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Reproductive cycle and minimal length at sexual maturity of *Engraulis encrasicolus* (L.) in the Zrmanja River estuary (Adriatic Sea, Croatia)

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Abstract

The reproductive cycle of anchovy, *Engraulis encrasicolus* (L.), was studied from monthly random samples of purse seine catches. A total of 1477 anchovy specimens were collected from January to December 2003 in the Zrmanja River estuary (Novigrad Sea). The analysis was based on the temporal evolution of gonadosomatic index, mass and stage of gonads. The total length of anchovy ranged from 4.5 to 14.5 cm and mass from 0.56 to 19.80 g. Sex ratio was slightly different from 1:1; the females were insignificantly predominated (♂/♀ = 0.99). The period of reproductive activity was from April to September coinciding with the most developed stages of gonads as well as with the highest gonad weights, and gonadosomatic indices. To estimate the length at maturity, a sub sample of 454 anchovy was taken from May to July (peak of anchovy spawning period). The length at which 50% of anchovy were mature (L_{50}) was calculated to be 8.2 cm. The length–weight relationship of anchovy was described by the expression: $W = 3.51 \times 10^{-3} L_T^{3.211}$ ($r^2 = 0.998$). The relationships between total length–standard length and total length–fork length are $L_T = 1.1405 L_S + 0.2420$ and $L_T = 1.0425\ L_F + 0.3944$, respectively.

Keywords: *Engraulis encrasicolus*; reproduction; gonadosomatic index; sex ratio; Zrmanja River estuary; Adriatic

1. Introduction

Anchovy is the only European species of the Engraulidae family and has a large distribution in the northeastern Atlantic, that is from the North Sea to near equator, including the entire Mediterranean basin. It is also one of the most important commercial fish species in the Adriatic Sea. Anchovy catches have experienced large interannual fluctuations in recent years (Sinovčić, 2001; Cingolani et al., 2003). A severe collapse happened from 1986 to 1998, caused by the absence of recruitment in that period. The lowest recorded Croatian landing was 298 tonnes (1996). The stock assessment of anchovy indicates that this species has recently been increasing in number throughout the whole Adriatic (Cingolani et al., 2003). The Croatian landings increased to a maximum value of 7473 tonnes in 2004. The reasons for this gap in recruitment are still unknown.

Anchovy is a multiple spawner with continuous gametogenesis, external fertilization and no parental care (Demir, 1965). As in other pelagic spawners, *Engraulis encrasicolus* fecundity is very high, though not predetermined. It depends on the spawning season duration and previously stored reserves and food availability to ensure the continuous development of gametes (Hunter and Goldberg, 1980). This species is a spring–summer spawner and it has been observed that the age of first maturity occurs at one year (Sinovčić, 1988, 2000). It probably varies in length from year to year because ecological conditions have an immense influence on the sexual maturity of fish, in particular the amount of available food and the temperature (Nikolsky, 1963; Blaxter, 1969).

The objective of this study was to gain information on the reproductive traits of anchovy, *Engraulis encrasicolus* (L.) in the Zrmanja River estuary, which is a nursery and spawning ground of this species. These traits are sex ratio, spawning period and size at sexual maturity.

The Novigrad Sea (44° 15′N; 15° 30′E) is the estuary of the Zrmanja River (Fig. 1). The values of phosphate reached

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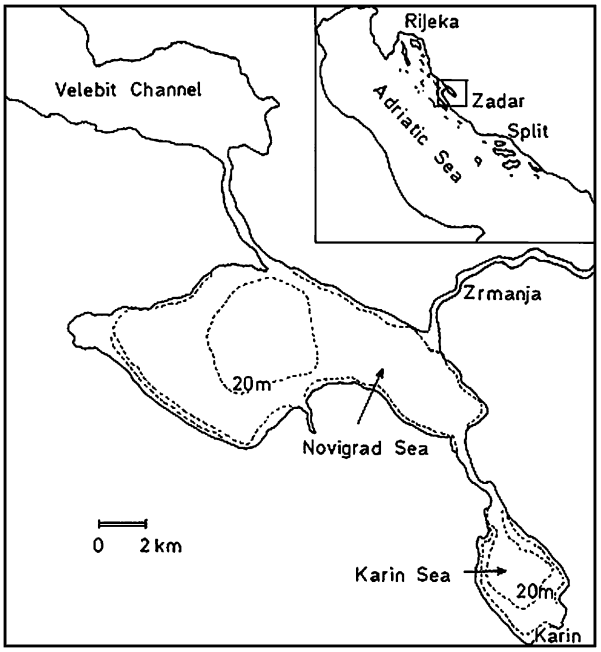

Fig. 1. Map of the study area.

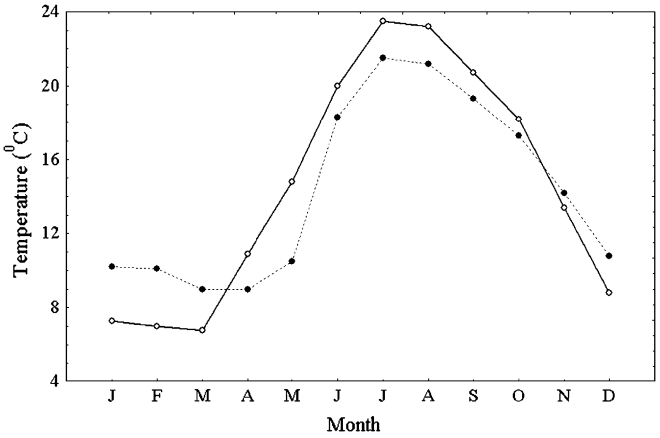

Fig. 2. Monthly variations of water temperature (○, 1 m; ●, 10 m) in the Novigrad Sea.

peak values of 12.8 μmol l^{-1} in the Novigrad Sea (Buljan, 1969; Škrivanić and Barić, 1979) and make this area one of the richest in the eastern part of the Adriatic, which, generally speaking, is otherwise oligotrophic. A rather high level of oxygen saturation, almost 100%, particularly during spring and summer was noticed in this area. In June the values were as high as 128% (Buljan, 1969). Based on the phytoplankton quantity, the Novigrad Sea is in the highest category of naturally eutrophied areas in the eastern part of the Adriatic Sea (Viličić, 1989) with a slight anthropogenic influence (Viličić et al., 2001). Results of quantitative research on tintinnids, which are components of juvenile small pelagic fish food (Shmeleva, 1963), have shown increased amounts in the Novigrad Sea, particularly during spring and summer (Kršinić, 1987).

2. Material and methods

Anchovy specimens ($n = 1477$) were obtained by sampling 12 purse seine catches of small pelagic species from the Zrmanja River estuary (Novigrad Sea). Anchovy were caught by purse seine using 8 mm mesh under artificial light, during the night but not during a full moon. Samples were collected monthly from January to December 2003. During that period, at water surface (1 m) and at 10 m, the temperature of Novigrad Sea varied between the lowest surface temperature of 6.0 °C (mean 6.8 °C) and of 8.0 °C (mean 9.0 °C) at 10 m depth (March, 2003), and the highest surface temperature of 26 °C (mean 23.5 °C) and 24 °C (mean 21.5 °C) at 10 m depth (July) (Fig. 2). An isotherm is evident in mid-March and in mid-October. During late autumn and winter (November–March), the existence of warmer seawater (thermal inversion) is noted in the deeper layer (10 m) of the Novigrad Sea.

In the laboratory, fish were measured (nearest mm in total/L_T/, fork/L_F/ and standard length/L_S/), weighed (nearest cg in wet mass) and dissected for determination of sex and assessment of gonad maturity stages immediately after landing.

Gonad maturity stages are:

I – Testis flattened, very small and translucent. Ovary rounded, translucent. Such can be seen only in specimens that have not reached their first maturity.
II – Testis flattened, grey, ovary rounded, pink; about a quarter of length of visceral cavity.
III – Testis becoming flatter, white; some oocytes visible to the naked eye; more than half the length of visceral cavity
IV – Testis firm, white; ovary orange, large oocytes visible, gonads fill about two-thirds of visceral cavity.
V – Testis creamy white, parts becoming soft; ovary light red, oocytes opaque; gonads almost fill visceral cavity.
VI – Milt and hyaline oocytes run from vent on slight pressure.
VII – Gonads smaller and less firm than in stage V. Patches of grey and white in testis give a mottled appearance. Ovary slack and bloodied; many oocytes still present.
VIII – Gonads flaccid, about a third of visceral cavity; testis grey-white, ovary dark red.

The analysis of the reproductive cycle was based on the monthly evolution of the gonad maturity stages, gonad weight (W_g) and gonadosomatic index (I_g). Gonadosomatic index (I_g) was calculated by expressing the monthly gonad weight as a proportion of the total body weight ($I_g = 100Wg/W$, where W is somatic fish mass and Wg is gonad weight). This index was calculated for each of the analysed individuals and finally, a mean monthly index was estimated.

The mean size at 50% sexual maturity was estimated for male ($n = 255$) and female ($n = 199$) anchovy in the peak of the anchovy spawning period (May–July). Ovaries with yolked, semi-hydrated and hydrated oocytes as well as ripe testis (V and VI maturity stages) were taken into account in order to establish the minimal and mean size at first maturity (L_{50}). The percentage of mature males and females in each 0.5 cm size class was fitted to a logistic