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AGE AND GROWTH OF SPINY ICEFISH (*CHAENODRACO WILSONI* REGAN, 1914) OFF JOINVILLE–D'URVILLE ISLANDS (ANTARCTIC PENINSULA)

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Abstract

Age and growth of spiny icefish (*Chaenodraco wilsoni*) were investigated using counts of annual growth increments from sagittal otoliths. Samples were collected during research surveys by benthic trawl carried out off Joinville–D'Urville Islands (Antarctic Peninsula) in February–March 2006 and January 2007. A total of 218 specimens were selected for the study, consisting of 120 females and 98 males. The age of fish was estimated by counting annuli on transverse sections obtained by grinding and polishing whole otoliths embedded in epoxy resin in moulds. The precision of age estimates between readings was tested applying both the average percent error (APE) and the coefficient of variation (CV). Conversely, the accuracy of age estimates was not tested, so that present ageing data have to be considered with caution.

The estimated age range was 1–5 years for males and 1–4 years for females of *C. wilsoni*. Applying the von Bertalanffy (VB) growth function to the age–length data, a growth curve was obtained for each sex. The estimated values of VB growth parameters L_∞ (cm) and k were respectively 32.7 and 0.81 for females and 32.7 and 0.68 for males. Age-at-sexual maturity was estimated to be about 2 years for females and 2.5 years for males. Like other icefishes, *C. wilsoni* exhibited a high growth rate until it reached sexual maturity, although it had a much shorter life span. The part of the population of *C. wilsoni* caught in the study area consisted mainly of adult individuals between 1 and 3 years of age, with very few older fish.

Résumé

L'étude de l'âge et de la croissance de la grande-gueule épineuse (*Chaenodraco wilsoni*) a été réalisée à partir de comptages des stries d'accroissement annuel sur des otolithes (sagittae). Des échantillons ont été collectés au cours des campagnes de recherche menées au chalut benthique au large des îles Joinville–D'Urville (péninsule antarctique) en février–mars 2006 et janvier 2007. Un nombre total de 218 spécimens, dont 120 femelles et 98 mâles, ont été choisis pour l'étude. L'âge des poissons a été estimé en comptant les anneaux sur les coupes transversales obtenues par ponçage et lissage d'otolithes entiers placés dans des moules et inclus dans de la résine époxy. La précision des estimations d'âge entre les lectures a été mesurée en appliquant tant l'erreur moyenne de pourcentage (APE, pour *average percent error*) que le coefficient de variation (CV). En revanche, l'exactitude des estimations d'âge n'a pas été vérifiée ; c'est donc avec prudence qu'il faut considérer les présentes données d'âge.

L'intervalle d'âges estimé est 1–5 ans pour les mâles et 1–4 ans pour les femelles de *C. wilsoni*. Une courbe de croissance a été obtenue pour chaque sexe en appliquant la fonction de croissance de von Bertalanffy (VB) aux données âge–longueur. Les valeurs des paramètres de croissance de VB L_∞ (cm) et k sont respectivement estimées à 32,7 et 0,81 pour les femelles et 32,7 et 0,68 pour les mâles. Il est estimé que l'âge à la maturité sexuelle est d'environ 2 ans chez les femelles et 2,5 ans chez les mâles. Comme les autres poissons des glaces, *C. wilsoni* affiche un taux de croissance élevé jusqu'à ce qu'il atteigne la maturité sexuelle, mais sa durée de vie est beaucoup plus courte. La partie de la population de *C. wilsoni* capturée dans la zone d'étude était principalement constituée d'individus adultes de 1 à 3 ans d'âge et de très peu de poissons plus âgés.

Резюме

Было проведено изучение возраста и роста белокровки Вильсона (*Chaenodraco wilsoni*) с использованием подсчета годового прироста сагиттальных отолитов. Образцы были собраны во время исследовательских съемок, проводившихся с помощью бентических тралов у о-вов Жуанвиль–Дюрвиль (Антарктический п-ов) в феврале–марте 2006 г. и в январе 2007 г. Для исследования было отобрано 218 особей, включавших 120 самок и 98 самцов. Возраст рыбы определялся путем подсчета колец на поперечных срезах, полученных путем стачивания и шлифования целых отолитов, залитых в формах эпоксидной смолой. Точность определения возраста между считываниями определялась с помощью как средней процентной ошибки (APE), так и коэффициента вариации (CV). В отличие от этого, правильность оценок возраста не проверялась, так что к имеющимся данным по определению возраста следует относиться с осторожностью.

Оценочный диапазон возраста составлял 1–5 лет для самцов и 1–4 года для самок *C. wilsoni*. Кривая роста для каждого пола была получена путем применения к данным о возрасте–росте функции роста Берталанфи (VB). Рассчитанные значения параметров роста VB L_∞ (см) и k составляли соответственно 32.7 и 0.81 для самок и 32.7 и 0.68 для самцов. По оценке, возраст по достижении половозрелости составлял около 2 лет для самок и 2.5 лет для самцов. Как и другие белокровки, *C. wilsoni* отличается высокими темпами роста до достижения половозрелости, хотя и имеет намного меньшую продолжительность жизни. Доля популяции *C. wilsoni*, пойманная в изучаемом районе, состояла преимущественно из взрослых особей в возрасте от одного до трех лет при почти полном отсутствии рыбы более старших возрастов.

Resumen

Se estudió la edad y el crecimiento del draco espinudo (*Chaenodraco wilsoni*) mediante el recuento de los anillos de crecimiento anual en los otolitos sagita. Se recolectaron muestras durante las prospecciones de investigación del bentos con redes de arrastre realizadas frente al Archipiélago de Joinville–D'Urville (Península Antártica) en febrero–marzo de 2006 y en enero de 2007. Se seleccionó un total de 218 peces para el estudio, 120 hembras y 98 machos. La edad de los peces fue estimada contando los anillos en las secciones transversales obtenidas puliendo y lijando otolitos enteros incrustados en moldes de resina epoxi. La precisión de las estimaciones de la edad de distintas lecturas fue evaluada calculando el porcentaje promedio de error (APE) y el coeficiente de variación (CV). No obstante, no se evaluó la exactitud de las estimaciones de la edad, de modo que estos datos sobre la edad deben ser considerados con mucha prudencia.

Las edades estimadas fueron de 1–5 años para los machos y 1–4 años para las hembras de *C. wilsoni*. Se obtuvo una curva de crecimiento para cada sexo aplicando la función de crecimiento de von Bertalanffy (VB) a los datos edad–talla. Los valores estimados de los parámetros de crecimiento de VB (L_∞ (cm) y k) fueron 32.7 y 0.81 respectivamente para las hembras, y 32.7 y 0.68 para los machos. Se estimó que la edad de madurez sexual es aproximadamente 2 años para las hembras y 2.5 años para los machos. Al igual que otros dracos, *C. wilsoni* tiene una alta tasa de crecimiento hasta que alcanza la madurez sexual, pero es de vida más corta. La proporción de la población de *C. wilsoni* capturada en el área de estudio consistió en su mayor parte de peces adultos de 1 a 3 años de edad, y muy pocos peces de mayor edad.

Keywords: spiny icefish, age and growth, Antarctic Peninsula, CCAMLR

Introduction

The fishing grounds off Joinville–D'Urville Islands at the tip of the Antarctic Peninsula (CCAMLR Statistical Subarea 48.1) in the western Atlantic Ocean sector of the Southern Ocean were exploited commercially by trawling at irregular intervals from 1978/79 to 1988/89, before the area was closed by CCAMLR to any harvesting after the 1989/90 fishing season (Kock, 1992; Kock et al., 2004). Catch records from this area are incomplete (Kock et al., 2004). This area was covered by a complete survey for the first time in February–March 2006. This survey will be used subsequently as a baseline study for further monitoring of the development of fish stocks in the area (Jones and Kock, 2006). A second survey covering the area incompletely was conducted in early January 2007 and provided additional biological samples of the most abundant species (Kock et al., 2007).

Among the commercially exploited fish in the Subarea 48.1, the spiny icefish (*Chaenodraco wilsoni*) was the only target species typical of the high-Antarctic fish fauna (*sensu* Kock, 1992). The fishery on *C. wilsoni* was carried out off Joinville Island by Polish and East German vessels, yielding an overall catch of 14 450 tonnes in the two fishing seasons 1979–1981. Additional catches of this species, about 4 600 tonnes, were also reported from the Indian Ocean sector (CCAMLR Statistical Division 58.4.2), close to the Antarctic Continent (Kock, 1992).

Chaenodraco wilsoni, a member of the family Channichthyidae (white-blooded or icefish), has a widespread distribution on the Antarctic continental shelf from 200 m to 800 m depth. Post-larvae and juveniles, to the extent it is known, inhabit the upper 100 m of the water column (Iwami and Kock, 1990). Its northernmost distribution lies on the island shelves of the southern Scotia Arc (South Orkney and South Shetland Islands). Most biological data on *C. wilsoni* have been either collected during the research surveys off Joinville–D'Urville Islands in 2006 and 2007 or during Russian commercial fishing operations mainly in the Cosmonauts and Cooperation Seas in the vicinity of the Antarctic Continent (Divisions 58.4.1 and 58.4.2).

Like most other channichthyids, *C. wilsoni* spawn large eggs (4.0–4.9 mm). Gonad maturation is completed within a year (Herasymchuk and Trozenko, 1988; Kock et al., 2008). Spawning occurs in October–November in the Antarctic Peninsula and in November–December in the Cosmonauts Sea (Pshenichnov, 1988; Kock et al., 2008). After a relatively long incubation period (8–9 months) during which males guard eggs, *C. wilsoni* hatch from late austral winter (August–September) onwards (Kock et al., 2008). Post-larvae and early juveniles are abundant in pelagic waters from December to February off the Antarctic Peninsula (Kellermann and Kock, 1984; Slosarczyk, 1986) and from January to March in the Indian Ocean sector (Pakhomov and Shumatova, 1992), often closely associated with dense krill aggregation (Slosarczyk and Rembiszewski, 1982; Kellermann, 1986; Pakhomov and Pankratov, 1992).

Several studies dealt with feeding habits of *C. wilsoni*. With little variation between different seasons or sites, post-larvae and juveniles feed on krill (both *Euphausia superba* and close to the Antarctic Continent also *E. crystallorophias*) and to a small extent on other euphausiids and hyperiids (Kellermann, 1986; Hubold and Ekau, 1990; Pakhomov and Pankratov, 1992). As adults, *C. wilsoni* feed primarily on krill and to a small extent on fish, especially the Antarctic silverfish (*Pleuragramma antarcticum*) and fish larvae (Gubsch, 1982; Takahashi and Nemoto, 1984; Takahashi and Iwami, 1997; Pakhomov and Tseitlin, 1992; Pakhomov and Shumatova, 1992).

Age and growth of *C. wilsoni* are poorly understood. The few available data are almost exclusively based on the analysis of length-frequency distributions, often restricted to 1-year-old juveniles (Kock et al., 2008). Ageing of larger *C. wilsoni* was so far restricted to individuals collected by the commercial fishery during the fishing seasons 1979–1981 (Cielniaszek, 1981) and still requires validation.

In this study, new data on age and growth rate derived from otoliths of *C. wilsoni* collected off Joinville–D'Urville Islands in 2006 and 2007 are reported. The reliability of the ageing procedure was tested by evaluating the precision of readings. Results were compared to previous age readings from 1979 to 1981.

Material and methods

Samples of *C. wilsoni* were collected during the US-AMLR cruise on RV *Yuzhmorgeologiya* in February–March 2006 and during the ANTXXIII/8 cruise of RV *Polarstern* in January 2007. Both cruises surveyed the area located on the continental shelf off Joinville–D'Urville Islands at the tip of the Antarctic Peninsula. The location of fishing stations is provided in Figure 1. Sampling was carried out using a commercially sized four-panel HBST trawl (2006) and a two panel 140' BT (2007) with a codend mesh size of 40 mm deployed down to 500 m depth. The survey was based on a stratified random sampling design (Jones and Kock, 2006;

Kock et al., 2007). As a rule, the net was generally towed at about 3–3.5 knots for 30 min on the bottom during daylight hours.

Each individual of *C. wilsoni* caught was measured to the nearest cm below (total length, TL), weighed in g (total weight, TW) and sexed. Gonad maturity was assessed macroscopically, using the five-points scale commonly in use in CCAMLR waters (Everson, 1977; Kock and Kellermann, 1991). Size-frequency distributions of males and females were compared using the two-sample Kolmogorov-Smirnov test (Sokal and Rohlf, 1995). Both sagittal otoliths were removed from each individual, cleaned and stored dry in numbered vials.

The weight of each otolith pair was recorded with an accuracy of 0.1 mg and compared using a *t*-test for paired comparisons (Sokal and Rohlf, 1995). As no statistically significant difference was found between the weight of left and right otoliths ($df = 184$, $t = 1.46$, $P > 0.1$), right otoliths were arbitrarily selected to measure their maximum length (O_L, 0.01 mm) and height (O_H, 0.01 mm) under a stereomicroscope linked to a CCD videocamera. All measures were conducted using image analysis software (Image-Pro Plus, Ver. 4.5.1, Media Cybernetics). The relationship between fish size (TL) and otolith size (O_L and O_H) was estimated applying linear regression analysis on log10-transformed data, in order to correct for nonlinearity and heterogeneity of variances.

As is common in icefish (La Mesa et al., 2004; La Mesa and Ashford, 2008), sagittal otoliths of *C. wilsoni* were relatively small and opaque with a dense calcareous matrix, requiring sectioning and grinding techniques to reveal the ring pattern. One otolith was randomly selected from each individual and embedded in epoxy resin. The otolith was then ground using decreasing grit abrasive papers and finally polished on lapping films with 0.05 micron alumina to obtain transverse sections without scratches. Otolith sections were then immersed in water to enhance the contrast between neighbouring zones and observed under reflected light at x25–40 magnification.

Using reflected light, the nucleus and the opaque zones appeared as light rings and the translucent zones as dark rings (Figure 2). As generally reported in notothenioids (Everson, 1980), each pair of opaque and subsequent translucent zones was considered to form an annulus. The count path showing the most unambiguous annulation pattern was generally found from the core towards the proximal-ventral side of the otolith section. As a rule, rings that did not persist far to either side of the count path were considered as false checks and not counted. Commonly, annuli were formed by wide opaque zones and very narrow translucent zones.

Assuming hatching from late austral winter onwards (August–early September), 1 September was considered as the birthdate of the species. It is assumed that the opaque nucleus was deposited in the course of the first summer after hatching, followed by the first translucent zone laid down in the following winter just prior to the first birthday. Assuming that annuli were laid down annually, the age of fish was estimated by counting all translucent zones plus five to six months (indicated as 1+, 2+ etc.), as all individuals were collected between January and March.

Overall, three readings were preliminarily made by one of the authors (La Mesa), without any ancillary data on fish (blind readings). When readings differed from each other by more than one year, a fourth reading was carried out. When the difference remained, the otolith section was discarded. To estimate the reproducibility of age estimates (or ageing precision) (Campana, 2001), the index of average percent error (APE) (Beamish and Fournier, 1981) and the mean coefficient of variation (CV) (Chang, 1982) were calculated comparing each reading to the others. Unfortunately, the short sampling period and the lack of juveniles did not allow testing of the accuracy (i.e. age validation) of age estimates through marginal increment analysis or daily increment counts, so that present ageing data should be considered with some uncertainty.

The von Bertalanffy growth function was fitted to the estimated age–length data set using the program FISHPARM of the statistical package FSAS (Saila et al., 1988), applying the Marquardt algorithm for non-linear least squares parameter estimation. The von Bertalanffy growth parameters (L_∞(cm), k and t_0(years)) were calculated for each sex and for the whole sample. Growth curve parameters for males and females were then compared by the likelihood ratio test (Kimura, 1980), using the full age–length dataset rather than the mean length-at-age (Haddon, 2001). The growth performance index ($\Phi' = 2 \log L_\infty + \log k$) (Munro and Pauly, 1983) was calculated to compare the growth of *C. wilsoni* with other channichthyids.

Gonad maturity of fish was used to estimate the age at which 50% of the population reaches sexual maturity (A_{50}). For each sex, the proportion-at-age (P) of fish in gonad maturity stages 2–5 was fitted to the following logistic equation (Ni and Sandeman, 1984):

$$P = \{1 + e^{-(\alpha + \beta A)}\}^{-1}$$

where A is the estimated age (years) and α and β are coefficients. Applying a ln-transformation to both terms of the equation, the coefficient values are derived by the following linearised equation:

$$\ln P\,(1 - P)^{-1} = \alpha + \beta A$$

where α is the intercept and β the slope. Hence, setting $P = 0.5$ in the equation, A_{50} is estimated as the negative ratio of coefficients ($-\alpha\beta^{-1}$).

Results

Length-frequency distribution

Overall, 218 specimens of *C. wilsoni* were selected for the study, consisting of 61 females and 44 males collected in February–March 2006 and 59 females and 54 males collected in January 2007. Applying the chi-square test for goodness of fit, the sex ratio did not differ significantly from 1:1 in both sampling periods ($\chi^2 = 0.22$, $df = 1$, $P > 0.5$; $\chi^2 = 2.75$, $df = 1$, $P > 0.05$). The length-frequency distribution of each sex in both periods is shown in Figure 3. Comparing the length-frequency distributions of fish sampled in the two periods, any comparison (males, females and whole sample) differed significantly from each other (Kolmogorov-Smirnov test, $P < 0.01$). Length-frequency distributions of males and females within each sampling period did not show any significant difference (Kolmogorov-Smirnov test, $P > 0.05$). In March 2006, the fish sample consisted almost exclusively of individuals larger than 25 cm TL, with an apparent mode at 28 cm TL (Figure 3a). In January 2007, the fish sample was largely dominated by a strong peak at 26 cm TL, with two other well-defined modes at 20 and 30 cm TL (Figure 3b). Pooled samples consisted of 120 females from 19–34 cm TL and 40–332 g and 98 males from 18–35 cm TL and 39–336 g.

Otolith size and morphology

The morphology of the sagittal otolith of *C. wilsoni* is characterised by a dorso-ventrally oval shape, being greater in height than in length (Figure 4), the prominent rounded rostrum, pseudo-rostrum and pseudo-antirostrum and the clearly defined excisura ostii and pseudo-excisura ostii (Hecht, 1987). The maximum otolith length (O_L) and height (O_H) ranged from 2.09 to 3.72 mm and from 1.96 to 3.55 mm respectively. Relationships between O_L and O_H (mm) and fish size (TL, cm) was described by the following equations:

$$\mathrm{TL} = 10.92\, O_L^{0.85} \quad n = 198 \quad r^2 = 0.73$$
$$\mathrm{TL} = 9.81\, O_H^{0.98} \quad n = 198 \quad r^2 = 0.84.$$

Otolith maximum length (O_L) was negatively allometric ($b = 0.85$, SE = 0.037), being significantly different from unity (t-test for allometry, $t = 3.94$, $P < 0.001$). Conversely, the slope of the relationship between fish size and otolith height ($b = 0.98$, SE = 0.030) was not significantly different from unity ($t = 0.43$, $P > 0.5$), indicating an isometric growth between the two parameters.

Age and growth

Overall, 210 individuals of *C. wilsoni*, 117 females and 93 males respectively, were successfully aged. Only eight otoliths (3.7%) were discarded because they were unreadable. Based on the assumption that annuli are laid down on an annual basis, the age composition of the sample of *C. wilsoni* is summarised in age–length keys reported for each sex (Table 1). Age estimates ranged between 1–4 years for females and 1–5 years for males. However, the sample consisted almost exclusively of 1–3 year-old fish, representing approximately 97% of the individuals aged.

The analysis of age precision was carried out by comparing each reading with the other two. In any comparison, counting variability indices APE and CV were both rather low (Table 2), with a relatively high percentage agreement between readings (61–72%). In turn, the good consistency or reproducibility among readings indicated the reliability of the ageing procedure adopted.

The von Bertalanffy (VB) growth parameters fitted to the age–length dataset were estimated for each sex separately and for the whole sample (Figure 5). The VB growth parameters and the derived growth performance index (Φ') are reported in Table 3. Applying the likelihood ratio test to the estimated VB growth parameters, no significant difference was found between sexes ($P > 0.5$ in any comparison), except if all parameters were pooled ($P < 0.001$) (Table 4). The index of growth performance Φ' was similar between sexes (Table 4). On the other hand, statistical difference in length-at-age data (Table 5) were observed between sexes (t-test for paired comparison; $t = 3.60$; $df = 3$, $P < 0.05$) as a consequence of the aforementioned differences between growth curves. The annual growth rate ranged from 1.9 to 9.8 cm in females and from 1.2 to 8.8 cm in males (Table 5), at least in the estimated age range. Both sexes of *C. wilsoni* showed a rapid growth during the first two years of life. The annual growth started to decline when sexual maturity was attained.

Finally, the proportion of maturing fish in relation to the estimated age for each sex is reported in

Table 1: Age–length key for *Chaenodraco wilsoni* from Joinville–D'Urville Islands.

TL (cm)	Age (years)								
	Females				Males				
	1	2	3	4	1	2	3	4	5
18					1				
19	2				2				
20	2				4				
21	2				2				
22	1								
23		1							
24		2				3			
25	1	7				9			
26		18				20	2		
27		12	1			9	6		
28		5	8			7	1		
29		7	4			4	7		
30		8	6			1	2	1	
31		7	9				8	1	
32		2	5				1	1	
33		1	3	1					
34				2					
35									1
n	8	70	36	3	9	53	27	3	1

Table 2: Index of average percent error (APE) and mean coefficient of variation (CV) between age readings; *n* is the number of pairwise age estimates.

Indices	Age readings		
	1–2	1–3	2–3
CV	8.9	10.8	8.5
APE	6.3	7.7	6.0
n	176	111	126

Table 3: von Bertalanffy growth parameters L_∞ (cm), k and t_0 (years) estimated for *Chaenodraco wilsoni* collected off the Joinville–D'Urville Islands. Φ′ = growth performance index; Ase = asymptotic standard error; CV = coefficient of variation.

	Males			Females			Whole sample		
	Value	Ase	CV	Value	Ase	CV	Value	Ase	CV
L_∞	32.78	1.18	0.03	32.74	1.21	0.04	32.55	0.85	0.03
k	0.68	0.12	0.18	0.81	0.18	0.23	0.78	0.12	0.15
t_0	0.11	0.22	2.08	0.24	0.27	1.11	0.23	0.17	0.74
Φ′	2.86			2.94			2.92		

Table 4: Likelihood ratio tests comparing von Bertalanffy parameter estimates for both sexes of *Chaenodraco wilsoni*. Statistics are based on seven null hypotheses, assuming that each parameter or a combination of them do not differ between sexes. RSS = residual sum of squares; *df* = degree of freedom; *significant at α = 0.05; ** significant at α = 0.01; ns = not significant.

	Males			Females			RSS	χ^2	*df*	*P*
Parameter:	L_∞	k	t_0	L_∞	k	t_0				
Hypothesis										
Independent	32.78	0.68	0.11	32.74	0.81	0.24	714.85			
H_0: = L_∞; = k; = t_0	32.55	0.78	0.23	32.55	0.78	0.23	782.72	19.04	3	**
H_0: = L_∞	32.75	0.68	0.11	32.75	0.81	0.24	714.86	0.001	1	ns
H_0: = k	32.22	0.74	0.21	32.21	0.74	0.13	715.99	0.33	1	ns
H_0: = t_0	32.47	0.71	0.17	32.98	0.77	0.17	715.28	0.12	1	ns
H_0: = L_∞; = k	33.19	0.69	0.20	33.19	0.69	–0.05	725.04	2.97	2	ns
H_0: = L_∞; = t_0	32.84	0.69	0.16	32.84	0.78	0.16	716.04	0.35	2	ns
H_0: = k; = t_0	32.01	0.75	0.18	33.34	0.75	0.18	717.56	0.79	2	ns

Table 5: Fish length-at-age of *Chaenodraco wilsoni* derived from the von Bertalanffy equations. Annual growth rates are calculated by difference of fish length between two subsequent years.

Estimated age (years)	Females		Males	
	Fish length (cm)	Annual growth (cm)	Fish length (cm)	Annual growth (cm)
1	15.1		14.9	
2	24.9	9.8	23.7	8.8
3	29.3	4.4	28.1	4.4
4	31.2	1.9	30.4	2.3
5			31.6	1.2

Figure 6. Fitting the logistic curves to the dataset, the age at which 50% of the population reached sexual maturity (A_{50}) was roughly 2 and 2.5 years for females and males respectively.

Discussion

The length composition was generally unimodal or bimodal, consisting mostly of fish 20–35 cm TL. Smaller fish have been sporadically taken, such as in February–March 1980 along the southwestern Antarctic Peninsula (Gubsch, 1982) and more recently off Joinville–D’Urville Islands (Kock et al., 2007). Length compositions of *C. wilsoni* off Joinville–D’Urville Islands changed little in more than 25 years between the turn of the 1980s and 2006–2007 (Cielniaszek, 1981; Gubsch, 1982; Kock et al., 2004, 2007; Jones and Kock, 2006). Abundance of *C. wilsoni*, however, varied remarkably with large interannual variation. It is likely that only part of the commercial catch taken from the late 1970s to the late 1980s has been reported (Cielniaszek, 1981; Gubsch, 1982; Shust, 1998). Unfortunately, the lack of juveniles in trawling catches and the limited sampling period did not allow determination of the timing of formation of the first annulus and the periodicity of deposition of subsequent annuli.

From an ecological perspective, *C. wilsoni* closely resembled life strategies exhibited by other icefish. Like other channichthyids (Kock and Kellermann, 1991; Duhamel et al., 1993; Vacchi et al., 1996; Detrich et al., 2005; Kock, 2005; Kock et al., 2006), *C. wilsoni* spend a considerable amount of energy per year on activities related to spawning, producing few large yolky eggs which are deposited on the sea floor and guarded by males for a long period (Herasymchuk and Trozenko, 1988; Kock et al., 2008). Similar to other icefish species, such as mackerel icefish (*Champsocephalus gunnari*), juvenile blackfin icefish (*Chaenocephalus aceratus*), Jonah’s icefish (*Neopagetopsis ionah*) and South Georgia icefish (*Pseudochaenichthys georgianus*) (Kock, 2005), *C. wilsoni* undertake regular diurnal migrations to feed in the water column on krill and, to a small extent, on fish (Gubsch, 1982; Takahashi and Nemoto, 1984; Takahashi and Iwami, 1997; Pakhomov and Tseitlin, 1992; Pakhomov and Shumatova, 1992).

During commercial fisheries, the age of *C. wilsoni* was determined for 287 specimens from Polish catches off Joinville–D'Urville Islands (Cielniaszek, 1981). In 1979, the stock consisted mainly of 2- and 3-year-old fish, with some fish aged 4 years and few fish aged 5 years. Similarly, in 1980 most fish belonged to age classes 3 and 4, with very few fish aged 2 and 5 years (Cielniaszek, 1981). This appears to be in good agreement with further information provided by Herasymchuk and Trozenko (1988) from the Cosmonauts Sea and by Slosarczyk (1987) from the Bransfield Strait, as well as with the present data from Joinville–D'Urville Islands. In comparison with previous studies, the step forward of this study was to test for the first time the precision of age estimates (and thus the reliability of ageing methodology). In addition, by adding a new species to the few channichthyids aged so far, the study provides encouraging evidence in ageing icefish by means of otolith reading.

Growth rates of juvenile *C. wilsoni* seem to be in line with other icefish in that they grow fast while juvenile (Gubsch, 1982; Chojnacki and Palczewski, 1981; Kompowski, 1990; Vacchi et al., 1992; Morales-Nin et al., 2000; La Mesa and Vacchi, 2001; La Mesa et al., 2004; Kock, 2005; La Mesa and Ashford, 2008). Growth slows down considerably when fish attain spawning maturity and a considerable amount of energy has to be invested in spawning and parental care (in males). The early age of sexual maturity and low longevity, however, are different to most other icefish species, which generally attain a maximum age between 15 and 18 years of age (Kock, 2005). It is, however, comparable to *C. gunnari* in the northern part of its range (Duhamel, 1991; Williams et al., 2001), in that fish attain sexual maturity at an early age and longevity appears to hardly exceed 6–7 years (Kock and Everson, 2003).

Based on logistic curves fitted to age and gonad maturity datasets, females and males of *C. wilsoni* would attain sexual maturity at about 2 and 2.5 years respectively. Derived from the length-at-age data, the length-at-sexual-maturity was estimated to be approximately 24.6 cm TL for females and 26.2 cm TL for males, which agrees with results reported for this species in the same area (Kock et al., 2008). If gonad maturation in *C. wilsoni* is completed within a year (Kock et al., 2008), as previously reported also in *C. gunnari* and *P. georgianus* (Everson et al., 1996), it can be assumed that *C. wilsoni* would spawn for the first time at about 3–3.5 years of age.

Conclusion

In conclusion, *C. wilsoni* closely resembles the low-Antarctic icefish *C. gunnari* in some of its major biological characteristics, such as maximum size and shape, longevity and feeding habits. Hence, *C. wilsoni* might be considered as an ecological vicariant species of *C. gunnari* in the high-Antarctic zone.

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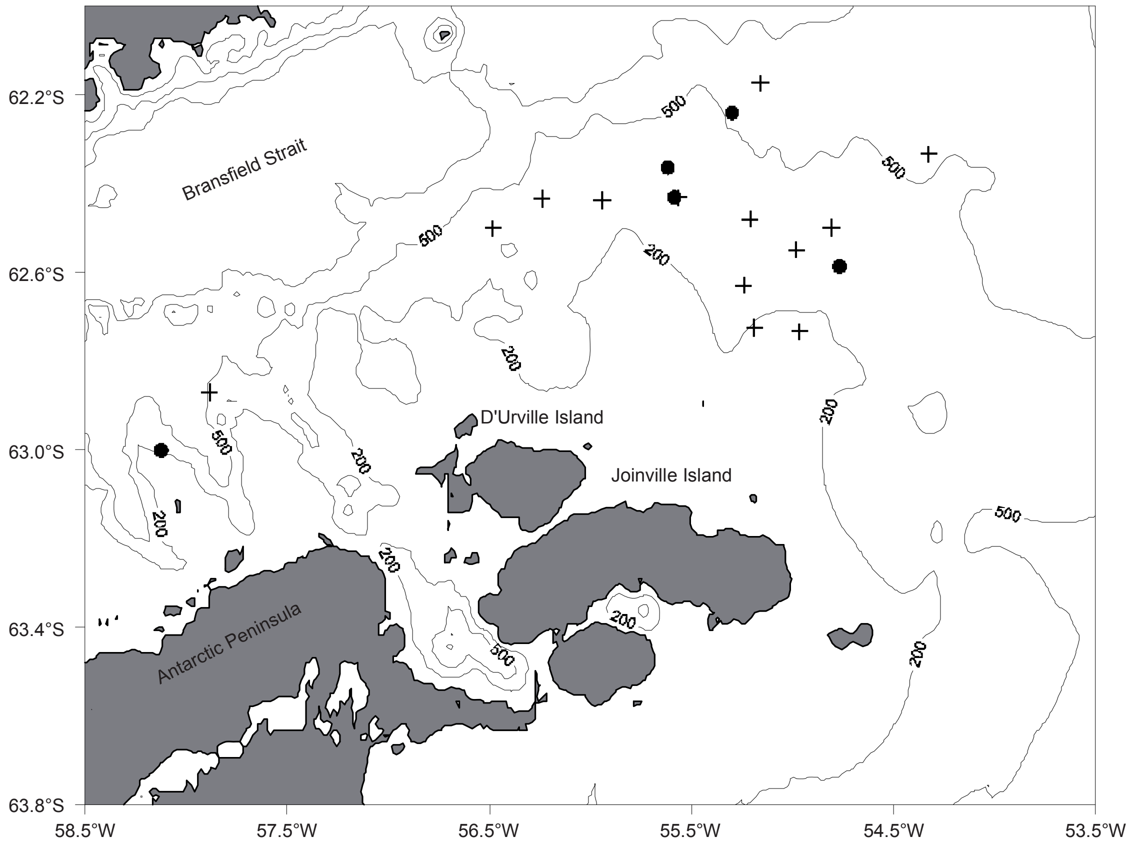


Figure 1: Study area showing sampling stations of *Chaenodraco wilsoni* off Joinville–D'Urville Islands in February–March 2006 (+) and January 2007 (•).

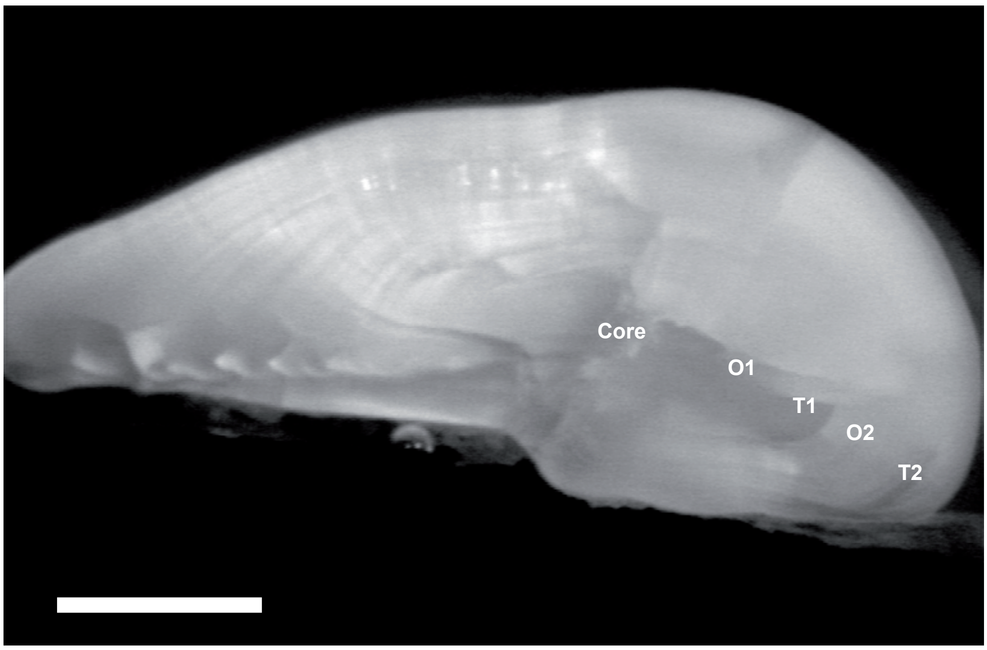
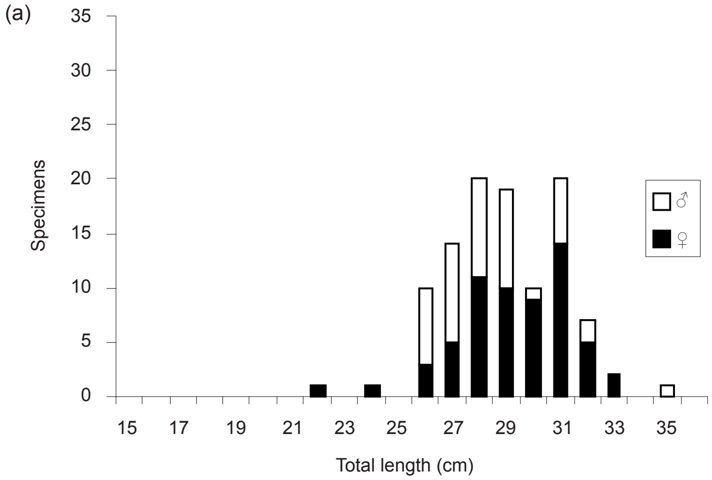


Figure 2: Transverse section of sagittal otoliths of *Chaenodraco wilsoni*, showing the pattern of opaque (O) and translucent zones (T) surrounding the core. Scale bar = 1 mm.



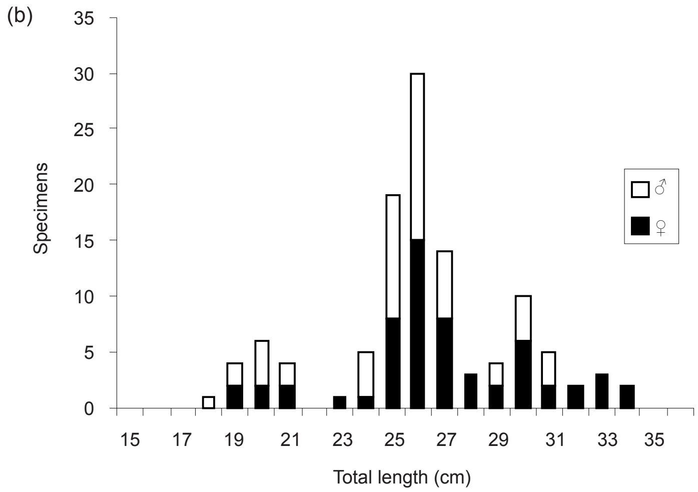


Figure 3: Length-frequency distribution of *Chaenodraco wilsoni* collected off Joinville–D'Urville Islands in February–March 2006 (a) and January 2007 (b).

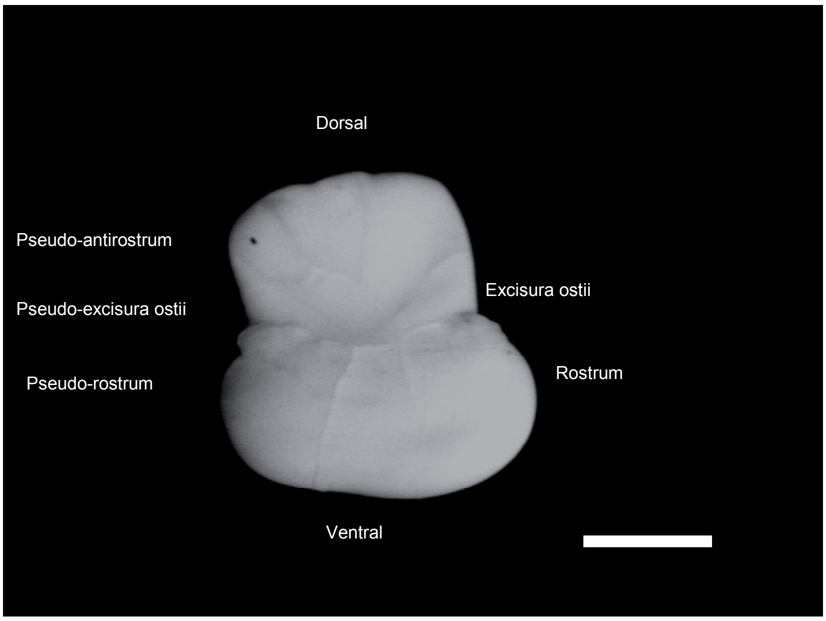


Figure 4: Proximal side of left sagittal otolith of *Chaenodraco wilsoni* male 26 cm TL collected off Joinville–D'Urville Islands. Scale bar = 1 mm.

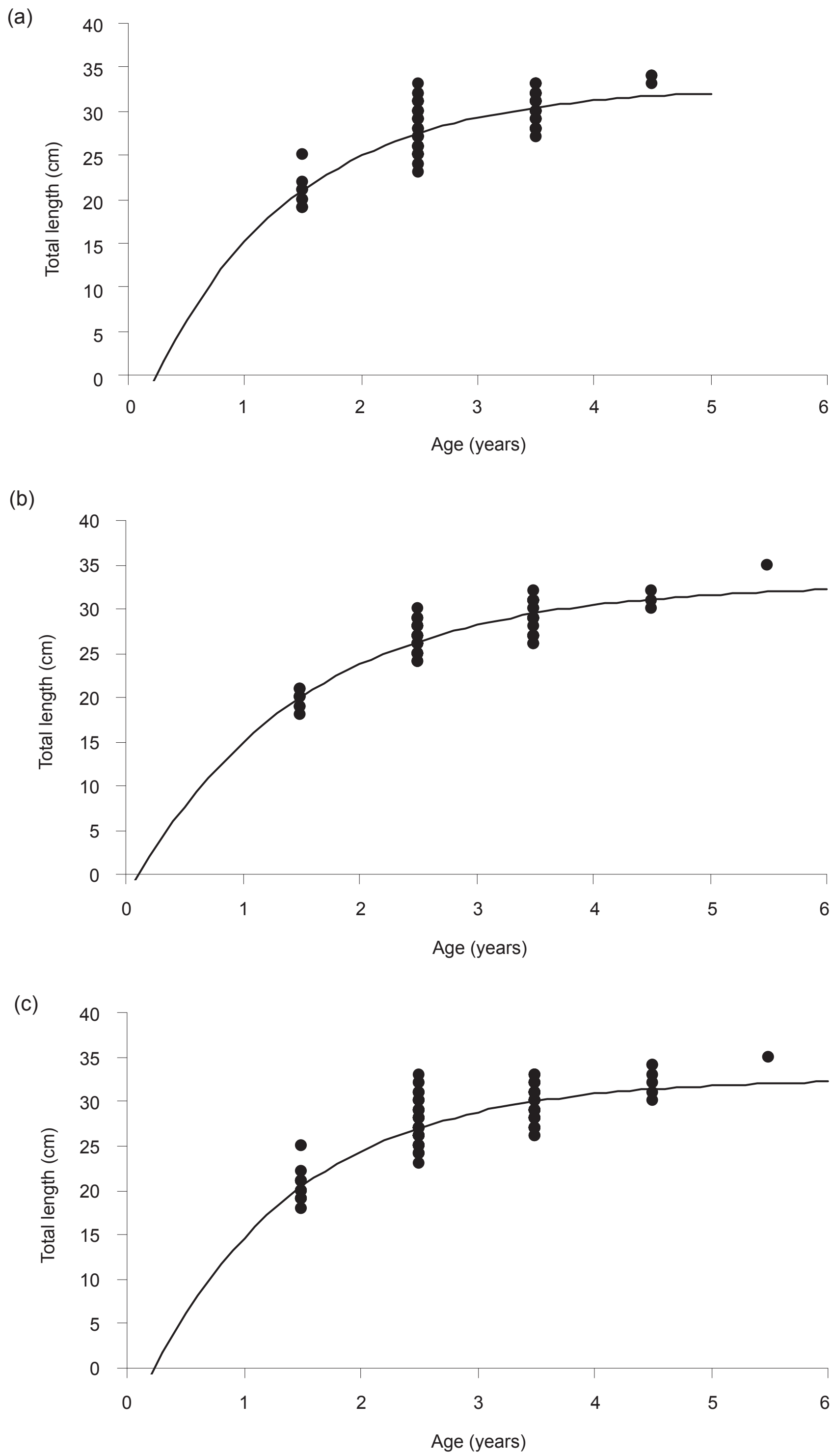
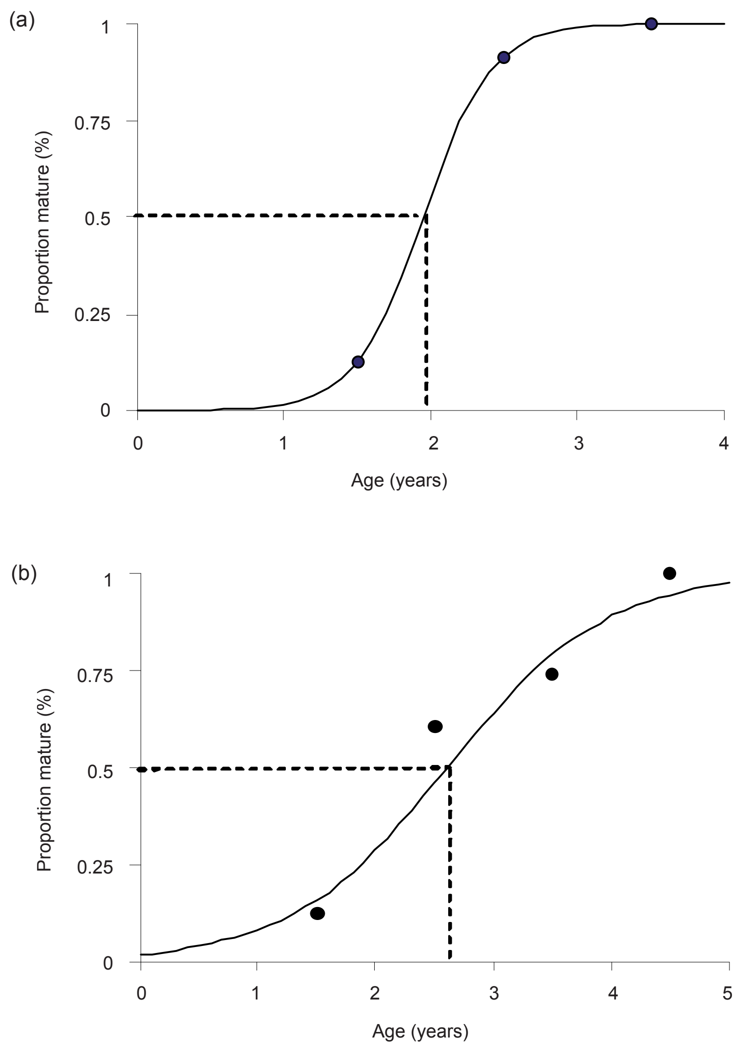


Figure 5: von Bertalanffy growth curves fitted to age–length data pairs for *Chaenodraco wilsoni* females (a), males (b) and whole population (c).



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