ICES CM 2013/N:12

A behavioural fish movement approach within an anchovy IBM model to study fish migration patterns in the Bay of Biscay

Dimitrios Politikos(1), Martin Huret(1), Pierre Petitgas(2)
(1) Ifremer, Centre de Brest, STH, BP 70, 29280, Plouzane, France ;(2)IFREMER, Centre de Nantes, EMH, BP 21105, 44311 Cedex 03, Nantes, France. Presenter contact details: Dimitrios.Politikos@ifremer.fr, Phone +33 02 98 22 40 40 (poste 3407)

Summary

Modelling of fish movement behaviour within a heterogeneous marine environment is a challenging but also key issue for understanding the effect of environmental factors and climatic change on fish processes (growth, distribution, mortality, reproduction). Fish movement models have the capability to encompass the combined effect of environment and empirical knowledge of fish individuals as energy requirements, known preys and predators, swimming capacities into a unified framework (Planque et al., 2011). Following an Individual Based Model (IBM) approach, a fish movement model has been developed to simulate the active movement of adult anchovy in the Bay of Biscay (BoB) in response to the spatio-temporal variations of both biotic and abiotic factors, as well as its internal conditions based on a bioenergetics model.

Introduction

The migration of anchovy in the Bay of Biscay patterns are documented in ICES (2010, Chap 8). Adult anchovies exhibit seasonal migrations within every year. The hypothesis is that they spawn at certain grounds in which the physical environment favors a successful recruitment and move to areas that will optimize their growth and survival. More particularly, spawning takes place mainly in the southern-east corner of the BoB in spring (April-July), where the adult population aggregates. After spawning (July-November), dispersal to the north and a northward migration has been documented by the analysis of fishing activity, while they are back for spawning in the south in spring of the next year. Coupled with a hydrodynamic model and a lower trophic level ecosystem model (ECO-MARS3D; Lazure and Dumas, 2008), a horizontal two-dimensional IBM model was developed to assess how the underlying fish movement assumptions influence anchovy's migration and growth patterns.

Material and Methods

A fish bioenergetics approach based on Dynamic Energy Budget (DEB) (Pecquerie et al., 2009) is followed to simulate the growth of particles. This model describes the energy flow through the processes of assimilation, ingestion, maintenance and reproduction. Adult fish, contrary to early life stages, can direct their own movement following favorable environmental and prey conditions. The physical and plankton outputs from the ECO-MARS3D model (temperature, bathymetry and zooplankton) were used to update the position of the fish. The new fish cell location is afterwards determined following equation (1). The movement model follows a gradient approach (Xu et al., 2013). Therefore, from the current fish location, the approach allows the fish to evaluate environmental (temperature), growth and feeding characteristics in the surrounding cells and then direct its orientation to the optimal cell.

The basic movement equation follows a Lagrangian approach with the position of each particle $\left(x(k+1), y(k+1)\right)$ at time step $k+1$ being calculated from the previous time step k :

$$x(k+1) = x(k) + (D(x(k)) + R(x(k)) \cdot \Delta t$$
$$y(k+1) = y(k) + (D(y(k)) + R(y(k)) \cdot \Delta t \quad (1)$$

where Δt is the time step and $D(x(k)), D(y(k))$ are the x, y components of the drift part and $R(x(k)), R(y(k))$ denote the random part of the movement process. For the north to south migration the potential factors that trigger spawning are related to the onset of thermocline formulation, the warming of surface temperature, the river plumes and the increase of zooplankton productivity. Thus, temperature and zooplankton are tested as potential environmental cues which define the drift part. The period of the simulation is from March to June.

Results and Discussion

Figure 1A shows the zooplankton field in June. Increased productivity is noticed in the southern part of BoB. The tracking positions of two fish particles (particle-1: black tracks and particle-2: blue tracks) are shown in Figure 1B. The movement of the particles to productive and warmer areas is the main characteristic of the simulation. At the same time, the evolution of their length is shown at Figure 1C. It is clear that from north to south migration is a favourable procedure for the fish, since there is an increase of growth and a favourable physiological status that will ensure a successful spawning period.

Additional effort to identify optimal and "poor" in terms of growth migration paths will improve our understanding on this annual migration cycle. Finally, the representation of realistic growth values and distribution maps is an important task for reproducing the documented adult migration behaviour.

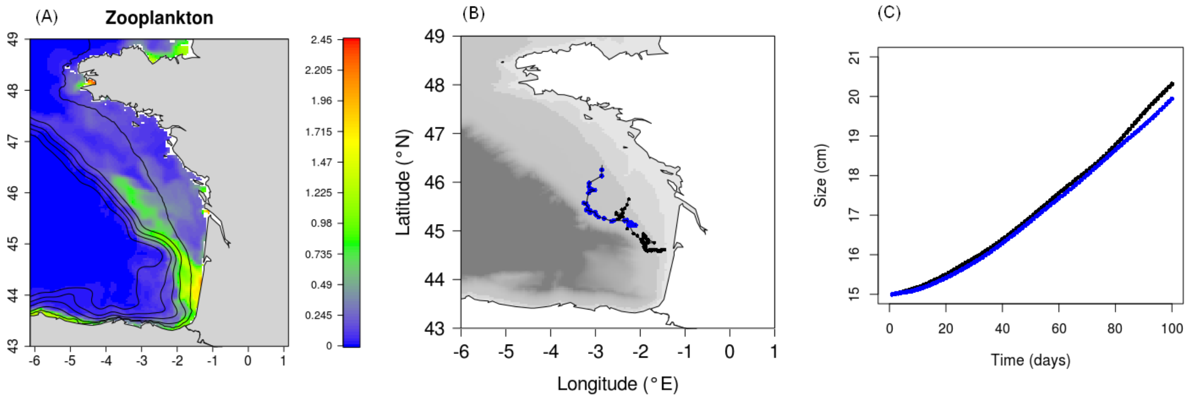

Figure 1. (A) Zooplankton field (June), (B) particles' positions, (C) length evolution of particles.

References

ICES. 2010. Life cycle spatial patterns of small pelagic fish in the Northeast Atlantic. ICES Cooperative Research Report, No. 306.

Lazure P., and Dumas F., 2008. An external–internal mode coupling for a 3D hydrodynamical model for applications at regional scale (MARS). Advances in Water Resources, 31(2), 233-250.

Pecquerie L., Pierre P., Sebastiaan K.,2009. Modeling fish growth and reproduction in the context of the Dynamic Energy Budget theory to predict environmental impact on anchovy spawning duration. Journal of Sea Research 62(2-3), 93-105.

Planque B., Loots C., Petitgas P., Ulf Lindstrøm U., Vaz S., 2011 Understanding what controls the spatial distribution of fish populations using a multi-model approach. Fisheries Oceanography 20(1), 1-17.

Xu Y, Fei Chai, Kenneth A. Rose, Miguel Ñiquen C., Francisco P. Chavez, 2013. Environmental influences on the interannual variation and spatial distribution of Peruvian anchovy (Engraulis ringens) population dynamics from 1991 to 2007: A three-dimensional modelling study. Ecological Modelling (In Press).