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M. Uttieri, I. Iermano, D. Cianelli, L. Sabia, R. Sandulli, G. Spezie, E. Zambianchi, M.G. Mazzocchi*

Department of Sciences and Technologies, University of Naples "Parthenope", Centro Direzionale di Napoli, Isola C4 - 80143 Napoli, Italy.
marco.uttieri@uniparthenope.it
*Lab. Ecology and Evolution of Plankton, Stazione Zoologica A. Dohrn, Villa Comunale - 80121 Napoli, Italy.

COUPLING OF AN INDIVIDUAL-BASED MODEL AND VERTICAL HYDRODYNAMICS TO INVESTIGATE THE CALANOID COPEPOD *CLAUSOCALANUS FURCATUS* VERTICAL DISTRIBUTION

INTEGRAZIONE DI UN INDIVIDUAL-BASED MODEL E DELL'IDRODINAMISMO VERTICALE PER STUDIARE LA DISTRIBUZIONE VERTICALE DEL COPEPODE CALANOIDE CLAUSOCALANUS FURCATUS

Abstract - *The swimming behaviour of individual specimens of the calanoid copepod* Clausocalanus furcatus *is coupled with the vertical velocity of the water column resulting from numerical simulations of the three-dimensional circulation of the Gulf of Naples. The results of this integrated Individual-Based Model provide new insights into the concomitant role of individual motion and water currents in depicting the vertical distribution of the copepod population, which is always confined to the upper layers of the water column.*

Key-words: *Individual-Based Model,* Clausocalanus furcatus*, ROMS, Gulf of Naples.*

Introduction - The calanoid copepod *Clausocalanus furcatus* (Brady, 1883) is a widespread species in epipelagic waters of oligotrophic (Peralba and Mazzocchi, 2004) and coastal eutrophic regions (Mazzocchi and Ribera d'Alcalà, 1995). A unique feature of this species is its incessant swimming behaviour, which consists of high-speed consecutive loops (10 mm s^{-1} on average) alternating with fast linear relocations (Mazzocchi and Paffenhöfer, 1999; Uttieri *et al.*, 2008). More recent observations (Bianco *et al.*, 2013) show regular patterns of motion in the horizontal plane, likely allowing the copepod to adapt its swimming to the conditions it experiences in the real environment. In the Gulf of Naples it presents a major peak of abundance in August and a secondary peak in October-November (Mazzocchi and Ribera d'Alcalà, 1995; Peralba and Mazzocchi, 2004). The copepod is always present above the thermocline, without any nycthemeral or seasonal variation in the vertical distribution (e.g., Peralba and Mazzocchi, 2004). In this work we investigate how the individual swimming motion, coupled with the vertical component of the water current, cooperate in depicting the vertical pattern of distribution of *C. furcatus*. In particular, we implemented an Individual-Based Model of copepod' swimming and we nested it with the vertical velocity of the water column as reconstructed through numerical simulations.

Materials and methods - The individual behaviour of *C. furcatus* was reconstructed starting from two-dimensional recordings of freely swimming specimens (Mazzocchi and Paffenhöfer, 1999; Uttieri *et al.*, 2008). In particular, kinematic properties related to the vertical component of the motion, turning rate and jump frequency were derived from video observations and used as input for the implementation of a species-specific realistic model based on a modulated random walk. A 3D numerical model implementation of the circulation of the Gulf of Naples was set up using the Regional Ocean Modeling System (ROMS), a 3D, free-surface, hydrostatic, primitive equation, finite difference model (Shchepetkin and McWilliams, 2003). The vertical component of the current velocity, as well as hydrological vertical profiles (temperature, salinity, density), were extracted in correspondence of fixed stations of the gulf in specific periods of the year. The horizontal resolution was 1 km, with a variable vertical resolution of 30 sigma layers. Initial and open boundaries conditions used in the numerical simulations were obtained from the daily output of Mediterranean Forecasting System (MFS) in the framework of MyOcean system. The ROMS model was forced by SKIRON atmospheric model outputs. Freshwater daily conditions of the Sarno river were also included in the model simulation.

Results - Modelled vertical distributions of *C. furcatus* show good agreement with *in situ* observations in the Gulf of Naples. In particular, the results of this integrated model reveal important interplay between individual motion and current dynamics in shaping the pattern of distribution of the copepod, and that the population vertical distribution can be considered as the result of processes acting over different spatial and temporal scales. Our results also highlight the critical relationship with the hydrology of the water column. The vertical distributions resulting from our simulations are further complemented with Richardson number profiles to relate copepod population structure to the turbulent structure of the flow field.

Conclusions - The coupled IBM discussed here provide interesting insights into the different roles of individual swimming behaviour and local hydrodynamics in determining the distributional patterns of the species, and hint at possible behavioural adjustments controlling the vertical displacements of the copepod population. In a more general view, this study stresses the importance of relating and complementing individual-scale observations to the hydrodynamics of the fluid environment to get a more accurate understanding of the processes shaping the distributional patterns observed.

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