

### Relationship between Age and Body Weight for Hippopotamus

Laws (1968) gives a relationship between age and body length for hippopotamus based on a sample of 1,219 hippos (505 males and 714 females) culled in Queen Elizabeth National Park, Uganda, between 1961 and 1966. Pienaar (*et al* 1966) give body length and weight data from a sample of 104 hippo (52 males and 52 females) culled in the Letaba River in Kruger National Park in 1964. These two data sets enable the construction of a formula which predicts body weight from age.

The data of Pienaar (*et al* 1966) were examined to see if there were any reasons why male and female data could not be combined into a single data set. Although the regressions on the separate data sets for males and females yield slightly different results, an inspection of the figures suggest that there is a wide overlap between the male and female body weights for any given body length. On allometric principles it would not be expected that animals of the same species which have same body length would differ in body weight. The data were combined and a regression was used to determine the values of the constants in the relationship –

$$\text{Body weight (kg)} = a.(\text{Body length (cm)})^b$$

The regression (performed on logarithms of the data values) yielded the results of  $a = 1.49 \times 10^{-4}$  and  $b = 2.79$ . Pienaar (*et al ibid*) point out that the hippo in the Letaba were in poor condition as a result of a drought which had affected Kruger National Park since 1962. Because of this, the regression constants were adjusted by inspection so that the body weights predicted by the formula were closer to the higher values in the data set rather than the central values. The final values used were  $a = 2.5 \times 10^{-4}$  and  $b = 2.70$ .

Laws (1968) used von Bertalanffy’s (1938) formula for predicting body length from age but notes that the derived values apply only to animals between the ages of 5 and 25 years old. Laws completes the curves for the full age span (0-50 years) by simply extrapolating graphically. von Bertalanffy’s curve has the form  $y = A(1 - e^{-Bt})$  which describes a growth curve where adult animals achieve an asymptotic weight. It is not suitable for hippo where adults continuing growing throughout their life. To rectify this I have added a ‘ramp’ function to the formula.

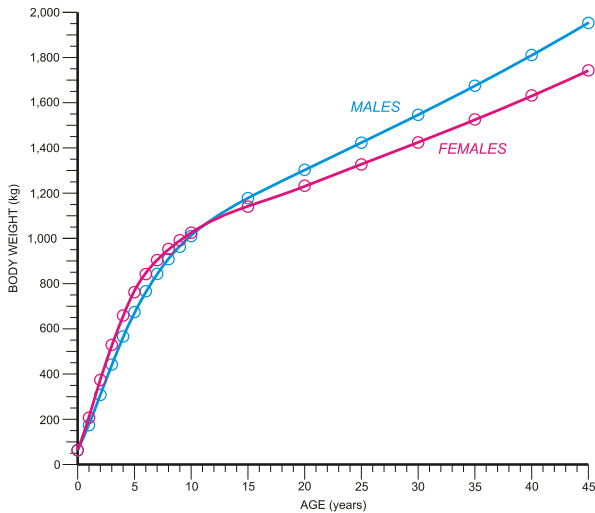
$$\text{Body length} = A (1 - e^{-B(\text{Age} + C)} + D.\text{Age})$$

Adult male hippo are heavier than females of the same age and Laws gives a separate von Bertalanffy formula for each sex. I used the values given by Laws’ two formulae to generate a set of body lengths for males and females between the ages of 5 and 20 years. To these data sets I added the value of 86.1cm for the body length of hippo at birth (which is the value which gives a birth weight of 42.14kg (Smuts & Whyte 1981 p171) and the values of 360cm and 343cm as the body lengths for the oldest males and females (from Pienaar *et al*’s data).

Curves were then fitted according to the above formula by iterating the values of the above constants (**A-D**) within a spreadsheet. The results were very satisfactory and permitted a close fit between the data and the predicted values for body length.

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
Males	268	0.3	1.56	$7.34 \times 10^{-4}$
Females	268	0.384	1.216	$6.12 \times 10^{-4}$

The analysis could have been left there but one feature of the fitted curves bothered me. When body weights are derived from the two body length formulae, female hippo up to the age of 11 years appear to be heavier than their male counterparts (see figure opposite). Both Laws’ and Pienaar *et al*’s data agree that adult hippo males are heavier than female hippos of the same age and it seems unlikely that the two curves ‘cross over’ in the manner shown. The effect is due to the body lengths given by Laws’ formulae for female hippo between the ages of 5 and 13 years and it seems likely that it is an artefact of the analytic technique. Up to a certain age, male and female hippo probably have identical body lengths and body weights and the differences only start to emerge at about 10 years old.



The data were re-analysed with the constraint that males and females must possess identical characteristics up to a certain age and only diverge thereafter. This necessitated some changes to the body length formula given on the previous page. For males to be able to grow larger than females only after the given age, the ‘ramp function’ must operate independently for each sex and must only come into play after the given age. The revised formula is –

$$Body\ length = A(1 - e^{-B(Age + C)}) + D(Age - E) \Big|_{Age > E}$$

*E* is the threshold age after which males and females diverge and it is determined by iteration along with the other constants. By using a logical function in the spreadsheet formula, the ramp function can be suppressed for ages less than *E*. The constants *A*, *B*, *C* and *E* are assumed to be identical for both males and females and only the slope of the ramp function (*D*) is allowed to differ between the two sexes. Iteration was performed by maintaining separate data sets for males and females and examining the combined sum of squares for the differences between observed and predicted values for both sexes simultaneously. The revised constants which come from this analysis are shown below –

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Males	281.4	0.347	1.054	7.49 x 10 <sup>-4</sup>	8
Females	281.4	0.347	1.054	5.87 x 10 <sup>-4</sup>	8

The body lengths and body weights corresponding to ages 0 - 45 years are shown in **Table 8** on the next page and depicted graphically in **Fig.3** on page 4.

Age years	Body Length		Weight	
	Males cm	Females cm	Males kg	Females kg
0	86	86	42	42
1	143	143	167	167
2	184	184	327	327
3	212	212	483	483
4	233	233	617	617
5	247	247	725	725
6	257	257	807	807
7	264	264	869	869
8	269	269	915	915
9	275	274	968	964
10	280	279	1,013	1,004
11	283	282	1,051	1,037
12	287	285	1,085	1,067
13	290	288	1,116	1,092
14	293	290	1,145	1,116
15	295	292	1,172	1,138
16	298	294	1,198	1,159
17	300	296	1,223	1,179
18	302	298	1,249	1,198
19	304	299	1,274	1,218
20	307	301	1,298	1,237
21	309	303	1,323	1,256
22	311	304	1,348	1,275
23	313	306	1,373	1,294
24	315	308	1,399	1,313
25	317	309	1,424	1,332
26	319	311	1,450	1,352
27	321	313	1,476	1,371
28	324	314	1,503	1,391
29	326	316	1,529	1,411
30	328	318	1,556	1,431
31	330	319	1,583	1,451
32	332	321	1,611	1,471
33	334	323	1,639	1,492
34	336	324	1,667	1,513
35	338	326	1,695	1,534
36	340	328	1,724	1,555
37	343	329	1,753	1,576
38	345	331	1,782	1,597
39	347	333	1,811	1,619
40	349	334	1,841	1,641
41	351	336	1,872	1,663
42	353	338	1,902	1,685
43	355	339	1,933	1,707
44	357	341	1,964	1,730
45	359	343	1,995	1,753

**Table 8. Age-specific body lengths and weights for hippo derived in this study**