

# A note on food consumption and growth of common dolphins (*Delphinus delphis*)

R.A. KASTELEIN, G.J. MACDONALD\* AND P.R. WIEPKEMA<sup>†</sup>

Harderwijk Marine Mammal Park, Strandboulevard Oost 1, 3841 AB Harderwijk, The Netherlands

Contact e-mail: r.kastelein@dolphinarium.nl

## ABSTRACT

Food consumption, body weight and body length were recorded in four female common dolphins (*Delphinus delphis*) at Marineland of New Zealand between 1974 and 1996. The study is based on historical data that were recorded 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 weight estimates of what wild conspecifics might eat (depending on their diet). Annual food intake of two dolphins increased to 3,300kg at around 12 years of age, after which it decreased, stabilising at around 2,200kg between the ages of 16 and 25 years. Annual food intake of the other two animals increased to 2,700kg at six/seven years of age, then declined and stabilised at around 2,100kg between the ages of seven/eight and 12 years. The weights of two of the animals were first recorded at the ages of seven and eight years. During the following 19 years, their body weight gradually increased by about 15kg. The other two animals grew from around 57kg at the age of two/three years to about 100kg at around 12 years of age. The two animals grew much in length when they were between two and eight years old. The other two animals appeared to have reached asymptotic length by 18 and 19 years of age when their length was measured for the first time. As body weight increased, daily food consumption as a percentage of body weight decreased. At a body weight of around 60kg, the dolphins consumed the equivalent of around 12% of their body weight per day. When body weight had reached around 100kg, daily consumption had fallen to around 6% of body weight.

KEYWORDS: ENERGETICS; FEEDING; NUTRITION; MORPHOMETRICS; COMMON DOLPHIN; CAPTIVITY

## INTRODUCTION

The common dolphin (*Delphinus delphis*) is found worldwide in temperate, tropical and sub-tropical seas. In those areas, it is present along most coasts over the continental shelf, roughly along the 200-300m isobath, or over prominent underwater topography such as the mid-Atlantic Ridge and sea mounts (Evans, 1994). Common dolphins feed on a wide variety of squid and fish species, particularly schooling fish such as sardines, anchovies, herring, mackerel and pilchards (Fitch and Brownell, 1968; Ross, 1984; Major, 1986; Overholtz and Waring, 1991; Gaskin, 1992; Evans, 1994; Kuiken *et al.*, 1994; Osnes-Erie, 1995). The diet varies seasonally and geographically (Evans, 1994). Herds frequently cooperate in prey capture; for example, they may dive below a school of fish to drive it to the surface. Common dolphins have also been reported to catch fish in mid-air. Off southern California, they feed mostly nocturnally, on organisms associated with the deep scattering layer, which rises at night (Gallo, 1991; Evans, 1994). Dives of up to 260m and eight minutes have been recorded (Evans, 1971).

Although this is one of the most widely distributed cetacean species (Gaskin, 1992) and much is known about its foraging habits, no information exists on its energetic requirements. Such information can, to some extent, be derived from studies of captive animals. However, the common dolphin is a species that has seldom been maintained in captivity (Evans, 1994), and no quantitative information is available in the literature on its food intake requirements. Marineland of New Zealand has kept four female common dolphins over a long period of time, and collected data on their food consumption, body weight and

body length. However, it should be stressed that these data were not collected as part of a long-term experiment to estimate the energetic requirements of common dolphins.

Records of food consumption, body weight and length in toothed whales kept in captivity may be of interest to other zoological institutions that keep the same species, providing a reference for veterinary and husbandry purposes; the records may also be used to estimate the relationship between wild individuals and their prey populations.

Given the lack of data available on the common dolphin, this paper summarises the available data for the four Marineland specimens.

## MATERIALS AND METHODS

### Study animals and measurements

The four female common dolphins used in this study were caught in Hawke Bay, North Island, New Zealand. The birth date of each animal was estimated from body length (based on the age-body length relationship of seven male and one female common dolphin caught in the eastern tropical Pacific as reported by André *et al.* (1990); it should be noted that the study animals came from a different population), weight, condition of the teeth and general body condition (Table 1). These estimates are believed to be fairly accurate for animals 003 and 004, as the animals were young and were measured on arrival. However, the age estimates for animals 001 and 002 are less accurate since the animals were not measured on arrival. Their ages may be overestimated by one to two years. Age one represents the first calendar year after the estimated year of birth. The number of body weight measurements per year increased during the study period from one per year in the beginning of the study to about five

\* Marineland of New Zealand, Marine Parade, P.O. Box 123, Napier, New Zealand.

<sup>†</sup> Emeritus Professor of Ethology, Wageningen Agricultural University, Stationsweg 1, 6861 EA Oosterbeek, The Netherlands.

Table 1  
The body length, body weight and estimated ages on arrival of the four female common dolphins at Marineland of New Zealand.

Animal	Body length (cm)	Body weight (kg)	Estimated age (year)	Estimated year of birth	Arrival date at Marineland
DdMNZ001	*	*	3	1971	13 Dec. 1974
DdMNZ002	*	*	4	1970	13 Dec. 1974
DdMNZ003	170	56	3	1984	27 Jan. 1987
DdMNZ004	162	57	2	1985	26 Jan. 1987

\* not measured on arrival

times per year towards the end. The data are insufficient to examine seasonal trends. The standard body length (straight line from tip of rostrum to notch of tail fluke) of each animal was measured three to four times between 1987 and 1997. None of the study animals reproduced during the study period as no males were present; hormone analyses were not conducted.

### Study area

The animals were maintained primarily in an outdoor pool system consisting of a main pool (30 × 15m, 4.1m deep) and an adjacent holding pool (9.2 × 9.2m, 2.3m deep). The animals had free access to both pools. The main pool was the location of the 2-3 daily shows. A second pool system, consisting of a round pool (15m diameter, 2.3m deep) and an adjacent holding pool (9.1 × 4.5m, 2m deep), was used during maintenance work on the main system. The dolphins had free access to both pools and shows were presented as usual. Maintenance work on the main pool was carried out in 1977, 1978, 1983, 1984, 1989, 1990, 1991, 1992, 1993 and 1995, generally in November. The water was pumped from the sea via feeder pipes laid under the seabed and wells on the beach front. The salinity was recorded from 1992 to 1996 and remained stable at around 35 parts per thousand. The average monthly water temperature from 1981 onwards varied from 11.1°C in June to 22.2°C in January. The average monthly air temperature at Marineland (1981-1996) ranged from 8.9°C in July to 28.4°C in February. Napier, the site of Marineland, lies on the east coast of the North Island, New Zealand (39°20'S and 176°56'E).

### Food

The study animals were fed primarily on a vitamin-enriched diet of defrosted fish. Until 1981, the enrichment consisted of a mixture of multi-vitamin tablets, vitamins A, B1 (Thiamine), C, E, K, kelp and cod liver oil. From 1981 this mixture was replaced by Sea Tabs (Pacific Research Laboratories, California, USA; these were later called 'Mazuri' Vita-zu). The diet consisted of a variety of fish species: jack mackerel (*Trachurus declivis*), barracouta (*Thyrsites atun*), Dutch herring (*Clupea harengus harengus*), king salmon (*Oncorhynchus tshawytscha*), yellow eyed mullet (*Aldrichetta forsteri*), tuna/albacore (*Thunnus alalunga*), sprat (*Sprattus antpodum*), gemfish (*Rexia solandri*), alfonsoino (*Beryx splendens*), pelagic cardinalfish (*Howella brodiei*), blue mackerel (*Scomber australasicus*), red gurnard (*Chelidonichthys kumu*), red cod (*Pseudophycis bachus/Phyculus bachus*), trevally (*Pseudocaranx dentex*), kahawai (*Arripis trutta*), hake (*Merluccius australis*), hoki (*Macruronus novaezelandiae*) and arrow squid (*Nototodarus sloanii*). Proportions varied, but jack mackerel and barracouta dominated the diet. When available (quite frequently in summer but infrequently in winter), the same species of fish were given fresh. The type

and amount of food eaten per feed was recorded for each dolphin; these historical 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, but probably varied per year class of fish, seasonally and depending on the location where the fish were caught. Given this variation, the total amounts per month and per year were used rather than attempting unreliable extrapolations based on unverifiable assumptions.

The animals were fed a fixed base ration each day, normally in three feeds. The base ration for each animal was monitored and, if necessary, adjusted weekly, on the basis of a number of factors including progress in training, speed at which the fish were swallowed and the animal's body weight.

## RESULTS

### Annual food consumption and growth

All ages reported in this study are estimated ages. Dolphin 001 showed an increase in annual food consumption from 1,800kg at four years of age to 3,300kg at 12 years of age. Thereafter, annual food intake gradually decreased, to stabilise at around 2,300kg at the age of 17 years (Fig. 1). Average annual body weight was stable between the ages of seven and eight years, after which it increased until the age of 11 years, then stabilised (Fig. 2). Between the ages of 18 and 26 years, standard body length showed little change (Fig. 3).

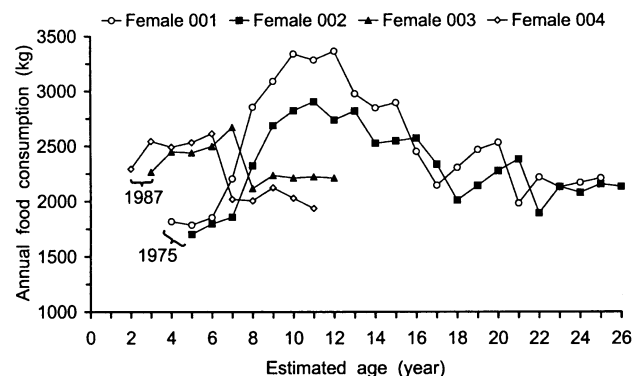


Fig. 1. The annual food consumption of four female common dolphins at Marineland.

Between the ages of five and 11 years, the annual food consumption of dolphin 002 increased rapidly from 1,700kg to 2,900kg, then gradually decreased, stabilising at around 2,100kg at the age of 18 years (Fig. 1). Average annual body weight increased gradually from eight to 26 years of age (Fig. 2). Between the ages of 19 and 27 years, there was little change in standard body length (Fig. 3).

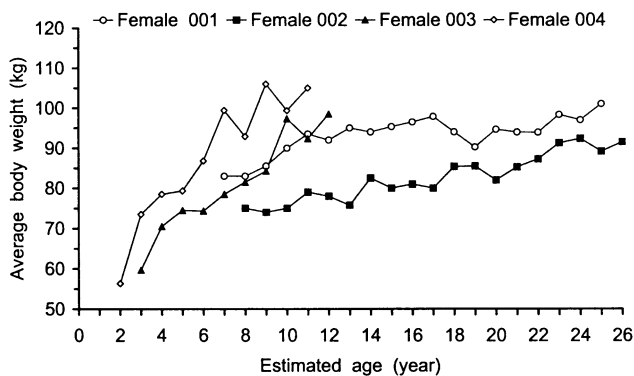


Fig. 2. Average annual body weight of four female common dolphins at Marineland ( $n = 1-5$  measurements per year).

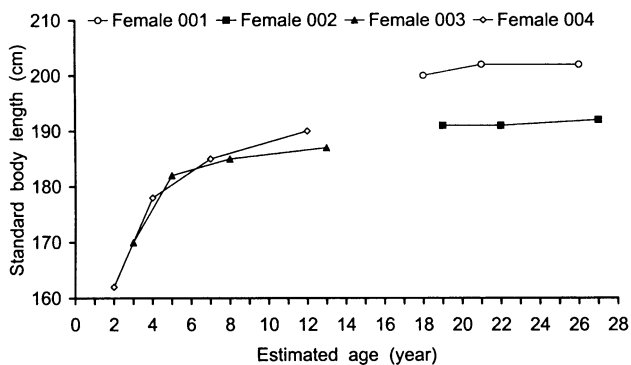


Fig. 3. Estimated age versus standard body length (single measurements per year) of the four study animals.

Dolphin 003 showed an increase in annual food consumption from 2,250kg to 2,700kg between the ages of three and seven years. Thereafter, annual food intake decreased rapidly and stabilised at around 2,200kg (Fig. 1). Between the ages of three and 12 years, her annual average body weight showed a gradual increase (Fig. 2). Standard body length increased greatly between the ages of three and five years, after which the growth rate decreased (Fig. 3).

Between the ages of two and six years, dolphin 004 showed an increase in annual food consumption from 2,300kg to 2,600kg. Thereafter, intake fell and stabilised at around 2,000kg (Fig. 1). Between two and 11 years of age, her average body weight increased gradually (Fig. 2). Standard body length increased much between the ages of two and four years, after which the growth rate decreased (Fig. 3).

During the course of a year, body weights fluctuated in all animals, but in years in which four or more weight measurements were made, these fluctuations were not seasonal.

**Body length-body weight relationship**

Based on the four study animals, the relationship (Fig. 4) between standard body length ( $L$  in cm) and body weight ( $W$  in kg) can be expressed as:

$$W = 7.5814 (L-140)^{0.5345}$$

**Food consumption as a percentage of body weight**

There is a negative relationship between body weight and average daily food consumption in the month in which the weight measurement was recorded as a percentage of body weight (Fig. 5). At around 60kg, the dolphins consumed, on average, the equivalent of around 12% of their body weight

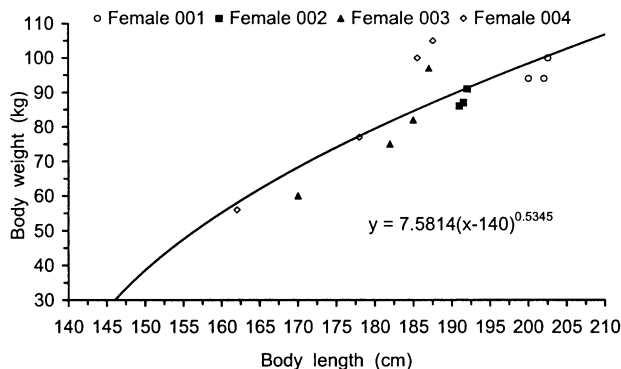


Fig. 4. The relationship between standard body length and body weight of the four study animals.

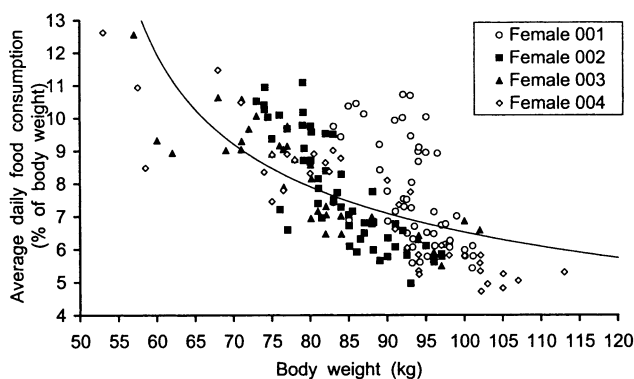


Fig. 5. The relationship between body weight and average daily food intake as a percentage of body weight for the four female common dolphins. Each point is the average daily food intake of the month in which the body weight was measured.

per day; this fell to an average of around 6% at a body weight of around 100kg. Dolphin 001 showed wide fluctuations around this pattern.

**DISCUSSION AND CONCLUSIONS**

**Annual food consumption**

As explained earlier, it was not possible to estimate food consumption in terms of actual caloric values. Weight of food per year is considered the most appropriate unit to use under these circumstances, given seasonal variation in the energy content of individual prey species and variation in the species composition of the diet.

Patterns in food intake and growth of the dolphins that arrived simultaneously were comparable. However, the intake of the first pair between the ages of four and seven years was lower than that of the second pair. While this could be due to natural variation, it may reflect a slow habituation to captivity by animals 001 and 002. During the first 2-3 years after arrival, these animals ate relatively little and their body weights showed little change. Animals 003 and 004 may have habituated faster to captivity in the presence of habituated animals 001 and 002 and due to the increased husbandry experience of the staff.

All four animals showed an initial increase in annual food intake, followed by a decrease and stabilisation. The maximum food intake in animals 001 and 002 was reached at 11-12 years of age, while the intake of animals 003 and 004 peaked at the ages of six and seven years. The high food intake of dolphin 001 between the ages of six and 12 years coincided with a period of strong weight increase,

suggesting extra food intake to fuel growth. Dolphin 002's food intake increased between the ages of seven and 11 years. However, her body weight did not increase greatly during that period and the extra food intake can therefore not be explained. The high food intake of dolphins 003 and 004 between the ages of two and seven years coincided with high growth rates (both in weight and length), suggesting that, as in dolphin 001, the high food intake fuelled growth.

The decline in food intake and reduction in growth rate in the present study occurred when the dolphins were between seven and 12 years old. This is around the age that growth curves of common dolphins in the wild reach an asymptote in most areas (André *et al.*, 1990; Ferrero and Walker, 1995) and the energetic requirements for growth are expected to decrease. The geographical distribution of the common dolphin is wide and regional variations in body size are large (Gühr and Pilleri, 1969; Evans, 1994; Ferrero and Walker, 1995). In the North Pacific, females are sexually mature at the age of approximately eight years, with an average length of 171cm and with a predicted asymptotic length of 179cm (Ferrero and Walker, 1995). Off southern California females mature at around seven to 12 years of age, at a length of between 165 and 182cm (Hui, 1979).

There are few available data on the relationship between age and body weight in common dolphins. The majority of studies of body weight used stranded animals, which are unlikely to be representative of healthy animals. A number of studies, however, relied on animals accidentally caught in fisheries and are thought to be more representative of healthy animals in a population. Although based on a sample size of only eight animals (seven of which were male), common dolphins in the eastern tropical Pacific generally appear to weigh slightly less than the animals in the present study (André *et al.*, 1990) (Table 2). Only a 93kg 14-year-old male was within the weight range of the females in the present study, possibly due to pronounced sexual dimorphism at an older age. Whether the weight difference between studies is due to sexual dimorphism, differences between stocks, or obesity of the study animals is not clear.

### Body length-body weight relationship

Gühr and Pilleri (1969) report on the body length-weight relationship of five female common dolphins captured in the Mediterranean. Those animals weighed approximately 10kg less at similar body length than the animals in the present study. André *et al.* (1990) report on the body length-weight relationship of one female common dolphin caught in the eastern tropical Pacific which was 145cm long and weighed 28kg. The measurements were close to the regression line based on the animals in the present study (Fig. 4). A captive adult female from waters around New Zealand (the area from which the animals in the present study originate) had a body length (201cm) to weight (94kg) relationship similar to that

Table 2  
Body measurements and estimated ages of common dolphins caught in the eastern tropical Pacific (from André *et al.*, 1990).

Sex	Body length (cm)	Body weight (kg)	Age (year)
M	128	27	0.6
F	145	28	0.8
M	165	49	2
M	179	60	3
M	195	73	12
M	205	80	10
M	206	78	14
M	210	93	14

of the animals in the present study (Logan and Robson, 1971). Ross (1984) reports on the length-weight relationship of eight common dolphins (sex unspecified) which were caught in shark nets on the southeast coast of southern Africa. The relationship is similar to that found in the present study. Ross noticed that the animals from southeast southern Africa were heavier per unit length than the animals reported by Gühr and Pilleri (1969) from the Mediterranean, and similar to those of the northeast Atlantic (Aloncle, 1964; 1968).

### Food consumption as a percentage of body weight

Four common dolphins accidentally bycaught off the northeastern United States were shown, on the basis of stomach contents, to have been feeding exclusively on Atlantic mackerel, *Scomber scombrus* (Overholtz and Waring, 1991). Their daily ration (Table 3) was estimated from a theoretical model of energetic needs and an assumed energy content of 1.43 kcal/g for Atlantic mackerel. The estimates generally agree with the food intake data from the present study (Fig. 5), although the daily food requirement of the 62kg animal was underestimated by Overholtz and Waring. They probably did not consider that common dolphins of that weight are young and undergoing rapid growth, and therefore require a relatively large amount of food. Adult animals require less energy per kg body weight than growing animals as was shown in the present study for common dolphins and for bottlenose dolphins (*Tursiops truncatus*) by Reddy *et al.* (1994).

### Ecological significance

The present study provides only a rough estimate of the food intake of wild common dolphin populations, as it is based on only four females and uses mass of a mix of fish species per year as the energy 'unit'. Common dolphins show distinct sexual dimorphism, the asymptotic length of adult males being on average 10cm greater than females from the same stock (Hui, 1979; Ferrero and Walker, 1995). After maturation, therefore, the food intake of males may differ

Table 3

The stomach contents weight of four common dolphins, caught incidentally off the northeastern United States, which had been feeding exclusively on Atlantic mackerel (*Scomber scombrus*). Also shown are the estimate of Overholtz and Waring (1991)\* for the daily required ration and the estimated daily ration based on the body weight-food intake relationship of the present study.

Body length (cm)	Body weight (kg)	Sex	Weight of stomach contents (kg)	Estimated % of ration	Estimated daily ration (kg) *	Estimated daily ration based on data of present study (kg)
170	62	M	0.7	20	3.5	5.5
200	94	M	1.2	23	5.2	4.9, 5.0, 5.6, 5.8, 5.9, 7.2, 8.5
207	104	F	2.4	44	5.5	5.1
213	110	M	0.3	6	5.0	5.0

from that of non-lactating females of similar age. Information on food intake of males is necessary to provide a more accurate estimate of the food intake of a common dolphin population. The females in the present study did not reproduce, as no males were present. Lactating bottlenose dolphins and Commerson's dolphins (*Cephalorhynchus commersonii*) require much more food than non-lactating females (Kastelein *et al.*, 1993; In press-a; b; Reddy *et al.*, 1994), suggesting that the average consumption of lactating female common dolphins is higher than that of the study animals.

Water temperature may influence food intake in cetaceans by affecting thermoregulation. While the common dolphin has been found in waters between 1-24°C, most sightings occur in waters between 7-23°C (Gaskin, 1968; Winn, 1982; Selzer and Payne, 1988). The water temperature at Marineland of New Zealand falls within this range, suggesting that the animals were maintained within the thermoneutral range for the species, assuming wild animals are well adapted to their environment. Therefore, when considering temperature, the food intake data from the present study may be considered representative of wild populations.

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