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Life-history of the meagre *Argyrosomus regius* in the Gulf of Cádiz (SW Iberian Peninsula)

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ABSTRACT

Argyrosomus regius is an important fishing resource in the Gulf of Cádiz and from the Gulf of Guinea to the Bay of Biscay, including the Mediterranean Sea. Large adult meagres, *c.* >110-cm total length (L_T), apparently reproduce in coastal brackish waters. The objective of this study was to analyse maturity and growth in this species, and together with the analysis of landings, formulate a conceptual model of its life-history along the Spanish coast of the Gulf of Cádiz. Large *A. regius* were landed near estuaries from March to August, all of which were mature. Small (20–70 cm L_T) *A. regius* were landed all year round; females were immature, whereas 26% of the males presented precocious maturation. The estimated length-at-first maturity was 61.6 cm for males and was inferred to occur within the 70–110 cm range in females. The estimated growth constant k and L_∞ of the von Bertalanffy model were 0.15 year^{-1} and 171.9 cm L_T respectively. Estimates of relative yield-per-recruit suggest that growth overfishing is likely to occur under the current absence of regulations. According to the proposed conceptual model, *A. regius* spawns in estuaries from March to August. Early stages inhabit the estuaries and then recruit to coastal waters where they stay during the first 2–3 years of life. Thereafter, intermediate–size *A. regius* (70–110 cm L_T) become unavailable to the local fishery. Once they mature, they migrate back to spawn, and to be fished again by the fishery.

1. Introduction

The meagre *Argyrosomus regius* (Asso, 1801) is a teleost fish of the family Sciaenidae distributed in subtropical waters of the Eastern Atlantic ranging from Norway to Congo, including the Mediterranean and the Black Seas (65°N–6°S, 23°W–36°E). *A. regius* can attain up to *c.* 200 cm total length (L_T; Quero and Vayne, 1987). Spawning is believed to occur within or nearby estuaries and salt marshes, where large-size specimens are observed during a certain period of the year (Champagnat and Domain, 1978; Quero and Vayne, 1987) and small-size juveniles (*c.* <20 cm) are found (Quero and Vayne, 1987; Cabral and Ohmert, 2001; Baldó and Drake, 2002; Catalán et al., 2006).

The other eight *Argyrosomus* species are distributed in tropical and subtropical waters of the south eastern Atlantic, Indian and western Pacific Oceans, also inhabiting coastal and inland brackish waters (Griffiths and Heemstra, 1995). The reported maximum sizes for half of them (*Argyrosomus japonicus*, *Argyrosomus inodorus*, *Argyrosomus coronus* and *Argyrosomus hololeptidotus*) are over 140 cm. These characteristics (large maximum sizes and reproduction in coastal waters) are frequent among other Sciaenids (e.g. *Sciaenops ocellatus*; Holt et al., 1983).

A. regius has been a fishing resource in the Gulf of Cádiz (SW Iberian Peninsula; Fig. 1) since the early first millennium B.C. (Morales-Muñiz and Roselló, 2008). Nowadays, the local Spanish fleet lands an average of 159 t year^{-1} (2005–2007), with a corresponding first-sale value of 1 million € (0.43% in weight and 1.09% in € of total landings in the Spanish coast of the Gulf of Cádiz; http://www.juntadeandalucia.es/agriculturaypesca/portal/opencms/portal/portada.jsp). Nevertheless, its relative final added value is possibly higher because it is highly appreciated in restaurants and by recreational anglers with a high percentage of landings by local artisanal fleets, which in general are more efficient in number of fishermen employed per capital invested, fish landed per tonne of fuel consumed

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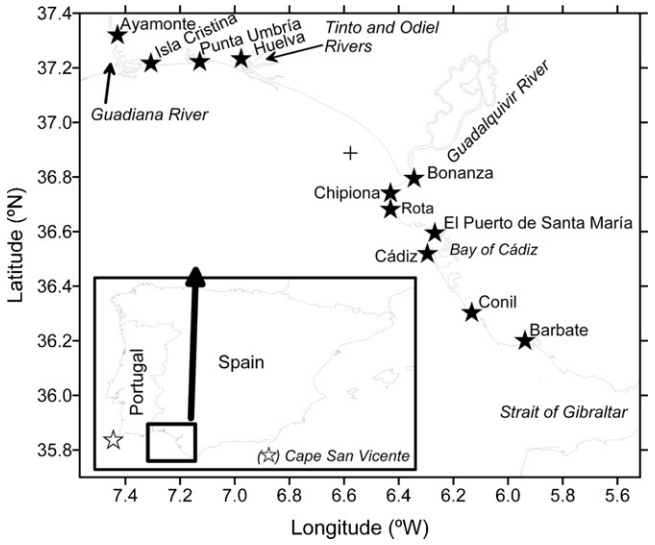

Fig. 1. Study area. Location of local fishing harbours (stars) with meagre landings in 2006 and 2007, the main estuarine and salt-marsh systems (italics) in the area and the coastal station (cross) at which surface water (5 m) temperature and salinity were measured.

and fish landed per fish bycatch discarded (Misund et al., 2002).

Average world catches of *A. regius* were 4408 t year^{-1} from 2005 to 2007 (FAO, 2007). The total real value of landings may, however, have exceeded that amount because FAO data for some countries were unavailable, estimated or incorrect (e.g. Spanish landings were 0 t). This underreporting and a general worldwide tendency to overfish top predators (Christensen et al., 2003) raises a concern about the status of *A. regius* stocks, exacerbated because of the lack of basic biological information on which to base management options. In fact, there are not specific regulations for the *A. regius* fishing along the Spanish coast of the Gulf of Cádiz. Most of the other eight *Argyrosomus* species, with the exception of *A. japonicus* (Silberschneider and Gray, 2008; Silberschneider et al., 2009), lack biological information.

The objectives of the present study were (1) to determine basic biological parameters (size at age, growth rate and size at maturity) for *A. regius* in the Gulf of Cádiz, and (2) together with the analysis of Spanish local *A. regius* landings and previous information about the presence and abundance of larval (Baldó and Drake, 2002) and juvenile stages (Baldó and Drake, 2002; Catalán et al., 2006) in the area, formulate a conceptual model of its life cycle.

2. Materials and methods

The analyses of the fishery information, size structure of landed *A. regius* and biological samples were from the Spanish coast of the Gulf of Cádiz (SGoC), although the geographical extension of the Gulf also includes the southern Portuguese coast, from the Guadiana River to Cape San Vicente (Fig. 1).

2.1. Landings statistics

Total weight of *A. regius* landed per fishing vessel and day in each fishing harbour of the SGoC was obtained from the data base *Id@pes* (Consejería de Agricultura y Pesca, Junta de Andalucía, Spain). Data from 2005 were used to establish the sampling strategy for the analysis of the size-structure of landed *A. regius*. Total length and fleet type (i.e. bottom-trawl, purse-seine, multi-gear artisanal, etc.) of each fishing boat were obtained from the Operating Fishing Fleet Census (http://www.mapa.es/es/pesca/pags/flota/consulta.asp; Ministerio de Medio Ambiente y Medio Rural y Marino, Government of Spain).

2.2. Sampling

The total length (L_T; to the lower centimetre) of all *A. regius* landed in the fishing harbours of Chipiona and Conil and by the bottom-trawl fleet of Isla Cristina was measured on 1 day each month from June 2006 to September 2007. This sampling targeted the two main fleet types landing *A. regius*: artisanal small-size vessels and bottom-trawlers, which respectively landed 72.1% and 17.3% of the total catch by weight in 2005; more than 90% of *A. regius* landings in Conil and Chipiona in 2005 were by small-size artisanal vessels, which capture this species using gill-nets and hook lines. Landings in Chipiona and Conil and from Isla Cristina bottom-trawlers accounted for 46.8% of the total tonnage of *A. regius* in the SGoC in 2005. These harbours are far from each other along the coast of the Gulf (Fig. 1) and the local coastal oceanographic regimes differ (Ruiz and García-Lafuente, 2006; Prieto et al., 2009), as do their bottom characteristics (sedimentary *vs.* rocky; Ramos et al., 1996) and faunal demersal assemblages (Catalán et al., 2006; Anon., 2008).

Individuals for otolith and gonad analysis were obtained from March 2006 to April 2008 through an agreement with a local dealer at the Chipiona fish market in order to reduce the cost of sampling a large, high-priced species. Large *A. regius* (*c.* >70 cm L_T) were targeted for the whole period. Their L_T was measured to the lower cm and their total (W_T) and eviscerated (W_E) weight were determined with 100-g precision at the dealer. Only the heads and the viscera, including the gonads, were transferred to the laboratory. Small individuals (*c.* <70 cm L_T) were sampled from April 2007 to April 2008 and were fully processed in the laboratory; L_T was determined in millimetres and W_T and W_E in grams. Occasionally, otoliths and information about sex were obtained from some *A. regius* measured during the monthly size-structure sampling at Chipiona (see above). Therefore, W_E, gonad weight or maturation stage of those specimens were not available. Another five *A. regius* were obtained from Conil harbour in March and April 2006 and another 13 from the Rota harbour in March and May 2005 in which the gonads were not analysed. In total, 432 *A. regius* were processed.

2.3. Gonads and maturation

The gonads were fixed in a 4% formaldehyde solution for 24–48 h. The formalin solution was injected into the internal tissue of the larger specimens to facilitate preservation. Thereafter, the gonads were dehydrated, embedded in paraffin, sectioned at 3 μm and stained with Harris haematoxylin, and counterstained with eosin. Maturation stages in males and females were classified after microscope observation according to Micale et al. (2002) and Wallace and Selman (1981), with stages III–V being considered as reproductively mature or active. Size at first maturity was analysed in *A. regius* sampled from March to August, i.e. during the reproductive period. A binomial Generalized Linear Model (GLM) with a *logit* link function was used to estimate the length-at-first maturity for males; i.e. the length at which the average probability of being reproductively mature is 0.5. There was no overlap in L_T between non-active and active females (*c.* a 30-cm gap). Therefore, no length-at-first maturity model could be estimated for females.

2.4. Otoliths and age

The sagitta otoliths were extracted and a 1-mm section was cut from each right otolith across the transversal plane at the nucleus (Fig. 2). The sections were examined under a stereomicroscope