Progress in Biological Sciences
Vol. 1, No.1, 25-30, Winter/Spring 2011

Determination of age and growth of the mudskipper *Periophthalmus waltoni* Koumans, 1955 (Actinopterygii: Perciformes) on the mudflats of Qeshm Island and Bandar-Abbas, Iran

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In order to determine the age structure, growth, and length-weight relationship of the mudskipper, *Periophthalmus waltoni*, from coastal mudflats of Qeshm Island, Soroo and Bandar-pol, in Hormuzgan Province, Iran, we collected 192 individuals in February 2007. Age was determined using the second pectoral radial bone and year class was based on length-frequency distributions. Growth was described by the von Bertalanffy growth model. For Bandar-Pol mudskippers, L_∞ = 141.51 mm, k = 0.46 year^{-1}, and t_0 = 0.79 year. For Qeshm mudskippers, L_∞ = 166.79 mm, k = 0.42 year^{-1}, and t_0 = 0.62 year. Overall, males grew larger than females (L_∞ = 208 mm vs. 147 mm), while females grew faster (k = 0.41 vs. 0.19 year^{-1}). The age when the theoretical length was 0 (t_0) was 1.46 year for males and 0.88 for females. Maximum age was estimated to be 4+ years. Total length for all specimens ranged from 69 to 154 mm, and for individuals of the same age, males were larger than females. Length-weight relationship indicated an isometric growth pattern.

KEY WORDS: age, growth, length-weight relationship, *Periophthalmus waltoni,* Qeshm Island and Bandar-Abbas

INTRODUCTION

Walton's mudskipper *Periophthalmus waltoni* Koumans, 1941, is an amphibious gobiid with a distribution from the Persian Gulf to Pakistan (Murdy, 1989). This species is found on open mudflats, in tidal mangrove forests, and sandy-muddy shores of coastal inlets and estuaries along Iran's southern coast (Abdoli, 2000).

Walton's mudskipper is not commercially valuable locally, but the species is preyed upon by sea birds. It may play an important role as a bio-indicator of anthropogenic impact on habitat in mangrove forests and intertidal areas (Wong et al., 2000; Polgar, 2008).

Although this species is a dominant component of the intertidal macrofauna, few data are available on the age structure of populations along Iran's coast, possibly due to difficulty in collecting specimens (Clayton, 1993). Reclamation projects have destroyed much of the mudskipper's intertidal habitat.

The objectives of the present study were to determine the age structure and growth of *P. waltoni* in three habitats on intertidal mudflats of southern Iran.

MATERIAL AND METHODS

Fish were collected from three habitats in Hormuzgan Province: Sarsoor, Qeshm Island; Bandar Pol; and Soroo, near Bandar Abbas. Sarsoor

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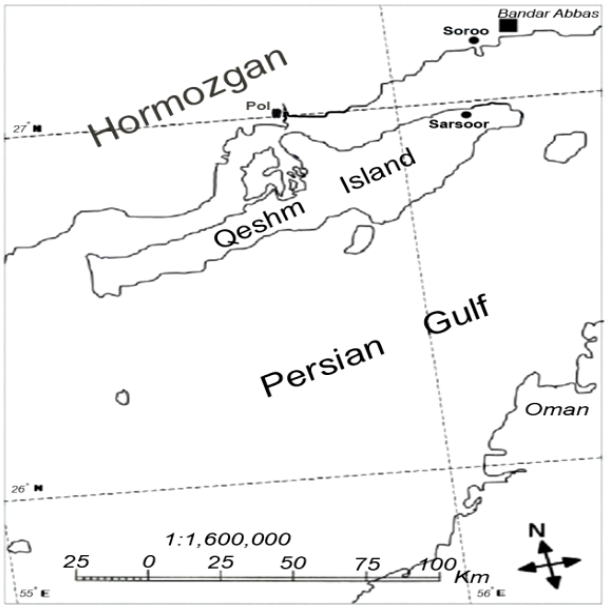

Fig. 1. Map showing sampling sites for *Periophthalmus waltoni*.

(26° 59' N, 56° 9' E) is characterized by undisturbed open mudflats with semi-compact mangrove shrubs (*Avicennia marina*) and is located far from residential areas. Bandar Pol (26° 56' N, 55° 49' E) is on a narrow inlet. It is completely undisturbed and supports dense stands of mangrove shrubs. The third habitat, Soroo (27° 9' N, 56° 13' E), consists of sandy-muddy intertidal areas near a residential development with no mangroves (Fig. 1).

Samples were collected by hand, by digging into burrows on the mudflats during a single week in February 2007. Altogether, 192 fish were preserved in 10% formalin at the collecting location.

Fish were measured for total length (L_T) and standard length (L_S) to the nearest 0.02 mm, using a dial caliper, and weight to the nearest 0.01 g (Bagenal, 1978). The length-weight relationship was calculated by the formula: W= a L_T^b, where *W* is weight in grams, L_T is total length in centimeters, and *a* and *b* are regression parameters (Zar, 1984).

The exponent *b* often has a value close to 3, but ranges between 2 and 4 (Tesch, 1971). The value b = 3 indicates that the fish grows symmetrically or isometrically. Values other than 3 indicate allometric growth (Tesch, 1971).

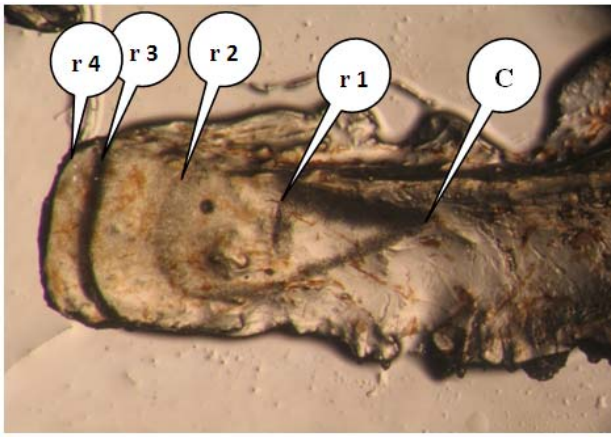

Fig. 2. The second pectoral radial bone showing the rings (C center; r rings).

Sex was determined by direct observation of gonads. In each individual, the sagittal otolith and second pectoral radial bones were removed to determine age. Pectoral fins were cut from the body and submerged in boiling water for about 15 min (based on the size of the bone, smaller ones needed less boiling time to soften muscles). The bones were then placed in a solution of 3% NaOH in water for 22 h to remove all muscle and spines. Finally, bones were washed in water (Takegaki and Nanami, 2005). The otoliths were not clear and readable after the preparation process, so age was determined from the second pectoral radial bones. The central area of each bone, including rings, was clearly visible by transmitted light microscopy at 10x magnification (Fig. 2). The rings were counted three times, and only those results that were in agreement were accepted.

The length-frequency distribution results supported the age estimation. In this way, it was possible to estimate the age structure of *P. waltoni* from the three sampling sites.

Estimation of theoretical growth was obtained by the standard form of von Bertalanffy's growth equation (Sparre and Venema, 1992):

$$L_t = L_\infty \{1 - \exp[-K(t - t_0)]\}$$

where L_t is total length at age *t*, L_∞ is asymptotic length, *K* is growth coefficient, and t_0 is theoretical age at zero length.

All data were analyzed using the SPSS package (SPSS Inc., Chicago).

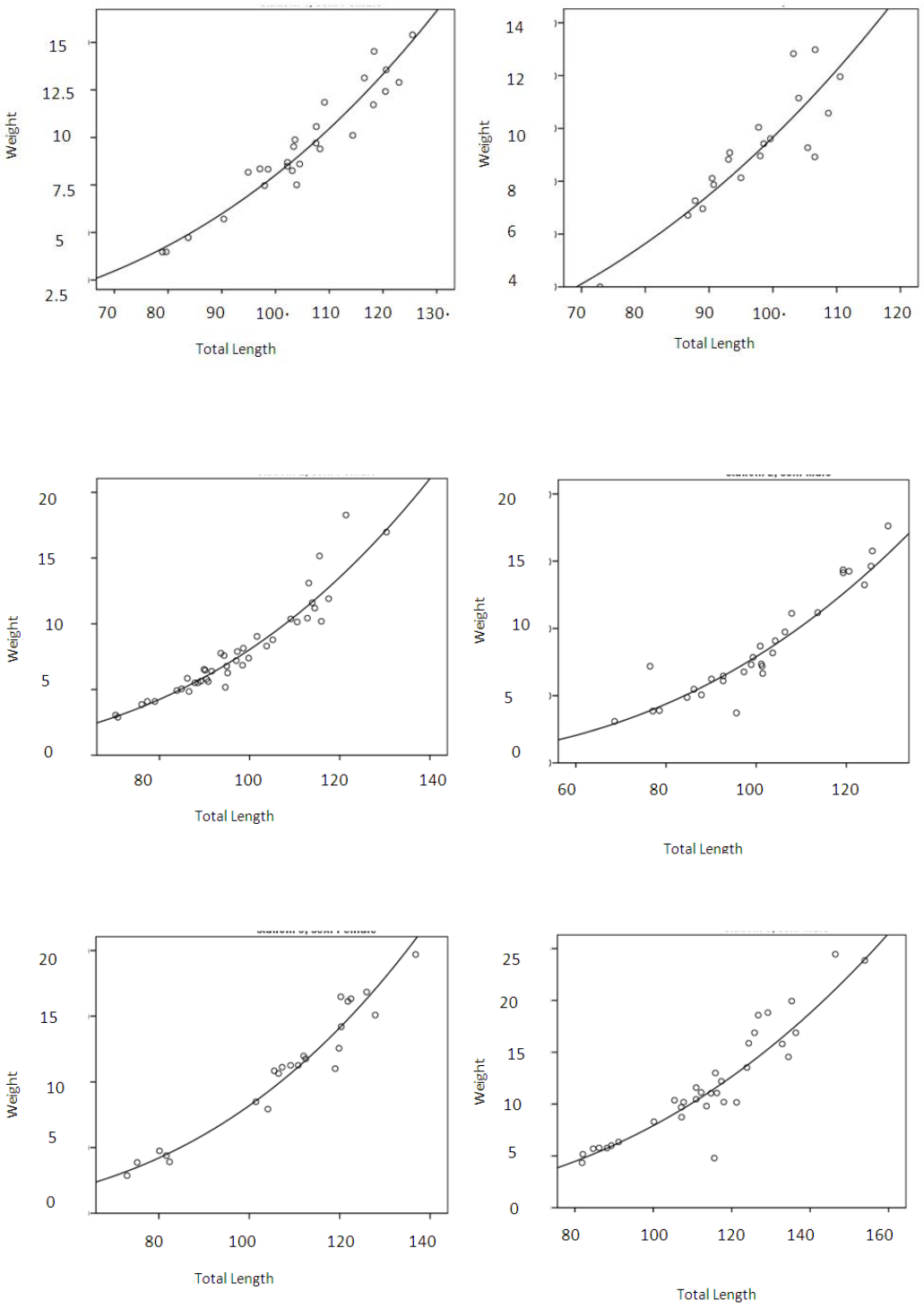

Fig. 3. Relationship between total length and weight of *Periophthalmus waltoni* collected from Bandar-Pol (top left: female; top right: male)),Soroo (middle left: female; middle right: male), and Sarsoor (bottom left: female; bottom right: male)

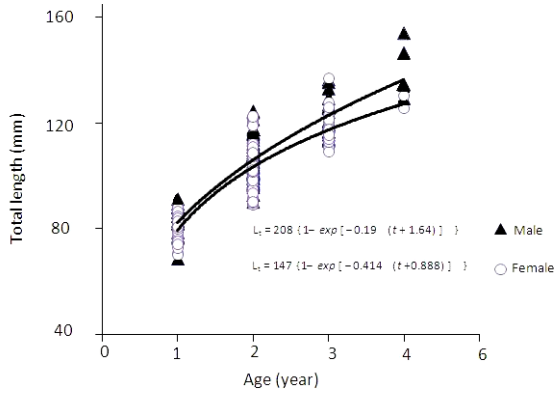

Fig. 4. Standard von Bertalanffy growth curves, fitted to length-at-age data, for male and female *Periophthalmus waltoni*.

Table 1. Age groups of *Periophthalmus waltoni* at the three sampling sites

Station	Age years	n	Mean Length	Mean Weight
Bandar-pol	1	5	80.4	3.97
	2	30	103.1	8.62
	3	14	113.2	11.86
	4	1	125.5	15.5
Sarsoor	1	16	83.7	4.94
	2	37	120.9	11.07
	3	9	130.77	71.61
	4	3	144.9	20.95
Soroo	1	19	80.8	4.68
	2	37	96.99	7.13
	3	19	109.14	13.19
	4	2	129.8	17.3

RESULTS

We identified four age groups from the three sites with 2+ year-old cohorts as the dominant category (Table 1). The largest specimen, 153.92 mm L_T, was a 4+ year-old male captured at Sarsoor, and the smallest specimen, 68.8 mm L_T, was a 1+ year-old male at Soroo. The results of length-weight relationship are presented in Table 2. The slope of the regression line revealed an approximately isometric growth pattern. The scatter plot reflects the exponential growth in weight with increasing length (Fig. 3). The study revealed that the second pectoral radial bone in *P. waltoni* provided a good indicator of age. The estimated age using the second pectoral radial bone was in agreement with the length-frequency distribution.

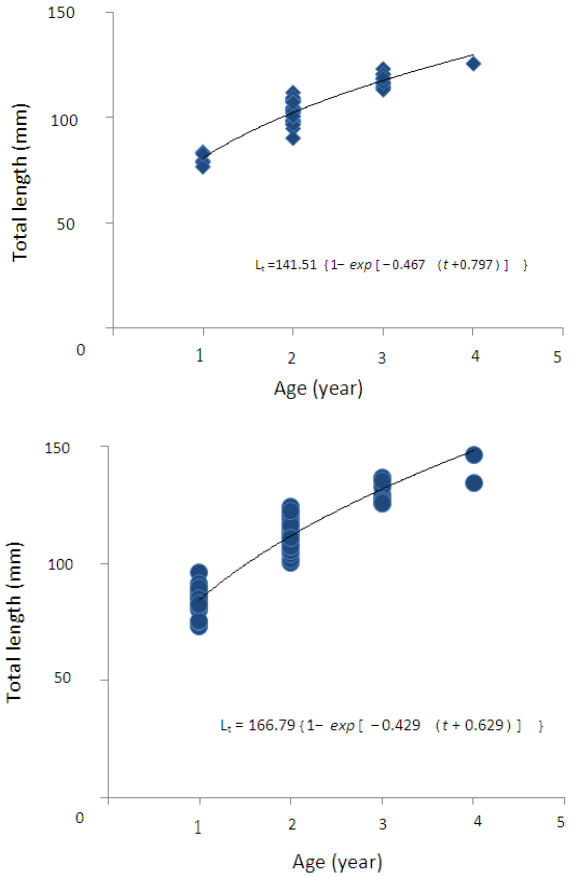

Fig. 5. Standard von Bertalanffy growth curves fitted to length-at-age data, for *Periophthalmus waltoni* in Bandar-Pol (up) and Qeshm Island, Sarsoor (below).

The von Bertalanffy growth curve indicated a greater rate of growth in females than males, but males reached overall larger sizes (Fig. 4).

Fish captured from Qeshm Island and Bandar-Pol showed different growth parameters. Both males and females of the Qeshm Island population showed greater size at a given age than did the same sex in Bandar-Pol (Fig. 5).

DISCUSSION

Despite the abundance of *P. waltoni* on the southern intertidal coast of Iran, the species is poorly known, and few data are available on its biology and ecology.

In the present study, the maximum L_T measured for *P. waltoni* was 153.92 mm. Abdoli *et al.* (2009) recorded a maximum L_T for this species of 176 mm. Barak *et al.* (1994) reported allometric growth for *P. waltoni* in the Khor Al-Zubair,

Table 2. Estimated parameters for length-weight relationships in *Periophthalmus waltoni* from the three sample sites

Site	sex	n	$W= aL^b$	b	Growth	95% CI of b	R^2
Bandar Pol	M+F	49	$W=1.93\times10^{-5}L^{2.801}$	2.633	Allometric	2.281 – 2.985	0.861
Bandar Abbas	M+F	77	$W=2.28\times10^{-5}L^{2.772}$	2.988	Isometric	2.774 – 3.202	0.92
Qeshm Island	M+F	64	$W=2.61\times10^{-5}L^{2.735}$	2.741	Isometric	2.415 – 3.066	0.848
Bandar Pol	M	20	$W=3.2\times10^{-5}L^{2.682}$	2.412	Isometric	1.645 – 3.17	0.75
Bandar Pol	F	27	$W=2.17\times10^{-5}L^{2.784}$	2.642	Isometric	2.268 – 3.015	0.91
Bandar Abbas	M	30	$W=4.13\times10^{-5}L^{2.641}$	2.959	Isometric	2.592 – 3.327	0.92
Bandar Abbas	F	41	$W=1.54\times10^{-5}L^{2.859}$	2.994	Isometric	2.68 – 3.307	0.91
Qeshm Island	M	34	$W=5.85\times10^{-5}L^{2.566}$	2.714	Isometric	2.3 – 3.127	0.86
Qeshm Island	F	23	$W=8.18\times10^{-6}L^{2.984}$	2.805	Isometric	2.39 – 3.216	0.94

n, number of specimens; F female; M male; $w= a L^b$; b, slope of the relationship $w= a L^b$; 95% CL of b, confidence limits of parameter b estimated at 95%; r^2, coefficient of the determination.

Iraq ($W= 1.74x10^{-4} L^{2.35}$; r = 0.99). Similar findings have also been reported by Abdoli *et al*. (2009), who calculated length-weight parameters for this species from the northern Persian Gulf (a = 0.00002 and b = 2.86). In the present study, the b value was found to be close to 3 for specimens from the Sarsoor and Soroo sampling sites. Various factors such as sex, maturity stage, food supply, stomach fullness, health, and preservation technique may have influenced the results, in addition to sampling locations, season, and environmental conditions (Pauly, 1984; Koutrakis and Tsikliras, 2003; Ferhat *et al*., 2007; Abdoli *et al.,* 2009).

The growth parameters obtained from this study appear reasonable, since the predicted asymptotic length value (L_∞) is higher than the size of the largest fish captured, and the growth coefficient value (k) for males indicated relatively low attainment of maximal size ($k = 0.19$ year^{-1}) and a slightly faster growth rate for females ($k = 0.41$ year^{-1}).

The breeding behavior of oxudercine gobies would suggest a size advantage for the male in digging a burrow and actively defending its territory. The males attract females by displaying courtship behavior including erecting dorsal fins and vertical jumping. They guard the eggs until hatching and gulp air from outside the burrows to aerate the eggs inside (Clayton, 1987; Clayton and Vaughan, 1988; Clayton and Wright, 1989; Clayton, 1993; Colombini 1995; Ikebe and Oishi, 1996; Calayton and Snowden, 2000).

Acknowledgements

We thank Bijan Darehshoori for advice about sampling sites and Mohammad Dakhteh for field assistance on at Qeshm Island. Many thanks also to the staff of Hormozgan University for providing facilities. This research was supported by Shahid Beheshti University.

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