Using satellite reanalysis to simulate interannual variability in recruitment of Patagonian toothfish on the Kerguelen Plateau

Mao Mori[1,2], Stuart P Corney[2], Jessica Melbourne-Thomas[2,3], Dirk C Welsford[3], Andreas Klocker[1] and Philippe E Ziegler[3]

[1]*Institute for Marine and Antarctic Studies,Hobart,Tasmania,Australia*
[2] *Antarctic Climate and Ecosystems Cooperative Research Centre,Private Bag 80,Hobart,Tasmania, Australia, 7001*
[3]*Australia Antarctic Division,203 Channel Highway,Kingston,Tasmania,Australia,7053*

Understanding the whole life stage of marine organisms is important for the management of fish populations and the study of the ecosystem in the Southern Ocean. However, major parts of the ecology and behavior of marine creatures during early life stages are uncertain because of the difficulties of *in situ* observations in such remote locations and at such depths. Therefore, various models based on altimetry data exist to examine larval transport of marine organisms and their recruitment levels. In this study, by modeling eggs' and larval transport of Patagonian Toothfish (*Dissostichus eleginoides*) which has a long life (at least 40 years (Fallon and Stratford 2003, Collins et al. 2010)) and vertically wide distribution (from -200 m to -2000 m (North 2002, Collins et al. 2010, Duhamel 2011, Welsford et al. 2011)) using multiple years of remotely sensed sea surface height, we can investigate the paths taken by eggs and larvae of toothfish so as to develop transport patterns and connectivity between regions of key larval sources and juvenile recruitment locations. Further, the relationship between the interannual variability in recruitment of Toothfish and successful recruitment patterns on the Kerguelen Plateau in the Southern Ocean is examined. Although the simulation of larval transport of toothfish is difficult because eggs are spawned at depth, the approximate equivalent-barotropic structure of the Southern Ocean enables us to approximate the water movement at depth from surface water movement.

In these simulation, the MATLAB 'Particle Tracking Model', originally developed by Fredj et al. (2008), is utilized to produce trajectories for 18 weeks (from 1 June to 30 September). This tie period coincides with the peak of spawning period from June to August (Duhamel 1987, Welsford et al. 2012). In addition to this, spawning and successful juvenile recruitment depths are defined as -1500 m and between -200 m to -1000 m respectively. To investigate the eggs and larvae transport, two original data sets are used: surface velocity field derived from altimetry (AVISO) and three dimensional velocity field from a reanalysis product (SOSE). Further, two different egg buoyancy characteristics are considered: positive buoyancy and neutral buoyancy. The differences between SOSE and AVISO are examined. In the positive buoyancy model, eggs quickly rise to near the surface because of their strong buoyancy calculated from a study by Tanaka (1992) and then float near the surface for the remainder of the simulation. After 18 weeks if larvae are at successful juvenile depths, they are deemed to be successful.

There are differences in routes taken by neutral buoyancy models derived between SOSE and AVISO data. Although results from AVISO show comparatively large transport distances for eggs and larvae, most eggs remain at their start locations in SOSE simulations. This difference might occur due to the lack of vertical movement and small velocities at depth in SOSE simulations, while AVISO simulations have comparatively fast velocities. In contrast, SOSE and AVISO positive buyancy models show high levels of successful transport and similar results. Both models have substantial levels of egg movement across the plateau and toward the deep ocean, The west side of the Kerguelen Plateau is a key location for successful eggs and larvae transport. On the other hand, the east side of the plateau has less successful larval transport because most of the eggs are transported far from the plateau. Multiple years of both nuetral and positive buoyancy AVISO simulations show interannual variability in transport success associated with differences in ocean currents. Moreover, in AVISO simulations, the coincidence of successful key spawning locations with observed and predicted locations for toothish spawning behavior is seen for 7 years. Our study shows the first approach for modeling mesoscale pelagic transport of Patagonian Toothfish eggs and larvae on the Kerguelen Plateau in the Southern Ocean. This model is still at an initial stage and may overestimate the rate of the successful eggs and larval transport. Future work will extend the model to provide improved understanding of larval behavior and whole life cycle of demersal fishes and connected management of various fish population in the Southern Ocean in the future.

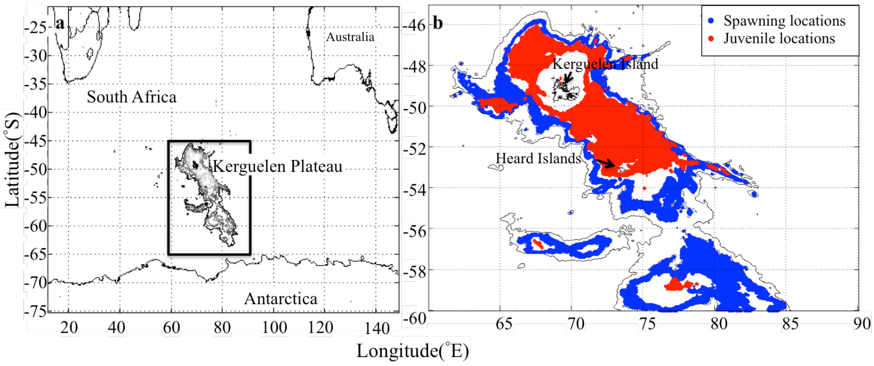

Fig.1. The Kerguelen Plateau (a), and locations of interest for this study (b). In panel (b), blue areas represent spawning locations and red areas represent suitable habitat for juveniles (based on bathymetry).

References

Kawamura, K. and T.F. Stocker, High-resolution carbon dioxide concentration record 650,000-800,000 years before present, Nature, 453(7193), 379-382 , 2008.

Collins, M. A., P. Brickle, J. Brown, and M. Belchier. 2010. Chapter Four - The Patagonian Toothfish: Biology, Ecology and Fishery. Pages 227-300 *in* L. Michael, editor. Advances in Marine Biology. Academic Press.

Duhamel, G. 1987. Ichtyofaune des secteurs Indien occidental et Atlantique oriental de l'Océan Austral: biogéographie, cycles biologiques et dynamique des populations.These de doctorat d'Etat thesis. Université Paris VI: 512 pp.

Duhamel, G., P. Pruvost, M. Bertignac, N. Gasco, M. Hautecoeur. 2011. Major fishery events in Kerguelen Islands: Notothenia rossi, Champsocephalus gunnari, Dissostichus eleginoides - Current distribution and status of stocks In The Kerguelen Plateau: marine ecosystem and fisheries. Societe francaise d'ichtyologie, Paris.

Fallon, L. and E. Stratford. 2003. Issues of sustainability in the southern ocean fisheries – the case of the Patagonian Toothfish. University of Tasmania, Hobart.

Fredj, E., H. Afargan, and H. Gildor. 2008. Particle Tracking Model Toolbox. The Jerusalem College of Technology & Weizmann institute of science, Jerusalem.

North, A. W. 2002. Larval and juvenile distribution and growth of Patagonian toothfish around South Georgia. Antarctic Science **14**:25-31.

Tanaka, Y. 1992. Japanese anchovy egg accumulation at the sea surface or pycnocline—Observations and model. Journal of Oceanography **48**:461.

Welsford, D. C., S. G. Candy, T. D. Lamb, G. B. Nowara, A. J. Constable, and R. Williams. 2011. Habitat use by Patagonian toothfish (Dissostichus eleginoides Smitt 1898) on the Kerguelen Plateau around Heard Island and the McDonald Islands.*in* G. Duhamel and D. C. Welsford, editors. The Kerguelen Plateau : marine ecosystem and fisheries. Societe francaise d'ichtyologie, Paris.

Welsford, D. C., J. McIvor, S. G. Candy, and G. B. Nowara. 2012. The spawning dynamics of Patagonian toothfish in the Australian EEZ at Heard Island and the McDonald Islands and their importance to spawning activity across the Kerguelen Plateau. Australian Antarctic Division, Fisheries Research and Development Corporation, Kingston, Tas.