



**UNIVERSITY OF THE AZORES**

**DEPARTMENT OF OCEANOGRAPHY AND FISHERIES**

## **Effects of natural mortality on the yield per recruit models**

**A thesis presented to the Department of Oceanography and Fisheries at the  
University of the Azores in partial fulfilment of the requirements for the degree in  
Master of Integrated Studies of the Oceans**

**Ana Maria Novoa Pabon**

**HORTA**

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## Abstract

Natural mortality ( $M$ ) is one of the most important parameter used on the Yield Per Recruit models and is commonly assumed as constant over time. However,  $M$  is strongly related to age, length or weight. This study analyses for the first time the effects of natural mortality in the yield per recruit estimates for the red black spot seabream (*Pagellus bogaraveo*) stock from the Azores archipelago. Input data were reviewed and length base YPR model was adopted in order to analyse the effect of  $M$  values, as input parameters, for constant  $M$  for all lengths ( $M_C$ ) and size-specific natural mortality ( $M_L$ ). Results show that estimated  $M_L$  for the *P. bogaraveo* decreases exponentially, with high mortality for juveniles ( $M=0.6$  for recruits) and low mortality for the adults ( $M\approx 0.2$  for Fork length  $>30$  cm). YPR curve at long term is virtually asymptotic for any option of  $M$  which the maximum is not possible to attain except for low level of  $M=0.2$ . Fishing mortality corresponding to maximum sustainable yield ( $F_{max}$ ) is not considered a useful target reference point for this species, because spawning biomass is usually very low (Spawning Potential Ratio - SSBPR  $<20\%$ ) at this level of fishing mortality. In general, increasing  $M_C$  produces a clear decrease on the cohort values by length for all stock characteristics (N/R, B/R, SSB/R, C/R and Y/R). For  $M_L$  hypotheses similar trends are observed on the behaviour of the stock characteristics but with important reductions on the maximum values. At the  $F_{0.1}$  strategy the yield value is lower as  $M$  increases but greater fishing mortality is required to produce the correspondent yield ( $Y_{0.1}/R$ ). Similar to the catch higher  $M$  implies higher depletion of the abundance (B or SSB). YPR analysis indicates that *P. bogaraveo* from the Azores is overexploited ( $F_{current} 53\% > F_{0.1}$  and SSBPR  $<20\%$ ). Changing the natural mortality does not change the perception of the stock status, with  $M_L$  implying higher reductions on the stock characteristics. The distribution of  $M_L$  has an effect similar to increase the  $M_C$ . However, the problem is how to reconcile the  $M_L$  with  $M_C$ . Under the same relative exploitation pattern ( $L_c$ ), increasing  $M_C$  has a high effect on YPR, reducing the stock characteristics and increasing the fishing mortality required to achieve the maximum sustainable catch. Implications of these variations for the stock assessment are discussed.

Keywords: Stock assessment, Yield per recruit, natural mortality, *Pagellus bogaraveo*, Azores.

## Resumo

A mortalidade natural ( $M$ ) é um dos mais importantes parâmetros utilizado nos modelos de captura por recruta e é geralmente assumido como constante ao longo do tempo. No entanto,  $M$  é fortemente relacionada com a idade, comprimento ou peso. Este estudo analisa pela primeira vez os efeitos da mortalidade natural na estimativa da captura por recruta para o stock de Goraz (*Pagellus bogaraveo*) no Arquipélago dos Açores. Os dados de entrada foram revistos e o modelo de YPR baseado no comprimento foi adotado a fim de analisar o efeito de  $M$  como parâmetros de entrada, considerando  $M$  constante para todos os comprimentos ( $M_C$ ) e mortalidade natural específico por comprimentos ( $M_L$ ). Os resultados mostram que  $M_L$  estimado para *P. bogaraveo* diminui exponencialmente, com elevada taxa de mortalidade nos jovens ( $M = 0,6$  para recrutas) e baixa mortalidade para os adultos ( $M \approx 0,2$  para comprimento furcal  $FL > 30\text{cm}$ ). A curva de YPR a longo prazo é praticamente assintótica para qualquer opção de  $M$ , o máximo não é possível atingir com exceção para baixos valores de  $M = 0,2$ . A mortalidade por pesca referente á captura máxima sustentável ( $F_{\max}$ ) não é considerado um ponto de referência alvo útil para a espécie, porque a biomassa desovante (proporção potencial de desova) correspondente é normalmente muito baixa ( $SSBPR < 20\%$ ). Em geral, o aumento de  $M_C$  produz uma clara diminuição sobre os valores da coorte por comprimento para todas as características do stock. Para a hipóteses  $M_L$  tendências semelhantes são observados no comportamento das características do stock ( $N/R$ ,  $B/R$ ,  $SSB/R$ ,  $C/R$  e  $Y/R$ ), mas com reduções importantes em relação aos valores máximos. Na estratégia  $F_{0.1}$  o valor de captura é inferior com o aumento de  $M$ , mas maior mortalidade por pesca é necessária para produzir a captura correspondente ( $Y_{0.1}/R$ ). Semelhante à maior captura  $M$  implica maior esgotamento da abundância ( $B$  ou  $SSB$ ). A análise de YPR para *P. bogaraveo* dos Açores indica que o stock está sobreexplorado ( $F_{\text{actual}} 53\% > F_{0.1}$  e  $SSBPR < 20\%$ ). Alterar a mortalidade natural não muda a percepção do estado do stock e a adopção de  $M_L$  a implica reduções mais elevadas sobre as características do stock. A distribuição de  $M_L$  tem um efeito semelhante ao de aumentar a  $M_C$ . No entanto, o problema é como conciliar a  $M_L$  com  $M_C$ . Sob o mesmo padrão relativo de exploração ( $L_c$ ), o aumento do  $M_C$  tem um alto efeito sobre YPR, reduzindo as características do stock e o aumento da mortalidade por pesca necessária para alcançar a captura máxima sustentável. São discutidas implicações destas variações para a avaliação do recurso.

Palavras-chave: Avaliação de recursos, captura por recruta, mortalidade natural, *Pagellus bogaraveo*, Açores

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## Introduction

The yield per recruit analysis (YPR) is the most commonly model used for fish stock assessment since its initiation with Beverton and Holt in 1957 (Xiao, 2002). Yield per recruit model assume that the population is in steady state conditions without major changes in mortality, growth and recruitment in the long term, but is independent of stock size (Kirchner, 2001; Xiao, 2002; Law *et al.*, 2012). Natural mortality (M) is the main parameter using in all mathematical models of fish stock dynamics and one of the most important parameter used on the YPR models. Usually it is difficult to measure natural mortality directly and for this reason is assumed in stock assessment as constant and independent for all age (Beverton & Holt, 1957; Gulland, 1965; Cadima, 2003). However, in many fish stock M is far from to be constant and this problem is extensive enough for not consider this variation (Vetter, 1988). M in general is extremely high for egg and larval stages, decrease in the juvenile, is low for old and mature fish, and increases again with senescence (Giménez-Hurtado *et al.*, 2008; Law *et al.*, 2012), indicating the variability of M with the age-structure. The main characteristic of M is to have influence on estimates of maximum yield (Y/RMAX; FMAX) as in Beverton and Holt yield models and cohort analyses (Vetter, 1988; Beyer *et al.*, 1999). However, these effects of M on the YPR models are not well addressed in the literature, particularly when related with the definition of the optimal exploitation pattern for the same M values considered as constant or when distributed by length (or ages).

The red black spot seabream (*Pagellus bogaraveo*) is considered a dominant species of the Azorean deep-water fishery (Pinho & Menezes, 2009). In the Eastern Atlantic red seabream distributed from south of Norway to Cape Blanc in Mauritania, Azores, Madeira and Canary Islands and Mediterranean Sea and in summer extends to west of Scotland (Pinho, 2003; Herrera, 2010; Lorange, 2010). Blackspot sea bream has been exploited in the Azores (Area Xa2), at least since the XVI century as part of the demersal fishery. The directed fishery is a hook and line fishery where two components of the fleet can be defined: the artisanal (hand lines) and the longliners (Pinho, 2003; Pinho & Menezes, 2005; Pinho & Menezes, 2009; Pinho *et al.*, 2014).

This stock has no management objectives defined because the uncertainty on the assessment, being precautionary managed based on trends of abundance indices and landings (ICES, 2014). Yield per recruit (YPR) analysis may be a useful tool to explore long term management objectives for red seabream and assess the actual state of the stock. Application of the YPR method to this species was already reported by Lorange (2010) for the Biscay Golf (ICES area VIII) and Pinho *et al.* (2014) for the Azores.

This study investigates for first time the effects of natural mortality in the yield per recruit estimates for the red seabream stock from the Azores archipelago. Main objectives are: a) Review the estimation procedures for natural mortality in order to evaluate the variability within and the difference between constant and size-specific  $M$  hypothesis; b) Analyse the effect of  $M$  on the behaviour of different YPR stock characteristics; c) Analyse the effect of changing  $M$  on the assessment results of Red blackspot seabream (*Pagellus bogaraveo*) stock of the Azores in order to define long term management objectives.

The following section presents a general background information about approaches for the natural mortality, gear selectivity, yield per recruit and optimal exploitation pattern often used in fisheries stock assessment models and implications in the management including a brief review of the Azorean red seabream stock and fisheries. Section 2 describes the methods undertaken, section 3 describe the results found and section 4 focus on the discussion of the results of this study.