The Feeding Cycles of Northern Fur Seals

Not all marine mammals are strictly marine. For example, while cetaceans (whales, dolphins, and porpoises) live entirely in an aquatic environment, pinnipeds (seals, sea lions, and walruses) maintain important ties to the terrestrial world. Although they spend most of their lives at sea and feed there exclusively, pinnipeds require land or ice for rearing their young.

Female pinnipeds have evolved two alternative strategies to deliver milk to their pups on land while the food they need to maintain themselves and produce milk is at sea. First, among the phocids or true seals (such as harbor seals and elephant seals) the females store large reserves of fat prior to coming on land and giving birth. Once the pup is born, the mother stays onshore nursing her pup and fasts until the pup is weaned. Time between birth and weaning among true seals is relatively short, lasting from only 4 days in hooded seals, to up to 6 weeks in ringed seals.

On the other hand, the otariids or eared seals (fur seals and sea lions) take a different approach. Rather than fattening up for one intensive marathon stay onshore, the otariid female alternates her nursing time onshore with feeding trips to sea, during which time the pup remains onshore fasting until the mother returns to nurse it. This strategy is characterized by longer periods of lactation than occur among phocids, lasting from 4 months in northern fur seals to up to 2 years in Galapagos fur seals. This period of postnatal maternal care is a crucial element in the overall reproductive success of otariid seals.

In order to improve our understanding of the otariid reproductive strategy and how it is affected by environmental variability, scientists of the National Marine Mammal Laboratory (NMML) have focused considerable effort on studying the feeding cycles of northern fur seals. In general, feeding cycles are monitored either by visual observations or by instruments attached to the animal, which record location, time, and diving behavior. Recently, another method has been employed to study feeding cycles of female fur seals. This method takes advantage of a natural record-keeping system within each seal--the teeth.

Throughout mammals' lives, a tissue called dentin forms in the pulp canal of the teeth. Variation in both the rate at which dentin forms and in the degree to which it is mineralized affects the teeth's appearance. Moreover, because teeth, unlike bone, do not decalcify during times of physical stress, any patterns which emerge due to this differential growth remain forever recorded in the teeth.

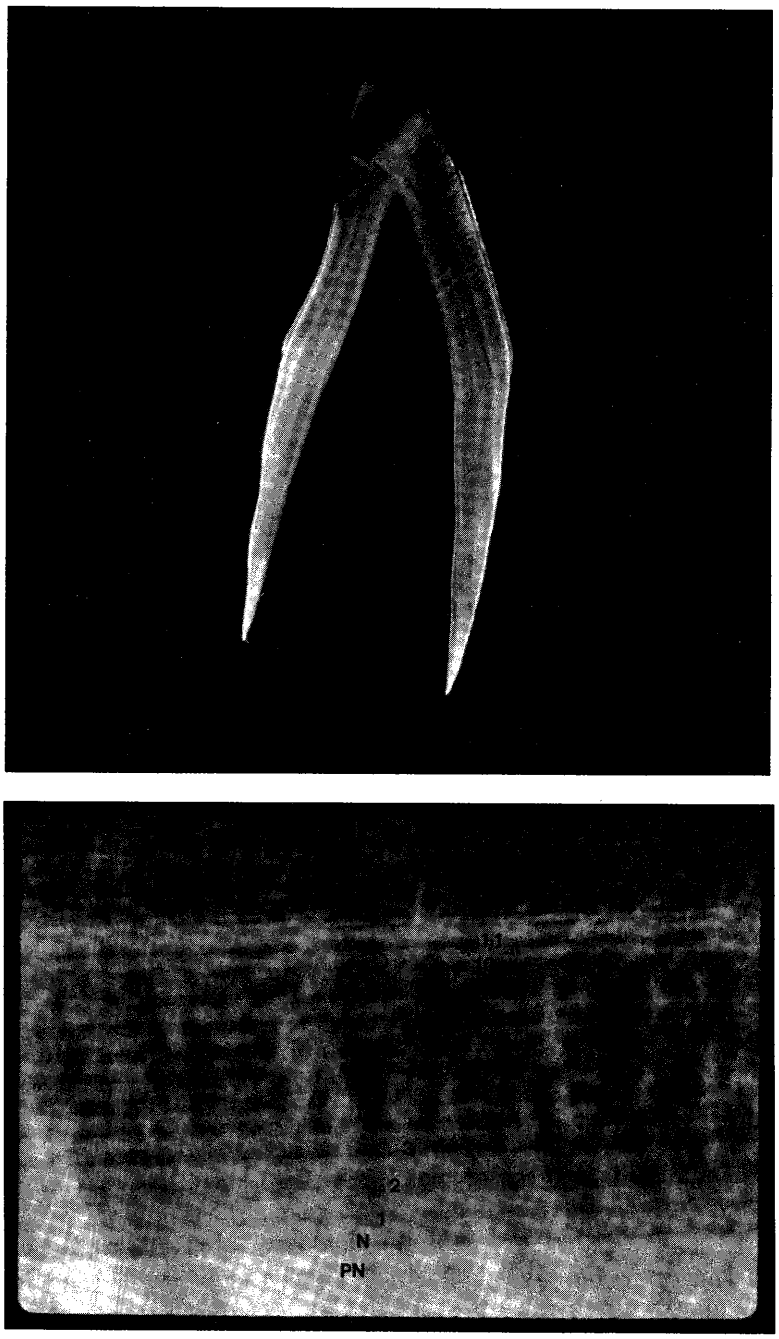

Figure 1. Upper photograph shows longitudinal thin section of a 3-year-old male northern fur seal's upper right canine tooth. Lower photograph shows nursing lines in the dentin of a 3-year-old male's tooth. Prenatal dentin (PN) and the neonatal line (N) are shown. Eleven nursing lines were counted in the tooth. Note that the last line counted (11) is the weaning line which is the last in the series of distinct and evenly spaced nursing lines.

By decoding information recorded in teeth, much can be learned about animals' lives. For example, most mammals that live in seasonal environments grow at different rates during different times of year. This cycle is manifested in teeth in such a way that the age of the animal can be estimated simply by counting annual growth lines in teeth, just as trees are aged by counting growth rings.

In addition to yearly patterns, teeth record smaller-scale events, as well. When a fur seal pup is born, its canine teeth, still embedded in the gums, are like thin, delicate, hollow cones. Prior to birth, some dentin forms in the teeth, followed by a distinct "neonatal line" formed at birth. For a week or so, the newborn pup is suckled by its mother who remains with it on land. Following this, the mother embarks on a feeding trip to sea, which lasts from a few days to over a week. Since females only feed their own pups, the pup remains fasting onshore during its mother's absence. When she returns, the mother spends 1-2 days nursing her pup before returning to sea again. This feeding pattern continues until the pup is weaned. During this time, the abruptly alternating cycle of feast and famine is recorded as a permanent pattern of distinct growth lines, called "nursing lines," in the dentin of the pup's teeth, representing the entire lactation period.

In 1990 the NMML initiated research on teeth to investigate the feeding cycles of northern fur seals on their main breeding site, St. Paul Island in the Pribilof Islands, Alaska. Beginning in the late 1940s, federal biologists began collecting fur seal teeth to determine the ages of male juveniles harvested on the island for their pelts. As a result, the NMML has a collection of thousands of northern fur seal teeth. Thin sections cut from the canine teeth of about 200 three-year-old male fur seals born during 1949-81 were examined under a microscope with transmitted polarized light. By counting the nursing lines, NMML staff were able to determine how many feeding trips the mothers made when the males were pups (Fig. 1). In this way, trends in the

number of feeding cycles completed by females were characterized over a 33-year period.

A key objective of the NMML study was to determine whether the number of feeding cycles females complete while rearing a pup is sensitive to changes in prey availability. Previous research has shown that females' feeding trips are characterized by transit to foraging areas (up to 350 km from the rookery), followed by alternating feeding and resting periods before the mothers return to their pups. It has been suggested that female fur seals probably feed until they attain a certain physiological condition, upon which they return to nurse their pups. It has also been shown that the duration of mothers' visits to shore do not vary as much as their trips to sea. Accordingly, when more food is available, less time would be required to attain satisfactory condition; feeding trips would be shorter in duration, and shorter feeding trips should result in more feeding cycles completed between birth and weaning. Results of the NMML study on nursing lines in teeth support the hypothesis that, indeed, there is a relationship between prey availability and the number of feeding cycles.

The St. Paul Island fur seal population was at it highest recorded level in the early 1950s, with estimates of over 400,000 pups born on the island each year. During this time, the population is believed to have been at, or near, the carrying capacity of the environment. In order to reduce the population to a level they believed would produce the maximum sustained yield annually, managers initiated a large-scale kill of females in 1956. Subsequently, over 250,000 northern fur seal females were killed on St. Paul Island from 1956 to 1968.

Figure 2 shows how the number of nursing lines in teeth changed during the female harvest. The decreasing number of pups born on St. Paul Island indicates the effect of the harvest on the population. As females were removed from the population in large numbers (about 20,000 per year), the trend in the number of nursing lines increased. If females were competing for food, especially when the population was at its peak, the removal of large numbers of them might have lessened competition, thereby increasing the availability of prey per female. This situation presumably would have allowed females to make shorter, more frequent feeding trips and, consequently, to complete more feeding cycles. The increasing number of nursing lines during the years of the female kill (Fig. 2) is consistent with the prey availability theory described above.

Nursing lines in teeth were also analyzed in relation to a more direct estimate of fur seal prey availability. Northern fur seals are feeding generalists, choosing from a diverse menu of squid and small schooling fishes. However, walleye pollock (*Theragra chalcogramma*) is the single most important prey species eaten by female fur seals during the summer in the Bering Sea. The seals especially consume the fish spawned earlier the same year. Estimates of the number of 2-year-old pollock in the eastern Bering Sea for the years 1962-81 were used as an index of the abundance of pollock spawned 2 years previously. This pollock abundance index weakly (but significantly) correlated with the number of nursing lines in teeth. That is, the greater the number of pollock available, the more trips females completed.

Although there does seem to be a connection between abundance of walleye pollock and fur seal feeding cycles, the relationship between feeding cycles and prey availability, in general, is complex. Abundance trends of one species are not a reliable representation of the full spectrum of fur

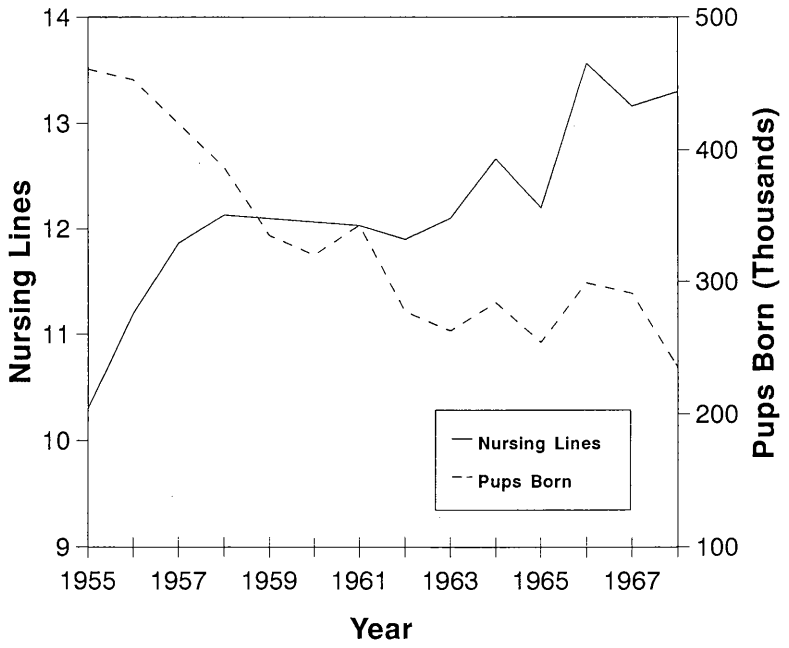

Figure 2. Trends in the mean number of nursing lines on northern fur seal teeth (smoothed by a running mean of 3) and the number of pups born during 1956-68.

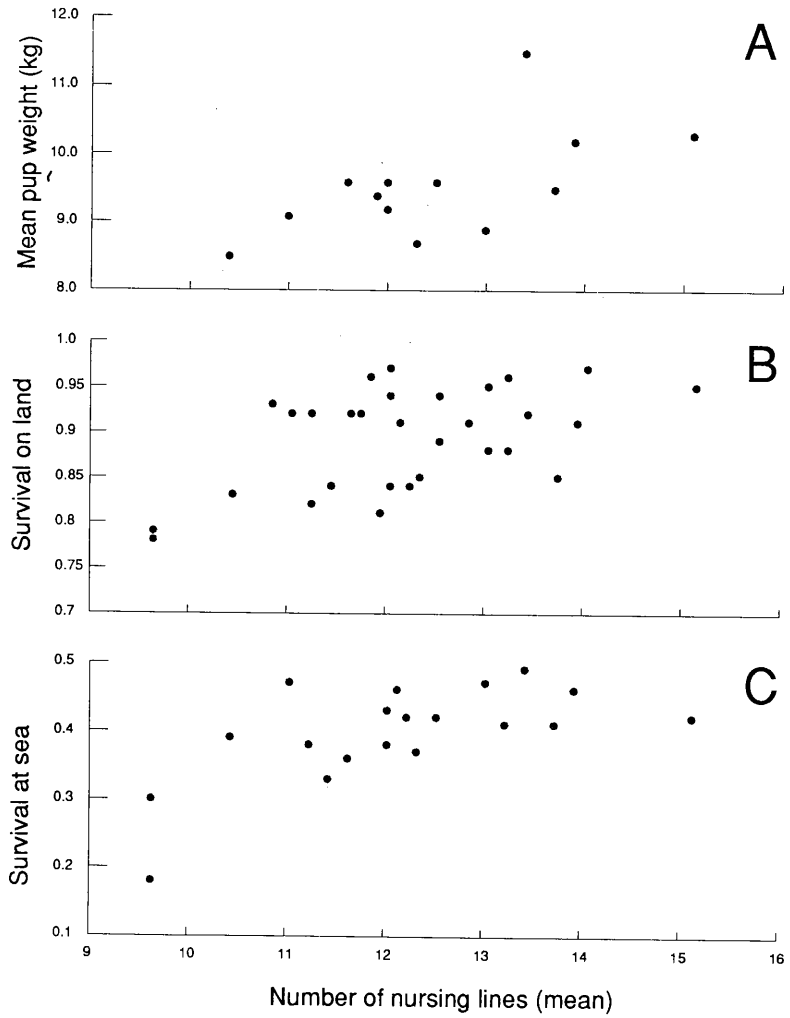

Figure 3. A) Mean weight (kg) of pups plotted against the mean number of nursing lines for years 1957-58 and 1961-71; B) Estimated preweaning survival rates on land plotted against the mean number of nursing lines for years 1950-81; C) Estimated postweaning survival rates during the first 20 months at sea plotted against the mean number of nursing lines for years 1950-70.

seal prey. Not only do fur seals prey on a wide variety of species, but their prey varies greatly in age and size, as well as in temporal and spatial distribution. However, the pollock analysis and the trend in nursing lines during the female harvest do provide evidence that feeding cycles are sensitive to changes in food availability.

The discussion above suggests that prey availability affects a measurable aspect of fur seal behavior. But what are the implications of this, if any, for the dynamics of the fur seal population? Figure 3a plots the mean weight of male pups for several years against the mean number of nursing lines in teeth from the same years. There is a significant trend indicating that in years when pups were fed more frequently, they grew larger. We know that larger pups, presumably with more accumulated fat reserves, stand a better chance of survival. A link between feeding cycles and survival of pups is supported in Figure 3b and 3c, which show a significant correlation between the number of feeding cycles completed and pup survival rates until weaning, and from weaning through the first 20 months at sea.

The period of lactation is a crucial element in the overall reproductive success of the female fur seal. It is her chance to prepare her offspring for the difficult transition to independence. Over half the pups who enter the cold waters of the Bering Sea in late autumn will perish during their first winter. The relationships between numbers of nursing lines and prey availability, pup weight, and pup survival indicate that the more times a female returns to nurse her pup before weaning, the better are the pup's chances. Because they reflect trends in prey availability and correlate with pup survival, nursing lines in teeth may prove to be a useful tool for monitoring important life history events in pinnipeds.

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