Relationships between the length of select head bones and body weight for *Pseudanthias* (Serranidae: Anthiinae), numerically important prey of the endangered Hawaiian monk seal

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Descriptions of the relationships between the size of durable structures (*e.g.*, bones) and the size of the organism that produced them are useful for describing past events. Examples include reconstructing diets from stomach contents, fecal or regurgitate samples, or middens; patterns of prehistoric human resource use from archaeological sites; and ancient communities from paleontological deposits (Longenecker, 2008).

Small-bodied anthiine serranids of the genus *Pseudanthias* have recently been found in the diet of the critically endangered Hawaiian monk seal (Longenecker, 2010). Numerically, these fishes are the overwhelmingly dominant prey of a sub-population of seals recently established in the main Hawaiian Islands, with as many as 886 individuals recovered from a single fecal sample (Cahoon, 2011). However, because of their small size, these fishes may not be an energetically important part of the diet. Equations that allow total body weight to be estimated from the size of prey remains will help resolve the importance of *Pseudanthias* in the monk seal diet. This will ultimately help inform conservation decisions for an apparently food-limited marine mammal.

Here I present the results of regression analyses examining the relationship between the dimensions of select head bones and the total body weight of *Pseudanthias* specimens. Because species-level identification of *Pseudanthias* remains recovered from monk seals has not been achieved, the equations are based on data from several species and are intended to represent Hawaiian members of the genus. The bones included in the analyses are those that have proven useful for idendifying *Pseudanthias* remains (Longenecker, 2010; Cahoon, 2011) and have consistently yielded the highest estimates of minimum number of individuals in fecal samples.

Materials and Methods

Thawed, previously frozen specimens of three *Pseudanthias* species collected from the Au‘au Channel were measured (total, fork, and standard lengths) and weighed. The number and size range of each species is presented in Table 1. The majority of scales, skin, viscera, and muscle was manually removed from each specimen. Carcasses were then

Table 1. *Pseudanthias* Specimens Examined.

Species	N	Range (mm fork length)
Pseudanthias bicolor	1	100
Pseudanthias hawaiiensis	13	33–88
Pseudanthias thompsoni	5	32–69

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dried in air to a jerky-like consistency, and placed in a culture of dermestid beetles to remove additional non-calcareous tissue. Resulting skeletons were soaked in water until disarticulated, then individual bones were cleaned with stiff-bristled brushes and air-dried. Specimens were deposited in the Bishop Museum faunal reference collection.

Dimensions of select head bones were measured with an ocular micrometer fitted to a dissecting microscope. Images of the bones examined and axes measured are presented in Figures 1–7 (terminology from Rojo, 1991). Regression analysis (2-parameter power function) was used to describe the relationship between bone size and total body weight. For paired bones (dentary, angular, maxilla, hyomandibular, preopercle, opercle), axes of both bones were measured and mean lengths were compared with a paired t-test. The mean of measurements from right and left bones from a single individual was used in regression analyses when no significant difference in axis length was detected between sides, otherwise side-specific equations were generated (dentary axis “B” and preopercle axis “B”).

Results and Discussion

All regression equations presented in Table 2 explain a high percentage of variation in the data ($r^2 \geq 0.840$) and should permit accurate estimates of the total body weight of individual *Pseudanthias* from the dimensions of select head bones. Of all bone axes examined, only the length of parasphenoid axis B was not adequately predictive of body weight. Because of its low r^2 value (0.583) that regression equation is not presented.

Figures 8–14 show regression curves in relation to axis-length-to-body-weight scatterplots for each bone. These are intended to allow users of the regression equations in Table 2 to judge whether extrapolation is appropriate, or whether some equations may provide more-accurate weight predictions within certain bone size ranges.

Because some investigators may be interested in reconstructing fish lengths, and because length-weight relationships are basic information needs for fishery modeling, a

Table 2. Relationships Between Bone Dimensions (x) in mm and Total Body Weight (y) in g.

Bone, Axis (side)	Equation	N	r^2
Dentary, A	$y = 10.1616(x)^{1.5485}$	18	0.920
Dentary, B (left)	$y = 0.0459(x)^{2.7365}$	17	0.935
Dentary, B (right)	$y = 0.0305(x)^{2.9201}$	17	0.947
Angular	$y = 0.0202(x)^{3.1806}$	18	0.938
Maxilla	$y = 0.0014(x)^{3.9132}$	18	0.916
Hyomandibular, A	$y = 0.0173(x)^{3.2343}$	15	0.965
Hyomandibular, B	$y = 1.2695(x)^{1.5400}$	17	0.846
Preopercular, A	$y = 0.1686(x)^{2.2809}$	19	0.840
Preopercular, B (left)	$y = 0.0198(x)^{2.7939}$	18	0.875
Preopercular, B (right)	$y = 0.0121(x)^{3.0685}$	14	0.963
Opercular, A	$y = 0.0053(x)^{3.5695}$	17	0.944
Opercular, B	$y = 0.0139(x)^{3.2066}$	18	0.945
Parasphenoid, A	$y = 2.6025 \cdot 10^{-5}(x)^{5.0841}$	11	0.952

Table 3. Length-weight and length-length regressions.

Equation	N	r^2
$Wt = 2.1970 \cdot 10^{-6}(FL)^{3.4890}$	19	0.986
$SL = -1.2106 + 0.8523(FL)$	19	0.992
$TL = -16.6347 + 1.5094(FL)$	16	0.902
$TL = -11.2361 + 1.7167(SL)$	16	0.850

Wt – weight (g); SL – standard length (mm); FL – fork length (mm); TL – total length (mm).

series of length-weight and length-length relationships are presented in Table 3. These will allow the conversion of any length or weight measurement or estimate into any other.

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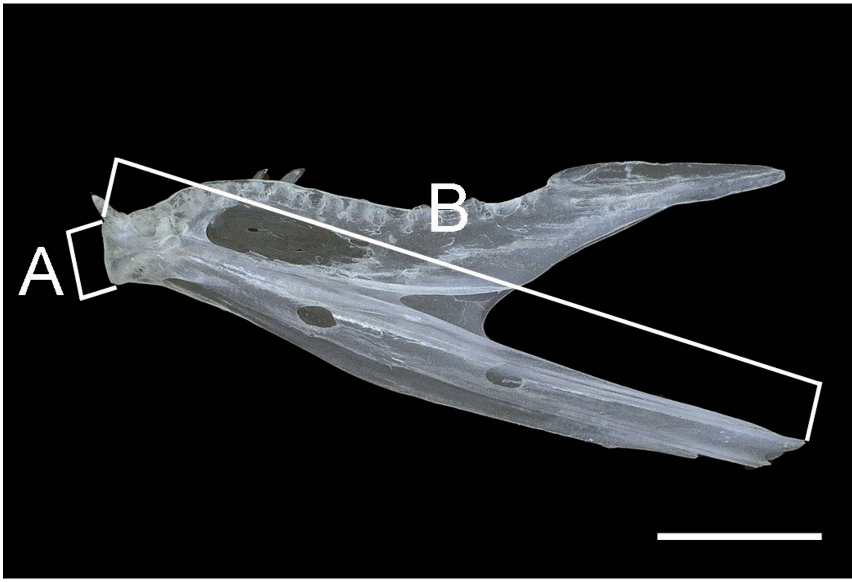

Figure 1. Axes measured on dentary (lateral aspect): A – height of mandibular symphysis; B – greatest distance between dorsal limit of mandibular symphysis and ventral process. Specimen: FR BPBM 0529, *Pseudanthias thompsoni*, 43.5 mm standard length. Scale bar = 1 mm.

Figure 2. Axis measured on angular (lateral aspect): greatest distance along bone, beginning at anterior limit of anterior process. Specimen data as in Figure 1. Scale bar = 1 mm.

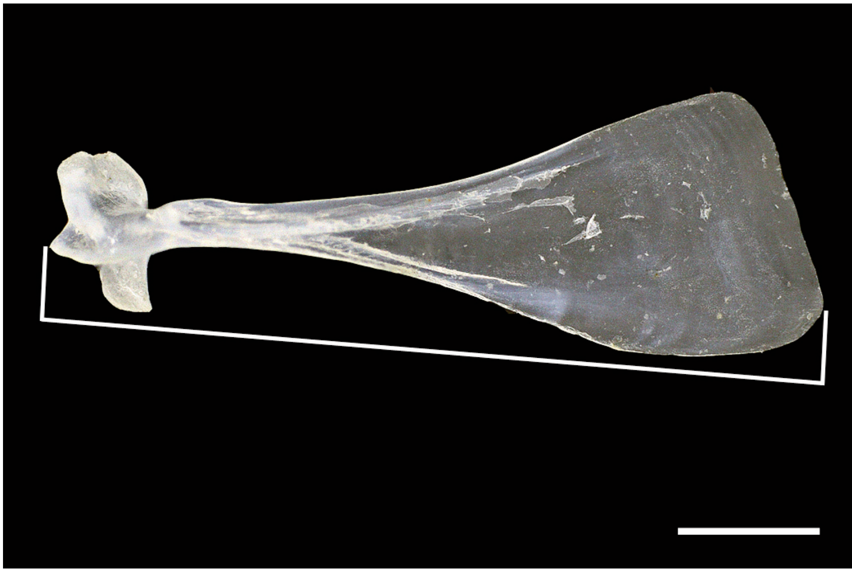

Figure 3. Axis measured on maxilla (lateral aspect): distance between the anterior limit of external process and posterior limit of caudal process. Specimen data as in Figure 1. Scale bar = 1 mm.

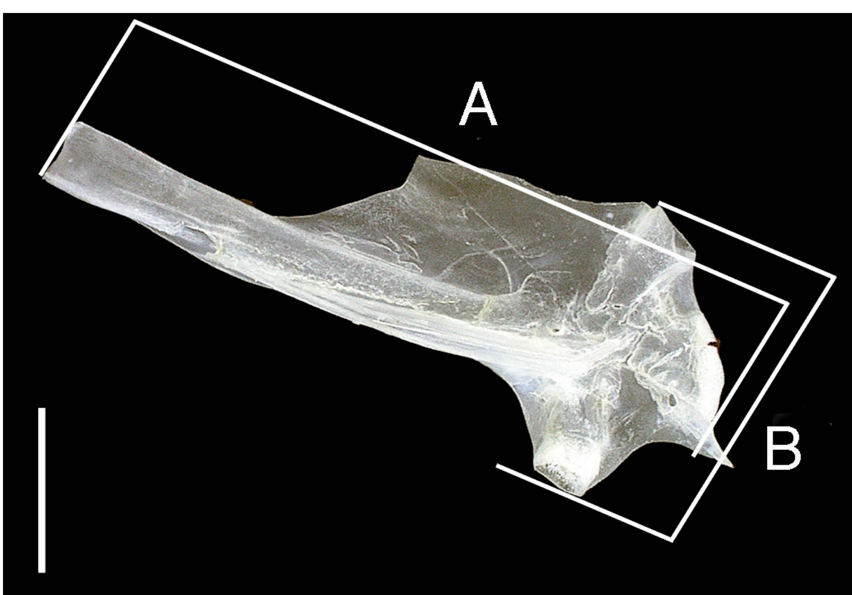

Figure 4. Axes measured on hyomandibular (lateral aspect, rotated 90° clockwise from its anatomical position): A – greatest distance between symplectic and pterotic facets; B – greatest distance between sphenotic facet and opercular process. Specimen data as in Figure 1. Scale bar = 1 mm.

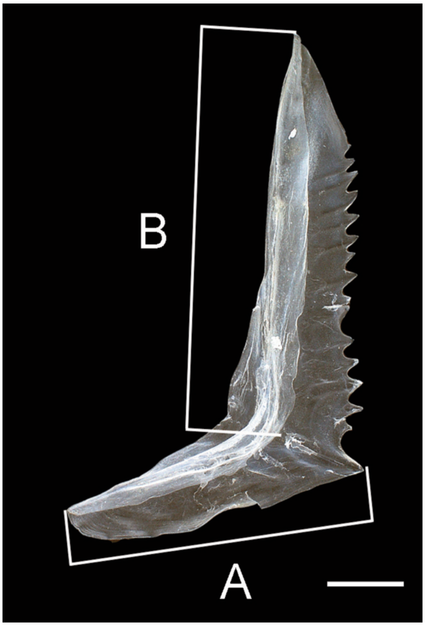

Figure 5. Axes measured on preopercle (lateral aspect): A – distance between anterior limit of quadrate crest and angle of posterior wing; B – distance between upper angle and free edge of sensory canal at its angle. Specimen data as in Figure 1. Scale bar = 1 mm.

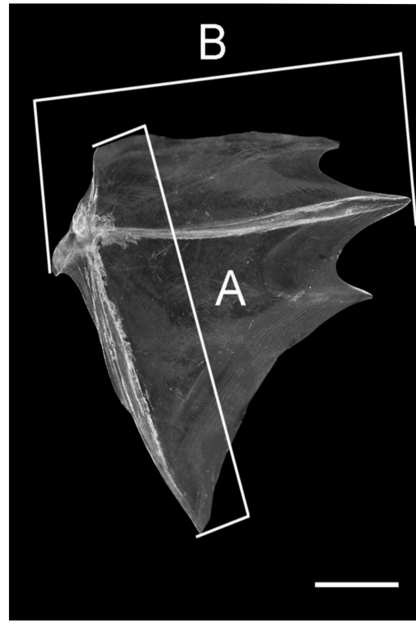

Figure 6. Axes measured on opercle (lateral aspect): A – distance between anterior limit of dorsal margin and inferior angle; B – distance between middle opercular spine and anterior limit of anterior margin near articular fossa. Specimen data as in Figure 1. Scale bar = 1 mm.

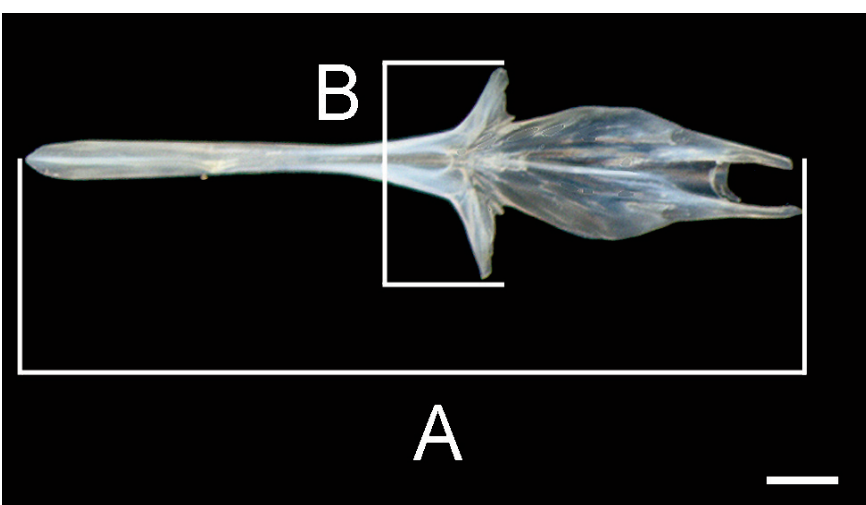

Figure 7. Axes measured on parasphenoid (ventral aspect): A – greatest distance along bone, beginning at anterior limit of anterior process; B – distance between lateral limits of alar processes. Specimen: FR BPBM 0526, *Pseudanthias thompsoni*, 56 mm standard length. Scale bar = 1 mm.

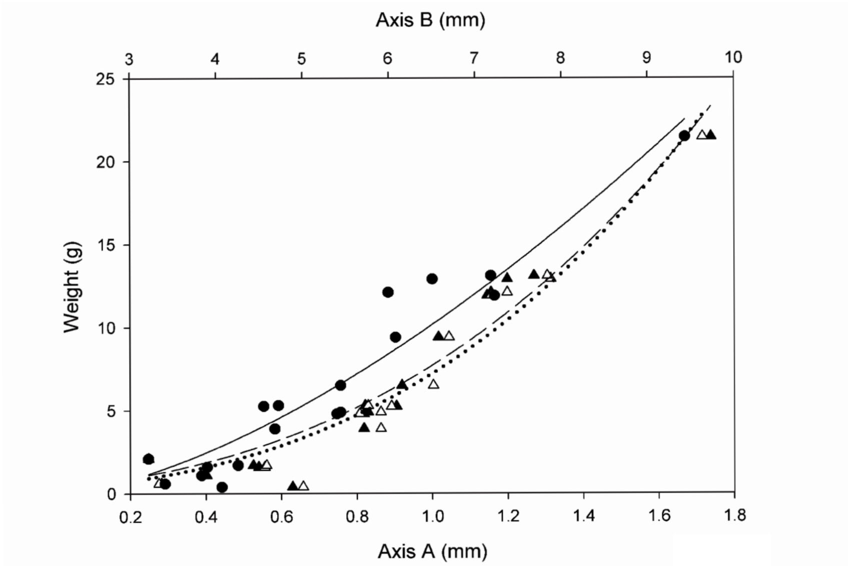

Figure 8. Relationships between dentary axis lengths and total body weight. A – circles, solid curve; B (left) – closed triangles, dashed curve; B (right) – open triangles, dotted curve.

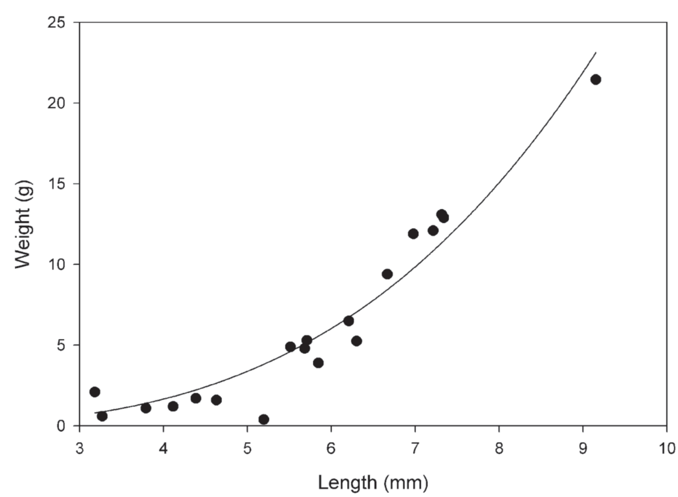

Figure 9. Relationship between angular length and total body weight.

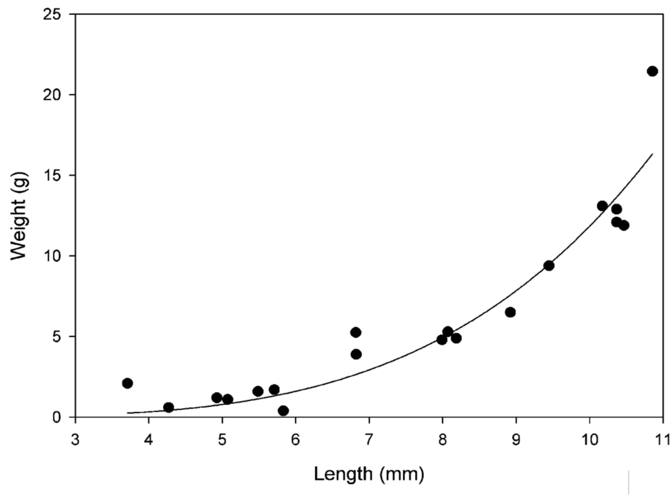

Figure 10. Relationship between maxilla length and total body weight.

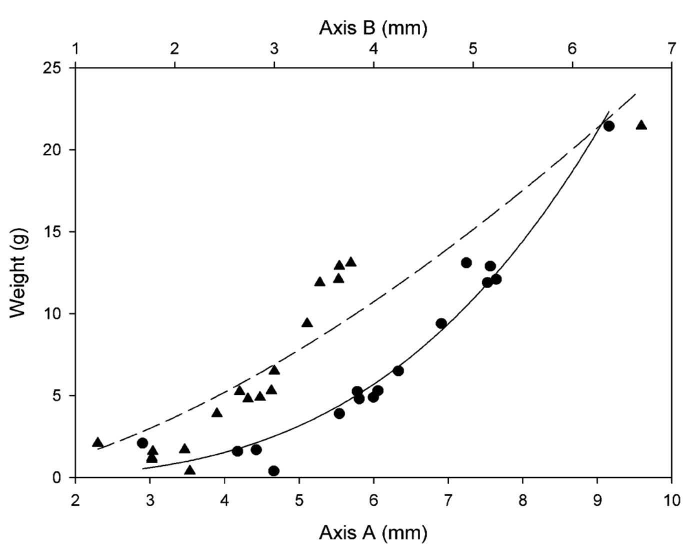

Figure 11. Relationships between hyomandibular axis lengths and total body weight. A – circles, solid curve; B – closed triangles, dashed curve.

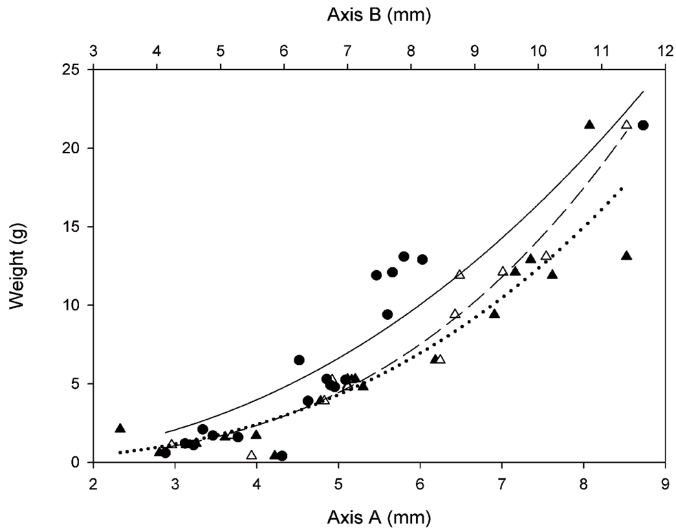

Figure 12. Relationships between preopercle axis lengths and total body weight. A – circles, solid curve; B (left) – closed triangles, dashed curve; B (right) – open triangles, dotted curve.

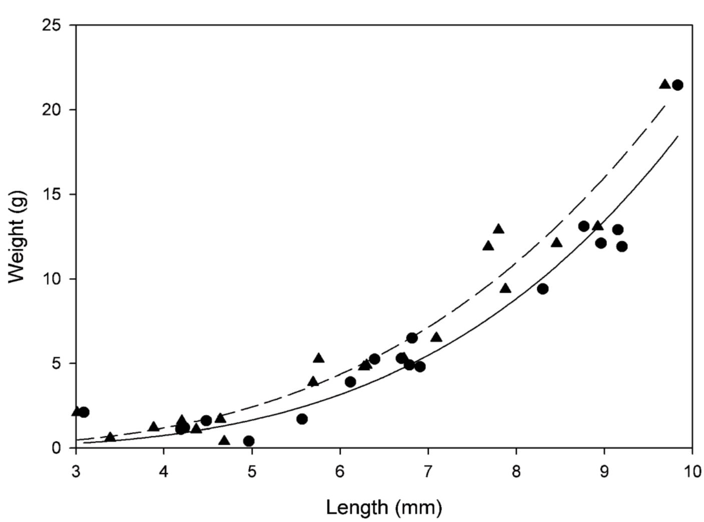

Figure 13. Relationships between opercle axis lengths and total body weight. A – circles, solid curve; B – closed triangles, dashed curve.

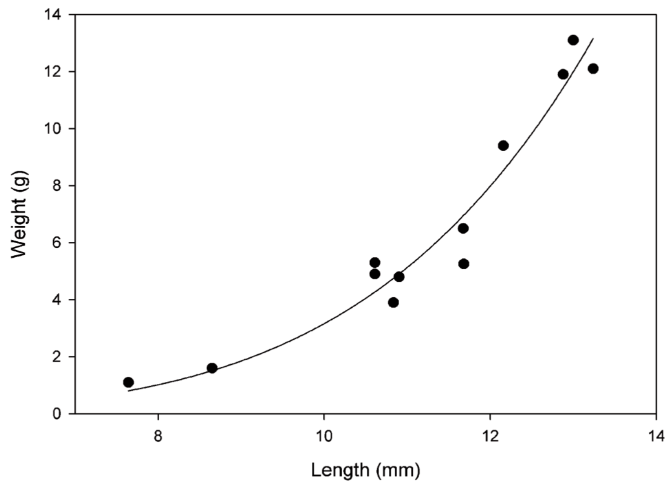

Figure 14. Relationship between parasphenoid axis A lengths and total body weight. Due to low descriptive power, the relationship for axis B is not shown.