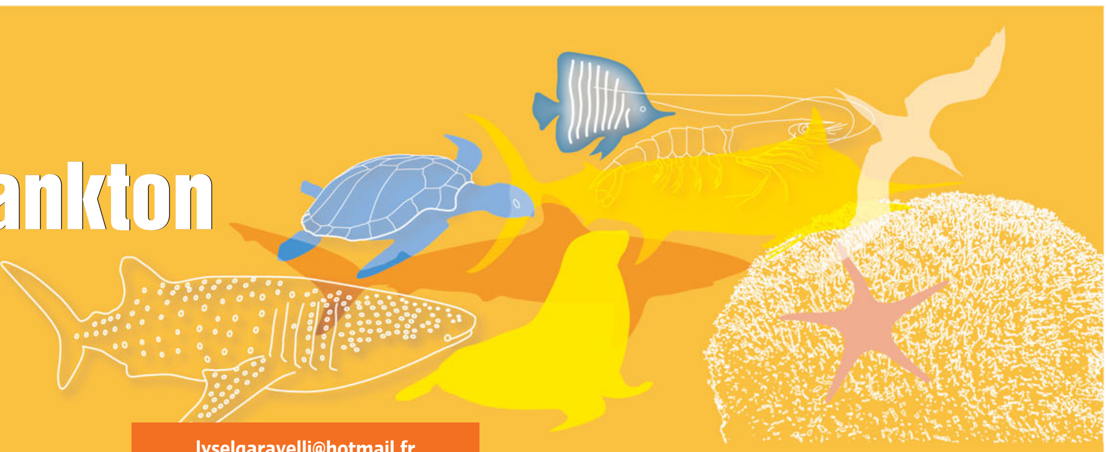
# Modelling the dispersal of Cape hake ichthyoplankton




**Garavelli L.[1], Grüss A.[2], Grote B.[3], Chang N.[4], Smith M.[5], Stenevik E. K.[6], Kaplan D. M.[2], Lett C.[1]**

*1. Institut de Recherche pour le Développement (IRD), UMI-209 UMMISCO, Centre de Recherche Halieutique Méditerranéenne et Tropicale, Avenue Jean Monnet, BP 171, 34203 Sète cedex, France*
*2. Institut de Recherche pour le Développement (IRD), UMR-212 EME, Écosystèmes marins exploités, Centre de Recherche Halieutique Méditerranéenne et Tropicale, Avenue Jean Monnet, BP 171, 34203 Sète cedex, France*
*3. Center for Tropical Marine Ecology, Fahrenheitstr. 6, 28359 Bremen, Germany*
*4. Center for High Performance Computing, CSIR, Cape Town, South Africa*
*5. CapFish, P.O. Box 50035, Waterfront, Cape Town, 8002, South Africa*
*6. Institute of Marine Research, P.O. Box 1870, Nordnes 5817, Bergen, Norway*

lyselgaravelli@hotmail.fr


## Introduction

Cape hakes constitute economically important marine resources in the southern Benguela ecosystem off South Africa. To ensure their sustainable exploitation, different management procedures are being considered, in particular the establishment of marine protected areas (MPAs). Areas where adults reproduce, ichthyoplancton (eggs and larvae) disperse, and juveniles recruit, are different possibilities for locating MPAs, and to assess their potential effects a better understanding of Cape hakes early life history is essential. The objective of our research is to investigate the recruitment success of Cape hakes using a model of ichthyoplankton dispersal. Several characteristics of Cape hakes ichthyoplanctonic phase are studied, spawning seasonality, spawning and nursery areas locations, and drift routes.

## Material and Methods

We use Chang's (2009) southern Benguela simulations of ROMS (Regional Oceanic Modelling System) hydrodynamic model into an individual-based model (Ichthyop, Lett *et al.*, 2008) to track virtual Cape hakes ichthyoplankton (Fig. 1). As a first approach, only passive transport of individuals is considered from different spawning areas, depths, months and years, and drift duration is set to one month. Ichthyop graphic interface allows visualizing dispersal from the eight spawning areas (coloured on Fig. 2) chosen to study spawning seasonality.

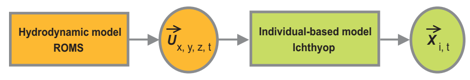



***Fig. 1. Schematic view of the modelling approach used to simulate ichthyoplankton dispersal.***


***Fig. 2. Ichthyop graphic interface.***

## Results

### 1 / SPAWNING SEASONALITY

Eggs and larvae monthly distribution assessed by Grote *et al.* (2007) (Fig. 3) until 90 m depth shows that Cape hakes spawning occurs mainly between June and October. Our simulations of eggs and larvae dispersal suggest that the seasonal pattern of transport success from the eight spawning areas (Fig. 2) to a coastal nursery area change significantly with spawning depth (Fig. 4). We obtained a peak in transport success from May to August for spawning depth 0-100 m. As this seasonal pattern coincides roughly with the one obtained by Grote *et al.* (2007) for reproduction (Fig. 3), it is possible that ensuring good conditions for transport of eggs and larvae to the coastal nursery area is a reason for Cape hakes spawning in winter-early spring. However, for spawning depth 100-300 m, we obtained an opposite seasonal pattern (Fig. 4). The lack of observations does not currently allow discussing if Cape hakes spawning seasonality depends on spawning depth, as our results suggest.

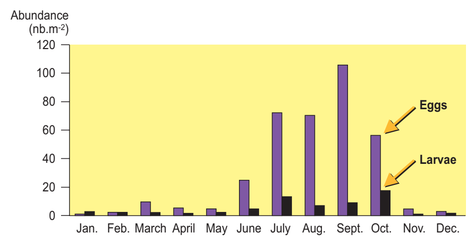



***Fig. 3. Observations. Grote et al. (2007).***

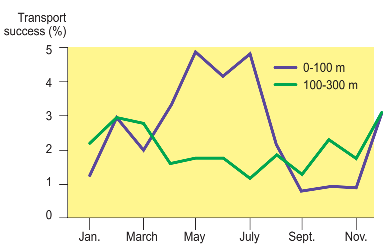



***Fig. 4. Model results.***

### 2 / CONNECTIVITY BETWEEN SPAWNING AND NURSERY AREAS

To evaluate transport success, or connectivity, from spawning to nursery areas at a smaller scale, both spawning and nursery grounds were subdivided into small areas, according to the grid used for current spatial assessment of Cape hakes stocks (Fig. 5). Higher simulated connectivity values (in black) reveal two privileged connectivity patterns. The first one (from spawning areas $S_1$ to nursery areas $N_1$), located on the west coast, is favored by the presence of a coastal current flowing northwards. The second one ($S_2$ to $N_2$) is situated on the south coast, inshore the westward-flowing Agulhas Current. Between these two main areas, simulated connectivity values are generally low (in white).

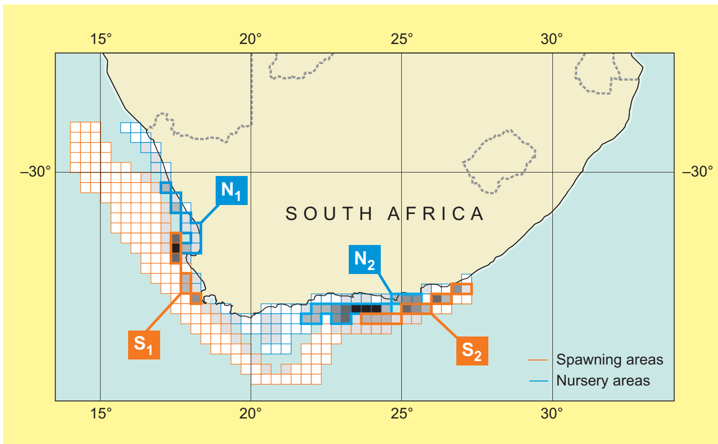



***Fig. 5. Connectivity between spawning and nursery areas.***

### 3 / DRIFT ROUTES

Stenevik *et al.* (2008) observed that the coastal current flowing along the west coast of South Africa divides into two branches off Cape Columbine (Fig. 6). Immediately south of this region, they collected deep-water hake (*Merluccius paradoxus*) eggs further offshore than shallow-water hake (*Merluccius capensis*) eggs. From these two observations they concluded that the two Cape hake species could follow different drift routes, with *M. paradoxus* following the western branch of the current and *M. capensis* the eastern branch. We tested this assumption with our dispersal model choosing two release areas, one offshore representing the *M. paradoxus* egg distribution reported by Stenevik *et al.* (2008) and one inshore for *M. capensis* eggs. Our simulation results support partially Stenevik *et al*'s (2008) hypothesis. They suggest that *M. paradoxus* eggs and larvae could follow more the offshore route and *M. capensis* eggs and larvae the inshore route. But they also show that both species would follow the two routes (Fig. 7).

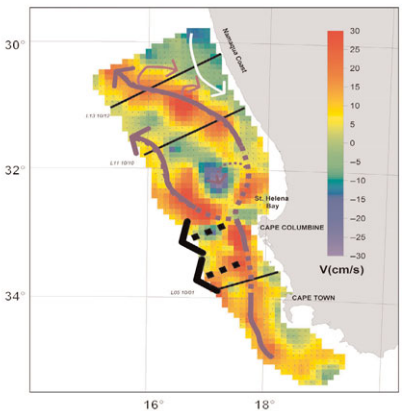



***Fig. 6. Current distribution in the Southern Benguela ecosystem. Stenevik et al. (2008).***

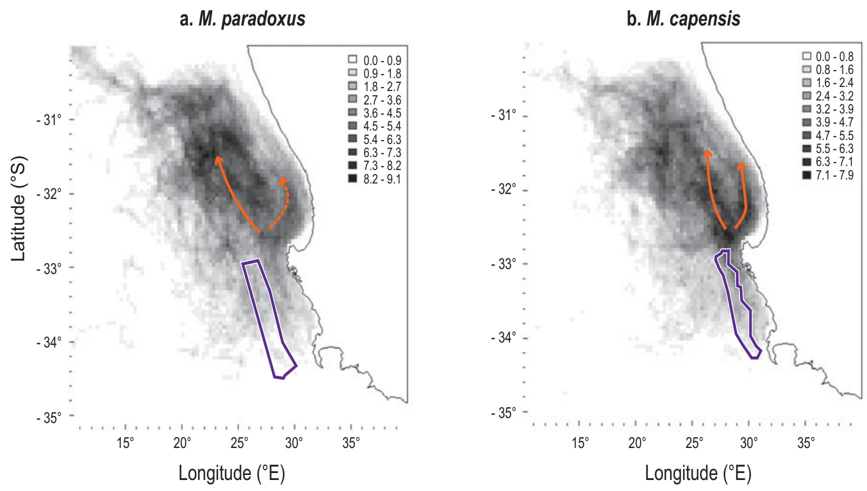



***Fig. 7. Eggs and larvae simulated distribution after 30 days of passive dispersal from release areas (shown in purple) for (a) M. paradoxus and (b) M. capensis.***

## Conclusion

This first attempt of using a model to study the environmental factors that influence Cape hake ichthyoplankton dispersal is promising. The main seasonal and spatial patterns obtained with the dispersal model correspond to observed reproduction patterns. This suggests that Cape hakes spawning strategy is influenced by eggs and larvae dispersal constraints. The connectivity values between spawning grounds and nursery areas obtained here will be incorporated into a spatial age-structured population model of Cape hake that aims at investigating the effects of marine protected areas (Grüss *et al.*, in prep.). The present study is also complementary to modelling works performed for anchovy (*Engraulis encrasicolus*, Parada 2003) and sardine (*Sardinops sagax*, Miller 2006) ichthyoplankton dispersal in the southern Benguela.

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