FIN WHALE SUBPOPULATIONS IN THE ANTARCTIC WHALING AREAS II, III AND IV

KAZUO FUJINO

Investigation on identifying breeding populations of wild-life is not only of significance as the first step of the stock assessment for management of the commercially exploited animals in fisheries, but also itself provides the biological bases for the physiological and the ecological studies and for the population genetics. For this purpose, marking investigations which were initiated by the 'Discovery Committee' in 1932 have been succeeded by the National Institute of Oceanography, United Kingdom. This program has been continued under a scheme for the international co-operation since 1953 (Clark & Brown, 1957). Bi-lateral investigations under the immunogenetical concepts were commenced in 1960/61 season (Fujino, 1962).

Reviewing knowledges obtained so far in relation to identification of stocks, major results of marking investigations for the Antarctic fin whales reported by Brown (1954 a, 1954 b, 1962 a and 1962 b) can be summarized as follows. 1) There distribute one or more populations in each area of the Antarctic whaling grounds. 2) Different stocks from separate breeding areas mingle in the feeding grounds each other. 3) The majority do not disperse more than 50° east or west of the positions of marking.

Basing upon the blood typing investigation which was undertaken in the 1960/61 Antarctic whaling season for the first time, Fujino (1962) states that there distribute at least two populations of fin whales which have different incidences of Ju blood types each other in area III and that this support the items 1) and 2) of the results of marking investigations stated above.

When the migratory ranges of different populations overlap each other, situation of problems concerned becomes to be much more complicated. After summarizing results of blood typing study obtained during three seasons from 1960/61 to 1962/63 and of marking investigations undertaken since 1932/33 season, the present paper deals with problems in 1) identifying breeding subpopulations, 2) migratory ranges and rates of intermingling of different populations in the feeding grounds of the Antarctic, and 3) some problems in physiology and in ecology relating to the differences of population.

The author acknowledges co-operation in collecting and transporting blood specimens of inspectors, biologists, and officers and crews of the whaling factory-ships. Staffs of the Kyokuyo Hogei Company kindly offered some detailed logs on their whaling operations. The author would like to express his sincere thanks in using the precious materials which were compiled from a series of publications of Mr. S. G. Brown, National Institute of Oceanography, United Kingdom. Sincere thanks also due to Dr. H. Omura, Director of the Whales Research

Institute who organized extensive collection of bloods, Dr. E. Matsunaga at the National Institute of Genetics and Dr. Y. Nose at the University of Tokyo who gave to the author valuable suggestions and advices.

BLOOD TYPING INVESTIGATIONS

Relative incidences of hereditary characteristics, of which the phenotypes reveal polymorphism, are of worth as genetic marker for identifying isolated breeding populations. Blood type antigen is generally inherited in simple way, so that it is understood to be one of the most useful characters for such analysis. In the present investigation, Ju blood type system was utilized similarly to that in the previous paper (Fujino, 1962)

Materials and Methods

Whale bloods Bloods spout out from the cut at the tip of snout or in the palate or remaining in the heart were collected into 50 ml. plastic bottles. In 1960/61 season, the fresh samples were used for examination which was made on board Kyokuyo-maru no. 2. In 1961/62 and 1962/63 seasons, the samples were collected by inspectors boading on Japanese seven whaling factory ships, and were successively kept frozen until the examination was undertaken at the laboratory of the Whales Research Institute, Tokyo. As shown in Fig. 1, localities, where blood specimens were taken, cover areas II, III and IV, including lower latitudinal portion of area III of north of 50° south. Number of whales examined and their percentages against the catch in each year was shown in Table 1. Approximately 6000 fin whales were

TABLE 1. NUMBER OF BLOOD SAMPLES EXAMINED IN THE THREE SEASONS DURING FROM 1960/61 TO 1962/63

Season	No. of samples examined*	No. of fin whales taken by Japanese fleets	Remarks
1960/61	1,266 (14.2%)	8,912	Tested for fresh samples+
1961/62	2,188 (18.5%)	11,861	Tested for preserved samples (Cushing et al., 1959)++
1962/63	2,483 (23.7%)	10,475	
Sum	5.937 (19.0%)	31,248	

* Samples, from which no cells were recovered, are excluded. In addition 21 and 41 whales were examined in 1961/62 and 1962/63 respectively, but no information was given. Numbers of hemolysed samples are 244 and 240 in the seasons 1961/62 and 1962/63 respectively. Figures in parentheses show percentages of samples examined against total catch.

\+ Examination was made on board Kyokuyo-maru no. 2 only.

++ Collected by inspectors and biologists boarding on Japanese seven whaling fleets.

examined during the three seasons, and this corresponds 19.0 per cent of the total number of this species taken by Japanese fleets in these periods.

Reagents After being diluted and absorbed, were used the following serums which were prepared by immunizing fowls or rabbits intraveneously with Ju1 type or Ju2-positive type erythrocytes of fin whales.

Anti-Ju1 immune fowl serums nos. 47 and 70
Anti-Ju2 immune rabbit serum no. 34
Anti-$Ju2_1$ immune rabbit serum no. 61
Anti-$Ju2_5$ immune rabbit serum no. 65

A part of each serum of no. 47 and no. 34, being prepared by injecting the erythrocytes of the north Pacific fin whales, had been used in the previous investigations (Fujino, 1960 & 1962). Serums nos. 61, 65 and 70 were prepared by immunizing with erythrocytes of the Antarctic fin whales which were taken in 1961/62 season and were successively stored by glycerol-freezing (Cushing et al., 1959).

Testing methods Test-tube method and slide-glass method were used for blood typing tests. To treat the large numbers of specimens taken in the 1961/62 and 1962/63 seasons efficiently, were made the following procedures. At first, all samples obtained during one whaling season were tested by 1 : 10 diluted anti-Ju2 no. 34 or 1 : 10 diluted anti-$Ju2_5$ no. 65 serums which were in advance sufficiently absorbed with Ju1 cells. After being classified into Ju1 and Ju2-positive groups by these tests, the samples of the latter group were subdivided into sub-specificities of Ju2 antigen complex, and were successively identified as heterozygous or homozygous types.

Reagents for subtyping five specificities in Ju2 antigen complex were prepared by absorbing nos. 34 and 61 serums with various subtypes of erythrocytes. A part of these absorbed reagents, being used for testing 1961/62 samples, were kept frozen for about one year to be used for 1962/63 samples.

Classification and Genetics of Ju Blood Groups

In the previous paper, Fujino (1962) states that bloods of the Antarctic fin whales can be classified into three major types of Ju1 homozygote, Ju1·2 heterozygote, and Ju2 homozygote similarly to those of this species in the North Pacific

TABLE 2. FIN WHALE JU BLOOD TYPES CLASSIFIED BY SIX KINDS OF ANTISERA*

Specificity of reagents**	*Ju1 homozygote***	*Ju1·2 heterozygotes***					*Ju2 homozygotes***				
	1***	$1\cdot2_1$	$1\cdot2_2$	$1\cdot2_3$	$1\cdot2_4$	$1\cdot2_5$***	2_1	2_2	2_3	2_4	2_5***
Anti-Ju1	+	+	+	+	+	+	−	−	−	−	−
Anti-$Ju2_5$	−	+	+	+	+	+	+	+	+	+	+
Anti-$Ju2_4$	−	+	+	+	+	−	+	+	+	+	−
Anti-$Ju2_3$	−	+	+	+	−	−	+	+	+	−	−
Anti-$Ju2_2$	−	+	+	−	−	−	+	+	−	−	−
Anti-$Ju2_1$	−	+	−	−	−	−	+	−	−	−	−

* Cited from Fujino (1963b).
** Major three types.
*** Eleven types subdivided by five specificities of Ju2 antigen complex.

by agglutination with the anti-Ju1 and the anti-Ju2 reagents, including three subtypic specificities in each group of the latter two. Large scale collection of frozen samples in 1961/62 season made it possible to make further detailed analysis by

repeated tests, and led to subdivide Ju2 antigen complex into five specificities. Then the blood types of this species amount to eleven kinds in all as shown in Table 2.

Table 3 shows differential partial agglutinin titres between immune serums nos. 65 and 61 after being absorbed with various types of erythrocytes. Anti-$Ju2_5$ no. 65 serum absorbed with Ju1 type erythrocytes agglutinates $Ju1 \cdot 2_1$ type cells up to dilution 1 : 320 and $Ju1 \cdot 2_5$ type cells up to 1 : 40, and the relative highest dilution against these two different subtypes of cells is only 8 : 1. On the other hand, anti-$Ju2_1$ no. 61 serum absorbed with Ju1 type cells agglutinate $Ju1 \cdot 2_1$ cells up

TABLE 3. AGGLUTININ TITRES AGAINST SUBTYPIC PARTIAL SPECIFICITIES IN DIFFERENT IMMUNE SERUMS

a) Anti-fin $Ju2_5$ serum (No. 65)

cells of no.	type	unabsorbed 10	20	40	80	160	320	abs. by Ju1 cells (2K 270) 10	20	40	80	160	320	abs. by $Ju1 \cdot 2_5$ cells (3K 70) 5	10	20
2K 270	Ju1	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
3K 70	$Ju1 \cdot 2_5$	++	++	++	+	−	−	++	++	+	−	−	−	−	−	−
3K 148	$Ju1 \cdot 2_4$	++	++	++	++	+	−	++	++	++	+	−	−	−	−	−
3K 83	$Ju1 \cdot 2_3$	++	++	++	++	++	+	++	++	++	+	−	−	−	−	−
3K 127	$Ju1 \cdot 2_2$	++	++	++	++	++	+	++	++	++	++	+	−	−	−	−
3K 12	$Ju1 \cdot 2_1$	++	++	++	++	++	++	++	++	++	++	++	+	−	−	−

b) Anti-fin $Ju2_1$ serum (No. 61)

cells of no.	type	unabsorbed 10	20	40	80	160	320	abs. by Ju1 cells (2K 270) 2	5	10	20	40	80	160	abs. by $Ju1 \cdot 2_2$ cells (3K 127) 10	20	40···1280	2560
2K 270	Ju1	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	− ···	−	−
3K 70	$Ju1 \cdot 2_5$	++	+	−	−	−	−	++	+	−	−	−	−	−	−	−	− ···	−	−
3K 148	$Ju1 \cdot 2_4$	++	++	+	−	−	−	++	++	+	−	−	−	−	−	−	− ···	−	−
3K 83	$Ju1 \cdot 2_3$	++	++	++	+	−	−	++	++	++	+	−	−	−	−	−	− ···	−	−
3K 127	$Ju1 \cdot 2_2$	++	++	++	++	++	+	++	++	++	++	+	+	−	−	−	− ···	−	−
3K 12	$Ju1 \cdot 2_1$	++	++	++	++	++	++	++	++	++	++	++	++	++*	++	++	++ ···	++	+

* Positively agglutinated up to dilution 1 : 2560.

to dilution 1 : 2560 and $Ju1 \cdot 2_5$ cells up to 1 : 5, and the relative titre reveals marked difference. According to these observations, it was noticed that degree of dilution of the latter serum (no. 61) should be carefully adjusted to avoid mistyping $Ju2_5$ or $Ju2_4$ specificities of cells into Ju2-negative types.

As regards the allelic system of Ju blood groups of the Antarctic fin whales, Fujino (1962) states that no significant difference was seen in the relative incidences of the major three blood types between the observed and the calculated figures expected from two equal allelic system. Table 5 shows the observed and the calculated (parenthesized) figures of frequency of occurrence of the major three types for each population which are expected from the allelic system noted above. Both these figures are well consistent each other, and this might support the hypothesis proposed.

Relative Incidences of Blood Types and Stock Identification

Existence of local subpopulations as shown by geographical non-random distribution of blood types In 1960/61 season localities, where blood typing investigation was made, cover mostly the southern part of 50° south of area III ranging from 0° to 70° east (Fujino, 1962). In the successive two seasons, further informations were added for this area, and the investigations were extended to the lower-latitudinal portion of area III of north of 50° south, eastern portion of area II, and western portion of area IV (Fig. 1). Table 4 shows the summary of relative incidences of the major three blood types for different localities obtained during the successive three seasons. 'Lower latitude' of area III in this table correspond the portion north of 50° south ranging from 20° to 50° east. Most samples (83.3 per cent) of area II were obtained from a sector ranging from 0° to 10° west. It can be seen from this table that percentage incidences of Ju2-positives (sum of Ju1·2 heterozygote and Ju2

TABLE 4. NON-RANDOM GEOGRAPHICAL DISTRIBUTION OF JU MAJOR BLOOD TYPE INCIDENCES IN THE AREAS II, III AND IV*

Major blood types	Area II***	Area III		Area IV	Sum
		High. latitude	Low. latitude**		
Ju1	692	3,323	889	704	5,608
Ju1·2	48	194	33	32	307
Ju2	4	16	1	1	22
Sum	744	3,533	923	737	5,937
% of Ju2-positives	7.0	5.9	3.7	4.5	5.5

* Summarized data obtained during from 1960/61 to 1962/63.

** North of 50°S, 20°E to 50°E.

*** 620 samples out of these were taken from a sector of 0° to 10° W.

homozygote) reveal the geographical cline in order of area II>southern part of 50° south of area III>area IV>northern part of 50° south of area III. This fact suggests that the fin whales which distribute in these areas do not belong to one homogeneous stock, but rather consist of at least two or more populations that have differential incidences of the blood types each other.

As noted in the previous paper, percentage incidence of Ju2-positive types reveals generally to be low figure of approximately 2 percent in the southern part of 50° south of area III, representing that of a population of which the major stock distributes in area III. Though previously being called as the aboriginal population in area III, this may be more appropriately named as the West Indian population. Superimposed upon the usual daily frequency of occurrence, sharp upward fluctuations in the take of Ju2-positive whales in the south-western portion of area III occurred in an intermittent series of days, and the upper limit of Ju2-positive incidence was estimated from the daily incidences as a constant figure of approximately 30 per cent. These whales were interpreted to represent a part of the Atlantic population which migrates eastwards in the previous paper by basing upon knowledges of marking returns (Brown, 1954). Figures of Ju2-positive incidences

of 30.7 per cent for the Atlantic population in Table 5 were drawn by summarizing data of days when incidence of Ju2-positive types jumped up markedly as noted above. In the west portion of area IV, Ju2-positive incidence reveals nearly the same figure as that of the West Indian population, but upwards fluctuations were observed in some days. Although these are not so marked as those in the case of mingling with the Atlantic population, this fact show that another population, which has some higher incidence of Ju2-positive types than that of the West Indian population and may be named as the East Indian population, distributes in this area. There can be seen some inconsistency in the estimates of the incidence of Ju2-positives between the results of both years in 1961/62 and 1962/63, which might

TABLE 5. FREQUENCIES OF OCCURRENCE OF JU MAJOR BLOOD TYPES IN EACH PURE POPULATION*

Major blood types	Atlantic population	Lower latitudinal population	West Indian population	East Indian population		
				1961/62	1962/63	Sum
Ju1	278 (276.2)	41 (41.8)	913 (910.9)	370	86	456 (456.2)
Ju1·2	109 (114.2)	19 (17.4)	21 (23.9)	13	6	19 (18.6)
Ju2	15 (11.6)	1 (1.8)	1 (0.2)	0	0	0 (0.2)
Sum	402	61	935	383	92	475
% of Ju2-positives	30.7	32.8	2.4	(3.4)	(6.5)	4.0

Remark, Figures in parenthesis show those expected from hypothetical major two equal allelic system.

* Summarized from data of days when whales belonging to each pure population were postulated to be taken in the seasons during from 1960/61 to 1962/63.

be derived from errors in summarizing the data, because they were taken from the localities where two different populations mingle each other. Actual figure for this population might be about 4.0 per cent of average for both seasons or higher. Precise estimation for this figure could be made by extending the investigation to the eastern portion of area IV where pure East Indian population may distribute.

In the lower latitude of area III also daily incidence of Ju2-positive types jumped up significantly in an intermittent series of days against the lower percentages of the backgrounds of the West Indian population. Ju2 incidence being summarized from data of these days is more than 30 percent which is shown as the figure for the ' Lower latitudinal population ' in Table 5. The Ju2-positive types incidence is close to that of the Atlantic population noted above, but these two groups of whales can be distinguished by the differential Ju2 subtypic incidences.

As shown in Table 6, relative incidences of $Ju2_1$ antigen among total Ju2-positives which can be definitely distinguished by its specificity and the strongest reactivity with reagents from other Ju2-positives are 33.7 per cent (35 out of all 104 Ju2 positives) for the Atlantic population and 50 percent (21 out of all 42 Ju2-positives) for the Lower latitudinal population, the difference can be accepted to be significant. In Table 6, it is also characteristic that no $Ju2_1$ antigen has been found in the East Indian population. Thus it became to be obvious that the four different breeding populations distribute in areas II, III and IV. These might support the results of marking investigations described by Brown (1954 a, 1954 b, 1962 a, &

Fig. 1. Geographical areas II, III and IV where blood typing investigations were undertaken in the three seasons during from 1960/61 to 1962/63. Four circles summarize data given in the text and Table 5. Black sectors correspond relative incidences of total Ju2-positive whales for the Atlantic, the aboriginals of areas III (West Indian), the aboriginals of area IV (East Indian), and the Lower latitudinal populations. Small circles, triangular spots, and crosses show the localities (noon positions of factory-ships) where whales belonging to the Atlantic, the Lower latitudinal, and the East Indian populations were taken respectively.

1962 b), however, in which no remark was given for the existence of the Lower latitudinal population.

TABLE 6. DIFFERENTIAL FREQUENCIES OF OCCURRENCE OF SUBTYPES IN JU2 ANTIGEN COMPLEX CONFIRMING EXISTENCE OF DIFFERENT POPULATIONS*

Ju2-subtypic specificities	Atlantic population	Lower latitudinal** population	West Indian** population	East Indian** population
$Ju2_1$	35	21	19	0
$Ju2_2$	21	2	11	9
$Ju2_3$	9	7	9	5
$Ju2_4$	16	3	10	6
$Ju2_5$	23	9	21	4
Sum	104	42	70	24

* Summarized results of 1961/62 and 1962/63 seasons.

** Including data of days when whales belonging to both of different populations were taken.

Direct evidences showing overlaps of migratory ranges of different populations in feeding grounds Basing upon results of marking investigations, Brown (1962 a) states that in the Antarctic feeding grounds, whales from two separate breeding areas are to be found in

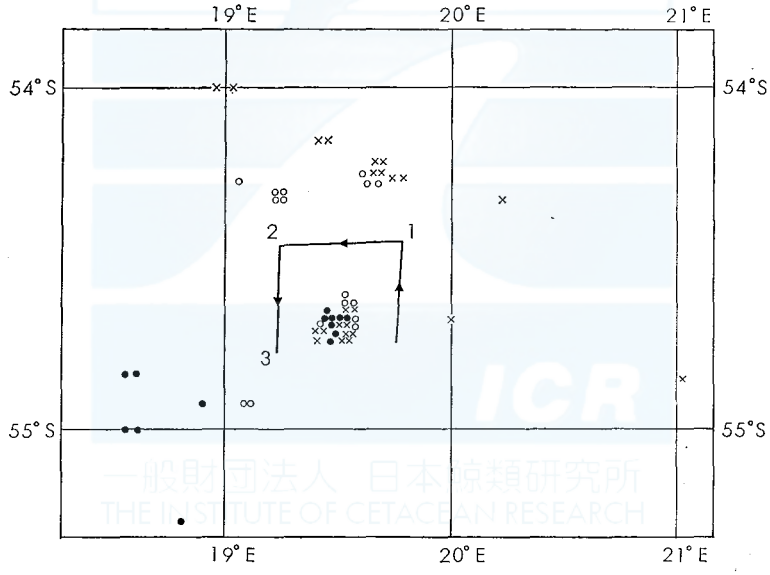

Fig. 2. Evidences showing mixing of the different populations in the feeding grounds as revealed by data of days when whales belonging to both the Atlantic and the West Indian populations were taken in a day. Population differences of whales grouped by three localities where whale carcasses were gathered, drawn by basing upon the logs in Feb. 23, 1961. Concrete lines with arrow show wakes of factory-ship. Three points with Nos. 1, 2 and 3 mean localities where factory ship gathered whales taken. Crosses, open and closed circles mean localities of capture of individual whales belonging to groups Nos. 1 (West Indian population), 2 and 3 (Atlantic population) respectively. (See Table 7).

association in summer, and Fujino (1962) also states that a portion of the Atlantic population from area II migrates to area III and mingles with the population there by basing on the immunogenetical study. No description, however, on direct evidences for overlaping of migratory ranges of different populations has been given. Detailed informations in some days when the whales belonging to both the Atlantic and the West Indian populations were taken might serve as the direct proof for intermingling of different populations in feeding grounds. Fig. 2 shows localities of capture for 54 whales taken by one fleet in Feb. 23, 1961. Carcasses of these whales were successively gathered at three points nos. 1, 2 and 3 on the wake of the factory-ship shown by concrete lines. Some remarks on these three groups of whales are given in Table 7. Number of Ju2-positive whales were

TABLE 7. LOG OF FEB. 23, 1961 SHOWING OVERLAPS OF MIGRATORY RANGES OF DIFFERENT BREEDING POPULATIONS

Locality no., gathering whales captured	Time of capture	No. of whales captured	Blood type incidences		Populations' belonging to		Group-composition			
			Ju1	Ju2-postives						
1	6.55–12.45*	24	23	1	West Indian population	male	13	imm. 2 mat. 11		
						female	11	imm. 1 mat. 10	preg. 4 ovul. 0** rest. 6	
2	10.35–20.20	16	10	6	Atlantic population	male	16	imm. 2 mat. 14		
3	13.00–20.00	14	8	6	Atlantic population	female	14	imm. 2 mat. 12	preg. 8 ovul. 2** rest. 2	

* Three out of these captured later (at 14, 16 and 18 o'clock).

** Having ovaries with functional corpora lutea but lacking fetus.

only one out of 24 examined for point no. 1 group (crosses), six out of 16 for no. 2 group (open circles), and six out of 14 for no. 3 (closed circles). These suggest that most whales of point no. 1 group belong to the West Indian population and whales of points nos. 2 and 3 to the Atlantic population. The later part in the range of time of capture for point no. 1 group overlaps with the early part in that of no. 2 group. These facts show that groups of whales belonging to different populations migrate to approximately same locality in the feeding grounds with slight time lags. This is a first example that can be regarded as the direct evidence for overlaping of migratory ranges of different populations. Further detailed evidences are shown in Figs. 3 and 4. Fig. 3 shows locations of capture of individual whales taken in Dec. 12, 1962 as grouped by catcher-boats. Ju2-positive type incidences were calculated as 27.8 per cent by testing 18 samples (5 Ju2-positives) for 26 whales taken by catcher-boats A, B, C, and D, and as 0.0 percent for 11 whales (all Ju1) by catchers E, F, G, and H. The former was regarded as those belonging to the Atlantic population (closed circles) and the latter to the West Indian population (open circles). Another chart basing on the log in Dec. 14, 1962

is drawn in Fig. 4 under the similar expression as previous one. There can be seen characteristic differences between these two figures as follows. Whales belonging to the Atlantic population were found and captured in the locations southern side of that for the West Indian population in the case of Fig. 3, but in Fig. 4 whales belonging to the Atlantic population were found at the both sides of locations for the West Indian population. While, the blood type incidence is maintained to be indigenous for each population, so that the observations described above can be

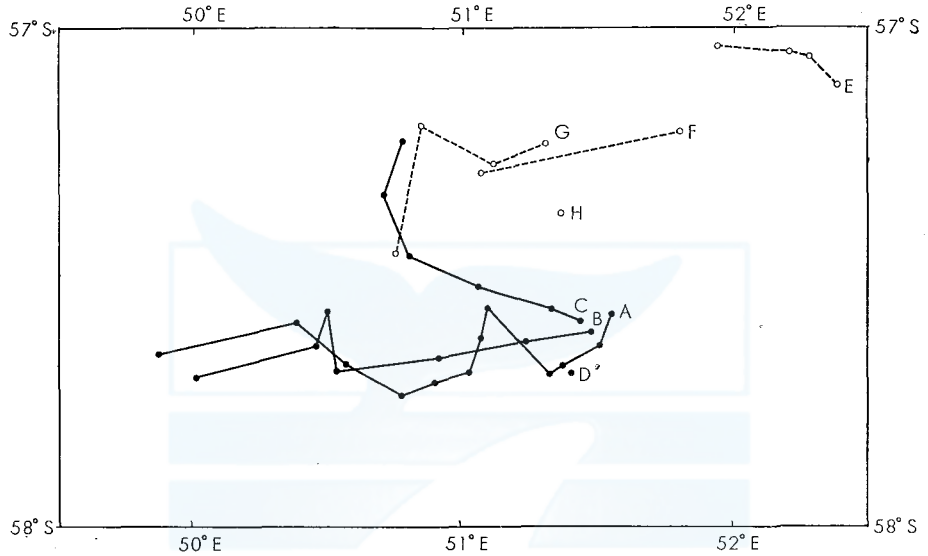

Fig. 3. Evidences showing mixing of the different populations in the feeding grounds as revealed by data of days when whales belonging to both the Atlantic and the West Indian populations were taken in a day. Population differences of whales grouped by catcher-boats, drawn by basing on the logs in Dec. 12, 1962, when 29 whales examined out of 37 those taken. Open and closed circles show the localities where individual whales belonging to the Atlantic and the West Indian populations respectively were taken. These were successively captured from 1st catch with alphabet letter showing different catcher-boats after chasing. All of 11 whales taken by catcher-boats E, F, G & H were typed as Ju 1. 13 and 5 taken by catcher-boats A, B, C & D were typed as Ju 1 and Ju 2-positives respectively.

interpreted as the most reliable evidences showing that despite of such interminglings in feeding grounds the different populations have been completely isolated each other in breeding from generation to generation.

Boundary of migratory ranges and rate of intermingling Table 8 shows frequency distribution of number of whales daily examined and of Ju2-positive whales occurred in those. In this table, scattered diagrams are divided into four zones by the three boundary lines corresponding to Ju2-positive incidences of 50, 33 and 20 percent respectively, and majority in zones more than 20 percent were identified as those representing whales which belong to the Atlantic or the Lower latitudinal populations. As stated already the former and the latter can be geographically distinguished each other. In Figure 1, are plotted noon positions of factory ships in some

intermittent days when the whales belonging to the Atlantic, the Lower latitudinal and the East Indian populations were taken during the three seasons. Small closed circles show those for the Atlantic population. According to this figure, this group of whales were taken on a band of ground which runs southeast direction from the whaling ground lying south of South Africa and extends to about 60° east, but did not occur in the catch from the northeastern side of this band in spite of fairly larger number of whales taken. This might suggest that the above-noted band might be interpreted as the east boundary of migratory range in feeding ground for the Atlantic population. According to the results obtained in the three seasons,

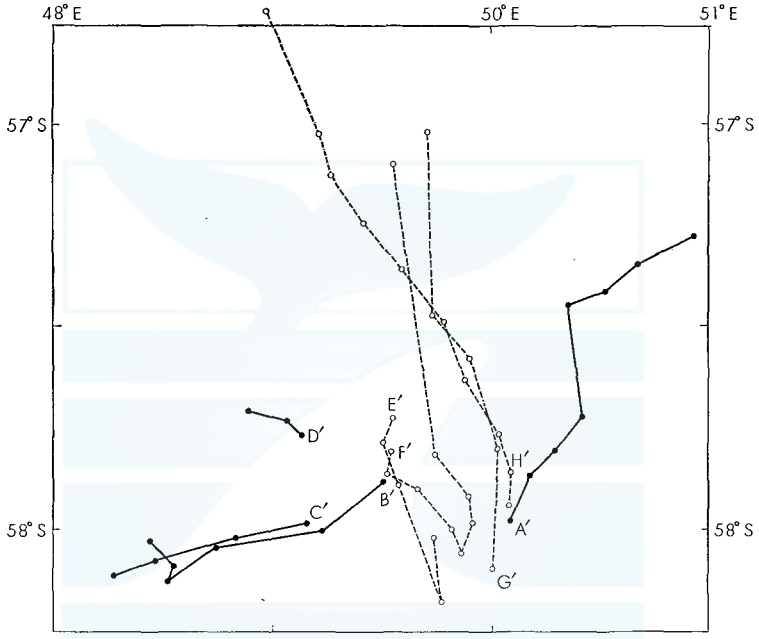

Fig. 4. Evidences showing mixing of the different populations in the feeding grounds as revealed by data of days when whales belonging to both the Atlantic and the West Indian populations were taken in a day. Population differences of whales also grouped by catcher-boats, drawn by basing on the logs of Dec. 14, 1962, when 45 whales were examined out of 50 those taken. 29 whales taken by E′, F′, G′ & H′ were typed as Ju1, so that, were regarded as those belonging to the West Indian population. 10 and 6 taken by A′, B′, C′ & D′ were typed as Ju1 and Ju2-positives and were recognized as those belonging to the Atlantic population.

in the east half of area III corresponding to the east end of the migratory range for this population distribute tolerable number of the Atlantic population in December at the beginning of whaling season, but hardly occur after January. Some exceptional records taking this group of whales in this ground, however, were made for each one day in mid- and late-March respectively in 1961/62 season. Ju2-positive type incidences in the east half of area II reveal fairly lower figures than those of pure Atlantic population, so that it can be thought that the West Indian population

TABLE 8. FREQUENCY DISTRIBUTION OF DAILY OCCURRENCE OF JU2-POSITIVE BLOOD TYPES

No. of whales daily examined	No. of Ju2-positives															Sum
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	79	4														83
2	95	4														99
3	71	5		1												77
4	65	9														74
5	59	6	2													67
6	52	6	2	1												61
7	48	5	1	3												57
8	26	4	2	1												33
9	32	1	2	1	2											38
10	26	4	3	1												34
11	20	2	1													23
12	13	4	1													18
13	8	3	2													13
14	2	3		1												6
15	5	1														6
16	8	2	2													12
17	11	2														13
18	1	1	1	1	1	1	1									7
19		1														1
20	3	1		1						1						6
21	2	1	1													4
22	4	1	1													6
23	1		1													2
24	2	1	1		1											5
25	1															1
26	1	2														3
27	1															1
28			1		1		1									3
29						1										1
30																0
31	1		1													2
32			1				1				1					3
33	1					1										2
34		1			1											2
35	2	2							1							5
36				1	1											2
37	1															1
38			1													1
39																0
40		1													1	2
41																0
42				1											1	2
43																0
44	1															1
45							1									1
46																0
47																0
48			1													1
49																0
53														1		1
Sum	642	77	28	13	7	3	4	0	1	1	1	0	0	1	2	780

100%
50%
33%
20%

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

disperses to this ground beyond the boundary between areas II and III. To make clear the west boundary of migratory range of the West Indian population should be extended the investigation hereafter to the western portion of area II. A part of the West Indian population disperses eastwards to the west portion of area IV and mingles with the East Indian population there. On the other hand, little numbers of East Indian population seem to distribute to area III, but inter-relation in boundaries of migratory ranges between West Indian population and East Indian population have not been made so clear as that between Atlantic population and West Indian population. As shown in Fig. 1 by small triangles, noon positions of factory ships in some intermittent days, when the whales of Lower latitudinal population were taken, mostly occur in the portion, of north of 50° south of area III, ranging from 30° east to 50° east.

Rates of intermingling of different populations can be estimated from blood type incidences for each pure population in Table 5 and those in various geographical grounds in Table 4. In area II (east half) and the higher latitudinal portion of area III (south of 50° south), 16 and 12 per cent of the samples respectively consist of the whales of Atlantic population and the residues are of West Indian population. As fairly large number of samples were tested for area III, the latter might be accepted to nearly represent actual figure of the population there for the periods of investigation. Rate of mingling of the Lower latitudinal population in the northern portion of 50° south of area III does not reach up more than 4.3 percent. As precise estimation of blood type incidences for the East Indian population has not been made, rate of mingling in the areas concerned should be postponed in future.

INTERMINGLING OF DIFFERENT POPULATIONS AS REVEALED BY RATE OF EMIGRATION OF WHALES MARKED

To obtain informations on migrations and on movements of whales, materials of marking investigations have been dealt in various ways (Brown, 1954 a, 1954 b, 1962 a, & 1962 b). For the purpose of identifying stocks, it might be more effective to analyse materials as geographical groups than to treat those as signs of movement of individual whales. Accordingly, in this paragraph will be mostly discussed the inter-areal relationships especially the problems of intermingling between areas II and III where different populations distribute respectively as clarified by blood typing investigations already. Calculations of rate of emigration between different areas will be made by basing on a method which was applied by the present author to the north Pacific fin whale stocks previously (Fujino, 1960).

Materials used Number of fin whales taken and number of fin whales marked and successively recaptured in the Antarctic during from 1932/33 to 1961/62 seasons were used to calculation. Table 12 shows the former figures which were cited from the International Whaling Statistics, and Tables 9, 10 and 11 show the latter figures which were arranged by compiling materials described in a series of Brown's reports (1954, '56, '57, '58, '59, '61 b & c). Number of whales taken and those recaptured at land stations in South Africa are not included in the figures of these tables. Fig.

5 shows the summarized results of marking investigations which were made in areas II, III and IV during the pre-war and the post-war seasons.

Methods and practice of calculations 1) Major points of calculations of rates of emigration between different areas follow those which were described in the previous paper (Fujino, 1960). For this purpose population sizes of the two different populations I and II of which the main stocks distribute in the grounds A and B neighbouring each other were expressed as N_1 and N_2, and their relative abundances in the grounds A and B as *a* and *1-a* for the population I and as *1-b* and *b* for the population II respectively as shown in Fig. 6 diagramatically. To make estimation of figures *a* and *b* averaging for the periods of investigations is the purpose of the present calculations.

2) In the light of length of lapse of years from marking to recapture and

TABLE 9. NUMBER OF FIN WHALES EFFECTIVELY MARKED IN AREA II AND SUCCESSIVELY RECAPTURED, 1932/33 TO 1961/62.

In the seasons of:

Recaptured in the area II,

	No. of whales effectively marked	Marked in the season:	'32/3	'35/6	'40/1	'45/6	'50/1	'55/6	'60/1	Sum
Pre-war marks	200	1932/3	3 2 — — 1 — — — — — — — 1 — — — — — — — — — — — — —							7
	—	'33/4	— —							—
	299	'34/5		8 2 3 6 1 — 1 — — — 1 2 — 1 2 2 — — 2 1 — — — — 1 — —						34
	572	'35/6		1 — 4 2 2 — — — — — — 1 2 — — — — — — — — 1 2 — — —						15
	652	'36/7		4 18 8 1 3 1 1 — 1 2 — 2 2 2 2 — 1 1 — 2 — 1 3 — — 1						56
	447	'37/8		13 5[a] 4 4[b] —[c] 1 —[d] 1 2 1 — 1 —[e] 3 —[f] 1 4 2 — — 2 2 3 1 1						51
	34	'38/9		— — — — — — — — — 1 — — 1 — — — — — — — — — — —						2
Post-war marks	—	1945/6~52/3					— —			—
	114	'53/4					4 2 5 — — 2 1 1			15
	41	'54/5					— 1 1 — — — — 1			3
	84	'55/6					1 10 1 — 1 — 1			14
	23	'56/7					2[g] — — — —			2
	4	'57/8					—[h] —[i] —[j] — 1			1
	—	'58/9					— — —[k] —[l]			—
	—	'59/60					— — —			—
	ND*	'60/1					— —			—
	ND*	'61/2					—			—
	Sum		3 2 8 3 8 41 16 7 8 1 2 — 3 7 2 6 5 4 6 — 4 10 4 9 14 6 6 6 2 7							200

Recaptured in the area III,

		'32/3	'35/6	'40/1	'45/6	'50/1	'55/6	'60/1	Sum
Pre-war marks	1932/3	— — — 1 —							1
	'33/4	— —							—
	'34/5	— — — 1 —							1
	'35/6	— 1 — — — — — — — — — 1 — — — — — — — — — — — — —							2
	'36/7	— —							—
	'37/8	— — — — — — — — — — 2 — — — — — — — — — — — — —							2
	'38/9	— —							—
Post-war marks	1945/6~52/3					— —			—
	'53/4					— —			1
	'54/5					— —			1
	'55/6					— —			2
	'56/7					— —			—
	'57/8					— —			—
	'58/9					— —			—
	'59/60					— —			—
	'60/1					— —			—
	'61/2					— —			—
	Sum		2 1		2 1		2 1	1	10

Remarks, * ND: No available data. In addition, one, two and three whales moved from area I were recaptured in c) d) f) g) h) j) l), in b) e) i) and in a) respectively Also excluding one and two whales moved from lower latitudes and recaptured from j) and k) respectively. One, three and two whales which were marked in 1935/36, 1936/37 and 1937/38 respectively with no information on area recaptured are excluded. Each one whale marked in area II in 1934/35, 1936/37, 1937/38 and 1938/39 was recaptured in area I, and three marked in area II in 1953/4 also recaptured in area I.

TABLE 10. NUMBER OF FIN WHALES EFFECTIVELY MARKED IN AREA III AND SUCCESSIVELY RECAPTURED, 1932/33 TO 1961/62

In the seasons of:

Recaptured in the area II,

	No. of whales effectively marked	Marked in the season:	1934/5	'40/1	'45/6	'50/1	'55/6	'60/1	Sum
Pre-war marks	463	1934/5	— — — — — 2 — — — — — — — 1 — — — — 1 — — — — — — 1 —						5
	285	'35/6	— — — 1 — — — — — — — 1 — — — — — — — — — — — 1 —						3
	395	'36/7	— —						—
	11	'37/8	— —						—
	15	'38/9	— —						—
Post-war marks	4	1945/6~52/3					— —		—
	7	'53/4					— —		—
	194	'54/5					— — 3 2 — 3 1 —		9
	102	'55/6					1 1 1 — — 1 —		4
	2	'56/7					— — — — — — —		—
	50	'57/8					— — — — — — —		—
	35	'58/9					1 — — —		1
	3	'59/60					— — — —		—
	ND*	'60/1					— — —		—
	ND*	'61/2					— —		—
	Sum		— — — — 1 2 — — — — — — 1 1 — — — — 1 — 1 4 3 1 3 4 —						22

Recaptured in the area III,

		1934/5	'40/1	'45/6	'50/1	'55/6	'60/1	Sum
Pre-war marks	1934/5	12 2 — — 1 1 — — — — 2 — 1 3 1 — 2 2 1 3 1 — 1 — 2 1 2						38a)
	'35/6	1 1 3 2 3 — — — — — — 1 1 — 1 — 3 3 2 — 2 — 2 1 1 1 1						29
	'36/7	1 — — — — — — — — — — — — — — — 1 1 1 — — — 1 — — —						5
	'37/8	— —						—
	'38/9	— —						—
Post-war marks	1945/6~52/3					— —		—
	'53/4					— —		—
	'54/5					5 1 2 2 1 1 5 6		23b)
	'55/6					1 — 2 1 2 4 1		11
	'56/7					— — — — —		—
	'57/8					2 — 1 1 —		4c)
	'58/9					3 — 2 1		6
	'59/60					— — —		—
	'60/1					8 11		19
	'61/2					9		9
	Sum	12 3 2 3 3 4 — — — — 2 1 2 3 2 — 5 6 4 9 5 2 9 7 7 22 31						144

Recaptured in the area IV,

		1934/5	'40/1	'45/6	'50/1	'55/6	'60/1	Sum
Pre-war marks	1934/5	— — 2 — — — — — — — — — — — — — — — — 1 1 5 — —						9
	'35/6	— — — — — — — — — — — — — — — — 1 — — — — — — 1						2
	'36/7	— —						—
	'37/8	— —						—
	'38/9	— —						—
Post-war marks	1945/6~52/3					— —		—
	'53/4					— —		—
	'54/5					— —		—
	'55/6					1 — — — 4 — —		5
	'56/7					— — — — — — —		—
	'57/8					— 3 — — —		3
	'58/9					1 3 — —		4
	'59/60					— — — —		—
	'60/1					2 1		3
	'61/2					1		1
	Sum	— — 2 — — — — — — — — — — — — — — — 1 — 1 — 1 5 12 2 3						27

Remarks, *ND: No available data. In addition, in lower latitude (land stations) were recaptured one in a) in 1937, two and one in b) in 1959 and 1962 respectively and two in c) in 1959. One whale moved from area I is excluded. One, two and two whales, which were marked in 1957/58, 1954/55 and 1961/62 respectively, with no information for area but recaptured, are also excluded.

complexity of the factors concerned, calculations were made with priority given to the pre-war marks and with a prospect obtaining complementary knowledges from the post-war marks.

3) Pre-war marks shot in area II in the five seasons of 1932/33, 1934/35, 1935/36, 1936/37 and 1937/38 and those in area III in the three seasons of 1934/35, 1935/36 and 1936/37 were used. Marks shot in area II in 1938/39 and those in area III in 1937/38 and 1938/39 were excluded from calculations because of few numbers of the whales effectively marked.

TABLE 11. NUMBER OF FIN WHALES EFFECTIVELY MARKED IN AREA IV AND SUCCESSIVELY RECAPTURED, 1932/33 TO 1961/62

In the seasons of:

Recaptured in the area III,

	No. of whales effectively marked	Marked in the season:	1934/5	'40/1	'45/6	'50/1	'55/6	'60/1	Sum
Pre-war marks	19	1934/5	—	—	—	—	—	—	—
	48	'35/6	—	—	—	—	—	—	—
	58	'36/7	—	—	1	—	—	—	1
	—	'37/8	—	—	—	—	—	—	—
	—	'38/9	—	—	—	—	—	—	—
Post-war marks	1	1953/4				—	—	—	—
	—	'54/5				—	—	—	—
	14	'55/6					1	—	1
	2	'56/7					—	—	—
	8	'57/8					—	—	—
	15	'58/9					—	—	—
	59	'59/60					2	—	2
	ND*	'60/1						—	—
	ND*	'61/2						—	—
	Sum		—	—	1	—	1	2	4

Recaptured in the area IV,

Pre-war marks	1934/5	1	1	—	—	1	1	—	4
	'35/6	1	1	—	—	—	1	—	3
	'36/7	—	—	—	—	—	—	—	—
	'37/8	—	—	—	—	—	—	—	—
	'38/9	—	—	—	—	—	—	—	—
Post-war marks	1953/4			—	—	—	—	—	—
	'54/5			—	—	—	—	—	—
	'55/6				—	—	1	—	1
	'56/7				—	—	—	—	—
	'57/8				1	—a)	—b)	—	1
	'58/9					—c)	1	—	1
	'59/60					9	1	2	12
	'60/1					3	—	—	3
	'61/2						—	—	—
	Sum	1	2	—	1	1	2	12	4	2	25

Remarks, *ND: No available data. In addition, were recaptured each one in a) and b) and three in c) which were marked in the area V. Three whales marked in 1959/60 but with no information on area recaptured are excluded. One whale marked in 1955/6 and moved to area V are also excluded.

4) Post-war marks shot in area II in the season of 1953/54, 1954/55 and 1955/56 and those in area III in the seasons of 1954/55 and 1955/56 were used.

5) As the numbers of whales effectively marked in area IV were small, calculations were not undertaken for these marks.

6) Number of whales taken and of those recaptured at land stations in South Georgia Islands were made together with those of the pelagic operations in area II for the calculation.

7) The following arrangements were made for various parameters necessary for calculations. a) As discussed in the previous paper (Fujino, 1960), errors in the estimates of rate of confirming (g) whales as 'Hit' among those effectively marked and of rate of recovery of marker (f) from whales actually recaptured do

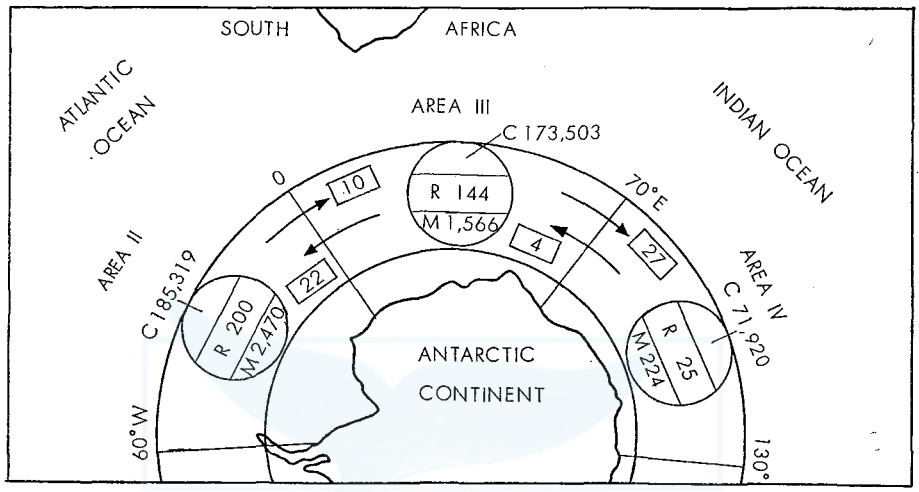

Fig. 5. Summarized results of emigration of marked fin whales between areas II, III and IV during from 1932/3 to 1961/2 seasons (compiled from reports by S. G. Brown). Figures in circles with alphabet letters C, R and M show summarized numbers of fin whales taken, of marked whales recaptured up to 1961/2 seasons and number of fin whales effectively marked respectively. Figures with arrow mean number of whales recaptured after moving to the different areas.

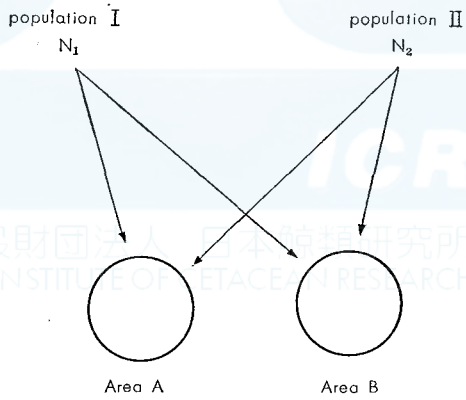

Fig. 6. Diagrammatic interrelationships between different two populations distributed in the neighbouring two areas as shown by movements of marked whales.

hardly effect upon final results of calculation for the rates of emigrations. Then no g- and f-corrections were made. Although materials have not been available, however, it could be assumed that there exist significant differences in the figures of f

between Japanese and the foreign fleets in relation to the methods of treating whale body especially whether or not utilize meats. Therefore the recoveries of pre-war marks in the seasons after 1960/61 when Japanese fleets commenced intensive operations in area III were not included. While, for calculation on the post-war marks, all recovery up to 1961/62 season was used because of avoiding reduction of number of data. b) Sufficient materials of age-composition, which can be used to estimate mortality rates for both pre-war and post-war seasons, are not available. It seems to be impossible, even if materials were available, to estimate precisely mortality rate for each year. Then figures 0.10 and 0.05 were arbitrarily used as annual rate of total mortality and annual rate of natural mortality respectively averaging for the whole periods of investigations involved. The latter figure was applied as annual mortality rate to five seasons from 1940/41 to 1944/45 for area III and to the

TABLE 12. NUMBER OF FIN WHALES TAKEN IN THE AREAS II, III AND IV DURING FROM 1933/34 TO 1961/62*

Area	1933/4	'34/5	'35/6	'36/7	'37/8	'38/9	'39/40	'40/1	'41/2	'42/3
S. Georgia	1,728	836	520	1,079	1,552	1,307	937	747	1,189	776
II	1,115	2,246	3,375	6,004	11,505	6,252	7,840	831	—	—
III	2,178	7,985	5,236	5,002	8,297	5,710	2,218	49	—	—
IV	2,177	1,368	548	2,285	6,610	5,540	574	—	—	—
Area	1943/4	'44/5	'45/6	'46/7	'47/8	'48/9	'49/50	'50/1	'51/2	'52/3
S. Georgia	632	987	1,456	1,670	2,142	1,922	1,999	1,982	2,007	1,670
II	529	679	4,901	4,655	6,136	4,995	7,150	5,081	5,977	4,551
III	—	—	2,800	4,382	6,483	6,457	5,117	4,133	7,122	11,364
IV	—	—	—	3,355	4,654	3,068	2,940	4,210	2,141	1,449
Area	1953/4	'54/5	'55/6	'56/7	'57/8	'58/9	'59/60	'60/1	'61/2	
S. Georgia	2,673	2,746	2,669	2,057	2,251	1,291	1,160	1,387	661	
II	7,653	4,963	6,619	10,697	5,211	4,298	4,920	5,223	6,650	
III	11,459	13,607	7,088	3,812	9,197	9,385	9,307	13,269	11,847	
IV	2,195	2,790	3,208	291	3,579	7,277	6,501	2,086	3,129	

* Cited from the International Whaling Statistics.

six seasons from 1940/41 to 1945/46 for area IV during the World War II. It was already discussed in the previous paper that these arrangements hardly influence upon the final results of calculations.

8) As lapse of years from marking to recapture for the Antarctic investigations is generally longer than that for the north Pacific, to obtain the mean value (r) from rate of recapture for each year of marking was made simple arithmetical averaging instead of that with weight expressed by formula 6 in the previous paper (Fujino, 1960, p.111).

9) According to the results of stock assessments on the Antarctic fin whale population (Fifteenth Annual Meeting of International Whaling Commission, June, 1963,), it is obvious that the stock of this species has not been in a stabilized state throughout pre-war and post-war seasons. For the convenience of calculation for the rate of emigration, however, number of survivors (C') of initial stocks at the time

of marking in the annual catches (C) in successive years were obtained by formula 12 in the previous paper (Fujino, 1960). It can be understood, even if such arrangements were made, from the definition of rate of emigration and formulae 5 and 6 in the previous paper that final results of calculation must be little biased from those to be obtained by considering annual stock size fluctuations which were demonstrated by the stock assessment.

Results of calculation and their interpretations Table 13 shows the results of calculations on the rates of emigration between areas II, III and IV. In this table figures are

TABLE 13. RATE OF EMIGRATION CALCULATED BY MARKING RETURNS FOR THE PRE-WAR AND THE POST-WAR MARKS[a)]

Rate of emigration	Pre-war marks*		Post-war marks
	A	B	
$r_2^2/r_2^2+r_3^2$	0.88 (0.88)[b)]	0.90	0.83
$r_3^2/r_2^2+r_3^2$	0.12 (0.12)	0.10	0.17
$r_3^3/r_3^3+r_2^3$	0.93	0.90	0.58
$r_2^3/r_3^3+r_2^3$	0.07	0.10	0.42
$r_3^3/r_3^3+r_4^3$	0.88 (0.88)[b)]	0.78	0.68 (0.77)[c)]
$r_4^3/r_3^3+r_4^3$	0.12 (0.12)	0.22	0.32 (0.23)
$r_2^3/r_2^3+r_3^3+r_4^3$	0.11 (0.10)[b)]	0.08	0.32 (0.35)[c)]
$r_3^3/r_2^3+r_3^3+r_4^3$	0.69 (0.61)	0.71	0.47 (0.50)
$r_4^3/r_2^3+r_3^3+r_4^3$	0.20 (0.29)	0.21	0.21 (0.15)

Remarks, Calculation was made for the two cases including (A) and excluding (B) recaptures in post-war seasons, 1945/46 through 1959/60. a) No calculation was made for recapture of whales marked in area IV. b), c) Figures in parenthesis correspond to those excluding higher rate of recovery for area II in 1940/41 and for area IV in 1959/60 respectively.

shown for both pre-war and post-war marks. The former those are further subdivided into two cases of A and B whether or not including the post-war recoveries respectively. Figures in parenthesis correspond those for the case excluding materials for the year when high rate of recovery was recognized. At first the results for pre-war marks will be discussed.

As regards inter-relations between areas II and III, rate of emigration from areas II to III, $r_3^2/r_2^2+r_3^2$, reveals figures of 0.10 and 0.12 for two cases A and B respectively, and that from areas III to II, $r_2^3/r_2^3+r_3^3$, 0.07 and 0.10 respectively. These results confirm the non-random distribution of whales in areas II and III, saying in other words, existence of the different populations, and show that approximately 10 percent of the Atlantic population contribute to the stock in area III and also approximately same percent of the West Indian population distribute to area II. Definite informations for relative stock size between the Atlantic and the West Indian populations have not been available. If both populations have comparable sizes of stocks, however, figures of the rate of emigration from areas II to III noted above correspond to the rate of intermingling of the Atlantic popula-

tion in area III which is close to that obtained from the blood typing investigations. The results may lead to obain following informations. Although in areas II and III distribute the different populations which migratory ranges overlap each other, the facts that both figures of rate of emigration reveal approximately 10 percent suggest that final surplus and deficit of the stock for each area are in consequence comparatively small. This might be important as a basic information to make stock assessment for each geographical area separately. Rate of emigration from areas III to IV, $r_4^3/r_4^3+r_3^3$, ranges from 0.12 to 0.22 which are bigger than those between areas II and III. Reasons that marked inconsistency was seen between figures for two cases A and B have not been made obvious.

Rates of emigration calculated from post-war marks reveal bigger figures than those from pre-war marks. Although no sufficient evidence has been given, the following probable reasons could be assumed to be concerned. Then it might be impossible to expect nothing more reference informations from the post-war marks at present. 1) In post-war seasons when marking investigations have been undertaken, the major whaling grounds in area III moved to the lower latitudes, so that whales of the Lower latitudinal population contribute to the catches in this area besides the West Indian population. 2) The Japanese fleets utilizing whale meats commenced their intensive operation in areas III and IV. 3) Scantiness of whales effectively marked might bring larger errors and some biases.

OTHER BIOLOGICAL CHARACTERISTICS RELATED TO DIFFERENCE OF STOCKS

As discussed in the previous paragraphs, it became to be obvious that in areas II, III and IV distribute at least four different fin whale populations. Some biological characteristics related to the difference of population will be described and discussed in this paragraph.

Differential Sizes of Group of Whales by Stock

As the numbers of samples daily collected by Kyokuyo-maru No. 2 in 1960/61 season and by Kyokuyo-maru Nos. 2 and 3 in 1962/63 season were generally large, majority of whales taken in these days can be identified as those of Atlantic population and of West Indian populations by basing on blood type incidences and localities of capture. In Table 14 are shown frequency distributions of ' number of whales observed ' for groups from which whales were taken according to four different classes of blood type incidences. In this table groups of whales, which Ju2-positive incidences show zero percent, were regarded as those of pure West Indian population, and those more than 11 percent as groups in which whales of Atlantic population mingle at fairly high percentages. Comparing these distributions between the two different stocks, in the former the classes less than 10 whales and more than 41 whales occupy 37 and 21 percent respectively on an average 29 whales, and in the latter those less than 10 whales only 5 percent and contrarily those more than 41

whales 44 percent on an average 48 whales. This result of observations suggests that size of group of whales migrating to the feeding grounds in the Antarctic is different by stocks each other. Although no available data has been obtained to

TABLE 14. FREQUENCY DISTRIBUTION OF NUMBER OF WHALES OBSERVED, SUGGESTING POSSIBLE DIFFERENTIAL SIZES OF SHOALS BY RACES IN THE FEEDING GROUNDS*

No. of whales observed	Percentage incidence of Ju2-positive types: 0		1 to 10		more than 11	
1- 5	4	*37%*	0	*0%*	1	*5%*
6-10	10		0		2	
11-20	8	*42*	2	*75*	14	*50*
21-40	8		7		14	
41-80	4	*21*	1	*25*	11	*45*
more than 81	4		2		14	
Sum	38		12		56	
Average no. of whales	29		42		48	

* Basing on the logs of catcher-boats.

discuss what other biological characteristics of the population correlates with this fact, this may bring some problems to the hypothetical basis on 'the geographical uniformity of distributing concentration of animals ' in stock assessments.

Natural Selection Related to Blood Types

Many discussions on natural selections related to blood types have been published in recent years from the view-points of Human Genetics and Anthropology. Although some informations concerning to relationships between blood types and fertility or age were noted already by the present author (1963b), additional evidences are described in this section.

Differential rates of pregnancy by blood types According to the results of the following observations, Fujino (1963a) describes for the first time that the fairly strong intra-uterine selection of Ju1•2 heterozygous fetuses might occur in whales in relation to the maternal-fetal incompatibility of blood types and states that incidences of the

TABLE 15. DIFFERENTIAL PERCENTAGE PREGNANCY BY BLOOD TYPES IN THE ATLANTIC FIN WHALE POPULATION

Blood types	1960/61	1961/62	Sum
Ju1 (P_1)	63.9 (36)	55.6 (18)	61.1 (54)
Ju2-positives (P_2)	78.9 (19)	75.0 (8)	77.8 (27)
P_1/P_2	0.81	0.74	0.78

Remark, Figures in parenthesis mean the number of mature females examined.

selection will closely relate to the frequency of occurrence of blood types of the population. The observations include that 1) rate of finding fetuses from mature females is lower in Ju1 type mothers than in Ju2-positive types those ; the differences are statistically significant and that 2) isoantibodies from Ju1 female donors reveal

hemolytic property and significant high titres were detected for the isoserums of Ju1 female donors from which fetus was not found in spite of having functional corpus luteum in their ovaries and congested uteruses. As shown in Table 15, observations in 1961/62 season confirm the results of differential apparent rate of pregnancy noted above.

Blood type and age Table 16 shows relative blood type incidences in connection with age classes which are expressed by number of laminae layers of ear-plug. It can be seen from this table that incidences of Ju2-positive types decline and contrarily those of Ju1 type ascend in accordance with increment of ages and that these trends are statistically significant. This observation suggests that relative viability between different blood types varies in relation to age classes. As reproducibility lastes to fairly older age classes in this species of whales, these facts can be assumed to play an important role in maintaining blood type gene frequencies in a population together with the differential rate of pregnancy noted already.

Relation between Intra-uterine Selection and Ovulating Cycle

Basing on knowledges in human genetics, Fujino (1963 b) noted that stages of the intra-uterine selection could be broadly divided into pre- and post-fertilization

TABLE 16. RELATIONSHIPS BETWEEN AGE AND BLOOD TYPES IN THE ATLANTIC POPULATION*

No. of laminae of ear-plug	Blood types**		Sum
	Ju1	Ju2-positives	
11-20	19 (55.9)	15 (44.1)	34
21-30	13 (72.2)	5 (27.8)	18
31-40	14 (82.4)	3 (17.6)	17
more than 41	14 (77.8)	4 (22.2)	18
Sum	60 (69.0)	27 (31.0)	87

Remark, * Sum of males and females, 1960/61 and 1961/62 seasons. Figures in parenthesis show relative incidences in percent.
** $X^2=4.98$, 7 d.f., $0.70>P>0.50$.

those which probably more intensive selective pressure plays in the former. If the differential rate of pregnancy shown in Table 15 is actually caused by in part descending of rate of fertilization in Ju1 type mother whales, it should lead to accelerate successive ovulations in the infertilized individuals. The frequencies of ovulation in a breeding period may be different by blood types of mother whales and also different on the average by races which have different incidences of blood types each other. In consequence it must reflect on geographical differences in accumulating rate of ovarian corpora as noted previously. Table 17 shows the comparison of accumulating rates of ovarian corpora per two laminae layers of ear-plug drawn by ovulation-lamination keys (Form D) which were submitted to the Joint Meeting of the Special Committee of Three and the Ad Hoc Scientific Committee of the International Whaling Commission held in Seattle, December, 1962.

Figures for area II in this table were cited from those of Laws (1961). Marked geographical differences are seen in these figures by area. Materials, by which these figures were drawn, base on the observations for ovaries and ear-plugs made by the several biologists of the Whales Research Institute. Even if some individual errors are involved in readings, it can be said that the geographical differences are significant. Among the materials for area III of Table 17, readings for number of ovarian corpora were made by author himself who served as a biologist on board in 1960/61 season and those for ear-plug laminae by several staffs of the Institute. The results show fairly marked differences between west-half and east-half of area III. It was noted aready (Fujino, 1963 b) that types of frequency distribution of accumulated number of ovarian corpora at an age class expressed by ear-plug lamine are not always symmetrical, but are rather different by area. Geographical differences in accumulating rate and type of frequency distributions of ovarian corpora between west- and east-halves of area III seem to support the concept proposed already. Fig. 7 shows the analysis of frequency distribution for west-half of area III, which was presented in Fig. 2 in the previous paper (Fujino, 1963 b), by normal probability paper. This figure shows that the bimodal distribution for this area can be divided into two components which correspond 0.6 (83 percent) and 1.4 (17 percent) of average rates of accumulating corpora per two laminae of ear-plug respectively. According to Fujino (1963 a), possible relationships of rates

TABLE 17. ACCUMULATION RATE OF OVARIAN CORPORA OF THE FIN WHALES TAKEN FROM DIFFERENT AREAS OF THE ANTARCTIC*

Areas					
II	W·III**	E·III**	IV	V	VI and I
2.80~3.00	2.31	1.91	1.84	1.80	1.60

* Cited from Fujino (1963b).

** Temporarily divided into the two portions of west-half and east-half at 35 degrees east longitude.

of pregnancy between three blood types for the Atlantic population can be expressed as Ju1 ≦ Ju2 ≦ Ju1·2. Basing on the above-noted concept, relative rates of accumulating corpora will be arranged in a reverse order. Therefore it can be thought that one components showing higher accumulating rate (1.4) corresponds to Ju1 group of the Atlantic population and another component of lower rate (0.6) consists of Ju1·2 group of the Atlantic population and also of all kinds of Ju blood groups of the West Indian population. Although distribution corresponding to Ju2 homozygote group of the Atlantic population does not appear clearly as a component in Fig. 7 probably because of its low incidence (less than 2 percent), it might constitutes a component which may have an intermediate mean between above-noted two figures. According to Fujino (1963a), intra-uterine selection related to Ju blood type incompatibility little occurs in the West Indian population because of the low incidences of Ju2-positive types, so that it can be assumed that type of distribution is nearly a symmetrical one at least regarding to Ju blood type system. By these concepts, relative incidences of the two components of the distribution in Fig. 7 well consistent with those calculated from rate of intermingling of both po-

pulations for this geographical area (Fujino, 1962). Thus the quantitative relationships will become to be obvious for a pure population between three factors of the relative incidences of blood types, the incidences of intra-uterine selection due to blood type incompatibility, and the rate of accumulating ovarian corpora in females. These observations and analyses could offer some reliable informations

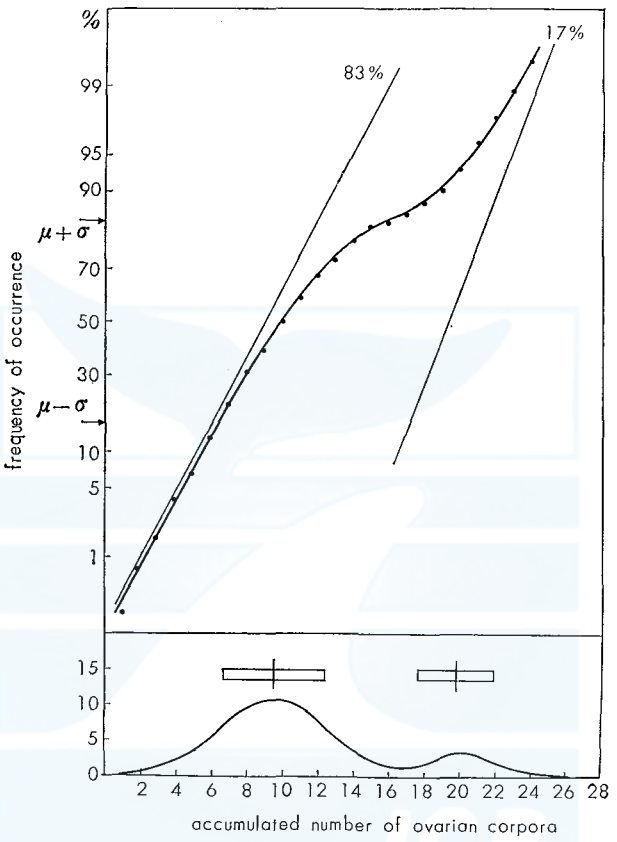

Fig. 7. Analysis of the bimodal frequency distribution of the accumulated number of ovarian corpora at an age class of 28 laminae of ear-plug for the west-half of area III by normal probability paper, showing that this consists of more than one component distributions (see text).

to an essential problems in ovulating cycles especially to the details in frequency of ovulation, if simultaneous examinations could be precisely made in blood typing, in counting accumulated number of ovarian corpora and in reading number of ear-plug laminae for each individual females belonging to a pure population such as the Atlantic one.

SUMMARY

This paper deals with problems of identification of breeding populations, migratory

range of each population and some other biological discussions on the fin whales taken from the Antarctic whaling areas II, III and IV by means of the blood typing and the marking investigations. These base upon the materials of approximately six thousands blood specimens collected by Japanese expeditions during three successive seasons from 1960/61 to 1962/63 and those of recoveries of the pre-war and the post-war marks compiled from data described in a series of Brown's publications. It was emphasized throughout this paper that the facts of overlap of migratory ranges of different populations made situations of problems in population study much more complex. The observations and the discussions in the present paper will be summarized as follows.

1. By the agglutination reactions with immune rabbits' and fowls' serums, erythrocytes of the Antarctic fin whales were classified into Ju major three groups, i.e., Ju1 homozygote, Ju1·2 heterozygote and Ju2 homozygote, in which the latter two were further divided into five subtypic specificities, amounting to eleven kinds in all.

2. Results of X^2 tests for the relative incidences of the major three blood groups for the pure population might support that the hypothetical major two equal allelic system is involved as noted in the previous paper (Fujino, 1962).

3. Non-random geographical distributions of Ju blood type incidences show that four different breeding populations distribute in the Antarctic whaling areas II, III and IV which can be named as the Atlantic, the West Indian, the East Indian, and the Lower latitudinal populations. Most of these results might support the Brown's findings (1962 b), but no specific description has been made for the Lower latitudinal population. Ju2-positive types incidences were estimated as 30.7, 2.4, 4.0 and 32.8 percent for each pure population noted above. As regards the latter two figures, more precise estimates will be expected after conducting further investigations. The Atlantic and the Lower latitudinal populations can be distinguished by the differential Ju2 subtypic incidences.

4. Direct evidences showing overlaps of the migratory ranges of the different populations in feeding grounds were described by basing on the logs of days when whales belonging to both the Atlantic and the West Indian populations were taken in the same day.

5. Boundaries of migratory ranges for some populations in the feeding grounds were estimated. Whales of the Atlantic population disperse eastwards to area III, and the east side boundary of migratory range of this population was became to be obvious. On the other hand whales of the West Indian population migrate westwards to the east-half of area II, but its west side boundary has not been made clear. Then migratory ranges of these two population overlap in the feeding grounds each other. Major migratory range of the Lower latitudinal population was estimated from locations of capture to cover a part of area III ranging from 30° east to 50° east, north of 51° south.

6. Rate of intermingling of the Atlantic population in the whales taken from area III was calculated to be 14 percent or less by blood typing data. According to the rates of emigration calculated from marking returns, approximate 10 percent

of the Atlantic population disperse to area III, and about 10 percent of the West Indian population disperse to area II. If the both sizes of the two populations are comparable each other, these figures show the rate of intermingle for each area as they are.

7. Significant difference was seen in the frequency distribution of number of whales observed from catcher-boats between the Atlantic and the West Indian populations in feeding grounds. Although it has not been made obvious what factors correlate with this result of observation, it may bring some problems to the hypothetical basis for the ' geographical uniformity in distributing concentration of animals ' in stock assessment.

8. Additional data were obtained to confirm the occurrence of intra-uterine selection due to maternal-fetal incompatibility of Ju blood types for the Atlantic fin whale population which was reported already (Fujino, 1963 a).

9. Relative incidences of Ju blood types were compared by different age classes for the samples taken from the Atlantic population. Slight but significant difference was seen between different blood groups in the relative viability in accordance with increment of ages. This fact was interpreted to play an important role in maintaining the blood type gene frequencies in a population together with the fact noted as item 8 in this summary.

10. Possible influences of the intra-uterine selection to the ovulating cycles were discussed, and the mechanisms that might bring geographical differences in the rate of accumulating ovarian corpora were considered as a prelimiary meaning.

REFERENCES

BROWN, S.G. (1954a). Dispersal in blue and fin whales. *Discovery Rept.*, 26 : 355–84.

BROWN, S.G. (1954b). The movements of fin and blue whales in Antarctic Waters. *Norsk Hvalfangst-Tid.*, 43 (6) : 301–9.

BROWN, S.G. (1956). Whale marks recently recovered. *Norsk Hvalfangst-Tid.*, 45(12) : 661–4.

BROWN, S.G. (1957). Whale marks recovered during the Antarctic Whaling Seasons 1956/57. *Norsk Hvalfangst-Tid.*, 46(10) : 535–9.

BROWN, S.G. (1958). Whale marks recovered during the Antarctic Whaling Season 1957/58. *Norsk Hvalfangst-Tid.*, 47(10) : 507–7.

BROWN, S.G. (1959). Whales marks recovered in the Antarctic Seasons 1955/56, 1958/59, and in South Africa 1958 and 1959. *Norsk Hvalfangst-Tid.*, 48(12) : 609–16.

BROWN, S.G. (1961). Whale marks recovered in the Antarctic Whaling Season 1960/61. *Norsk Hvalfangst-Tid.*, 50(10) : 407–10.

BROWN, S.G. (1962a). A note on migration in Fin Whales. *Norsk Hvalfangst-Tid.*, 31(1) : 13–6.

BROWN, S.G. (1962b). The movements of Fin and Blue Whales within the Antarctic Zone. *Discovery Rept.* 33 : 1–54.

BROWN, S.G. (1962c). Whale marks recovered during Antarctic Seasons 1960/61, 1961/62, and in South Africa 1962. *Norsk Hvalfangst-Tid.*, 51(11) : 429–34.

CLARK, R. & BROWN, S. G. (1957). International co-operation in Antarctic whale marking from 1945 to 1957. *Norsk Hvalfangst-Tid.*, 46(9) : 513–17.

CUSHING, J.E., K. FUJINO & K. TAKAHASHI (1959). Glycerol-freezing technique as an aid in blood-typing of whales. *Sci. Rept. Whales Res. Inst.*, 14 : 89–100.

FUJINO, K. (1960). Immunogenetic and marking approaches to identifying sub-populations of the north

Pacific whales. *Sci. Rept. Whales Res. Inst.*, 15 : 85–142.

FUJINO, K. (1962). Blood types of some species of the Antarctic whales. *American Naturalist.* 96 (889) : 205–210.

FUJINO, K. (1963a). Intra-uterine selection due to maternal-fetal incompatibility of blood types in the whales. *Sci. Rept. Whales Res. Inst.*, 17 : 53–65.

FUJINO, K. (1963b). Population genetics of whales with reference to blood types. *Bul. Jap. Soc. Sci. Fisheries*, 29(12) : 1133–38.

LAWS, R.M. (1961). Reproduction, growth and age of Southern Fin Whales. *Discovery Rept.*, 31 : 327–486.

Office of the International Whaling Commission (1963). International Whaling Commission, Fifteenth Annual Meeting. *Norsk Hvalfangst-Tid.*, 52(8) : 225–26.

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