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LENGTH-WEIGHT RELATIONSHIPS IN THE SPINNER DOLPHIN (*STENELLA LONGIROSTRIS*)

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Models of weight relative to length have a number of uses in marine mammalogy. For example, as recommended by Ridgway and Fenner (1982) and McBain (2001), in husbandry the condition of a captive or rescued dolphin can be assessed by comparing its weight with normative values at length in healthy animals. Comparative studies of functional morphology and behavior, such as those of Pabst *et al.* (1999) and the recent study showing a positive correlation in primates between testis/body weight ratio and sperm competition in breeding (Dixson 1998), require information on body weight, but few weight data are available for large marine vertebrates; often only lengths are collected. Models of ecosystem structure and energetics, such as those of Tamura (2003) and Trites *et al.* (1997) in attempting to assess prey consumption and competition with fisheries by marine cetaceans, depend critically on estimates of mass for the various species components, but again few estimates are available for whales and dolphins. Length-weight models serve as tools for conversion of large bodies of length data to weight estimates for such studies. We provide here length-weight equations for the spinner dolphin to complement those available for a number of other small cetaceans (values and references provided below).

Table 1. Sample of length/weight data used to model length/weight relationship in the spinner dolphin, *Stenella longirostris*. See Dizon *et al.* (1994) and Perrin (1990) for description of forms in eastern tropical Pacific. Dwarf subspecies, *S. l. roseiventris*, described by Perrin *et al.* (1999).

Region	Subspecies	Number and sex	Source
Eastern tropical Pacific	*S. l. orientalis* ("eastern") & *S. l. orientalis/ S. l. longirostris* hybrid/intergrade ("whitebelly")	48 males, 53 females	Southwest Fisheries Science Center, unpublished data; Harrison *et al.* 1972; Perrin and Roberts 1972; Marino *et al.* 2004
Hawaii & central Pacific	*S. l. longirostris*	3 males, 1 female	Harrison *et al.* 1972; Sea Life Park, unpublished data; California Academy of Sciences, unpublished data
Philippines	*S. l. longirostris*	29 males, 18 females	Perrin *et al.* 1999; Perrin and Dolar, unpublished data
New Guinea	*S. l. longirostris*	2 males	Harrison *et al.* 1972
Inner Southeast Asia (Thailand, northern Australia, Indonesia)	*S. l. roseiventris*	18 males, 10 females	Perrin *et al.* 1999; Hembree 1986; National Science Museum of Japan, Western Australian Museum, and Northern Territories Museum, unpublished data
Australian Pacific coast	*S. l. longirostris*	1 female	Queensland Museum, unpublished data
West Africa	*S. l. longirostris*	3 males, 2 females	Cadenat and Doutre 1959; Edward D. Mitchell, unpublished data
Western North Atlantic and Gulf of Mexico	*S. l. longirostris*	13 males, 16 females	Schmidly and Shane 1978; Layne 1965; Mead *et al.* 1980; U. S. Museum of Natural History, unpublished data

Total body lengths and weights for 217 spinner dolphins (116 males and 101 females) from several regions were available (Table 1). Twelve females were pregnant and seven of unreported reproductive condition; we eliminated these from the analyses.

Most males and females that stranded or died in captivity (as opposed to being deliberately killed, dying during capture, or taken as fishery bycatch) were of below-average weight for length (Fig. 1). This suggests that these animals were not in good condition when they died. An alternative possible explanation is that spinner dolphins in the northwestern Atlantic and Gulf of Mexico (where the strandings occurred) and Hawaii and Queensland (where the animals died in captivity) are proportionately slimmer than in the other regions represented in the sample. While this possibility cannot be discounted completely, it does not seem to be the most parsimonious explanation, and we eliminated these specimens from further analysis.

The remaining specimens from the regions for which larger samples were available

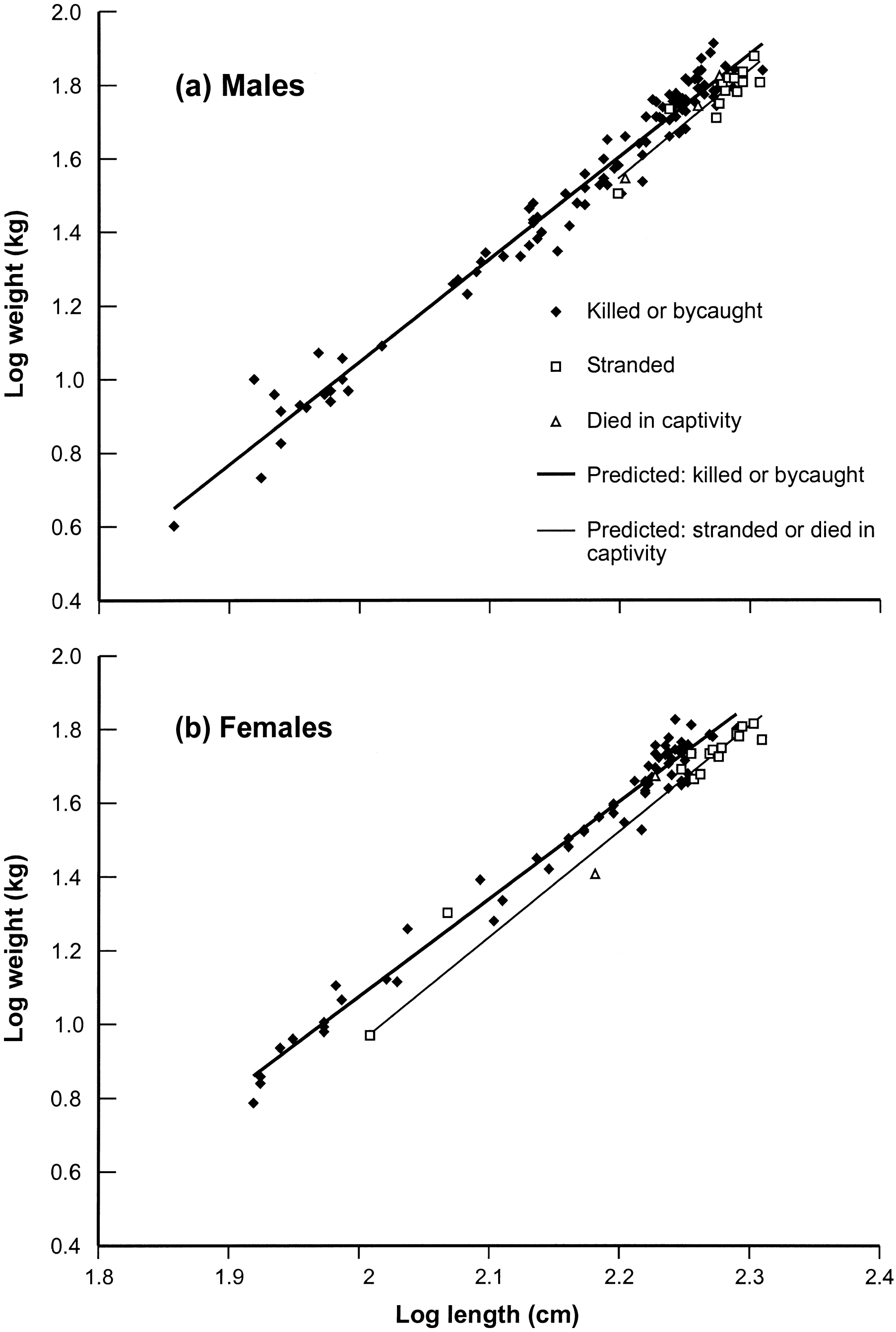

Figure 1. Scatter plot of log weight (kg) on log length (cm) for male (a) and female (b) spinner dolphins, showing origin of specimen (killed or bycaught, stranded, or died in captivity). Lines fitted by linear regression. Equations for upper lines same as given in text for samples in Figure 3.

(eastern tropical Pacific, Philippines, and inner Southeast Asia) had a similar and relatively tight length-weight relationship across regions for both males and females (Fig. 2), and we therefore pooled the samples by sex across all regions. Physically mature specimens were included in all the larger regional/subspecies samples.

The linear regression equation for 99 killed-in-the-wild males (Fig. 3) was

$$\log W = 2.80\ \log L - 4.55; \quad r^2 = 0.971,$$

where W = weight in kg and L = length in cm, and for 67 non-pregnant killed-in-the-wild females (Fig. 3) was

$$\log W = 2.65\ \log L - 4.22; \quad r^2 = 0.975.$$

For males the 95% confidence intervals for the slope and intercept were 2.70 to 2.89 and –4.75 to –4.33, respectively. For females, they were 2.54 to 2.75 and –4.45 to –3.99. Both confidence intervals overlapped for the two sexes. The equation for males and females pooled ($n = 166$) was

$$\log W = 2.74\ \log L - 4.417; \quad r^2 = 0.972.$$

The 95% confidence intervals for the pooled slope and intercept were 2.67 to 2.81 and –4.57 to –4.26, respectively.

The scatter plot in Figure 3 is provided as a basis for quick comparison of weight of a dolphin in hand with the range of weight for wild dolphins of similar length; an animal with a weight within this range can be considered to be of healthy nutritive status. The equations are provided for use in converting length data to estimated weights in modeling exercises.

The small sample of eastern spinners (*S. l. orientalis*) did not allow meaningful comparative analysis of the eastern and whitebelly forms in the eastern tropical Pacific, but any difference is likely to be slight, given the similarity of length-weight relationships among regions and forms of the species.

While the few captive and stranded values available would likely not make a statistically detectable difference in the present analysis because of the proportionately large number of wild-caught specimens, the fact that most of them lie below the trend line suggests that any length-weight relationship based *substantially* on animals that stranded or died in captivity may not accurately represent the length-weight relationship of healthy animals in the wild.

Length-weight relationships have been published previously for a number of small cetaceans, including at least 15 delphinids, two phocoenids, one monodontid, one ziphiid, and four river dolphins (Table 2). We encountered some problems and inconsistencies in reviewing these equations. The equations as published are in various forms; we converted those not in the log*W*/log*L* form to that form for purposes of comparison (Table 2). An equation for *Steno bredanensis* published by Miyazaki and Perrin (1994) based on 15 dolphins yields unrealistic values of weight (*e.g.*, less than one kg for a length of 240 cm) and must contain an error of notation or analysis. We therefore include here (Table 2) instead an earlier equation based on a smaller sample (Miyazaki 1980). Similarly, the equation for *Platanista gangetica* published by Gihr and Pilleri (Table 2) yields estimates of weight much greater than

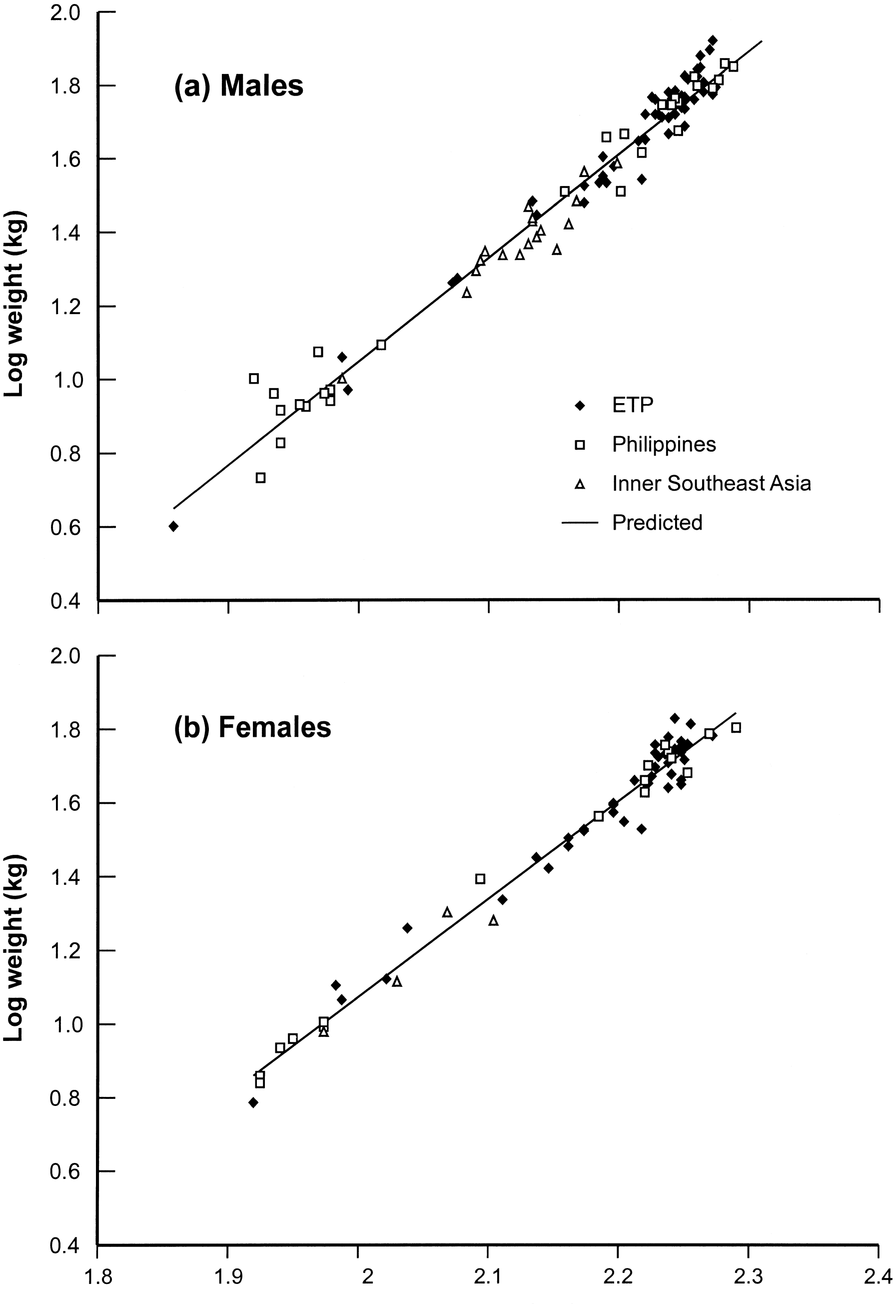

Figure 2. Scatter plot of log weight (kg) on log length (cm) by region, for male (a) and female (b) spinner dolphins. Lines fitted by linear regression. Equations same as given in text for samples in Figure 3.

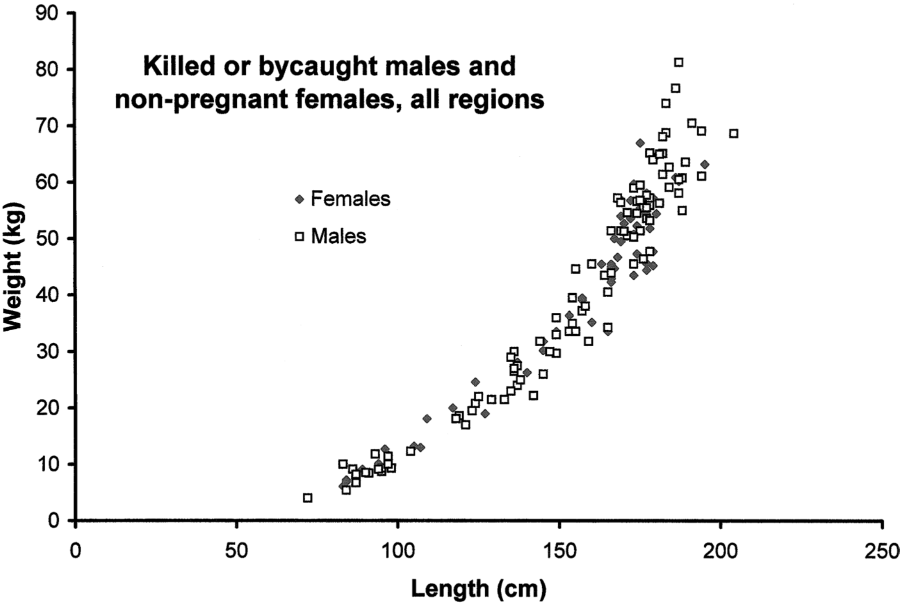

Figure 3. Scatter plot of weight (kg) on length (cm) for males and non-pregnant female spinner dolphins killed as bycatch in fisheries, dying during capture, or taken in directed fisheries, from all regions.

other equations for the same species and for other species of similar size and shape; this equation also likely contains an error. The equations published by Sergeant and Brodie for *Delphinapterus leucas* yield estimated weights at length differing by more than a factor of two between whales from Hudson Bay and the St. Lawrence River. The authors assert that this is a real difference, but the possibility remains that the data or analysis contained errors in one case or the other. (Weights for Hudson Bay were estimated from weights for gutted animals, and the St. Lawrence weights came from a 1944 unpublished manuscript by V. D. Vladykov). The equations by Best (1988) for *Cephalorhynchus heavisidii* and by Lockyer (1993) for *Globicephala melas* are in terms of m and g, respectively; in Table 2 we convert the usage of units to cm and kg. The equations given by Jefferson *et al.* (1995) are exponential fits not directly convertible to log/log form.

Cross-species comparisons are difficult because of several factors beyond the problems described above: frequent small sample size, varying sex composition of the samples, lack of information on reproductive condition of females, and varying origin of the samples (from directed catch, bycatch, captivity and strandings). However, a few conclusions can be drawn for some of the delphinids. As noted by Perrin *et al.* (1987), the Atlantic spotted dolphin *Stenella frontalis* is heavier-bodied at maturity than the pantropical spotted dolphin (coefficient b in $\log W/\log L$ regression 3.1087 *vs.* 2.873, with all 16 specimens in the analysis above the regression line for the latter species). The lower coefficients (2.80 for males and 2.65 for females) for the spinner dolphin suggest that this species gains weight with length less rapidly and is

Table 2. Length-weight relationships for small cetaceans. Where published equation not in $\log W/\log L$ form, converted here where feasible.

No.	Species	Origin of sample	Number and sex	$\log W/\log L$ equation (kg & cm)	Other forms of equation as published (kg & cm unless otherwise indicated)	r^2	Source	Modal adult length (cm)	Predicted W at modal L (kg)
1.	*Stenella longirostris*	Bycatch, directed catch	101 males	$\log W = 2.78\log L - 4.52$	—	0.968	This study	180	56
2.	”	”	67 non-pregnant females	$\log W = 2.65\log L - 4.22$	—	0.975	”	170	49
3.	*S. attenuata*	Bycatch	66 males	$\log W = 2.87\log L - 4.71$	—	—	Perrin *et al.* 1976	200	79
4.	”	”	33 non-pregnant females	$\log W = 2.61\log L - 4.16$	—	—	”	190	62
5.	”	Directed catch	35 males & females	$\log W = 2.93\log L - 4.90$	$\log W(\mathrm{g}) = 2.928\log L - 1.900$	0.962	Miyazaki *et al.* 1981	220	91
6.	*S. coeruleoalba*	Directed catch	16 males	$\log W = 2.98\log L - 4.86$	$\log W(\mathrm{g}) = 2.975\log L - 1.856$	0.960	”	225	139
7.	”	”	30 females	$\log W = 2.90\log L - 4.74$	$\log W(\mathrm{g}) = 2.910\log L - 1.737$	0.972	”	215	112
8.	”	Directed catch	12 males & females	$\log W = 2.61\log L - 4.10$	—	—	Gihr and Pilleri 1979	220	104
9.	*S. frontalis*	Stranded & captive	14 males	$\log W = 3.11\log L - 5.16$	—	—	Perrin *et al.* 1994	200	98
10.	*S. clymene*	Stranded	16 males	—	$W = 1.605 \times 10^{0.009L}$	0.883	Jefferson *et al.* 1995	185	74
11.	”	”	16 females	—	$W = 2.010 \times 10^{0.008L}$	0.786	”	180	55

Table 2. Continued.

No.	Species	Origin of sample	Number and sex	Log$W$/log$L$ equation (kg & cm)	Other forms of equation as published (kg & cm unless otherwise indicated)	r^2	Source	Modal adult length (cm)	Predicted W at modal L (kg)
12.	*Delphinus delphis* (Atlantic)	Directed catch	19 males & females	$\log W = 2.91\log L - 4.80$	—	—	Gihr and Pilleri 1979	230	120
13.	" (Mediterraneam)	"	24 males & females	$\log W = 2.36\log L - 3.56$	—	—	"	220	92
14.	*Tursiops truncatus*	Directed catch, captive	8 males & females	$\log W = 2.73\log L - 4.40$	—	—	"	240	128
15.	"	"	129 males & females	—	None; Scatterplots only	—	Ridgway and Fenner 1982	—	—
16.	*Sousa plumbea*	Bycatch	42 males & females	$\log W = 3.18\log L - 5.34$	$W = 4.57 \times 10^{-6}L^{3.183}$	0.98	Ross *et al.* 1994	220	131
17.	*Steno bredanensis*	Directed catch	10 males & females	$\log W = 3.79\log L - 6.91$	$\log L = 1.8253 + 0.2641\log W$	0.713	Miyazaki 1980	240	126
18.	*Lagenorhynchus acutus*	Stranded	14 males	$\log W = 2.89\log L - 4.63$	$W = 2.32 \times 10^{-5}L^{2.892}$	0.992	Geraci *et al.* 1978	250	200
19.	"	"	37 females	$\log W = 2.92\log L - 4.67$	$W = 2.12 \times 10^{-5}L^{2.920}$	0.980	"	220	127
20.	"	"	53 males & females	$\log W = 2.97\log L - 4.80$	$W = 1.59 \times 10^{-5}L^{2.970}$	0.986	"	230	164
21.	*Cephalorhynchus heavisidii*	Directed catch, bycatch, stranded	9 males, 17 females	$\log W = 2.85\log L - 4.50$	$W = 15.95L(\mathrm{m})^{2.85}$	—	Best 1988	160	61
22.	*Feresa attenuata*	Stranded, captive	11 males & females	$\log W = 2.88\log L - 4.60$	$W = 2.502 \times 10^{-5}L^{2.882}$	0.971	Ross and Leatherwood 1994	230	160

Table 2. Continued.

No.	Species	Origin of sample	Number and sex	Log$W$/log$L$ equation (kg & cm)	Other forms of equation as published (kg & cm unless otherwise indicated)	r^2	Source	Modal adult length (cm)	Predicted W at modal L (kg)
23.	*Pseudorca crassidens*	Stranded	4 females	$\log W = 2.44\log L - 3.67$	$W = 2.16 \times 10^{-4}L^{2.437}$	—	Odell *et al.* 1980	420	534
24.	*Globicephala melas*	Directed catch	30 males & females (fetuses and small calves)	$\log W = 2.90\log L - 4.60$	$W = 0.000025L^{2.895}$	—	Sergeant 1962	550	2145
25.	”	Directed catch	248 males	$\log W = 2.48\log L - 3.59$	$W = 0.00026L^{2.484}$	0.951	Lockyer 1993	550	1667
26.	”	”	373 females	$\log W = 2.52\log L - 3.70$	$W = 0.00020L^{2.521}$	0.927	”	450	977
27.	*G. macrorhynchus*	”	10 females	$\log W = 2.662\log L - 4.08$	$\log W = 2.6642\log L + \log(8.403 \times 10^{-5})$	0.865	Kasuya and Matsui 1984	350	540
28.	*Phocoena phocoena*	Directed catch	208 males	$\log W = 2.80\log L - 4.35$	$\log L = 1.552 + 0.357\log W$	—	Bryden 1972	150	56
29.	”	”	164 females	$\log W = 3.04\log L - 4.88$	$\log L = 1.606 + 0.329\log W$	—	”	165	72
30.	”	Bycatch, stranded	41 males	$\log W = 2.89\log L - 4.64$	$\log L = 1.607 + 0.346\log W$	—	van Utrecht 1978	150	44
31.	”	”	58 females	$\log W = 2.88\log L - 4.64$	$\log L = 1.609 + 0.347\log W$	—	”	165	57
32.	*Neophocaena phocaenoides*	Bycatch, directed catch, stranded	42 males & females	$\log W = 2.48\log L - 3.74$	$\mathrm{W} = 1.816 \times 10^{-4}L^{2.477}$	0.902	Kasuya 1999	160	52

Table 2. Continued.

No.	Species	Origin of sample	Number and sex	Log$W$/log$L$ equation (kg & cm)	Other forms of equation as published (kg & cm unless otherwise indicated)	r^2	Source	Modal adult length (cm)	Predicted W at modal L (kg)
33.	*Delphinapterus leucas* (Hudson Bay)	Directed catch	16 males	$\log W = 2.54\log L - 3.35$	—	—	Sergeant and Brodie 1969	400	1794
34.	*Delphinapterus leucas* (St. Lawrence R.)	”	10 males	$\log W = 2.61\log L - 3.81$	—	—	”	440	1200
35.	*Delphinapterus leucas* (Hudson Bay)	”	36 males & females	$\log W = 2.58\log L - 3.84$	$W = 10^{-3.84}L^{2.58}$	0.92	Doidge 1990	400	747
36.	*Pontoporia blainvillei*	Bycatch	14 of unstated sex	$\log W = 2.99\log L - 4.95$	—	—	Gihr and Pilleri 1979	140	30
37.	*Inia geoffrensis*	—	4 of unstated sex	$\log W = 2.26\log L - 3.51$	—	—	”	200	51
38.	*Lipotes vexillifer*	Bycatch, stranded	3 of unstated sex	$\log W = 4.44\log L - 8.30$	—	—	”	200	84
39.	*Berardius bairdii*	Directed catch	4 females	$\log W = 3.08\log L - 5.20$	$W = 6.339 \times 10^{-6}L^{3.081}$; $\log W = 3.081\log L + \log(6.339 \times 10^{-6})$	0.980	Kasuya *et al.* 1997	1000	11092

Table 2. Continued.

No.	Species	Origin of sample	Number and sex	Log$W$/log$L$ equation (kg & cm)	Other forms of equation as published (kg & cm unless otherwise indicated)	r^2	Source	Modal adult length (cm)	Predicted W at modal L (kg)
40.	*Platanista gangetica*	Stranded, bycatch	6 females	$\log W = 2.29\log L - 3.52$	$W = 0.0003025L^{2.290}$	—	Kasuya 1972	240	85
41.	”	”	15 males & juvenile females	$\log W = 2.83\log L - 4.61$	$W = 0.00002456L^{2.826}$	—	”	210	90
42.	”	”	16 of unstated sex	$\log W = 2.63\log L - 3.91$	—	—	Gihr and Pilleri 1979	240 (fem.)	227

also lighter-bodied in adulthood than the Atlantic spotted dolphin and possibly slightly lighter-bodied than the pantropical spotted dolphin. The equations reported by Miyazaki *et al.* (1981) and Gihr and Pilleri (1979) for a fourth member of the genus, the striped dolphin *S. coeruleoalba*, suggest that it may be intermediate between the Atlantic spotted dolphin and the pantropical spotted dolphin.

In the two cases based on large samples and where the relevant statistics are available, the present study and that of the long-finned pilot whale *Globicephala melas* (Lockyer 1993; SE of coefficient = 0.36 for males and 0.37 for females), the regression lines are not statistically different for males and females (95% confidence intervals = ±2 SE). This result suggests that a single regression based on a mixed sample of males and non-pregnant females may be adequate for modeling the length-weight relationship of a delphinid species, increasing the precision of an estimate because of resulting greater sample size.

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