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Growth of an Inshore Antarctic fish, *Trematomus newnesi* (Nototheniidae), off Adelie Land

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ABSTRACT

Dusky rockcod, *Trematomus newnesi*, is a widely distributed neritic circumpolar Antarctic fish species. We conducted a study on age and growth of *T. newnesi* in coastal waters of Adélie Land in East Antarctica. A total of 289 specimens were collected in 2003, 2005, 2006 and 2009. They consisted of 122 females, 132 males and 35 immature specimens. Total length (TL) and total weight (W) of these fish ranged from 13.5 to 25 cm and 19.7–174 g respectively for females and from 12 to 20.9 cm and from 24.1 to 144.1 g for males. The TL/W relationship was described by the following parameters: $a = 7.2.10^{-3}$ and $b = 3.127$, showing no significant difference between sex (ANCOVA, $P < 0.05$). Fish age was estimated by counting annual growth increments on polished transverse sections of sagittal otoliths. Age estimates varied from 3 to 14 years. There was a significant relationship between otolith morphological features (weight and *radius*) and age with no difference between males and females ($p > 0.05$). The estimated values of Von Bertalanffy growth curve $L\infty$ (cm), W_∞ (g) and k were 26.6, 200.6 and 0.13 for females and 24.5, 147.0 and 0.15 for males respectively. The indices of growth performance between sexes were not significant. However, potential difference in growth rate between the morphs cannot be neglected.

1. Introduction

Dusky rockcod, *Trematomus newnesi* Boulenger 1902 is a member of the Antarctic/Sub-Antarctic endemic family Nototheniidae (Suborder Notothenioidei) (DeWitt et al., 1990). It is the only known example of phenotypic plasticity in Antarctic notothenioid fish, existing as populations of a typical common morph (benthic morph *versus* semipelagic morph), a large mouth morph and forms which are intermediate between the two morphs. Its large morphological plasticity distinguishes *T. newnesi* from all other notothenioids (Eastman and De Vries, 1997; Eastman and Barrera-Oro, 2010; Barrera-Oro et al., 2012).

The depth range of this species varies from shallow waters to 400 m (Tiedtke and Kock, 1989), but it is more abundant in inshore waters within the 20–50 m depth range, mainly over rocky bottoms or macroalgae beds (Moreno et al., 1982; Barrera-Oro, 2002). Andriashev (1970) and Williams (1988) identified *T. newnesi* as a coastal cryopelagic species which is associated with the underside of the sea-ice. Its diet varies in accordance with the sea ice cover (La Mesa et al., 2000). Gammarideans amphipods and copepods are the main prey of this species (Casaux et al., 1990; Vacchi and La Mesa, 1995; Eastman and De Vries, 1997; La Mesa et al., 2000; Barrera-Oro and Piacentino, 2007; Casaux et al., 2003). *T. newnesi* spawns from March to April in the Ross Sea (Shust, 1987).

T. newnesi is a common species in the Pointe Géologie Archipelago in East Antarctica where large shoals have been observed by Remotely Operated Vehicles. It is less common offshore (Causse et al., 2011). Together with *Pagothenia borchgrevinki*, it constitutes the coastal cryopelagic fish community in this area. Larvae are known to be present in this area but are rarely collected (Koubbi et al., 2009). Some isolated individuals were also caught on the upper side of the Adélie Basin, just north of the archipelago (Koubbi et al., 2009).

The *sagittae*, the largest of the three pairs of otoliths, are widely used to describe age and growth in fish (Campana and Thorrold, 2001). Radtke et al. (1989) estimated the age of early life stage of *T. newnesi* of the Antarctic Peninsula population on 390 larvae and juveniles and only on 32 adults. The first year of *T. newnesi* was validated (Radtke et al., 1989). Age was determined by micro-

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increments with the daily periodicity because the annual growth rings were very difficult to analyse on these very small otoliths. The first year of *T. newnesi* was validated (Radtke et al., 1989). This paper presents the analysis of the growth of adult *T. newnesi* in coastal waters of Adélie Land.

2. Materials and methods

Fish were collected in Pierre Lejay Bay covering an area of 25 km^2 and around Pointe Géologie Archipelago where the French Scientific station Dumont d'Urville is located (66°40′S and 140°00′E). Fish were caught by lines through holes drilled in the ice during 2003, 2005, 2006 and 2009, in the coastal zone around the French Scientific station Dumont d'Urville mainly from August to November about depths from 20 to 40 m. For each fish, total (TL) and standard (SL) length (measured to the nearest millimetre), sex, macroscopic maturation stage and total weight (W ± 0.1 g) were recorded. Sagittal otolith pairs were removed from the cranium, cleaned by ultrasonic bath and stored in plastic tubes. The weight of both otoliths from left and right head sides of each specimen was measured from an electronic balance (Wo ± 0.0001 mg). The weight of both otoliths was used to check of a potential asymmetry between left and right otoliths. Only the right sagittal otolith was used for age estimation. Different techniques (whole otolith, burnt otolith, frontal and transverse sections) were used in order to gain the most precise evaluation of the fish age. The transverse sectioning technique was the most suitable technique for age determination, as it improves the detectability of slow growth areas. The otoliths were embedded in epoxy resin and transverse sections (TS) through the core (or *nucleus*), were made using a precision saw with a blade thickness of 0.3 mm. Finally, the TS were ground and polished on both sides until the core was visible (thickness of 0.21 mm). Under transmitted light, TS were examined using 50× magnification connected to a video camera and an image-analysis system (TNPC software, www.tnpc.fr). Growth rings were counted following the ventral otolith *radius* from the *nucleus* to the otolith edge (Ro ± mm). When viewed with transmitted light, alternating translucent and opaque bands were visible. It was assumed that one annular growth ring consisted of one opaque and one translucent band while allowing for the presence of many split increments. About one month after the first reading, all otoliths were drawn at random and read a second time by the same reader. This double reading of otoliths was carried out to measure the precision of ageing data. Precision is defined as the reproducibility of repeated measurements on a given otolith, whether or not measurements are accurate (Chilton and Beamish, 1982). Three common statistical measures were used to determine the amount of variation between the two sets of readings: coefficient of variation (CV), percent agreement (PA) within one year (± 1 yr) and absolute percent error (APE). CV and PA were proposed by Kimura and Lyons (1991). Beamish and Fournier (1981) suggested use of an average percent error (APE), which is dependent on the average age of the fish species investigated:

$$CVj(\%) = 100.\frac{\sqrt{\sum_{i=1}^{R}\frac{(X_{ij}-X_j)^2}{R-1}}}{x_j}$$

$$PA = \frac{\sum\left|n_{diff} \leq 1\right|}{n}$$

$$APEj(\%) = 100.\frac{1}{R}\sum_{i=1}^{R}\frac{|Xij + Xj|}{Xj}$$

Where R is the number of times each fish is aged, Xij the i(th) age determination of the j(th) fish, Xj is the mean age calculated for the j(th) fish, and n_{diff} is the difference in age determination between the first and second readings.

Variations of the relationship between age and morphometric parameters of otolith, according to the sex (S), were investigated with a complete Generalized Linear Model. The model was build taking into consideration that individual age depends on otolith shape parameters (continuous effect) and sex (factor):

$$Age \sim Ro + Wo + S + Ro{*}S + Wo{*}S$$

Total Length (TL)/Total Weight (W) regressions were calculated according to Ricker's (1975) formula expressed as:

$$W = a.TL^b$$

Where a and b are the constants of the regression. Growth rate (k), asymptotic length (TL_∞) and weight (W_∞) were estimated, from the Von Bertalanffy (1938) growth equation ($t_0 = 0$; Age where length or weight is equal zero, is 0):

$$TL_t = TL_\infty\left(1 - e^{-k(t)}\right)$$

$$W_t = W_\infty\left(1 - e^{-k(t)}\right)^b$$

Where TLt and Wt refer to length and weight at age t, respectively translucent. Three length/weight relationships of males, females and both sexes combined were fitted using linear regression after log transformation of the length and weight data. Analysis of covariance (ANCOVA) was used to estimate the differences between the fitted length/weight relationships for males and females.

Growth performance was estimated using the index of growth performance (φ′) (Pauly and Munro, 1984):

$$\varphi' = \log k + 2.\log TL_\infty$$

Likelihood Ratio Tests were used to compare the von Bertalanffy growth curves between sexes (Kimura, 1980). Moreover, in order to compare growth between sexes, the index of growth performance also was used, because the two parameters L_∞ and K are inversely correlated (Pauly, 2010).

Statistical analyses were conducted using the open-source statistical package “R” (R Core Team, 2015).

3. Results

Total and standard lengths ranged from 14.2 to 19.4 cm (mean 16.5 ± 2.2 cm) and 12.5–17.0 cm (mean 14.6 ± 2.0 cm) respectively. The TL-SL relationship (TL = 1.114.SL+0.272; N = 289) showed a statistically significant correlation of the two parameters (P = 0). Of the 289 fish analysed, 132 (45.7%) were male, 122 (42.2%) were female and 35 (12.1%) were immature. The TL of males ranged from 12.0 to 20.9 cm (mean 18.0 ± 2.0 cm), and their W from 24.1 to 144.1 g (mean 47.0 ± 24.0 g). The TL of females ranged from 13.5 to 25.0 cm (mean 18.0 ± 2.3 cm), and their W from 19.7 to 174 g (mean 62.0 ± 26.0 g). Females attained larger sizes than males (Fig. 1). All immature fishes were identified at size of 12.0–14.9 cm, and weights of 21.0–36.0 g. TL was correlated significantly with W ($W = 7.2.10^{-3}.TL^{3.13}$; $P < 2.2.10^{-16}$). The length–weight relationship (Fig. 1) showed a positive allometric growth, regardless of sex. The