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Food consumption of a captive female killer whale (*Orcinus orca*)

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Abstract

This report is on the food consumption of a captive female killer whale between 1978 and 1996 (estimated age 3–21 years), while she was at 3 different zoological parks. The study is based on historical data collected for short-term husbandry purposes. The composition and caloric value of the diet sometimes varied from day to day. The food intake quantities should therefore be viewed as rough estimates of what wild, non-reproducing, female conspecifics might eat. Although differences in activity levels caused by social factors and changes in the caloric value of the food could have played a role, the whale's annual food consumption after the initial growth spurt appears to have been affected primarily by the water temperature in the pools. She ate less when the water temperature was increased, and more when it was decreased. When she was around 18 years old she was weighed and found to eat on average 3.6% of her body weight per day. Despite seasonal water temperature fluctuations at Windsor Safari Park, there were no obvious seasonal patterns in her food intake. She grew in length at least until she was approximately 19 years old.

Key words: energetics, killer whale, nutrition, odontocete, *Orcinus*, *orca*.

Introduction

Because relatively few killer whales (*Orcinus orca*) are kept at zoological parks and oceanaria, much less information about their food consumption has been published than is available for terrestrial mammals. Kastelein and Vaughan (1989) described the food consumption of a female killer whale at the Harderwijk Marine Mammal Park, The Netherlands. Kriete (1995) described the food consumption and metabolic rates of killer whales at Vancouver Aquarium, Canada, and Marine World Africa/USA. Kastelein *et al*. (2001) described the food consumption of 8 killer whales at Marineland Antibes, France. Information on food consumption of toothed whales could be useful to personnel at zoological parks that keep odontocetes, so they can compare the food intake of their animals to a reference for husbandry or veterinary purposes. For the management of toothed whales in the wild, information on food consumption is needed to evaluate interactions between whales and fish populations. This report is on the food consumption of a female killer whale kept at 3 different parks.

Materials and Methods

Study animal

The female killer whale was caught in the waters around Iceland in 1978 and was estimated from her body length, body weight, and the general appearance of her skin, to have been born in 1974, 1975, or 1976. For the purpose of this study, the year of birth was assumed to be 1975, and age 1 represents the first calendar year after 1975. From 1978 to 26 October 1991, the study animal was housed at Windsor Safari Park, London, UK. After that date she was transported to Sea World of Florida, Orlando, USA. In April 1993, she was moved to Sea World of Ohio, Aurora, USA. This study is based on her feeding records between 1978 and 1996. She was healthy and not pregnant during the entire study period.

Study areas

At Windsor Safari Park, the killer whale was kept outdoors in a main pool (26 m × 14 m; depth 3.5 m) and a side pool (10 m × 7.6 m; depth 3 m). She shared these rectangular pools with up to 9 bottlenose dolphins (*Tursiops truncatus*). During the study animal's 10th and 11th years, a male killer whale (estimated to be 7 years old, 432 cm long and with a body weight of 1200 kg) was also in the pool system. During the year, the salinity varied between

2.2 and 3.4% NaCl, and the average monthly water temperature varied between 15.1°C in winter and 21.2°C in summer (when the temperature dropped below 14°C, the water was heated). In years when bottlenose dolphin calves were present in the pools (1985 and 1986), the water temperature was maintained above 17°C. The average annual air temperature was 10.7°C (the average monthly air temperature varied between 4.3°C in January and 17.7°C in July). Windsor Safari Park is at 0°39′W and 51°29′N.

At Sea World of Florida, the study animal was kept in an outdoor pool system consisting of a main pool (50 m diameter; depth 12 m) and 2 small pools (each 21 m × 19 m; depth 5 m). These pools were connected to a breeding and research pool (31 m × 21 m; depth 5 m) via 2 examination pools (each 12 m × 6 m; depth 4 m; Asper *et al.*, 1988). She shared these pools with up to 6 other killer whales. The average water temperature was 13.5°C (range 13–14°C) and the salinity was kept at 3% NaCl. The average annual air temperature was 24.0°C (the average monthly air temperature varied between 19.4°C in January and 27.9°C in August). Sea World of Florida is at 81°W and 29°N.

At Sea World of Ohio, the study animal was kept in an outdoor pool system consisting of a main pool (30 m × 15 m; depth 5–9 m; volume 4000 m^3) and 2 circular side pools (each 12 m diameter; depth 3 m) which also were connected to a hexagonal examination pool (22 m diameter; depth 4–5 m). In these pools she was kept with 2 young female killer whales and 3 female Pacific white-sided dolphins (*Lagenorhynchus obliquidens*). During the year the water temperature was on average 13°C (ranging from 12.7°C in January to 14.7°C in August) and the salinity varied between 3.0 and 3.2% NaCl. The annual average air temperature was 9.9°C (the average monthly air temperature varied between − 2.8°C in January and 23.3°C in July). Sea World of Ohio is at 81°W and 41°N.

Food

At Windsor Safari Park, between 1978 and October 1991, the study animal was fed 3 to 7 times per day on an average diet of 85% herring (*Clupea harengus;* approx. 8880 kJ/kg), 9% whiting (*Merlangius merlangus;* approx. 4750 kJ/kg) or squid (*Illex* sp.; approx. 1000 kJ/kg), 5% sprat (*Sprattus sprattus;* approx. 10.400 kJ/kg) and 1% boiled lamb or pig liver. The percentages are based on weight. Vitamins (Aquavits®) and iron tablets were added to the thawed fish. The animal was allowed to eat as much as she wanted during the last meal of the day; feeding was stopped when she lost interest or played with the fish.

At Sea World of Florida, between October 1991 and April 1993, the animal was fed a varying number of times per day. On average, her diet consisted of 30% herring, 35% capelin (*Mallotus villosus*), 32% smelt (*Osmeridae* species) and 8% mackerel (*Scomber scombrus*). The percentages are based on weight. At Sea World of Ohio, between April 1993 and December 1995, the animal was fed a varying number of times per day. On average, her diet consisted of 46% herring, 28% capelin, 15% smelt, 10% mackerel and 1% salmon (*Salmo* spp.). At both Sea World parks, Multi-vitamins (Mazuri® and Sea World© Marine Mammal Vitamins) were added to the thawed fish. The amount of food given depended on the estimated weight of the animal (based on length and girth measurements) and her appetite. Because the animal was still growing in length, her food was adjusted so she also would grow in weight.

Daily food records, originally collected for short-term husbandry purposes, form the basis of the present study. The composition and caloric content of the fish and squid species were not measured at 2 of the parks, but probably varied per year class of fish, seasonally and per location where the fish was caught. For the analysis, the total amounts per month and per year were used. To roughly estimate the energy used by the animal, the food intake at Windsor Safari Park was calculated in kJ using average values for the fish species supplied by The Netherlands Commodity Board for Fish and Fishery Products.

Results

Annual food consumption

The female killer whale was estimated to be 3 years old on arrival at Windsor Safari Park. During her 4th calendar year (1979) she consumed around 7000 kg of fish (Fig. 1). Her food intake increased to around 14000 kg during her 8th year, after which it decreased to around 12000 kg/year when she was 11 years old. Her low food intake during her 10th and 11th year coincided with an increase in water temperature to accommodate bottlenose dolphin calves in the same pool system, and with the introduction and later death of a killer whale pool mate. During her 12th year, the study animal's annual food intake increased greatly, but temporarily, to 17000 kg. This high food intake coincided with the return of the water temperature to the previous lower level. In her 12th year, she also was fed more than usual in an attempt to control her habit of regurgitation. This was a behavioral problem rather than a pathological one. She would regurgitate a small amount of food, play with it in her mouth and eventually swallow it. Between her 13th and 16th year her food intake was around 14000 kg/year. After her transport to Sea World of Florida in October 1991, her food intake increased

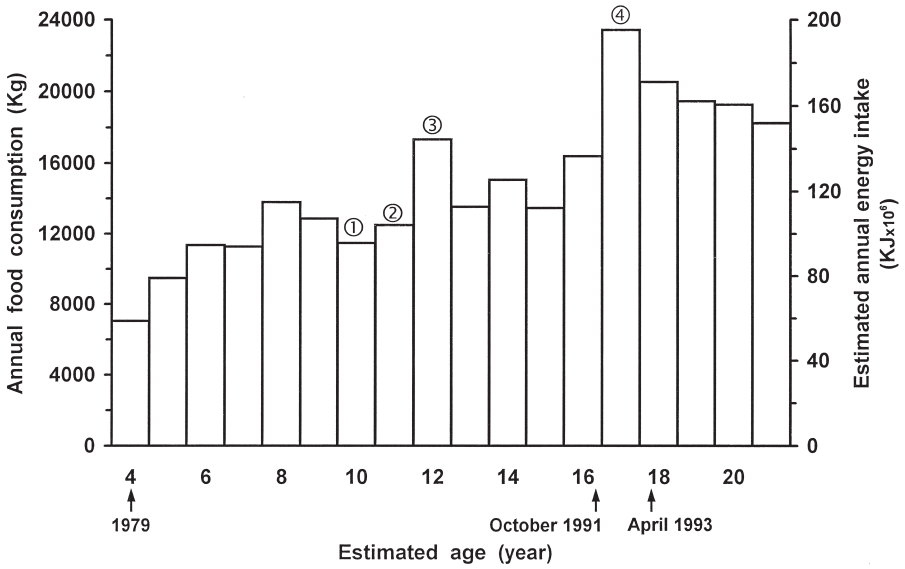

Figure 1. The annual food consumption of the female killer whale when at Windsor Safari Park (1979–October 1991), Sea World of Florida (October 1991–April 1993) and at Sea World of Ohio (after April 1993). Age 1 represents the first calendar year after the estimated year of birth. 1) low food intake coinciding with relatively warm water and the introduction of a male killer whale, 2) low food intake coinciding with relatively warm water and the death of the male killer whale, 3) high food intake coinciding with reduced water temperature and increased food given in an attempt to prevent regurgitation, and 4) high food intake coinciding with the first full year at Sea World of Florida, where the water was much colder than at Windsor Safari Park. The conversion of weight intake (left y-axis) to estimated energy intake (right y-axis) is based on the average energetic values for the fish species consumed.

strongly to 24000 kg/year during her 17th year. When she was moved to Sea World of Ohio (after her 17th year), her food intake dropped and stabilized at around 19000 kg/year.

Seasonal fluctuation in food consumption

The study animal's monthly food intake varied very little during the year, and no systematic seasonal pattern could be detected.

Body measurements and food intake relative to body weight

The animal was weighed only once in May 1993, at the age of 18 years. She weighed 1530 kg, had a standard body length of 441 cm and a girth in front of the dorsal fin of 296 cm. At this time, she consumed on average 56 kg fish per day or 3.6% of her body weight per day. Between May 1993 and July 1994, her standard body length increased from 441 cm to 474 cm.

Discussion

Annual food consumption

Although social factors (causing differences in activity level) and energy density of the diet could have played a role in food intake, water temperature appears to be the main factor influencing the food consumption of the study animal. She ate less than usual when the water temperature at Windsor Safari Park was suddenly increased. When the water temperature returned to the previous lower level, her food intake increased temporarily, perhaps because her blubber layer had become thinner in the warmer water. She could have lost more heat to her environment because of this, and might have eaten more to rebuild her blubber layer. Williams and Friedl (1990) showed that bottlenose dolphins adapt their thermal neutral zone (the water temperature range at which the metabolic rate is lowest) by varying blubber thickness; perhaps killer whales also can do this. During gradual seasonal changes in water temperature the blubber thickness can co-adapt gradually, whereas when an animal is moved to a pool with a different water temperature, or the temperature setting of pool water is suddenly changed, the blubber layer needs time to adapt. In this adaptation period, the food intake can increase or decrease depending on the direction of the temperature change.

When she arrived at Sea World of Florida, where the water temperature was cooled to be on average

3°C lower than at Windsor Safari Park, the animal's food intake first increased strongly and then dropped after a period of adaptation, but remained higher than when she was at Windsor Safari Park. As well as the change in water temperature, she experienced a change in diet at this age, which also could have influenced her food consumption. It seems unlikely that a difference in activity level was responsible for the increase in energy intake at Sea World of Florida. The study animal was small and very active at Windsor Safari Park, interacting strongly with the bottlenose dolphins. The same interspecies behavior was observed in a female killer whale at Harderwijk Marine Mammal Park (Kastelein and Vaughan, 1989). A larger pool does not necessarily result in a higher activity level, unless space previously limited an animal's swimming movements.

In general, the annual food consumption of the study animal was similar to that of killer whales of similar ages kept at Harderwijk Marine Mammal Park, The Netherlands (Kastelein and Vaughan, 1989), Marineland Antibes, France (Kastelein *et al*., 2001), and Vancouver Aquarium, Canada, and Marine World Africa/USA (Kriete, 1995).

The food consumption of the study animal increased at least until she was 17 years old (although the increase, at least partly, could have been caused by diet and water temperature changes). At Marineland Antibes, the food consumption of male and female killer whales continued to increase, at least until the age of 20 years (Kastelein *et al*., 2001). The body length of the study animal increased at least until the age of 19 years. This length increase corresponds to the duration of growth of wild killer whales, which reach physical maturity at the age of 20–25 years (Christensen, 1984). At the age of 18 years (body weight of 1530 kg), the study animal consumed a similar amount of food per day in percentage of body weight as other captive killer whales of the same body weight (Kastelein *et al*., 2001).

Seasonal fluctuation in food consumption

Like the animal in the present study, a female killer whale kept indoors at Harderwijk Marine Mammal Park did not have seasonal fluctuations in food intake (Kastelein and Vaughan, 1989). This suggests that the seasonal temperature changes experienced by both animals were within their thermal neutral zones.

Body measurements

Kastelein and Vaughan (1989) presented a formula to estimate the body weight of killer whales based on the standard body length and the girth in front of the dorsal fin ($W = L^2 \times G/44000$; in which W = the estimated weight in kg, L = the standard body length in cm, and G is the maximum girth between pectoral fins and the dorsal fin in cm). Using this formula, the estimated weight of the study animal in May 1993, when she was 441 cm long, would have been 1310 kg, 220 kg less than her actual weight. Bigg and Wolman (1975) gave a formula with which the body weight (W in kg) of killer whales can be estimated based on body length (L) in cm ($W = 0.000208\ L^{2.577}$). Using this formula, the estimated weight of the study animal in May 1993 would have been 1357 kg, 170 kg less than her actual weight. This suggests that either both formulas slightly underestimate the weight of female killer whales of this length, or the study animal was slightly overweight at the time of measurement. The latter seems to be the case, when her body length-body weight relationship is compared to other captive killer whales (Kastelein *et al*., 2001).

Ecological significance

To predict the amount of food killer whales consume in the wild, information is needed on their natural diet, activity level, and water temperatures they encounter.

Around 30 species of fish have been found in the stomachs of wild killer whales in various parts of the world (Hoyt, 1990). Therefore, it is impossible to say whether their diet in the wild generally has a higher or lower calorific value than the diet of the killer whale in the present study. The diet of wild killer whales probably depends on the individual, season and geographic area, and could vary from one year to another, depending on fish stocks. In addition to fish, 13 odontocete, 9 baleen whale, 14 pinniped, 1 mustelid, 9 bird, 1 turtle, and 2 cephalopod species have been reported to be eaten by killer whales (Hoyt, 1990; Silber *et al*., 1990).

Killer whales have a large geographical range, and individuals are likely to encounter wide temperature ranges. Therefore, this species probably has a large and possibly flexible thermal neutral zone.

The amount of time wild killer whales spend foraging probably depends on the availability of prey, the animal's ability to catch prey, its age, the geographical area, and the season. When salmon (*Oncorhynchus* spp.) are plentiful, killer whales off Alaska spend a great deal of time investigating boats, perhaps because finding prey and feeding takes up less of their time than usual (Hall, 1986). Although the animal in the present study was active most of the time (she swam day and night), she could not dive as deep as wild conspecifics often do when foraging. Therefore, non-reproductive wild female killer whales probably consume more than the animal in the present study and other captive conspecifics (Kriete, 1995).

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