

## Geographical variation in the reproductive potential of European anchovy in the central Mediterranean Sea.

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**Summary:** The Strait of Sicily (GSA 16) it is characterized by an high interannual variability in circulation, resulting in very different environmental conditions. The Central Tyrrhenian area (GSA 10) displays a lower variability of circulation in comparison to other areas of the same basin and the Strait of Sicily. Adult specimens of European anchovy (*Engraulis encrasicolus*) were collected in 2011 and 2013, during surveys conducted in order to evaluate anchovy spawning biomass in both central Mediterranean and Tyrrhenian Sea. Both years, the surveys were carried out during the anchovy spawning season, as confirmed by histological analysis of anchovy ovaries, showing the presence of active spawning females. Results highlighted significant differences in reproductive parameter only in some of the analyzed surveys. Batch fecundity in 2013 showed higher values in 2011 the Strait of Sicily than in the Tyrrhenian Sea and gonadic state presented a certain variability among surveys. These results about reproductive traits of the same species in different habitat conditions may allow to develop assessment models of the stock status, according to the European Union's ambitious Marine Strategy Framework Directive (2008/56/EC).

**Introduction:** The European anchovy (*Engraulis encrasicolus*) represents one of the main commercial resource for Mediterranean fishery (Leonart et al., 2003). In the Strait of Sicily, corresponding to the Geographical Sub Area (GSA) 16, where the average annual catches have been estimated around 5000 t, while in the Tyrrhenian Sea (GSA 9 and 10) this resource is more important with recorded catches higher than 10.000 t (DCF 2007-2012). Although the economic importance of this species there is still a lack of scientific data to provide a stock assessment especially with regard to the new EU Marine Strategy framework Directive (2008/56/EC). Variability in reproductive parameters of an anchovy stock, such as fecundity, spawning frequency or sex ratio, has been showed to affect heavily the spawning stock biomass fluctuations (Somarakis et al., 2012). In the Strait of Sicily reproductive aspects of *E. encrasicolus* were assessed together with the environmental variability (Basilone et al., 2006 and 2013), while for the Tyrrhenian area poor data are still available in literature. The areas selected for this study are clearly different from the oceanographic point of view mainly due to the general Mediterranean circulation features. Water circulation in the Strait of Sicily, connecting Eastern and Western Mediterranean basins, is mainly driven by Atlantic Ionian Stream (AIS). The AIS is characterized by high inter-annual variability in intensity and path (Basilone et al. 2013); despite this variability the AIS generates semi-permanent upwelling phenomena. The surface circulation in the Strait of Sicily, together with South Tyrrhenian, presents higher dynamism than in central and North Tyrrhenian, both at inter and intra annual scales (Astraldi et al., 2002). This study represents the first attempt to carry out a comparison among the main reproductive traits of anchovy stocks inhabiting two different Mediterranean areas, the Strait of Sicily and the Tyrrhenian Sea.

**Materials and Methods.** In 2011 and 2013, bioacoustics surveys, for monitoring anchovy population, were conducted in the Strait of Sicily and the Tyrrhenian Sea, during its spawning season. Adult females of European anchovy were caught on board a R/V equipped with a pelagic trawl net. From each trawls 60 ( $\pm 16$ ) specimens were random selected and measuring total length ( $\pm 1$ mm), total and somatic weight ( $\pm 0.1$ gr), further sex and maturity stages were determined on fresh material by macroscopic examination. Ovaries were extracted and preserved in buffered formalin (4%) and analyzed by traditional histological preparation and stained by Haematoxylin and Eosin (H&E) Harris Method (Hunter and Macewicz, 1985). After preparation each ovary thin section was examined under an optical microscope according to ICES guidelines (ICES, 2008). To avoid bias in weight measurement of somatic and gonadic tissues, due to the hydration process, all the spawning females (stage 4) were not included in the analysis. Batch fecundity (BF), spawning fraction (S), sex ratio (R) and average female weight (W) were estimated as weighted mean values, using the equations proposed by Stauffer and Picquelle (1985) for the Daily Egg Production Method (DEPM). Since were sampled a low number of hydrated females to apply the gravimetric method, BF estimation was obtained by the direct relationship between the number of eggs per batch and the ovary-free weight (Draped and Smith, 1966). Daily specific fecundity (DSF) for each survey were obtained as the ratio between BF, S, R and W. The reproductive parameters were estimated only for females.

**Results and Discussion.** A total amount of 2630 anchovy specimens were processed: 1336 females and 1294 males. Results of a Kruskal-Wallis H test, showed significant differences in length ( $p < 0.001$ ) mainly between Strait of Sicily and Tyrrhenian Sea in 2013 and to less extent also in 2011 ( $p < 0.005$ );

while no differences were recorded between the two areas in 2011 (Table 1a). Similar results were observed also for weight of fishes with similar values (Table 1b).

Average values obtained for each reproductive parameters (BF, S, R and DSF) were showed in table 2 with their coefficient of variations.

Although no significant differences were observed for S, R or DSF (Kruskall-Wallis H test;  $p > 0.1$ ) the analysis of GSI and BF median values recorded some variability (Fig. 1). Significant lower values in GSI were recorded mainly between Ancheva 2011 and the other surveys. Batch fecundity differences were observed mainly in Ancheva 2013 with higher median values ( $F \sim 7000$ ) than the other three surveys ( $F \sim 5000$ ).

To evaluate the effect of size on the in sexual maturity or in batch fecundity, an ANCOVA was performed taking GSI or BF as dependent variable, the logarithm of weight as continuous predictor and the survey as factor. Results showed for both variables significant differences respectively in the gonadic state ( $F_{3,1226} = 233.89$ ;  $p < 0.001$ ) and in fecundity ( $F_{3,1228} = 34.45$ ;  $p < 0.001$ ). Although both areas present several distinctive physical and biological features, in this study the differences in reproductive parameters appear moderate and in some case less important than interannual variability also within the same area. Such preliminary results suggest careful attention when reproductive potential parameter are incorporated in stock assessment model for the SSB estimation of anchovy stocks. Namely the use of parameters from literature or past studies appear potentially dangerous when significant variation in weight or length may exist. Otherwise the observed inter areas similarity could become important when some parameter is not available for some area or year. Although these data are the first attempt to analyse the anchovy reproductive biology in south and central Tyrrhenian sea, however further data have to be explored in the future to obtain more conclusive and exhaustive results.

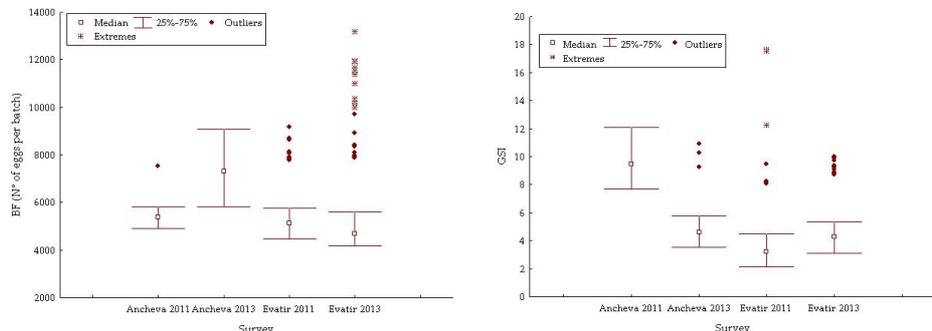
**Table 1: "Multiple Comparisons z' values by Survey. K-W test on Length (a): H (3,N= 1335) =206.09  $p < 0.001$ ; and on weight (b): H (3, N= 1335) =275.17  $p < 0.001$ .**

	(a) Length			(b) Weight		
	Ancheva 2013	Evatir 2011	Evatir 2013	Ancheva 2013	Evatir 2011	Evatir 2013
Ancheva 2011	5.96**	0.41	3.25*	7.98**	1.84	1.93
Ancheva 2013		9.20**	14.35**		14.13**	15.62**
Evatir 2011			4.55*			0.01

Significance level of dissimilarity (\*\* \*) ( $p < 0.001$ ); (\*) ( $p < 0.005$ )

**Table 2: Mean values and relative coefficient of variations (CV) of each reproductive parameters, estimated for each survey**

Parameters	Strait of Sicily		Tyrrhenian Sea	
	2011	2013	2011	2013
TL ( $\pm$ SD)	122.72 ( $\pm$ 8.46)	133.53 ( $\pm$ 15.04)	123.93 ( $\pm$ 11.03)	118.34 ( $\pm$ 14.88)
TW ( $\pm$ SD)	11.06 ( $\pm$ 2.62)	17.09 ( $\pm$ 5.96)	10.98 ( $\pm$ 3.38)	10.90 ( $\pm$ 5.07)
F (CV)	6592 (0.13)	5428 (0.21)	5234 (0.15)	5091 (0.15)
S (CV)	0.09 (0.51)	0.11 (0.25)	0.18 (0.24)	0.15 (0.24)
R (CV)	0.35 (0.48)	0.48 (0.31)	0.39 (0.46)	0.41 (0.25)
DSF	16.84	15.75	33.57	29.9



**Fig.1: median values with their percentiles of batch fecundity (a) and GSI (b) for each survey. Outliers and extreme values were also plotted.**

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