PART 2

General Biology
Age and Growth

CHAPTER 3

Age determination and growth in the male Cape fur seal *Arctocephalus pusillus pusillus* (Pinnipedia: Otariidae): part one, external body

C. L. Stewardson, T. Prvan and M. A. Meÿer

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ABSTRACT

Morphology, relative size and growth of the Cape fur seal, *Arctocephalus pusillus pusillus*, from the coast of southern Africa are described. External body measurements (*n* = 12 linear variables) were examined in relation to standard body length (SBL) and chronological age (y) using linear regression. Animals ranged from < 1 mo to ≥ 13 y. Of the 149 animals in the study 39 were animals of known-age; 34 were aged from counts of incremental lines observed in the dentine of upper canines (i.e., range 1–10 y); 10 were identified as adults > 12 y (i.e., pulp cavity of the upper canine closed); and 66 were not aged. Counts of growth layer groups in the dentine of upper canines were found to be highly reproducible. At birth, male Cape fur seals are 35% (*c*. 69 cm) of their mean adult size. At puberty, they are 57% (*c*. 113 cm). The foreflippers are relatively long measuring 25–26% (*c*. 18 cm) of standard body length (SBL) in pups, and 24% (*c*. 48 cm) of SBL in adults. The hind flippers are considerably shorter measuring 19% (*c*. 13 cm) in pups, and 14.5% (*c*. 29 cm) in adults. Axillary girth is usually about 57–67% of SBL. For the range of ages represented in this study, growth of SBL was rapid during the early postnatal period with a significant growth spurt occuring at the onset of puberty (2–3 y). The rate of growth slowed significantly between 6 and 7 y. A weak growth spurt was observed at 9 and 10 y (social maturity) but could not be examined statistically. Growth slowed thereafter, i.e., the mean for males > 10 y (including unaged animals > 200 m) was 199 cm. Relative to SBL, facial variables and the fore/hind limbs scaled with negative slope relative to SBL or were negatively allometric; tip of snout to genital opening scaled with positive slope; and tip of snout to anterior insertion of the foreflipper was positively allometric. Relative to age, body variables scaled with negative slope or were negatively allometric. In animals 1–10 y, SBL was found to be a very 'rough indicator' of age and age group.

Key words: Pinnipeds; body; growth; allometry

INTRODUCTION

Knowledge of the physical growth of pinnipeds is fundamental to understanding biological, evolutionary and functional links within and between populations.

Within the Otariidae (fur seals and sea lions) quantitative descriptions of growth in body length based on animals aged from tooth structure, or on animals of known-age (i.e., animals tagged or branded as pups), are available for several species including *Eumetopias jubatus*, northern (Steller) sea lion (Fiscus, 1961; Thorsteinson & Lensink, 1962; Calkins & Pitcher, 1983; Loughlin & Nelson, 1986; McLaren, 1993), *Arctocephalus gazella*, Antarctic fur seal (Payne 1979; Krylov & Popov, 1980; McLaren, 1993); *Callorhinus ursinus*, northern fur seal (Scheffer & Wilke, 1953; Bychkov, 1971; Bigg, 1979; Lander, 1979; McLaren, 1993; Trites & Bigg, 1996); and *Otaria byronia*, South American sea lion (Rosas, Haimovici & Pinedo, 1993). Apart from studies by Scheffer & Wilke (1953) and Payne (1997), information on growth of other external body measurements is scant, e.g., axillary girth; length of limbs.

Physical growth in the northern fur seal has been studied in most detail. The general growth curve for this species is presumably representative of all highly polygynous male otariids. Male pups measure *c*. 66 cm at birth and grow at a steady rate (Scheffer & Wilke, 1953). Growth increases suddenly at 3–4 y (puberty) and slows soon after attainment of social maturity (McLaren, 1993). Estimated asymptotic length is *c*. 189 cm for males > 4 y, and is reached by *c*. 12 y in most animals (McLaren, 1993).

Here we examine the body measurements of 149 male Cape fur seals, *Arctocephalus pusillus pusillus*, from Southern Africa. Specific objectives were to: (i) describe the general morphology of the animal; (ii) quantify growth of body measurements (n = 12 variables) relative to standard body length (n = 134 animals) and chronological age (n = 83 animals); and (iii) determine if standard body length is a useful indicator of age. This study is the first in a series of papers initiated to develop baseline descriptions of Cape fur seal morphology and to examine growth patterns.

Information on growth in body size is available for Cape fur seals (Rand, 1956); however, this information is based on measurements that were aged physiologically (cranial suture age) rather than chronologically (y).

MATERIALS AND METHODS

Collection of specimens

Cape fur seals were collected along the Eastern Cape coast of South Africa between Plettenberg Bay (34° 03'S, 23° 24'E) and East London (33° 03'S, 27° 54'E), from August 1978 to December 1995, and accessioned at the Port Elizabeth Museum (PEM). From this collection, 110 males were selected for examination (Appendix 3.1). Apart from specimens collected before May 1992 (n = 38), all specimens were collected by the first author. One animal (PEM2238) was collected NE of the study area, at Durban.

The sample was supplemented with measurements from 39 males from Marine and Coastal Management (MCM), Cape Town. These measurements were from animals that had been tagged as pups, and were therefore of known-age (1–13 y). MCM seal specimens are accessioned as AP followed by a number.

Body measurements

Standard necropsies were performed and biological parameters recorded, based on recommendations of the Committee on Marine Mammals, American Society of Mammalogists (1967). Upper canines were collected for age determination.

Measurements (12 variables) were taken to the nearest 5 mm using a flexible tape measure or vernier callipers as appropriate (Fig. 3.1). Although body weight and blubber thickness were recorded, these measurements were not included in the analysis because they can vary according to physiological condition, e.g., body condition is influenced by seasonal fluctuations in food supply, illness or injury, and breeding condition. Apart from specimens collected before May 1992, all PEM measurements were recorded by the first author. The majority of MCM measurements were recorded by the third author.

Age determination

The age of animals was estimated from counts of growth layer groups (GLGs) observed in the dentine of thin tooth sections (Fig. 3.2). Upper canines were sectioned longitudinally using a circular diamond saw. Sections were ground down to 280–320 μm, dehydrated, embedded in resin and viewed under a stereomicroscope in polarised light (Oosthuizen, 1997). Each section was read by one individual five times, without knowledge of which animal was being examined (repeated blind counts). Ages were rounded off to the nearest birth date. The median date of birth was assumed to be 1 December (Shaughnessy & Best, unpubl. report). The median of the five readings was used as an estimate of age. Outliers were discarded as reading errors.

Currently, examination of tooth structure is the most precise method of age determination in pinnipeds (McCann, 1993), including Cape fur seals Oosthuizen (1997). However, this method can only be used in animals ≤ 13 y. At about 13 y of age, closure of the pulp cavity terminates tooth growth.

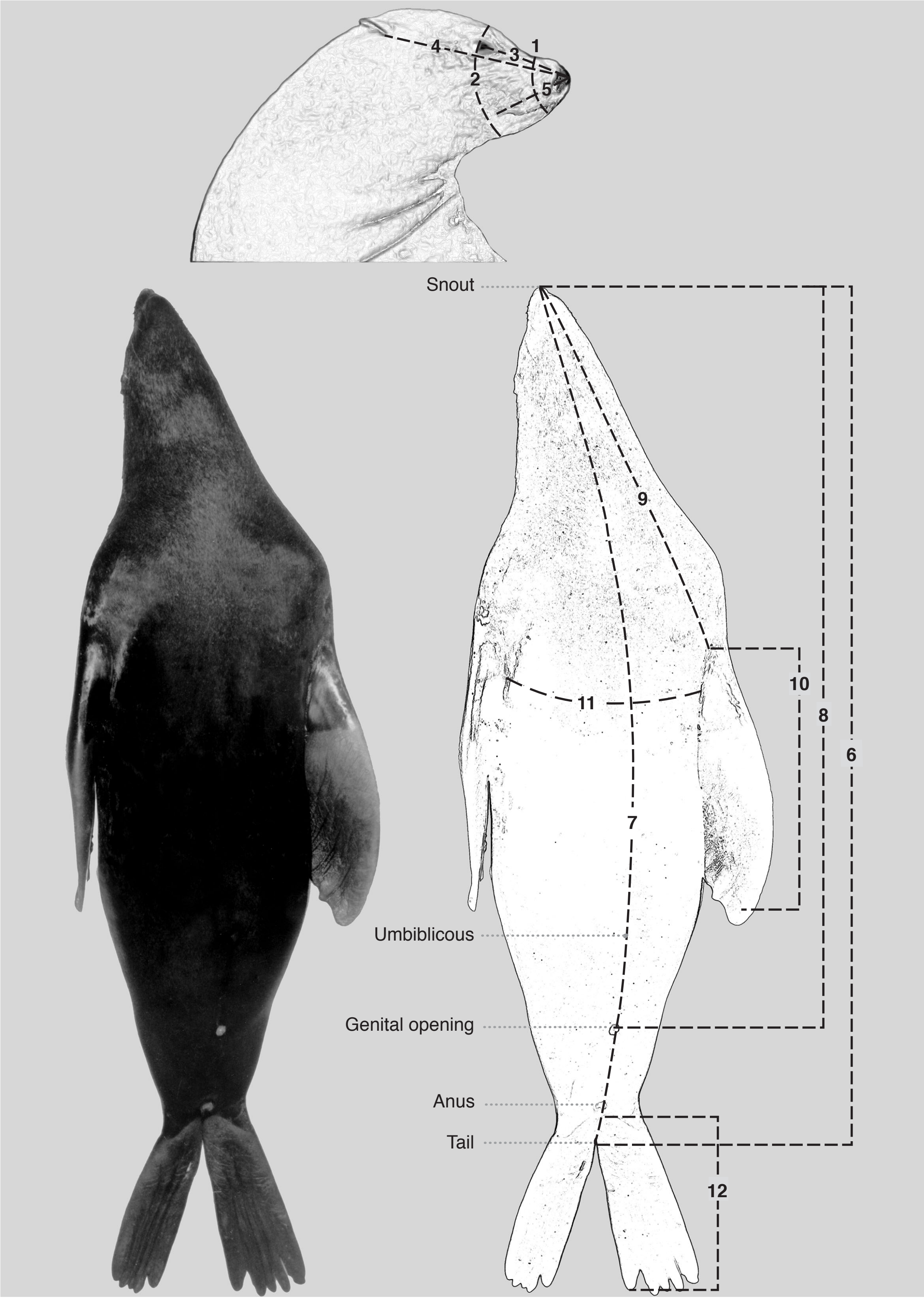


Fig. 3.1 Diagram of a male Cape fur seal showing how individual body measurements were taken. All measurements were taken with the animal lying on its back.
1. Circumference of head at canine; 2. circumference of head at eye; 3. tip of snout to centre of eye; 4. tip of snout to centre of ear; 5. tip of snout to angle of gape; 6. standard body length (straight line from tip of snout to tip of tail with animal lying on its back); 7. ventral curvilinear length (tip of snout to tip of tail over body curve); 8. tip of snout to genital opening; 9. tip of snout to anterior insertion of the foreflipper; 10. length of foreflipper (anterior insertion to tip of first claw); 11. axillary girth; and 12. length of hind flipper (anterior insertion to tip of first claw).

Of the 149 animals in the study: (i) 39 were known-age MCM animals; (ii) 34 were aged from counts of incremental lines observed in the dentine of upper canines, i.e., range 1–10 y; (iii) 10 were identified as adults > 12 y (i.e., pulp cavity of the upper canine closed); and (iv) 66 were not aged.

For this study, the following age groups were used: pup (< 1 mo to 6 mo); yearling (7 mo to 1 y 6 mo); subadult (1 y 7 mo to 7 y 6 mo); and adult (≥ 7 y 7 mo) (Table 3.1). Very old animals of known-age were not available for examination (estimated longevity is *c.* 20 y).

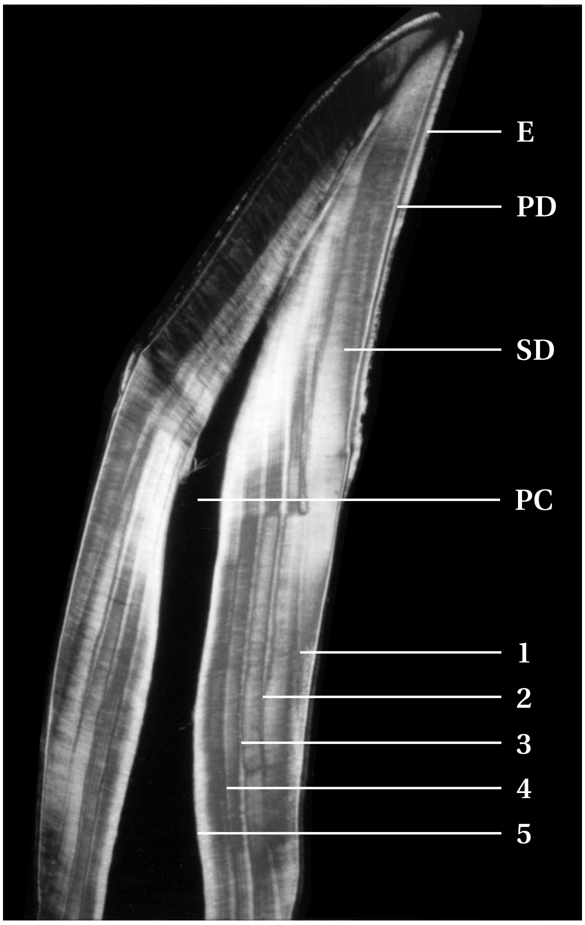


Fig. 3.2 Longitudinal section of a upper canine from a Cape fur seal, showing 5 growth layer groups (GLGs).
E, enamel; PD, primary/pre-natal dentine; SD, secondary dentine; PC, pulp cavity; 1–5, successive growth layer groups (GLGs) in the secondary dentine.

Statistical analysis

Body variable expressed in relation to standard body length

Growth in body measurement, relative to standard body length (SBL), was calculated as follows, using paired samples only:

body measurement (mm) / SBL (mm) × 100%

As the approximate variance of the ratio estimate is difficult to calculate, percentages must be interpreted with caution, i.e., both y and x vary from sample to sample (Cochran, 1977, p. 153).

Body length as an indicator of age

The degree of linear relationship between log body measurement, log SBL and age (y) was calculated using the Spearman rank-order correlation coefficient. Linear discriminant function analysis was used to predict the likelihood that an individual seal will belong to a particular age group using one independent variable, body length. Here we use the Mahalanobis squared distance of observation x to the mean of group i:

$$D_i^2(x) = -2\left[\bar{x}_i^T S^{-1} x - \tfrac{1}{2}\bar{x}_i^T S^{-1}\bar{x}_i\right] + x^T S^{-1} x$$

where S is the pooled covariance matrix. An observed value x is classified into the age group (pup, yearling, subadult, adult) which gives the smallest calculated Mahalanobis squared distance. This is equivalent to the term in square brackets being maximised for group membership (Anderson, 1984).

Bivariate allometric regression

The relationship between value of body measurement and: (i) SBL and (ii) age (y), was investigated using the logarithmic (base e) transformation of the allometric equation, y = ax^b, which may equivalently be written as log y = log a + b log x. 'Robust' regression (Huber M-Regression) was used to fit straight lines to the transformed data. The degree of linear relationship between the transformed variables was calculated using the Spearman rank-order correlation coefficient, r (Gibbons & Chakraborti, 1992). It is important to note that the regression equations relating to overall growth do not consider variations in body condition that are known to occur in this species (e.g., Rand, 1956).

Statistical tests of hypotheses about model parameters are only valid if the model assumptions hold (i.e., errors are independently and identically Normally distributed with zero mean and variance σ^2) (Weisberg, 1985, p. 24, 156). The standard approach is to first examine the residules versus fitted plot. If this is a random scatter about zero, then the Normality assumption can be assessed. In the present study, the following tests for Normality were used: (i) Anderson-Darling, (ii) Ryan-Joiner and (iii) Kolmogorov-Smirnov.

The appropriate test statistic was calculated as follows:

$$T = \frac{\hat{\beta} - 1}{S.E.(\hat{\beta})}$$

where T has a student t distribution with $d.f. = n$–2.

The following hypotheses were tested:

$H_0 : \hat{\beta} = 1$ (isometric) versus $H_1 : \hat{\beta} \neq 1$ (either positively or negatively allometric); $H_1 : \hat{\beta} > 1$ (positively allometric); $H_1 : \hat{\beta} < 1$ (negatively allometric).

Statistical analysis and graphics were implemented in Minitab (Minitab Inc., State College, 1999, 12.23); Microsoft ® Excel 97 (Microsoft Corp., Seattle, 1997), and S-PLUS (MathSoft, Inc., Seattle, 1999, 5.1).

Terminology

Puberty is when reproduction first becomes possible (production of sperm in quantity), and social maturity is the age when the animal reaches full reproductive capacity (physically able to establish and maintain a harem).

RESULTS

Age determination (intra-observer variability)

Counts of GLGs were found to be highly reproducible. Of the 34 PEM animals for which GLGs were counted, 14 (41%) had all five readings equal; 16 (47%) had one reading out of 5 different from the mode; and 4 (12%) had 2 readings out of 5 different from the mode (Table 3.2).

Table 3.1 *The age distribution of Cape fur seals*

Age group	Age[a] (y)	Frequency	Percentage
Pup[b]	0	3	3.6
Yearling	1	8	9.6
Subadult	2	5	6.0
	3	5	6.0
	4	9	10.8
	5	5	6.0
	6	10	12.1
	7	11	13.3
Adult	8	6	7.2
	9	5	6.0
	10	4	4.8
	13	2	2.4
	> 12	10	12.1
Total		**83**	**100**

[a] **Animals** 1–10 y: 37 MCM animals were of known-age; 34 PEM animals were aged from counts of incremental lines observed in the dentine of upper canines.
Animals > 12 y: 2 MCM animals were 13 y; 10 PEM males were > 12 y, i.e., the pulp cavity of the upper canine was closed.
[b] < one month of age.

Age determination (variability between known-age and canine aged animals)

Standard body length was selected to investigate whether MCM (animals of known-age) and PEM (canine aged animals) animals were similar with respect to age. When comparing the (robust) regression line for MCM SBL on age with PEM SBL on age, partial t-tests indicate that age is important (t = 7.07, p = 0.000), even after adjusting for group and age-group interaction; but they provide little information on group (t = -0.82, p = 0.42) and age-group interaction (t = 0.87, p = 0.58), hence one straight line can be fitted to the data. These statistical conclusions were verified by examining graphical displays of fitted values and residuals. Thus PEM and MCM animals were not significantly different with respect to age.

This conclusion is supported by the sequential F test, provided the sequence of terms added sequentially (first to last) was: (i) none (i.e., fitting a line parallel to the x axis); (ii) age (F = 817.69, p = 0.000) (one straight line); (iii) museum (ie., MCM and PEM) (F = 0.0659, p = 0.7984) (two parallel lines); (iv) age × museum (F = 0.1883, p = 0.6661) (two lines not necessarily parallel).

Table 3.2 *Intra-observer variability (number of tooth readings different from the mode)*

Range	0	1	2	Total
0	14 (100%)	0	0	14 (100%)
1	0	14 (82%)	3 (18%)	17 (100%)
2	0	1 (50%)	1 (50%)	2 (100%)
3	0	1 (100%)	0	1 (100%)
Total	**14 (41%)**	**16 (47%)**	**4 (12%)**	**34 (100%)**

Age was taken as the mode of the 5 readings for each animal. For our data, the mode and median were concurrent.

Bivariate allometric regression

Regression statistics for body measurements on SBL and age (1–10 y) are given in Appendix 3.3 and 3.4. Overall, correlation coefficients were moderately to strongly positive, i.e., most points on the scatter plot approximated a straight line with positive slope, $r \geq 0.70$. Exceptions included tip of snout to centre of eye (V3) with age and SBL (r = -0.008 and 0.15 respectively); tip of snout to angle of gape (V5) with age (r = 0.56); circumference of head at canine (V1) with age (r = 0.59).

Although correlation coefficients indicate that linearity was reasonably well approximated for most variables by log-log transformations, a linear relationship did not necessarily best describe the relationship.

Growth of body variables

Most variables were significantly positively correlated with each other, $r \geq 0.68$ (Appendix 3.2). Exceptions were: (i) tip of snout to centre of eye (V3) with all variables; (ii) circumference of head at eye (V2) with tip of snout to angle of gape (V5) ($r = 0.61$); and (iii) circumference of head at canine (V1) with tip of snout to angle of gape (V5) ($r = 0.63$).

Circumference of head at canine (V1)

Growth of circumference of head at canine (V1) was variable relative to age, $r = 0.59$ (Appendix 3.4). Overall growth expressed negative allometry relative to SBL and age (Appendix 3.3, 3.4), increasing by 57% at 10 y relative to pups (RTP) (Table 3.3). Growth increment decreased with increasing SBL until about 7 y (*c.* 15% of SBL) (Table 3.4).

Mean SBL of males > 10 y (including unaged animals > 200 cm) was 31.8 ± 1.2 cm ($n = 5$). Maximum recorded value was 35.0 cm (animal AP3017, SBL 209 cm, 12 y 11 mo).

Circumference of head at eye (V2)

Growth of circumference of head at eye (V2) was rapid during the early postnatal period and continued to increase until at least 13 y. Overall growth expressed negative allometry relative to SBL and scaled with negative slope relative to age ($b = 0.12$) (Fig. 3.3a; Appendix 3.3), increasing by 65% at 10 y (RTP) (Table 3.4). Growth increment decreased with increasing SBL until about 7 y (*c.* 22% of SBL) (Table 3.3).

Mean SBL of males > 10 y (including unaged animals > 200 cm) was 45.8 ± 1.8 cm ($n = 6$). Maximum recorded value was 53.0 cm (animal PEM676, SBL 197 cm).

Tip of snout to centre of eye (V3)

Growth of tip of snout to centre of eye (V3) was highly variable relative to age, $r = -0.008$, and SBL, $r = 0.15$ (Appendix 3.3 and 3.4). Growth increment decreased with increasing SBL until about 9 y (*c.* 5% of SBL) (Table 3.3).

Mean SBL of males > 10 y (including unaged animals > 200 cm) was 10.4 ± 0.6 cm ($n = 10$). Maximum recorded value was 14.4 cm (animal PEM2194, SBL 194 cm).

Tip of snout to centre of ear (V4)

Growth of tip of snout to centre of ear (V4) was rapid during the early postnatal period and continued to increase until at least 13 y (Table 3.3 and 3.4). Overall growth expressed negative allometry relative to SBL and scaled with negative slope relative to age ($b = 0.04$) (Fig. 3.3b; Appendix 3.3), increasing by 70% at 10 y RTP (Table 3.4). Growth increment decreased with increasing SBL until about 7 y (*c.* 12% of SBL) (Table 3.3).

Mean SBL of males > 10 y (including unaged animals > 200 cm) was 22.7 ± 0.8 cm ($n = 7$). Maximum recorded value was 25.2 cm (animal AP3125, SBL 204 cm, 13 y).

Tip of snout to angle of gape (V5)

Growth of tip of snout to angle of gape (V5) was variable relative to age, $r = 0.56$ (Appendix 3.4). Overall growth scaled with negative slope relative to SBL ($b = 0.64$) and expressed negative allometry relative to age (Appendix 3.4), increasing by 55% at 10 y RTP (Table 3.4). Growth increment decreased with increasing SBL until about 7 y (*c.* 6% of SBL) (Table 3.3).

Mean SBL of males > 10 y (including unaged animals > 200 cm) was 13.2 ± 0.7 cm ($n = 7$). Maximum recorded value was 15.0 cm (animal PEM676, SBL 197 cm).

Standard body length (V6)

Growth of SBL (V6) was rapid during the early postnatal period with a significant growth spurt between 2 and 3 y (two sample t test[1]: p-value = 0.008; df = 5).

The rate of growth slowed significantly between 6 and 7 y (two sample t test[1]: p-value = 0.011; df = 9). A weak growth spurt was observed at 9 and 10 y but could not be examined statistically, i.e., this secondary growth spurt may be attributed to sampling error. Growth increased by 164% at 10 y RTP (Table 3.4).

Considering that the 13 y old males measured 206.5 ± 2.5 cm ($n = 2$), and mean SBL of males > 10 y (including unaged animals > 200 cm) was 199.4 ± 3.6 cm ($n = 17$), growth appears to slow after attainment of social maturity (Table 3.3).

Tip of snout to genital opening (V8)

Growth of tip of snout to genital opening (V8) was rapid during the early postnatal period and continued to increase until at least 13 y (Table 3.3 and 3.4). Growth increased by 186% at 10 y RTP (Table 3.4). In subadults and adults, mean value remained at about 86% of SBL (Table 3.3). Overall growth scaled with weak positive slope relative to SBL ($b = 1.04$) and negative slope relative to age ($b = 0.02$).

[1]The two sample t test assumed unequal variances.

Table 3.3 ***Summary statistics for body variables (1–12), according to age (y) and age group.*** **Data presented as mean body measurement in cm ± S.E., followed by coefficient of variation in round brackets, and body variable expressed as a percentage of SBL. Maximum value of each variable (males of unknown-age) is also presented.**

Age group	Age (y)	*n*[a]	Var 1	Var 2	Var 3[c]	Var 4	Var 5	Var 6	Var 7[d]	Var 8	Var 9	Var 10	Var 11[e]	Var 12
Pup	< 1	3	16.9 ± 1.1 (11.3) 24.4%	24.1 ± 1.4 (10.3) 34.7%	9.1 ± 0.9 (16.4) 13.1%	11.8 ± 0.1 (2.1) 17.0%	7.1 ± 0.7 (16.5) 10.3%	69.3 ± 2.8 (7.1) –	70.9 ± 3.6 (8.7) –	55.6 ± 1.7 (5.3) 80.2%	31.7 ± 0.9 (4.8) 45.7%	17.6 ± 1.6 (16.2) 25.4%	39.6 ± 3.5 (15.5) 57.1%	13.3 ± 0.7 (9.4) 19.2%
Yearling	1	8	19.6 ± 0.9 (12.5) 21.6%	27.9 ± 1.4 [7] (13.2) 30.9%	8.3 ± 0.6 [7] (18.2) 9.0%	13.7 ± 0.4 (7.6) 15.1%	7.7 ± 0.3 (12.3) 8.4%	90.8 ± 2.4 (7.4) –	95.3 ± 3.9 [3] (7.1) –	75.9 ± 2.2 (8.1) 83.7%	41.1 ± 1.7 (11.6) 45.3%	22.4 ± 1.2 (15.0) 24.7%	53.1 ± 4.6 (24.4) 58.5%	15.1 ± 0.4 (8.0) 16.6%
Subadult	2	5	21.1 ± 1.1 (12.1) 22.5%	30.8 ± 1.6 (11.7) 32.8%	10.2 ± 1.3 [4] (25.5) 10.8%	14.9 ± 0.5 (7.7) 15.9%	7.8 ± 0.4 (11.4) 8.3%	93.8 ± 1.9 (4.5) –	– [0]	79.6 ± 2.4 (6.8) 84.9%	37.7 ± 0.8 (4.6) 40.2%	23.5 ± 0.4 (4.3) 25.1%	58.2 ± 3.1 (11.8) 62.0%	16.0 ± 0.6 (8.3) 17.0%
	3	5	22.2 ± 0.5 (4.8) 19.7%	32.2 ± 0.8 (5.3) 28.5%	10.7 ± 1.2 [4] (23.2) 9.6%	17.1 ± 0.4 (5.8) 15.2%	8.6 ± 0.6 (14.3) 7.6%	112.8 ± 4.0 (8.0) –	– [0]	98.1 ± 2.1 (4.9) 87.0%	48.9 ± 2.1 (9.5) 43.3%	27.4 ± 1.4 (11.2) 24.3%	73.9 ± 2.0 (6.2) 65.5%	18.1 ± 0.8 (9.3) 16.0%
	4	9	24.1 ± 0.6 (7.6) 19.6%	34.3 ± 0.5 (4.8) 27.7%	9.1 ± 0.5 (17.7) 7.6%	18.3 ± 0.5 (7.9) 14.8%	9.9 ± 0.3 (7.8) 7.9%	124.3 ± 5.0 [8] (11.4) –	– [0]	107.2 ± 3.6 [8] (9.5) 86.2%	52.5 ± 1.7 (9.8) 42.6%	30.1 ± 1.1 (11.0) 24.5%	80.2 ± 2.3 (8.5) 64.7%	18.6 ± 0.5 (8.8) 15.2%
	5	5	24.0 ± 0.4 [4] (3.4) 17.9%	34.8 ± 1.4 [4] (7.9) 26.8%	9.9 ± 0.7 (15.4) 6.6%	18.8 ± 0.9 (11.3) 13.4%	8.6 ± 0.7 [3] (14.7) 6.8%	136.5 ± 2.5 [2] (2.6) –	149.7 ± 2.7 [3] (3.2) –	124.5 ± 4.8 (8.7) 84.4%	62.7 ± 4.2 (14.9) 40.5%	35.7 ± 1.4 (9.0) 23.9%	85.8 ± 0.8 [2] (1.2) 62.8%	21.7±13[3] (10.1) 15.0%
	6	10	24.9 ± 0.6 (7.8) 17.0%	37.1 ± 0.8 (7.0) 25.3%	10.4 ± 0.5 [8] (14.6) 7.2%	19.3 ± 0.5 (8.2) 13.0%	10.2 ± 0.3 [9] (7.6) 7.0%	145.8 ± 1.4 [9] (2.8) –	155.3 ± 5.2 [3] (5.8) –	126.7 ± 1.7 (4.2) 87.2%	65.5 ± 3.4 (16.3) 43.6%	33.6 ± 0.9 [9] (7.7) 23.0%	91.4 ± 2.1 [9] (6.8) 62.7%	21.2 ± 0.4 [9] (5.9) 14.5%
	7	11	23.7 ± 0.8 [10] (10.6) 15.1%	34.7 ± 0.8 [10] (7.2) 22.3%	9.0 ± 0.6 [7] (18.6) 6.2%	18.2 ± 0.4 (7.7) 11.5%	9.3 ± 0.5 (16.7) 6.3%	157.5 ± 3.4 [8] (6.2) –	158.5 ± 4.3 [5] (6.0) –	132.5 ± 2.5 (6.3) 84.9%	71.8 ± 2.1 (9.6) 45.8%	34.7 ± 1.1 (10.1) 22.4%	100.2 ± 3.1 [7] (8.3) 64.4%	23.6±0.7 [10] (9.1) 15.2%
	2–7	**45**	**23.6 ± 0.3 [43] (9.5) 17.9%**	**34.5 ± 0.5 [43] (8.9) 26.2%**	**9.8 ± 0.3 [37] (18.5) 7.7%**	**18.0 ± 0.3 (10.5) 13.6%**	**9.3 ± 0.2 [42] (14.1) 7.2%**	**131.7 ± 3.8 [37] (17.5) –**	**155.2 ± 2.6 [11] (5.5) –**	**115.7 ± 2.9 [44] (16.5) 86.0%**	**59.2 ± 2.0 (22.2) 43.4%**	**31.6 ± 0.7 [44] (15.3) 23.6%**	**83.2 ± 2.4 [37] (17.5) 63.8%**	**20.2 ± 0.5 [41] (15.0) 15.3%**
Adult	8	6	24.2 ± 1.0 [5] (9.6) 14.8%	38.6 ± 1.8 [5] (10.5) 21.4%	8.8 ± 0.6 (16.2) 5.7%	18.9 ± 0.7 (9.2) 11.7%	9.9 ± 0.8 [5] (19.0) 6.8%	161.0 ± 3.5 [3] (3.8) –	166.0 ± 2.1 [5] (2.8) –	136.6 ± 3.1 (5.5) 85.8%	76.6 ± 2.2 (7.1) 50.1%	35.2 ± 1.6 (11.5) 21.3%	90.6 ± 4.6 [2] (7.2) 57.5%	26.0 ± 1.0 (9.7) 15.8%
	9	5	26.0 ± 0.5 [4] (4.2) 15.2%	37.4 ± 1.0 (5.8) 21.6%	8.1 ± 0.7 [4] (18.1) 4.6%	20.5 ± 0.8 (9.1) 12.0%	10.7 ± 0.4 (8.8) 6.4%	170.8 ± 2.3 [4] (2.7) –	185.8 ± 3.4 [4] (3.7) –	152.6 ± 2.6 (3.8) 89.6%	83.8 ± 5.8 (15.6) 48.4%	40.6 ± 0.9 (5.0) 24.1%	114.5 ± 2.9 [4] (5.1) 67.0%	28.2 ± 1.3 (10.1) 16.5%
	10	4	26.6 ± 1.1 [3] (7.4) 14.7%	39.7 ± 1.8 [3] (7.7) 21.9%	9.5 ± 1.1 [3] (20.7) 5.2%	20.0 ± 0.2 (1.9) 10.9%	11.1 ± 0.4 (6.7) 6.0%	182.9 ± 6.0 (6.6) –	203.7 ± 4.9 [3] (4.2) –	159.3 ± 5.4 (6.8) 87.1%	87.8 ± 8.5 (19.5) 48.1%	40.3 ± 2.1 [3] (10.2) 22.0%	111.9 ± 6.9 (12.2) 61.2%	27.1 ± 1.6 (11.7) 14.8%
	13	2	31.5 ± 3.5 (15.7) 15.3%	44.5 ± 5.5 (17.5) 21.5%	11.1 ± 0.9 (11.5) 5.3%	24.6 ± 0.6 (3.4) 11.9%	13.5 ± 0.5 (5.2) 6.5%	206.5 ± 2.5 (1.7) –	– [0]	178.5 ± 3.5 (2.8) 86.4%	91.5 ± 3.5 (5.4) 44.3%	48.4 ± 3.6 (10.5) 23.4%	– [0]	27.7 ± 1.5 (7.7) 13.4%
	8–13	**17**	**26.3 ± 0.9 [14] (12.2) 15.0%**	**39.2 ± 1.1 [15] (10.5) 21.6%**	**9.1 ± 0.4 [15] (18.4) 5.2%**	**20.3 ± 0.5 (11.0) 11.6%**	**10.9 ± 0.4 [16] (14.7) 6.4%**	**177.7 ± 4.7 [13] (9.4) –**	**182.0 ± 4.9 [12] (9.2) –**	**151.6 ± 3.8 (10.2) 87.4%**	**83.1 ± 2.9 (14.1) 47.9%**	**39.5 ± 1.3 [16] (13.5) 22.7%**	**108.7 ± 4.1 [10] (12.0) 62.8%**	**27.1 ± 0.46 (9.8) 15.3%**
Total		**73**	**68**	**68**	**62**	**73**	**69**	**61**	**29**	**72**	**73**	**72**	**58**	**69**
Mean for males > 200 cm[b] [max. value in brackets]			31.3 ± 2.0 [35.0] *n* = 3	44.3 ± 3.2 [50.0] *n* = 3	11.8 ± 0.6 [13.0] *n* = 4	24.4 ± 0.4 [25.2] *n* = 3	14.0 ± 0.5 [14.9] *n* = 3	210.7 ± 5.7 [243.0] *n* = 7	211.8 *n* = 1	172.0 ± 5.9 [182.0] *n* = 4	91.0 ± 3.4 [98.0] *n* = 4	49.0 ± 2.7 [55.0] *n* = 4	135.0 ± 34.0 [169.0] *n* = 2	28.8 ± 1.4 [29.2] *n* = 3

Variables: 1. Circumference of head at canine; 2. circumference of head at eye; 3. tip of snout to centre of eye; 4. tip of snout to centre of ear; 5. tip of snout to angle of gape; 6. standard body length; 7. ventral curvilinear length; 8. tip of snout to genital opening; 9. tip of snout to anterior insertion of the foreflipper; 10. length of foreflipper; 11. axillary girth; 12. length of hind flipper.

[a] Number of canine aged and known-age animals. Sample size given in square brackets where this does not equal total sample size.

[b] Mean value of variable ± S.E. for the 7 largest males (> 200 cm) of unknown-age; maximum value in square brackets, followed by sample size.

[c] V3 was poorly correlated with body variables and age (Appendix 3.2, 3.3 and 3.4), therefore had been excluded from further analysis.

[d] V7 was shown to be a poor indicator of SBL, therefore has been excluded from further analysis.

[e] V11 may be influenced by seasonal change and illness, therefore has been excluded from further analysis.

Table 3.4 *Growth in body variables (1–12) relative to the mean value of body measurement: (i) at age zero, RGR $\bar{y}_0$; and (ii) from the previous year, RGR $\bar{y}_{t-1}$*. **All measurements are in cm.**

Age group	Age (y)	n[a]	Var 1	Var 2	Var 4	Var 5	Var 6[b]	Var 8	Var 9	Var 10	Var 12
Pup	< 1	3	–	–	–	–	–	–	–	–	–
Yearling	1	8	15.7; 15.7	16.1; 16.1 [7]	16.5; 16.5	7.1; 7.1	30.9; 30.9	36.5; 36.5	29.9; 29.9	27.1; 27.1	13.3; 13.3
Subadult	2	5	24.6; 7.7	28.0; 10.2	26.7; 8.8	9.2; 2.0	35.3; 3.4	43.2; 4.9	19.1; -8.3	33.6; 5.1	19.7; 5.7
	3	5	31.0; 5.1	33.7; 4.5	45.7; **15.0**	20.7; 10.5	62.7; **20.3**	76.4; **23.2**	54.3; **29.6**	55.8; 16.6	35.5; 13.2
	4	9	42.6; 8.9	42.7; 6.7	55.4; 6.6	38.1; 14.5	79.3; 10.2 [8]	92.7; 9.2 [8]	65.8; 7.4	71.2; 9.9	39.5; 3.0
	5	5	41.7; -0.6 [4]	44.6; 1.3 [4]	59.5; 2.6	20.9; -12.5 [3]	96.9; 9.8 [2]	124.0; 16.2	98.0; 19.4	103.0; 18.5	63.0; 16.8 [3]
	6	10	47.1; 3.8	54.3; 6.7	64.0; 2.8	42.3; 17.8 [9]	110.3; 6.8 [9]	127.8; 1.7	106.8; 4.5	90.9; -5.9 [9]	58.9; -2.5 [9]
	7	11	40.0; -4.9 [10]	44.3; -6.5 [10]	54.8; -5.7	29.9; -8.7	127.2; 8.1 [8]	138.3; 4.6	126.7; 9.6	97.3; 3.3	76.8; 11.3 [10]
Adult	8	6	42.8; 2.0 [5]	60.2; **11.0** [5]	61.0; 4.0	38.6; 6.7 [5]	132.2; 2.2 [3]	145.7; 3.1	142.0; 6.8	99.7; 1.2	95.1; **10.4**
	9	5	53.5; **7.5** [4]	55.2; -3.1	74.0; **8.1**	50.1; **8.3**	146.3; **6.1** [4]	174.5; **11.7**	164.6; **9.3**	130.5; **15.4**	111.4; 8.3
	10	4	57.3; 2.4 [3]	64.8; 6.2 [3]	69.9; -2.4	54.7; 3.1	163.7; **7.1**	186.4; 4.4	177.3; 4.8	128.7; -0.8	103.4; -3.7
	13	2	86.0; –	84.9; –	109.2; –	89.0; –	197.8; –	221.0; –	188.9; –	175.0; –	107.8; –
Total		**73**	**68**	**68**	**73**	**69**	**61**	**72**	**73**	**72**	**69**

Variables: 1. Circumference of head at canine; 2. circumference of head at eye; 4. tip of snout to centre of ear; 5. tip of snout to angle of gape; 6. standard body length (straight line from tip of snout to tip of tail); 8. tip of snout to genital opening. 9. tip of snout to anterior insertion of the foreflipper; 10. length of foreflipper (anterior insertion to tip of first claw); 11. axillary girth; and 12. length of hind flipper (anterior insertion to tip of first claw).

[a] Number of canine aged and known-age animals.

[b] For animals measured at sea (by-catch) it was not always possible to record SBL because of rough conditions, i.e., SBLs for 12 of these animals were not recorded.

Values for growth relative to age zero are presented on the left hand side of the relevant columns, i.e., $[(\bar{y}_t - \bar{y}_0)/\bar{y}_0] \times 100\%$. Values for growth relative to the previous year are presented on the right hand side of the relevant columns, i.e., $[(\bar{y}_t - \bar{y}_{t-1})/\bar{y}_{t-1}] \times 100\%$. Sample size given in square brackets where this does not equal total sample size.

Variables 3, 7 and 11 excluded from analysis (see footnotes in Table 3.3).

Mean SBL of males > 10 y, including unaged animals > 200 cm was 171.1 ± 3.4 cm (n = 7). Maximum recorded value was 184.0 cm (animal PEM2256, SBL 198 cm).

Tip of snout to anterior insertion of the foreflipper (V9)

Growth of tip of snout to anterior insertion of the foreflipper (V9) was rapid during the early postnatal period and continued to increase until at least 10 y (Table 3. 3 and 3.4). Overall growth expressed positive allometry relative to SBL, and negative allometry relative to age (Fig 3.3c; Appendix 3.3) (Fig 3.4c; Appendix 3.4). Growth increased by 177% at 10 y RTP (Table 3.4).

Mean SBL of males > 10 y, including unaged animals > 200 cm was 94.2 ± 3.1 cm (n = 7). Maximum recorded value was 110.0 cm (animal PEM2374, SBL 186 cm).

Length of foreflipper (V10)

Growth of length of foreflipper (V10) was rapid during the early postnatal period and continued to increased until at least 13 y (Table 3.3 and 3.4). A significant growth increment was evident between 4 and 5 y (two sample t test[1]: p-value = 0.015; df = 8). Overall growth scaled with negative slope relative to SBL (b = 0.89) and age (b = 0.07). Growth increased by 129% at 10 y RTP (Table 3.4). Growth increment decreased with increasing SBL until about 6 y (*c.* 23% of SBL) (Table 3.3).

Mean SBL of males > 10 y, including unaged animals > 200 cm was 47.2 ± 1.9 cm (n = 8). Maximum recorded value was 55.0 cm (animal PEM1560, SBL 201 cm).

Length of hind flipper (V12)

Growth of length of hind flipper (V12) was rapid during the early postnatal period and continued to increase until at least 8–9 y (Table 3.3 and 3.4). Overall growth scaled with negative slope relative to SBL (b = 0.81) and expressed negative allometry relative to age (Fig. 3.4d; Appendix 3.4), increasing by 103% at 10 y RTP (Table 3.4). Growth increment decreased with increasing SBL until about 4 y (*c.* 15% of SBL) (Table 3.3).

Mean SBL of males > 10 y, including unaged animals > 200 cm was 28.7 ± 0.9 cm (n = 7). Maximum recorded value was 32.0 cm (animal PEM1890, SBL 192 cm, ≥ 12 y).

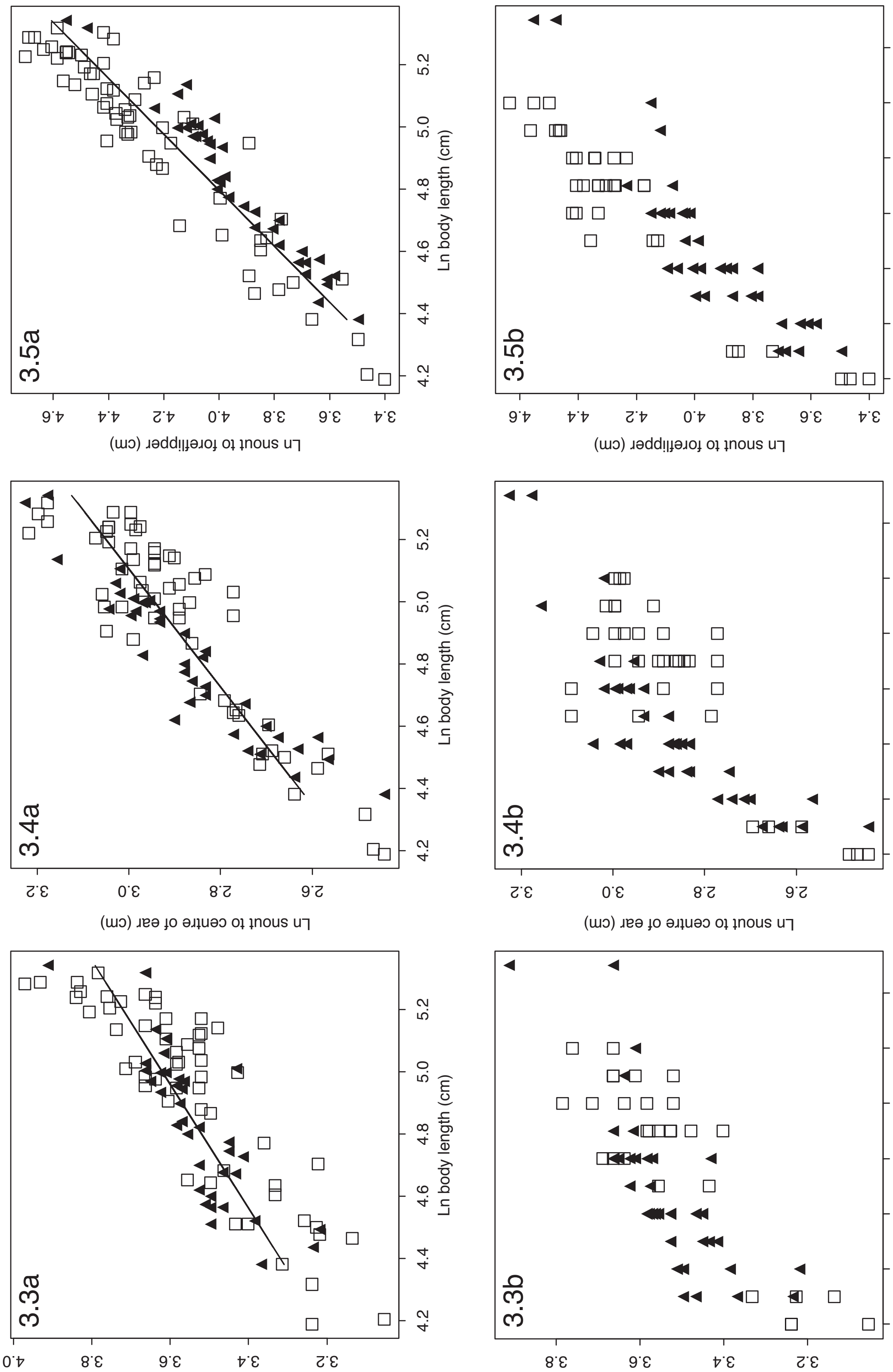
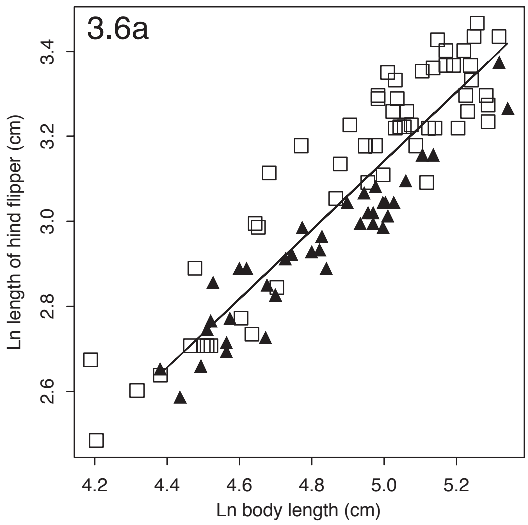
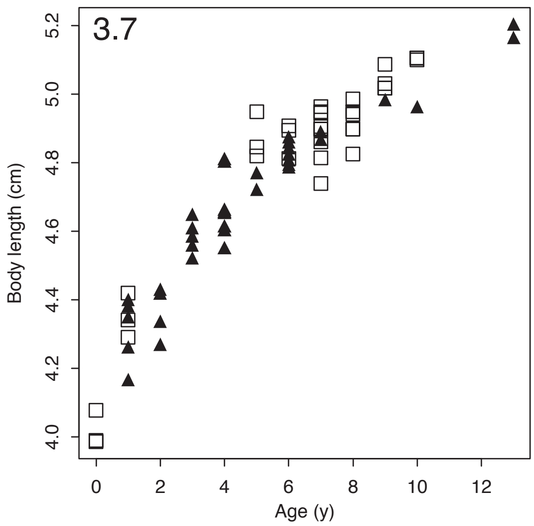


Fig. 3.3a, 3.3b Bivariate plot of log circumference of head at canine (cm) on: (a) log length of seal (cm) and (b) age (y).
Fig. 3.4a, 3.4b Bivariate plot of log tip of snout to centre of ear (cm) on: (a) log length of seal (cm) and (b) age (y).
Fig. 3.5a, 3.5b Bivariate plot of log tip of snout to anterior insertion of the foreflipper (cm) on: (a) log length of seal (cm) and (b) age (y).





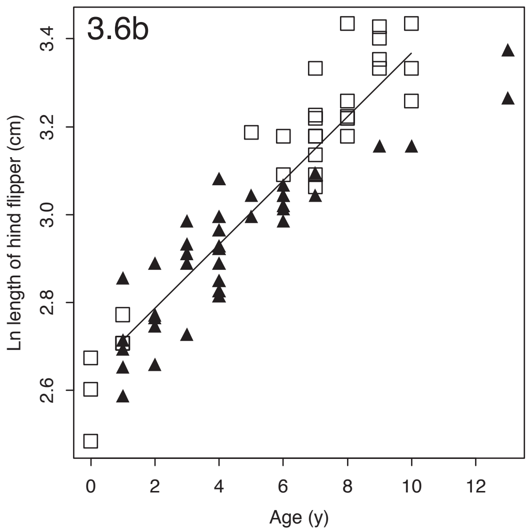


Fig. 3.6a, 3.6b Bivariate plot of log length of hind flipper (cm) on: (a) log length of seal (cm) and (b) age (y).
Fig. 3.7 Bivariate plot of log length of seal (cm) on age (y).

Body length as an indicator of age

In animals 1–10 y, growth in SBL was highly positively correlated with age (y) (r = 0.96, n = 56) (Appendix 3.4). After fitting the (robust) straight line model of age on standard body length, graphical displays of residuals and fitted values were examined, and the straight line model was found to be adequate. Thus, the following equation can be used as a very 'rough indicator' of absolute age for animals 1–10 y.

$$\text{age} = - 6.54 + 0.0087 \times \text{SBL}, n = 56$$

The coefficient of variation in SBL for young males 1–5 y (17.2%) was considerably higher than in older males (8–10 y, 6.9%; ≥ 12 y, 5.3%).

Body length as an indicator of age group

When SBL is known, the following linear discriminant functions can be used to categorise each observation into one of four age groups–pups, yearlings, subadults or subadult:

$$y_1 = -6.50 + 0.19x$$

$$y_2 = -11.14 + 0.25x$$

$$y_3 = -23.46 + 0.36x$$

$$y_4 = -45.28 + 0.50x$$

where x = SBL (cm); subscript 1 = pup; subscript 2 = yearling; superscript 3 = subadult; superscript 4 = adult. The seal is classified into the age group associated with the linear discriminant function which results in the minimum value. Of the 70 observations in this study 77% were correctly

Table 3.5 ***Discriminant analysis for seal age group (pup, yearling, subadult, adult) inferred from body length***

Known age group	n[a]	Classification into age group 0: Pup (< 1 mo)	1: Yearling (7 mo to 1 y 6 mo)	2: Subadult (1y 7 mo to 7 y 6 mo)	3: Adult[b] (≥ 7 y 7 mo)
0	**3**	3 (100%)	1	0	0
1	**8**	0	7 (88%)	9	0
2	**37**	0	0	23 (62%)	1
3	**22**	0	0	5	21 (96%)
Total	**70**	**3**	**8**	**37**	**22**

[a] Number of seals of known-age (MCM animals tagged as pups), and aged from counts of incremental lines observed in the dentine of upper canines (PEM animals), n = 70. Percentage of animals correctly classified into age group is given in brackets.
[b] Included animals > 12 y.

classified using this method (Table 3.5).

Curvilinear length as an indicator of SBL

Curvelinear length was found to be approximately 10.0 cm longer than SBL (SBL: 146.7 ± 5.6; CBL: 157.1 ± 6.2, *n* = 50 paired samples only). However, CBL was greatly influenced by the quantity of food in the stomach and by the degree of postmortem bloating. For example, CBL was 20–25 cm longer than SBL in 5 animals that had been dead for several days, or had consumed large quantities of fish; therefore, CBL was not consider to be a useful substitute for SBL.

DISCUSSION

Age determination

Although the possibility of error must be taken into consideration when interpreting the data, age estimates were considered to be reliable, with inconsistencies among readings mitigated by repeated estimates (Doubleday & Bowen, 1980).

Body size

Arctocephalus pusillus is the largest of the fur seals. Male SBL ranged from 66 to 243 cm. The largest animal in the collection (PEM952) was measured in 1980 at Kings Beach, Port Elizabeth, by V. Cockcroft and A. Bachelor. This is of similar length to an unusually large male (SBL 241 cm) measured by Rand in 1946 (Rand, 1949). The largest animal measured by the first author was 203 cm in 1994 (PEM2201).

At birth, male Cape fur seals are about 35% (*c*. 69 cm) of their mean adult size[2] (*c*. 199.4 cm). At puberty they are about 57% (*c*. 112.8 cm at 3 y) of their mean adult size[2]. Although axillary girth varies with body condition, it is usually about 57–67% of SBL. The foreflippers are relatively long measuring 25–26% (*c*. 18 cm) of SBL in pups, and 24% (*c*. 48 cm) of SBL in adults[2]. The hind flippers are considerably shorter measuring 19% (*c*. 13 cm) of SBL in pups, and 14.5% (*c*. 29 cm) of SBL in adults[2].

Body shape

Male Cape fur seals are exceptional swimmers and divers, and haul out on land to rest, moult and breed. Body shape and general physiology have been modified to accommodate the demands of both marine and terrestrial environments (Bryden, 1972). For example, bulls spend most of their life at sea, hauling out to moult (predominantly February and March), rest, and reproduce (establish territories and breed from late October to late December/early January).

The body is streamlined with a rounded head and a relatively short snout; small external ear pinnae (narrow and pointed); a small tail positioned between the hind flippers; a retractable penis that can be withdrawn into a cutaneous pouch; and modified fore/hind limbs (flippers).

The strong fore limbs have been modified into elongated flippers for propulsion through the water (forceful strokes towards the body) and terrestrial locomotion (palm extends laterally with the flipper bending between the two rows of carpal bones). Characteristic features include predigital cartilage, a long first digit, reduced fifth digit, rudimentary nails and hairless palms.

Unlike the foreflippers which are the primary appendage used for propulsion through the water, the smaller hind flippers have been modified for terrestrial locomotion (soles extends laterally with the flipper bending forward at the ankle). Characteristic features include predigital cartilage; long grooming claws on digits 2–4; enlargement of digits one and five; and hairless soles.

Function and growth

Overall growth in SBL was similar to that of other highly polygynous male otariids including *A. gazella* and *C. ursinus*, with rapid early postnatal growth; a sudden increase in body size at puberty; and a reduced rate of growth soon after attainment of social maturity (McLaren, 1993).

Cape fur seals pups are born on land between October to late December. New born pups are *c*. 35% (60–70 cm at birth) of mean adult size. During the first week, pups are largely inactive. As they become older, they gradually learn swimming skills in pools and sheltered channels. Growth during this period is rapid (present study), with males growing faster than females. For example, in November (when the majority of pups are born), mean length and weight is about 76 .0 cm and 5 kg 986 g for males, and 73 cm and 5 kg 487 g for females (Rand, 1956). By April, mean length and weight is about 82 .0 cm and 19 kg 183 g for males, and 84 cm and 15 kg 147 g for females (Rand, 1956).

When juveniles gain their permanent teeth (June) they disperse to deeper water for short periods, supplementing their milk diet with solids (Rand, 1956). During this period they learn foraging skills while accompanying their lactating mothers to sea. Most animals feed independently at 9–11 mo (Rand, 1956). There is a decline in body weight soon after weaning (Rand, 1956).

Most males attain puberty between 3–4 y, with sperm evident in the epididymis of some animals at 2 y 10 m (Stewardson *et al.*, 1998). The onset of puberty (2–3 y) is associated with a sudden increase in body size (present study). It is thought that puberty is attained when mammals reach a certain threshold size in body weight, with slower-growing animals

[2]Mean adult size, SBL for animals > 10 y including unaged animals > 200 cm.

reaching puberty later than faster-growing animals (Laws & Sinha, 1993). Although pubertal males produce sperm, they do not have the ability to acquire and maintain a harem. Small body size and inexperience prevents young males form gaining high social status.

Growth in SBL continues to increase steadily until about 6 y. In animals ≥ 7 y, growth continues to increase but at a slower rate (present study).

Social maturity is attained at about 9–10 y and appears to be associated with a weak secondary growth spurt in body size (present study). At this age, large body size has a direct advantage in competitive interactions with rival males, and an indirect effect through the presence of large stores of fat which enable males to remain on territory for up to 40 days (Rand, 1967; Wartzok, 1991). Successful bulls may mate multiple times over a two to three year period and are likely to die before reaching reproductive senescence (see Stewardson *et al.,* 1998). Growth in body size slows soon after attainment of social maturity (present study).

Growth of length of the foreflippers continued to increased until at least 13 y, with a significant increase in length at 4–5 y (present study). This increase may partially reflect changes in swimming and/or diving behaviour, with older animals presumably diving to deeper depths in search of prey. Growth of the smaller hind flippers slowed much earlier (8–9 y) than growth of the foreflippers. No special development of the foreflippers or hind flippers associated with locomotion was reported in *A. gazella*, i.e., a more or less constant rate of growth from age one to 7 (Payne, 1979).

Body length as an indicator of age

SBL could not be used reliably to assign a seal to a particular age because there was considerable overlap between year classes, especially among older animals. Similar findings have been reported in other species of pinnipeds (e.g., Laws, 1953; Bryden 1972; Bengtson & Sniff, 1981). However, SBL was found to be a 'very rough indicator' of age for animals 1–10 y, and of age group.

The classification criteria for age and age group developed in this study will be particularly useful when canines are not available for age determination, e.g. behavioural studies.

CONCLUSION

Information presented in this study contributes to earlier descriptions of the Cape fur seal (Rand, 1956), and provides new information on body growth according to age (y).

In male Cape fur seals, post natal growth is rapid with a significant growth spurt at at the onset of puberty (2–3 y) and a weak growth spurt at social maturity (9–10 y). Growth continues to increase but at a slower rate between 6 and 7 y, and then slows soon after the attainment of social maturity. Growth was a differential process and not simply an enlargement of overall size. Relative to SBL, facial variables and the fore/hind limbs scaled with negative slope relative to SBL or were negatively allometric; tip of snout to genital opening scaled with positive slope; and tip of snout to anterior insertion of the foreflipper was positively allometric. Relative to age, body variables scaled with negative slope or were negatively allometric. SBL was found to be a 'very rough indicator' of age and of age group.

Further information is needed on animals of known-age in order to accurately estimate asymptotic size. In the present study, low sample size at the intermediate ages, and the absence of very old animals of known-age (18–20 y), made it difficult to determine the exact shape of the growth curve. Furthermore, information on the breeding status of known-age males is required. Breeding bulls are thought to be larger in size than non-breeding bulls of the same age, therefore, the observed growth pattern is more complex than is presented in this study.

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Appendix 3.1 ***Cape fur seals (n = 149) examined in this study.*** **Animals were collected from the coast of southern Africa between August 1978 and September 1997.**

	ID No.	Date of collection	Approximate location[b]	Region[c]	Method of collection[d]	SBL (cm)
1.	PEM603	2 Aug 78	Bell Buoy, Algoa Bay (AB) (33º 59'S, 25º 42'E)	ECP	sci. permit	150
2.	PEM605	4 Apr 79	Riy Bank, AB (34º 00'S, 25º 53'E)	ECP	sci. permit	153
3.	PEM607	30 Sep 79	King's Beach, Port Elizabeth (PE) (33º 58'S, 25º 39'E)	ECP	rehab. (D)	91
4.	PEM608	29 Aug 79	Cape Recife–Riy Bank, AB (34º 02'S, 25º 42'E– 34º 00'S, 25º 53'E)	ECP	sci. permit	182
5.	PEM658	17 July 80	2 km E Kabeljous River Mouth, Jeffreys Bay	ECP	stranding	106
6.	PEM661	17 July 74	Riy Bank–St. Croix, AB (34º 00'S, 25º 53'E– 33º 48'S, 25º 46'E)	ECP	sci. permit	141
7.	PEM670	5 Mar 79	King's Beach, PE (33º 58'S, 25º 39'E)	ECP	stranding	158
8.	PEM676	16 Feb 81	NR	ECP	oceanarium	197
9.	PEM824	23 Mar 82	Pollock Beach, PE (33º 59'20"S, 25º 40' 30"E)	ECP	stranding	174
10.	PEM828	26 Mar 82	Port Elizabeth Harbour (33º 58'S, 25º 37'E)	ECP	stranding	158
11.	PEM834	21 Apr 82	22 km E of Sundays River Mouth, Woody Cape (WC)	ECP	stranding	162
12.	PEM852	21 July 82	15 km E Sundays River Mouth, WC	ECP	stranding	195
13.	PEM874	18 Oct 82	32 km E of Sundays River Mouth, WC	ECP	stranding	157
14.	PEM875	20 Sep 82	1 km W of Van Starden's River Mouth	ECP	stranding	165
15.	PEM877	2 Oct 82	E of Swartkops River Mouth, AB	ECP	stranding	165
16.	PEM886	23 Oct 82	Pollock Beach, PE (33º 59'20"S, 25º 40' 30"E)	ECP	stranding	193
17.	PEM888	2 Nov 82	7 km E of Kasuga River Mouth, Port Alfred (PA)	ECP	stranding	212
18.	PEM889	2 Nov 82	4 km E of Kasuga River Mouth, PA	ECP	stranding	138
19.	PEM898	22 Dec 82	1 km E of Van Starden's River Mouth, St. Francis Bay (FB)	ECP	stranding	200
20.	PEM916	Jan 1983	Willows, PE (34º 03'S, 25º 35'E)	ECP	stranding	91
21.	PEM917	11 Jan 83	2 km W of Maitland River Mouth, FB	ECP	stranding	104
22.	PEM928	14 Mar 82	28 km E of Sundays River Mouth, WC	ECP	stranding	140
23.	PEM951	16 May 83	35 km E of Sundays River Mouth, WC	ECP	stranding	170
24.	PEM952[a]	22 Feb 80	King's Beach, PE (33º 58'S, 25º 39'E)	ECP	stranding	243
25.	PEM958	13 Dec 83	Humewood, PE (33º 59'S, 25º 40'E)	ECP	other	190
26	PEM975	7 Oct 83	40 km E of Sundays River Mouth, WC	ECP	stranding	172
27.	PEM1073	12 Sep 84	Oyster Bay (34º 10'S, 24º 39'E)	ECP	stranding	133
28.	PEM1135	6 Feb 85	15 km E Sundays River Mouth, WC	ECP	stranding	141
29.	PEM1159	20 May 85	3.5 km W of Woody Cape Point	ECP	stranding	190
30.	PEM1453	30 Jan 88	3 km E Kabeljous River Mouth, Jeffreys Bay	ECP	stranding	193
31.	PEM1507	5 Feb 88	King's Beach, PE (33º 58'S, 25º 39'E)	ECP	stranding	198
32.	PEM1560	26 Oct 88	Seaview (34º 01'E, 25º 17'S)	ECP	stranding	201
33.	PEM1587	18 May 89	Amsterdamhoek (33º 52'S, 25º 38'E)	ECP	stranding	192
34.	PEM1696	12 Apr 90	5 km E of Sundays River Mouth, WC	ECP	stranding	202
35.	PEM1697	12 Apr 90	15 km E of Sundays River Mouth, WC	ECP	stranding	192
36.	PEM1698	12 Apr 90	25 km E of Sundays River Mouth, WC	ECP	stranding	190
37.	PEM1706	12 July 90	1.5 km E of Sundays River Mouth, WC	ECP	stranding	126
38.	PEM1879	13 Apr 92	Flat Rocks, PE (34º 00'S, 25º 42'E)	ECP	stranding	200
39.	PEM1882	6 May 92	King's Beach, PE (33º 58'S, 25º 39'E)	ECP	stranding	180
40.	PEM1885	17 June 92	1 km W of Cape Recife, PE	ECP	stranding	80
41.	PEM1890	13 July 92	Cape Recife, PE (34º 02'S, 25º 42'E)	ECP	stranding	192
42.	PEM1892	27 July 92	Sardinia Bay (34º 02'S, 25º 29'E), 800 m E of boat shed	ECP	stranding	185
43.	PEM1895	29 July 92	Cape Recife, PE (34º 02'S, 25º 42'E), 2 km E of lighthouse	ECP	stranding	188
44.	PEM1999	20 July 92	EC trawl grounds (34º 52'S, 23º 35'E–34º 50'S, 23º 48'E)	ECP	by-catch	–
45.	PEM2000	21 July 92	EC trawl grounds (34º 50'S, 23º 48'E–34º 48'S, 24º 00'E)	ECP	by-catch	–
46.	PEM2002	22 July 92	EC trawl grounds (34º 55'S, 23º 14'E–34º 53'S, 23º 26'E)	ECP	by-catch	–
47.	PEM2003	24 July 92	EC trawl grounds (34º 51'S, 23º 42'E–34º 49'S, 23º 53'E)	ECP	by-catch	–
48.	PEM2004	25 July 92	EC trawl grounds (34º 45'S, 24º 18'E–34º 48'S, 24º 00'E)	ECP	by-catch	–
49.	PEM2006	13 Aug 92	EC trawl grounds (34º 45'S, 24º 25'E–34º 42'S, 24º 40'E)	ECP	by-catch	–
50.	PEM2007	14 Aug 92	EC trawl grounds (34º 42'S, 24º 51'E–34º 42'S, 24º 42'E)	ECP	by-catch	–
51.	PEM2008	14 Aug 92	EC trawl grounds (34º 41'S, 24º 42'E–34º 38'S, 24º 54'E)	ECP	by-catch	–
52.	PEM2009	22 Aug 92	EC trawl grounds (34º 41'S, 24º 45'E–34º 37'S, 24º 59'E)	ECP	by-catch	–
53.	PEM2010	22 Aug 92	EC trawl grounds (34º 47'S, 24º 11'E–34º 46'S, 24º 25'E)	ECP	by-catch	–
54.	PEM2013	14 Sep 92	EC trawl grounds (34º 24'S, 25º 50'E–34º 25'S, 26º 02'E)	ECP	by-catch	–
55.	PEM2014	25 Sep 92	EC trawl grounds (34º 23'S, 26º 04'E–34º 23'S, 25º 58'E)	ECP	by-catch	–
56.	PEM2015	3 Nov 92	EC trawl grounds (34º 17'S, 24º 36'E–34º 20'S, 24º 23'E)	ECP	by-catch	–
57.	PEM2020	28 Jan 93	Kenton-on-sea (33º 40'S, 26º 40'E)	ECP	euthanased	66
58.	PEM2021	28 Jan 93	Swartkops River Mouth	ECP	stranding	75
59.	PEM2036	19 Mar 93	Black Rocks, AB (33° 50'S, 26° 15'E)	ECP	stranding	–

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	ID No.	Date of collection	Approximate location[b]	Region[c]	Method of collection[d]	SBL (cm)
60.	PEM2045	30 May 93	Schoenmakerskop (34° 02'S, 25° 32'E)	ECP	stranding	145
61.	PEM2046	19 May 93	EC trawl grounds (35° 09'S, 21° 28'E)	ECP	by-catch	141
62.	PEM2047	20 May 93	EC trawl grounds (34° 53'S, 23° 27'E–34° 50'S, 23° 40'E)	ECP	by-catch	167
63.	PEM2048	20 May 93	EC trawl grounds (34° 53'S, 23° 27'E–34° 50'S, 23° 40'E)	ECP	by-catch	157
64.	PEM2049	7 June 93	Kini Bay (34° 01'S, 25° 26'E), Western Beach	ECP	stranding	174
65.	PEM2051	28 June 93	EC trawl grounds (34° 44'S, 24° 29'E–34° 45'S, 24° 20'E)	ECP	by-catch	168
66.	PEM2052	28 June 93	EC trawl grounds (34° 44'S, 24° 29'E–34° 45'S, 24° 20'E)	ECP	by-catch	171
67.	PEM2053	28 June 93	EC trawl grounds (34° 46'S, 24° 21'E–34° 44'S, 24° 32'E)	ECP	by-catch	153
68.	PEM2054	29 June 93	EC trawl grounds (34° 45'S, 24° 28'E–34° 47'S, 24° 18'E)	ECP	by-catch	165
69.	PEM2081	19 July 93	Cape Recife, PE (34° 02'S, 25° 42'E)	ECP	stranding	162
70.	PEM2082	July 93	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	176
71.	PEM2087	17 Aug 93	Plettenberg Bay (34° 07'S, 23° 25'E), Robberg	ECP	stranding	190
72.	PEM2131	13 Dec 93	Sundays River Mouth, AB	ECP	rehab. (D)	67
73.	PEM2132	20 Dec 93	Woody Cape, AB (33° 46'S, 26° 19'E)	ECP	stranding	195
74.	PEM2137	5 Jan 94	Summerstrand, PE (34° 00'S, 25° 42'E)	ECP	rehab. (D)	118
75.	PEM2140	17 Jan 94	40 km E of Sundays River Mouth, WC	ECP	stranding	187
76.	PEM2141	17 Jan 94	39 km E of Sundays River Mouth, WC	ECP	stranding	198
77.	PEM2143	21 Jan 94	Seaview (34° 01'S, 25° 17'E)	ECP	stranding	189
78.	PEM2186	7 Apr 94	Amsterdamhoek (33° 52'S, 25° 38'E)	ECP	rehab. (D)	90
79.	PEM2188	17 Apr 94	NR	ECP	oceanarium	132
80.	PEM2191	4 May 94	Port Alfred (33° 36'S, 26° 55'E)	ECP	euthanased	100
81.	PEM2194	2 June 94	Schoenmakerskop (34° 02'S, 25° 32'E)	ECP	stranding	194
82.	PEM2197	12 July 94	Cape Recife, PE (34° 02'S, 25° 42'E)	ECP	stranding	160
83.	PEM2198	July 94	Plettenberg Bay (34° 03'S, 23° 24'E)	ECP	stranding	105
84.	PEM2201	5 July 94	Schoenmakerskop (34° 02'S, 25° 32'E)	ECP	stranding	103
85.	PEM2203	18 July 94	Port Elizabeth Harbour (33° 58'S, 25° 37'E)	ECP	other	204
86.	PEM2238[e]	1994	Durban (29° 50'S, 31° 00'E)	ECP	rehab. (D)	96
87.	PEM2248	12 Aug 94	Seaview (34° 01'S, 25° 27'E)	ECP	stranding	158
88.	PEM2252	22 Aug 94	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	172
89.	PEM2253	27 Aug 94	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	152
90.	PEM2254	27 Aug 94	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	146
91.	PEM2256	17 Sep 94	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	198
92.	PEM2257A	19 Sep 94	EC trawl grounds	ECP	by-catch	142
93.	PEM2257B	8 Oct 94	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	170
94.	PEM2348	14 Nov 94	Humewood, PE (33° 59'S, 25° 40'E)	ECP	stranding	189
95.	PEM2359	21 Feb 95	Sundays River Mouth, AB	ECP	stranding	108
96.	PEM2374	24 Mar 95	Jeffreys Bay (34° 03'S, 24° 55'E)	ECP	stranding	186
97.	PEM2379	12 Apr 95	Bokness (33° 41'S, 26° 31'E)	ECP	stranding	189
98.	PEM2400	13 July 95	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	176
99.	PEM2401	13 July 95	EC trawl grounds	ECP	by-catch	146
100.	PEM2403	July 95	NR	ECP	rehab. (D)	88
101.	PEM2404	July 95	NR	ECP	rehab. (D)	92
102.	PEM2405	July 95	NR	ECP	rehab. (D)	87
103.	PEM2406	July 95	Swartkops River Mouth	ECP	stranding	154
104.	PEM2409	24 Aug	Oceanarium animal (Muti)	ECP	oceanarium	135
105.	PEM2411	24 Aug 95	Plettenberg Bay (34° 03'S, 23° 24'E)	ECP	by-catch	155
106.	PEM2414	25 Aug 95	EC trawl grounds (c. 30 nm S of Cape St. Francis)	ECP	by-catch	148
107.	PEM2415	27 Aug 95	Sardinia Bay (34° 02'S, 25° 29'E)	ECP	stranding	130
108.	PEM2454	8 Nov 95	Noordhoek (34° 02'S, 25° 39'E)	ECP	stranding	196
109.	PEM2455	27 Nov 95	2.3 km W of Maitland River Mouth, FB	ECP	stranding	124
110.	PEM2458	3 Dec 95	Cape St. Francis (34° 12'S, 24° 52'E)	ECP	rehab. (D)	110
111.	MCM1565	25 Sep 84	Vondeling area (33° 18'S, 18° 06'E), 2 miles offshore	WC	sci. permit	118
112.	MCM1786	30 Sep 94	St Helena Bay	WC	stranding	85
113.	MCM2763	10 Feb 85	Doringbaai area (31° 30'S, 16° 30'E)	WC	by-catch	127
114.	MCM2795	27 July 88	Demersal fishing grid 502	SWC	by-catch	158
115.	MCM3017	14 Nov 85	Kleinzee seal colony	WC	sci. permit	209
116.	MCM3125	17 Nov 85	Kleinzee seal colony	WC	sci. permit	204
117.	MCM3582	6 June 86	Offshore Dassen Island (33° 21'S, 17° 40'E)	WC	by-catch	142
118.	MCM3586	22 Apr 86	8 miles off Wilderness	SC	by-catch	144
119.	MCM3587	5 June 86	25 nm west of Mossel Bay	SC	by-catch	145

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	ID No.	Date of collection	Approximate location[b]	Region[c]	Method of collection[d]	SBL (cm)
120.	PEM3589	8 Dec 86	West of Slangkop	WC	by-catch	148
121.	MCM3636	17 July 87	West of Dassen Island (37° 45'S, 17° 35'E)	WC	by-catch	148
122.	MCM4023	28 June 89	St Helena Bay (32° 30'S, 18° 16'E)	WC	sci. permit	113
123.	MCM4365	13 Mar 90	3.5 nm off Gouritz River Mouth (34° 23'S, 21° 51'E)	SC	by-catch	124
124.	MCM4388	23 Oct 90	20 nm south of Gouritz River Mouth (34° 26'S, 21° 53'E)	SC	by-catch	122
125.	MCM4577	17 Jan 94	Cape Town Harbour	WC	stranding	150
126.	MCM4584	19 Jan 95	St Helena Bay (32° 44'S, 18° 08'E)	WC	by-catch	125
127.	MCM4585	19 Jan 95	St Helena Bay (32° 44'S, 18° 08'E)	WC	by-catch	–
128.	MCM4595	17 Oct 95	Off Cape Point (34° 45'S, 21° 49'E)	SW	by-catch	134
129.	MCM4597	15 Sep 95	South of Dassen Island (33° 30'S, 17° 40'E)	WC	by-catch	170
130.	MCM4985	26 June 96	1 nm off Sandy Point harbour	WC	by-catch	92
131.	MCM4987	8 May 96	Offshore Hut Bay (34° 16'S, 17° 43'E)	WC	by-caych	144
132.	MCM4989	14 Aug 96	St Helena Bay	WC	by-catch	99
133.	MCM4991	15 Aug 96	St Helena Bay	WC	by-catch	102
134.	MCM4992	13 Sep 96	Demersal fishing grid 493 (35° 30'S, 18° 56'E)	SW	by-catch	165
135.	MCM4996	28 Sep 96	Offshore Saldahna Bay (33° 10'S, 17° 14'E)	WC	by-catch	115
136.	MCM4998	10 July 96	Seal Island, St Helena Bay	WC	by-catch	93
137.	MCM4999	10 July 96	Seal Island, St Helena Bay	WC	by-catch	80
138.	MCM5000	10 Jan 96	Seal Island, St Helena Bay	WC	by-catch	96
139.	MCM5001	10 Jan 96	Seal Island, St Helena Bay	WC	by-catch	96
140.	MCM5002	10 June 96	Offshore Saldahna Bay (33° 16'S, 17° 07'E)	WC	by-catch	108
141.	MCM5005	18 Oct 96	Off Paternoster Island	WC	by-catch	91
142.	MCM5021	26 Dec 96	Offshore Saldahna Bay (33° 12'S, 17° 13'E)	WC	by-catch	141
143.	MCM5022	26 Nov 96	18 nm East of Mossel Bay (34° 25'S, 25° 50'E)	SC	by-catch	139
144.	MCM5133	14 Jan 97	Offshore Plettenberg Bay (34° 30'S, 23° 30'E)	ECP	by-catch	153
145.	MCM5134	22 May 97	8 nm off Shelly Point, St Helena Bay	WC	by-catch	97
146.	MCM5135	23 July 97	Offshore Stompneus Lighthouse	WC	stranding	110
147.	MCM5136	15 July 97	Offshore St Helena Bay (32° 27'S, 17° 38'E)	WC	by-catch	149
148.	MCM5142	19 Aug 97	Vondeling Island	WC	by-catch	107
149.	MCM5145	Nov 94	St Helena Bay	WC	by-catch	90

[a] Animal collected in 1980 and issued with a new identification number in 1983, i.e., PEM952.
[b] Kabeljous River Mouth (34° 00'S, 24° 56'E); Maitland River Mouth (33° 59'S, 25° 18'E); Sundays River Mouth (33° 43'S, 25° 51'E); and Van Starden's River Mouth (33° 58'S, 25° 13'E).
[c] WC (west coast), north of Cape Point Lighthouse (34° 21'S, 18° 29'E); SWC (south west coast), south of Cape Point Lighthouse to Cape Agulhas (34° 50'S, 20° 00'E); SC (south coast), east of Cape Agulhas, but excluding the Eastern Cape; and ECP (Eastern Cape Province), Plettenberg Bay (34° 03'S, 23° 24'E) to East London (33° 03'S, 27° 54'E).
[d] Stranding, animal washed up dead on beach (n = 62). By-catch, animal incidentally caught in a commercial trawl net during fishing operations (n = 63). Rehab. (D), animal died during rehabilitation at the Port Elizabeth Oceanarium (n = 9). Euthanased, animal suffering from illness/injury and was put down to prevent further suffering (n = 2). Sci. permit, animal collected under scientific permit or harvested (n = 8). Oceanarium, captive animal of the Port Elizabeth Oceanarium (n = 3, PEM676 Tommy; PEM2188 Rascal; PEM2409 Muti). Other, animal died from other causes (n = 2, PEM958 found floating in the ocean off Humewood Beach; PEM2203 stoned to death by fisherman).
[e] Animal PEM2238 collected NE of the Eastern Cape, i.e., Durban (29° 50'S, 31° 00'E).
NR, not recorded.

Appendix 3.2 ***Spearman rank-order correlation coefficients for log body variables***

	Var 1	**Var 2**	**Var 3**	**Var 4**	**Var 5**	**Var 6**	**Var 7**	**Var 8**	**Var 9**	**Var 10**	**Var 11**	**Var 12**
Var 1	1.00 (99)	0.82* (98)	_0.12_ [0.27] (85)	0.74* (97)	0.63* (94)	0.77* (87)	0.84* (54)	0.76* (96)	0.71* (98)	0.71* (96)	0.82* (81)	0.72* (93)
Var 2	0.82* (98)	1.00 (102)	_0.17_ [0.11] (87)	0.76* (100)	0.61* (97)	0.62* (90)	0.81* (57)	0.78* (97)	0.73* (101)	0.74* (99)	0.86* (83)	0.72* (96)
Var 3	_0.12_ [0.27] (85)	_0.17_ [0.11] (87)	1.00 (101)	_0.25**_ [0.02] (93)	_0.25**_ [0.02] (89)	_0.15_ [0.17] (87)	_0.002_ [0.99] (54)	_0.08_ [0.46] (90)	_0.17_ [0.10] (92)	_0.12_ [0.26] (90)	_0.07_ [0.54] (71)	_0.15_ [0.16] (87)
Var 4	0.74* (97)	0.76* (100)	_0.25**_ [0.02] (93)	1.00 (108)	0.85* (104)	0.84* (93)	0.68* (61)	0.79* (103)	0.74* (106)	0.85* (104)	0.79* (85)	0.76* (101)
Var 5	0.63* (94)	0.61* (97)	_0.25**_ [0.02] (89)	0.85* (104)	1.00 (105)	0.78* (94)	0.68* (57)	0.69* (100)	0.68* (103)	0.72* (102)	0.71* (86)	0.68* (101)
Var 6	0.77* (87)	0.82* (90)	_0.15_ [0.17] (87)	0.84* (93)	0.78* (94)	1.00 (131)	0.96* (51)	0.99* (94)	0.93* (95)	0.92* (93)	0.94* (86)	0.90* (92)
Var 7	0.84* (54)	0.81* (57)	_0.002_ (54)	0.68* (61)	0.68* (57)	0.96* (51)	1.00 (65)	0.97* (60)	0.92* (61)	0.74* (59)	0.92* (45)	0.82* (57)
Var 8	0.76* (96)	0.78* (97)	_0.08_ [0.46] (90)	0.79* (103)	0.69* (100)	0.99* (94)	0.97* (60)	1.00 (107)	0.93* (104)	0.89* (102)	0.94* (84)	0.90* (99)
Var 9	0.71* (98)	0.73* (101)	_0.17_ [0.10] (92)	0.74* (106)	0.68* (103)	0.93* (95)	0.92* (61)	0.93* (104)	1.00 (109)	0.82* (105)	0.89* (87)	0.91* (102)
Var 10	0.71* (96)	0.74* (99)	_0.12_ [0.26] (90)	0.85* (104)	0.72* (102)	0.92* (93)	0.74* (59)	0.89* (102)	0.82* (105)	1.00 (107)	0.88* (85)	0.87* (101)
Var 11	0.82* (81)	0.86* (83)	_0.07_ [0.54] (71)	0.79* (85)	0.71* (86)	0.94* (86)	0.92* (45)	0.94* (84)	0.89* (87)	0.88* (85)	1.00 (87)	0.85* (86)
Var 12	0.72* (93)	0.72* (96)	_0.15_ [0.16] (87)	0.76* (101)	0.68* (101)	0.90* (92)	0.82* (57)	0.90* (99)	0.91* (102)	0.87* (101)	0.85* (86)	1.00 (103)
Total	**99**	**102**	**101**	**108**	**105**	**131**	**65**	**107**	**109**	**107**	**87**	**103**

Variables: 1. Circumference of head at canine; 2. circumference of head at eye; 3. tip of snout to centre of eye; 4. tip of snout to centre of ear; 5. tip of snout to angle of gape; 6. standard body length; 7. ventral curvilinear length; 8. tip of snout to genital opening; 9. tip of snout to anterior insertion of the foreflipper; 10. length of foreflipper; 11. axillary girth; and 12. length of hind flipper.
Pups excluded from analysis.
p = 0.00 unless otherwise stated in square brackets.
* Significant at 2% level (2-tailed).
** Significant at 1% (2-tailed).
Sample size in round brackets.

Appendix 3.3 ***'Robust' least squares straight line equations, Spearman rank-order correlation coefficients, and allometry for log body measurement (cm) on log seal body length (cm)***

Dependent variable	Linear regression				Allometry		
	n^a	Intercept ± S.E.	Slope ± S.E.	r (p)	Alternative hypothesis	d.f.	p
1. Circumference of head at canine	87	0.89 ± 0.18	0.47 ± 0.04	0.77 (0.00)	$H_1 : \hat{\beta} < 1$	85	0.00
2. Circumference of head at eye	90	1.09 ± 0.18	0.50 ± 0.04	0.82 (0.00)	$H_1 : \hat{\beta} < 1$	88	0.00
3. Tip of snout to centre of eye[b]	87	–	–	0.15 (0.16)	–	–	–
4. Tip of snout to centre of ear	93	0.30 ± 0.14	0.53 ± 0.03	0.84 (0.00)	$H_1 : \hat{\beta} < 1$	91	0.00
5. Tip of snout to angle of gape	94	-0.82 ± 0.22	0.64 ± 0.04	0.78 (0.00)	NA	NA	NA
8. Tip of snout to genital opening	94	-0.35 ± 0.07	1.04 ± 0.01	0.99 (0.00)	NA	NA	NA
9. Tip of snout to anterior insertion of the foreflipper	95	-1.33 ± 0.22	1.11 ± 0.05	0.93 (0.00)	$H_1 : \hat{\beta} > 1$	93	0.007
10. Length of foreflipper	93	-0.91 ± 0.18	0.89 ± 0.04	0.92 (0.00)	NA	NA	NA
12. Length of hind flipper	92	-0.91 ± 0.19	0.81 ± 0.04	0.90 (0.00)	NA	NA	NA
Total	**116**						

[a] Number of aged and unaged animals with SBL recorded (pups were excluded from analysis, and SBLs from 15 aged/unaged males were not recorded, i.e., $n = 116$).
r, Spearman rank-order correlation coefficient.
All correlations are significant at the 1% level (2-tailed) apart from V3.
NA, model assumptions required to test hypotheses about the slope of the line (b) were not met, i.e., test not applicable.
[b] Model assumptions met; however, linear regression not significant.
Variables 7 and 11 excluded from analysis (see footnotes in Table 3.3).

Appendix 3.4 ***'Robust' least squares straight line equations, Spearman rank-order correlation coefficients, and allometry for log body measurement (cm) on age (y)***

Dependent variable	Linear regression				Allometry		
	n^a	Intercept ± S.E.	Slope ± S.E.	r (p)	Alternative hypothesis	d.f.	p
1. Circumference of head at canine	63	-2.59 ± 0.50	0.17 ± 0.021	0.59 (0.00)	$H_1 : \hat{\beta} < 1$	61	0.00
2. Circumference of head at eye	63	-2.63 ± 0.43	0.12 ± 0.01	0.69 (0.00)	NA	NA	NA
3. Tip of snout to centre of eye[b]	57	–	–	-0.008 (0.95)	–	–	–
4. Tip of snout to centre of ear	68	2.67 ± 0.02	0.04 ± 0.004	0.69 (0.00)	NA	NA	NA
5. Tip of snout to angle of gape	64	2.03 ± 0.03	0.04 ± 0.005	0.56 (0.00)	$H_1 : \hat{\beta} < 1$	62	0.00
6. Standard body length	56	4.45 ± 0.02	0.08 ± 0.003	0.96 (0.00)	NA	NA	NA
8. Tip of snout to genital opening	67	-1.28 ± 0.14	0.02 ± 0.001	0.93 (0.00)	NA	NA	NA
9. Tip of snout to anterior insertion of the foreflipper	68	3.56 ± 0.03	0.10 ± 0.005	0.90 (0.00)	$H_1 : \hat{\beta} < 1$	66	0.00
10. Length of foreflipper	67	3.10 ± 0.03	0.07 ± 0.005	0.82 (0.00)	NA	NA	NA
12. Length of hind flipper	64	2.64 ± 0.02	0.07 ± 0.004	0.93 (0.00)	$H_1 : \hat{\beta} < 1$	62	0.00
Total	**68**						

[a] Number of skulls with body variable and age recorded (only animals 1–10 y were included in analysis, i.e., $n = 68$).
r, Spearman rank-order correlation coefficient.
All correlations are significant at the 1% level (2-tailed), except for V3.
NA, model assumptions required to test hypotheses about the slope of the line (b) were not met, i.e., test not applicable.
[b] Model assumptions met; however, linear regression not significant.
Variables 7 and 11 excluded form analysis (see footnotes in Table 3.3).