Hydrobiologia **503:** 117–120, 2003.
M.B. Jones, A. Ingólfsson, E. Ólafsson, G.V. Helgason, K. Gunnarsson & J. Svavarsson (eds), Migrations and Dispersal of Marine Organisms.

Anchovy egg and larval distribution in relation to biological and physical oceanography in the Strait of Sicily

A. Cuttitta[1], V. Carini[1], B. Patti[1], A. Bonanno[1], G. Basilone[1], S. Mazzola[1], J. García Lafuente[2], A. García[3], G. Buscaino[4], L. Aguzzi[5], L. Rollandi[1], G. Morizzo[1] & C. Cavalcante[1]
[1]*Istituto di ricerche sulle Risorse Marine e l'Ambiente, Consiglio Nazionale delle Ricerche – Via L.Vaccara 61, 91026 Mazara del Vallo (TP), Italy*
[2]*Department of Applied Physics, University of Malaga, Campus de Teatinos, E.T.S.I. Telecomunicacion, Malaga, Spain*
[3]*Instituto Español de Oceanografia (IEO), Fuengirola, Spain*
[4]*Dipartimento Scienze Ambientali, Università di Venezia "Ca Foscari", Calle Santa Marta, Italy*
[5]*Agenzia Regionale per la Protezione dell'Ambiente Lazio – Via Garibaldi 114, 02100 Rieti, Italy*
E-mail: angela@irma.pa.cnr.it

Key words: Engraulis encrasicolus, anchovy, zooplankton, eggs, larvae, Strait of Sicily

Abstract

The European Anchovy (*Engraulis encrasicolus*, Linnaeus, 1758) represents one of the most important fishery resources in some areas of the Mediterranean. This short-lived, small pelagic fish is characterized by large interannual fluctuations, probably as a result of environmental variability. As part of the European Project Med 98-070, the main aim of which was the study of the anchovy population in the Strait of Sicily, icthyoplankton surveys were carried out between 1999 and 2001, during the peak spawning season for anchovy. Present work reports the relationship between meso-zooplankton biomass and the abundance of anchovy eggs and larvae in the Strait of Sicily. Data on anchovy egg abundance showed that the main spawning area was located in the north-western region of the study area. The branch of the Atlantic Ionian Stream, running parallel to the southern Sicilian coast, acts as a transport mechanism for anchovy eggs and larvae towards the southernmost end of the island, off Cape Passero. Observed distributions were largely consistent with local hydrographic features, which allow larvae to be retained in areas providing the necessary feeding conditions for recruitment success.

Introduction

The European anchovy (*Engraulis encrasicolus*, Linnaeus, 1758) represents one of the most important fishery resources in some areas of the Mediterranean (Fig. 1). Interannual variability in biomass of such small pelagic fish species may be due to fishing effort and/or recruitment success (Borja et al., 1996). The latter is dependent on several biological and environmental parameters, amongst which the most important limiting factor is the presence and availability of food (Casavola et al., 1998; Tikhonova et al., 2000; James et al., 2003). The dynamics of the biomass of the anchovy population in the Strait of Sicily were addressed by two European projects (Med 96-052 and Med 98-070). Within the framework of these projects, relationships between meso-zooplankton biomass and anchovy egg and larval abundance and distribution in the Strait of Sicily were examined in relation to possible transport mechanisms and interannual variations of their distribution. Distribution of anchovy early stages is highly dependent on surface water dynamics (García Lafuente et al., 2002). The surface circulation in the study area is controlled mainly by the Modified Atlantic Water (MAW) motion, the so-called Atlantic-Ionian Stream (AIS, Fig. 1) (Robinson et al., 1999). According to Robinson et al. (1999), the current enters the Strait of Sicily from the west, describing a large cyclonic meander which embraces the Adventure Bank, then approaches the shore near

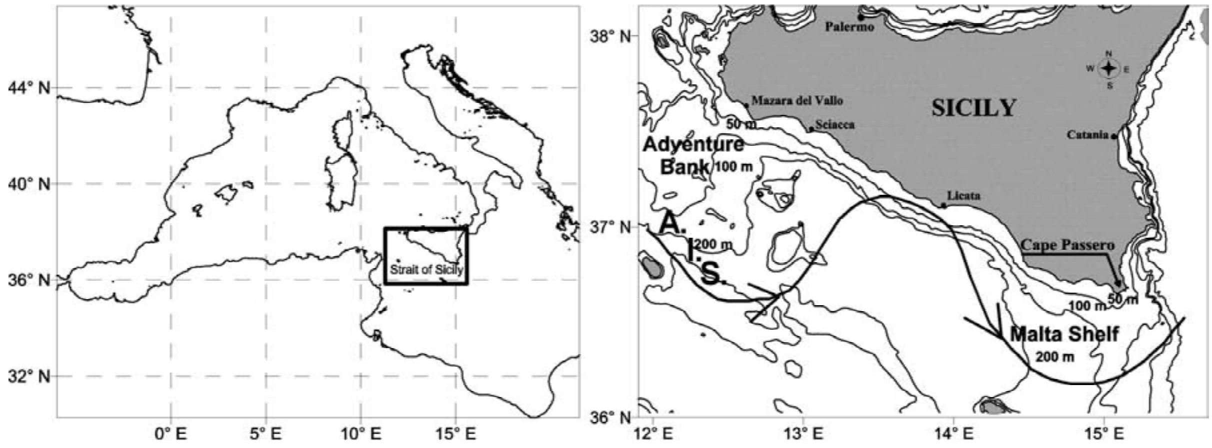

Figure 1. Western and Central Mediterranean, with the Strait of Sicily shown within the box (left panel), and a detailed map of the study area shown in the right panel with the average path of Atlantic Ionian Stream (A.I.S.) superimposed.

the middle of the southern coast of Sicily and separates again when it encounters the shelf of Malta. In doing so, the AIS forms two large cyclonic vortices, the first, already mentioned, and the second around the Malta shelf, off Cape Passero. The path of AIS and its year-to-year variability has consequences for other predominant hydrological phenomena occurring in the region, such as the extension of upwelling and the formation of frontal structures.

To achieve the aims of this study, hydrological and ichthyoplanktonic surveys were conducted from 1999 to 2001, during the peak of the anchovy spawning period (Giráldez & Abad, 1995; Cuttitta et al., 1999).

Materials and methods

Annual summer cruises were carried out from 1999 to 2001 using the O/V “Urania”. In 1999, the cruise was carried out from 6 to 17th June; in 2000, from 23rd June to 13th July; and in 2001, from 5th to 26th July. Plankton samples, collected on the continental shelf of the southern Sicilian coast from stations based on a 4 n/mile step grid, were obtained using Bongo 40 oblique hauls carried out at a speed of 2 knots using a 200 μm mesh size net for both sides of the frame. Hauls were towed from the bottom to the surface or from 100 m to the surface where depth was more than 100 m. Ichthyoplankton and meso-zooplankton samples were collected simultaneously. A total of 345 stations was carried out: 70 stations in 1999, 131 stations in 2000, and 144 stations in 2001. Hydrological data were acquired during the same cruises by means of a CTD probe model SBE 911. CTD casts were analyzed using Ocean Data View software and the path of AIS was depicted by the minimum salinity technique. Biological samples were preserved in 4% buffered formaldehyde and seawater solution. Sorting of ichthyoplankton was performed in the laboratory by means of a stereo binocular at $\times 12$ magnification. Fish eggs and larvae were extracted, and anchovy eggs and larvae counted. Zooplanktonic biomass, as dry weight (mg/m^3), was obtained by drying half the sample in an oven at 60 °C for 48 h, after removing the fish eggs and larvae. Data interpolation (kriging method) and drawing of surface distribution maps was done by means of Surfer Golden software.

Results

Presence of eggs in the middle and southern part of the continental shelf (Fig. 2 a, b, c) was interpreted as indicating the spawning areas. Development from egg to larval stage is temperature dependent and, for this species in this area, takes about 36 h (Holden & Raitt, 1975). The 1999 and 2000 distributions, in particular, indicated high interannual variability in egg distribution. The 2001 data identified a main spawning ground in the northern area, with additional spawning noted in the south area of Cape Passero. Larval distribution maps (Fig. 3 a, b, c), particularly for 2000 and 2001, indicated a more regular pattern than that for eggs, with a clear are of concentration on the southernmost Maltese shelf. Offshore larval transport was indicated, probably due to local circulation features

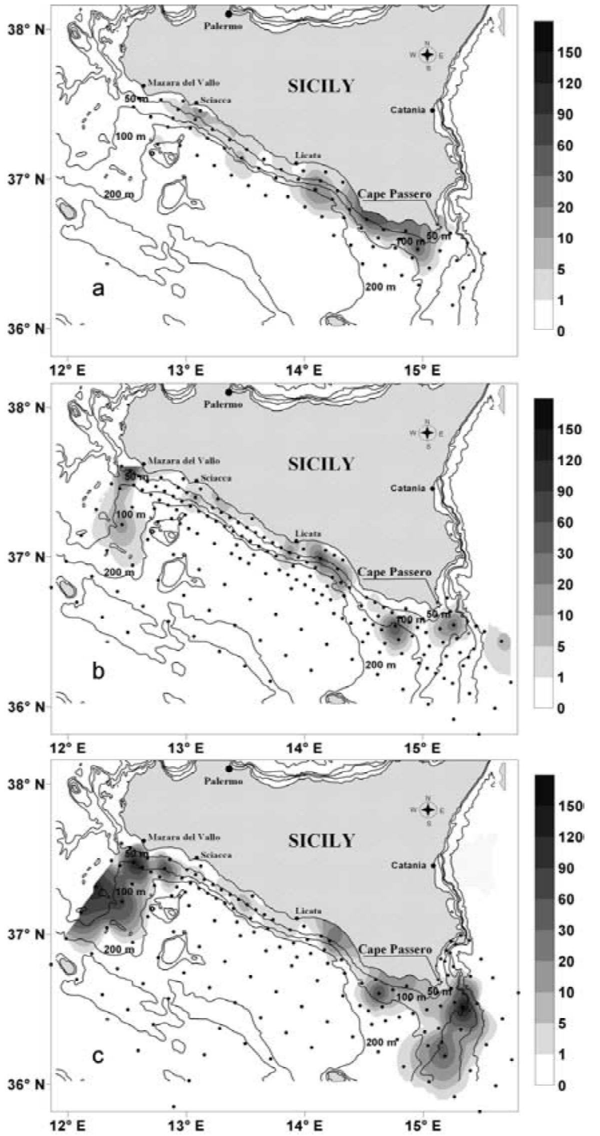

Figure 2. Distribution of anchovy eggs (counts) during surveys carried out along the Sicilian coast in 1999 (a), 2000 (b) and 2001 (c).

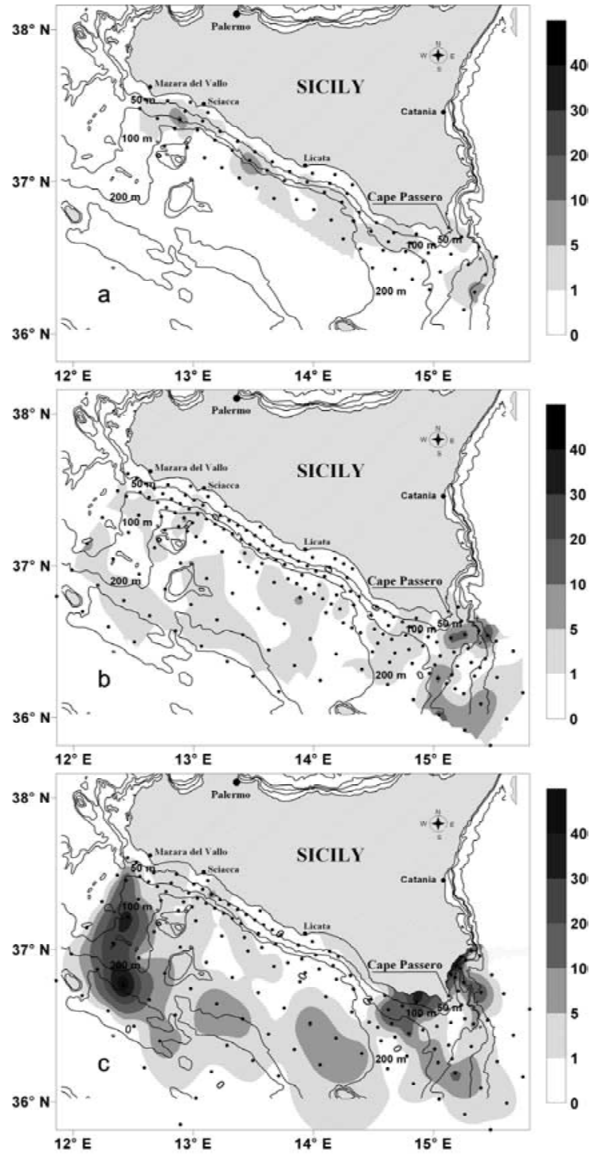

Figure 3. Distribution of anchovy larvae (counts) during surveys carried out along the Sicilian coast in 1999 (a), 2000 (b) and 2001 (c).

(García Lafuente et al., 2002). Zooplankton distribution (Fig. 4 a, b, c) reflected the same trends shown by eggs and larvae (i.e. concentrated mainly in the north and off the southern tip of the Sicilian coast); highest densities were found in Mazara del Vallo and the Cape Passero sea areas. Analysis of CTD casts showed that the AIS path deviated from the 'mean' path shown in Figure 1, especially in 1999 and 2000, when the AIS flow was much more distant from the shore, and only closed in to the shores of Sicily in the southern region. As a consequence, coastal waters in the northern and central regions were relatively colder. In 2001, there was an indication of a warmer and fresher vein of Atlantic water in the northern region.

Discussion

The hydrographic features of the circulation in the Strait of Sicily indicate that the main feature responsible for the distribution of anchovy early life stages is

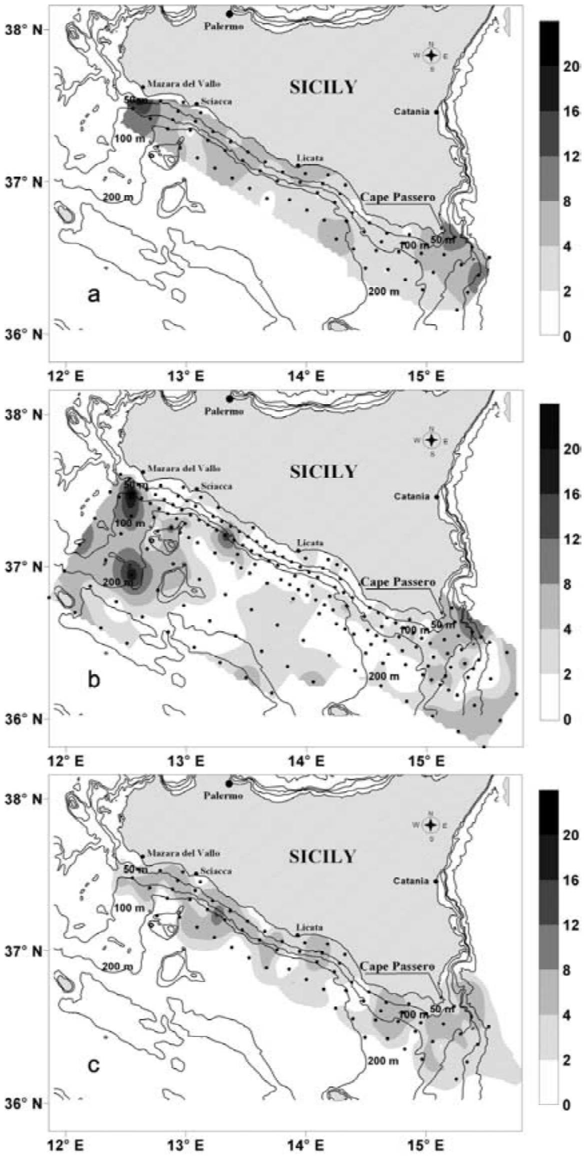

Figure 4. Distribution of meso-zooplankton (dry weight, mg/m^3) during surveys carried out along the Sicilian coast in 1999 (a), 2000 (b) and 2001 (c).

the Atlantic Ionian Stream (AIS). García-Lafuente et al. (2002) proposed a conceptual model for anchovy spawning strategy, whereby, the AIS is a transport mechanism for eggs and larvae towards the southernmost region of the Sicilian coastline. In this area, the presence of a cyclonic gyre aids retention of the early life stages of anchovy, and the convergence of different water masses forms a front that concentrates the food (zooplankton) required by the larvae. Present data on anchovy eggs and larvae and zooplankton are consisted with such a model, which explains the contemporary presence of fish eggs and larvae, and food (zooplankton). However, the AIS path was quite variable from year-to-year, and such variability may cause changes in temperature and extent of upwelling in the northern part of the area. In turn, this may have consequences for the distributional pattern of the anchovy spawning grounds, as low temperature can inhibit the spawning process (see Figs 2 a, b and 3 a, b). Conversely, the relatively high egg and larval densities, characterizing the northern region during the 2001 survey (Figs 2 c and 3c), appear to be related to the warmer surface temperature conditions induced by the intrusion of modified Atlantic water. Our findings support the hypothesis that the distributional patterns of anchovy eggs and larvae are linked to changes in the AIS path and distance from the shoreline.

References

Borja, A., A. Uriarte, V. Valencia, L. Motos & A. Uriarte, 1996. Relationships between anchovy (*Engraulis encrasicolus,* L.) recruitment and the environment in the Bay of Biscay. Sci. mar. 60: 179–192.

Casavola, N., E. Hajderi & G. Marano, 1998. Relationship between the density of *Engraulis encrasicolus* eggs and zooplanktonic biomass in the southern adriatic sea. Biol. mar. Mediterr. 5: 56–62.

Cuttitta, A., G. Basilone, B. Patti, A. Bonanno, S. Mazzola & B. Giusto, 1999. Trends of anchovy (*Engraulis encrasicolus*) condition factor and gonadosomatic index in the Sicilian Channel (in Italian). Biol. mar. Mediterr. 6: 566–568.

García-Lafuente, J., A. García, S. Mazzola, L. Quintanilla, A. Delgado, A. Cuttita & B. Patti, 2002. Hydrographic phenomena influencing early life stages of the Sicilian Channel anchovy. Fish. Oceanogr. 11: 31–44.

Giráldez, A. & R. Abad, 1995. Aspects on the reproductive biology of the Western Mediterranean anchovy from the coast of Málaga (Alboran Sea). Sci. mar. 59: 15–23.

Holden, M. J. & D. F. S. Raitt (eds), 1975. Manual de Ciencia Pesquera. Parte 2 - Métodos Para Investigar los Recursos y su Aplicaciòn. Doc. Tec. FAO Pesca, (115) Rev. 1. 211 pp.

James, A., J. W. Pitchford & J. Brindley, 2003. The relationship between plankton blooms, the hatching of fish larvae, and recruitment. Ecol. Model. 160: 77–90.

Robinson, A. R., J. Sellschopp, A. Warn-Varnas, W. G. Leslie, C. J. Lozano, P. J. Haley, L. A. Anderson & P. F. J. Lermusiaux, 1999. The Atlantic Ionian Stream. J. mar. Syst. 20: 113–128.

Tikhonova, I., O. Arino, G. Ivanitskii, H. Malchow & A. Medvinskii, 2000. The dependence of fish school movement and plankton spatial distributions on the phytoplankton growth rate. Biofizika 45: 352–359.