DIMENSIONS AND BODY FORM OF A SEVEN-GILLED SHARK, *Notorynchus cepedianus* (PÉRON) FROM THE TAMAR ESTUARY, TASMANIA

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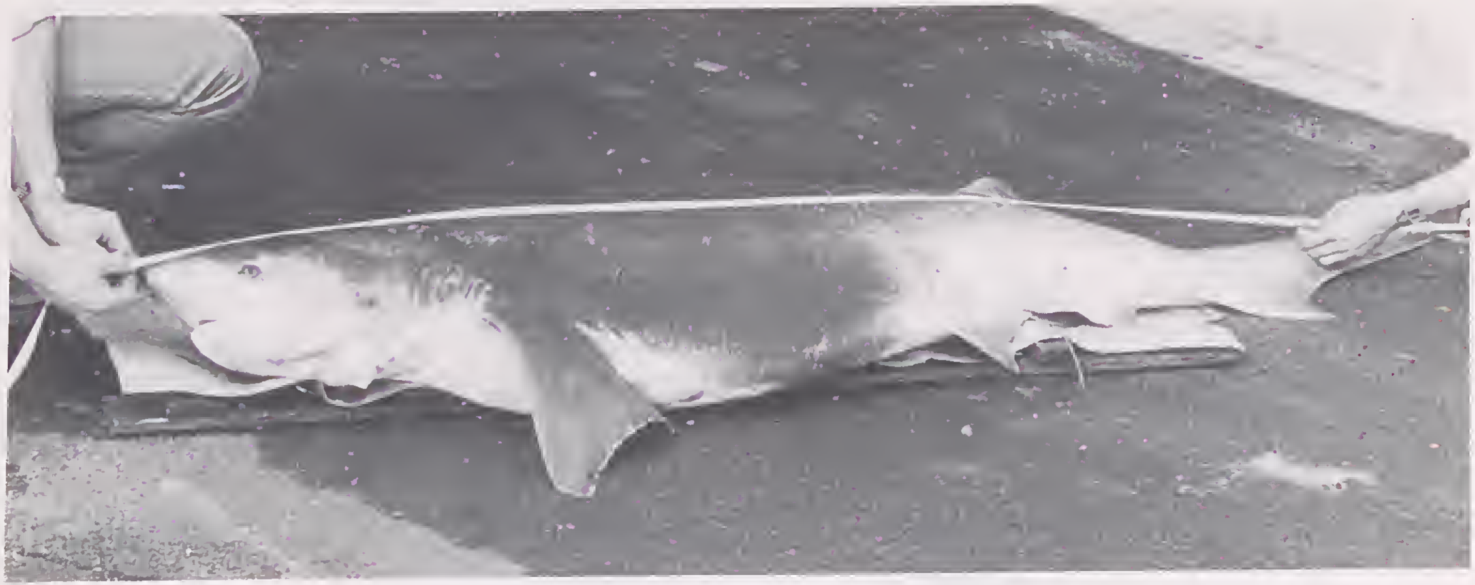
ABSTRACT

A set of morphometric data, based on the schedule for sharks proposed by Whitley (1943a), is provided for an adult female Seven-gilled Shark, *Notorynchus cepedianus* (Péron, 1807) from Tasmania; some comparative measurements for a Tasmanian juvenile male (Scott, 1974) and a Victorian adult female (McCoy, 1880) are noted. Some aspects of form are examined. Head in plan is adequately fitted by a 2° polynomial. Girth and depth are shown to be functions of logarithmic length to level of measurement, girth over gills a function of ordinal gill number. For much of the lateral line its depth below dorsal profile increases linearly. Each of the four following features is found to be specifiable by the relation $L = b\,l^k$ where l is an integer: length to gill slits; length of gill slits, length to 1st gill slit, to vent and to end of vertebral column; length to origins of dorsal anal and caudal together with terminations of dorsal and anal.

INTRODUCTION

Early Australian writers have in general provided very little information on the morphometrics of sharks. A notable exception is McCoy who published (1879-1887) biometric tables ranging from 13 to 45, with an average of 30, measurements for no fewer than 14 species referable to 8 families. Probably the next significant local event was the appearance, more than half a century later, of 'a set of standard measurements for comparative and biometric studies of Australian sharks' by Whitley (1943a). This schedule, specifying 15 head, 9 body and 22 fin measurements, was subsequently employed by its author in descriptions of some dozen species (1943a, 1943b, 1944, 1945, 1947, 1948, 1950, 1951).



Pl. 1 Seven-gilled Shark, *Notorynchus cepedianus* (Péron, 1807) from estuary of the Tamar, northern Tasmania; total length 2 348 mm.

Photo: *Examiner*

Species of which accounts based on Tasmanian material include tabulated measurements are as follows: *Notorynchus cepedianus* (Péron, 1807) (1974), *Heterodontus portusjacksoni* (Meyer, 1793) (1963), *Sphyrna zygaena* (Linné, 1758) (1973, 1977), *Parascyllium multimaculatum* Scott, 1935 (1935, 1962), *Parascyllium ferrugineum* McCulloch, 1911 (Olsen, 1958; species ascribed by Olsen, p.156, to Waite), *Galeus boardmani* (Whitley, 1928) (Olsen, 1958, Scott, 1980), *Cephaloscyllium isabella laticeps* (Duméril, 1853) (1963), *Halaelurus vincenti* (Zietz, 1908) (Olsen, 1958, Scott, 1969), *Isurus oxyrinchus* Rafinesque, 1810 (1978), *Furgaleus ventralis* (Whitley, 1943) (1980), *Galeorhinus australis* (Macleay, 1881) (1969), *Carcharhinus greyi greyi* (Owen, 1853) (1977) and earlier (1942) as *Carcharhinus brachyurus* Günther, 1870, *Squalus megalops* (Macleay, 1881) (1969), *Centroscymnus waitei* (Thompson, 1930) (Olsen, 1958), *Scymnodon plunketi* (Waite, 1910) (Olsen, 1958), *Pristiophorus nudipinnis* Günther, 1870 (1969). Papers cited by date only are by the writer.

Examination of a fine example of the Seven-gilled Shark, *Notorynchus cepedianus* (Péron, 1807), has made possible the compilation of a comprehensive set of dimensions. Some aspects of body form have been investigated, leading to the recognition of nine metrical patterns enumerated above in the Abstract.

MATERIAL

(a) An adult female, total length 2 348 mm, length to base of caudal 1 605 mm, taken by Mr D.G. Penneyston, George Town, in a deep area in the river off the power station, Bell Bay, in the estuary of the Tamar, northern Tasmania, in the course of an Apex Fishing Contest held at Ilfraville, 29 March 1981 (in which it took prizes for the largest and for the most unusual fish). Some comparative published measurements for (b) a Tasmanian juvenile male, total length 1 355 mm, (Scott, 1974) and for (c) a Victorian adult female, total length 8 feet 1 inch (1 164 mm) (McCoy, 1880)—as *Notidanus (Heptanchus) indicus* (Cuv.)—are noted. Of McCoy's 31 entries, 10 are not relevant here, relating to teeth.

METHODS

Where it is appropriate to do so, dimensions are regularly measured between parallels; some alternative versions taken point-to-point are shown in parentheses, while measurements following curves are placed in square brackets. All measurements were made in millimetres but unless otherwise indicated are recorded as millesimals of 'standard length', *i.e.*, length from snout tip to origin of anterior (here upper) caudal lobe. A third measure of length, vertebral length, length to level of end of vertebral column, suggested by a relation involving head, trunk, tail, is proposed.

The symbols *Ls, Lt, Lv* denote standard length, total length, vertebral length, while thousandths of these are designated by *Tls, TLt, TLv*. By the termination of a fin is meant the end of the base.

RESULTS

DIMENSIONS

Dimensions of the present specimen are set out in Table 1, being entered both as *TLs* and *TLt*, the latter permitting direct comparison with the corresponding variates, also noted, of the earlier Tasmanian and the Victorian examples, for both of which only *Lt* is available.

ASPECTS OF FORM

Several aspects of body form of the specimen exhibit precise patterns that appear not hitherto to have been the subject of investigation, but to be of considerable interest, both in themselves and as relations inviting further investigation in other species.

Head in plan. A tracing of the outline was made, the anteroposterior axis marked off in deciles between snout tip and 1st gill slit (immediately behind which the head becomes less rigid and subject to casual displacement), and widths measured at these levels. The head thus viewed is somewhat bluntly pointed, with widths at the anterior one-tenth and one-fifth of its length (the former approximately coinciding with the *latus rectum*) 0.42 and 0.57 maximum width. It is a parabola, adequately fitted with a 2° polynomial (R = 0.9976, mean variation of estimated from measured widths 1.3%): though it provides little increase in goodness of fit (R = 0.9991, mean variation 1.2%), the 3° equation also is reported, the former yielding better estimates for the more posterior variates, the latter for the anterior ones. With W = width, as *TLs*, N = serial number of decile measurement;

$$W = 57.00 + 27.427\,N - 1.3182\,N^2.$$

$$W = 46.60 + 36.651\,N - 3.3812\,N^2 + 0.121212\,N^3.$$

By differentiation of the 2° equation the slope of the tangent can be found thus providing a measure of pointedness of curve, so permitting direct comparison of this character in two or more species, or specifying intraspecific variation known to be associated with age and sex in some sharks.

Girth. Measurements of girth were made at 10 equal intervals along anteroposterior axis between snout tip and origin of anterior caudal lobe. On plotting these magnitudes on an abscissal length-scale of log l-log 10 it is found deciles 1-4 give a significantly straight line of positive slope, while deciles 5-10 give a significant straight line of negative slope, that is, $G = m \log N + c$, with for the anterior part of the shark $N = \{1, 2, 3, 4\}$ and for the posterior part $N = \{5, 6, 7, 8, 9, 10\}$.

G_a = 343.1 log N + 437.6; t = 14.574**; percentage divergence of estimated from measured girths 0.9-1.5, mean 1.2.

G_p = –1 471.0 log N + 1 643.7; t = 31.803**; percentage deviation 0.3-4.4, mean 2.6.

Extrapolation of the two graphs with acceptance of their point of intersection as representing maximum girth would assess this at 666 *TLs* units, located at 0.66 of standard length; the present specimen is noticeably swollen in the vicinity of the pelvic fin.

General depth. With the shark lying on its side, measurements of depth (vertical height of dorsal profile above supporting platform) were taken in succession at levels of front of mouth, pectoral origin and termination, pelvic origin and termination, dorsal origin, anal origin, dorsal termination, anal termination, caudal origin: lengths to termination of pelvic (745 *TLs*) and to origin of dorsal (748 *TLs*) are virtually identical and their mean is here associated with a common depth magnitude. Plotting the depths on logarithmic lengths to level of their occurrence yields two good straight lines, that for the first 3 points with a positive slope, that for the remaining 6 points with a much steeper negative slope.

D_a = 245.75 log L – 352.90; t = 15.742*; percentage divergence of estimated from measured depths 1.5-3.0, mean 2.2.

D_p = – 685.74 log L + 2 118.89; t = 11.736***; percentage deviation 3.4-10.1, mean 6.4.

Solution of these equations indicates a maximum depth of 299 *TLs* units (480 mm) located at 450 *TLs* behind snout tip, a little in advance of midpoint between pectoral bases, about at same level as in figure by Macdonald & Barron (1868) [as *Heptranchus indicus* Macdonald & Barron, 1868 (= *H. griseus* Macdonald, 1873 (*nom. nov.*)], noticeably caudad of that in figure by McCoy (1880) [as *Notidanus (Heptranchus) indicus* (Cuv.)]: measured maximum depth is 280 *TLs* (450 mm), behind snout tip by 405 *TLs*.

Depth at gill slits. Over the short section of the gill region (66 *TLs*) the depth increases caudad, its magnitude being an exponential function of serial slit number:

D = 54.16 log N + 173.99; t = 7.068***; percentage divergence of estimated from measured depths 0.0-1.8, mean 0.8.

Course of lateral line. In its early section over the gill region the well marked lateral line falls away from the dorsal profile rather sharply, while behind anal origin its distance from the profile markedly decreases. The long intervening section, though exhibiting some minor local fluctuations, overall gradually swings away linearly from the profile. For measurements at levels of 7th gill slit, maximum depth, ventral origin and termination, anal origin,

D = 0.04105 L + 33.42; t = 8.188*; percentage divergence of estimated from measured depths 0.6-5.3, mean 2.3.

Features specified by $L = b\ l^k$. The following 4 features are specified, with conventional significance, by this relation, where L is length to or length of variate, l is a natural number that may take one of three forms, N, the serial number of the variate counting caudad, N', the reverse serial number (that counting cephalad), N^*, an arbitrary integer, determined empirically: length to gill slits; length of gill slits; length to 1st gill slit to vent and to end of vertebral column (*i.e.,* length of head, of head + trunk, of head + trunk + tail); length to origin and termination of dorsal, origin and termination of anal, origin of caudal. The relation may conveniently rectified as log $L = k$ log l + log b. Parameters for this formulation, specification of l, estimated and measured values, together with a measure of significance (t) are set out in Table 2. The relation $L = b\ l^k$ is interpretable as a special case of $Y = aX^k$, the equation of allometric growth.

DISCUSSION

In accordance with traditional practice measurements capable of being made along the anteroposterior axis have been taken between parallels. Recent years have seen a movement, largely stemming from proposals for teleost measurements by Hubbs & Lagler (1958), and developing for rajid studies through Ishiyama (1958) to a formal schema in Hubbs & Ishiyama (1968) based wholly on point-to-point procedures. While it is evident this measurement technique is in most (not all) instances at once capable of more ready performance and likely in general to result in more precise determinations, it is at the same time open to methodological stricture. Size differences in different specimens (whether ascribable to sex, age, or mere individual variation) are by point-to-point assessment liable to be compounded by the involvement of two planes (in a few measurements, *e.g.,* tip of snout to eye, of three) instead of being confined to a single plane. If it is the case, as length-to relations such as the three specifiable by $L = b\ l^k$ here reported (and by other examples elsewhere reported by the writer) would suggest, that there exists some morphogenetic gestalt in the form of a gradient along the anteroposterior axis, appropriately noded at locations at which basic structures, including fins, are developed, recognition of the relevant patterns would clearly be facilitated by a strictly longitudinal system of measurement. Unfortunately it is not wholly clear how Whitley's measurements were carried out. Introducing his schema he stated (1943a, p.114), 'The shark being measured is placed as straight as possible on a horizontal axis, and measurements are taken between parallels by means of dividers'. If between parallels, why dividers? Inspection of his table shows that at least in the posterior part of the body points such as fin origins are commonly determined not by lengths to them but by intervals between them, suggesting such sectional dimensions at least were taken point-to-point. It has previously been pointed out (Scott, 1980, p.93) that entry F16 in the schedule, 'Origin of pectoral to that of ventral' is superfluous, the dimension being directly derivable from H5 ('Snout [tip] to origin of ventrals'.)

While in those size or position relations of the form $L = bl^k$ in which l takes the form of N or N', serial numbers of the variates, the abscissal scale is directly determined by the situation, it is otherwise with formulations with an arbitrary N^*. Theoretically, the status as an independent variable of a series of such postulated magnitudes, involving some subjectivity of enumeration, is by no means evident; the difficulty would be resolved, however, by the acceptance of the existence of a noded anteroposterior morphogenetic gradient such as that hypothesized above. Pragmatically, the extensive applicability and precise character of the formulation for a wide range of teleost species referable to a number of families (Scott 1977-1980 and unpublished) would seem to indicate its validity; certainly establishing its usefulness in systematic diagnosis. The rationale of the use of the logarithms of natural numbers for N^* receives support from their significant role in variates involving N and N'.

The absence from published data for specimens (b) and (c) of some critical measurements precludes full-scale comparison with the patterns shown for (a) in Table 2; however, examination of available figures leads to some more or less parallel conclusions. By a typographical omission lengths of only six gill slits were published for (b): if the missing datum is that for the 1st, the length-position pattern conforms with that for (a) (Table 2). It is of interest to note the graphing divides the gill set into two (intersecting) subsets, one being for numbers 1 and 2 (and 3), suggesting the two supernumerary gills that distinguish this species from the generality of sharks could be those at the front of the series. In the absence of an entry for length to caudal origin in (b) and (c), the equation in which this dimension is associated with locations of the vertical fins has been calculated with the 4 measurements available, yielding a graph that as far as it extends is comformable with that for the full suite (the fit for this pattern is less good than that of any other here reported).

For the situation involving head, trunk, tail no calculation can be made for (c) (no head measurement), while for (b) neither Ls nor Lv is available (the notation TLs in the account of this specimen is a typographical error for TLt) — however, with Lt adopted as a reasonable approximation for Lv (in (a) $Lt = 1.021\ Lv$), the third ordinate on the abscissal 3 is clearly, as with (a), Lv, not Ls. For numerous teleosts it has been found that the third dimension is that conventionally recognized as standard length, namely, length to the hypural joint, this level also representing length to caudal origin: a similar situation obtains with some sharks, *e.g. Galeus boardmani* (Whitley, 1928) (Scott 1980: 90) and *Furgaleus ventralis* (Whitley, 1943) (Scott, 1980: 97). On the other hand data for *Cephaloscyllium isabella laticeps* (Duméril, 1853) and for *Isurus oxyrinchus* (Rafinesque, 1810) make it evident the relevant dimension is in them, as in the present species, Lv (judgement based on measurements (Scott, 1963: 7, 1978: 272) of Lt). Hence, for teleosts examined and for some sharks 'tail' as here recognized terminates, but for some other sharks does not terminate, at base of caudal fin; the critical point being for some sharks, as for all teleosts, the end of the vertebral column.

COLORATION

General color above dark elephant, invading much of the lateral surface between pectoral and pelvic, where it darkens, approaching black; rest of side and whole undersurface off-white. On dorsum of head about 40, between head and dorsal origin about 170, behind dorsal about 30 (some two dozen extending on to side) more or less rounded or elliptical grey spots 2-15 mm in diameter. Whole of dorsal and lateral surfaces with several hundred black spots, smaller than the grey; most evident below dorsal fin, extending along anterior half of dorsal ridge of caudal peduncle. Pectoral mostly concolorous with upper body, a large whitish patch on under surface; without spots. Dorsal lightish with very narrow dusky distal band; many spots. Anal largely flesh colored, somewhat darker proximally; no spots. Pelvic greyish olivaceous, central lightish area on inner surface; numerous black spots, especially in anterior half. Caudal a little lighter than dorsum of body along narrow dorsal ridge; lateral surface narrowly light greyish above, fleshy ventral strip dark somewhat purplish grey; between off-white.

Table 1

Notorynchus cepedianus (Pēron, 1807): dimensions

Dimensions, as millesimals of standard length, *TLs*, or millesimals of total length, *TLt*, of (a) a Tasmanian adult female, *Ls* 1 605mm, *Lt* 2 348, (b) a Tasmanian juvenile male (Scott, 1974) and (c) a Victorian adult female (McCoy, 1880). Measurements taken point-to-point are shown in parentheses, those following curve in square brackets; all other measurements made between parallels.

Dimension	(a) *TLs*	(a) *TLt*	(b) *TLt*	(c) *TLt*
Length to gill slits	204,227,239, 247,256,264, 270	140,156,164, 169,175,181, 185	1st 131, 7th 176	–
Anteroposterior length of gill slit region	66	45	45	67
Length of gill slits	(97,92,83, 77,62,54, 44)	(66,63,57, 49,43,37, 30)	–,60,54, 49,42,37, 32	1st,82, 7th,36
Distance from dorsal profile to 1st gill slit, to 7th	84,139	57,102	–	–
Length to front of orbit, to back	59,81	40,59	–	54 –
Length to front of eye, to back	62,80	43,55	–	
Interorbital	117 [140]	80 [95]	96	72
Length to front of mouth, to angle	50,134	34,92	46 –	41 –
Length to end of oral groove on lateral surface	147	101	–	–

Continued overleaf

Table 1 Continued

Dimension	(a) *TLs*	(a) *TLt*	(b) *TLt*	(c) *TLt*
Width of mouth	153 [190]	104 [129]	122	–
Length to nostril	19 (50)	13 (34)	9	18
Length of nostril	6.2 (14)	4.3 (10)	–	–
Internarial	62 [68]	43 [46]	43	–
Length to spiracle	153 (168)	104 (115)	–	–
Length of spiracle, width	2.5,3.7	1.7,2.6	–	–
Interspiracular	123 [134]	84 [92]	–	–
Length to front of vent, to back	704,31	481,21	–	–
Girths at 10 equal intervals between snout tip and insertion of anterior (upper) caudal lobe	[442,536,592, 654,617,511, 386,305,243, 181]	[302,366,405, 447,422,349, 364,209,166, 124]	–	–
Girth at front of pectoral	–	–	–	[381]
Depths at front of mouth, pectoral origin, pectoral termination, pelvic origin, vent, pelvic termination (= dorsal origin), anal origin, dorsal termination, anal termination, caudal origin	65,234,280, 209,–,137, 125,103,87, 69	44,160,192, 143,–,94, 85,70,60, 47	33,85,–, –,69,–, –,–,–, –	–

Continued overleaf

Table 1 Continued

Dimension	(a) *TLs*	*TLt*	(b) *TLt*	(c) *TLt*
	280 [368] ,64	192 [251] ,43		
Greatest depth, least	[85]	[58]	–	–
	174,187,202,	119,128,138,		
	209,212,215,	143,145,147,		
Depth at gill slits	219	149	–	–
	80,110,130,	55,75,89,		
	145,158,174,	99,108,119,		
Width of head at 10 equidistant intervals between	186,191,197,	127,131,134,		
snout tip and level of 1st gill slit	200	137	–	–
Widths at front of mouth, pectoral origin, vent,			90,144,	
caudal origin	–	–	70,33	–
Distance of lateral line from dorsal profile at level of 1st	36,44,52,	24,30,35,		
gill slit, 7th gill slit, greatest depth, pelvic origin and	56,64,69,	38,44,47,		
termination, anal origin and termination, caudal origin	64,42	44,29	–	–
	748 (775),859,	511 (530),587,	476,543,41,	557,642,
Dorsal: length to origin, to termination, vertical height,	75,125,89,	51,85,60,	–,–,–	–,64,–
anterior distal and hind borders	29	20		–

Continued overleaf

Table 1 Continued

Dimension	(a) *TLs*	(a) *TLt*	(b) *TLt*	(c) *TLt*
Anal: length to origin, to termination, vertical	832,900,43,	569,615,29,	556,608,27,	634,688,–,
height, anterior distal and hind borders	66,67,28	45,46,19	–,–,–	44,–,–
	624 (636),733,	427 (434),509,	415,–,55,	602,–,–,
Pelvic: length to origin, to termination, vertical	72,101,110,	49,69,75,	–,–,hind	–,–,–
height (maximum width), anterior distal and hind	hind total 49,	hind total 33,	total 70,	
borders	free 31	free 21	free 48	
Interpelvic at anterior insertion	95 [108]	65 [74]	–	–
Pectoral: length to origin, to termination, anterior	265,355,193,	181,243,132,	170,253,146,	196,271,–,
distal and hind borders	174,75	119,51	107,55	108,–,
	178 [243] ,150,	121 [166] ,102,	105,–,	–,–
Interpectoral at anterior insertion, posterior	[179]	[123]		
Caudal: length to origin of upper lobe (standard length,	1 000,1 002,	684,685,756,	–,–,	–,–
Ls) to origin of lower lobe, to lowest point on fin (angle	1 106,1 249,	960,1 000,	–,–	–,–
of lower lobe), to distal notch, to tip of fin (total length,	1 463,1 433	979.6	–,–	–,–
Lt), to end of vertebral column (vertebral length, *Lv*)				

Continued overleaf

Table 1 Continued

Dimension	(a) *TLs*	(a) *TLt*	(b) *TLt*	(c) *TLt*
	466 [480] ,125	319 [328] ,85	–,89,–,	283,88,–,
Caudal: length of upper lobe, of lower lobe from insertion	[138] ,(300),	[94] ,(205),	27,46	–,–
to lowest point of ventral border, from lowest point to	[348] ,42 [45] ,	[231] ,29 [31] ,		
notch, of hind border of notch, of segment behind notch	59 [60]	40 [41]		
Caudal: depth at notch, greatest depth behind notch,	–,–,(29),	–,–,20,	21,34,–,	–,–
depth of flexible ventral border (subtending fleshy	(33)	(23)	–	–,–
column surrounding vertebrae) at its middle, at				
immediately behind ventral angle of fin				

Table 2

Notorynchus cepedianus (Péron, 1807): aspects of form

Dimensions exhibiting the relation $L = bl^k$ (rectified as $\log L = k \log l + \log b$) where L = length to or length of feature, l is a natural number specifiable as N, the serial number of the variate, or N', the reverse serial number, or N^*, an arbitrary integer determined empirically: all dimensions as millesimals of standard length, *TLs*, or millesimals of total length, *TLt*. Original data from (a) a Tasmanian adult female; some supplementary entries based on published measurements of (b) a Tasmanian juvenile male (Scott, 1974) and (c) a Victorian adult female (McCoy, 1880).

Specimen	Unit	Dimension	l	Set of l	k	$\log b$	Percentage deviation: range, mean	t
(a)	*TLs*	Length to gill slits	N	{1-7}	0.1401	2.3116	0.0-1.5, 0.6	41.748***
		Length of gill slits (anterior)	N'	{1-5}	0.5425	1.5354	0.0-3.9, 1.7	10.760**
		Length of gill slits (posterior)	N'	{5-7}	0.3235	1.6377	0.0-2.3, 0.7	57.382*
		Length to first gill slit, to vent (middle), to end of vertebral column	N^*	{1,2,3}	1.7770	2.3147	0.0-1.4, 0.4	57.995*
		Length to dorsal origin, anal origin, dorsal termination, anal termination, caudal origin	N^*	{3,4,5,6,10}	0.2351	2.7683	0.0-6.0, 0.2	12.667**
(b)	*TLt*	Length of gill slits (anterior) [datum for 1st presumed missing]	N'	{2-5}	0.5067	1.3822	0.3-0.9, 0.5	30.604**
		Length of gill slits (posterior)	N'	{5-7}	0.2434	1.5624	0.6-1.6, 1.1	28.390*
		Length to first gill slit, to vent (middle), to end of caudal [substitute for end of vertebral column]	N^*	{1,2,3}	1.8480	2.1159	0.0-0.9, 0.5	134.438*

Continued overleaf

Table 2 Continued

Specimen	Unit	Dimension	l	Set of l	k	log b	Percentage deviation: range, mean	t
(b) continued		Length to dorsal origin, anal origin, dorsal termination, anal termination [datum for caudal origin missing]	N^*	{3,4,5,6}	0.3295	2.5287	0.3-5.6, 2.8	4.851*
(c)	TLt	Length to dorsal origin, anal origin, dorsal termination, anal termination [datum for caudal origin missing]	N^*	{3,4,5,6}	0.2852	2.6159	0.0-4.5, 2.2	5.170*

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