Population characteristics of *Helicolenus dactylopertus* in the Azores.

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Bluemouth rockfish (*Helicolenus dactylopterus*) is a valued commercial species in the Azores. Captures of this species have been steadily declining over time. Knowing specific information about the population structure and separation of populations is essential in managing this resource. Here we explore age and growth of bluemouth (n = 186), with lengths ranging from 11 - 41 cm, using whole and sectioned otoliths. We compare the performance of various models (Von Bertalanffy, Gompertz, and others) for explaining growth patterns. We also use otolith elemental composition derived through solution-based inductively coupled plasma mass spectroscopy (SBICPMS) as a tool to distinguish fish from different regions of the archipelago, under the influence of the North Atlantic Current, Azores Current, and to some extent the Mediterranean Water Plume[1].

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Introduction

The fisheries sector is a vitally important industry in the Azores Archipelago, with large numbers of the population relying on its prosperity as their sole source of income. Target species here differ from continental Europe owing to the geological and topological landscape around these mid-Atlantic islands. Deeper species are common, not least among them the bluemouth rockfish, *Helicolenus dactylopterus* (Delaroche, 1809).

Previous attempts to model growth in *H. dactylopterus* have relied on fitting a Von Bertanlaffy growth function (VBGF) to age-at-length data for ages determined from whole otoliths (Sequeira et al. 2009, Consoli et al. 2010), sectioned otoliths (White et al. 1998) or both (Kelly et al. 1999, Abecasis et al. 2006). More recently, approaches to growth modelling evaluating a selection of models, both asymptotic and non-asymptotic, have indicated that not only are other growth models adequate for modelling growth, but that VBGF often performs poorly against alternative approaches (Katsanevakis and Maravelias 2008, Barreto et al. 2011, Mercier et al. 2011).

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[1]   Extended abstract does not report the findings of the elemental composition analysis since these data were not available at the time of writing.

Our objective then was to determine the performance of a number of growth models and assess their utility in modelling growth of bluemouth.

Materials and Methods

Otolith increments were used to estimate the ages of a selection of *H. dactylopterus* specimens (n=186). Annual demersal surveys of the entire Azores region are conducted by the RV Arquipelago, under the auspices of the Department of Oceanography and Fisheries, University of the Azores. This study focussed on samples from the central group of islands of the Azores, collected during cruises in 1999, 2001, and 2003; catch depth was 200 -800 m.

Incremental periodicity was clearly visible in all otolith specimens. Ages were determined by counting macro-structural formations, considered to be annual increments through verification by previous research (Abecasis et al. 2006). Whole and sectioned otoliths were prepared following the methods of Secor et al. (1992).

Five different models were applied to length-at-age data: the Von Bertalanffy growth function, Gompertz model, logistic model, power function, and simple linear model. All models were fitted under the assumption of homoscedasticity and normality (Wilks'-Shapiro test), using least squared non-linear regression, with the exception of the linear model, with residual sums of squares (RSS) as a criterion, using the software R (R Development Core Team 2011).

Typical growth parameters (L_∞, t_0 and k) were derived for each model. Akaike's Information Criterion with second order bias correction for small sample sizes (AICc) was used to evaluate models along with a rescaled estimate of AIC_c, Δ_i. (Burnham and Anderson 2004). Strength of evidence, was assessed through normalised likelihood estimations w_i, for each model.

Since the objective of growth modelling is often to infer a robust estimate of typical growth parameters, we used multi-model inference to reach an approximation of L_∞ by model averaging for the three asymptotic models, a strategy that has previously proved effective in cases where no one single model provided an optimal approximation of growth (Katsanevakis & Maravelias 2008, Mercier et al. 2011).

Results and Discussion

Analysis of length with age was found to vary with sex for both whole (F=5.759, p=0.017) and section counts (F=8.528, p=0.004) and therefore six treatments were considered throughout: entire population from entire otoliths (E_T), female whole otoliths (E_F), male whole otoliths (E_M), entire population from sectioned otoliths (S_T), female sectioned otoliths (S_F) and male sectioned otoliths (S_M). Fish for which no sex was recorded were only considered in the "T" treatments since these individuals

were few (n_E = 5; n_S = 3). Not all whole otoliths proved viable for reading as sections, but length ranges of fish whose otoliths were read whole (L_{EF} = 18.0 -40.0 cm, L_{EM} = 18.0 – 41.0 cm) were similar to those read as sections (L_{SF} = 19.0 - 40.0 cm, L_{SM} = 18.0 – 41.0 cm). Treatments were always considered separately in the calculation of rescaled model evaluation criteria.

RSS values were high across all treatments and models indicating that none of the models tested were an ideal fit for the data but this is not unusual in studies of this nature (e.g. Mercier et al. 2011). Comparing whole otoliths, models for individual sexes (RSS_{EF}= 863.5 – 891.4, RSS_{EM} = 1176.7 - 1252.7) fitted better than for the entire population (RSS_{EF}= 2350.0 – 2406.1), whereas for sectioned otoliths, fit for males approximated the population at large (RSS_{SM}= 1153.1 – 1196.7, RSS_{ST} = 1844.8 – 1197.7), while for females was somewhat lower (RSS_{SF}= 428.4 – 467.5).

Ranking models for whole otolith ages based on their re-scaled information criteria (Δ_i), no consistent hierarchy emerged in terms of best model beyond the first rank. Age-length relationships described through whole otolith ageing were best approximated with a linear model for the E_T and E_F only, with the logistic model being the most efficient in modeling growth in males. A similar situation was evident for ages determined from sectioned otoliths, with the linear model scoring best in all treatments. In this case, however, a trend emerged whereby the logistic modelwas consistently rated second, followed by the Gompertz, Von Bertanlaffy, and power models, respectively.

No single model stood out as being the most likely (w_i > 0.9) (Burnham and Anderson 2004). Model-averaged values were naturally modest (L_∞ = 49.8, whole; L_∞ = 47.5, section) and tended towards estimates derived for the Gompertz model, even though this did not bear the highest weight in most treatments. Published reference L_∞ values for *H. dactylopterus* vary considerably, from as little as 26.1 cm (Consoli et al. 2011) to as much as 70.7 cm (Peirano and Tunesi 1986), both from the Mediterranean Sea. Typical values from the Azores have ranged from 38.7 cm (Isidro 1987) to 59.1 cm (Abecasis et al. 2006). Both our direct estimations (L_∞ = 41.8 – 56.2 cm) and model averaged estimates (L_∞= 43.5 - 51.5 cm) are well within this range, with the latter bearing a more robust strength of evidence, and we are therefore confident that our data is representative of the fish populations in this region.

Since attempts to model the growth of commercially and ecologically important species is vitally important in stock management, it is somewhat incredible that a single growth model (VBGF) is consistently called up without consideration of other valid and possibly superior alternatives. A common characteristic of age-length data is the scarcity of data at one or other end of the distribution and it can, therefore, be a leap of reasoning to assume that growth fits neatly into an asymptotic model. The convenience of achieving readily comparable parameters has to be weighed against the performance of the model, and here again we add support to seeking alternatives to VBGF, particularly by way of the logistic and Gompertz models.

While we acknowledge a dearth of samples from younger age groups but others have shown that the pattern of growth in immature individuals is better modelled apart from adult fish (Mercier et al. 2011). *H. dacytlopterus* in the Azores matures between 3 and 5 years-of-age (Mendonça et al. 1998). Immature individuals, therefore, were not considered in our models. We would like to extend these evaluations to smaller size classes to investigate how VBGF performs in this context.

References

Abecasis, D.; Costa, A. R.; Pereira, J. G., and Pinho, M. R. 2006. Age and growth of bluemouth, Helicolenus dactylopterus (Delaroche, 1809) from the Azores. Fisheries Research, 79(1-2):148-154.

Burnham, K. P. and Anderson, D. R. 2004. Multimodel inference - understanding AIC and BIC in model selection. Sociological Methods and Research, 33(2):261-304.

Consoli, P.; Battaglia, P.; Castriota, L.; Esposito, V.; Romeo, T., and Andaloro, F. 2011. Age, growth and feeding habits of the bluemouth rockfish, *Helicolenus dactylopterus dactylopterus* (Delaroche 1809) in the central Mediterranean (southern Tyrrhenian Sea). Journal of Applied Ichthyology, 26(4):583-591.

Katsanevakis, S. and Maravelias, C. D. 2008. Modeling fish growth: multi-model inference as a better alternative to *a priori* using Von Bertalanffy equation. Fish and Fisheries, 9(2):178-187.

Kelly, C.J.; Connolly, P.L., and Bracken, J.J. 1999. Age estimation, growth, maturity, and distribution of the bluemouth rockfish *Helicolenus d. dactylopterus* (Delaroche 1809) from the Rockall Trough. Ices Journal of Marine Science, 56(1):61-74.

IsidroIsidro, E.J. 1987. Age and growth of the bluemouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809) off the Azores. ICES Doc C.M., 1987/G:63, 6 pp.

Mercier, L.. Panfili, J., Paillon, C., Ndiaye, A., Mouillot, D., and Darnaude, A. M. 2011. Otolith reading and multi-model inference for improved estimation of age and growth in the gilthead sea bream *Sparus aurata* (L.). Estuarine, Coastal and Shelf Science, 92(4): 534-545.

Peirano, A., andTunesi, L., 1986. Preliminary notes on the biology of *Helicolenus dactylopterus* (Delaroche) in the Ligurian Sea. Rapp. Comm. Int. Mer. Medit. 30, 233.

R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/

Secor David H.; Dean John Mark, and Laban Elisabeth H. 1992. Otolith removal and preparation for microstructural examination. In: Stevenson, D. K. Campana S. E., (Eds.). Otolith Microstructure Examination and Analysis. pp. 19-57.

White, D.B., Wyanski, D.M., Sedberry, G.R., 1998. Age, growth, and reproductive biology of the bluemouth from the Carolinas, U.S.A. Journal of Fish Biology, 53: 1274–1291.