UNIVERSIDADE FEDERAL DO RIO GRANDE - FURG

INSTITUTO DE OCEANOGRAFIA

PROGRAMA DE PÓS-GRADUAÇÃO EM OCEANOGRAFIA BIOLÓGICA

História de vida e avaliação dos impactos da pesca sobre a espécie *Dules auriga* (Teleostei: Serranidae), componente da captura incidental no Sul do Brasil.

AMANDA TOMAZELE ROVANI

Dissertação apresentada ao Programa de Pós-graduação em Oceanografia Biológica da Universidade Federal do Rio Grande, como requisito parcial à obtenção do título de MESTRE.

Orientador: Prof. Dr. Luís Gustavo Cardoso

RIO GRANDE

Fevereiro de 2017

"A mente que se abre a uma nova ideia jamais volta ao seu tamanho original".

Albert Einstein

"Aqueles que passam por nós não vão sós, não nos deixam sós. Deixam um pouco de si, levam um pouco de nós".

Antoine de Saint-Exupéry

AGRADECIMENTOS

À FURG e ao PPGOB por terem me acolhido como aluna nesses dois anos e a Capes pela concessão da bolsa de mestrado.

Aos membros da banca, Prof. Dr.ª Beatrice Padovani, Prof. Dr. Jorge Castello e Prof. Dr. Manuel Haimovici por contribuírem de forma valiosa com o manuscrito.

Ao meu orientador, Prof. Dr. Luis Gustavo, por se fazer presente e não medir esforços para nos auxiliar, pela amizade e aprendizado transmitido nessa jornada.

Aos colegas do laboratório de Recursos Pesqueiros Demersais e Cefalópodes pela colaboração no desenvolvimento do trabalho.

À minha família por ser alicerce e fonte inesgotável de amor. Obrigada por me apoiarem a cada passo, sem vocês eu nada seria.

Ao Estevan por seu amor, carinho, apoio e muita paciência.

Aos “Desnecessauros”, “Xerecas”, “Winter is coming”, “BFF” e demais amigos por serem a extensão da minha família, por recarregarem as minhas energias e pela vivência de momentos inesquecíveis.

.

ÍNDICE

RESUMO

Dules auriga, um pequeno peixe serranídeo, habita águas profundas e é um componente frequente na captura descartada do arrasto de fundo no sul do Brasil. Para avaliar a vulnerabilidade desta espécie em relação ao nível atual de pesca, foram estudados seu crescimento e sua reprodução. Desta maneira, foram realizadas amostragens ao longo do ano, que incluíram indivíduos para determinar a maturidade sexual e a idade, a qual foi validada pelo tipo de borda e análise de incremento marginal dos otólitos. Verificou-se que os indivíduos mais velhos e maiores tinham 9 anos e 195 mm de comprimento total, atingindo a idade e comprimento de maturação aos 2 anos e aos 140,72 mm, respectivamente. Os parâmetros de crescimento ajustados à equação de von Bertalanffy foram L_∞=178,34 mm, k=0,641 ano-1 e t_0=-0,341 anos. O período reprodutivo se estendeu ao longo da primavera e do verão austral. Uma avaliação dos impactos da pesca foi feita baseada na comparação de uma composição hipotética de tamanho inexplorada e as composições de tamanho atual. Isto levou à conclusão de que a remoção da biomassa pela pesca pode ter resultado em uma perda de 50% do potencial de desova da população. O rápido crescimento, a longevidade moderada, o longo período reprodutivo, o tamanho pequeno e a idade de maturação tornam *D. auriga* uma espécie relativamente resistente à remoção de biomassa pela pesca. No entanto, a perda de potencial de desova pode reduzir a capacidade de armazenamento frente a variações climáticas.

PALAVRAS-CHAVE

Captura incidental; Serranídeo; Sul do Brasil; Estoque com dados limitados.

ABSTRACT

Dules auriga, a small serranid fish, inhabits deep waters and is a frequent component of the discharged catch of the bottom trawling of southern Brazil. To assess the vulnerability of this species to the current level of fishing, its growth and reproduction were studied. In this way, sampling was conducted throughout the year to determine the sexual maturity and age of the individuals, which was validated by the edge type and marginal increment analysis of otoliths. It was verified that the oldest and largest individuals were 9 years old and 195 mm of total length, reaching age and length at first maturation at 2 years and 140.72 mm, respectively. Growth parameters fitted to von Bertalanffy equation were L_{∞}=178.34 mm, k=0.641 year^{-1} and t_0=−0.341 years. Reproductive season extended along the austral spring and summer. An assessment of the fishing impacts was based on the comparison of a hypothetical unexploited size composition and the current size compositions. An evaluation of the impacts of fishing was made based on the comparison of a hypothetical composition of unexplored size and compositions of current size. This led to the conclusion that the removal of the biomass by fishing may have resulted in a loss of 50% of the spawning potential of the population. Fast growth, moderate longevity, long spawning season, small size and age at maturity make *D. auriga* relatively resilient to the removal of biomass by fishing. However, the loss of spawning potential can reduce the capacity of storage in front of climatic variations.

KEY WORDS

Bycatch; Serranidae; Southern Brazil, Data poor stock.

INTRODUÇÃO

Atualmente, os esforços de monitoramento e gestão das espécies de peixes exploradas centram-se principalmente nas espécies importantes comercialmente. As espécies não-alvo recebem baixa prioridade nas pesquisas e, por isso, pouco se sabe sobre suas histórias de vida (Pope *et al.*, 2000). Como elas também estão expostas à mortalidade por pesca através da captura acessória (Cheung *et al.*, 2005), é importante conhecer suas histórias de vida para avaliar o impacto da pesca nessas populações, uma vez elas determinam as respostas das populações à explotação pesqueira (Adams, 1980, Kirkwood *et al.*, 1994, Pope *et al.*, 2000). Em geral, espécies com história de vida rápida, isto é, com baixa idade de maturação e rápido crescimento corporal, suportam uma mortalidade por pesca mais elevada do que as espécies com história de vida lenta (Reynolds *et al.*, 2001). Portanto, os parâmetros da história de vida podem ser usados para identificar as espécies que devem ser prioritárias nos estudos pesqueiros (Reynolds *et al.*, 2001; Cheung *et al.*, 2005).

O pequeno serranídeo demersal *Dules auriga* (Cuvier, 1829) habita fundos arenosos e consolidados na plataforma continental do Atlântico Sudoeste. A espécie pode ser encontrada entre o estado do Rio de Janeiro (Brasil) e a Argentina, em profundidades que variam de 15 a 140 m (Fischer *et al.*, 2011). Sua presença é relativamente comum em capturas de arrasto de fundo nas águas costeiras da Argentina, do Uruguai e do sul do Brasil (Militelli & Rodrigues, 2011). Apesar da sua frequência nas capturas, os indivíduos de *D. auriga* são descartados ao mar após a seleção a bordo, uma vez que a espécie não possui valor econômico. Aqueles acidentalmente desembarcados são destinados à produção de farinha de peixe (Militelli & Rodrigues, 2011).

Pouco se sabe sobre a história de vida de *D. auriga*. Cussac & Molero (1987) observaram que a espécie se alimenta principalmente de crustáceos e a classifica como um hermafrodita simultâneo. As gônadas masculinas e femininas estão presentes no mesmo indivíduo, o que foi confirmado posteriormente por exames histológicos de Militelli & Rodrigues (2011). Chaves (1989) relatou a presença de gônadas funcionais, com porções testiculares agregadas aos ovários em indivíduos sexualmente maduros e imaturos.

A maioria das pescarias ao redor do mundo é limitada em termos de dados, pois carecem de dados e/ou recursos para gerar estimativas estatísticas do estado do estoque (Dowling *et al.*, 2016). No entanto, a pobreza de dados não deve ser usada como desculpa para deixar de avaliar o status dos estoques, o qual é um passo fundamental para desenvolver qualquer estratégia de manejo (Dowling *et al.*, 2016). Atualmente, existem diversas opções para avaliar estoques com limitação de dados, ou seja, modelos com distintos níveis de requisitos de dados (Dowling *et al.*, 2016). Uma delas utiliza informações de história de vida para construir uma composição hipotética de tamanho inexplorado e a compara com a composição de tamanho atualizada do estoque (Hordyk *et al.*, 2015 a, b). Esta abordagem pode permitir a identificação da taxa de potencial de desova (do inglês "Spawning potential ratio – SPR") que permanece na população (Hordyk *et al.*, 2015 a, b).

Como *D. auriga* é descartado a bordo, na maioria das vezes, e o seu desembarque não é registrado, conhecer a sua história de vida pode contribuir para uma melhor compreensão sobre o impacto da pesca sobre a sua população. Neste contexto, o presente estudo teve como objetivo fornecer informações sobre a dinâmica populacional de *D. auriga* e avaliar o impacto da pesca sobre a sua taxa de potencial de desova

(SPR). Para tanto, a idade foi determinada por meio da análise de seções de otólitos e parâmetros de história de vida sobre a reprodução e crescimento foram estimados.

MATERIAL E MÉTODOS

Indivíduos foram coletados mensalmente, entre setembro de 2014 a abril de 2016, nos desembarques comerciais de arrasteiros de fundo que operam na plataforma continental do sul do Brasil (28º 36' 14"S e 33º 44' 39"S) em profundidades que variam de 9 a 130 m (Figura 1, apêndice).

As amostragens compreenderam medidas do comprimento total (mm), peso total (g) e o peso da gônada (g) de cada indivíduo. Além disso, o par de otólitos *sagittae* foi removido para se estimar as idades.

Seções finas de cada otólito foram examinadas com luz refletida sob um fundo preto em microscópio estereoscópico binocular. Imagens foram digitalizadas, sob as quais as bandas opacas foram contadas, as distâncias entre o núcleo e o final de cada banda opaca e entre o núcleo e a borda foram medidas e o tipo de borda registrado (Figura 2, apêndice). O número de bandas opacas foi contado independentemente por dois leitores e uma terceira leitura conjunta foi realizada. Nos casos de desacordo, as leituras foram descartadas. O coeficiente médio de variação foi usado para avaliar a precisão na estimativa de idade entre as leituras de acordo com Campana & Jones (1992).

O tipo de borda e a análise de incremento marginal (AIM) foram usados para avaliar a periodicidade de formação das bandas opacas e translúcidas nos otólitos. A frequência relativa (%) de cada tipo de borda foi plotada mensalmente para corroborar a AIM.

O modelo de von Bertalanffy foi ajustado por meio de uma abordagem Bayesiana para descrever o crescimento de *D. auriga*. Os parâmetros da equação potencial de comprimento-peso foram calculados a partir de regressões lineares, as quais foram baseadas em pesos e comprimentos logaritmizados.

Médias mensais do índice gonadossomático (IG) foram calculadas para analisar o período reprodutivo. A maturação dos indivíduos foi determinada pelo IG e os dados ajustados a um modelo logístico para estimar as ogivas de maturação por comprimento e idade.

A taxa de potencial reprodutivo na população foi estimada pelo método SPR, baseado em informações de história de vida para construir uma composição hipotética de tamanho inexplorado e compará-la com a composição de tamanho atualizada do estoque (Hordyk *et al.*, 2015a, b, para maiores informações sobre o método vide o apêndice).

RESULTADOS

No total, foram amostrados 973 indivíduos com comprimento total de 77 a 195 mm para análise reprodutiva. Destes, 409 tiveram seções de otólitos examinadas para se estimar idades. As leituras iniciais coincidiram em 56% entre os dois leitores. No entanto, após a leitura conjunta esta coincidência aumentou para 87%. O coeficiente médio de variação obtido foi de 7,69%. Dos 409 otólitos examinados, 54 foram excluídos da análise devido à ausência de concordância entre as leituras.

As leituras das imagens de otólitos seccionados mostraram um padrão alternado na formação de bandas: bandas translúcidas estreitas e opacas largas (Fig. 2, apêndice). A análise do tipo de borda indicou maior frequência de otólitos com bordas opacas de outubro a junho, atingindo picos em dezembro e janeiro (ambos os valores de 95%), enquanto as bordas translúcidas ocorreram com maior frequência em julho, agosto e setembro (81, 89 e 53%, respectivamente) (Fig. 3, apêndice). O incremento marginal médio (IM) confirmou o padrão sazonal de formação de bandas translúcidas, em julho e agosto. Os valores de IM foram muito baixos em dezembro e janeiro, e aumentaram gradualmente até atingir os valores mais altos em julho e agosto, seguidos por uma tendência decrescente até dezembro (Figura 4, apêndice).

As idades de *D. auriga* variaram de 1 a 9 anos, baseado na leitura dos 355 otólitos legíveis. A maioria dos indivíduos amostrados teve idades entre 3 e 4 anos, representando 53% (Tabela I, apêndice). Os três indivíduos mais velhos amostrados com 9 anos mediam 173, 182 e 183 mm de comprimento total.

O modelo de crescimento de von Bertalanffy aplicado ao comprimento por idade mostrou que a espécie cresce rapidamente, atingindo seu comprimento e peso assintóticos no quinto ano de vida (Tabela II e Fig. 5, apêndice). Com base na relação comprimento-peso, o peso assintótico foi estimado em 100,47 g (93,02 e 110,91 g, Intervalo de credibilidade de 95%).

Os valores médios mensais do índice gonadossomático foram maiores entre outubro e março, indicando o período de atividade reprodutiva, o qual atingiu picos em dezembro e janeiro (Figura 7, apêndice). Ao longo dos outros meses, isto é, meses não reprodutivos, nenhum peixe teve valores de índice gonadossomático superiores a 3,5. Portanto, os indivíduos com IG maior que 3,5 foram considerados maduros. A partir do modelo logístico, estimou-se a idade e o comprimento de primeira maturação (A_{50} e L_{50}) em 2,29 anos e 140,72 mm, respectivamente (Tabela III e Fig. 8, apêndice).

Os valores estimados de mortalidade natural (M) foram 0,61 para 9 anos como idade máxima, 0,46 para 11 anos e 0,37 para 13 anos. Para esses valores de M, a taxa de potencial de desova da população de *D. auriga* no sul do Brasil foi de 61% (± 4%, 95% IC), 53% (± 4%) e 47% (± 4%), respectivamente. Isto pode ser interpretado como perdas de 39%, 47% e 53% do potencial de desova.

CONCLUSÕES

Os resultados apresentados destacam a importância do monitoramento em longo prazo de *Dules auriga* e de outras espécies da captura acessória. O rápido crescimento, a longevidade moderada, o longo período de desova, o tamanho pequeno e a idade de maturação tornam *Dules auriga* uma espécie relativamente resistente à remoção, de biomassa pela pesca, mesmo que incidental. No entanto, a pesca pode ter resultado em uma perda de 50% do potencial de desova da população, o que pode reduzir a capacidade da sua população de enfrentar grandes mortalidades devidas, por exemplo, a variações climáticas. Além disso, a pesca pode afetar o seu papel funcional, como por exemplo, a disponibilidade como presa para outras espécies, causando efeitos negativos na rede alimentar.

LITERATURA CITADA

Adams, P. B. (1980). Life history patterns in marine fishes and their consequences for fisheries management. *Fish Bull* **78**, 1-12.

Campana, S. E. & Jones, C. M. (1992). Analysis of otolith microstructure data. In O*tolith Microstructure Examination and Analysis* (Stevenson, D. K. & Campana,

S. E., eds.), pp. 73–100. Ottawa, CA: Canadian Special Publication of Fisheries and Aquatic Sciences 117.

Chaves, P. T. C. (1989). Nota sobre o hermafroditismo em 3 espécies de Serranidae do litoral de São Paulo (Peixes, Perciformes). *Bioikos* **3**, 26-32.

Cheung W. W. L., Pitcher T. J. & Pauly D. (2005) A fuzzy logic expert system to estimate intrinsic extinction vulnerability of marine fishes to fishing. *Biol Conserv* **124**, 97–111.

Cussac, V. & Molero, A. M. (1987). Contribución al conocimiento de la biologia de *Dules auriga* Cuvier (Pisces, Serranidae). *Rev Bras Biol* **47**, 375-384.

Dowling, N.A., Wilson, J.R., Rudd, M.B., Babcock, E.A., Caillaux, M., Cope, J., Dougherty, D., Fujita, R., Gedamke, T., Gleason, M., Gutierrez, N., Hordyk, A., Maina, G.W., Mous, P.J., Ovando, D., Parma, A.M., Prince, J., Revenga, C., Rude, J., Szuwalski, C., Valencia, S. & Victor, S. (2016). FishPath: A Decision Support System for Assessing and Managing Data- and Capacity Limited Fisheries. In *Assessing and Managing Data-Limited Fish Stocks* (Quinn, T.J., Armstrong, J.L., Baker, M.R., Heifetz, J. & Witherell, D., eds.). Alaska Sea Grant, University of Alaska Fairbanks.

Fischer, L. G., Vieira, J. P. & Pereira, L. E. D. (2011). *Peixes estuarinos e costeiros*. 2nd edn. Rio Grande: Gráfica Pallotti.

Hordyk, A. R., Ono, K., Sainsbury, K. J., Loneragan, N. & Prince, J. D. (2015a) Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio. *ICES J Mar Sci* **72**, 204-216.

Hordyk, A. R., Ono, K., Valencia, S. R., Loneragan, N. R. & Prince, J. D. (2015b). A novel length-based empirical estimation method of spawning potential ratio

(SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES J Mar Sci* **72**, 217-231.

Kirkwood, G. P., Beddington, J. R. & Rossouw, J. A. (1994). Harvesting species of different lifespan. In *Large-scale ecology and conservation biology*, Vol. 35 (Edwards, P. J., May, R. M. & Webb, N. R., eds), pp. 199-227. Oxford, UK: Blackwell Scientific Publications.

Militelli, M. I. & Rodrigues, K. A. (2011). Morphology of the ovotestis of a hermaphroditic teleost, *Serranus auriga* (Osteichthyes: Serranidae). *Pan-Am J Aquat Sci* **6**, 320-324.

Pope, J. G., Macdonald, D. S., Daan, N., Reynolds, J. D. & Jennings, S. (2000). Gauging the impact of fishing mortality on non-target species. *ICES J Mar Sci* **57**, 689 – 696.

Reynolds, J. D., Jennings, S. & Dulvy, N. K. (2001). Life histories of fishes and population responses to exploitation. In *Conservation of Exploited Species* (Reynolds, J. D., Mace, G. M., Redford, K. H. & Robinson, J. G., eds.), pp 148-168. Cambridge, UK: Cambridge University Press.

APÊNDICE

Manuscrito submetido à revista "Fisheries Research":

Life history and assessment of fishing impacts on the bycatch species *Dules auriga* (Teleostei: Serranidae) in the southern Brazil

AMANDA TOMAZELE ROVANI [a*] AND LUIS GUSTAVO CARDOSO [a]

[a] Laboratório de Recursos Pesqueiros Demersais e Cefalópodes, Instituto de Oceanografia, Universidade Federal do Rio Grande (FURG), Caixa Postal 474, Avenida Itália Km 8, CEP 96201-900, Rio Grande, RS, Brazil.

* Corresponding author. Tel: +55 53 32336525.

E-mail addresses: amandatrovani@gmail.com (A.T. Rovani), cardosolg15@gmail.com (L.G. Cardoso).

ABSTRACT

Dules auriga, which is a small hermaphrodite inhabiting deep waters, is a serranid species and a frequent component of the discharged catch of the bottom trawling of southern Brazil. Its growth and reproduction has been studied to assess the vulnerability of this species in relation to the current level of fishing. Sampling was conducted throughout the year, and included specimens to determine sex maturity and age. Age was validated by the edge type and marginal increment analysis. The oldest and the largest individuals were 9 years old and 195 mm total length. Growth parameters fitted to von Bertalanffy equation, and were L_∞=178.34 mm, k=0.641 year^{-1} and t_0=−0.341 years. Length and age at first maturity were 140.72 mm and 2 years, respectively. Reproductive season extended along the austral spring and summer. An assessment of the fishing impacts was based on the comparison of a hypothetical unexploited size composition and the current size compositions. This led to the conclusion that the removal of the biomass by fishing may have resulted in a loss of 50% of the spawning potential of the population. Fast growth, moderate longevity, long spawning season, small size and age at maturity make *D. auriga* relatively resilient to the removal of biomass by fishing. However, the loss of spawning potential can reduce the capacity of storage in front of climatic variations.

KEY WORDS

Bycatch; Serranidae; Southern Brazil, Data poor stock.

1. INTRODUCTION

Currently, monitoring and management efforts of exploited fish species are mainly focused on the commercially important ones. Usually, non-target species receive lower priority in research and, because of that little is known about their life histories (Pope *et al.*, 2000). As they are also exposed to fishing mortality from bycatch (Cheung *et al.*, 2005), it is important to know its life history to assess somehow the impact of fishing on these populations. The responses of fish populations to fishing are influenced by their life histories (Adams, 1980; Kirkwood *et al.*, 1994; Pope *et al.*,, 2000). In general, species with faster life histories, i.e., earlier age at maturity and faster body growth, support higher fishing mortality than species with slower life histories (Reynolds *et al.*, 2001). Therefore, life history parameters can be used to identify species that should be priority in fisheries research (Reynolds *et al.*, 2001; Cheung *et al.*, 2005).

The small demersal serranid species *Dules auriga* (Cuvier, 1829) inhabits sand and consolidated bottoms on the Southwestern Atlantic continental shelf. The species can be found between Rio de Janeiro state (Brazil) and Argentina, at depths ranging from 15 to 140 m (Fischer *et al.*, 2011). Their presence is relatively common in demersal bottom trawl catches in the coastal waters of Argentina, Uruguay and southern Brazil (Militelli & Rodrigues, 2011). Despite its frequency in the catches, individuals of *D. auriga* are discharged back to the sea after the selection on board, since the species has no economic value. Those that are accidentally landed are destined to the production of fish meal (Militelli & Rodrigues, 2011).

Little is known about *D. auriga* life history. Cussac & Molero (1987) observed that it feeds mainly on crustaceans and classified the species as a simultaneous hermaphrodite. Both male and female gonads are present in the same individual, which was confirmed later by histological examinations by Militelli & Rodrigues (2011). Chaves (1989) reported the presence of functional gonads, with testicular portions aggregated to the ovaries in both sexually mature and immature individuals.

Dowling, N.A., J.R. Wilson, M.B. Rudd, E.A. Babcock, M.

The majority of fisheries across the globe are data-limited, as they lack data and/or resources to generate statistical estimates of the stock status (Dowling *et al.* 2016). However, data poverty should not be used as an excuse to forego the assessment of stock status, which is a fundamental step to develop any management strategy (Dowling *et al.* 2016). Nowadays, many options exist to assess data-limited stocks with several levels of data requirements (Dowling *et al.* 2014). A recent one uses life history information to build a hypothetical unexploited size composition and compares with the updated size composition of the stock (Hordyk *et al.* 2015 a, b). This approach can allow the identification of the know spawning potential ratio (SPR) that remains in the population (Hordyk *et al.* 2015 a, b).

As *D. auriga* is mostly discharged on board and its landing are not recorded, understand its life history can contribute to a better comprehension about the impact of fishing on their population. In this context, the present study aimed to provide information of *D. auriga* population dynamics and to assess the impact of fishing on its spawning potential ratio (SPR). For this, age was determined by using the analysis of otolith sections and life history parameters on reproduction and growth were estimated.

2. MATERIALS AND METHODS

2.1. SAMPLING AND STUDY SITES

Individuals were collected monthly, from September 2014 to April 2016, from the fishing landings in Rio Grande (Brazil). Landings were from the commercial fishing fleet equipped with bottom trawls that operate on the Southern Brazil continental shelf between latitudes 28º 36' 14''S and 33º 44' 39''S at depths between 9 and 130 m (Fig. 1).

Samplings comprised measurements of total length (L, mm), total weight (Wt, g) and gonad weight (GW, g) for each specimen. In addition, the pair of *sagittae* otoliths were removed during the sampling, which were cleaned and stored dry for ageing at the laboratory.

2.2. AGEING

One otolith from each pair was embedded in a polyester resin, left to dry and then sectioned transversely through the nucleus using a diamond low speed saw. Sections of 0.2 mm were mounted on glass slides with synthetic mounting media.

Sections were then examined under a binocular stereoscopic microscope with reflected light over a black background and images were digitized, under which the opaque bands were counted (Fig. 2). Distances from the core to the end of each opaque band (R_i) and to the inner edge (R) of the otoliths along the dorsal border of the *sulcus acousticus* were recorded together with the type of band on the edge (opaque or translucent). The number of opaque bands was read independently by two readers. If discrepant, a third reading was made jointly. In cases on which disagreement persisted, the readings were discarded.

The mean coefficient of variation (CV) was used to evaluate the precision of the age estimation between readings, following Campana and Jones (1992):

$$CV_j = 100\% \times \frac{\sqrt{\sum_{i=1}^{R} \left(X_{ij} - X_j\right)^2 \Big/ (R-1)}}{X_j}$$

where CV_j is the age precision estimate for the j^{th} fish; X_{ij} is the age determination of the j^{th} fish by the i^{th} reader; X_j is the mean age of the j^{th} fish and R is the number of readings.

Type of edge and marginal increment analysis (MI) were used to validate the periodicity of formation of the opaque and translucent bands. The relative frequencies of each edge type were plotted monthly. The translucent MI was calculated for each specimen by the formula:

$$MI = \frac{R - Rn}{Rn - (Rn - 1)}$$

where MI is the marginal increment; R is the distance from the nucleus to the edge; Rn is the distance from the nucleus to the end of last opaque band and Rn – 1 is the distance from the nucleus to the end of the last but one opaque band. Monthly means MI were calculated and its annual variation analyzed.

2.3. GROWTH MODEL

The von Bertalanffy growth model was adjusted using a Bayesian approach to describe the growth of *Dules auriga*. It was assumed that the age-length data followed a log-normal distribution: $y_i = \log N\ (\mu_i\,, \sigma^2)$, where y_i is the length distribution with an average expected length at an age class (or band class) *i* with variance σ^2. A logarithmic version of the von Bertalanffy equation was used for computational convenience:

$$\mu_i = log(TL_\infty) + log(1^{-k(i-t_o)})$$

Uninformative priors were constructed:

$$p(logTL_\infty) \sim dN(0{,}0.001)\ I\ (-5{,}5)$$

$$p(log\ k) \sim dN(0{,}0.001)\ I\ (-5{,}5)$$

$$p(log\,t_0) \sim\; dU\,(-\,3{,}0)$$

$$p(\sigma) \sim dU(0{,}5)$$

The posterior distribution of each estimated parameter was obtained via the stochastic process of Monte Carlo Markov Chain (MCMC). After 10,000 burn-in runs, every second value of the remaining 31,000 was retained, resulting in a final sample of 10,500 in the posterior distribution p (log TL_∞, log k, log t_0|D) (Kinas & Andrade, 2010). The MCMC was performed by OpenBUGS, using the libraries R2WinBUGS (Sturtz *et al.*, 2005) and BRugs (Thomas *et al.*, 2006). All statistical analysis in this study were performed in the software R version 3.1.3.

The parameters of the weight-length equations ($W_t = a{L_t}^b$) were calculated using a linear regression, which was based on log transformed weights and lengths.

2.4. SEXUAL MATURATION ANALYSIS

The gonadosomatic index (GSI) was calculated as the ratio between the gonad weight (GW) and total weight (Wt) in each individual sampled (n= 973), as follows (Wootton, 1998):

$$GSI = 100.\frac{GW}{Wt}$$

Mean GSI values were calculated monthly to analyze the reproductive period. The maturation was also defined by the GSI, since the absence of histological staging studies for the species and macroscopic analysis was suspected to have a large amount of errors (Flores *et al.*, 2015). The GSI value in which individuals were considered mature was determined by the analysis of the dispersion of the index by month. The total number (n_i) and the number of mature specimens (y_i) were calculated at each total length intervals of 10 mm and at each age. Only data of the breeding season was chosen to estimate the maturation ogives by length and age. If θ_i denotes the probability of an individual of the *i*th age or *i*th length class being, y_i was assumed to follow a binomial distribution *Bin* (n_i,θ_i).

Data were fitted to a logistic model, defined by a logit link function that transforms the parameter θ_i, restrict to the range [0,1] in the binomial distribution, in *m* defined between (−∞, +∞) (Kinas & Andrade, 2010). The logistic model was defined as follows:

$$m_i = g(\theta_i) = log\left(\frac{\theta_i}{1-\theta_i}\right)$$

$$m_i = \beta_0 + \beta_1 . x_1$$

where m_i is the probabilities at each x_i that are each age or length class.

From this model, the age at first maturation (A_{50}) and the length at first maturation (L_{50}) were defined as:

$$A_{50} \ or \ L_{50} = -\frac{\beta_0}{\beta_1}$$

The posterior distribution p (β_0, $\beta_1|D$), where D = {(y_i, n_i, x_i); i = 1,…,k}, was obtained via the stochastic process of Monte Carlo Markov Chain (MCMC). To obtain the posterior distribution of β_0 and β_1, they were considered independent and normally distributed with mean 0 and with a large variance (1000), used as a priori distribution. The number of simulations and sample selection to compose the posterior distribution was the same used for the estimation of the VB growth parameters.

2.5. SPAWNING POTENTIAL RATIO ASSESSMENT

The spawning potential ratio (SPR) in the population was estimated by the length-based SPR method (Hordyk *et al.*, 2015a, b) which is calculated as the difference between the expected length composition in a virginal situation and the observed one from the catch. The expected length composition is calculated from the life history parameters such as the natural mortality (M), the von Bertalanffy growth parameters L_∞ and *k*, and the size at 50% and 95% of maturity.

The updated size structure was obtained by measuring the total length of 590 individuals from commercial pair bottom trawl fishing, which were considered to be representative from the population. The natural mortality (M) was calculated as the average of results from three methods that uses maximum ages as predictor of M (Then *et al.*, 2014). M was calculated for three values of maximum age: the observed at the otolith readings, 25% higher than the maximum observed age and 50% higher. This was done considering that the pair bottom trawl fishery operates in the region for, at least, 50 years (Yesaki & Bager, 1975; Haimovici, 1998; Haimovici & Cardoso, 2016) and the removal of older age classes via fishing occurs at even moderate levels of exploitation (Berkeley *et al.*, 2004).

3. RESULTS

3.1. AGE AND GROWTH

Overall, 973 specimens measuring from 77 to 195 mm total length (TL) were sampled for reproductive analysis. From that, 409 had otoliths sections examined for ageing. The initial readings coincidence between the two readers was 56%. However, after the joint reading this coincidence increased to 87%. The mean coefficient of variation obtained was 7.69%. Out of 409 otoliths examined, 54 were excluded from the analysis because of the absence of agreement among readings.

The readings of the sectioned otoliths images showed an alternating pattern in the formation of bands: narrow translucent and wide opaque bands (Fig. 2). The analysis of the edge type indicated a greater frequency of otoliths with opaque edges from October to June, reaching peaks in December and January (both values of 95%), while the translucent edges occurred more frequently in July, August and September (81, 89 and 53%, respectively) (Fig. 3). The mean translucent marginal increment (MI) confirmed the seasonal pattern of translucent bands formation, in July and August. The MI values were very low in December and January, and increased gradually to reach the higher values in July and August followed by a decreasing trend up to December (Fig. 4).

Based on 355 readable otoliths, *D. auriga* ages ranged from 1 to 9 years. Most of the samples were between 3 and 4 years, accounting for 53% (Table I). The three sampled older fish, aged 9 years, measured 173, 182 and 183 mm L. The von Bertalanffy growth model applied to length and weight at age data showed that the species grows fast, attaining its asymptotic length and weight at the fifth year of life (Table II and Fig. 5).

The weight-length relationship based on a potential model was (Fig. 6):

$$\boldsymbol{Wt = 4 \times 10^{-6} \times Lt^{3.29}} \qquad (\boldsymbol{R^2 = 0.9489, n = 1669})$$

where the average value of the exponent *b* was 3.29 and the coefficient of determination r^2=0.9489. Based on this relationship the asymptotic weight was estimated at 100.47 g (93.02 and 110.91 g, 95% credible intervals).

3.2. SEXUAL MATURATION ANALYSIS

The mean monthly gonadosomatic index (GSI) values were higher between October and March, indicating a reproductive activity period, which reached peaks in December and January (Fig. 7). Along the other months, that is, non-reproductive months, none fish had GSI values greater than 3.5. Therefore, the individuals with gonadosomatic index greater than 3.5 were considered mature.

From the logistic model, the mean age and length at first maturation (A_{50} and L_{50}) were estimated in 2.29 years and 140.72 mm, respectively (Table III and Fig. 8).

3.3. SPAWNING POTENTIAL RATIO ASSESSMENT (SPR)

The estimated natural mortality (M) values were 0.61 for 9 years old as the maximum age, 0.46 for 11 years old and 0.37 for 13 years old. For these M values, the remaining spawning potential ratio of the *D. auriga* population from southern Brazil was 61% (±4%, 95% CI), 53% (±4%) and 47% (±4%), respectively. This can be interpreted as losses of 39%, 47% and 53% of the spawning potential.

4. DISCUSSION

The present study has generated valuable life history data of *Dules auriga* by providing validated age and growth parameters, age and size at maturity data and a stock assessment by the spawning potential ratio. These information represent the first estimates for this species.

Out of 409 thin otolith sections, only 54 were excluded, remaining 355 legible otoliths. Otoliths that were excluded presented several difficulties for interpretation of the growth band or edges type, including sections that did not passed through the otolith nucleus, problems with the glass slides mounting, and even non-readable otolith structures. In this study, the otolith reading precision between readers (CV= 7.7%)

agreed with precision presented by many ageing studies (CV = 7.6%) analyzed by Campana (2001). Both edge type and marginal increment analysis consistently showed an annual periodicity in the formation of an opaque band from spring to summer and of a translucent band from autumn to winter, which allowed consistent ageing validation of *Dules auriga* in southern Brazil.

This pattern may occur due to a combination of endogenous and exogenous factors (such as water temperature, reproduction and feeding regime) that influence in the alternating deposition of dense mineral and less dense mineral bands with an annual periodicity in most species (Morales-Nin, 2000; Green *et al.*, 2009). The deposition of opaque bands in *D. auriga* coincide with the peaks of its spawning season. The seasonal pattern of band formation is also in agreement with the same process in other demersal fish species from the study area: *Macrodon atricauda* (Cardoso & Haimovici, 2011), *Epinephelus marginatus* (Condini *et al.*, 2014), *Cynoscion guatucupa* (Vieira & Haimovici, 1993), *Umbrina canosai* (Haimovici & Reis, 1984).

As the genus *Dules* is monospecific, its growth strategy was compared with other small sized species of the genus *Serranus*: *S. cabrilla, S. hepatus, S.atricauda* and *S. scriba* (Table IV). In figure 9, their relative TL at ages (L_i/ L_∞) were plotted against ages to evaluate the speed that each species approximate to L_∞. It can be observed that *D. auriga* grows much faster than the other species, achieving 42% of its L_∞ in the first year of life and 80% in the second year compared to 10 to 38% of L_∞ in the first year and 80% at 3 to 9 years old. Faster growth can be attributed both to the environmental characteristics of their habitats and to specific evolutionary pressures. It is noteworthy that each species used in the comparison comes from sites with different environments and population structures, which may reflect in the observed differences between the growth parameters.

Before this study, *D. auriga* could be considered as a little-known species, and regarding the assessment on the fishing impacts, as a data poor stock. The estimation of the basic life history of this species (reproduction, growth and longevity) combined with a representative size structure of the population allowed us to assess the spawning potential ratio (SPR) of the stock by applying the length-based SPR method developed by Hordyk *et al.* (2015a). This approach is one of many methods of great importance that have been developed recently to assess data limited stocks (Carruthers *et al.*, 2014; Newman *et al.*, 2015).

The values of spawning potential ratio (SPR) estimated for *D. auriga* population from southern Brazil were sensible to the maximum age used to calculate the natural mortality. Depending on the assumed longevity (9, 11 or 13 years old) the removal by fishing may have result in a loss of 39%, 47% or even 53% of the spawning potential, respectively. It’s plausible to assume that the maximum age of the species is higher than the maximum observed one. *D. auriga* is a non-target specie, but occurs in 32% of tows of the pair bottom trawl fishery in southern Brazil (Cardoso, LG, personal communication) which makes its population susceptible to fishing impacts. The bottom trawl fishery operates in the region for, at least, 50 years (Yesaki & Bager, 1975; Haimovici, 1998; Haimovici & Cardoso, 2016) and the removal of older age classes is one of the first populations impacts of the fishing exploitation (Berkeley *et al.*, 2004). Thus, it is safe to assume that fishing had removed at least around 50% of the spawning potential of the *D. auriga* population from southern Brazil.

5. CONCLUSION

The results presented here highlight the importance of long-term monitoring of *D. auriga* and other bycatch species. Although *D. auriga* may seem to be a resilient species due to its life history characteristics (long spawning period, early maturity at small sizes and fast growth), it probably has been affected by fishing mortality operating in the last 40 years in southern Brazil. These effects render populations less resilient to stochastic effects such as climatic variations by reducing storage effects. Furthermore, fishing may affect its functional role, for instance, availability as prey for other species, causing negative effects on the food web.

ACKNOWLEDGEMENTS

We are grateful to the fishing industries of Rio Grande that allowed us to follow the commercial landings and to collect the fishes. Also, thanks the colleagues of the "Laboratório de Recursos Pesqueiros Demersais e Cefalópodes" from FURG for collaborating in the processing of the samples. Rovani, A.T. was granted by the "Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES" and the study was financially supported by the Brazilian Environmental Ministry and the "Fundação Grupo Boticário de Proteção à Natureza".

REFERENCES

Adams, P. B. (1980). Life history patterns in marine fishes and their consequences for fisheries management. *Fish Bull* **78**, 1-12.

Berkeley, S. A., Hixon, M. A., Larson, R. J., Love, M. S. (2004). Fisheries sustainability via protection of age structure and spatial distribution of fish populations. *Fisheries* **29**, 23–32. doi: 10.1577/1548-8446(2004)29[23:FSVPOA]2.0.CO;2.

Campana, S. E. (2001). Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *J Fish Biol* **59**, 197-242. doi:10.1006/jfbi.2001.1668.

Campana, S. E. & Jones, C. M. (1992). Analysis of otolith microstructure data. In *Otolith Microstructure Examination and Analysis* (Stevenson, D. K. & Campana, S. E., eds.), pp. 73–100. Ottawa, CA: Canadian Special Publication of Fisheries and Aquatic Sciences 117.

Cardoso, L. G. & Haimovici, M. (2011). Age and changes in growth of the king weakfish *Macrodon atricauda* (Günther, 1880) between 1977 and 2009 in southern Brazil. *Fish Res* **111**, 177-187. doi:10.1016/j.fishres.2011.06.017.

Carruthers, T. R., Punt, A. E., Walters, C. J., MacCall, A., McAllister, M. K., Dick, E. J., & Cope, J. (2014). Evaluating methods for setting catch limits in data-limited fisheries. *Fish Res* **153**, 48-68. doi: 10.1016/j.fishres.2013.12.014.

Chaves, P. T. C. (1989). Nota sobre o hermafroditismo em 3 espécies de Serranidae do litoral de São Paulo (Peixes, Perciformes). *Bioikos* **3**, 26-32.

Cheung W. W. L., Pitcher T. J. & Pauly D. (2005) A fuzzy logic expert system to estimate intrinsic extinction vulnerability of marine fishes to fishing. *Biol Conserv* **124**, 97–111. doi:10.1016/j.biocon.2005.01.017.

Condini, M. V.; Albuquerque, C. Q. & Garcia, A. M. . (2014). Age and growth of Dusky Grouper (*Epinephelus marginatus*) (Perciformes: Epinephelidae) from its southernmost population in Southwestern Atlantic, with a size comparison between offshore and littoral habitats. *Fish Bull* **112**, 311-321. doi:10.7755/FB.112.4.7.

Cussac, V. & Molero, A. M. (1987). Contribución al conocimiento de la biologia de *Dules auriga* Cuvier (Pisces, Serranidae). *Rev Bras Biol* **47**, 375-384.

Dowling, N.A., Wilson, J.R., Rudd, M.B., Babcock, E.A., Caillaux, M., Cope, J., Dougherty, D., Fujita, R., Gedamke, T., Gleason, M., Gutierrez, N., Hordyk, A., Maina, G.W., Mous, P.J., Ovando, D., Parma, A.M., Prince, J., Revenga, C., Rude, J., Szuwalski, C., Valencia, S. & Victor, S. (2016). FishPath: A Decision Support System for Assessing and Managing Data- and Capacity Limited Fisheries. In *Assessing and Managing Data-Limited Fish Stocks* (Quinn, T.J., Armstrong, J.L., Baker, M.R., Heifetz, J. & Witherell, D., eds.). Alaska Sea Grant, University of Alaska Fairbanks. http://doi.org/10.4027/amdlfs.2016.03

Dulčić, J., Matić-Skoko, S., Paladin, A. & M. Kraljević, M. (2007). Age, growth and mortality of brown comber, *Serranus hepatus* (Linnaeus, 1758) (Pisces: Serranidae), in the eastern Adriatic (Croatian coast). *J Appl Ichthyol* **23**, 195-197. doi: 10.1111/j.1439-0426.2006.00840.x

Fischer, L. G., Vieira, J. P. & Pereira, L. E. D. (2011). *Peixes estuarinos e costeiros*. 2nd edn. Rio Grande: Gráfica Pallotti.

Flores, A., Wiff, R. & Díaz, E. (2015). Using the gonadosomatic index to estimate the maturity ogive: application to Chilean hake (*Merluccius gayi gayi*). *ICES Journal of Marine Science* 72, 508-514. doi: 10.1093/icesjms/fsu155

Green, B. S., Mapstone, B. D., Carlos, G. & Begg, G. A. (2009). *Tropical Fish Otoliths: Information for Assessment, Management and Ecology*, 1st edn. Netherlands: Springer.

Haimovici, M. (1998). Present state and perspectives for the southern Brazil shelf demersal fisheries. *Fish Manag Ecol* **5**, 277-299.

Haimovici, M. & Cardoso, L. G. (2016). Colapso do estoque de *Umbrina canosai* do Sul do Brasil devido à introdução do arrasto-de-meia-água. *Bol Inst Pesca* **42**, 258–267. doi: 10.5007/1678-2305.2016v42n1p258.

Haimovici, M. & Reis, E. G. (1984). Determinação de idade e crescimento da castanha *Umbrina canosai*, (Pisces, Sciaenidae) do sul do Brasil. *Atlântica* **7**, 25-46.

Hordyk, A. R., Ono, K., Sainsbury, K. J., Loneragan, N. & Prince, J. D. (2015a) Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio. *ICES J Mar Sci* **72**, 204-216. doi: 10.1093/icesjms/fst235.

Hordyk, A. R., Ono, K., Valencia, S. R., Loneragan, N. R. & Prince, J. D. (2015b). A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES J Mar Sci* **72**, 217-231. doi: 10.1093/icesjms/fsu004.

Kinas, P. G. & Andrade, H. A. (2010). *Introdução à Análise Bayesiana (com R)*, 1st edn. Porto Alegre, BR: Mais Que Nada.

Kirkwood, G. P., Beddington, J. R. & Rossouw, J. A. (1994). Harvesting species of different lifespan. In *Large-scale ecology and conservation biology*, Vol. 35 (Edwards, P. J., May, R. M. & Webb, N. R., eds), pp. 199-227. Oxford, UK: Blackwell Scientific Publications.

Militelli, M. I. & Rodrigues, K. A. (2011). Morphology of the ovotestis of a hermaphroditic teleost, *Serranus auriga* (Osteichthyes: Serranidae). *Pan-Am J Aquat Sci* **6**, 320-324.

Morales-Nin, B. (2000). Review of the growth regulation processes of otolith daily increment formation. *Fish Res* **46**, 53–67. doi: 10.1016/S0165-7836(00)00133-8.

Newman, D., Berkson, J. & Suatoni, L. (2015). Current methods for setting catch limits for data-limited fish stocks in the United States. *Fish Res* **164**, 86-93. doi: 10.1016/j.fishres.2014.10.018.

Pope, J. G., Macdonald, D. S., Daan, N., Reynolds, J. D. & Jennings, S. (2000). Gauging the impact of fishing mortality on non-target species. *ICES J Mar Sci* **57**, 689 – 696. doi:10.1006/jmsc.2000.0729.

Reynolds, J. D., Jennings, S. & Dulvy, N. K. (2001). Life histories of fishes and population responses to exploitation. In *Conservation of Exploited Species* (Reynolds, J. D., Mace, G. M., Redford, K. H. & Robinson, J. G., eds.), pp 148-168. Cambridge, UK: Cambridge University Press.

Sturtz, S., Ligges, U. & Gelman, A. (2005). R2WinBUGS: A Package for Running WinBUGS from R. *J Stat Softw* **12**, 1–16. doi: 10.18637/jss.v012.i03.

Then, A. Y., Hoenig, J. M., Hall, N. G. & Hewitt, D. A. (2014). Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. *ICES J Mar Sci* **72**, 82-92. doi: 10.1093/icesjms/fsu136.

Thomas, A., O’Hara, B., Ligges, U. & Sturtz, S. (2006). Making BUGS Open. *R News* **6**, 12–17.

Tserpes, G. & Tsimenides, N. (2001). Age, growth and mortality of *Serranus cabrilla* (Linnaeus, 1758) on the Cretan shelf. *Fish Res* **51**, 27-34.

Tuset, V. M., González, J. A., Lozano, I. J. & García-Díaz, M. M. (2004). Age and growth of the blacktail comber, *Serranus atricauda* (Serranidae), off the Canary Islands (centraleastern Atlantic). *Bull Mar Sci* **74**, 53-68.

Tuset V. M., García-Díaz, M. M., Gonzalez, J. A., Lorente M. J. & Lozano I. J. (2005). Reproduction and growth of the painted comber *Serranus scriba* (Serranidae) of the Marine Reserve of Lanzarote Island (central–eastern Atlantic). *Estuar Coast Shelf Sci* **64**, 335-346. doi:10.1016/j.ecss.2005.02.026.

Vieira P. C. & Haimovici, M. (1993). Idade e crescimento da pescada olhuda *Cynoscion striatus* (Pisces, Sciaenidae) no sul do Brasil. *Atlântica* **15**, 73-91.

Wootton, R. J. (1998). *Ecology of Teleost Fishes*, 2nd edn. Dordrecht; Boston: Kluver Academic Publishers.

Yesaki M. & Bager, K. J. (1975). *Histórico da evolução da pesca industrial em Rio Grande.* Programa de Pesquisa e Desenvolvimento Pesqueiro do Brasil PNUD/FAO: Ministério da Agricultura SUDEPE. Ser. Doc. Técnicos no. 11:1-15. Rio de Janeiro.

TABLES

Table I. Observed mean total length-at-age (L, mm) and calculated mean total length-at-age (L, mm) of *Dules auriga* in the southern Brazil. (*n*= number of individuals, Ci = confidence interval (α= 0.05)).

Age classes (yr)	*n*	Observed mean L (mm)	Ci 95%	Calculated mean L (mm)
1	24	116.6	7.8	97.6
2	55	138.7	5.6	138.3
3	91	157.4	3.2	158.6
4	98	168.5	2.1	168.6
5	45	173.8	2.7	173.6
6	26	180.4	3.1	176.1
7	9	179.6	7.2	177.4
8	4	183.0	4.9	178.0
9	3	179.3	6.2	178.3
Total	355			

Table II. Von Bertalanffy growth parameters and their credible intervals of *Dules auriga* from southern Brazil.

Parameters	Mean	Cr I $_{2.5\%}$	Cr I $_{97.5\%}$
L_∞	178.34	172.44	186.04
k	0.641	0.482	0.796
t_0	-0.341	-0.778	-0.040

Table III. Model parameters (β_0 and β_1) and estimated maturation indexes (L_{50} and A_{50}) of *Dules auriga*. A_{50} β_0 and A_{50} β_1 are the estimated logistic model parameters for the calculation of the age at first maturity (A_{50}). L_{50} β_0 and L_{50} β_1 are the estimated logistic model parameters for the calculation of the length at first maturity (L_{50}). All parameters and indexes are presented as the mean of their posterior distribution obtained via stochastic procedure. The credibility intervals (Cr I) of 2.5 and 97.5% are presented for all parameters and indexes.

Parameters	Mean	Cr I $_{2.5\%}$	Cr I $_{97.5\%}$
A_{50} β_0	-0.93	-1.91	0.05
A_{50} β_{10}	0.39	0.10	0.68
A_{50} (yr)	2.29	-0.14	3.30
L_{50} β_0	-4.49	-6.59	-2.69
L_{50} β_1	0.03	0.02	0.05
L_{50} (mm)	140.72	129.27	148.87

Table IV. The von Bertalanffy growth parameters of *Dules auriga* examined in this study were compared with the parameters of four *Serranus* small sized species: *Serranus cabrilla, S. hepatus, S. atricauda, S. scriba*. The table shows: reference, specie, study site, aging structure, range of total lengths (*L*), age range, number of specimens sampled (*n*), the VBTF parameters (L_∞, *k*, t_0) and reference.

Species	Study site	Ageing structure	*L* range (mm)	Age range (yr)	*n*	L_∞ (mm)	*k* (yr^{-1})	t_0 (yr)	Reference
Dules auriga	Southern Brazil continental shelf	sectioned otolith	77-195	1 - 8	356	178.34	0.641	-0.341	This study
S. cabrilla	Eastern Mediterranean - Crete coast	whole otolith	63-197	1 - 5	864	222.93	0.39	-0.59	Tserpes & Tsimenides (2001)
S. hepatus	Adriatic sea - Croatian coast	scale	58-130	2 - 7	440	148.10	0.217	-1.672	Dulčić *et al.* (2007)
S. atricauda	Canary Islands coast	whole otolith	162-432	2 - 16	406	438.75	0.16	-0.158	Tuset *et al.* (2004)
S. scriba	Canary Islands coast	whole otolith	150-294	2 - 11	336	341.80	0.13	-2.5	Tuset *et al.* (2005)

FIGURES

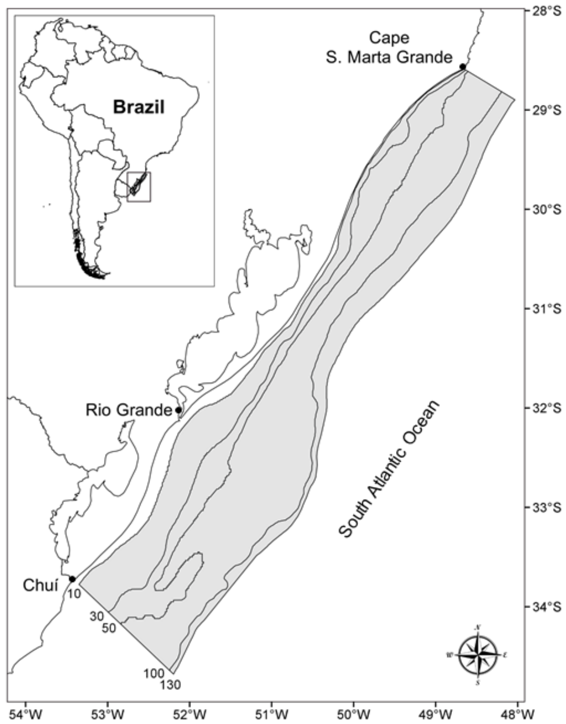

Figure 1. Fishing area from pair bottom trawlers that incidentally catch *Dules auriga* in the southern Brazil (light gray).

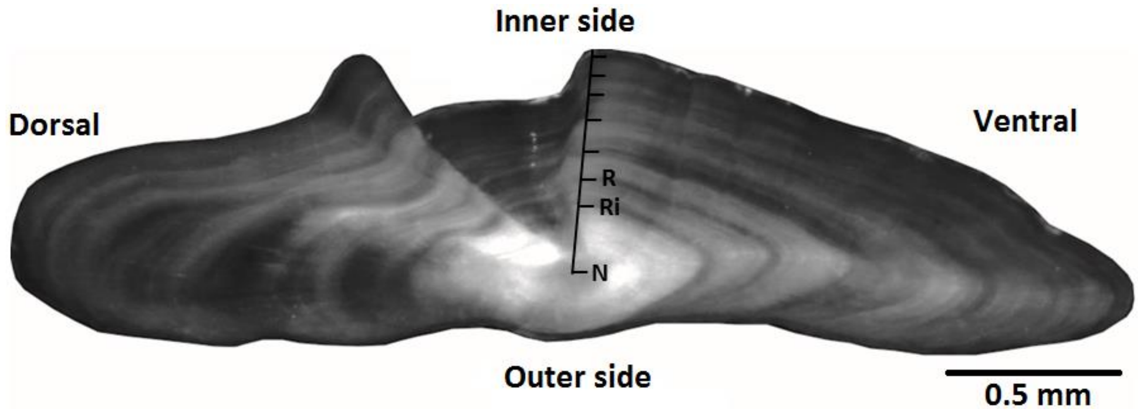

Figure 2. Thin section examined with reflected light of a six-year-old fish (L: 194 mm) of *Dules auriga* from the southern Brazil. Black bars indicate the end of each opaque band. N: nucleus, R_i: the distance from the nucleus to the end of each opaque band; R: the distance from the nucleus to the inner edge. Opaque bands can be seen as white bands whereas translucent ones can be seen as dark bands.

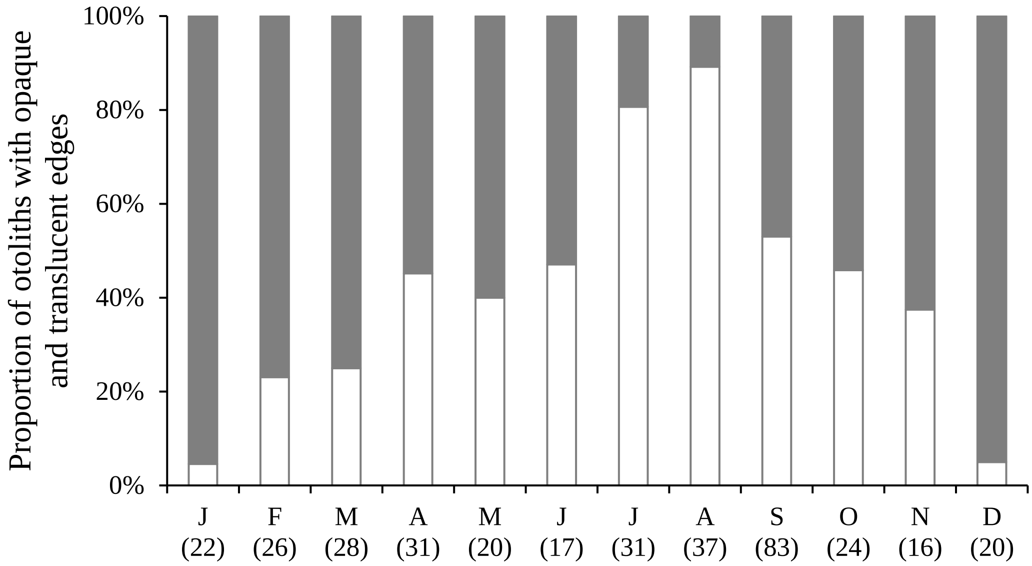

Figure 3. Seasonal pattern of opaque (■) and translucent (□) edges of the otoliths thin sections of *Dules auriga* in the southern Brazil (Number of examined otoliths monthly are in brackets).

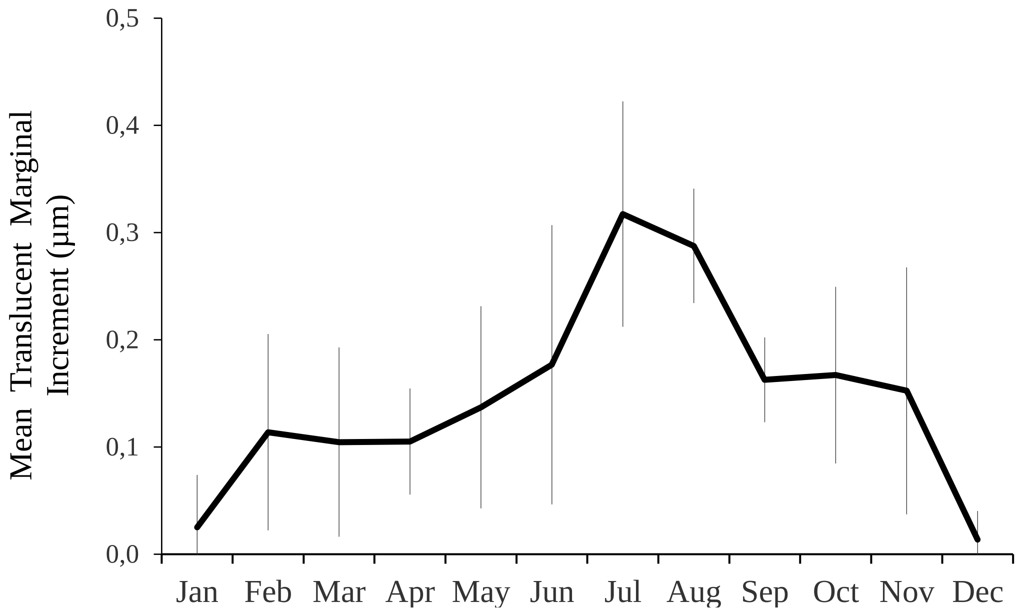

Figure 4. Seasonal pattern of the mean translucent marginal increment (µm) on sectioned otoliths of *Dules auriga* in the southern Brazil. Vertical black bars indicate the confidence interval (α= 0.05).

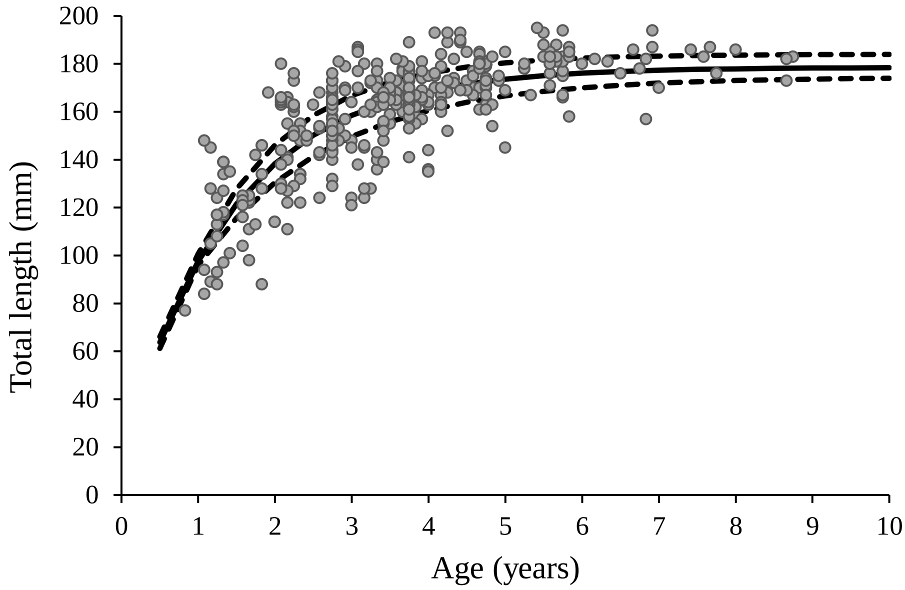

Figure 5. Observed total length at age data for *Dules auriga* from the southern Brazil and fitted von Bertalanffy growth curve. Continuous black line indicates the mean growth in length and the dashed lines indicate the credible intervals (CrI) of 2.5 and 97.5%.

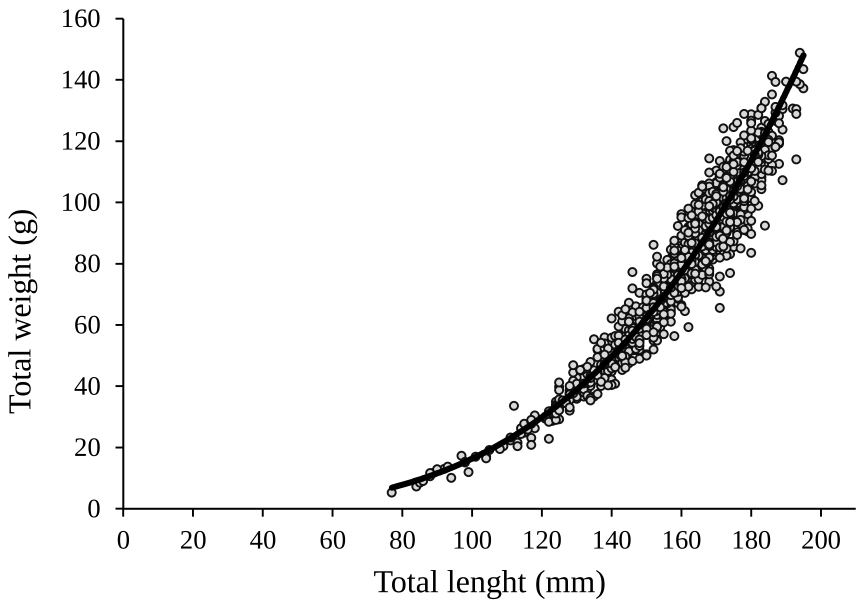

Figure 6. Weight-length relationship of *Dules auriga* from the southern Brazil. Continuous black line indicates the regression line.

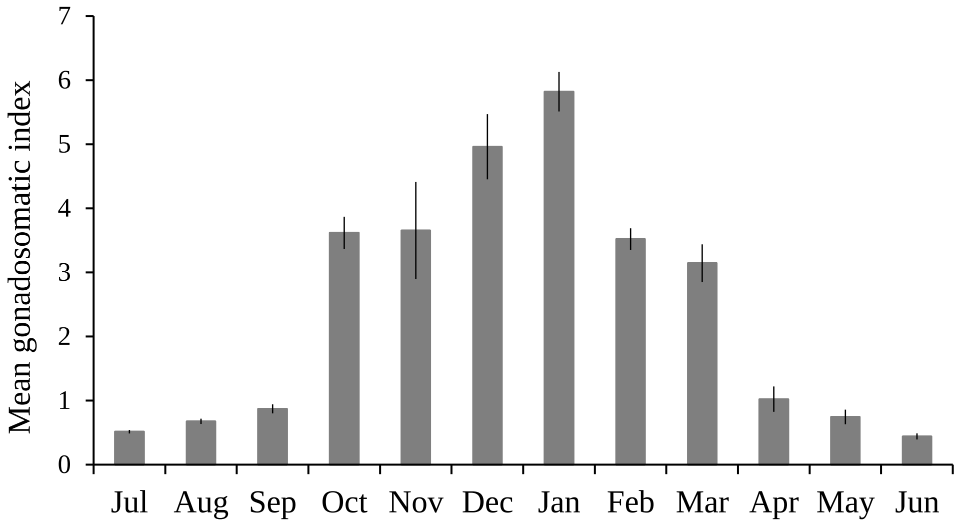

Figure 7. Mean gonadosomatic index by month for *Dules auriga* from the southern Brazil. Vertical black bars indicate the confidence interval (α= 0.05).

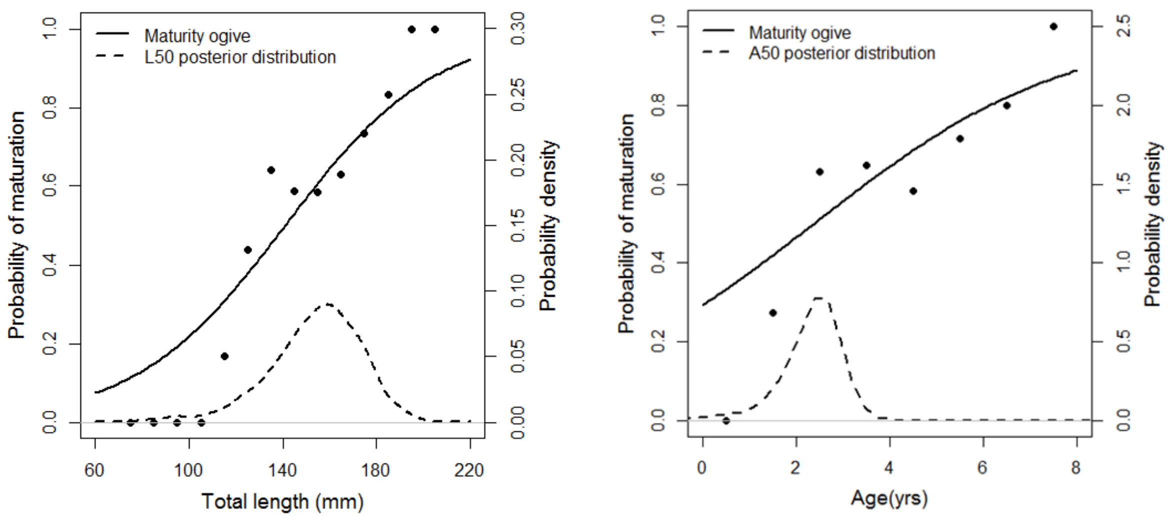

Figure 8. Length maturity ogive (solid line) and the posterior distribution (dashed line) of the estimated size at first maturity (left panel) and age maturity ogive and the posterior distribution of the estimated age at first maturity (right panel) of *Dules auriga* from the southern Brazil.

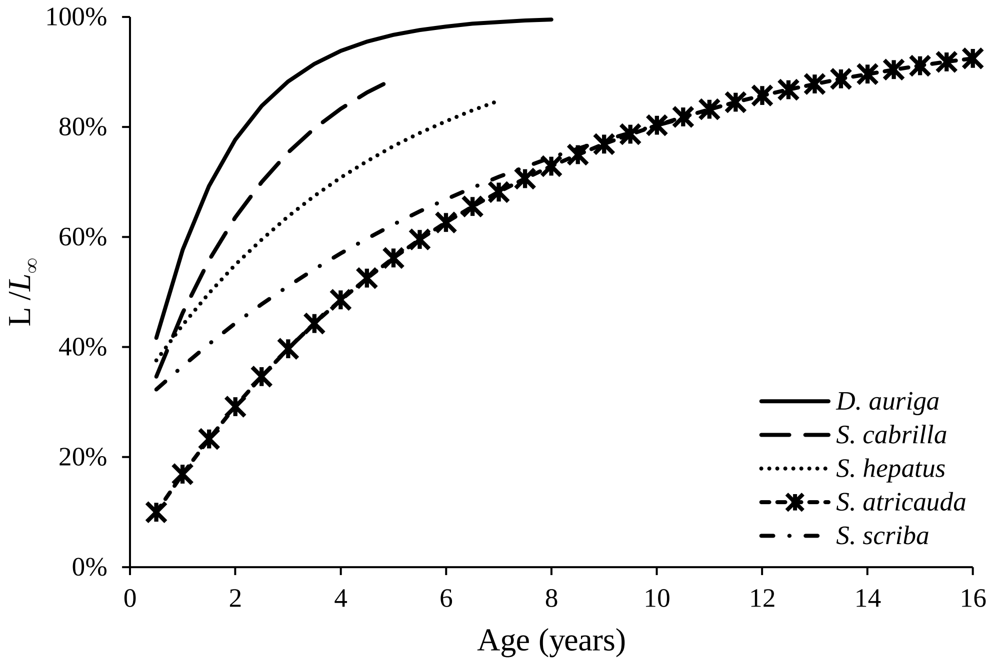

Figure 9. Sizes at age relative to the asymptotic lengths (L_∞) of *Dules auriga* from southern Brazil and four *Serranus* species: *S. cabrilla* from Canarian Island coast, *S. hepatus* from Adriatic Sea – Croatian coast, *S. atricauda* from Canarian Island coast and *S. scriba* from Eastern Mediterranean - Crete coast. Sources in Table III.