NUMERICAL SIMULATIONS OF SMALL PELAGIC FISHES EGGS AND LARVAE IN THE ADRIATIC SEA

R. Gramolini [1], A. Russo [1]*, A. Coluccelli [1], M. La mesa [2], M. Panfili [2], E. B. Morello [2] and E. Arneri [3]
[1] Dept. of Marine Science, Polytechnic University of Marche - a.russo@univpm.it
[2] Institute of Marine Sciences, CNR, Ancona, Italy
[3] Fisheries and Aquaculture Department, FAO, Rome, Italy

Abstract
An Individual Based Model (ICHTYOP) was applied in the Adriatic Sea with the aim of studying the mechanisms regulating spawning and recruitment success of small pelagic fishes. ICHTYOP numerical simulations have been driven by realistic current fields derived by an hydrodynamic model, and outputs were analyzed in a GIS environment. Preliminary results indicate that most recruits are along the western Adriatic coast and that the total interannual variability could be low compared to monthly variability. Specific simulations driven by position and ages of larvae caught in the Gulf of Manfredonia provide interesting insights for this important nursery area.
Keywords: Adriatic Sea, Spawning, Recruitment, Larvae, Models

Introduction.
The fishery for small pelagic, particularly for anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*), is important in the Adriatic Sea, being the largest of the Mediterranean Sea. Anchovy and sardine are species with a short life cycle, so a key factor regulating their abundance is recruitment success which in turn is considerably influenced by the passive transport from spawning areas to recruitment areas.

Materials and Methods.
Transport of small pelagic fishes eggs and larvae has being studied within the framework of the EU project "SARDONE" by using an Individual Based Model (IBM), ICHTYOP [1], already used in similar studies conducted in other areas with relevant small pelagic fisheries like the Benguela Current and the Peru upwelling systems. Realistic environmental conditions (in particolar 3-D currents and temperature over the whole Adriatic Sea) were provided to ICHTYOP as daily averages of the Regional Ocean Modelling System (ROMS; [2]) outputs. The Adriatic ROMS implementation is adequate to resolve mesoscale features (two numerical grids are being using, one with a resolution variable between 3 and 12 km and the other with constant spacing of 2 km; both having 20 *s*-levels in vertical). ROMS deduces fluxes of momentum, heat and water through the air-sea interface from outputs of a high resolution operational atmospheric model, COSMO-I7, managed by the Hydro-Meteo-Clima Service of ARPA Emilia-Romagna (Bologna, Italy), in agreement with the Meteorological Office of the Italian Air Force and Piemonte Region.
The whole Adriatic basin was arbitrarily divided into 36 regions according to morphology, bathymetry and general circulation. For a preliminary trial aiming to investigate the general behavior of the basin, eggs were released in ICHTYOP from each of the 36 regions (in a number proportional to the respective areal surface) and their trajectories followed for 60 days, representing the maximum duration of the passive larval transport. Eggs were released every 10 days during two years characterized by contrasting environmental characteristics (in terms of Po River runoff and wind stress). After 3 days, larvae hatch from eggs, and larval diel vertical migration was considered in the ICHTYOP run. The numeric outputs have been collected in a database for subsequent analysis in GIS, allowing for rapid and extensive result summaries and for more detailed studies.

Results and Discussion.
The GIS analysis of the ICHTYOP simulations provided the following main results: sea currents transport larvae ready to recruit in high concentration along the western Adriatic coast, especially in the central area, whilst very low concentrations are present on the eastern part of the basin (fig. 1); monthly variability is relevant; overall there are almost no differences between the two contrasting years, but there are differences in the monthly distributions.
ICHTYOP was applied also in "backward" mode to carry out a data-driven study. During two surveys conducted in the Gulf of Manfredonia (southern Adriatic Sea, Fig. 1), anchovies and sardine larvae were caught and their ages estimated by otholith microincrement counts. The Gulf of Manfredonia is known as an important recruitment area, hosting a valuable larval fishery, but it is not considered a spawning area. ICHTYOP integrations starting from date and position of anchovy and sardine larvae catches going backward up to their spawning date demonstrate a full consistency with known spawning areas.

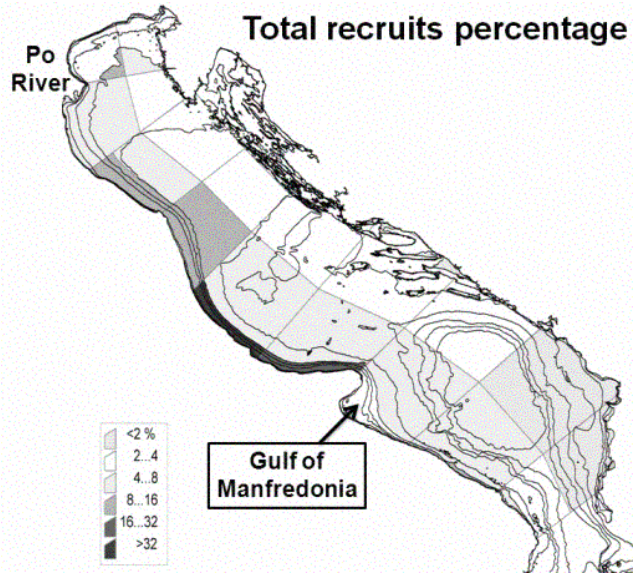

Fig. 1. Percentage of total recruits in the 36 regions chosen for the Adriatic Sea as resulting from two years of ICHTYOP exploratory simulations

References
1 - Lett C., Verley P., Mullon C., Parada C., Brochier T., Penven P., Blanke B., 2008. A Lagrangian tool for modelling ichthyoplankton dynamics. *Environ. Modell. Softw.*, 23:1210-1214.
2 - Haidvogel D.B., Arango H., Budgell W.P., Cornuelle B.D., Curchitser E., Di Lorenzo E., Fennel K., Geyer W.R., Hermann A.J., Lanerolle L., Levin J., McWilliams J.C., Miller A.J., Moore A.M., Powell T.M., Shchepetkin A.F., Sherwood C.R., Signell R.P., Warner J.C. and Wilkin J., 2008. Ocean forecasting in terrain-following coordinates: Formulation and skill assessment of the Regional Ocean Modeling System. *J. Comput. Phys.*, 227: 3595-3624.