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The food consumption of Steller sea lions (*Eumetopias jubatus*)

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Summary

The food consumption of one male and two female Steller sea lions and their eight offspring at the Harderwijk Marine Mammal Park was measured during several successive years. Food intake changes due to age, sex, time of year, reproductive stage and individuality of each animal are described, and compared to data from field studies.

Introduction

Several authors have studied the stomach contents of Steller sea lions in the wild (Evermann, 1921; Imler and Sarber, 1947; Wilke and Kenyon, 1952; Thorsteinson and Lensink, 1962; Mathisen *et al.*, 1962; Fiscuss and Baines, 1966; Pitcher, 1981 and Lowry *et al.*, 1982). Through this research, information about the species taken as prey by Steller sea lions, and the proportions in which they are eaten, has become available. The research showed regional, seasonal and historical changes in the diet of Steller sea lions. Still, very little is known about the amount of food consumed per day, or about the fluctuations or variations in food intake due to the time of year, the female reproductive cycle, or due to the age, sex, or individuality of an animal. Such data can be partially derived from food records of animals kept in marine mammal facilities. Studies on certain parameters influencing the food intake have already been carried out on a few sea lion species, for example by Schusterman and Gentry (1971), who suggested that a cyclic weight change in adult California sea lions (*Zalophus californianus*) might be hormone-dependent.

Only a few parks keep Steller sea lions because they are much more aggressive than most other sea lion species. However, the Harderwijk Park has had experience in keeping Steller sea lions since 1972. The amount of food offered per day is always determined by how much food the individual animals accept. Therefore, any changes in daily food intake are mainly determined by endogenous factors that regulate the individual's satiety. This paper is concerned with the food consumption of one male and two female Steller sea lions and their offspring during several successive years. The results may be useful for other marine mammal parks which keep or consider keeping Steller sea lions, for energetic studies, or for the evaluation of the impact of this species on certain fish populations.

Materials and Methods

Study animals

The age and sex of 10 Steller sea lions (*Eumetopias jubatus*) have been given in Table 1. The food consumption of the 3 adult animals will be analysed in more detail.

Study area

The animals are kept in an outdoor freshwater pool (28 m × 5 m × 2 m deep). Since 1972, the water temperature has varied between about 0°C and +14°C, while air temperature varied between approximately −15°C and +35°C. The Harderwijk Park is located at 5°37′ East longitude and 52°20′ North latitude.

Feeding

The Steller sea lions are fed 3 to 6 times per day on a mixed diet of on average 22% Mackerel (*Scomber scombrus*), 40% Herring (*Clupea harengus*), 10% Sprat (*Sprattus sprattus*), 14% Whiting (*Merlangius merlangus*), and 14% Squid (*Illex spp.*), based on weight. Vitamins are added to this diet. During the first or last feed of the day the sea lions are given as much as they want to eat. Feeding is stopped as soon as an animal starts to play with its food instead of consuming it immediately. This is considered a sign of satiety. Since 1972, records have been kept of the amount and type of food consumed by each individual during each feed. For the present analysis daily food intake is used as the basic measurement.

To assess the maximum stomach capacity of the animals in the present study, they were kept without food for one day on January 2, 1989 (a month during which the animals eat more than in other months of the year). The next day they were offered as much food as they wanted during the first feeding.

Table 1. The 11 study animals (*Eumetopias jubatus*) and their affinity

Code	Sex	Date of birth	Code father	Code mother
EjZH001	M	00-04-1972	wild	wild
EjZH002	F	00-04-1972	wild	wild
EjZH003	F	00-04-1972	wild	wild
EjZH004	M	26-06-1979	EjZH001	EjZH003
EjZH005	F	17-09-1980	EjZH001	EjZH002
EjZH006	M	12-07-1981	EjZH001	EjZH003
EjZH007	F	15-06-1983	EjZH001	EjZH003
EjZH008	M	31-05-1984	EjZH001	EjZH003
EjZH009	F	11-06-1985	EjZH001	EjZH003
EjZH010	F	11-06-1986	EjZH001	EjZH003
EjZH011	M	09-06-1987	EjZH001	EjZH003

Results

Age related changes and sexual differences

For the last 15 years, the total annual food consumptions of one male and 2 females are compared in Figure 1. Because Steller sea lions usually suckle for about 6 months, age 1 in the figure represents the first calendar year after the year of birth. The male's food intake increased steadily until his 16th year. Both females' food consumption increased until their 7th year. Female 002 gave birth to two pups (during her 8th and 16th year). After her first year with a birth, her food intake, which until then had been almost the same as that of female 003, dropped 35% and became very constant. In the second year with a birth her food intake increased 37%. After her 7th year the food intake of female 003 dropped only 10%, except for her 10th year, a year during which she did not give birth. That year her food intake dropped 35% and reached the level of that of female 002 between her 10th and 15th year (years in which she was not pregnant or lactating). This large drop is probably partly caused by environmental factors, since the food intake of the male also dropped much during the same year. The food intake of female 003 did not drop during her 16th year, a year during which she was not pregnant, but was still suckling her previous year's pup.

Table 2 shows the average daily food intake during the first 5 years of all the available animals. The males generally eat more than the females, but there are marked differences in average daily food consumption between individual animals of the same age in both sexes. At age 1 the males consumed almost as much food as the females did. The following 4 years the males consumed more than the females.

Seasonal changes

The food consumption record of male 001 can be divided into 3 periods. During the first 3 years of his life he showed a rather constant monthly food intake (Fig. 2A). It increased steadily throughout the year as the animal grew, without marked fluctuations. Between his 4th and 7th year the monthly food intake started to fluctuate, but still no specific pattern was apparent (Fig. 2B). The increase in food intake due to growth still dominated the monthly intake pattern. From his 8th year onwards the animal developed a distinct annual cycle in food intake. The deviation (%) of the average monthly food intake over 8 years shows that he consumed less than average between April and September and more than average between November and March (Fig. 2C). The extreme reduction in food intake between May and July coincides with an increase in aggression towards both conspecifics and man.

Female 003 seems to have gone through 2 phases in her food intake. During the first 10 years of her life (Fig. 3A) it did not change according to a regular monthly pattern, but the food intake during each of the first 5 years increased as she grew. From her 11th year onwards she developed a distinct annual cycle in her food intake. The deviation (%) of the average monthly food intake over 5 years shows that the animal always consumed less than average between February and June and more than average between July and December (Fig. 3B).

During her first 10 years, female 002 also showed no monthly pattern in her food intake. This intake steadily increased over the months of the first 5 years as she grew. Later in life, between age 11 and 15 (the same 5 years as shown for female 003 in Figure 3B) the deviation (%) of the average monthly food intake shows a considerably less pronounced annual cycle than that of female 003 (Fig. 4B).

Perinatal changes

In the last 5 days before birth, the pregnant females reduced their intake significantly and almost always fasted for at least one day (Fig. 5). However, reductions in average daily food intake also occurred at

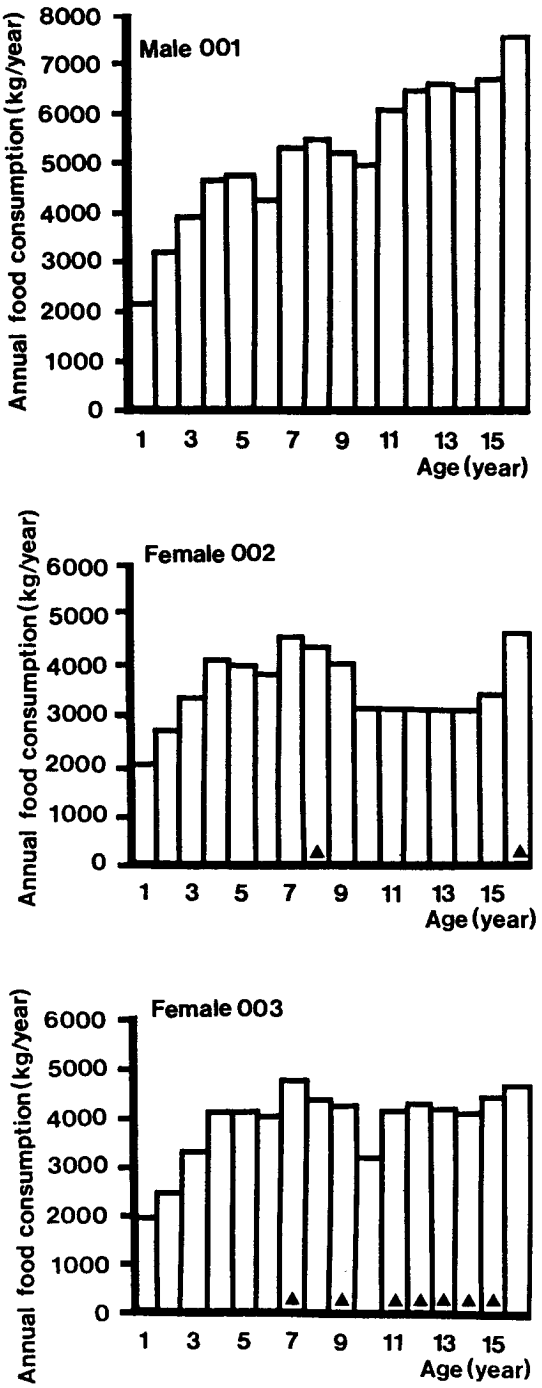

Figure 1. The annual food intake of one male and two female Steller sea lions. A triangle indicates a year during which birth took place. Age 1 represents the first calendar year after the year of birth.

random throughout the year. They cannot always be related to events such as birth or illness with certainty.

Stomach capacity

The maximum food intake, after a day of fasting, is shown in Figure 6. In both sexes, older animals seem to have relative large stomach capacities.

Discussion and Conclusions

Age related changes and sexual differences

Some differences in food intake between animals of the same age, when expressed as kg per day, may be partially due to changes in diet composition. Different species of fish can have a different energy content per unit of weight, and 2 fish of the same species can also show a difference in nutritional or calorific value depending on the season and geographical area in which the fish was caught. The diet of Steller sea lions in the wild is not limited to a few prey species. They eat a variety of prey, including relatively shallow water fish (less than 180 m), squid, shellfish and crustaceans, depending on the geographical area and the availability (Mathisen *et al*, 1962; Fiscus and Baines, 1966).

Unfortunately the weight changes of the animals in this study could not be recorded, because the Steller sea lions' aggressive behaviour makes them difficult to weigh. Fiscus (1961) reported on the total body length and girth measurements (behind the fore flippers) of Steller sea lions taken in Alaska. Bryden (1972) derived growth curves of male and female Steller sea lions by using only the standard length given by Fiscus (1961). These growth curves can be improved by also taking the girth into account. By calculating the surface area of the cross section at the place where the girth was measured and by multiplying this with the body length, a relative volume scale (which corresponds approximately to a relative weight scale) can be derived from these data. Data on the average weight of adult males and females (Calkins and Pitcher, 1982) were included to make this calculated weight scale more realistic (Fig. 7). Although the study was done on only a few specimens, the data show that the males continue to grow steadily up to the age of 12 years. Thorsteinson and Lensink (1962) studied Steller sea lions in Alaska and found that males are sexually mature when 6 or 7 years old, but that they are physically unable to compete successfully for harems until they are approximately 10 years old. Males older than 12 years probably have problems defending their territories because their canine teeth begin to wear out. So in the wild, male Steller sea lions are probably sexually active for only a few years. Between the ages of 4 and 7 the monthly food intake of the male in the

Table 2. The range of average daily food consumption (taken over one year) of a number of Steller sea lions of certain ages. N = the number of animals recorded

Age (yr)	Range average food consumption males (kg/day)	N	Range average food consumption females (kg/day)	N
1	4.3–5.8	4	4.0–5.8	6
2	5.8–10.4	3	6.7–7.4	5
3	10.7–12.2	2	8.1–9.1	4
4	12.6–12.8	2	8.7–11.3	4
5	12.9	1	9.7–11.1	3

present study started to fluctuate. This corresponds with the age of maturation observed in the field.

Figure 7 shows a large difference in calculated body weight between males and females. The sexual difference in food intake of the present study (Fig. 1) corresponds well with this sexual dimorphism. Although no data is available on the females' weight from their 2nd to their 8th year, it can be said that they stop increasing in weight around their 9th year at the latest (Fig. 7). Spalding (1964) noted no further increase in female body length after their 8th year. Comparison of the food intake of the non-reproducing female 002 with that of the lactating and pregnant female 003 between their 10th and 15th years of age shows a difference in annual food intake of approximately 1000 kg. The annual food consumption of female 003 dropped about 1000 kg during her 10th year when she did not give birth and was not lactating. Her food intake did not drop during her 16th year of age, when she was not pregnant. However, her last pup, although readily consuming whole fish, was still suckling strongly, which he continued to do for eighteen months after he was born. Although based on food records of only two females, it seems clear that reproduction requires an annual food consumption increase of approximately 30%. Keyes (1968) suggested that captive, adult, non-pregnant, non-lactating Steller sea lions require 1.6–3% of their body weight in food per day, and that growing, pregnant, or lactating sea lions require more food. The present study shows that one cannot generalize between sexes, that only growing females require more food than non-reproducing adult females, and confirms and quantifies an increase in food consumption during pregnancy and lactation in a particular environment.

Seasonal changes

The seasonal reduction in food intake of the adult male (EjZH001) coincides with the breeding season, which is between the end of May and the end of July (Mathisen 1962; Pitcher & Calkins, 1981; and Schusterman, 1981). Territorial male Steller sea lions do not leave their territory during the breeding season, in contrast to the females who periodically leave the rookeries and go to sea (Orr & Poulter, 1967). Olesiuk (1987) showed that the male Steller sea lions start to fluctuate in weight during the year when they become sexually mature. He reported an average weight of 750 kg for a number of adult males which were weighed between March and April. The average weight of a number of adult males from the same colony was 493 kg when weighed between October and November, after the breeding season. The food intake of the male in the present study started to fluctuate between his 4th and 7th year, when he became sexually mature. The resulting changes in body weight can only be confirmed by qualitative observation and not by quantitative measurements because the animal could not be weighed. The storage of fat in males seems to have a clear advantage. The longer a male Steller sea lion can go without food to hold his territory, the more females he can impregnate, and the more offspring he can produce. The reduction in food intake in the male Steller sea lion in the present study is associated with an increase in aggressive behaviour. Because the present study shows that the changes in food intake are independent of food availability, and coincide with an increase of aggressive behaviour, it seems likely that this seasonal food intake fluctuation is controlled by an endogenous rhythm in which testosterone is involved.

A similar monthly fluctuation in male food intake and resulting weight changes has been described in two other species of sea lions. Spotte and Adams (1979) report on the food intake and weight change of two 7-year-old male Northern fur seals (*Callorhinus ursinus*) in human care. They show a reduced food intake during the summer; between May and October. This corresponds to breeding activity in the territories between May and August. In the wild, the males of this species ordinarily fast, and show a visible weight loss during this period. Rand (1959) observed an increase in body weight in South African fur seals (*Arctocephalus pusillus*) before the breeding season

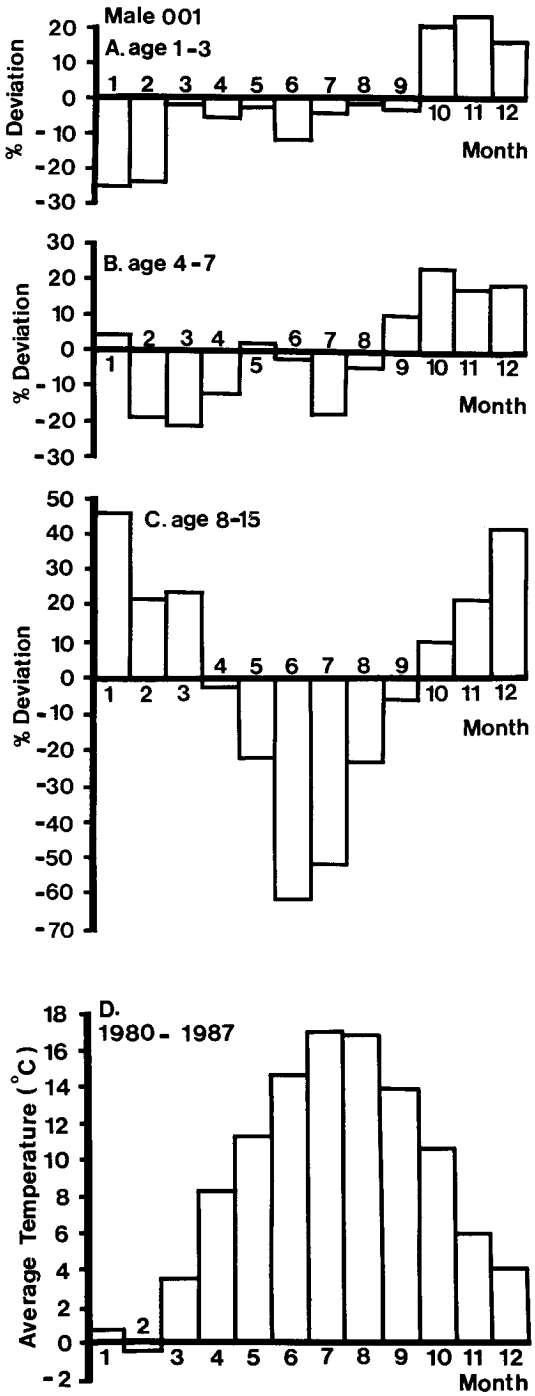

Figure 2. The deviation (%) of the average monthly food consumption of male Steller sea lion 001; (A) between age 1–3, (B) between age 4–7, (C) between age 8–15, and (D) the average monthly temperature at the Harderwijk Park between 1980 and 1987.

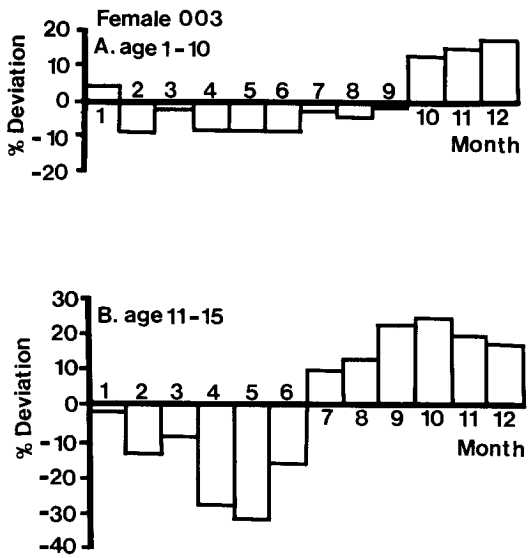

Figure 3. The deviation (%) of the average monthly food consumption of female Steller sea lion 003; A) between age 1–10, and B) between age 11–15.

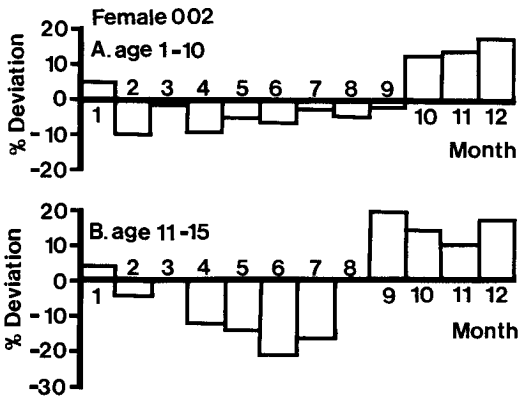

Figure 4. The deviation (%) of the average monthly food consumption of female Steller sea lion 002; (A) between age 1–10, and (B) between age 11–15.

and a loss of weight during the breeding season. Schusterman and Gentry (1971) reported on the seasonal fattening of California sea lions (*Zalophus californianus*) in human care, which increased in weight before the onset of the breeding season when they became mature at 5 years of age. This seasonality became more prominent when the animals reached full maturity. The suggestion is put forward that this cyclic weight change might be hormone-dependent.

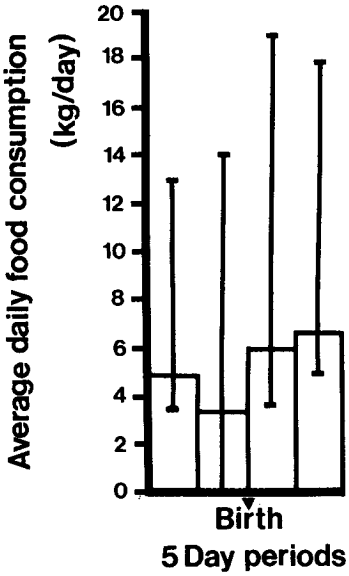

Figure 5. The average daily food intake over 5 day periods around 7 births of pups from female 003. The vertical bars indicate the minimum and maximum values.

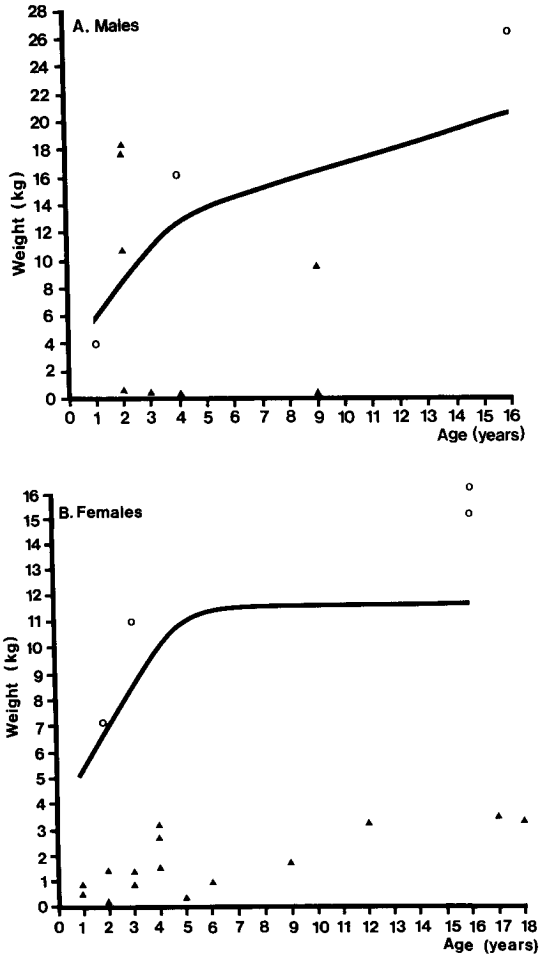

Figure 6. The lines indicate the average daily food requirements (taken over a year) of males (A) and females (B) in the present study.

Circles indicate the maximum food intake after a day of fasting of animals in the present study, and triangles indicate the weight of undigested food found in stomachs of 23 Steller sea lions taken at sea (derived from Fiscus and Baines, 1966).

The adult females in this study show a less dramatic monthly food intake fluctuation than the adult male. This might be because females in the wild go to sea during the breeding season and probably feed during that period. Female 003 usually gives birth in June and copulation takes place soon after birth, which is normal in Steller sea lion cows. Also her energy requirements change during the year. Between January and July she carries a growing foetus, while from August to December she carries a very small foetus and also has to suckle her pup. It seems plausible that suckling and simultaneously nourishing a small foetus requires more energy than nourishing a foetus during its last 6 months, when there is no pup suckling.

Apart from hormonal influences and changes in energy requirements due to reproduction, seasonal temperature changes may also influence the food intake of Steller sea lions. In the present study, the male especially eats less when the temperature is high (Fig. 2D). During this season the animal would not require such a well-insulating fat layer to maintain an internal body temperature of 37°C. In the wild, the males lose less energy through conductance during the breeding season, because they spend very little time in the water, a medium which conducts heat 25 times more efficiently than air.

Perinatal changes

The reduction in food intake during the last 5 days pre partum may be due to a hormonal change that, in the wild, urges the female to look for a suitable place to give birth (Sandegren, 1970). The females in the Harderwijk Park started to eat normal amounts of food immediately post partum. This does not occur in the wild, where females stay beside their pup for 5 to 13 days post partum (Sandegren, 1970). Possibly

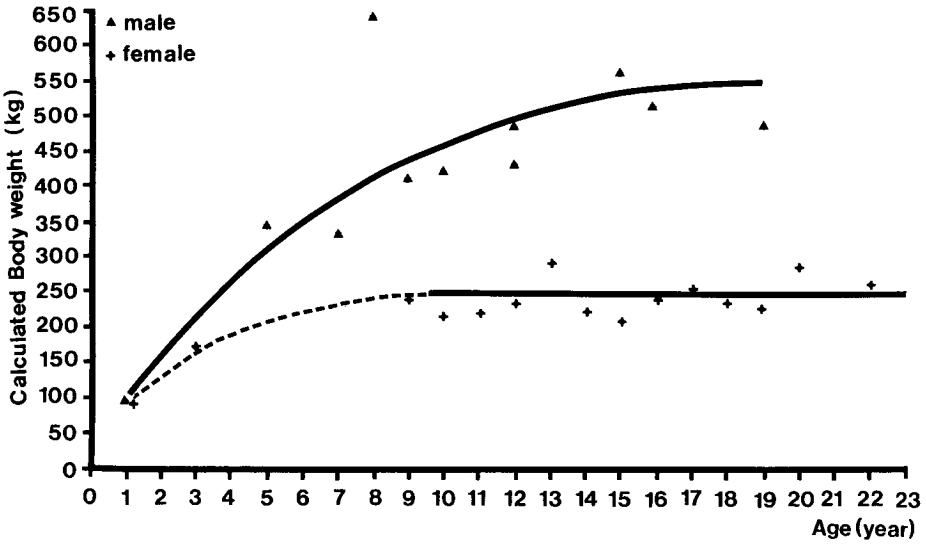

Figure 7. The calculated weight of male and female Steller sea lions of different ages (derived from length and girth measurements from Fiscus, 1961 and from average weights of adult males and females from Calkins and Pitcher, 1982).

they stay on land to protect the pup, and to establish a mother-pup bond. These activities can continue without the mother fasting in the Harderwijk Park since the animals are hand fed. Therefore, the post partum fasting, as observed in the wild, may not be determined by endogenous factors.

Stomach capacity

The few data of this study seem to indicate that older animals have a relative large stomach volume compared to stomachs of younger animals. This might be related to the fact that the sexually mature animals go through (breeding) periods with a low food intake, and later have to eat much to re-gain their weight.

Fiscus and Baines (1966) report on the stomach contents of 23 Steller sea lions. These animals were taken at sea, so that the food they had consumed was still undigested. The weight (expressed in kg, which is nearly equal to volume in dm^3) of the food found in the stomachs of 8 males and 15 females is presented in Figure 6. The amount of food found in the stomachs of the females (Fig. 6B) was roughly one fourth of the average daily food requirement seen in this study (also taken over the whole year). This seems reasonable since the animals in the field study were taken at sea, and this might have taken place when only a portion of their daily feeding time was over. One 2-year-old male, weighing 191 kg, had his stomach filled to near maximum capacity, and it contained 1280 Capelin (*Mallotus villosus*), weighing 18.05 kg (Fig. 6A). This was 9.4% of the animal's body weight. Fiscus and Baines (1966) do not report their age determination technique, but comparing the weight of this presumed 2-year-old male with the weight of 2-year-old males in Figure 7, and comparing its stomach capacity with data from the present study, its seems likely that the animal was 3–4 years old instead of 2 years. Two and three year old Stellers are extremely difficult to differentiate on basis of their morphology. Comparison of the stomach capacities found in the present study and in the field, with the mean food consumption per day in this study (taken over the whole year) indicates that older animals can take much more food during one feeding than their daily food requirements. This suggests that, in the wild, these animals may not eat every day, and/or that food is not always abundant enough to fulfil their daily requirements. Few other data on stomach capacities are published. Thorsteinson and Lensink (1962) report on large quantities of stones, up to 10 kg, found in stomachs of Steller sea lions. The reason for the intake of stones in unknown. Wilke and Kenyon (1952) describe a female with 9.1 kg of fish in its stomach in addition to 4 stones. Evermann (1921) reports on a Steller sea lion with 17.5 kg of fish in its stomach. Unfortunately the age and sex of the animal were not recorded. However, this agrees with the suggestion that wild Steller sea lions will eat to excess when they find food, since the adult male in the present study eats on average 18 kg per day at the age of 15 years.

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