		1164	927.0	12.260	11,832.9	20,385.4	10.8	34,489.1

Table 11. Catch and products by all fleets, 1950/51 Antarctic season

Fleet	Species						Production in brls			No. of factory ship	No. of catcher boat	No. of processed whale B.W.U.	Oil product per B.W.U. in brls
	Blue	Fin	Hump	Sei	Sperm	Total	Whale oil	Sp. W. oil	Total				
Norway													
Thorshammer	124	934	401	—	268	1,727	78,000	13,160	91,160	1	12	751.0	103.9
Thorshavet	643	234	—	—	333	1,210	99,790	17,939	117,729	1	14	760.0	131.3
Thorshörvdi	231	1494	2	18	207	1,952	122,222	10,985	133,207	1	15	974.0	125.5
Kosmos III	502	1087	349	11	422	2,371	129,380	22,020	151,400	1	14	1,187.0	109.0
Kosmos IV	328	1643	6	—	575	2,552	124,921	27,079	152,000	1	14	1,160.0	107.7
Sir James Clark Ross	325	833	5	—	235	1,398	85,000	12,500	97,500	1	13	742.0	114.6
Antarctic	248	609	14	—	132	1,003	69,265	7,030	76,295	1	10	556.0	124.6
Pelagos	161	1047	356	—	131	1,695	84,012	6,500	90,512	1	12	827.0	101.6
Norhval	339	718	82	—	154	1,293	89,200	7,800	97,000	1	13	753.0	118.5
Suderöy	181	411	—	—	21	613	50,100	1,025	51,135	1	7	387.0	129.5
United Kingdom													
Southern Harvester	355	916	—	16	322	1,609	111,060	18,455	129,515	1	15	816.0	136.1
Southern Venturer	341	1190	—	42	210	1,783	125,558	10,747	136,305	1	14	943.0	133.1
Balaena	1,045	207	21	—	493	1,766	130,600	22,100	152,700	1	16	1,163.4	112.3
South Africa													
Abraham larsen	584	1463	1	—	455	2,503	138,100	23,900	162,000	1	15	1,315.0	104.9
Netherlands													
Willem Barendsz	306	851	265	1	237	1,660	91,369	12,191	103,560	1	12	837.7	109.1
Panama													
Olympic Challenger	565	774	114	—	53	1,506	122,000	3,000	125,000	1	12	997.6	122.3
Japan													
Hashidatemaru	134	825	9	—	243	1,211	59,412	12,865	72,277	1	9	550.1	108.0
Nisshinmaru No. 1	137	1227	—	—	166	1,530	88,000	9,482	97,482	1	9	750.5	117.3
U.S.S.R.													
Slava	380	949	—	279	81	1,689	106,752	4,901	111,653	1	15	901.0	118.5
Total	6,929	17,412	1625	367	4,738	31,071	1,904,751	243,678	2,148,430	19	241	16,371.3	116.3

Table 12. Body length composition

Fin, Total

Body length \ Sex	Male			Female						Total			
	Immature	Mature	Total	Immature	Mature: Pregnant	Mature: Resting	Mature: Lactating	Unknown	Total	Immature	Mature	Unknown	Total
55ft.				2					2	2			2
6	1		1	1					1	2			2
7	2		2	1					1	3			3
8	9		9	8					8	17			17
9	10	1	11	9					9	19	1		20
60	18	2	20	8					8	26	2		28
1	20	8	28	16					16	36	8		44
2	22	24	46	24	1				25	46	25		71
3	19	48	67	16	2	1			19	35	51		86
4	7	81	88	10	3	2			15	17	86		103
65	7	137	144	28	7	3			38	35	147		182
6	4	159	163	14	18	9			41	18	186		204
7		170	170	10	18	13		1	42	10	202		212
8	3	158	161	9	33	26			68	12	117		229
9		92	92	2	60	27			89	2	179		181
70		51	51	3	79	38			120	3	168		171
1	1	23	24	3	91	38			132	4	152		156
2		15	15		71	28			99		114		114
3		5	5		61	35			96		101		101
4					49	23			72		72		72
75					19	9			28		28		28
6					14	5			19		19		19
7					2	1			3		3		3
8					1	1			2		2		2
Total	123	974	1097	164	529	259	0	1	953	287	1762	1	2050
Average	66.1ft.			69.6ft.						67.7ft.			
Sex ratio	53.5%			46.5%						100.0%			
%	11.2	88.8	100.0	17.2	55.5	27.2	0.0	0.1	100.0	14.0	86.0	1	100.0

Fin, Section I

Body length \ Sex	Male			Female						Total			
	Immature	Mature	Total	Immature	Mature: Pregnant	Mature: Resting	Mature: Lactating	Unknown	Total	Immature	Mature	Unknown	Total
55ft.				2					2	2			2
6	1		1	1					1	2			2
7	2		2							2			2
8	7		7	8					8	15			15
9	6		6	7					7	13			13
60	10	1	11	6					6	16	1		17
1	16	1	17	9					9	25	1		26
2	15	9	24	12	1				13	27	10		37
3	10	19	29	9	2	1			12	19	22		41
4	4	27	31	5	3				8	9	30		39
65	7	45	52	12	4	1			17	19	50		69
6	2	62	64	7	10	3			20	9	75		84
7		59	59	7	8	3			18	7	70		77
8	2	65	67	3	12	6			21	5	83		88
9		38	38	1	24	9			34	1	71		72
70		26	26	1	30	12			43	1	68		69
1		10	10	2	35	12			49	2	57		59
2		2	2		31	3			34		36		36
3		2	2		28	11			39		41		41
4					22	7			29		29		29
75					15	4			19		19		19
6					4	2			6		6		6
7					1				1		1		1
8													
Total	82	366	448	92	230	74	0	0	396	174	670	0	844
Average	65.8ft.			68.9ft.						67.3ft.			
Sex ratio	53.1%			46.9%						100.0%			
%	18.3	81.7	100.0	23.2	58.1	18.7	0.0	0.0	100.0	20.6	79.4	0.0	100.0

Fin, Section II

Sex / Body length	Male Immature	Male Mature	Male Total	Female Immature	Female Mature Pre-gnant	Female Mature Resting	Female Mature Lac-tating	Female Unknown	Female Total	Total Immature	Total Mature	Total Unknown	Total Total
55ft.													
6													
7													
8	1		1							1			1
9	1		1							1			1
60	1		1							1			1
1		1	1	1					1	1	1		2
2	2	4	6	3					3	5	4		9
3		4	4								4		4
4	1	5	6							1	5		6
65		10	10	2					2	2	10		12
6	2	10	12	1					1	3	10		13
7		9	9			1			1		10		10
8		11	11		1	5			6		17		17
9		4	4		3	1			4		8		8
70		2	2		7	1			8		10		10
1		1	1		6	5			11		12		12
2					3	2			5		5		5
3					3	5			8		8		8
4					5	2			7		7		7
75					1	1			2		2		2
6					1				1		1		1
7						1			1		1		1
8													
Total	8	61	69	7	30	24	0	0	61	15	115	0	130
Average	65.6ft.			70.5ft.						67.9ft.			
Sex ratio	53.1%			46.9%						100.0%			
%	11.6	88.4	100.0	11.5	49.2	39.3	0.0	0.0	100.0	11.5	88.5	0.0	100.0

Fin, Section III

Sex / Body length	Male Immature	Male Mature	Male Total	Female Immature	Female Mature Pre-gnant	Female Mature Resting	Female Mature Lac-tating	Female Unknown	Female Total	Total Immature	Total Mature	Total Unknown	Total Total
55ft.													
6													
7				1					1	1			1
8	1		1							1			1
9	3	1	4	2					2	5	1		6
60	7	1	8	2					2	9	1		10
1	4	6	10	6					6	10	6		16
2	5	11	16	9					9	14	11		25
3	9	25	34	7					7	16	25		41
4	2	49	51	5		2			7	7	51		58
65		82	82	14	3	2			19	14	87		101
6		87	87	6	8	6			20	6	101		107
7		102	102	3	10	9		1	23	3	121		125
8	1	82	83	6	20	15			41	7	117		124
9		50	50	1	33	17			51	1	100		101
70		23	23	2	42	25			69	2	90		92
1	1	12	13	1	50	21			72	2	83		85
2		13	13		37	23			60		73		73
3		3	3		30	19			49		52		52
4					22	14			36		36		36
75					3	4			7		7		7
6					9	3			12		12		12
7					1				1		1		1
8					1	1			2		2		2
Total	33	547	580	65	269	161	0	1	496	98	977	1	1076
Average	66.3ft.			69.9ft.						68.0ft.			
Sex ratio	53.9%			46.1%						100.0%			
%	5.7	94.3	100.0	13.1	54.2	32.5	0.0	0.2	100.0	9.1	90.8	0.1	100.0

Blue whales, Total

Body length \ Sex	Male Immature	Male Mature	Male Total	Female Immature	Female Mature Pre-gnant	Female Mature Resting	Female Mature Lac-tating	Female Unknown	Female Total	Total Immature	Total Mature	Total Unknown	Total Total
70ft.	2		2	4					4	6			6
1	3		3	4					4	7			7
2	4	1	5	5					5	9	1		10
3	3		3	15					15	18			18
4	4	6	10	10					10	14	6		20
75		4	4	7					7	7	4		11
6	1	7	8	6					6	7	7		14
7		12	12	8	1	1			10	8	14		22
8		14	14	3	1	1			5	3	16		19
9		15	15		4	2	1		7		22		22
80		17	17		3	3			6		23		23
1		9	9			4			4		13		13
2		14	14		5	2			7		21		21
3		9	9		3	10			13		22		22
4		3	3		9	3			12		15		15
85					2	2			4		4		4
6		1	1		4	2	1		7		8		8
7					3	4			7		7		7
8					2	3			5		5		5
9						2			2		2		2
90													
1													
2					1	1			2		2		2
Total	17	112	129	62	38	40	2	0	142	79	192	0	271
Aver-age	78.3ft.			79.3ft.						78.9ft.			
Sex ratio	47.6%			52.4%						100.0%			
%	13.2	86.8	100.0	43.7	26.8	28.2	1.3	0.0	100.0	29.2	70.8	0.0	100.0

Blue whales, Section I

Body length \ Sex	Male Immature	Male Mature	Male Total	Female Immature	Female Mature Pre-gnant	Female Mature Resting	Female Mature Lac-tating	Female Unknown	Female Total	Total Immature	Total Mature	Total Unknown	Total Total
70ft.	1		1	3					3	4			4
1				2					2	2			2
2				1					1	1			1
3	1		1	3					3	4			4
4	2		2	3					3	5			5
75		1	1	5					5	5	1		6
6	1	3	4	2					2	3	3		6
7		3	3	3					3	3	3		6
8		1	1	1					1	1	1		2
9		1	1		1		1		2		3		3
80		4	4		2	1			3		7		7
1						2			2		2		2
2		3	3		2				2		5		5
3		1	1		2	3			5		6		6
4		2	2		2	2			4		6		6
85													
6					1				1		1		1
7						1			1		1		1
8													
9													
90													
1													
2													
Total	5	19	24	23	10	9	1	0	43	28	39	0	67
Aver-age	78.1ft.			77.9ft.						78.0ft.			
Sex ratio	35.8%			64.2%						100.0%			
%	20.8	79.2	100.0	53.5	23.3	20.9	2.3	0.0	100.0	41.8	58.2	0.0	100.0

Blue whales, Section II

Body length \ Sex	Male: Immature	Male: Mature	Male: Total	Female: Immature	Female: Mature: Pre-gnant	Female: Mature: Resting	Female: Mature: Lac-tating	Female: Unknown	Female: Total	Total: Immature	Total: Mature	Total: Unknown	Total: Total
70ft.													
1													
2				1					1	1			1
3	1		1	3					3	4			4
4													
75													
6		2	2	1					1	1	2		3
7		3	3								3		3
8		3	3								3		3
9		1	1		1	1			2		3		3
80													
1		1	1								1		1
2					1	1			2		2		2
3					1				1		1		1
4					1				1		1		1
85						1			1		1		1
6													
7													
8													
9													
90													
1													
2													
Total	1	10	11	5	4	3	0	0	12	6	17	0	23
Aver-age		77.3ft.							78.4ft.				77.9ft.
Sex ratio		47.8%							52.2%				100.0%
%	9.1	90.9	100.0	41.7	33.3	25.0	0.0	0.0	100.0	26.1	73.9	0.0	100.0

Blue whales, Section III

Body length \ Sex	Male: Immature	Male: Mature	Male: Total	Female: Immature	Female: Mature: Per-gnant	Female: Mature: Resting	Female: Mature: Lac-tating	Female: Unknown	Female: Total	Total: Immature	Total: Mature	Total: Unknown	Total: Total
70ft.	1		1	1					1	2			2
1	3		3	2					2	5			5
2	4	1	5	3					3	7	1		8
3	1		1	9					9	10			10
4	2	6	8	7					7	9	6		15
75		3	3	2					2	2	3		5
6		2	2	3					3	3	2		5
7		6	6	5	1	1			7	5	8		13
8		10	10	2	1	1			4	2	12		14
9		13	13		2	1			3		16		16
80		13	13		1	2			3		16		16
1		8	8			2			2		10		10
2		11	11		2	1			3		14		14
3		8	8			7			7		15		15
4		1	1		6	1			7		8		8
85					2	1			3		3		3
6		1	1		3	2	1		6		7		7
7					3	3			6		6		6
8					2	3			5		5		5
9						2			2		2		2
90													
1													
2					1	1			2		2		2
Total	11	83	94	34	24	28	1	0	87	45	136	0	181
Aver-age		78.5ft.							80.2ft.				79.3ft.
Sex ratio		51.9%							48.1%				100.0%
%	11.7	88.3	100.0	39.1	27.6	32.2	1.1	0.0	100.0	24.9	75.1	0.0	100.0

Sperm whales

Body length \ Sex	Male			
	Under 5 kg in testes weight	5kg and over in testes weight	Unknown	Total
40 ft.				
1				
2	1	1		2
3	1	6		7
4	2	8		10
45	5	10	2	17
6	7	25	1	33
7	3	32	1	36
8	6	47	1	54
9	1	63	1	65
50	1	52	1	54
1		52		52
2		32	1	33
3		24	1	25
4		15		15
55		5		5
6		1		1
Total	27	373	9	409
Average body length				49.2ft.
Sex ratio				100.0%

Humpback whales

Body length \ Sex	Male			Female						Total			
	Immature	Mature	Total	Immature	Mature			Unknown	Total	Immature	Mature	Unknown	Total
					Pergnant	Resting	Lactating						
35 ft.													
6													
7				1					1	1			1
8													
9													
40													
1					2				2		2		2
2													
3						1			1		1		1
4		2	2								2		2
45					1				1		1		1
6					2				2		2		2
7													
8													
9													
Total	0	2	2	1	5	1	0	0	7	1	8	0	9
Average body length			44.0ft.						42.7ft.				43.0ft.
Sex ratio			22.2%						77.8%				100.0%

Table 13. Classification of catch by length group

Blue whales

Group \ Season	Number 1946~47	1947~48	1948~49	1949~50	1950~51	% 1946~47	1947~48	1948~49	1949~50	1950~51
Group I (under 71 ft.)	23	9	5	1	6	3.3	1.3	0.8	0.1	2.2
Group II (71~85 ft.)	634	639	583	763	241	91.0	90.0	92.4	93.4	88.9
Group III (over 85 ft.)	33	62	43	53	24	4.8	8.7	6.8	6.5	8.9
Total	690	710	631	817	271	100.0	100.0	100.0	100.0	100.0
Immature male (under 74 ft.)	85	28	30	40	13	23.0	8.7	7.7	7.2	10.1
Mature male (over 73 ft.)	284	310	361	517	116	77.0	91.3	92.3	92.8	89.9
Total	369	338	391	557	129	100.0	100.0	100.0	100.0	100.0
Immature female (under 78 ft.)	131	71	44	57	51	40.8	19.1	18.3	21.9	35.9
Mature female (over 77 ft.)	190	301	196	203	91	59.2	80.9	81.7	78.1	64.1
Total	321	372	240	260	142	100.0	100.0	100.0	100.0	100.0

Fin whales

Group \ Season	Number 1946~47	1947~48	1948~49	1949~50	1950~51	% 1946~47	1947~48	1948~49	1949~50	1950~51
Group I (under 56 ft.)	2	0	0	0	2	0.4	0.0	0.0	0.0	0.0
Group II (56~65 ft.)	217	110	237	283	556	45.8	18.1	23.4	26.8	27.2
Group III (over 65 ft.)	255	498	775	773	1492	53.8	81.9	76.6	73.2	72.8
Total	474	608	1012	1056	2050	100.0	100.0	100.0	100.0	100.0
Immature male (under 63 ft.)	54	6	43	36	117	21.6	2.3	8.8	5.8	10.7
Mature male (over 62 ft.)	196	257	445	583	980	78.4	97.7	91.2	94.2	89.3
Total	250	263	488	619	1097	100.0	100.0	100.0	100.0	100.0
Immature formale (under 65 ft.)	72	13	39	33	104	32.1	3.8	7.4	7.6	10.9
Mature female (over 64 ft.)	152	332	485	404	849	67.9	96.2	92.6	92.4	89.1
Total	224	345	524	437	953	100.0	100.0	100.0	100.0	100.0

Humpback whales

Group \ Season	Number 1946~47	1947~48	1948~49	1949~50	1950~51	% 1946~47	1947~48	1948~49	1949~50	1950~51
Group I (under 36 ft.)				0	0				0.0	0.0
Group II (36~45 ft.)				57	7				85.1	77.8
Group III (over 45 ft.)				10	2				14.9	22.2
Total				67	9				100.0	100.0
Immature male (under 39 ft.)				0	0				0.0	0.0
Mature male (over 39 ft.)				24	2				100.0	100.0
Total				24	2				100.0	100.0
Immature female (under 41 ft.)				8	1				18.6	14.3
Mature female (over 40 ft.)				35	6				81.4	85.7
Total				43	7				100.0	100.0

Table 14. Semimonthly pregnant ratio

Fin whales

	Dec.	Jan.		Feb.		Mar.	Total
	latter half	former half	latter half	former half	latter half	former half	
Total female whales	196	186	154	161	150	105	952
Mature whales	142	150	135	145	122	93	787
Pregnant whales	112	109	80	104	72	48	525
Pregnant ratio	78.9%	72.6%	59.3%	71.7%	59.0%	51.6%	66.7%

Blue whales

	Dec.	Jan.		Feb.		Mar.	Total
	latter half	former half	latter half	former half	latter half	former half	
Total female whales	23	20	33	23	25	18	143
Mature whales	10	10	24	16	9	11	80
Pregnant whales	8	3	11	6	3	7	38
Pregnant ratio	80.0%	30.0%	45.8%	37.5%	33.3%	63.6%	47.5%

Humpback whales

	Feb.		Total
	former half	latter half	
Total female whales	7		7
Mature whales	6		6
Pregnant whales	5		5
Pregnant ratio	83.3%		83.3%

Table 15. Dimensions and weight of whales

Sperm whales (in meters)
(1) Total length
(2) Lower jaw, projection beyond tip of snout
(3) Tip of snout to blowhole
(4) Tip of snout to angle of gape
(5) Tip of snout to center of eye
(6) Tip of snout to tip of flipper
(7) Eye to ear (centers)
(8) Notch of flukes to posterior emargination of dorsal fin
(9) Flukes, width at insertion
(10) Notch of flukes to anus

Serial No.	(1) (ft.)	Sex	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
H 155	(43) 13.05	M	0.76	—	2.75	3.40	5.50	—	4.35	—	4.25
H 195	(43) 13.15	M	0.78	—	3.15	3.77	5.90	—	4.50	—	3.80
H 192	(43) 13.20	M	0.56	—	2.90	3.45	5.65	—	4.50	—	3.90
H 111	(44) 13.32	M	0.70	—	3.20	3.55	5.95	—	3.65	—	3.80
H 152	(44) 13.40	M	0.98	—	3.12	3.90	6.10	—	4.00	—	3.70
N 103	(45) 13.80	M	1.00	0.50	3.29	3.65	5.98	0.43	4.30	1.00	4.22
H 104	(46) 13.95	M	0.70	—	3.00	3.65	5.90	—	4.55	—	4.20
N 119	(46) 13.95	M	1.11	0.46	3.67	3.95	6.33	0.46	4.75	1.13	4.11
N 102	(46) 13.96	M	0.87	0.52	3.35	3.72	6.14	0.44	4.24	1.00	4.08
H 21	(46) 14.00	M	1.00	0.55	3.80	4.15	6.40	—	4.50	—	4.00
N 9	(46) 14.11	M	1.00	0.75	3.00	4.30	—	0.46	4.55	1.15	4.24
H 204	(46) 14.15	M	1.10	0.50	3.40	3.80	6.25	0.45	5.15	—	4.20
N 113	(47) 14.33	M	1.03	0.55	3.52	3.93	6.50	0.43	4.50	1.03	4.08
H 208	(47) 14.35	M	1.20	0.48	3.35	3.80	6.20	0.40	5.30	1.15	3.75
H 213	(47) 14.40	M	1.16	0.70	3.71	4.10	6.56	0.40	4.42	—	3.90
H 203	(48) 14.55	M	0.85	0.65	3.35	3.85	6.20	0.45	5.20	—	4.10

N: Nisshinmaru fleet H: Hashidatemaru fleet

(11) Notch of flukes to umbilicus
(13) Anus to reproductive aperture (centers)
(14) Dorsal fin, vertical height
(15) Dorsal fin, length of base
(16) Flipper, tip to axilla
(17) Flipper, tip to anterior end of lower border
(18) Flipper, length along curve of lower border
(19) Flipper, greatest width
(20) Severed head, condyle to tip
(21) Skull, greatest width
(22) Skull length, condyle to tip of premaxilla
(23) Skull, height
(24) Tail flukes, tip to notch
(25) Tail flukes, total spread

(11)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
6.50	1.45	—	—	0.84	1.24	—	0.62	—	1.80	3.60	1.30	—	—
6.30	1.50	—	—	0.82	1.20	—	0.60	—	1.90	4.00	1.26	—	—
6.45	1.50	—	—	0.83	1.25	—	0.64	—	1.70	4.10	1.40	—	—
6.55	1.60	—	—	0.88	1.36	—	0.64	—	1.70	3.85	1.40	—	—
6.00	1.45	—	—	0.91	1.29	—	0.61	—	1.80	3.80	1.30	—	—
6.53	1.44	0.25	1.40	1.28	1.32	1.47	0.62	4.78	1.75	3.89	1.23	1.66	3.17
6.75	1.65	—	0.90	0.70	1.30	—	0.68	—	1.80	4.30	1.30	—	—
6.63	1.69	0.34	1.25	0.97	1.29	1.30	0.66	4.95	—	3.70	1.42	1.97	3.79
6.48	1.42	0.28	1.42	0.92	1.30	1.40	0.68	4.98	1.90	4.09	1.25	1.97	3.98
6.40	1.30	—	—	1.00	1.30	—	0.60	5.30	1.85	4.45	1.45	—	—
6.75	1.75	0.30	1.20	0.70	1.00	1.38	0.40	—	1.90	4.20	1.30	—	—
6.70	1.65	—	—	0.98	1.48	—	0.68	—	1.85	4.00	1.35	—	—
—	1.08	0.35	1.60	1.00	1.35	1.38	0.68	4.98	1.92	4.10	1.26	1.77	—
6.40	1.60	—	—	1.00	1.42	—	0.67	—	1.85	3.75	1.30	1.95	—
6.70	1.80	—	—	0.77	1.25	—	0.60	—	2.05	4.30	1.35	—	—
6.80	1.65	—	—	1.00	1.33	—	0.67	—	1.85	4.10	1.40	—	—

Sperm whales (continued)

Serial No.	(1) (ft.)	Sex	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
N 112	(48) 14.63	M	1.15	0.71	3.92	4.50	6.86	0.48	4.55	1.16	4.30
H 202	(48) 14.65	M	0.80	0.75	3.35	3.95	6.50	—	4.50	—	4.30
N 166	(48) 14.66	M	0.64	0.71	2.90	4.56	6.80	0.51	4.58	0.95	4.13
H 81	(48) 14.70	M	0.95	—	3.75	4.15	6.60	0.45	4.55	1.10	4.35
H 37	(49) 14.80	M	0.95	0.60	3.83	4.30	6.10	—	4.60	—	4.20
H 205	(49) 14.82	M	0.90	0.65	3.50	3.95	6.25	0.45	5.45	1.08	4.25
H 3	(49) 14.90	M	1.15	0.70	3.80	4.30	6.90	—	4.70	—	4.15
H 79	(49) 14.90	M	0.90	0.85	3.50	4.10	6.65	0.45	4.90	—	4.20
N 65	(49) 14.94	M	0.90	0.50	3.74	4.06	6.95	0.47	4.60	0.93	4.33
N 125	(49) 14.97	M	1.07	0.55	3.74	4.17	6.65	0.50	4.63	1.28	3.82
N 74	(49) 15.04	M	1.03	0.62	3.37	4.55	7.00	0.51	4.88	1.12	4.05
N 121	(50) 15.18	M	1.05	0.80	3.79	4.28	6.74	0.50	5.07	1.14	4.30
H 53	(50) 15.20	M	0.92	0.55	3.60	3.96	6.30	—	—	—	4.40
N 10	(50) 15.24	M	—	0.50	3.34	4.23	6.90	0.52	4.80	1.10	4.60
H 4	(50) 15.25	M	0.95	0.90	3.70	4.30	6.85	—	4.75	—	4.35
H 63	(50) 15.30	M	1.25	0.70	3.90	4.30	7.15	—	4.56	—	4.35
H 97	(51) 15.45	M	1.35	—	4.15	4.45	7.30	0.46	4.65	—	3.90
H 117	(51) 15.45	M	1.20	0.75	4.00	4.40	7.05	0.40	4.60	—	4.40
H 36	(51) 15.50	M	0.70	0.65	3.80	4.40	7.00	—	5.05	—	4.60
N 36	(51) 15.57	M	1.15	0.57	3.77	4.43	7.06	0.50	5.08	1.18	4.30
N 159	(51) 15.60	M	1.18	0.60	4.10	4.47	7.15	0.45	4.98	1.08	4.50
N 62	(51) 15.62	M	1.10	0.60	3.80	4.31	6.90	0.43	5.37	1.11	4.88
H 64	(52) 15.85	M	0.95	0.75	4.05	4.50	7.20	—	4.75	-	4.45

(11)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
6.80	1.52	0.25	1.20	0.99	1.31	1.33	0.73	5.00	2.06	4.48	1.40	2.00	3.96
6.90	1.50	—	—	0.95	1.40	—	0.62	—	1.90	4.30	1.30	—	—
6.70	1.67	0.23	1.30	1.00	1.34	1.38	0.62	—	2.26	4.30	1.46	2.04	3.70
7.10	1.50	—	1.05	1.10	1.53	—	—	—	1.95	4.80	1.40	1.90	—
6.90	1.60	—	—	0.73	1.08	—	0.65	—	1.95	4.60	—	—	—
7.10	1.85	—	—	1.06	1.33	—	0.70	—	1.90	4.10	1.40	2.18	—
7.20	1.65	—	—	0.84	1.35	—	0.63	5.35	1.90	4.20	1.45	—	—
7.00	1.80	—	0.80	1.30	1.75	—	0.65	—	1.90	5.05	—	—	—
6.80	1.47	0.28	1.56	1.20	1.38	1.45	0.73	—	—	—	—	2.00	—
6.45	1.78	0.26	1.37	0.94	1.39	1.48	0.66	5.42	2.18	4.68	1.43	1.90	—
6.63	1.54	0.31	1.40	1.01	1.36	1.39	0.67	5.76	2.20	4.90	1.49	1.91	3.20
6.95	1.60	0.27	1.16	0.94	1.31	1.33	0.72	5.48	2.04	4.39	1.64	1.91	3.54
7.05	1.70	—	—	0.84	1.30	—	0.65	—	1.82	4.20	1.51	—	—
7.00	1.40	0.30	1.40	1.03	1.44	1.50	0.75	5.20	2.00	4.50	1.42	—	—
7.15	1.75	—	—	1.15	1.50	—	—	—	2.00	4.75	—	—	—
7.10	1.30	—	1.14	0.90	1.40	—	0.69	—	2.25	4.70	1.50	—	—
6.70	1.60	—	—	0.96	1.45	—	0.67	—	2.10	4.85	1.45	—	—
7.15	1.90	—	1.50	—	1.40	—	0.76	—	1.90	4.50	—	—	—
7.30	1.60	—	—	0.96	1.28	—	0.66	—	2.00	4.65	1.55	—	—
6.98	1.62	0.38	1.25	1.40	1.10	1.34	0.73	5.38	2.06	4.49	1.50	2.09	3.87
7.21	1.70	0.25	1.74	1.12	1.63	1.69	0.72	5.02	1.80	4.78	1.38	1.96	3.80
7.58	1.62	0.26	1.37	1.51	1.06	1.26	0.74	5.20	2.10	4.80	1.48	2.04	4.02
7.45	1.85	—	—	1.00	1.40	—	0.71	5.80	2.20	5.30	1.60	—	—

Sperm whale (continued)

Serial No.	(1) (ft.)	Sex	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
H 200	(52) 15.85	M	1.15	0.55	3.95	4.55	7.20	—	5.00	—	4.50
N 11	(52) 15.87	M	1.26	0.63	3.80	4.75	6.65	0.47	5.05	1.08	4.53
N 160	(52) 15.87	M	1.12	0.53	—	3.87	6.92	0.52	4.98	0.98	4.80
N 75	(52) 15.89	M	1.20	0.65	3.64	4.57	7.27	0.53	5.07	1.30	4.71
N 7	(53) 16.00	M	1.31	0.70	3.91	5.00	7.55	0.54	4.86	1.16	4.45
N 6	(53) 16.15	M	1.35	0.40	4.10	4.80	7.60	0.53	5.15	1.16	4.40
N 35	(53) 16.15	M	1.11	0.52	4.10	4.60	7.20	0.50	4.91	1.15	4.78
H 1	(53) 16.20	M	1.30	0.70	4.35	4.65	7.30	—	5.60	—	4.20
H 136	(53) 16.20	M	1.20	0.70	4.25	4.70	7.50	0.45	4.55	—	—
N 5	(54) 16.30	M	1.02	0.59	3.83	4.52	6.83	0.53	5.00	—	4.70
N 76	(54) 16.60	M	0.97	0.60	4.08	4.17	—	0.60	5.16	1.30	4.86

(11)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
7.25	1.90	—	1.20	—	1.38	—	0.70	—	2.05	4.85	1.60	—	—
7.70	1.70	0.47	1.50	1.24	1.45	1.48	0.67	—	2.15	5.05	1.60	2.17	—
7.58	1.78	0.26	1.44	1.05	1.39	1.46	0.70	5.34	2.08	4.56	1.47	—	—
7.45	1.89	0.32	1.37	0.98	1.47	1.57	0.77	5.65	1.97	4.92	1.47	—	3.76
7.20	1.80	0.30	1.37	1.57	1.17	1.34	0.76	6.30	2.30	5.10	1.60	2.08	4.12
7.20	1.70	0.35	1.26	1.56	1.09	1.28	0.71	—	2.30	4.80	1.50	2.25	4.36
7.48	1.55	0.34	1.68	1.43	1.06	1.32	0.68	6.00	2.30	5.05	1.36	—	—
6.95	1.75	—	—	1.21	1.94	—	0.73	6.09	—	5.20	1.38	—	—
7.40	1.80	—	—	1.05	1.55	—	0.80	—	2.05	5.00	1.60	—	—
7.50	1.50	0.26	1.55	0.70	0.96	1.00	0.52	—	2.15	4.90	1.50	1.90	—
7.75	1.87	0.36	1.48	1.10	1.60	1.73	0.77	5.67	2.20	4.95	1.58	2.24	4.32

Weight of Sperm

	1950~1951					
Serial No.	H No. 3	H No. 37	H No. 104	H No. 117	H No. 200	H No. 202
Body length (ft.)	49	49	46	51	52	48
Blubber						
Blubber	6,312	5,929	6,880	6,200	6,964	5,938
Head blubber	4,520	4,808	3,306	5,015	3,075	4,223
Blubber of lower jaw	112	150	160	160	184	150
Tail flukes	330	326	318	479	410	295
Dorsal fin	—	—	—	—	—	—
Blubber of flipper	216	193	226	270	260	190
Other blubber	—	—	037	70	106	85
Total	11,490	11,406	10,927	12,194	10,999	10,881
Meat						
Red meat	7,152	4,900	4,600	4,400	6,052	5,065
Other meat	2,030	2,612	3,235	3,185	3,914	2,078
Total	9,182	7,512	7,835	7,585	9,966	7,143
Internal organs						
Heart	150	87	97	095	160	109
Lungs	170	112	136	214	210	150
Tongue	317	202	90	150	165	273
Gum	—	—	—	—	—	—
Oesophagus	—	—	—	—	—	—
Stomachs	212	220	180	210	267	199
Small intestine	265	300	297	217	220	285
Large intestine	53	61	102	123	89	131
Pancreas	—	—	—	—	—	—
	—	—	—	—	—	—
Kidney	165	148	170	133	154	138
Liver	480	450	463	380	575	492
Bladder	—	—	—	—	—	—
Testes	—	—	—	—	—	—
Penis	—	—	—	—	—	—
Internal fats	442	372	250	197	261	280
Diaphragm	159	220	157	196	183	209
Others	179	—	5	126	—	—
Total	2,592	2,172	1,947	2,041	2,284	2,266
Bones						
Skull	2,063	1,819	1,370	2,020	2,341	1,873
Vertebrae	1,355	1,505	1,385	1,941	2,119	1,452
Ribs	510	450	0,382	630	564	530
Jaw bones & teeth	240	325	84	300	312	175
Scapula	96	100	96	110	132	090
Hyoid bone	—	—	—	—	—	—
Pharyngeal bone	—	—	—	—	—	—
	—	—	—	—	—	—
Other bones	369	270	336	290	120	404
Total	4,633	4,469	3,653	5,291	5,588	4,524
Miscellaneous						
Spermaceti case	4,510	5,370	3,661	6,497	7,108	4,820
Fibrous head tissue	250	450	91	0,178	150	66
Spermaceti	1,733	1,810	1,275	2,371	2,780	2,078
Suprarenal body	—	—	—	—	—	—
Other	2,196	1,278	565	850	1,050	605
Total	8,689	8,908	5,592	9,896	11,088	7,569
Grand total	36,586	34,467	29,954	37,007	39,925	32,383

Whales (in kilograms)

1950～1951									
H No. 203	H No. 204	N No. 5	N No. 7	N No. 36	N No. 76	N No. 125	N No. 103	N No. 159	N No. 166
48	46	54	53	51	54	49	45	51	48
6,523	6,930	5,827	6,891	7,150	8,615	6,520	4,659	7,533	6,342
4,300	4,065	6,482	6,777	5,929	5,669	3,851	2,616	4,842	4,885
163	110	250	274	206	245	118	96	212	129
338	340	568	614	815	467	510	283	424	537
—	—	—	—	113	—	—	—	27	12
126	102	—	—	—	—	—	—	—	—
095	70	—	—	—	—	—	—	—	—
11,545	11,617	13,127	14,556	14,213	14,996	10,999	7,654	13,038	11,905
5,530	4,390	9,255	9,401	9,839	11,946	9,394	4,656	10,450	8,363
2,745	2,765	—	—	—	—	—	—	—	—
8,275	7,155	9,255	9,401	9,839	11,946	9,394	4,656	10,450	8,363
115	095	102	118	118	145	108	92	110	99
208	225	363	384	355	308	308	186	221	305
290	235	140	102	98	35	85	74	77	103
—	—	—	29	18	18	20	9	14	18
—	—	064	—	—	88	94	112	33	96
225	180	301	337	212	234	157	151	245	197
250	230	260	230	208	381	257	192	353	278
125	110	162	90	99	61	70	53	97	107
—	—	4	10	12	10	14	6	11	8
—	—	—	—	—	—	—	—	—	4
157	127	172	179	162	218	157	95	182	205
405	340	517	513	483	567	430	327	300	445
—	—	—	14	011	14	12	7	6	9
—	—	11	12	007	14	10	3	10	12
—	—	083	74	064	83	40	30	73	88
370	250	347	359	444	511	515	354	340	406
190	160	—	238	212	197	118	182	—	140
88	104	—	—	—	—	—	—	—	—
2,423	2,056	2,526	2,689	2,503	2,884	2,395	1,873	2,072	2,520
1,727	1,784	2,745	2,833	2,283	2,591	2,354	1,386	1,981	2,346
1,775	1,604	2,337	2,075	2,089	3,493	2,466	1,679	2,333	1,872
535	518	676	742	647	879	442	480	553	662
265	192	326	391	284	350	261	185	280	279
86	108	150	263	232	135	82	119	113	161
—	—	2,223	377	358	323	300	200	283	271
—	—	135	85	82	159	68	30	100	135
—	—	10	—	6	—	—	4	—	1
335	280	—	—	—	—	—	—	—	—
4,723	4,486	6,602	6,776	5,953	7,930	5,973	4,083	5,642	5,727
4,971	4,360	1,255	1,774	1,198	1,366	1,069	490	1,115	1,219
167	60	8,007	8,802	6,664	9,825	6,741	4,405	6,925	7,543
1,820	1,540	2,020	2,858	2,643	2,748	2,371	1,290	2,130	1,806
—	—	—	—	1	—	—	—	—	1
470	400	—	—	—	—	—	—	—	—
7,428	6,360	11,282	13,434	10,506	13,939	10,181	6,194	10,170	10,569
34,394	31,674	42,792	46,846	43,014	51,695	38,942	26,251	41,373	39,084

Dimensions of Baleen Whales

Serial Number	487	417	507	1207	919	1208	961	596
Sp.	Fin	Fin	Fin	Fin	Fin	Blue	Blue	Hump-back
Sex	Male	Male	Female	Female	Female	Male	Male	Female
Factory ship	Nisshin	Hashidate	Nisshin	Nisshin	Hashidate	Nisshin	Hashidate	Hashidate
Length of whales (ft.)	67	67	67	57	68	83	78	41
Linear measurements (in m)								
Total length	20.42	20.45	20.32	17.40	20.60	25.32	23.80	12.47
Lower jaw, projection beyond tip of snout.	0.36	ND	0.22	0.31	ND	0.60	ND	0.50
Tip of snout to blowhole	3.73	3.85	4.00	3.25	3.95	4.80	4.30	2.55
Tip of snout to angle of gape	3.98	ND	4.25	3.28	4.55	5.12	4.60	3.05
Tip of snout to center of eye	4.12	4.15	4.27	3.45	4.40	5.23	4.55	3.15
Tip of snout to tip of flipper	7.98	7.70	7.91	6.76	7.70	11.00	10.30	ND
Eye to ear (centers)	0.94	0.85	0.94	0.81	ND	1.42	ND	0.65
Notch of flukes to posterior emargination of dorsal fin	4.12	ND	4.45	3.76	5.00	5.30	4.70	4.10
Flukes, width at insertion	1.14	ND	0.90	0.98	ND	1.55	ND	ND
Notch of flukes to anus	5.54	ND	5.70	4.90	5.75	6.70	6.70	2.60
Notch of flukes to umbilicus	9.14	9.50	9.11	7.63	8.90	10.50	10.70	ND
Notch of flukes to end of ventral grooves	8.53	9.25	8.91	7.50	8.70	9.80	9.50	5.20
Anus to reproductive aperture (centers)	1.35	1.55	0.54	0.38	0.60	1.62	1.60	1.00
Dorsal fin, vertical height	0.48	ND	0.41	0.47	0.60	0.12	0.62	0.60
Dorsal fin, length of base	1.27	ND	1.92	1.31	1.20	1.25	1.30	ND
Flipper, tip to axilla	1.78	1.60	1.71	1.32	1.90	2.30	2.45	3.40
Flipper, tip to anterior end of lower border	2.59	2.10	2.35	1.83	2.70	2.85	3.30	3.85
Flipper, length along curve of lower border	2.62	ND	2.42	1.88	ND	3.03	ND	ND
Flipper, greatest width	0.70	0.54	0.61	0.46	0.54	0.85	0.85	1.00
Severed head, condyle to tip	5.38	ND	5.50	ND	5.55	ND	5.90	3.70
Skull, greatest width	2.25	2.10	2.20	1.84	2.27	3.06	3.09	3.10
Skull length, condyle to tip of premaxilla	5.35	5.10	5.20	4.50	5.50	6.43	5.85	3.65
Flipper, tip to head of humerus	ND	ND	ND	ND	ND	ND	ND	ND
Tail, depth at dorsal fin	1.78	ND	2.00	ND	ND	ND	ND	ND

ND : No. Date available.

Weight of Baleen Whales

Serial No: Sp. Sex.	487 Fin male	417 Fin male	507 Fin female	1207 Fin female	919 Fin female	1208 Blue male	961 Blue male	596 Humpback female
Factory Ship	Nisshin	Hashidate	Nisshin	Nisshin	Hashidate	Nisshin	Hashidate	Hashidate
Length of whale (ft.)	67	67	67	57	68	83	78	41
Weight of Parts: (kgs)								
Blubber								
Blubber	5,004	4,264	4,970	3,351	5,004	11,768	11,068	4,307
Head blubber	1,177	1,203	1,072	616	1,026	2,370	2,122	603
Blubber of ventral grooves	3,965	4,635	3,509	2,227	5,215	11,200	12,305	ND
Blubber of lower jaw	840	966	657	514	814	2,204	1,460	615
Flukes	332	346	391	245	310	546	625	290
Total	11,318	11,414	10,599	6,953	12,369	28,088	27,580	5,815
Meat								
Red meat	19,889	17,742	24,663	16,213	18,455	40,954	25,860	6,195
Ventral meat	237	3,033	1,218	662	3,250	3,406	855	3,754
Connective tissues	1684	ND	1,353	753				
Total	21,810	20,775	27,234	17,628	21,705	44,360	26,715	9,949
Internal organs								
Heart	207	398	246	162	210	412	430	90
Lungs	414	387	658	343	260	960	730	175
Tongue	1,343	1,347	1,386	844	1,450	2,708	1,938	1,080
Stomachs	250	201	249	231	201	420	223	165
Oesophagus	22	ND	32	79	ND	67	ND	ND
Small intestine	177	202	332	334	610	824	1,001	276
Large intestine	608	472	429	347	445	380	667	184
Pancreas	20	ND	32	28	ND	40	ND	ND
Spleen	5	ND	2	4.5	ND	16	ND	ND
Kidney	142	211	210	134	160	290	262	145
Liver	503	515	531	397	518	1,047	625	420
Bladder	21	ND	13	16	ND	22	ND	ND
Penis (Ovaries)	44	ND	1	0.5	1	105	ND	4
Testes (Uterus & Vagina)	5	11	144	30	ND	64	39	ND
Diaphragm	218	121	220	142	290	490	325	180
Internal fats	1,769	813	1,850	770	2,089	5,952	2,798	994
Total	5,748	4,678	6,335	3,862.5	6,243	13,797	9,038	3,713
Bones								
Skull	2,084	2,065	2,218	1,186	2,280	5,328	2,645	1,180
Vertebrae	3,605	3,387	3,928	2,569	3,527	10,109	6,510	1,288
Ribs	1,281	1,032	1,574	174	835	2,409	1,040	715
Jaw bones	880	938	1,010	544	974	1,907	1,668	431
Scapula	263	195	240	158	188	393	475	160
Hyoid bone	45	ND	48	42	30	175	ND	ND
Nasal Cartilage	110	ND	85	ND	ND	230	ND	ND
Total	8,268	7,617	9,103	5,173	7,834	20,551	12,338	3,774
Miscellaneous								
Gums	129	ND	202	131	ND	450	ND	ND
Jaw ligaments	321	184	276	191	310	985	370	183
Baleen	315	415	552	184	504	1,053	465	234
Tendons	ND	ND	ND	ND	ND	ND	ND	ND
Flippers	411	263	467	226	352	640	912	706
Scraps	10	461	ND	2	265	7	1,836	443
Total	1,186	1323	1,497	735	1,431	3,135	3,583	1,566
Total weight	48,330	45,807	54,768	34,351.5	49,582	109,930	79,254	24,817

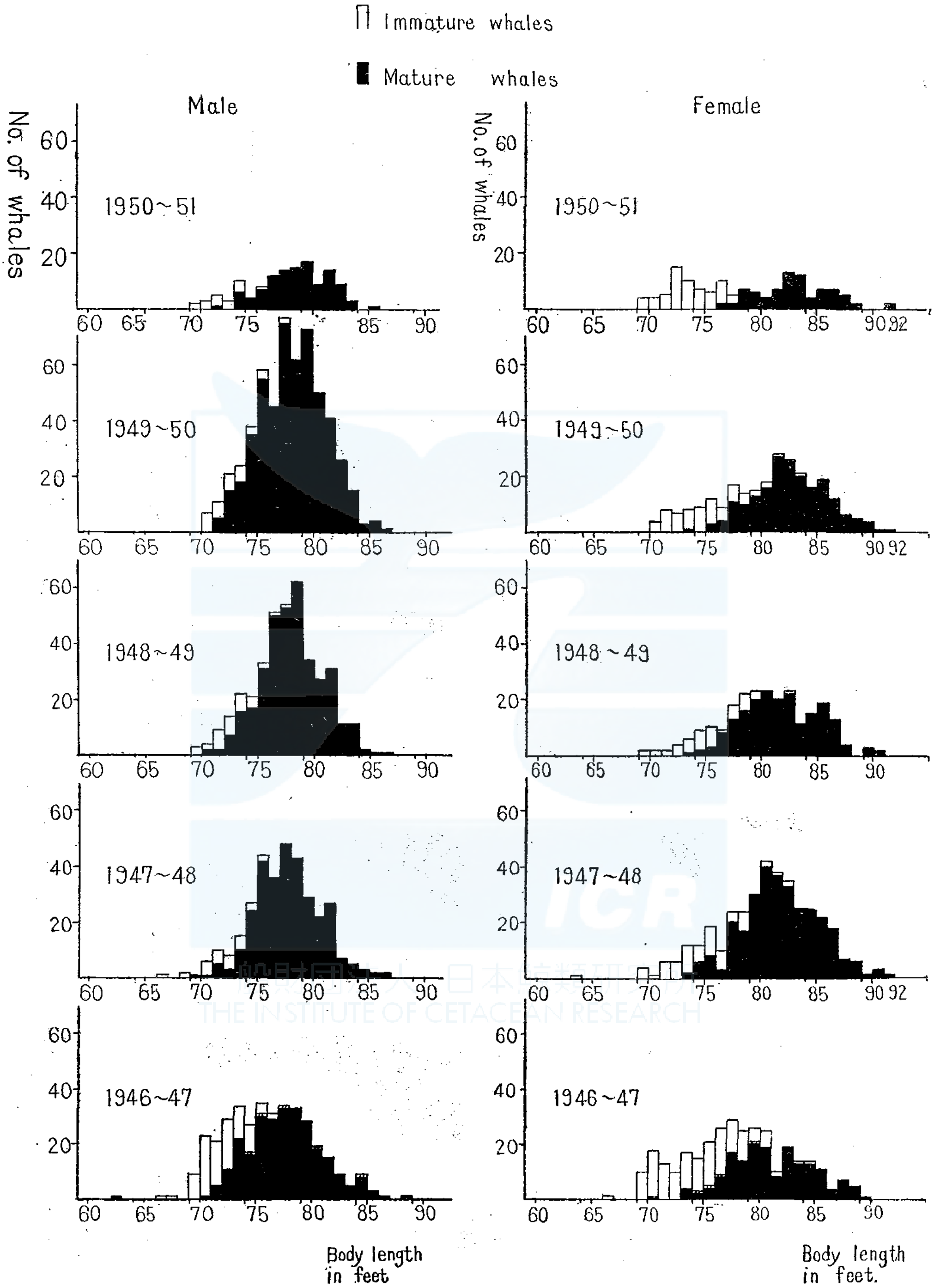


Fig. 1. Length frequencies of Blue whales.

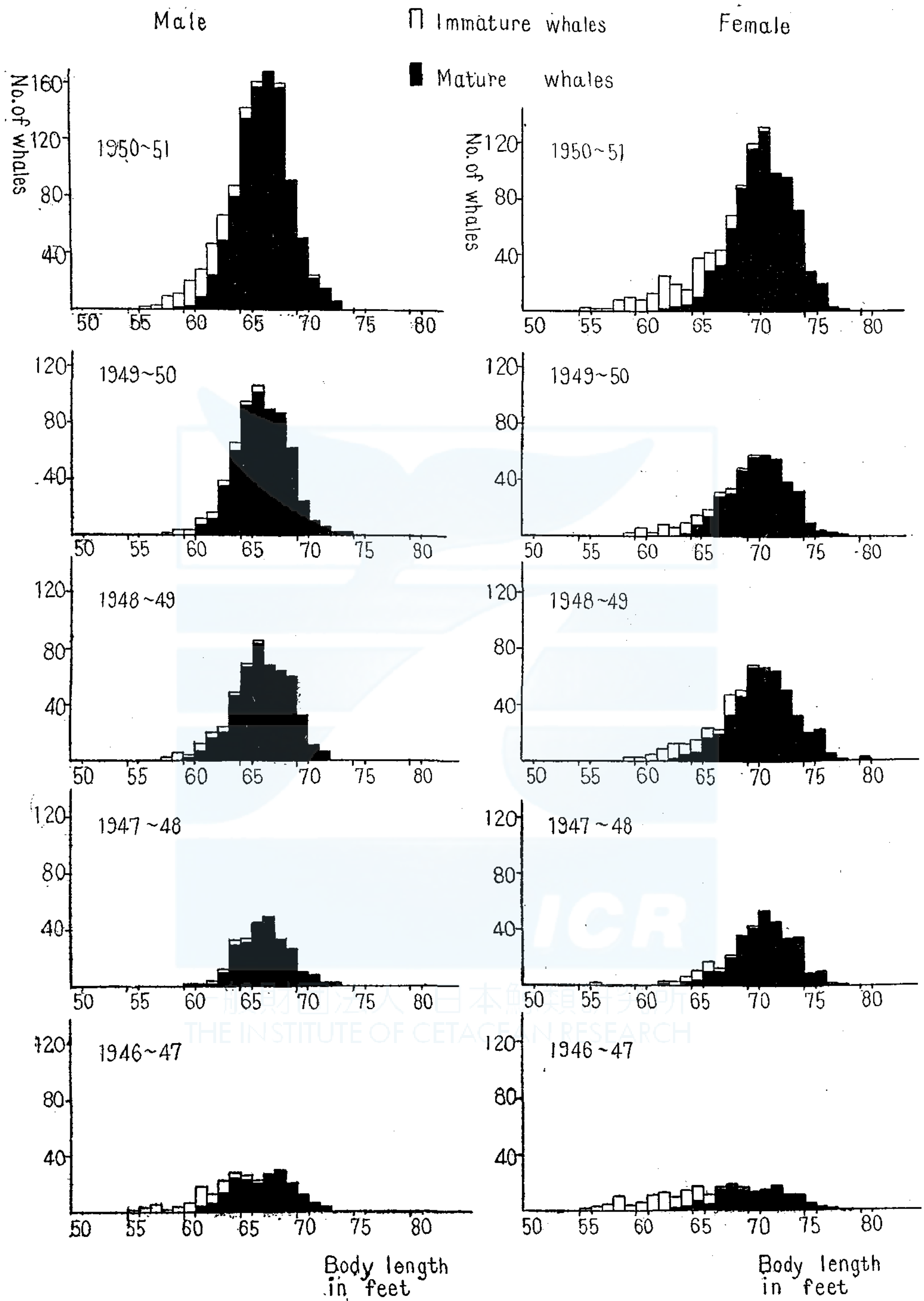


Fig. 2. Length frequencies of Fin whales.

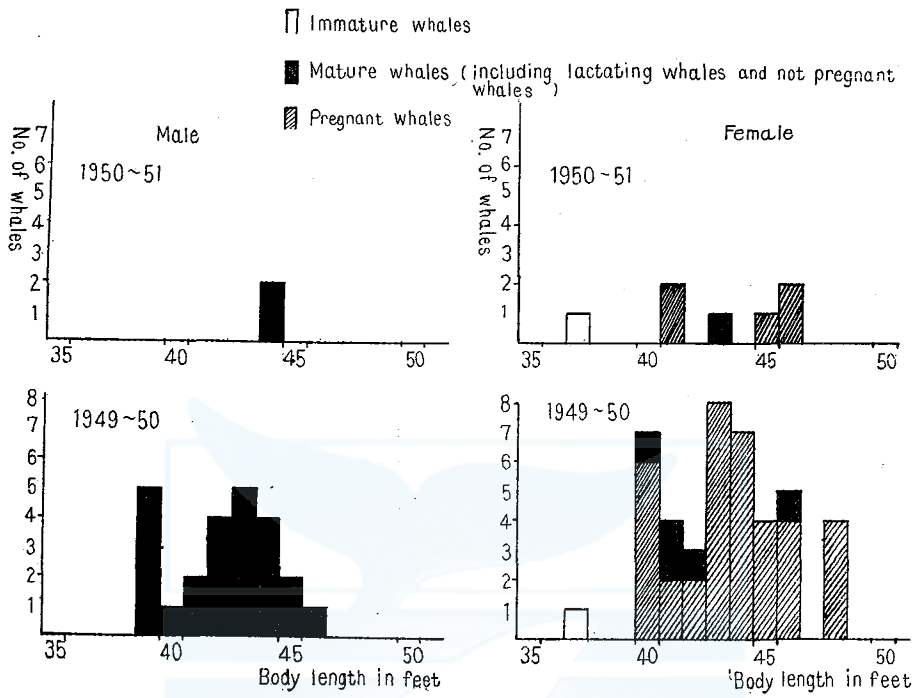


Fig. 3. Length frequencies of Humpback whales.

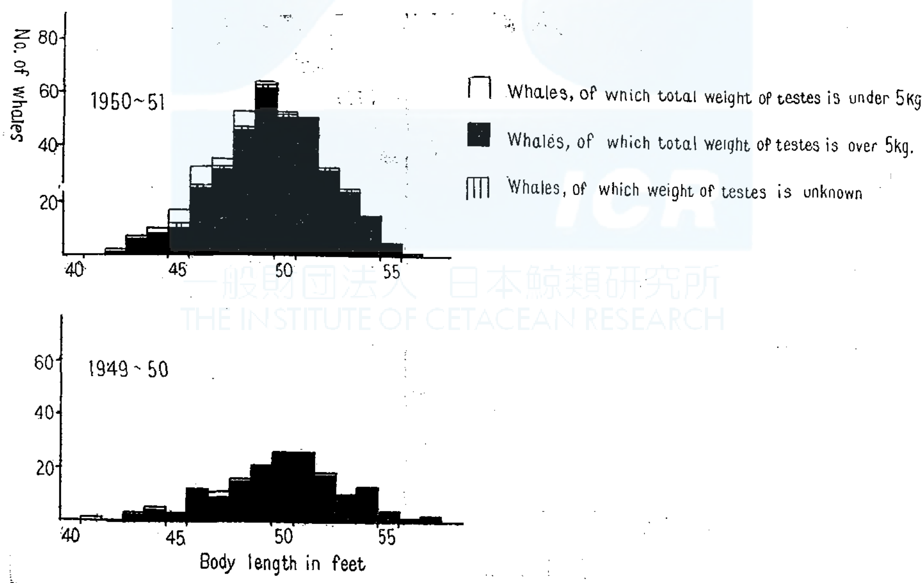


Fig. 4. Length frequencies of Sperm whales.

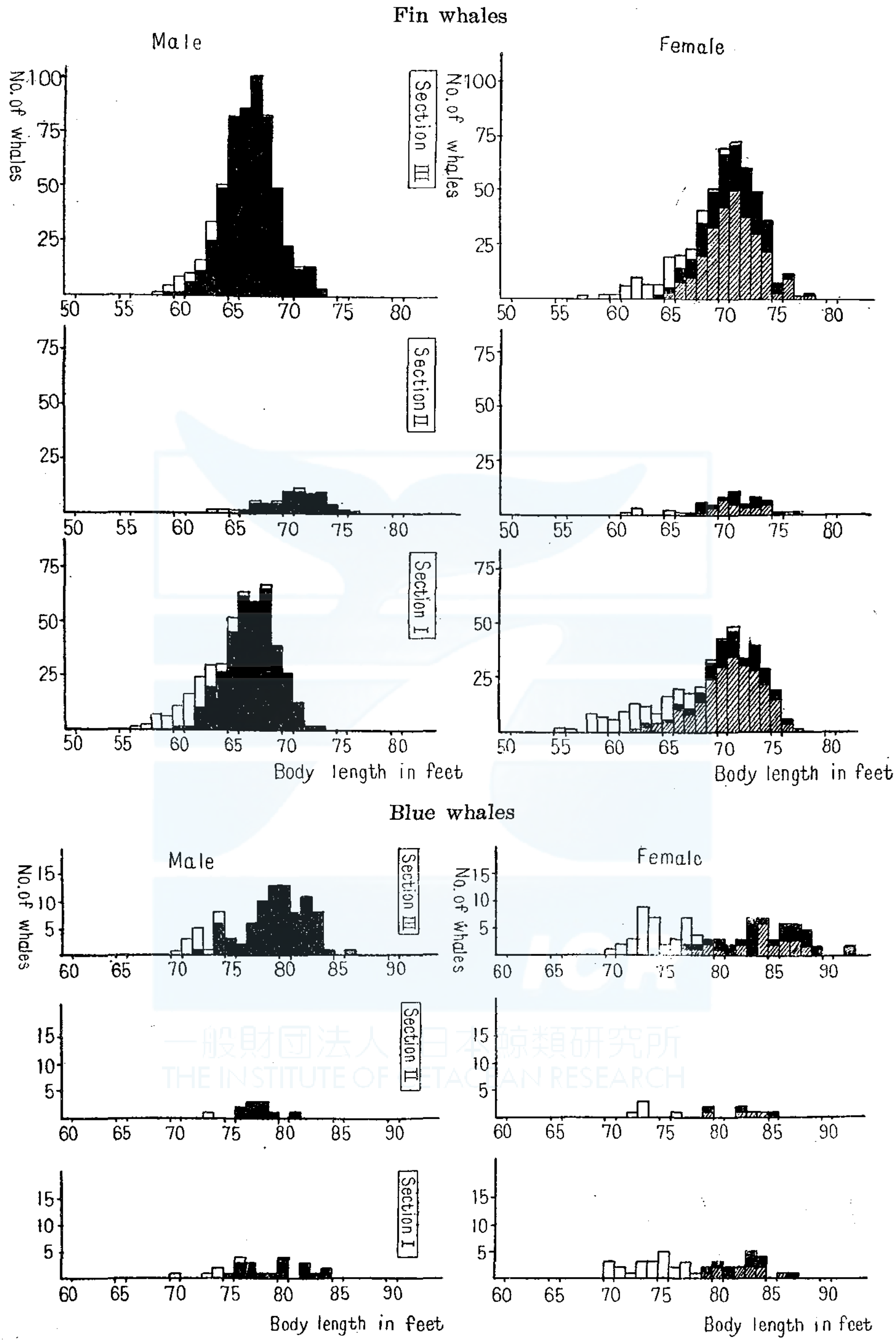


Fig. 5. Length frequencies of whales by sections.

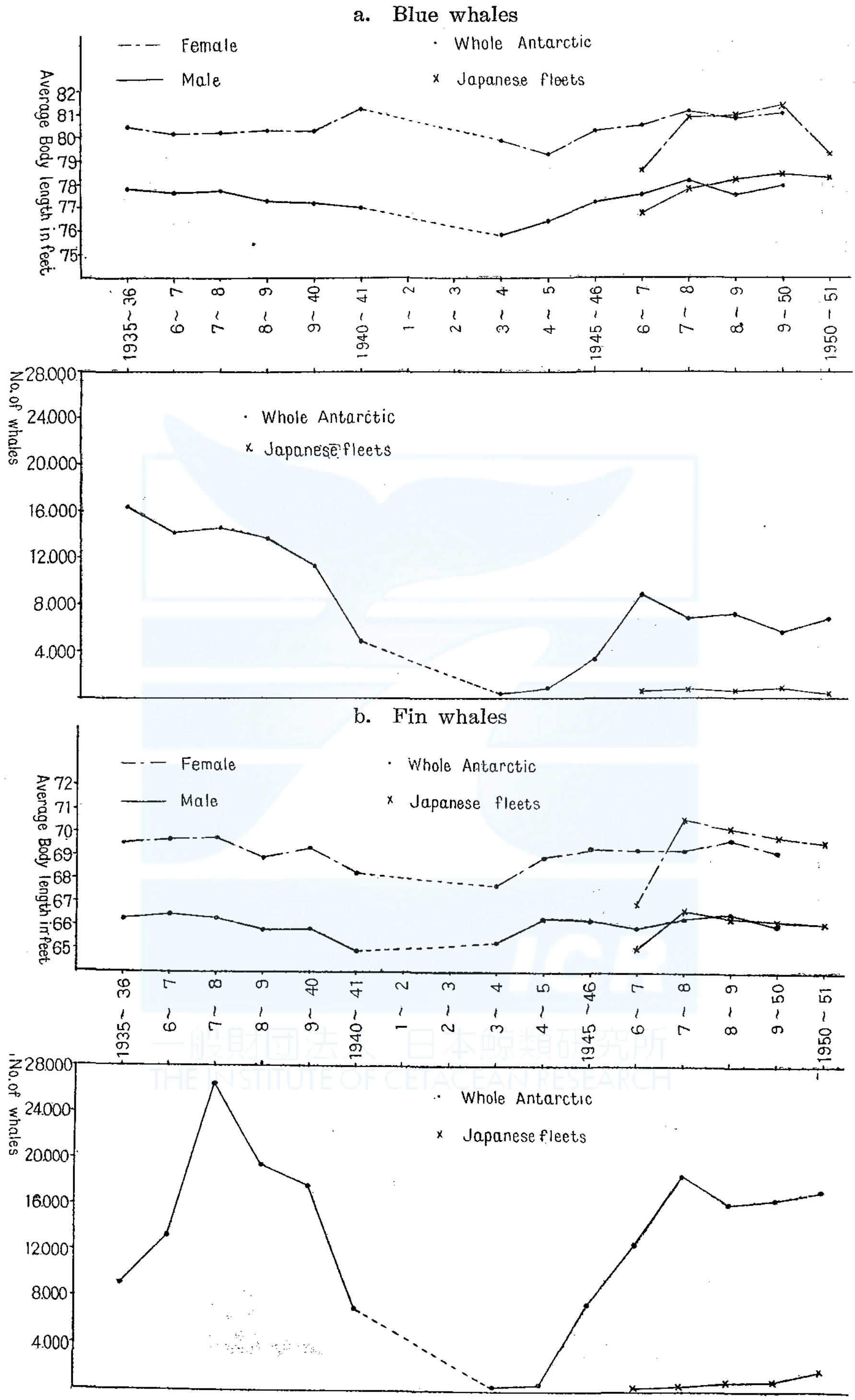
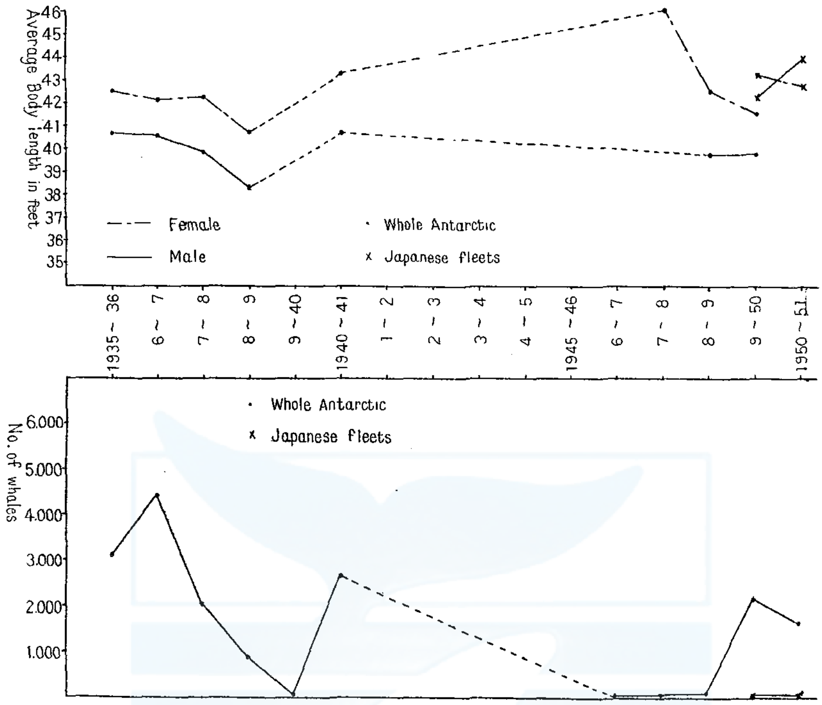


Fig. 6 a-d. Number of whales and average body length.

c. Humpback whales



d. Sperm whales

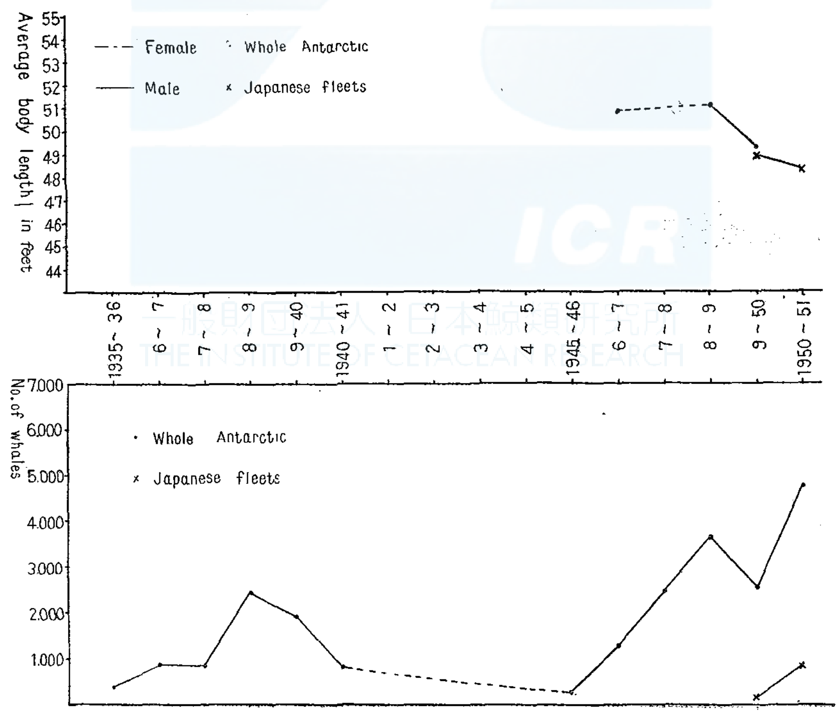
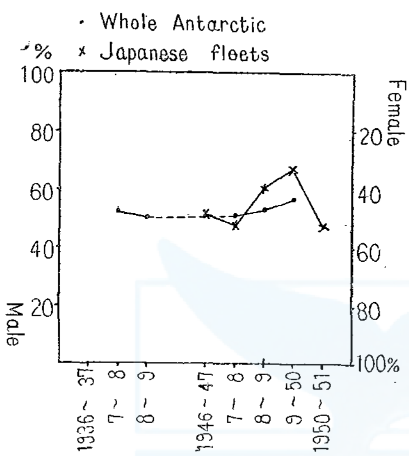
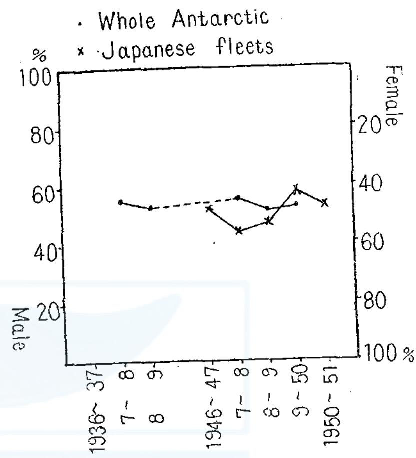


Fig. 7. Seasonal & monthly fluctuation of sex ratio.

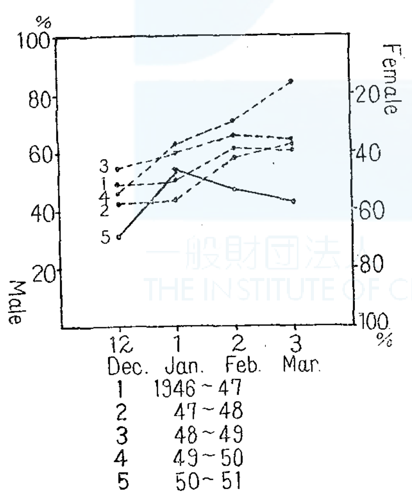
Blue whales



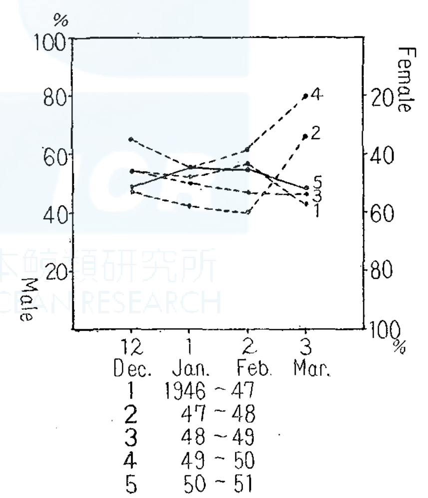
Fin whales



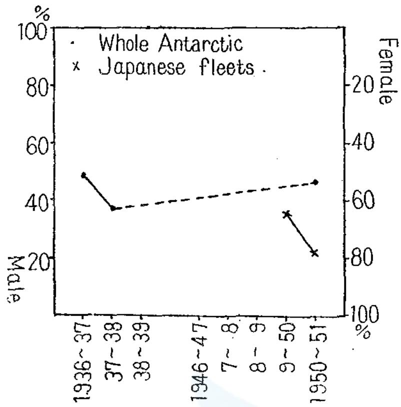
Blue whales (caught by Japanese fleets)



Fin whales (caught by Japanese fleets)



Humpback whales



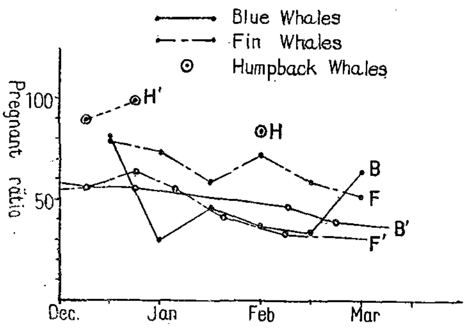


Fig. 8. Semi-monthly pregnant ratio.
B, F, H for 1950/51 season
B′, F′, H′ for average for post-war 4 seasons

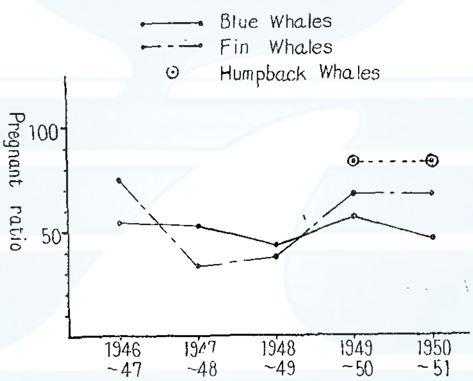


Fig. 9. Seasonal pregnant ratio.

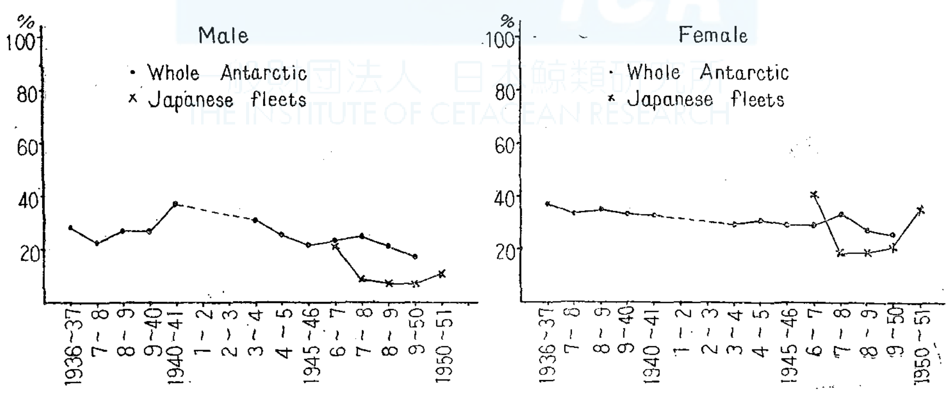


Fig. 10. Number of immature blue whales caught.

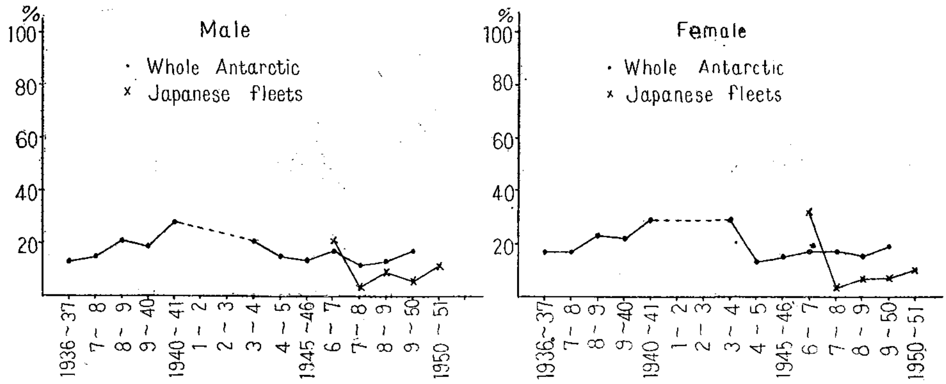


Fig. 11. Number of immature fin whales caught.

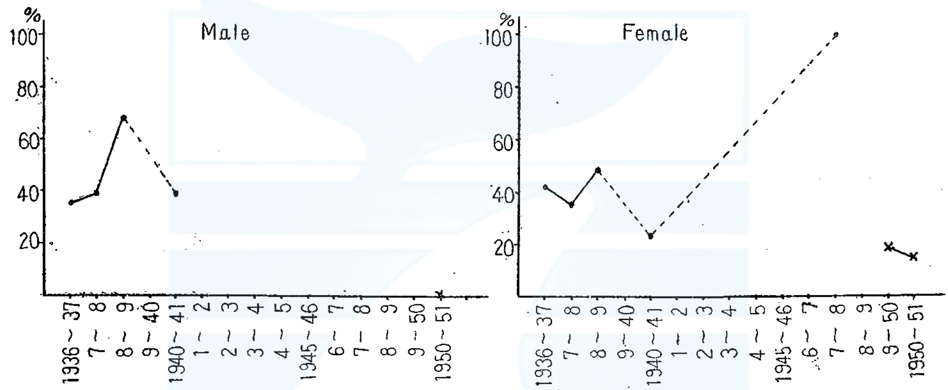


Fig. 12. Number of immature humpback whales caught.

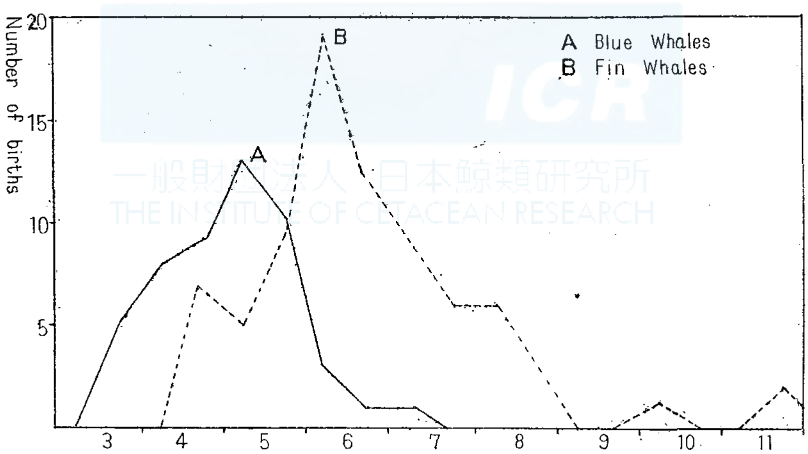


Fig. 13. Curve of frequency of births (Source: Discovery Reports Vol. 1)
A: Blue whales B: Fin whales

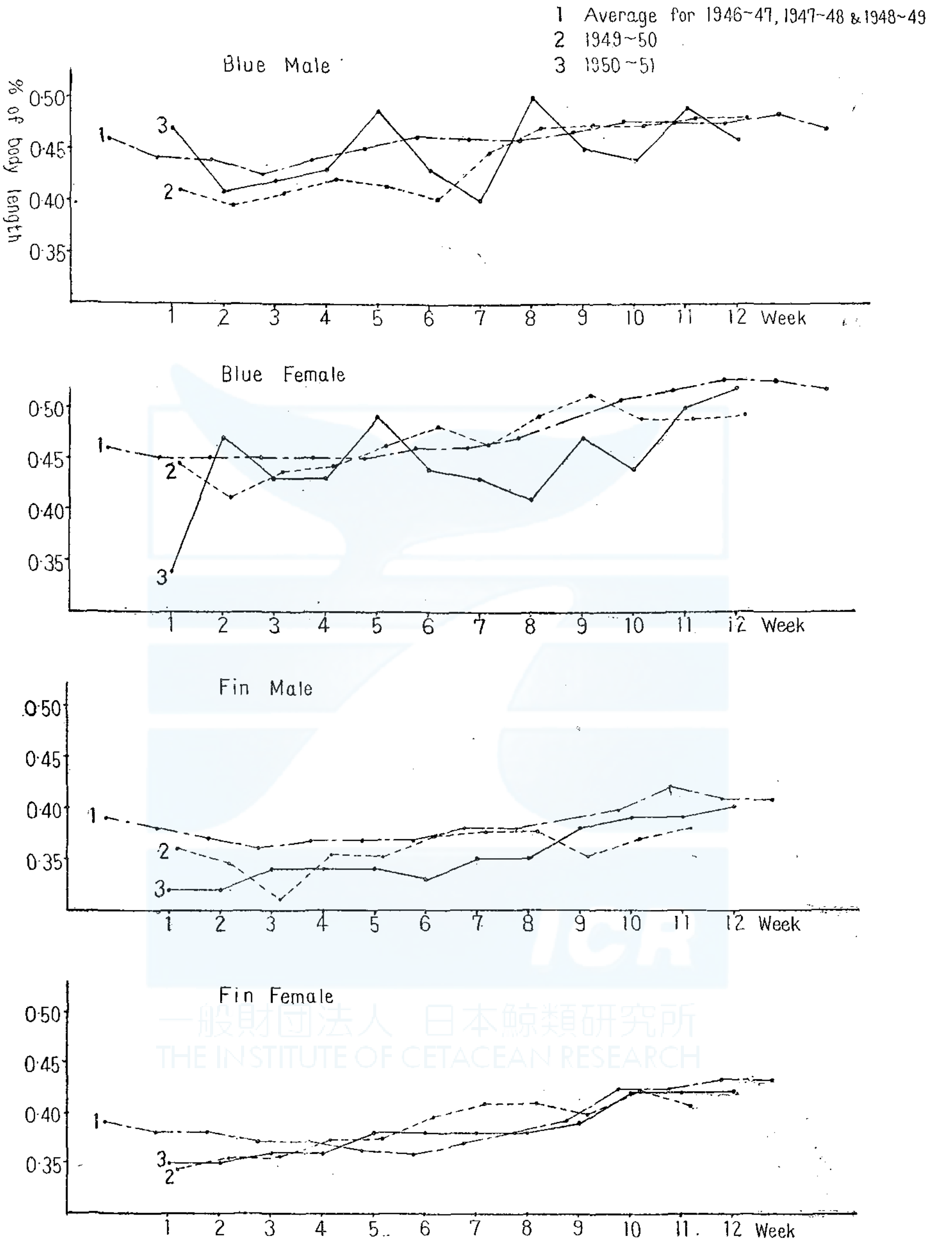


Fig. 14. Weekly fluctuation of thickness of blubber.

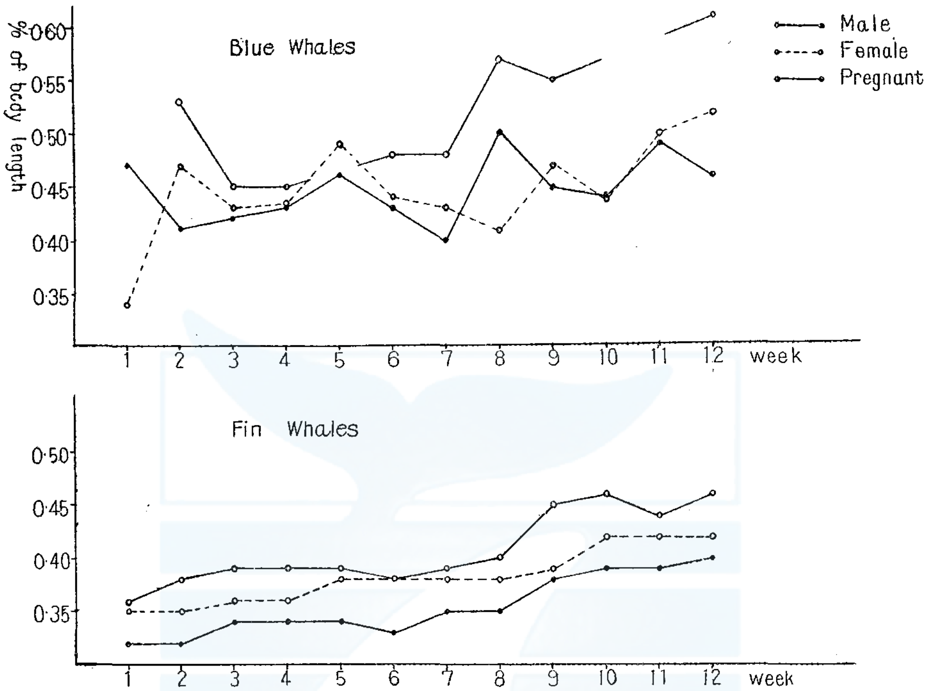


Fig. 15. Comparison of weekly fluctuation of blubber thickness.

1st week	Dec. 22-23
2nd week	Dec. 24-30
3rd week	Dec. 31-Jan. 6
4th week	Jan. 7-13
5th week	Jan. 14-20
6th week	Jan. 21-27
7th week	Jan. 28-Feb. 3
8th week	Feb. 4-10
9th week	Feb. 11-17
10th week	Feb. 18-24
11th week	Feb. 25-Mar. 3
12th week	Mar. 4-9

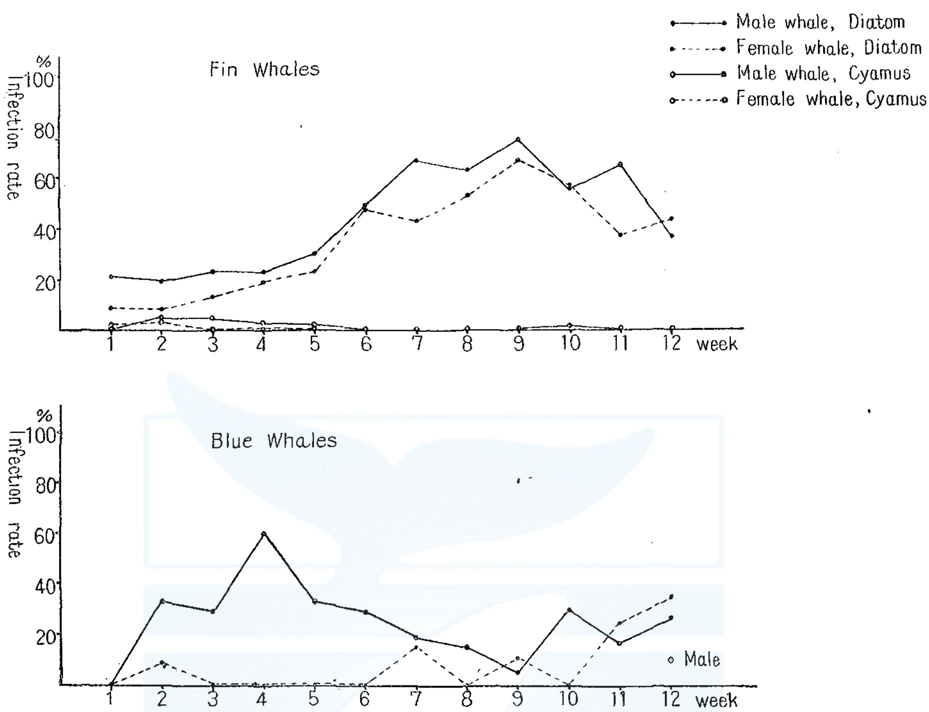
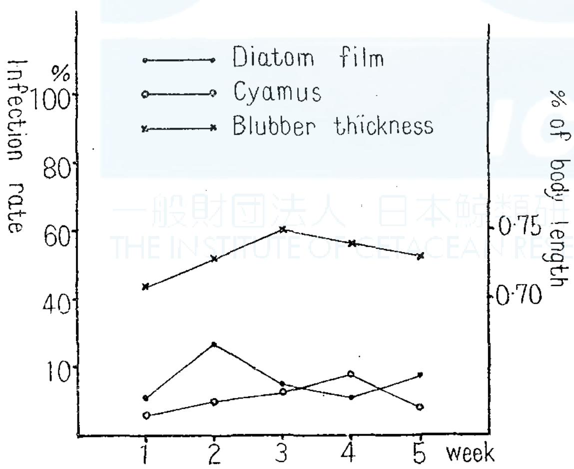


Fig. 16. Weekly fluctuation of infection rate of Diatom film and Cyamus



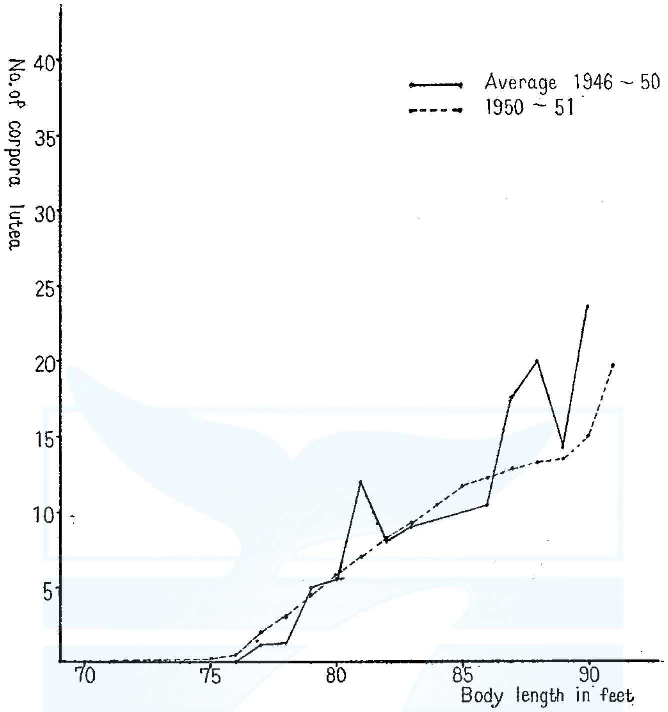
Sperm whale season

1st week	Nov. 23-25
2nd week	Nov. 26-Dec. 2
3rd week	Dec. 3-9
4th week	Dec. 10-16
5th week	Dec. 17-21

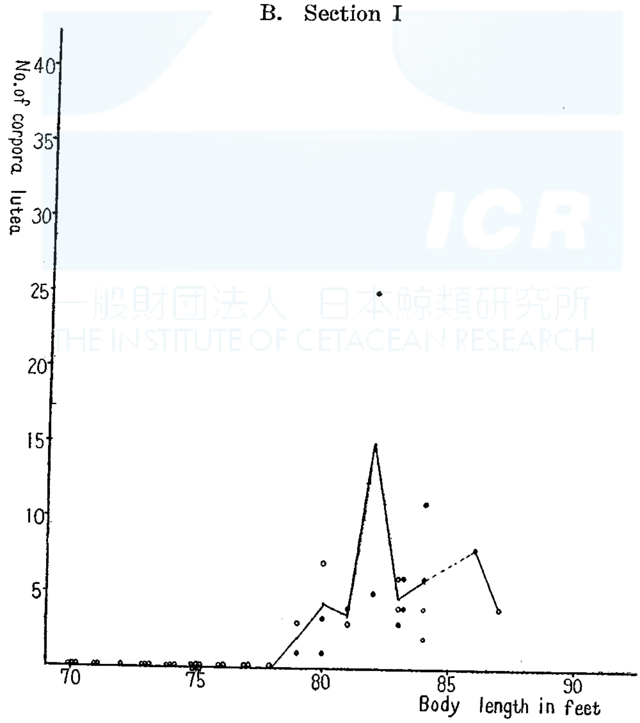
Fig. 17. Weekly fluctuation of blubber thickness and infection rate of Diatom film and Cymus

Fig. 18. Relation between number of corpora lutea and body length of blue whales.

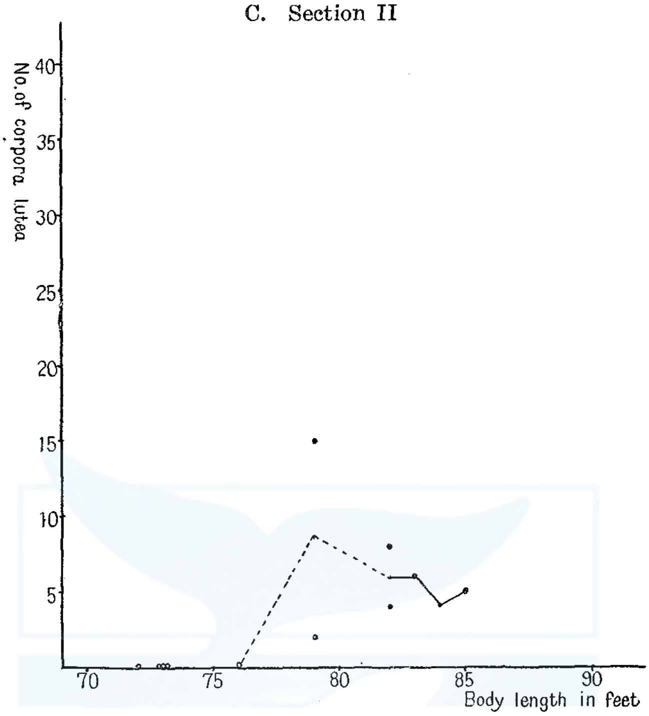
A. Entire ground



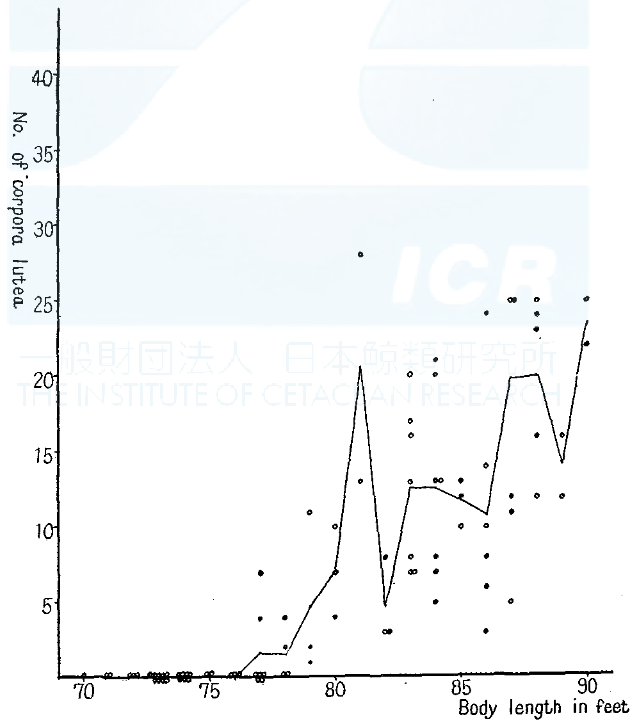
B. Section I



C. Section II



D. Section III



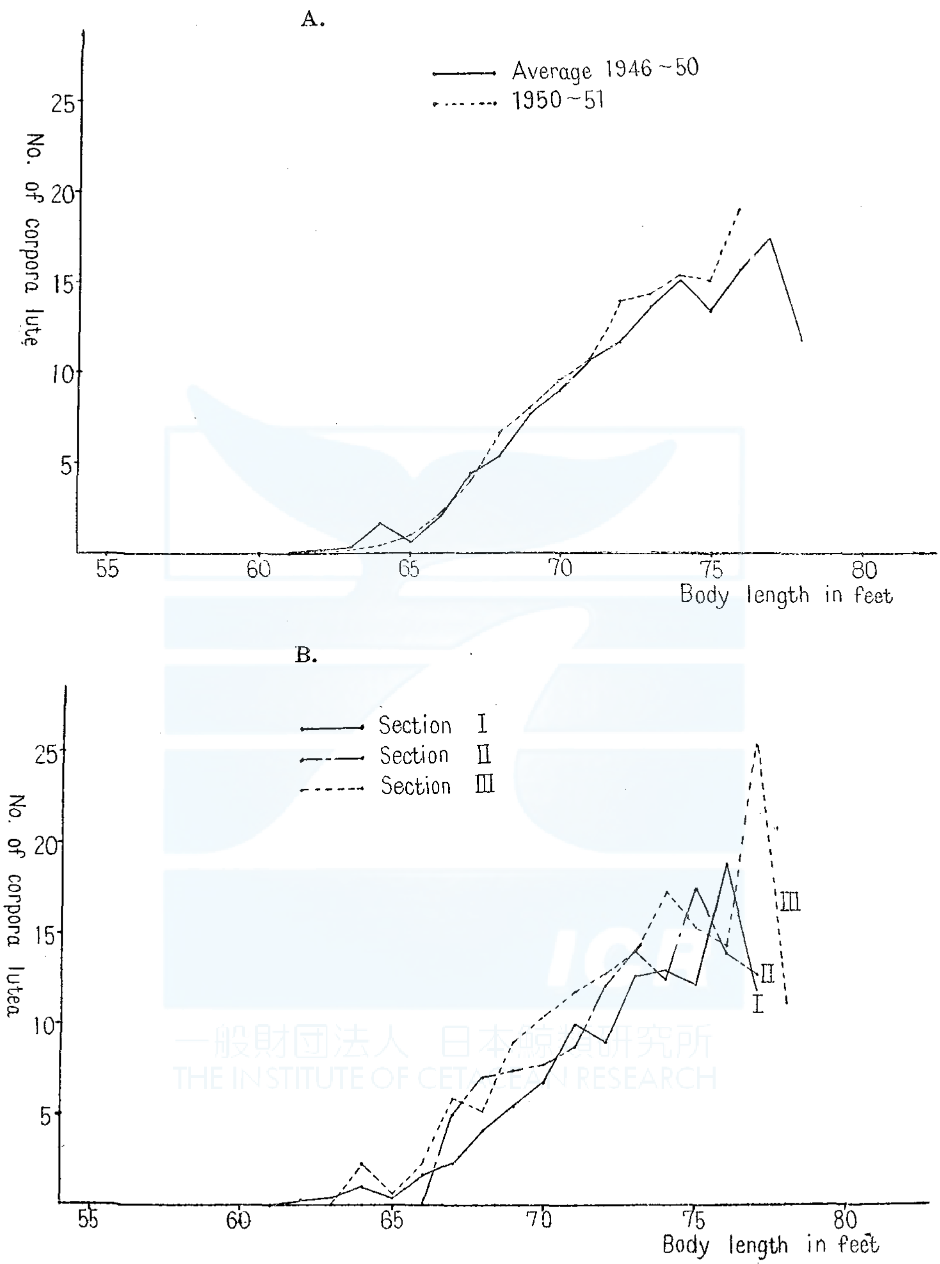
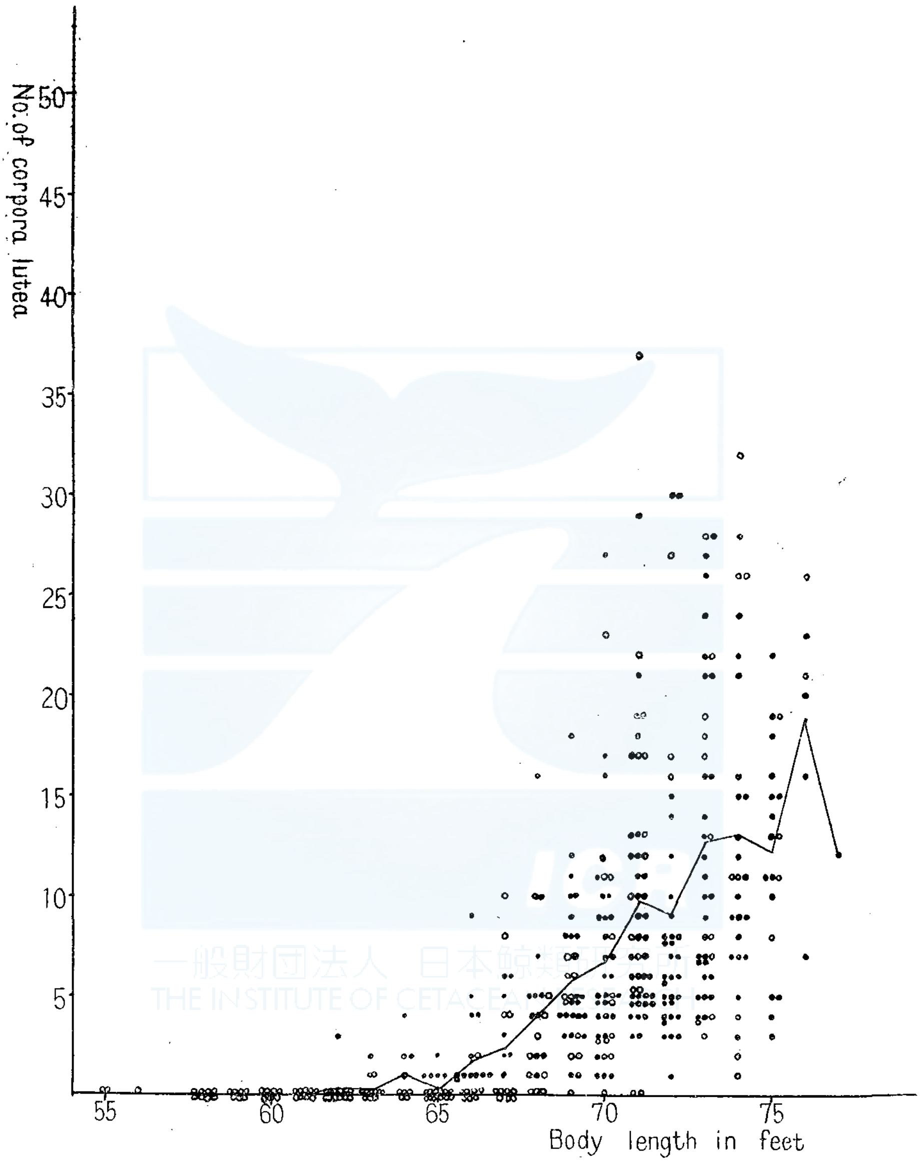
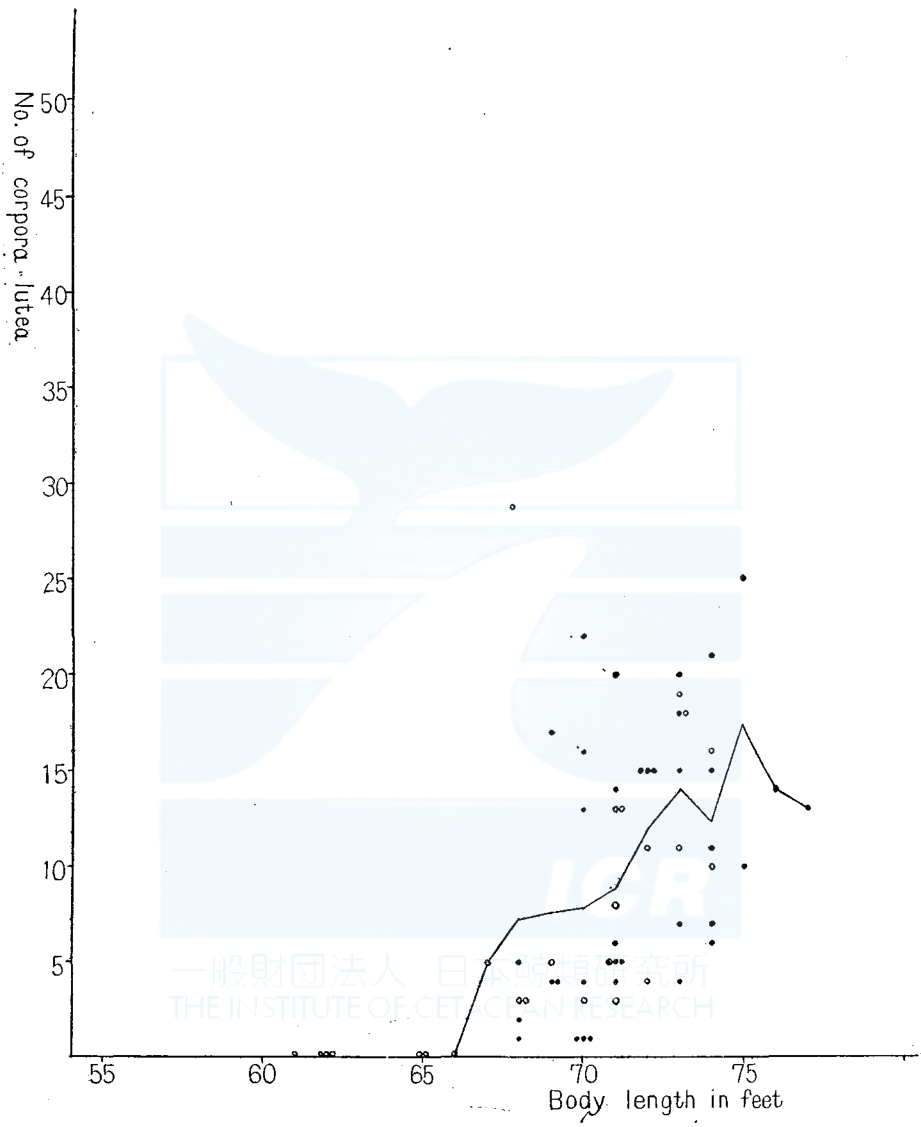


Fig. 19. Relation between number of corpora lutea and body length of fin whales.

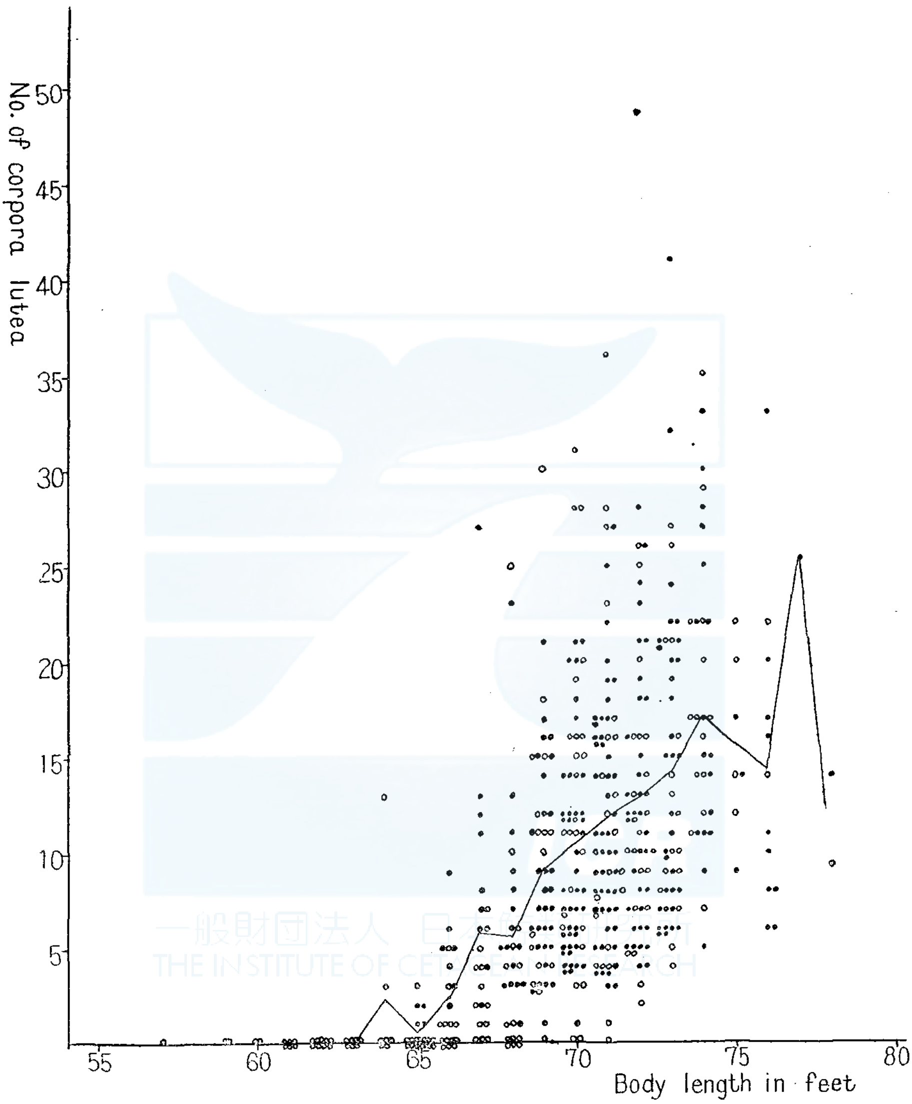
C. Section I


No. of corpora lutea
50
45
40
35
30
25
20
15
10
5
55
60
65
70
75
Body length in feet

D. Section II


No. of corpora lutea
50
45
40
35
30
25
20
15
10
5
55
60
65
70
75
Body length in feet

E. Section III



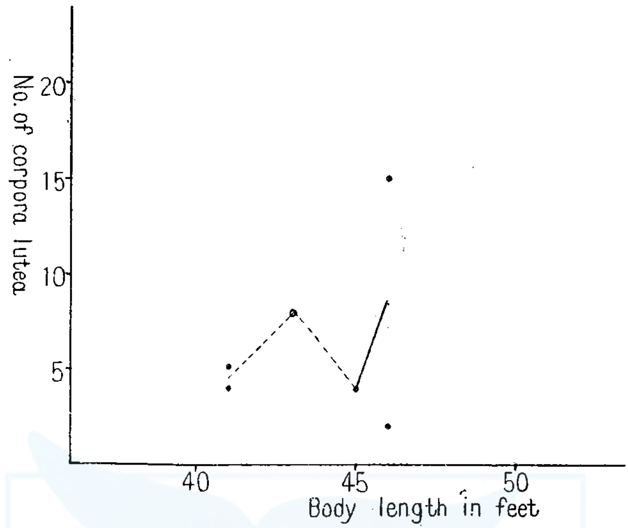


Fig. 20. Relation between number of corpora lutea and body length of humpback whales.

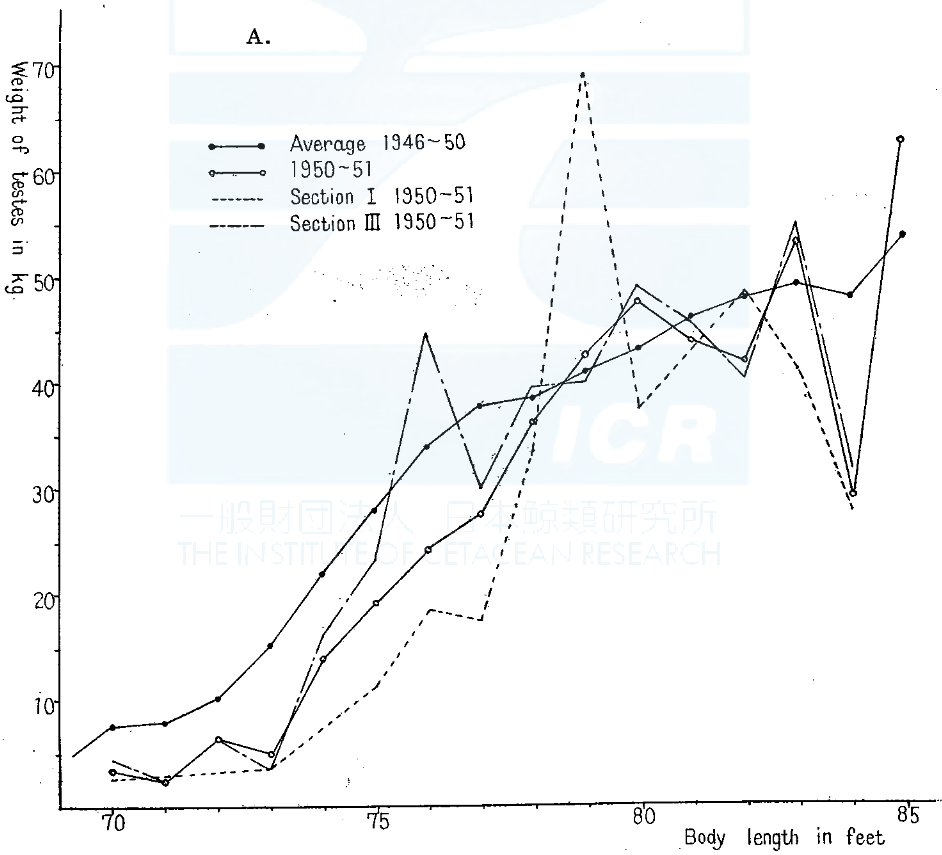
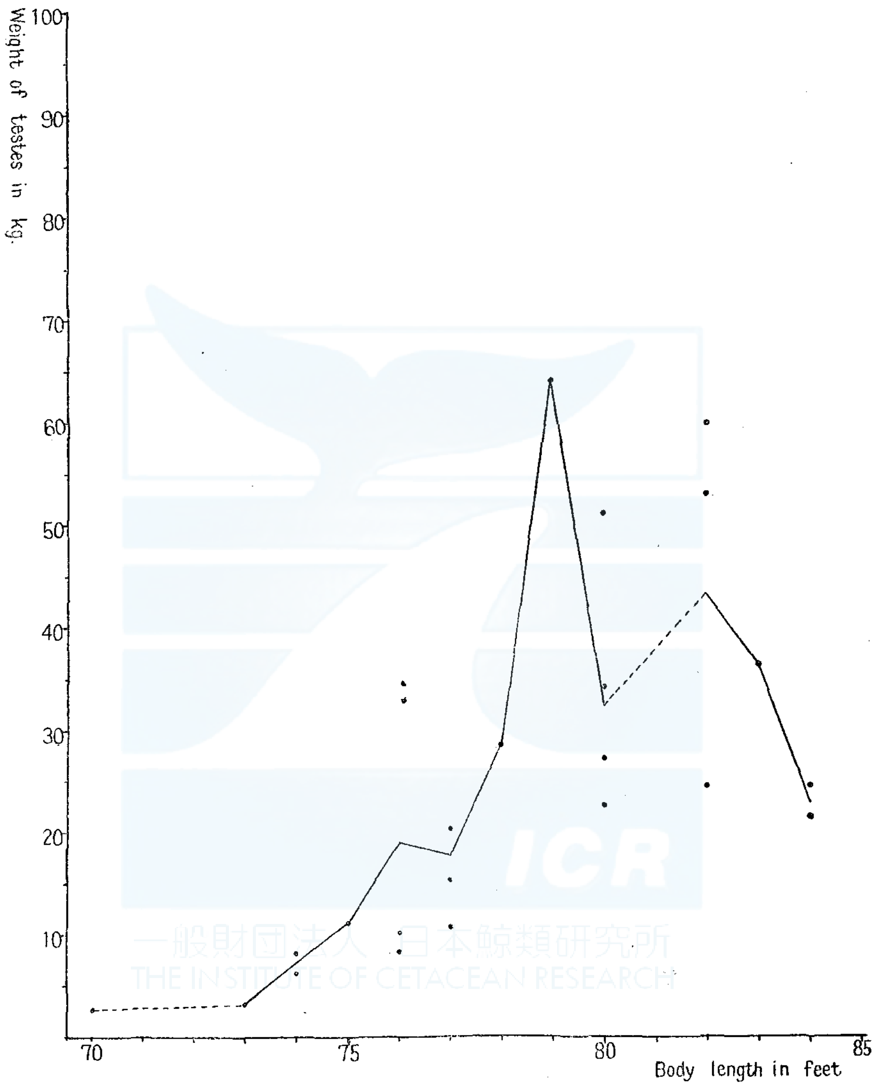
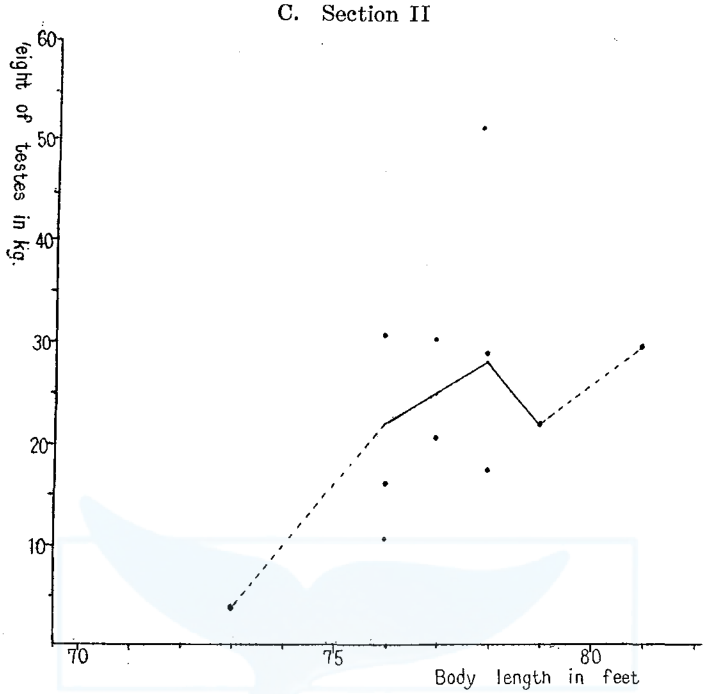


Fig. 21. Relation between weight of testes and body length of blue whales.

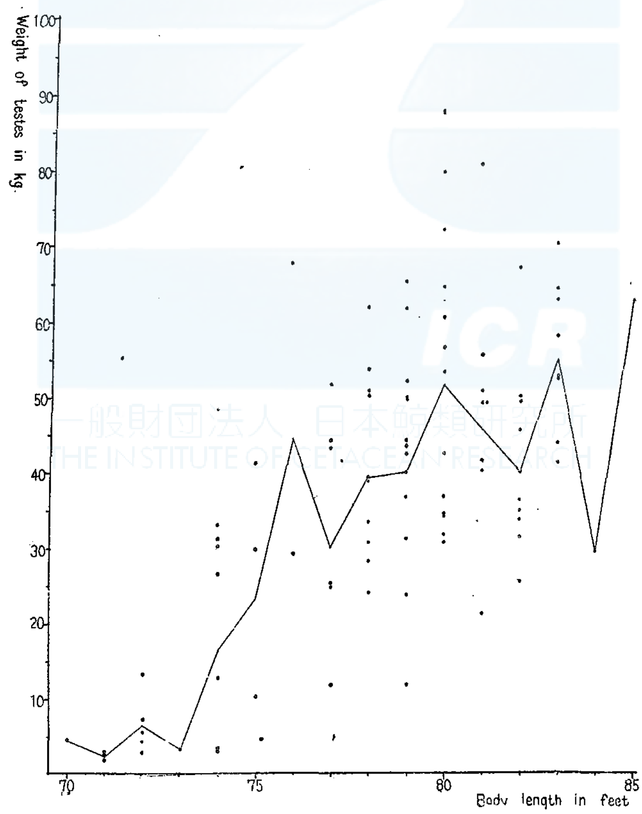
B. Section I


Weight of testes in kg.
100
90
80
70
60
50
40
30
20
10
70
75
80
85
Body length in feet

C. Section II



D. Section III



A. Comparison between section I and III

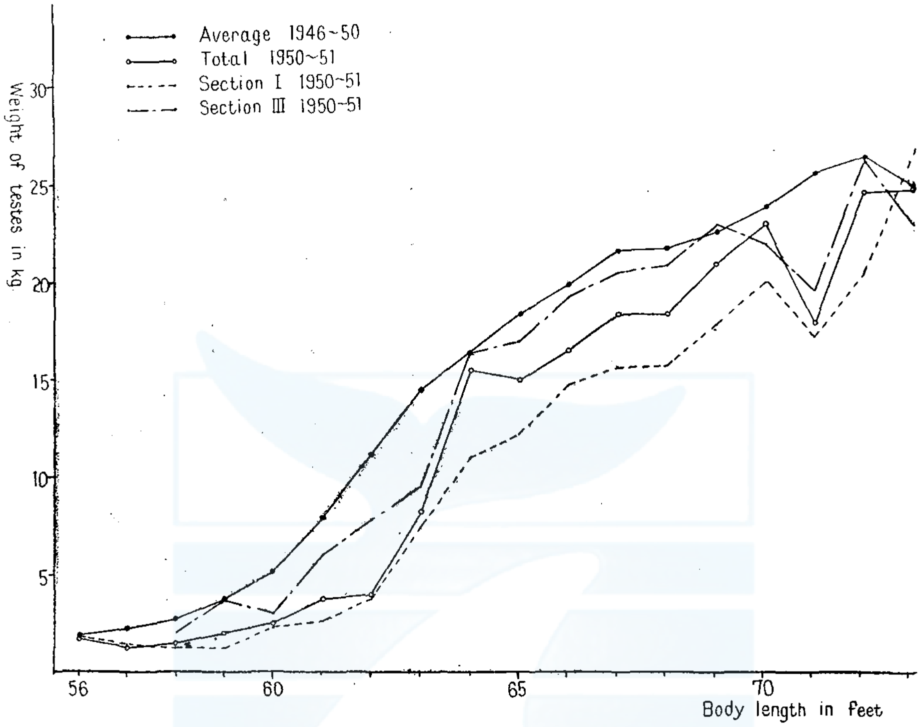
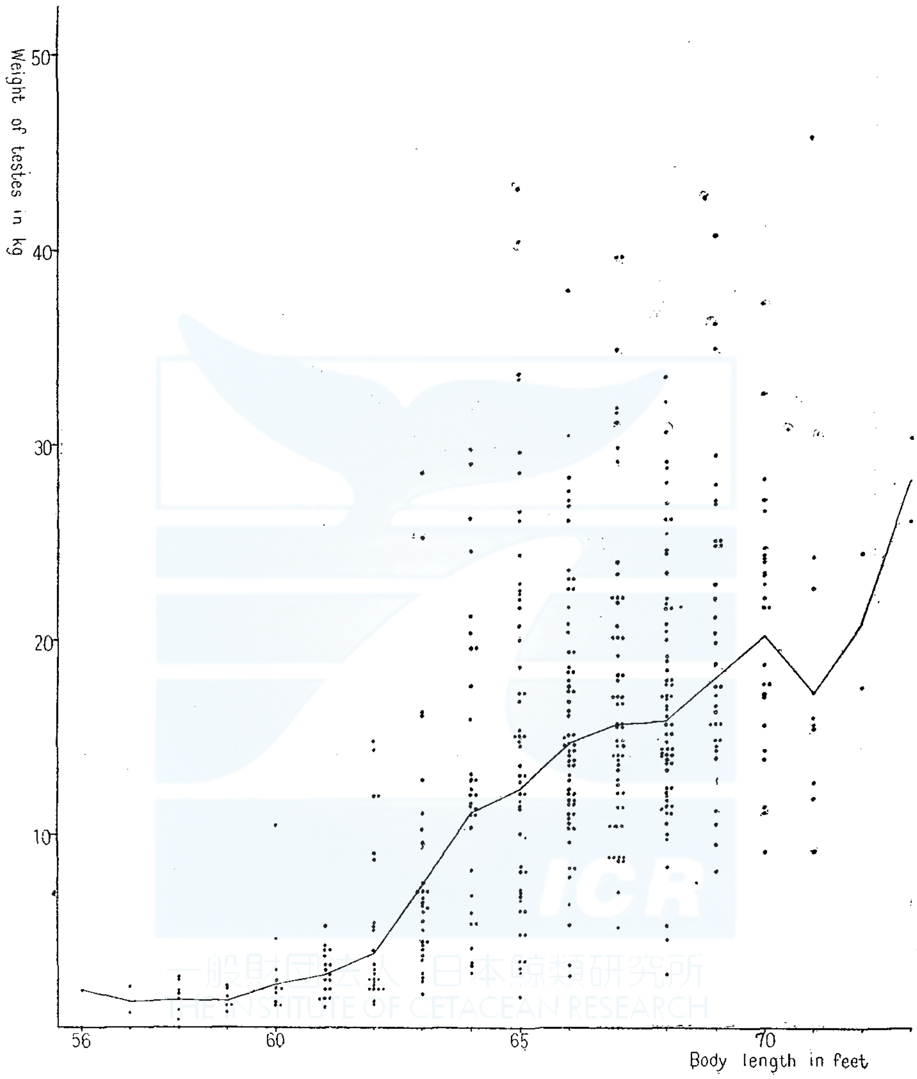
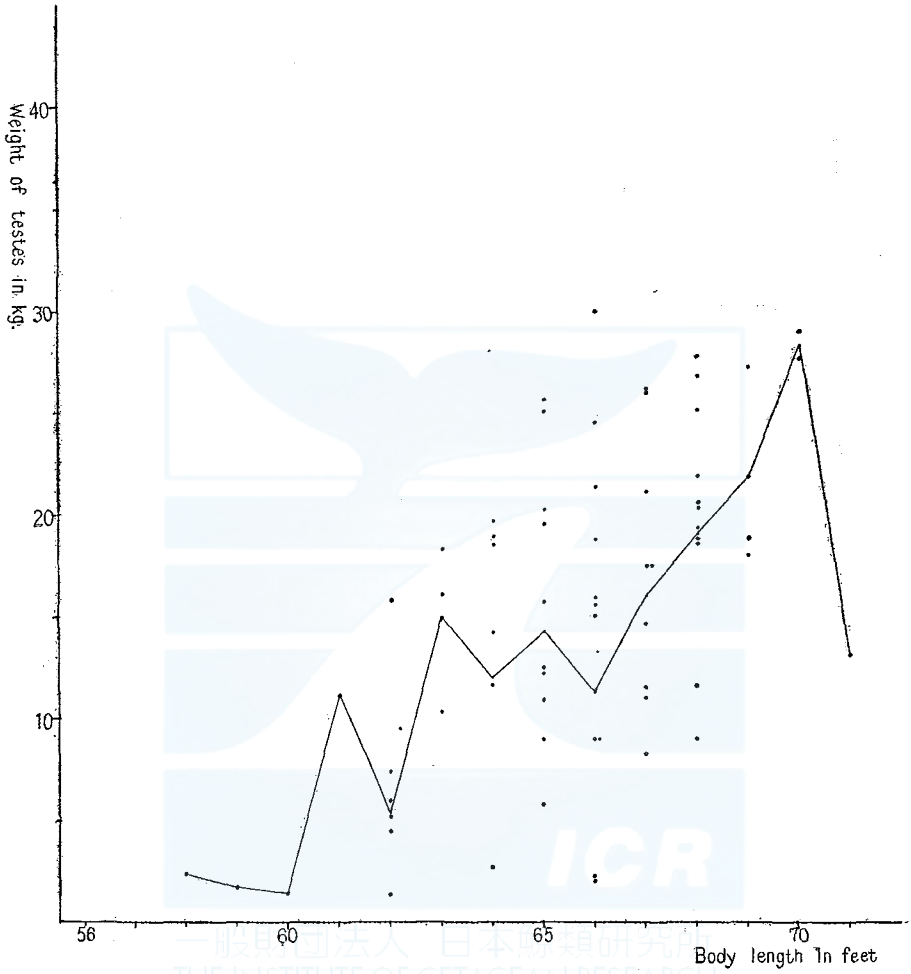


Fig. 22. Relation between weight of testes and body length of fin whales.

B. Section I

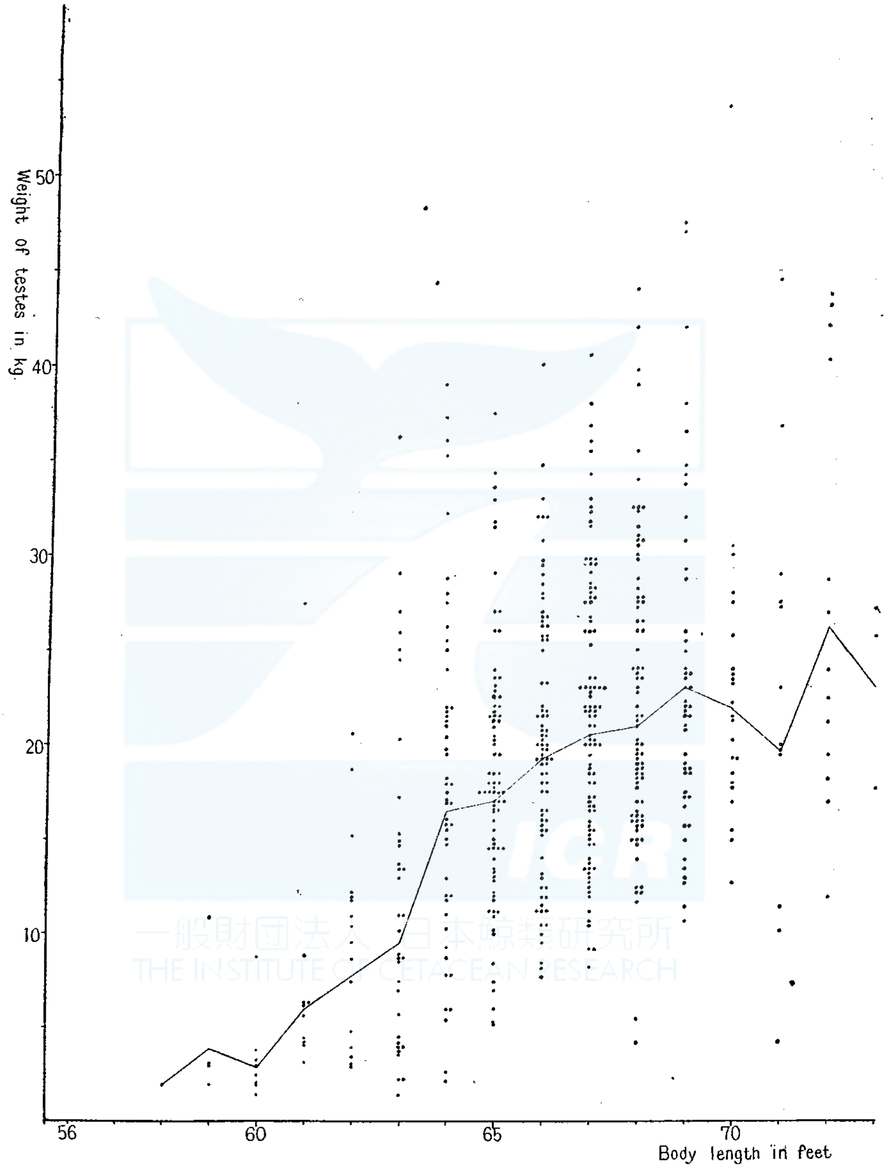

Weight of testes in kg
50
40
30
20
10
56
60
65
70
Body length in feet

C. Section II



Weight of testes in kg.
40
30
20
10
56
60
65
70
Body length in feet

D. Section III



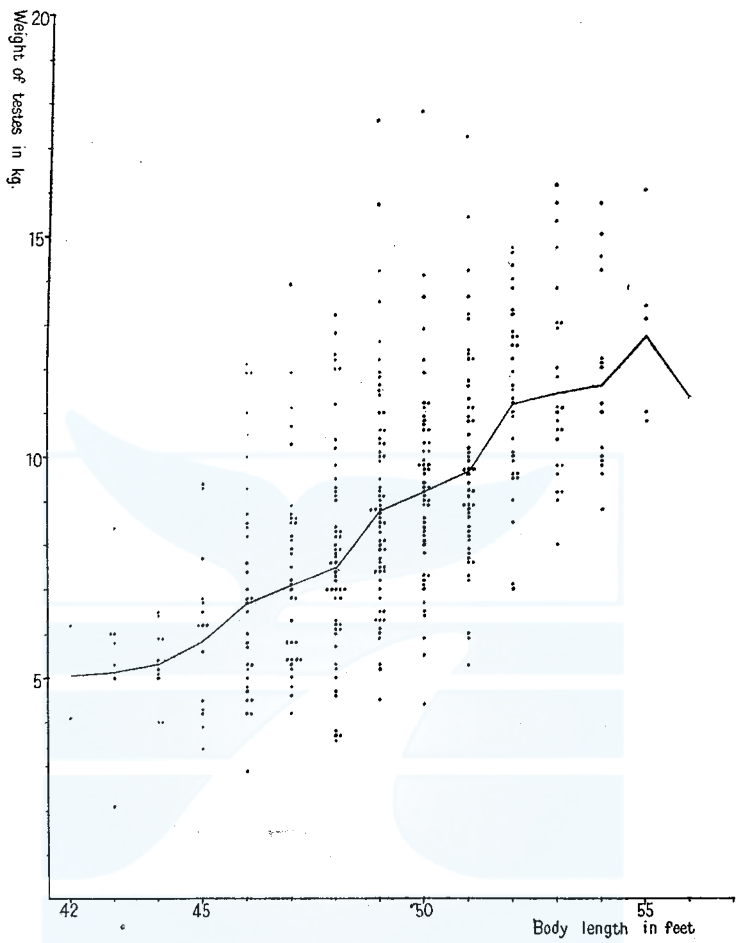


Fig. 23. Relation between weight of testes and body length of Sperm whales.

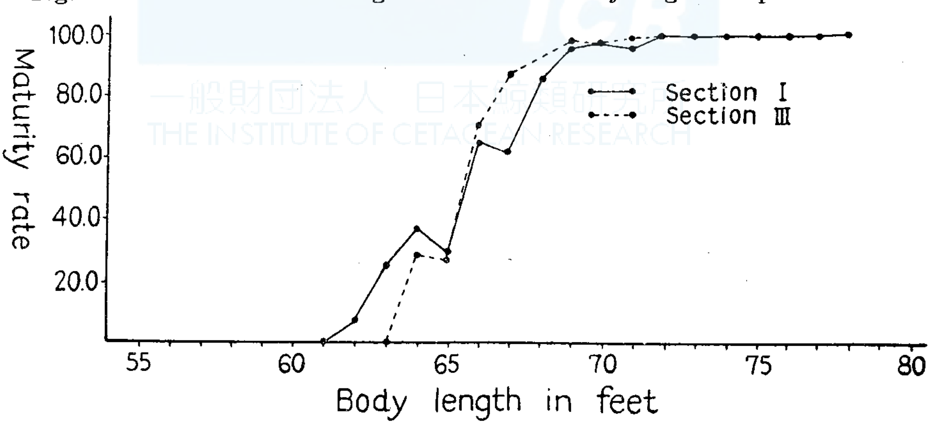


Fig. 24. Comparison of maturity ratio of fin whales between Section I and Section III.

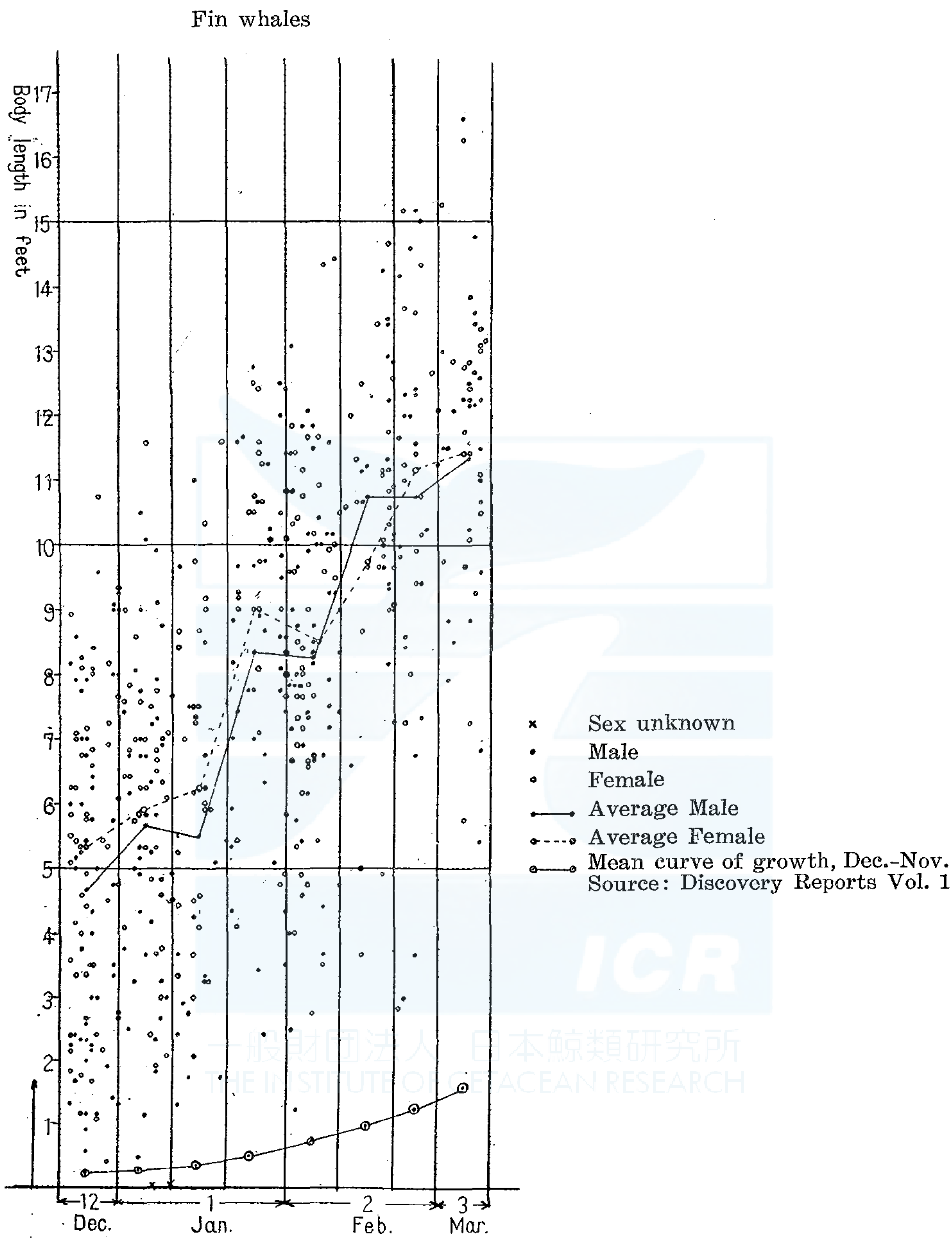
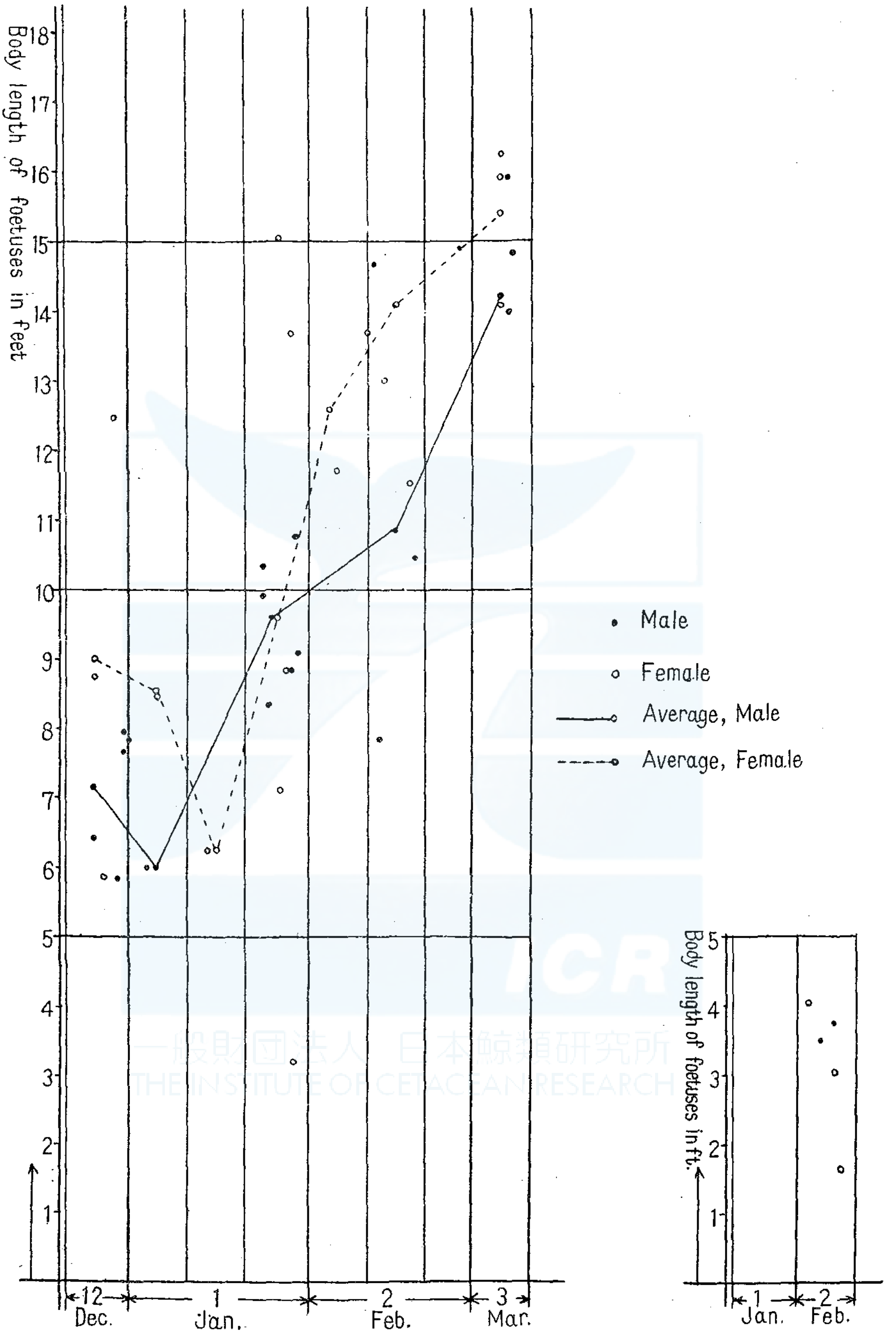


Fig. 25. Growth curve of foetuses.

Blue whales



Body length of foetuses in feet
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
12
Dec.
1
Jan.
2
Feb.
3
Mar.
Male
Female
Average, Male
Average, Female
Body length of foetuses in ft.
5
4
3
2
1
1
Jan.
2
Feb.

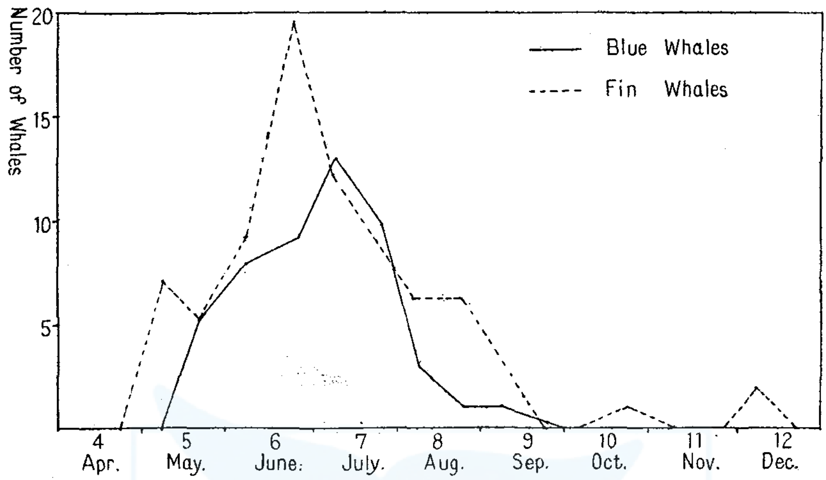


Fig. 26. Curve of frequency of pairing (Source: Discovery Reports Vol. 1)

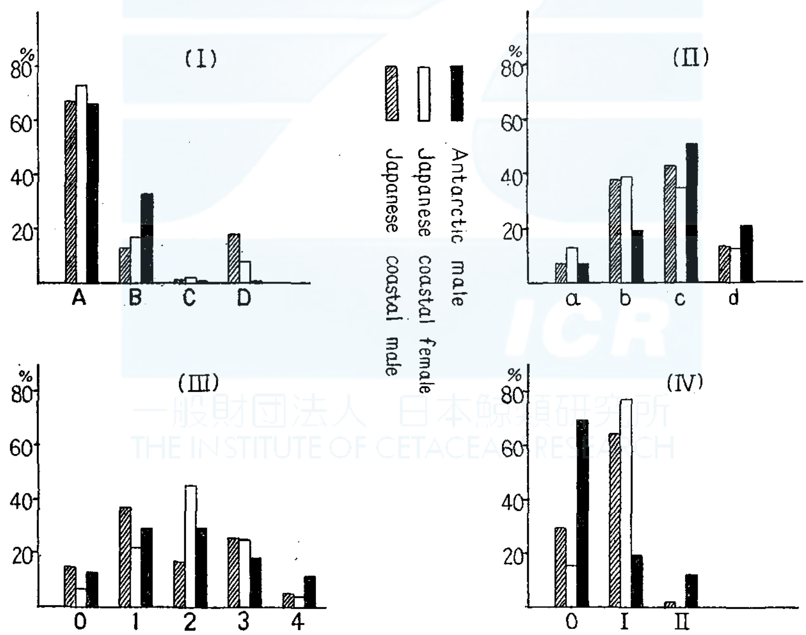


Fig. 27. Frequencies of body colour of sperm whales.

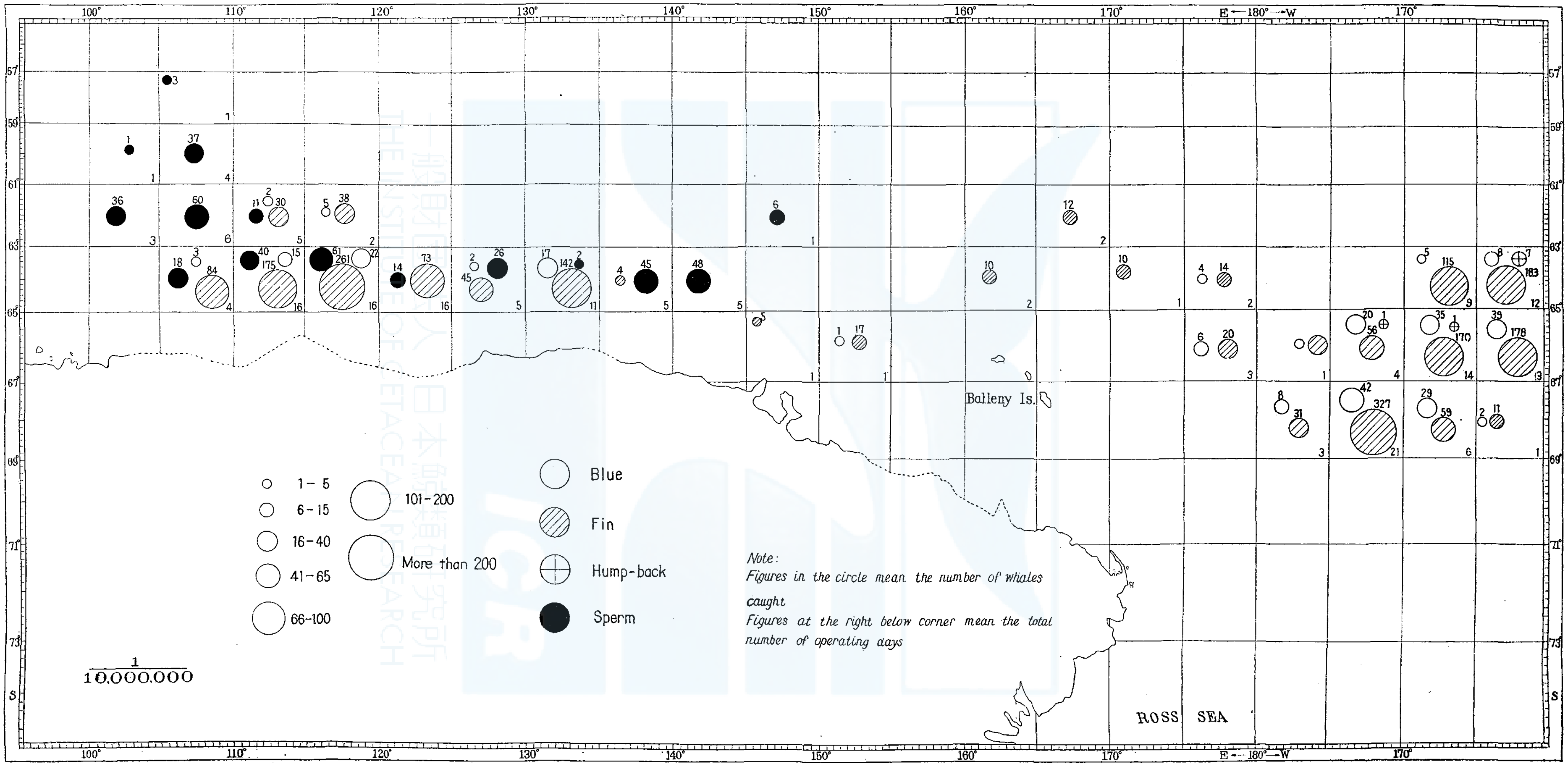


Fig. 28. Locality of whales caught by Japanese Fleets, 1950/51.

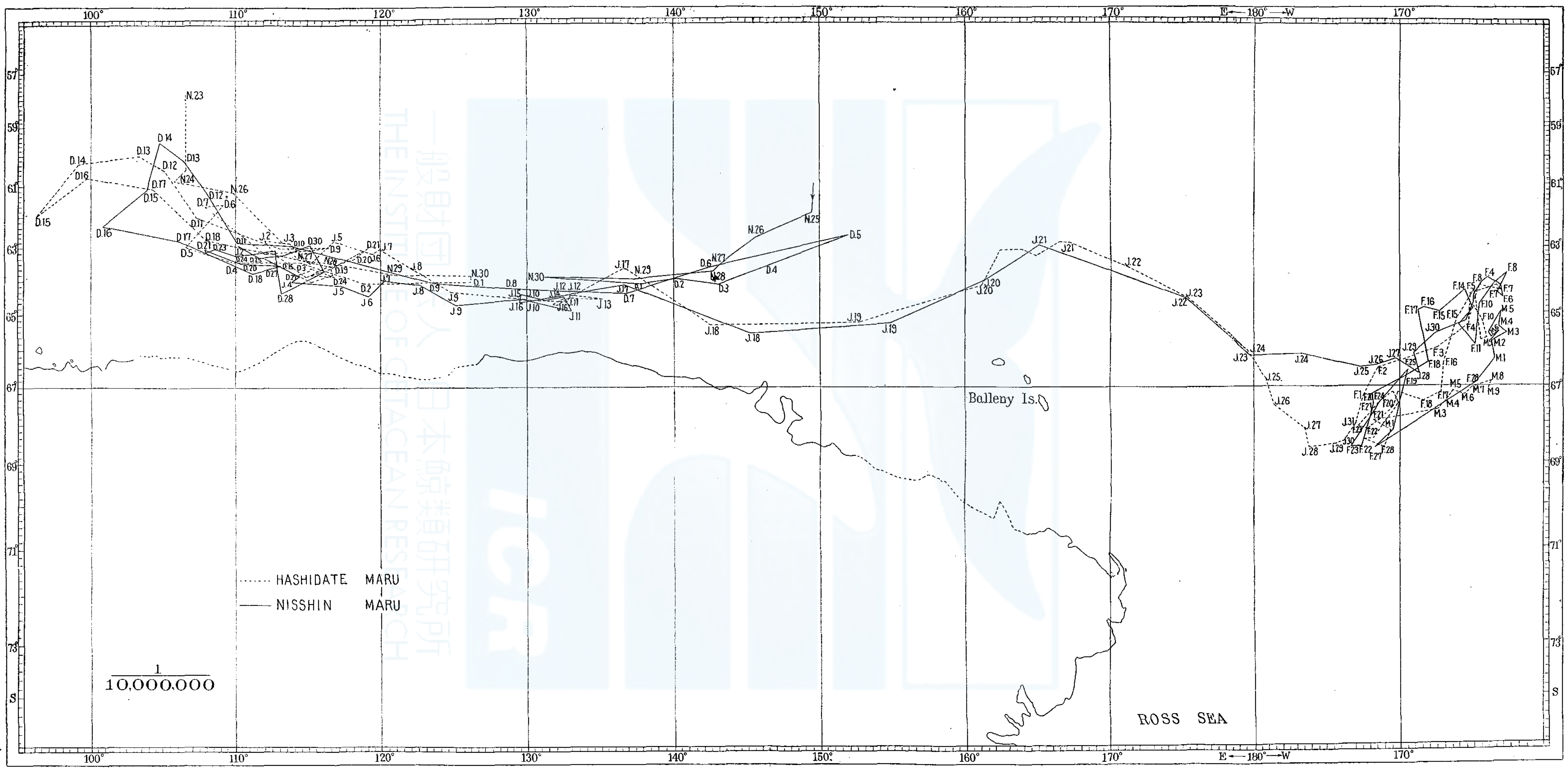


Fig. 29. Movement of Japanese Fleets, 1950/51.

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