Journal of Applied Ichthyology

J. Appl. Ichthyol. (2013), 1–4

ISSN 0175–8659

Received: October 17, 2012
Accepted: March 30, 2013
doi: 10.1111/jai.12244

Total length estimation of the Brazilian flathead *Percophis brasiliensis*, using morphometric relationships of skull, pectoral girdle bones, otoliths and specific body measures, in Argentine waters

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Summary

Predictive regression equations were generated to estimate total length of the Brazilian flathead (*Percophis brasiliensis*) fish using skull and pectoral girdle bones as well as specific body and otolith lengths. All regressions were statistically significant. The features of bone and external body regressions evidently have the capability to increase the amount of dietary information obtainable from stomach content analyses of the Southwest Atlantic piscivores.

Introduction

The Brazilian flathead *Percophis brasiliensis* Quoy & Gaimard 1824, is a coastal and bottom dwelling fish inhabiting sandy beds at depths up to 50 m. Distribution ranges from 23°S in Brazil to 44°S in Argentine waters (Cousseau and Perrotta, 1998; Carozza, 2000). Maximum length registered for the species is 74 cm; in the meantime the size most frequently landed by commercial fishery ranges between 25 and 60 cm (Carozza, 2000). The size of first maturity was estimated by Carozza (2000) as 28.98 cm for males and 38.34 cm for females; Rodrígues (2009) estimated size of first maturity as 25.5 for males and 35.6 for females.

Percophis brasiliensisis constitute a prey for top predators such as the smooth-hound shark (*Mustelus schmitti*), copper shark (*Carcharhinus brachyurus*), school shark (*Galeorhinus galeus*), sand tiger shark (*Carcharias taurus*) and the angel shark (*Squatina guggenheim*) (Dávolos, 2003; Lucífora, 2003; Vögler et al., 2003; Lucífora et al., 2006).

A fish community's structures are strongly influenced by the effects of piscivorous predators (Lyons and Magnuson, 1987; Tonn et al., 1992; Scharf et al., 1997). Moreover, in recent years, works in trophic ecology became relevant through the use of ecosystemic indexes for evaluating the health of ecosystems (Pauly et al., 1998a,b). The trophic level is one of these indexes and used for extensive evaluation of the state of fisheries and to determine the existence of over-exploitation or sustainability over the years (Pauly et al., 1998a, 2001, 2002). Thus, trophic ecology became important to attain great precision in the evaluation of the diet of any predator, including the size and weight of the consumed prey, information that becomes essential in defining conservation and management strategies.

As it is often difficult to assess the diet of predators directly in field observations, studies of their diet rely upon the examination of undigested remains in their stomachs. Commonly, the length and weight identification of prey species is determined by the use of otoliths, structures that due to the high speed of degradation are not always found in the stomach contents (North et al., 1984; Jobling and Breiby, 1986). Thus, due to their low rate of digestion the skull and pectoral girdle bones become an alternative or complementary to the otoliths in diet studies (Hansel et al., 1988; Scharf et al., 1997, 1998; Gosztonyi et al., 2007; González Zevallos et al., 2010.

In order to improve the evaluation of the quantitative contribution of *P. patagonicus* in the diet of marine piscivores, predictive regressions equations were generated to estimate fish total length using skull and pectoral girdle bones, as well as specific body and otolith lengths.

Materials and methods

A total of 203 *P. brasiliensis* obtained between February and June of 2011 from the commercial bottom trawl vessels operating at Puerto Quequén, Buenos Aires Province, Argentina (fishing area: 38°40′-39°50′S; 57°68′-60°08′W), were analyzed. Body measurements were taken in centimeters (±1 mm) (Fig. 1), all specimens were then dissected and immediately frozen. The diagnostic bones were selected following Gosztonyi and Kuba (1996). The bones chosen are found frequently in stomach contents of predators and allow identification to species level. To remove diagnostic bones, fish were placed in boiling water for a maximum of 2 min, depending on fish size. Bones were removed from the tissues and measured to the nearest 0.05 mm using a caliper according to the schemes described in Fig. 2. Least squares regression equations were generated using INFOSTAT/L (Di Rienzo et al., 2010) to predict original total length from measurements of head length, predorsal length, preanal length, hyoid bar length, cleithrum length, dentary lengths, angular length, maxillary length, opercular length, premaxillar lengths, preopercular lengths, vomer lengths, hyomandibular lengths, parasphenoid length and otoliths length. Total lengths were regressed on measurements of the remaining bones.

Results

Regressions relating body measurements to total length were highly significant ($P < 0.0001$), with r^2 values ranging from

0.89 to 0.95. Regression from measurements of preanal length to predict total length was the least variable compared to those from predorsal and head lengths (Table 1).

Regressions relating diagnostic bony measurements to total length were also very significant (P < 0.0001) with r^2 values ranging from 0.86 to 0.93, showing maxillar, premaxillar, dentary, parasphenoid, cleitrum, hyomandibular and preopercular bones as the best adjustment (Table 1).

There was a positive linear relationship between the otolith length to the total length, which was very significant (P < 0.0001) with an r^2 value of 0.91 (Table 1).

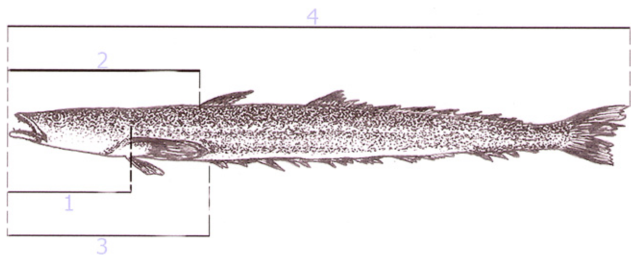

Fig. 1. Body length measurements. 1: head length; 2: predorsal length; 3: preanal length; 4: total length

Discussion

Each of the measurements, including those from diagnostic bones, body and otolith lengths, were significantly associated to total length. Measurements taken from diagnostic bones, particularly cleithrum length, dentary lengths, maxillary length, premaxillar length, preopercular lengths, hyomandibular length and paraesphenoid length, seem to be reliable predictors of the original size of *P. brasiliensis*.

Assessment of the original length of prey fishes from measurements of the diagnostic bones should result in an improvement in the quality and quantity of diet information

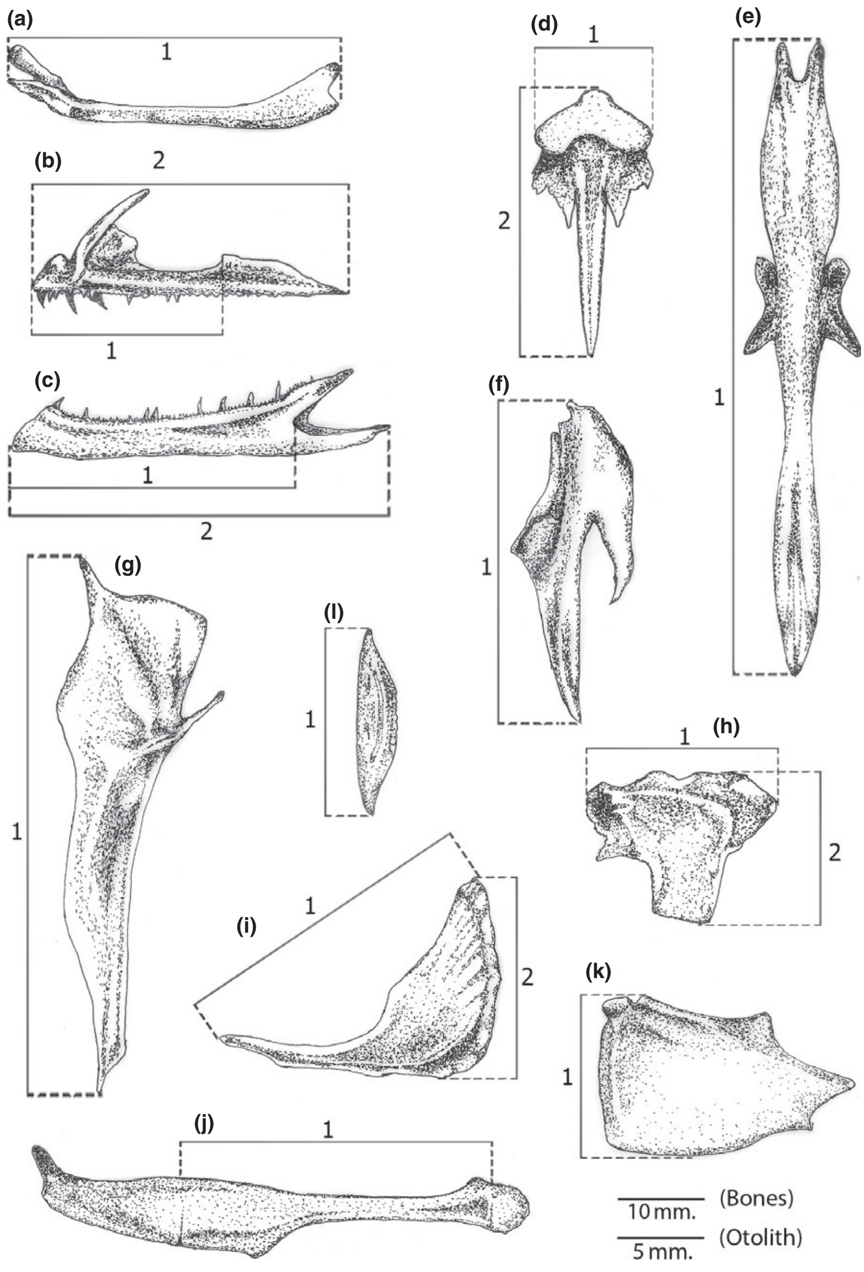

Fig. 2. Body and otolith measurements. (a) maxilla; (b): premaxilla; (c): dentary; (d): vomer; (e): parasphenoid; (f): angular; (g): cleitrum; (h): hyomandibular; (i): otolith; (j): hyoid bar; (k): opercular; (l): preopercular. Numbers (1) and (2) = registered measurements

Table 1
Estimated parameters of predictive regression equations of data vs total length, *P. brasiliensis* (y = a + bx). x = variable in mm, y = total length in mm, n = sample size, r^2 = coefficient of determination, SE = standard error, IC = confidence interval. Numbers (1) and (2) = measurements illustrated in Fig. 2.

Variables (mm)	n	r^2	a ± SE (CI 95%)	b ± SE (CI 95%)
(a). Maxilla				
(1)	202	0.92	25.88 ± 9.77 (6.62–45.14)	14.24 ± 0.29 (13.65–14.83)
(b). Premaxilla				
(1)	202	0.88	65.11 ± 10.00 (43.43–86.80)	24.09 ± 0.62 (22.87–25.31)
(2)	202	0.92	16.19 ± 9.99 (−3.50 to 35.89)	15.25 ± 0.32 (14.62–15.88)
(c). Dentary				
(1)	202	0.91	33.96 ± 10.34 (13.57–54.36)	15.87 ± 0.36(15.17–16.58)
(2)	202	0.93	14.54 ± 9.33 (−3.86 to 32.94)	11.48 ± 0.22 (11.04–1.92)
(d). Vomer				
(1)	198	0.88	74.20 ± 10.94 (52.64–95.77)	46.78 ± 1.22 (44.37–49.19)
(2)	195	0.88	26.21 ± 12.21 (2.13–50.28)	17.36 ± 0.46 (16.46–18.26)
(e). Parasphenoid				
(1)	177	0.93	19.34 ± 9.97 (−0.34 to 33.02)	7.29 ± 0.15 (6.98–7.59)
(f). Angular				
(1)	202	0.86	−20.43 ± 14.40 (−48.83 to 7.98)	15.23 ± 0.43 (14.39–16.07)
(g). Cleithrum				
(1)	113	0.92	41.22 ± 12.57 (16.32–66.12)	8.37 ± 0.23 (7.91–8.83)
(h). Hyomandibular				
(1)	202	0.92	33.25 ± 9.83 (13.86–52.64)	23.67 ± 0.51 (22.67–24.67)
(2)	201	0.88	90.91 ± 10.57 (70.07–111.74)	20.42 ± 0.75 (16.95–29.90)
(i). Otolith				
(1)	198	0.91	0.98 ± 11.33 (−21.36 to 23.32)	42.83 ± 0.99 (40.88–44.78)
(j). Hyoid bar				
(1)	202	0.90	35.39 ± 10.74 (14.21–56.57)	15.59 ± 0.37 (14.87–16.31)
(k). Opercular				
(1)	199	0.90	77.56 ± 9.96 (57.92–97.19)	23.01 ± 0.55 (21.92–24.09)
(l). Preopercular				
(1)	202	0.92	46.65 ± 9.37 (28.17–65.13)	16.33 ± 0.34 (15.66–17.1)
(2)	202	0.92	88.50 ± 8.68 (71.38–105.62)	20.14 ± 0.43 (12.29–20.99)
Head length	203	0.94	27.07 ± 8.59 (10.14–44.00)	4.24 ± 0.08 (4.08–4.39)
Predorsal length	203	0.89	125.24 ± 9.38 (106.76–143.73)	2.55 ± 0.07 (2.42–2.68)
Preanal length	203	0.95	72.67 ± 7.05 (58.78–86.57)	2.42 ± 0.04 (2.34–2.50)

for predatory species and their role in the structure of marine fish communities.

The calculation of original prey dimensions from the sizes of diagnostic bones is not as susceptible to measurement error as are estimates from external body lengths. External morphology can be distorted during the digestive process, which may cause external characteristics to produce defective measurements. Nevertheless, as stated by Scharf et al. (1997), external morphometric measurements of recently-consumed prey fishes can be highly consistent estimators of the original prey size and represent an appropriate alternative to diagnostic bones.

The rebuilding of initial prey sizes from external body or diagnostic bone measurements has limitations. The effects of preservatives on bone sizes need to be considered when stomach contents are stored in a chemical stabilizer (Hansel et al., 1988; Scharf et al., 1997). This is not the case of the fish used in the present study, as it was stored frozen before being measured. Another potential problem is the use of boiling water in aiding the removal of soft tissues as it can cause bone deformation and contraction with sufficient time elapses between the boiling process and the conclusion of bone measurements; however, our analyses were completed immediately after removal of the soft tissues.

Our results show that maxilla, premaxilla, dentary, parasphenoid, cleitrum, hyomandibular and preopercular bones are good regressors of the original fish size and that the preanal regression was the best among the external body measurements. We also provided an accurate relationship between otolith length and total fish length.

The bone and external body feature regressions offered in this study evidently have the capability to increase the amount of dietary information obtainable from stomach contents analyses of the Southwest Atlantic piscivores.

Acknowledgements

We thank L. Tamini for the field assistance. We also acknowledge R. Bruno and Juan from the fish processing plant “Santa Cecilia”, Miguel, Colo, and Maxi from the fish processing plant “Pesquera Iglesias”, J. Ricci for providing us with biological material and allowing us the use of their facilities, L. Meloni for the drawings and F. Welch for help with the English version of the manuscript.

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