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Age and growth of longnose trevally (*Carangoides chrysophrys*) in the Arabian Sea

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Summary

The ages and growth of longnose trevally (*Carangoides chrysophrys*), caught in the northwest Arabian Sea between April 2005 and September 2006, were investigated. Age and growth of 336 fish specimens were determined using sectioned sagittae otoliths. Annual opaque growth rings were formed between December and March, with the majority being laid down in February and March, coinciding with the spawning period and high water temperatures. Marginal zone or edge analysis was used to validate the annual deposition of the opaque zone in the otoliths. This species showed large variations in length-at-age, suggesting large growth variations among individuals of the same cohort. The estimated von Bertalanffy growth model differed significantly between the sexes, with males having larger mean lengths at age and reaching a larger asymptotic size. The von Bertalanffy growth models were TL (cm) = 73.34[1-exp (−0.25 (t + 1.21))] and TL(cm) = 73.26[1-exp (−0.24 (t + 1.20))] for males and females, respectively.

Introduction

The longnose trevally, *Carangoides chrysophrys*, is distributed along the continental shores of the Indian Ocean, including the Red Sea and the Arabian Gulf, to the western Pacific where it ranges from the coast of New South Wales to the Ryukyu Islands and Australia (Lieske and Myers, 1994). Insular coastal localities for the species in the Indian Ocean include Madagascar, the Comoros and the Seychelles (Smith-Vaniz, 1984).

In Oman, the species is regularly caught along the coast and occurs from the southern Arabian Sea to the Gulf of Oman and the Arabian Gulf (Al-Abdessalaam, 1995) and is most commonly fished at depths of 30–60 m where they feed on small fishes and benthic crustaceans (Randall, 1995). Oman is one of the primary harvesters of the reported global capture of Carangids (Food Agricultural Organization of United Nations (FAO), 2005; Griffiths et al., 2006). Although no separate catch statistics are available for *C. chrysophrys* in Oman, catch data for large jacks, which include nine commercially important species of family Carangidae (including longnose trevally), suggest a total landing of 2359 tonnes (t) with a 2007 value of 1.822 million Omani Rials (1 OR = 2.6 USD) (GoSO, 2008).

Age determination using sagittal otoliths has been problematic with tropical carangids (Griffiths et al., 2006), with the alternating translucent and opaque bands often being absent or difficult to discern. For example, Grandcourt et al. (2004a) were unable to distinguish annuli in 60 burnt sagittal otoliths of two similar-sized tropical carangids: Gnathanodon speciosus and Carangoides bajad. Similar problems were encountered in studies of the carangid Trachinotus falcatus from Florida waters (Crabtree et al., 2002). Fry et al. (2006) concluded that the direct age validation of growth increments in shallow-water fast-growing carangids such as Caranx tille and Caranx lugubris was impracticable.

The use of otoliths for ageing tropical species has only become commonplace since the early 1980s (Morales-Nin and Ralston, 1990; Ferreira and Russ, 1992; Francis et al., 1992; Fowler, 1995; Milton et al., 1995) and the application of this technique has provided invaluable information on the growth of tropical fishes that are often difficult age because of a lack in seasonality. In fact, Milton et al. (1995) argued that whole sagittal otoliths as compared to sectioned ones provide more reliable age estimates for lutjanids, while researchers such as Newman et al. (1996) and Stephenson and Hall (2003) have shown the opposite for other species.

Availability of reliable ageing methods is critical to the ultimate development of effective fisheries management strategies. The present study was designed to examine whether it was possible to employ and effectively interpret annular growth rings in the sagittal otoliths for estimating ages and growth patterns of *Carangoides chrysophrys* in the Omani Arabian Sea because of the lack of reliable data.

Materials and methods

A total of 336 *C. chrysophrys* (155 females and 181 males) encompassing a size range from 24 to 77 cm total length (TL) were randomly sampled for age determination. However, samples were collected from the commercial fishery, whereby this size range did not include individuals of all life history stages, particularly from fish smaller than the size at first capture because they were not selected by the commercial fishing gear.

Freshly landed fish were randomly selected and purchased from commercial fishermen at two landing sites on the Arabian Sea coast of the Sultanate of Oman: Al Lakbi (18º11′1″N; 56º 32′56″E) and Raysut (16º57′37″N; 53º59′52″E). Sampling took place from April 2005 to September 2006. Specimens were caught with handlines, gillnets and traps. Annual southwest monsoon winds (between May and September) result in poor weather conditions, and fishing activity in Al Lakbi ceases; hence, all biological sampling took place at Raysut.

Readings and interpretation of otoliths were based on the sagitta, the largest and most easily extracted otolith (Beckman and Wilson, 1995). Each sagitta was embedded in clear epoxy resin and a thin section (300 μm) taken through the nucleus along a transverse, dorsoventral plane with a

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Buehler Isomet low-speed saw with a diamond wafering blade. A grinding wheel fitted with silicon carbide paper of various grit sizes (400–1200 grit) and flushed with water was used to remove excess resin on the face of the sections and provide a polished face for viewing. Sections were mounted on glass slides for reading annuli increments under a compound microscope at 60× magnification using transmitted light. The relative precision of age estimates between the two readers was calculated using an index of the average percentage error (IAPE) (Beamish and Fournier, 1981) and the variance, expressed as a coefficient of variation (CV), was also calculated (Chang, 1982).

Longnose trevally was aged by counting opaque growth rings from the nucleus to the otolith margin using sagittal otoliths. Estimates of age were performed twice by two different readers along the same transect from the nucleus to the outer edge of the otolith, as indicated by dots in Fig. 1. Age readings were undertaken without prior knowledge of fish length or any other data and the age estimates recorded as the average of the two readings. The opaque bands were clearly defined near the nucleus and were more condensed at the outer edge of the otolith. In this study, the terminology employed follows those recommended by Secor et al. (1995), and the opaque zone or band refers to the dark area that appears under transmitted light.

A von Bertalanffy growth curve (Ricker, 1975) was fitted to the observed TL-at-age data using a nonlinear regression procedure. The von Bertalanffy growth equation is $L_t = L_\infty(1 - \exp(-K(t - t_0)))$ where L_t is the mean length at observed age t, L_∞ is the asymptotic length, K is the growth coefficient and $t_0$is the hypothetical age at zero length. The negative log likelihood, assuming an additive normally distributed error structure with mean = 0 and variance = σ^2, was minimized to estimate the parameters. A likelihood profile technique (Efron, 1981; Punt, 1994) was used to estimate the confidence intervals of the estimates of the parameters. Growth curves were fitted separately for females and males as well as to data pooled by sexes and compared using the analysis of residual sums of squares method (ARSS; Chen et al., 1992). An age–length key was constructed (Ricker, 1975).

Marginal zone or edge analysis was used to validate the annual deposition of the opaque zone in the *C. chrysophrys* otoliths. Growth zones on the proximal (in situ) margin of the otolith were recorded as either translucent or opaque (Hecht and Baird, 1977) for age classes 2–7 years. The frequency of the opaque margin per month was then plotted to determine the period of opaque zone deposition.

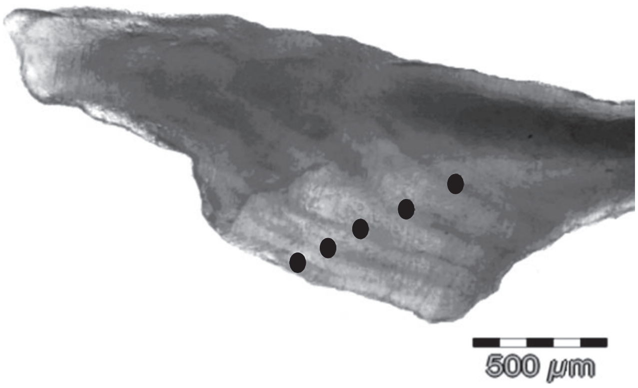

Fig. 1. Sectioned otolith, 5-year old female *Carangoides chrysophrys* (TL = 66.5 cm, W = 3.09 kg). Black dots = annual bands

Results

Sectioned *C. chrysophrys* otoliths showed clear wide translucent and thin opaque layers when viewed. Opaque bands were most distinct and easily counted in the mid-portion of the ventral lobe of each section (Fig. 1). The otolith bands were successfully read only for ages ranging between 2–16 years. The IAPE and the CV values were both 5.3%, representing good reproducibility between readings.

Opaque and translucent edges were noted for the sampled months, except September, and the general pattern indicated that one opaque and one translucent zone were deposited each year (Fig. 1). September otoliths, derived from two individual fish samples, were rejected because of poor resolution of the ring structure at the otolith margin. The opaque zone is formed between December and March, mainly being deposited in February and March, while the translucent band is formed during the remaining months of the year. Generally, fishing activity along the coast of Oman decreases during the holy month of Haj; in 2006 this was in February, which resulted in few samples being collected (Fig. 2).

For the age–length key, wide length ranges (50–75 cm) within most age classes were observed (Table 1). Growth in length for both sexes was relatively rapid up to age 4, slowing thereafter (Fig. 3). Males and females showed different growth rates (ARSS $F_{3330} = 5.52$; $P < 0.001$), with males attaining, on average, greater lengths-at-age and a larger asymptotic size. The von Bertalanffy growth parameters and their confidence limits, estimated separately for males and females and for pooled sexes, are presented in (Table 2).

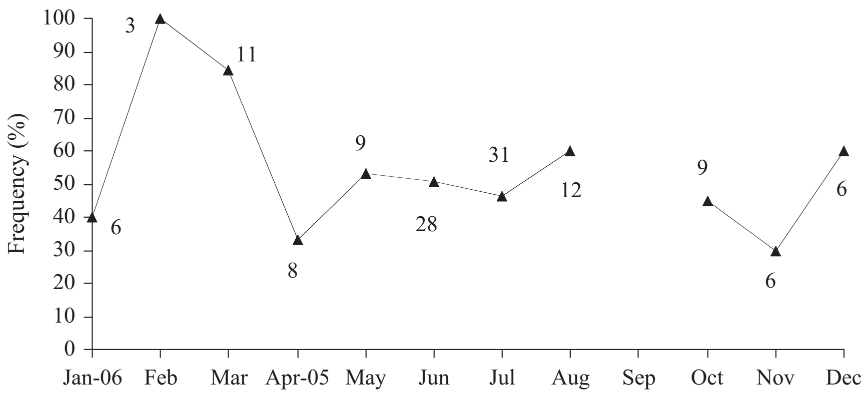

Fig. 2. Monthly mean frequency (%), *Carangoides chrysophrys* otoliths with opaque edges. Numbers = sample size per month

Table 1
Age–length key, *Carangoides chrysophrys* (sexes combined). Length = upper limit of each 5 cm total length (TL) class

Length	Age 2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5
20														
25														
30							1							
35	1								1					
40	1		1	2			3							
45	3	5	6	1			12		5	2			3	
50	9	3	7	4	2		12	1		4	5			
55	5	5	7		11			6			5		4	
60			23		14		1	1	7		3	2	6	
65			1		11				1			3	3	
70			1	4	15	2	3							4
75					9	9	6							
80					1									
Total	19	13	55	11	63	11	38	8	14	6	13	5	16	4

Length	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	15.5	16
20															
25	1														
30															
35															
40															
45															
50	3		1												
55	5						1	1							
60	2	1	2						1						
65		1		1	1						2		2		2
70	3	1	4		1	2						3	1	6	7
75							2						1	1	1
80															
Total	14	3	7	1	2	2	3	1	1	0	2	3	4	7	10

Discussion

In this study longnose trevally, *Carangoides chrysophrys*, were successfully aged using otoliths, shown to be problematic for other tropical carangids in previous studies (Crabtree et al., 2002; Grandcourt et al., 2004a; Griffiths et al., 2006). Two independent readers produced similar IAPE and CV values. The latter is considered more rigorous and thus more flexible statistically (Chang, 1982). The IAPE and CV values were 5.3%, less than the IAPE of 12.2% recorded for the Talang queenfish (Griffiths et al., 2006).

Sagittal otoliths have proved useful for age determination of *C. chrysophrys*. However, because the fishing gear employed for the sampling (handlines and traps) were size-selective (Siddeek et al., 1999) and specimens were generally caught at a distance from inshore locations, 0 and 1 age year-classes for this species were absent in this study. In Oman, the traditional fishery for Carangids operates far from estuaries at depths of 70 m (Al-Mamry et al., 2009); juveniles generally inhabit only inshore areas, reef-associated brackish waters and estuaries (Smith-Vaniz, 1984; Randall, 1995; Grandcourt et al., 2004b). Considerable variation in size was observed for longnose trevally within most age groups and for both genders examined, suggesting that variable growth rates are experienced by different cohorts and individuals. This phenomenon is commonly encountered in many tropical fish species (Goodwin and Johnson, 1986).

Because clear alternating opaque and translucent bands were observed and sagittal otolith ring periodicity could be validated, results from the present study indicate that these structures are consistent and stable enough to age *C. chrysophrys*. These seasonal bands are generally associated with changes in water temperature. In the Arabian Sea, the annual arrival in June of the southwest monsoon, or Khareef, drives temperatures and other oceanographic conditions. The Khareef results in major changes in coastal water temperatures, with seawater temperatures declining to 20°C (Sheppard et al., 2000; Wilson et al., 2002), and strong upwelling bringing up nutrients (Smith, 2001; Claereboudt et al., 2002). Pelagic productivity during the Khareef may be two orders of magnitude greater than that during winter (Sheppard et al., 2000). This enhanced period of primary productivity may assist in optimising larval survival and growth. Following the Khareef, the sea surface temperatures can increase to above 23°C (Rayner et al., 2005) while the food supplies decline (Sheppard et al., 2000). In *C. chrysophrys* opaque band deposition, representative of discontinuous or slow growth (Campana and Neilsen, 1985), and its spawning period (Al-Rasady et al., 2011) overlap with high average sea surface temperatures (Rayner et al., 2005) and reduction in food availability, typified by inter-monsoonal months. Similar observations have also been made for the spangled emperor Lethrinus nebulosus and king soldier bream Argyrops spinifer in the Arabian Sea during the same period (Al-Mamry et al., 2009). Likewise, Northern Australian stocks of Scomberoides commersonnianus lay down opaque bands between September and December (Griffiths et al., 2006), comparable to the observations presented herein.

The ARSS suggests that the von Bertalanffy growth models estimated for females and males differ significantly. However, the differences in each of the three von Bertalanffy growth parameters were small (e.g. the asymptotic length difference between males and females is 0.64 cm). Thus, although statistically different, such small differences in the

Table 2
Carangoides chrysophrys von Bertalanffy growth parameter estimates. CL = lower and upper values of 95% confidence limits

Sex	L_∞ cm (TL)	CL	K yr^{-1}	CL	t_0	CL
Female	73.26	63.99–96.59	0.24	0.05–0.34	−1.20	−3.0 to −0.94
Male	73.34	72.04–148.03	0.25	0.02–0.30	−1.21	−3.27 to −0.77
Pooled	73.01	69.78–86.48	0.25	0.05–0.73	−1.21	−3.17 to −0.82

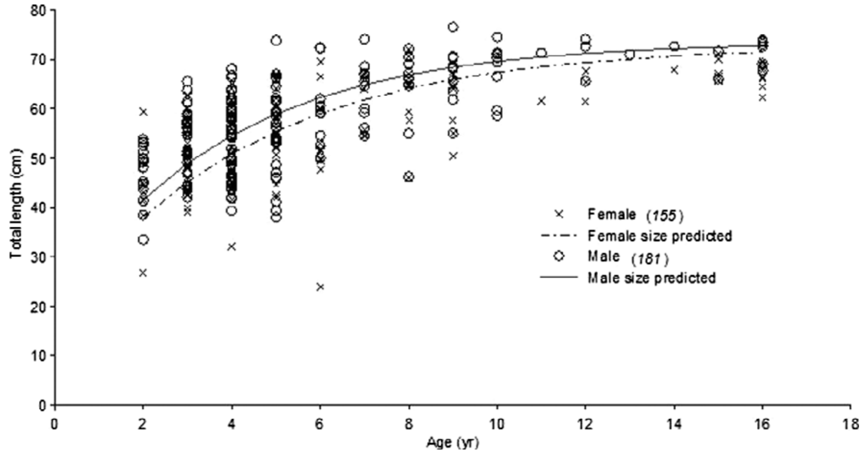

Fig. 3. *Carangoides chrysophrys* female and male von Bertalanffy growth curves

growth model between the sexes had limited biological implications. With this in mind we recommend that a combined growth curve be used for stock assessment purposes.

The estimated growth parameters of the von Bertalanffy growth model can vary in a variety of factors such as geographic areas, ecology, and sampling methodology (McIlwain et al., 2005). Carangid growth parameters using otoliths are poorly studied (Thompson et al., 1999), with most investigations opting to apply length frequency distributions to estimate growth. This is because carangids represent fast-growing pelagic species (Kalita and Jayabalan, 1997) while many slower-growing species have an absence of translucent and opaque bands (Grandcourt et al., 2004a). Because of the lack of young fish in the study sampling, the parameter t_0 might not be well estimated in this study (Ricker, 1975). The t_0 value estimated in this study with otoliths (-1.21 yr^{-1}) is similar to that of Griffiths et al. (2006), which is the only study done using otoliths to estimate the growth parameters in the Indian Ocean.

Our study suggests that the longnose trevally in the Omani Arabian Sea area is moderately long-lived, with a life expectancy of up to 16 years.

This study suggests that we can reliably age longnose trevally using sectioned sagittae otoliths, making the estimation of growth model possible. The results derived in this study provide essential information needed for stock assessment and management. However, no sample of juveniles is included in this study, which makes the growth estimation of fish at young ages less reliable. This study is also missing monthly data from February and September. Further studies of longnose trevally are needed to examine ageing and growth in juvenile specimens as well as to complete the time series for the missing months.

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