The Fattyness of the Antarctic Minke Whale and Its Yearly Change

Seiji Ohsumi, Yoshihiro Fujise, Hajime Ishikawa,
Takashi Hakamada, Ryoko Zenitani
and Koji Matsuoka

The Institute of Cetacean Research,
4-18 Toyomi-cho, Chuo-ku, Tokyo 104, Japan

ABSTRACT

Many matters related to the fattyness of the Antarctic minke whale were studied by use of body weight which could be measured directly by the JARPA surveys. The difference of degree of fattyness between the minimum and maximum is within two times. The pattern of fattyness is not different between sexes. The degree of fattyness (f) is relatively large in the infant and then it becomes almost constant. From analysis of seasonal change in f, existence of wintering whales and delay of arrival in the feeding ground are confirmed. The increase rate of f will be around 32 % during the stay in feeding ground. The blubber thicknss at 18 body parts were examined on the merit as the indicator of fattyness. The degree of fattyness by use of blubber thickness is estimated to have decreased gradually since 1978.

INTRODUCTION

As the cetacea lives swimming in the waters, the storage of fat, of which the specific gravity is lower than water, in its body contributes to increase its buoyancy, to be active and to enlarge its body. Nextly, by use of the nature of fat of low conductivity of heat, the cetacea forms fatty layer of thick blubber, and the fat is used to cut off the body heat of cetacea to the waters.

Because the fat is high calorific and very effective for the storage substance of energy, most animals store the fat in their various parts of body tissues. Furthermore, the cetaceans, especially most baleen whales, have long distanced breeding and feeding grounds, and they migrate between these two grounds every year. They feed actively in the feeding ground, and prepare to migrate to and to stay in their breeding ground by storage of fat in their body by feeding of food.

The whaling is a kind of industries which produce substances which are useful for the human welfare from whale bodies, and the whaling hopes to produce as much products as possible from a whale body, as it is an economic activity under the severe management system of whale stocks. Then, whalers need to understand on the fattyness of whales correctly for their rational whaling operation.

Therefore, the problems on the fattyness of baleen whales should be studied not only from the pure biology but also from the side of rational utilization of whale resources.

Nevertheless, the basic study on the fattyness of baleen whales has not developed enough yet. The true fattyness is related directly to the data of body length and weight. This kind of knowledge is also important to estimate biomass of a whale stock and to elucidate the role of whales in their ecosystem.

However, baleen whales are too large to be easy for man to measure their body weight directly. The body weight of a whale has been usually estimated by summing up measured small tissue blocks after flensing its carcass on a deck. This kind of weighing method has many weak points such as need of much labor power and long time to measure a whale. Then, it is practically difficult to measure body weight of many individuals in a short time. In addition, most body fluid and some body tissues are lost usually during the flensing and measurement of tissue blocks.

Fortunately, a special large weighing machine, as shown in Fig. 1, was equipped on the flensing deck of a research mother ship for the JARPA survey in 1988/89 season, and it has become to measure the body weight of every minke whale sampled by the JARPA directly since then.

In addition to above, very detailed measurements, including of blubber thickness and girth length on various parts of a body, have been carried out on every minke whale sampled by the JARPA. The thickness of blubber has been regarded as an index of fattyness of whales since the pioneering work by Mackintosh and Wheeler (1929) on the Southern blue and fin whales, and the blubber thickness at a body part was measured on each whale caught by Japanese commercial whaling since 1946, and data of blubber thickness were accumulated on all the Antarctic minke whales caught from 1971/72 to 1986/87 seasons.

"The elucidation of role of cetaceans in the Antarctic ecosystem" is one of four objectives of the JARPA project (Government of Japan,1996), and the study on fattyness will contribute for this research object ive related to the energy flow of the Antarctic minke whale.

"The elucidation of effect of environmental change on whale stocks" is also another objective of the JARPA project (Government of Japan, 1996), and examination of blubber thickness as an indicator of fattyness by use of longly accumulated data will also contribute to the study on this field.

MATERIALS AND METHODS

Although two forms of ordinary and dwarf minke whales (*Balaenoptera acutorostrata*) were collected by the JARPA survey, only ordinal form minke whales are used as materials in this study.

The minke whales which were collected by the JARPA surveys and weighed their body directly with a weighing machine from 1988/89 to 1995/96 were mainly used for the analysis related to fattyness in this study. Data on the thickness of blubber in 1987/88 are also used for the analysis of its yearly change. The number of material whales of which body weights were measured are shown in Table 1. The kinds of data used in this study are sex, body length, body weight, blubber thickness, age, maturity, sexual condition of females, body length of foetuses, degree of diatom adhesion, position and date sampled.

The degree of fattyness was calculated with the following equation (1):

$$f = W / L^3 \text{..........(1)}$$

where, f is the degree of fattyness, W is body weight in kg, and L is body length in cm.

Relations between f and body length, age, maturity, sexual conditions, body length of foetuses, diatom adhesion, latitude and date sampled, respectively, are examined then.

Next, the effectiveness of blubber thickness as an index of fattyness is examined. As shown in Fig. 2, blubber thickness at 18 body parts of every whales sampled was measured in JARPA surveys. The correlation coefficient of relation between f value and the index of fattyness of blubber thickness (bf) which is calculated by the following equation (2) on these 18 body 1parts:

$$bf = b / L \text{ ....(2)}$$

where, b is thickness of blubber in cm and L is body length in cm. And then, the correlation coefficient at the Part 11, which has been used and measured traditionally as the standard part of blubber thickness of whales in the commercial waling age, is compared with those coefficients at other body parts.

Finally, yearly change in the bf values of the sexually mature Antarctic minke whales which were caught from Areas IV and V is examined by use of data of commercial whaling age from 1971/72 to 1986/87 seasons and those of the JARPA surveys from 1987/88 to 1995/96 seasons.

RESULTS

Individual variation of fattyness

Fig. 3 shows frequency distributions of f values for the Antarctic minke whales by sex, and Table 2 shows the figures of the minimum, maximum, average and standard error by sex. It is found from the Figure and Table that the average is a little biased to lower part and there are large individual variations in fattyness values in both sexes. The maximum f value (15.9) is 2.01 times larger than the minimum value (7.9). This suggests that the minke whale will get fat at the most two times of body weight during the stay in the feeding ground of the Antarctic. However, considering the existence of individual variation of f values at the time of arrival at and departure from the feeding ground, actual figure of ratio of getting fat in the feeding ground must be less than two times.

It is also found that there is no significant difference in pattern of fattyness between both sexes, although males seem to be a little fatty than females in average.

Relation between body length and fattyness

The range of body lengths of the Antarctic minke whales which were collected by the JARPA surveys was from 4.55 to 10.15 m. When the relation between body length (L) and f value is plotted on each individual, the correlation coefficients of f values to L is -0.239 and -0.317 for males and females, respectively.

Then, there is negative correlations between them, although they are not significant. This means that the fattyness decrease slightly with the growth of the Antarctic minke whale.

Fig. 4 shows the average and range of standard error of f values of each sex in each L class. It is found that there is no difference of these values between both sexes in each body length class.

Relation between age and fattyness

Fig. 5 shows the relation between age and f values in both sexes. There is large individual variation of f values in each age class, and fattyness is almost constant through ages, although those in the juvenile stage of 1-5 years old seem to be a little more fatty than older individuals.

Change in fattyness with sexual maturity

Table 3 compares values of average and standard error of f values of sexually immature individuals with those of mature individuals in both sexes. It seems that the average f value of immature whales is a little larger than mature whales in both sexes and that f values of males are a little larger than those of females in both maturity stages.

This pattern agrees with those in body length and age.

Difference of fattyness among sexual conditions

Table 4 shows the minimum, maximum, average and standard error of f values by sexual conditions (pregnant, lactating, resting and ovulating) in sexually mature females. Because most whales are pregnant and data of other sexual conditions are few, it is difficult to compare those figures among different sexual conditions. However, the average of lactating females is smaller than those of other sexual conditions, and this lets us estimate that the lactating females are leaner than females of other sexual conditions. Those of other sexual conditions are almost the same each other.

Change in fattyness with gestation period

The gestation period of a pregnant whale is usually estimated by body length of foetus in the individual. And, f value is regarded as an indicator of time length of staying of a whale in the feeding ground. Fig. 6 shows the relation between the body length of feotus and f value of its mother.

It is found that there are large variations of f value in the same body length class of foetuses. This phenomenon cannot be explained only by the individual variations of fattyness in the same condition of migration. There is a possibility that the migration period of pregnant females is not closely related to gestation period and there are large individual variations in reaching and staying times of pregnant whales. The fact that there are some pregnant whales of which foetuses are small and have large f values indicates that they get pregnant during stay in higher latitudinal waters for relatively long time. On the other hand, some pregnant whales which have large foetuses have still low f values. This may mean that these individuals stay outside of the Antarctic feeding ground for relatively long time after the conception.

From Fig. 6 it is also found that there is a trend of increase in f values with body length of foetuses, although there are large individual variations of f values. This means that a pregnant female gets fat gradually during it stays in the feeding ground. Although it is impossible to chase the actual increase of fattyness of an individual with this method, it can be estimated that a pregnant minke whale gets fat 32 % in average from the conception (f=10.5) to the period in which a foetus grows to 250 cm (f=13.9) which is shorter than the body length at birth (290 cm: Kato, 1982) in the Antarctic. The existence of fatty individuals in the early stage of gestation contributes to the rise of apparent f value from actual f at conception, and occurence of low figures of f value in long gestation time acts to lower the apparent figure. Therefore, the estimated increasing rate by use of apparent figures will be lower than actual rate of an individual.

Relation between adhession of diatom film and fattynees

It has been supposed that whales are adhessed by diatom film on the skin in the colder waters. Therefore, it has been believed that the degree of the diatom adhession on the skin of a whale indicates the time length of staying of the whale in the cold waters.

The degree of diatom adhession on the skin is divided into 5 classes by visual observation of a whale skin in the case of JARPA survey. Table 5 shows the minimum, maximum, average and standard error of f values on these 5 classes of diatom adhession. Accompanying with the increase of the degree, the minimum figures increase, but the maximum keep the similar figures. The average figures of f values increase with degree of adhession in both sexes, although it is not so significant.

These results may suggest that the degree of diatom adhession becomes a rough indicator of time length for the whale to stay in the cold waters in general. However, the fact that the maximum figure of f values in the class of no diatom adhession is almost the same as that of the largest class of adhession means that the degree of diatom adhession is not an excellent indicator of the time length of stay of minke whales in the Antarctic.

Relation between latitude and fattyness

Fig. 7 shows relation between latitude and f values in Areas IV and V by sexes. Even in high latitudinal waters such as 75 degee South and more in Area V very lean individuals are distributed. Furthermore, even in lower latitudinal waters very fat individuals are distributed. Although a trend for average f values to increase gradually accompanying with increase of latitude is found, it is not significant. The sexual difference in this relation is not observed.

These phenomena give some suggestion that some minke whales migrate rapidly to the higher latitudinal waters, and others migrate slowly to the feeding ground by feeding on the way or they wintered there before the sampling.

Seasonal change in fattyness

Fig. 8 shows the relation between the date of sampling and f value of the Antarctic minke whales, and Table 6 shows the minimum, maximum, average and standard deviation of f values in each decade by sexes. The minimum figures increase from 8 to 11 accompanying with season, but some whales have f values of 8 even in February. This phenomenon indicates that there are large individual variations in the arrival date of minke whales in the Antarctic, and minke whales arrive continuously in the Antarctic until February, if the lowest f value of 8 indicates an individual which just arrived in the Antarctic from lower latitudinal waters. This kind of phenomenon is more clear in females than males. This indicates that females have a tendency to arrive in the Antarctic later than males.

On the other hand, there appears some whales of which the maximum f value of 15 from the begining of research season, and the maximum figures are almost constant through all the research seasons. This phenomenon suggests that there are some whales which spend winter season in the Antarctic in both males and females.

The average figures of f value increase accompanied with the season from 11.3 in early December to 12.5 in late March, except figures in November in which data are scarce in number. This phenomenon is the same in both sexes. It is clear from this analysis that the fattyness of minke whales increases in the Antarctic during about 120 days from late spring to early autumn. However, apparent rate of increase is about 11 %. This figure does not mean the true incresing rate of f value of an individual during the stay in the Antarctic. As examined above, all the minke whales do not arrive in and secade from the Antarctic all together. Some whales stay there even in winter, and some others arrive there even in late summer from warm waters. Furthermore, some whales secade earlier season from the Antarctic. The average figure includes those of all such cases. Thus, apparent average figure of f value in earlier season is higher than true figure by the existence of wintering individuals. In the middle season the individuals which arrive late in the Antarctic lower the apparent figure from true one. In the later season the individuals which secade from the Antarctic earlier season lower further the apparent figure of f value from true one. Therefore, the increasing rate of apparent average f values (11 %) must be lower than the true one.

On the other hand, the increasing rate from the minimum f value (7.9) and the maximum one (15.9) is 101 %. This figure does not also mean the true increasing rate of f values. There are individual variation in the fattyness even in the same staying condition, and the minimum and maximum figures are both extremes. Therefore, the true increasing rate of f value of an individual must be some figures between 11 and 101 %.

The figures of standard error do not change seasonally in both sexes.

Yearly change in fattyness

Table 7 shows yearly change in average f values by sexes from 1988/89 to 1995/96 seasons of the JARPA surveys. The data in February are used for this examination, for it will be reasonable to consider that the data in later season indicates the result of accumulation of nutrition of whales in the feeding ground in the year, and February is better than March considering the amount of data.

There are yearly fluctuation in the average figures of f values, and average f values are high in 1991/92 and 1992/93. If the fattyness in February reflects the availability of food of whales, this phenomenon indicates that food availability in 1991/92 and 1992/93 was more than those in other years. Trend of yearly change in the fattyness is not detected during these 8 years.

Fig. 9 shows yearly change in the relation between latitude and f values in Area V in February. There are fatty and lean years, and the most fatty year was 1992/93, and the most lean year was 1988/89. There is no trend of change in fattyness with latitude in every year.

Evaluation of blubber thickness as an indicator of fattyness

The index of fattyness (bf) on each whale is calculated in the case of blubber thickness on 18 body parts (B1-18) in Fig. 2.

Table 8 shows figures of correlation coefficient between f and bf on these body parts. The largest figure of correlation coefficients is 0.54 at B16, and then the blubber thickness cannot be regarded as a good indicator of the fattyness of the minke whale.

The correlation coefficient figures at head parts (B1-3) are the lowest, and those at the neck parts (B4-6) follow the head parts. The correlation coefficients between f and bf at the trunk parts (B7-10) are the largest, and those at anus parts (B11-14) are nextly large. Although correlation coefficients at B16 is the largest (0.54) among all body parts, B15 or 17 in the same tail part is the smallest (0,19), so that the average figure of correlation coefficients in the tail parts is low in total.

The correlation coefficient figures in the back parts (B5, 8, 12, and 16) are large in general, those in ventral parts (B10, 14 and 18) follow the back parts, and those of body side parts (B4, 7, 11 and 15) are the lowest. These results indicate that the blubber thickness at back parts are largely related to the fattyness among 19 body parts.

The blubber thickness at B11 or 13 has been measured routinely by Japanese whalers for long years, and large amount of data have been accumulated for the Antarctic minke whales from 1971/72 to 1986/87 seasons. The present study reveals that the figure of correlation coefficient between f and bf in this body part is the thirdly large among 18 body parts. Although blubber thickness at B16 and B8 are better than this body part, it is difficult to measure the thickness of blubber at B8 or B16, because it is difficult to decide the correct measurement portion and to cut vertically at flensing of a whale carcass. Additionally the blubber thickness at these body parts have not measured routinelly in the past. On the other hand, body part of B11 or 13 is superior on these problems, so that it is still the most practical as the measurement point of blubber thickness, although there are problems that figure of correletion coefficient at this point is not so large (0.52).

Yearly change in index of blubber thickness

For the analysis of change in a biological parameter it is better for us to examine related data of long term. Fortunately the data of blubber thickness have been accumulated for 24 years from 1971/72 to 1995/96 for the analysis of yearly change in fattyness of the Antarctic minke whale.

Before the examination, data should be standardized: The area of data is limited in Areas IV and V and south of 60 degree South. Month is selected to February of which reason was described above. Sexually mature whales are used, for young whales have larger value of fattyness as examined above.

Fig. 10 and Table 9 show yearly change in average value of blubber thickness index (bf) at the body part 11 in February by sex in combination of Areas IV and V for recent 24 years by use of above selected data. There is a trend of decrease in the average values of bf from 1978. This trend is close each other in both sexes. Data of only two years are available before 1977, and they are both lower than those in years around 1980.

If this trend is true, this indicates that the food availability of the Antarctic minke whale has become to be decreasing since around 1978. Whether the food availability before the year had been increasing or not is unknown from the present data, although some indications are shown in Fig. 9.

DISCUSSION

Importance of study on fattyness

It is realised from the present work that studies on the fattyness are widely related to many fields of cetacean ecology. From studies of fattyness our thought on migration and food availability developed widely. Many other works to be studied further are remained.

The present study has become to be carried out by direct measurement of body weight by the JARPA surveys. We should recognize that this kind of study cannot be developed without lethal investigation.

Increasing rate of fattyness in the feeding ground

Three figures were estimated from above examinations on the increasing rate of fattyness: one is 11 % from seasonal change in average figures of f values, and this is clearly lower than actual increasing rate as examined before. The second is 32 % which was obtained from change in fattyness with gestation period. It is estimated that this is also lower than the actual rate. The third is 101 % which was obtained by use of the minimum and maximum f values, and it it clearly larger than the actual rate of increase of f value in the feeding ground.

The actual figure should be between 32 and 101 %, and considering from the paper by Tamura et al. (this meeting), it will be close to lower figure.

Lockyer (1981) investigated the seasonal change in body weight of the larger rorguals from the Antarctic and estimated that the total increase in the body weight over the summer feeding was 30 to 100 % and noted the hibernating mammals offen doubled their weight.

Blubber thickness as an indicator of fattyness

As examined in this paper, it is found that the blubber thickness which has been measured routinely in the whale resources biology is not so good indicator. This finding can be obtained by comparison of the index of fattyness by use of blubber thickness with the true degree of fattyness which was obtained from direct measurement of body weight.

However, the blubber thickness will still keep a practical index of fattyness because of its simplicity of measurement compared with other index such as body weight. Furthermore, large amount of data on this kind of measurement have been accumulated for long time. Therefore, we should need to continue the accumulation of the same data for the monitoring of fattyness. In the same time we must accumulate simultaniously other kinds of indicator of fattyness such as the girth length. It is natural to measure body weight on individual whale by use of body weight measurement machine for the thourough study of fattyness.

Yearly change in fattyness

It is thought that the fattyness of a whale stock in late feeding season represents the accumulation of total food intake in the season. If it is true, two cases are considered as food availability: one is the shortage of total production and abundance of food species in the environment and another is the shortage of food intake by individual whale by the increase of competition with other individuals or other animal species in the same abundance of total food in the environment. Anyway both cases act to the phenomenon that the Antarctic minke whale population is approaching to the carrying capacity in recent years.

This is largely related to the management policy of the Antarctic minke whale, so that the continuation of monitoring of the fattyness of the Antarctic minke whale will be important.

From the examination by blubber thickness, the average value of bf was estimated to turn to decreasing from 1978. In this connection, Shimadzu (1989) shows a similar figures. According to the figures, the blubber thickness of minke whales from Areas III and IV seems to had increased till about 1978, and tended to decrease since the year, although his interest was yearly fluctuation of food availability. This phenomenon coincides to the present result in spite of different method was used.

The change in fattyness will affect to the change in other biological parameters such as the age at sexual maturity and growth. The decrease of fattyness will cause the decrease of growth rate and increase of age at sexual maturity of the whale stock. Then, it will be needed to examine the change in such biological parameters to confirm the real change in fattyness.

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Table 1. Number of the Antarctic minke whales sampled by JARPA used for this study.

Year	Male	Female	Total
1987/88	0	0	0
1988/89	84	150	234
1989/90	184	142	326
1990/91	164	159	323
1991/92	158	116	274
1992/93	166	160	326
1993/94	200	130	330
1994/95	200	130	330
1995/96	272	167	439
Total	1,428	1,154	2,582

Table 2. Comparision of f values by sexes in the Antarctic minke whales.

				Range	
Sex	n	Mean	se.	Min.	Max.
Males	1,428	11.73	0.037	7.9	15.7
Female	1,154	11.65	0.038	7.9	15.8
Total	2,582	11.69	0.024	7.8	15.8

Table 3. Comparision of f values between sexually immature and mature whales.

Sex	Maturity	n	Mean	se.	Range Min.	Range Max.
Males	Immat.	167	12.18	0.11	9.1	15.6
	Mat.	928	11.70	0.04	7.9	15.7
Females	Immat.	305	11.98	0.10	7.9	15.5
	Mat.	676	11.49	0.05	8.4	15.8
Total	Immat.	472	12.05	0.06	7.9	15.6
	Mat.	1604	11.61	0.03	7.9	15.8

Table 4. Comparision of f among various sexual conditions.

Condition	n	Mean	se.	Range Min.	Range Max.
Pregnant	606	11.51	0.05	8.4	15.8
Lactating	15	10.37	0.21	9.3	12.5
Resting	53	11.31	0.19	8.5	15.7
Ovulating	16	11.53	0.27	10.1	14.1
Unknown	6	11.24	0.41	9.3	12.3

Table 5. Change in f Values with degree of adhesion of diatom film.

Degree	Sex	n	Mean	se.	Range Min.	Range Max.
−	Males	424	11.66	0.06	8.5	15.6
	Females	469	11.44	0.06	7.9	15.8
	Total	893	11.55	0.04	7.9	15.8
+−	Males	110	11.43	0.11	9.2	14.3
	Females	125	11.39	0.11	8.7	14.8
	Total	235	11.41	0.07	8.7	14.8
+	Males	596	11.74	0.05	7.9	15.4
	Females	437	11.78	0.06	8.9	15.7
	Total	1033	11.75	0.04	7.9	15.7
++	Males	191	11.88	0.09	8.8	15.7
	Females	90	12.14	0.13	9.7	15.5
	Total	281	11.97	0.07	8.8	15.7
+++	Males	105	11.95	0.11	9.2	14.6
	Females	32	12.60	0.21	10.8	15.3
	Total	137	12.10	0.10	9.2	15.3

Table 6. Seasonal change in f values.

Decade	Sex	n	Mean	se.	Range	
					Min.	Max.
Late Nov.	Male	5	10.59	0.37	9.1	11.5
	Female	3	10.32	0.47	9.2	11.0
	Total	8	10.49	0.29	9.1	11.5
Early Dec.	Male	58	11.29	0.14	8.8	14.1
	Female	53	11.40	0.18	7.9	15.3
	Total	111	11.34	0.11	7.9	15.3
Mid. Dec.	Male	117	11.15	0.10	8.9	15.2
	Female	65	11.46	0.15	8.9	15.4
	Total	182	11.26	0.08	8.9	15.4
Late Dec.	Male	196	11.32	0.07	9.1	15.1
	Female	71	11.19	0.12	8.5	13.2
	Total	267	11.29	0.06	8.5	15.1
Early Jan.	Male	166	11.37	0.09	8.9	15.1
	Female	96	11.25	0.12	9.4	13.8
	Total	262	11.32	0.07	8.9	15.1
Mid. Jan.	Male	143	11.43	0.09	7.9	14.0
	Female	99	11.56	0.11	8.4	14.3
	Total	242	11.49	0.07	7.9	14.3
Late Jan.	Male	192	11.63	0.08	8.5	14.7
	Female	133	11.35	0.10	8.7	14.0
	Total	325	11.51	0.06	8.5	14.7
Early Feb.	Male	117	11.92	0.09	9.6	14.8
	Female	187	11.74	0.09	8.7	15.8
	Total	304	11.81	0.07	8.7	15.8
Mid. Feb.	Male	154	12.27	0.09	9.4	15.4
	Female	146	11.71	0.10	9.0	15.4
	Total	300	12.00	0.07	9.0	15.4
Late Feb.	Male	116	12.29	0.11	10.1	15.6
	Female	155	11.92	0.11	8.5	15.4
	Total	271	12.08	0.08	8.5	15.6
Early Mar.	Male	96	12.60	0.12	10.3	15.7
	Female	110	12.14	0.13	9.7	15.7
	Total	206	12.35	0.09	9.7	15.7
Mid. Mar.	Male	55	12.30	0.13	9.9	14.3
	Female	35	12.49	0.20	9.9	15.5
	Total	90	12.38	0.11	9.9	15.5
Late Mar.	Male	13	12.59	0.26	11.2	14.6
	Female	1	12.07	-	-	-
	Total	14	12.55	0.24	11.2	14.6

Table 7. Yearly change in f values in February.

Year	Sex	n	Mean	se.	Range	
					Min.	Max.
1988/89	Males	26	11.82	0.19	8.5	14.7
	Females	77	11.15	0.14	9.4	13.6
	Total	103	11.32	0.12	8.5	14.7
1989/90	Males	22	12.08	0.23	9.7	15.8
	Females	29	11.81	0.27	10.0	14.8
	Total	51	11.93	0.19	9.7	15.8
1990/91	Males	41	12.01	0.15	9.0	14.4
	Females	91	11.81	0.12	10.3	14.8
	Total	132	11.87	0.09	9.0	14.8
1991/92	Males	79	12.43	0.14	9.6	15.4
	Females	62	12.22	0.18	9.8	15.4
	Total	141	12.34	0.11	9.6	15.4
1992/93	Males	61	12.56	0.14	8.8	15.4
	Females	49	12.47	0.19	10.1	15.3
	Total	110	12.52	0.12	8.8	15.4
1993/94	Males	51	12.36	0.16	8.7	15.1
	Females	31	11.61	0.28	9.6	15.6
	Total	82	12.07	0.15	8.7	15.6
1994/95	Males	46	11.85	0.14	9.2	15.2
	Females	72	11.65	0.14	9.9	14.3
	Total	118	11.73	0.10	9.2	15.2
1995/96	Males	61	11.82	0.11	9.5	14.9
	Females	77	11.82	0.12	10.3	14.1
	Total	138	11.82	0.08	9.5	14.9

Table 8. Correlation coefficient between f and bf on each body part.

Body parts	r
B1	0.37
B2	0.24
B3	0.32
B4	0.35
B5	0.45
B7	0.47
B8	0.53
B10	0.44
B11	0.52
B12	0.42
B14	0.45
B15	0.19
B16	0.54
B18	0.48

Table9. Yearly variation of a ratio of blubber thickness (cm) to the body length (m) of minke whales for mature males and females in Antarctic Areas IV and V.

Year	February									
	Male					Female				
	Mean	sd	Min	Max	n	Mean	sd	Min	Max	n
1972	4.9	0.9	3.0	7.9	195	5.0	1.0	2.6	8.1	105
1973										
1974										
1975										
1976										
1977	4.9	0.8	3.0	6.5	47	5.0	1.0	3.4	7.8	21
1978	5.5	1.0	3.2	8.3	64	5.5	0.9	3.4	7.9	211
1979	5.4	0.9	3.0	10.0	375	5.5	0.9	3.3	8.2	374
1980										
1981	5.5	0.9	4.1	8.8	76	5.2	0.9	3.3	7.8	179
1982	5.2	0.9	2.6	8.7	350	5.4	0.9	3.1	8.8	638
1983	5.6	0.8	3.5	8.2	114	5.6	0.9	3.4	7.8	348
1984	5.2	0.8	3.2	6.8	101	5.3	0.9	3.1	8.1	167
1985	5.1	1.0	3.5	8.6	187	5.2	1.0	3.2	9.1	440
1986	5.4	1.0	3.1	8.4	278	5.4	1.0	2.9	10.2	347
1987	5.0	0.8	3.4	7.1	51	4.9	0.9	3.1	8.3	220
1988	5.3	1.2	2.8	8.0	82	5.4	1.1	3.5	8.2	45
1989	5.5	1.1	4.0	7.7	26	5.1	1.1	2.6	7.8	65
1990	4.9	1.4	2.6	8.1	17	5.0	1.0	2.7	6.7	21
1991	5.8	1.0	4.0	8.2	41	5.6	1.1	3.5	8.4	70
1992	5.2	1.2	3.2	9.7	72	5.2	1.2	2.5	7.1	42
1993	5.3	1.4	0.4	7.5	57	5.4	1.1	2.5	6.8	29
1994	4.8	1.6	2.6	11.1	46	4.3	1.0	2.3	6.4	22
1995	5.0	1.1	2.6	7.6	43	5.4	1.0	3.0	8.2	56
1996	4.8	1.1	2.9	8.2	58	5.0	0.9	3.6	7.2	46

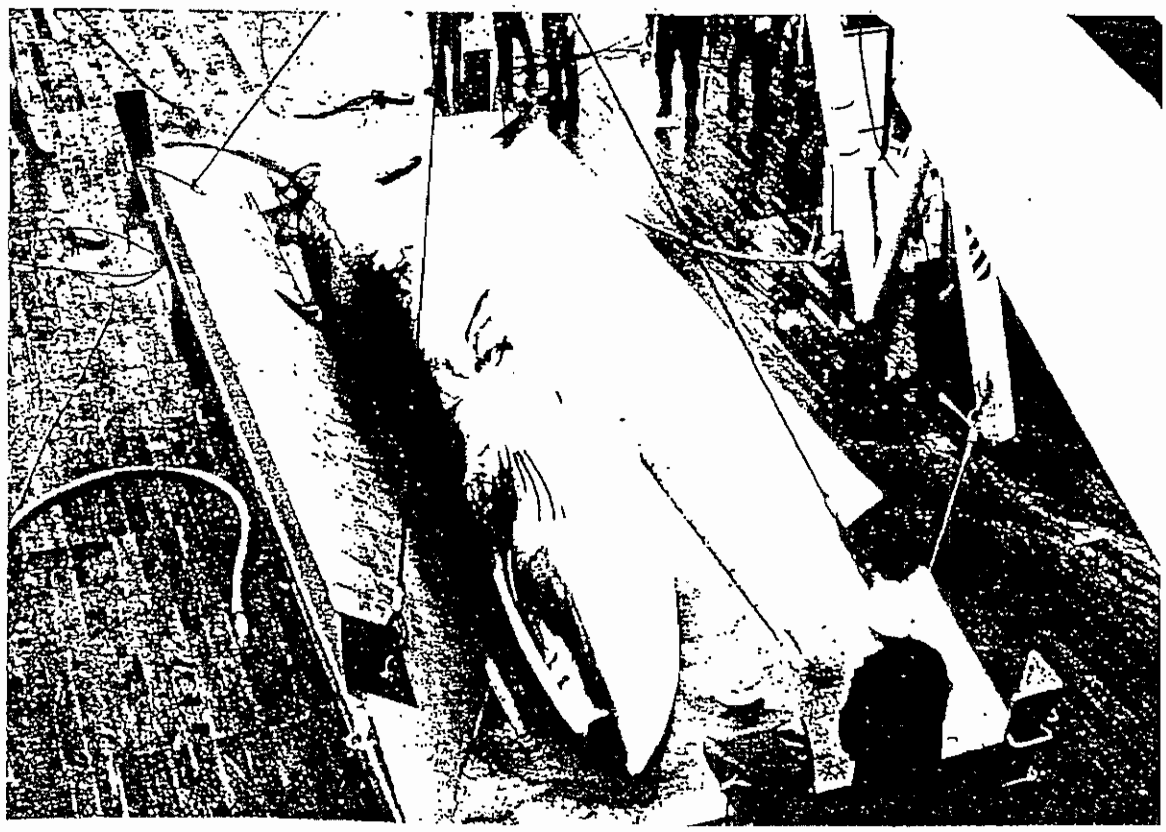

Fig 1. A weighing machine equipped on the flensing deck of a research mother ship.

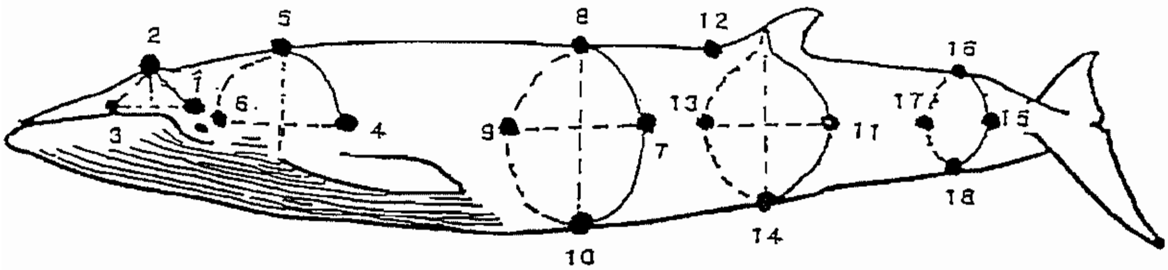

Fig. 2. Positions at which blubber thickness is measured. Numbers represent position numbers.

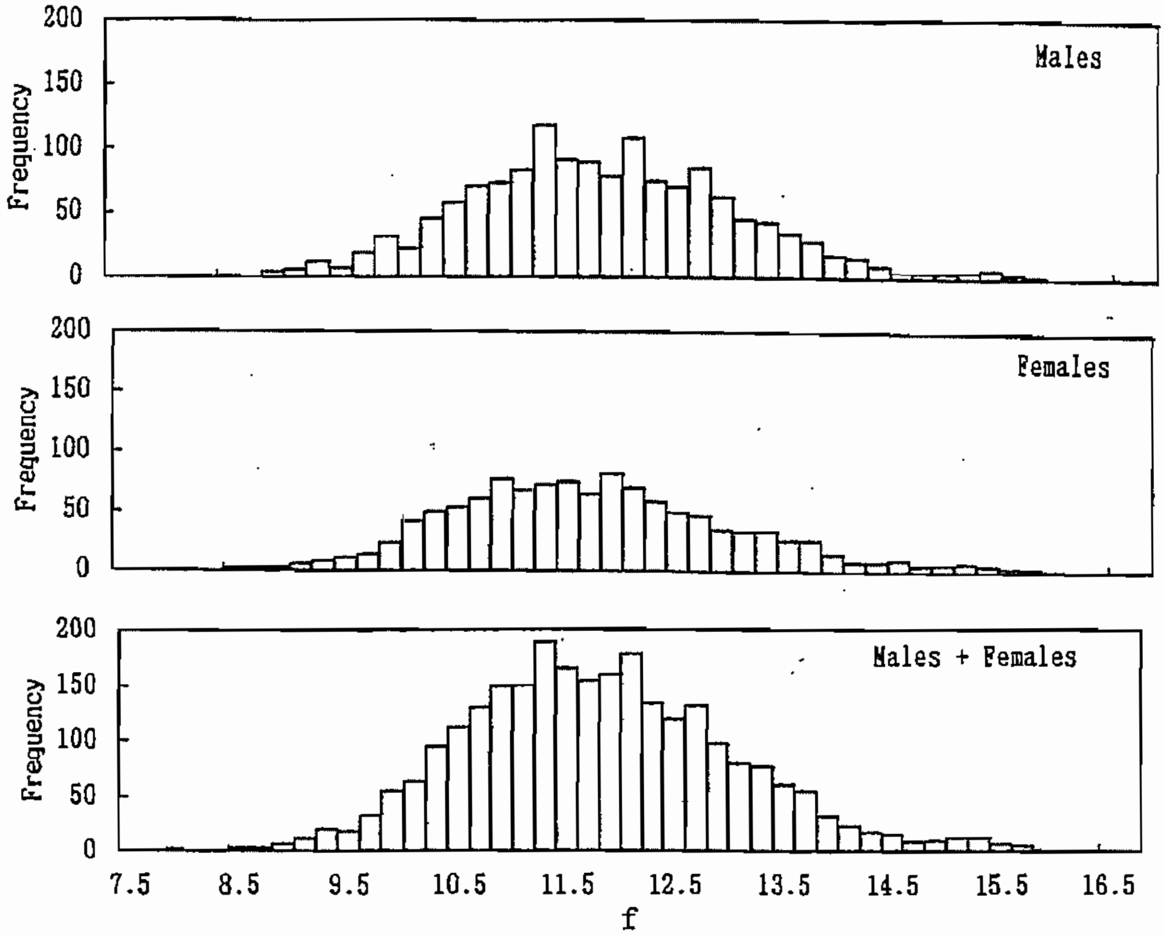

Fig. 3. Frequency distribution of f value in males, females and males and females conbined in the Antarctic minke whale.

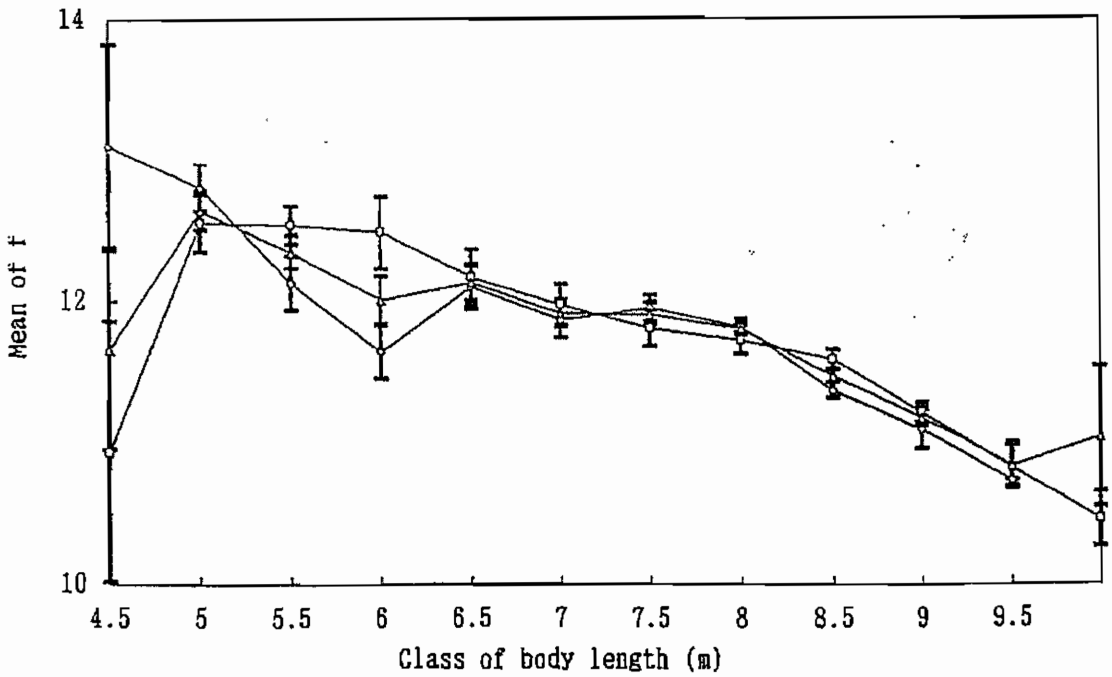

Fig. 4. Change in mean value of f and se. with class of body length.

—○— M —□— F —△— M + F

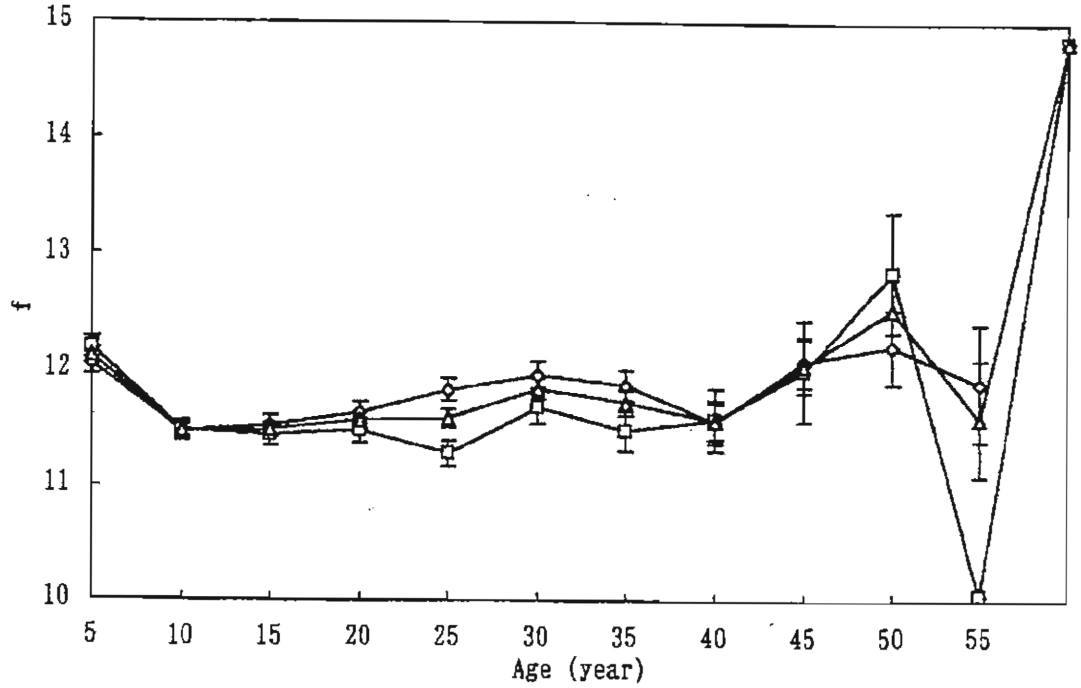

Fig. 5. Change in mean value and se. of f with age.

—◇— M —□— F —△— M + F

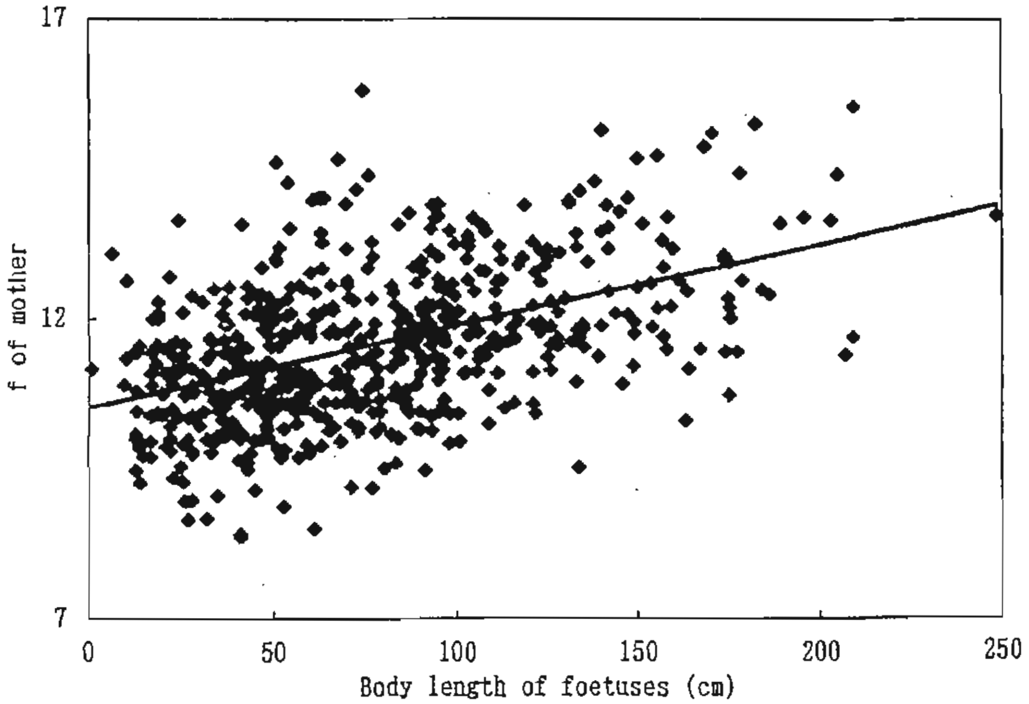

Fig. 6. Relation between body length of foetus and f value of its mother.

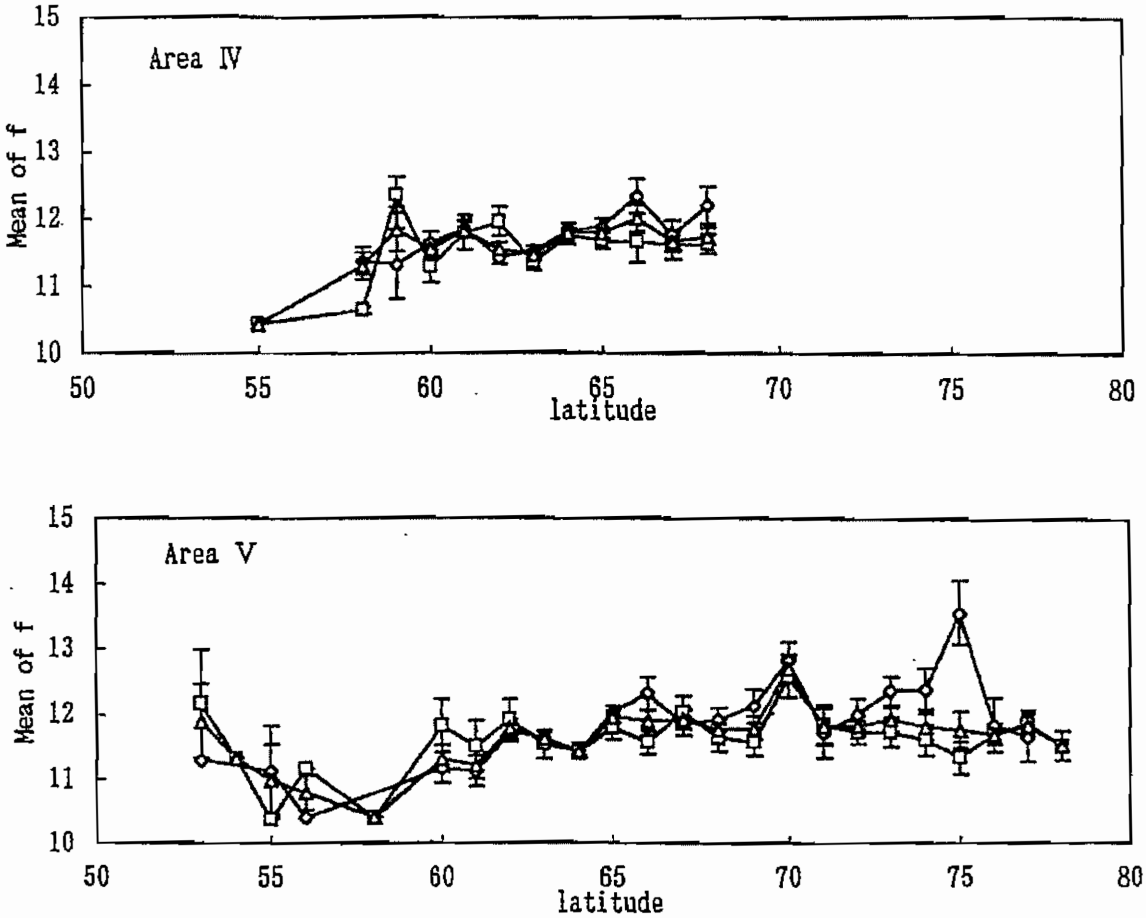

Fig. 7. Change in mean and se. of f with latitude in AreaⅣ and Area Ⅴ.

—◇— M —□— F —△— M+F

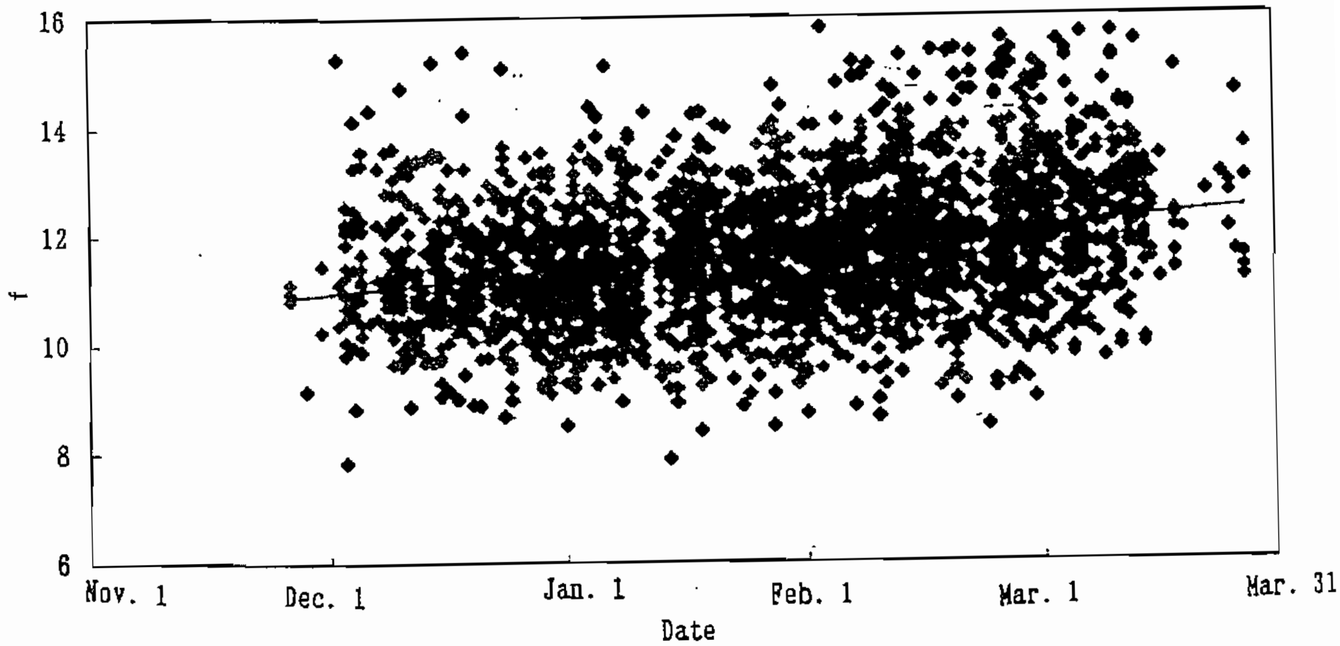

Fig. 8 Relation between date and f values.

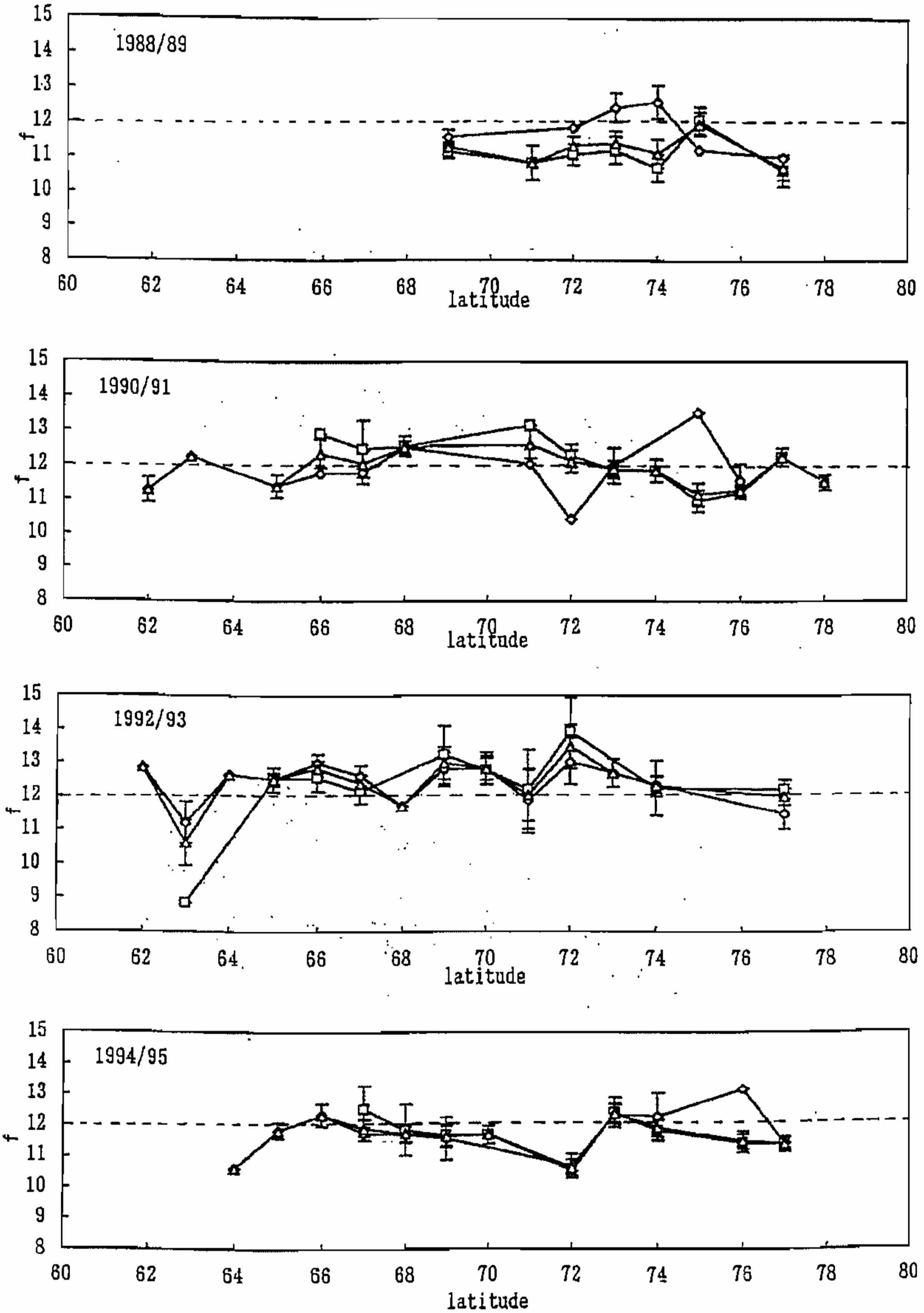

Fig.9 Yearly change in mean and se. of f with latitude in February in Area V.

—◇— M —□— F —△— M+F

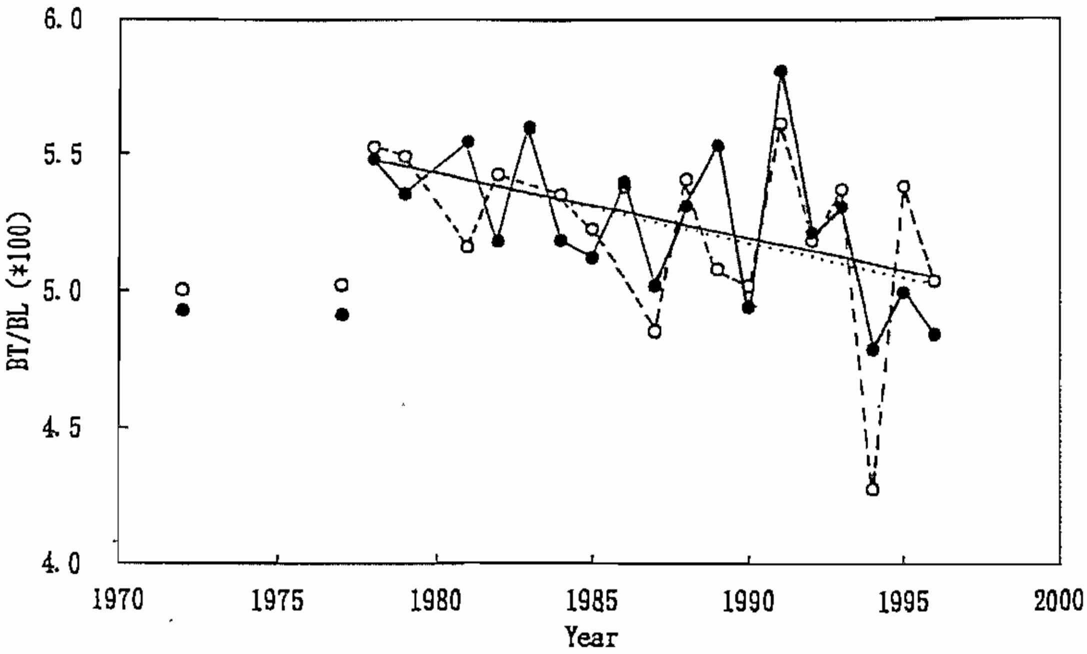

Fig.10. Yeearly change in average fattyness index of blubber thickness in February.

● Males ○ Females