Reviewing the use of computer-based modelling to study squid larval dispersal: experiences from South Africa and Brazil

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Introduction

- Loliginid squids inhabits coastal and neritic waters all over the world, excluding the polar latitudes
- Loliginid catches fluctuate greatly, and this is, at least partially, attributed to the success of the recruitment
- thus, the role of local circulation is crucial during the paralarval phase. Why?

1) their dispersal is result, at least in part, from the circulation patterns
2) currents may carry/retain the paralarvae in suitable or improper areas

Doryteuthis plei

Loligo reynaudii

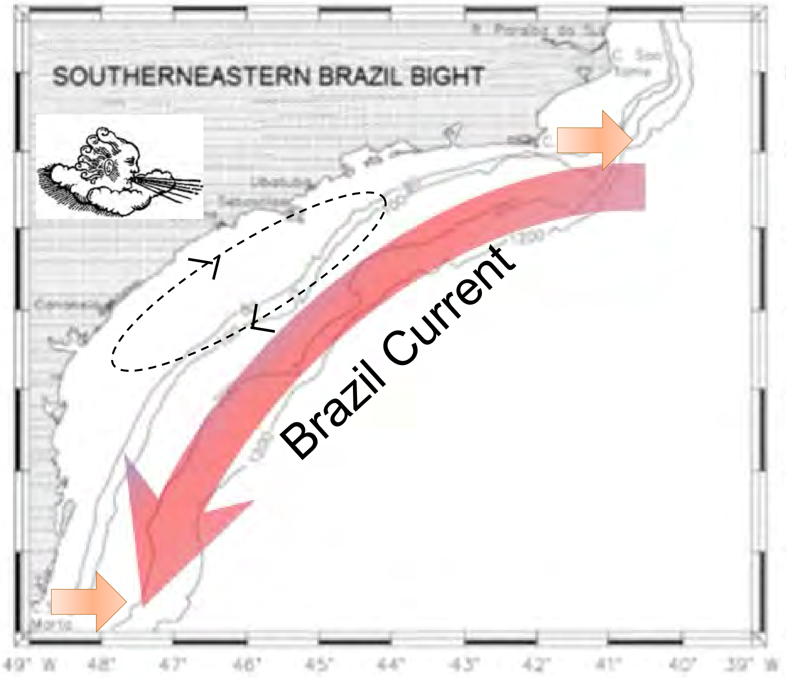
Rationale: why use coupled IBM-circulation models to study larval dynamics?

- studying dispersal patterns may be laborious and costly in planktonic organisms
- Individual-Based Models (IBMs) coupled to 3D circulation models can be used to investigate dispersal patterns
- in areas where circulation and distribution data of the target organism is lacking or poor, the IBM-3D circulation models approach may be useful
- allows the investigation of spatial and temporal variability on plankton dynamics
- There are free particle-tracking IBM tools available (e.g. ICHTHYOP, Lett et al., 2008)

Circulation patterns on the shelf systems

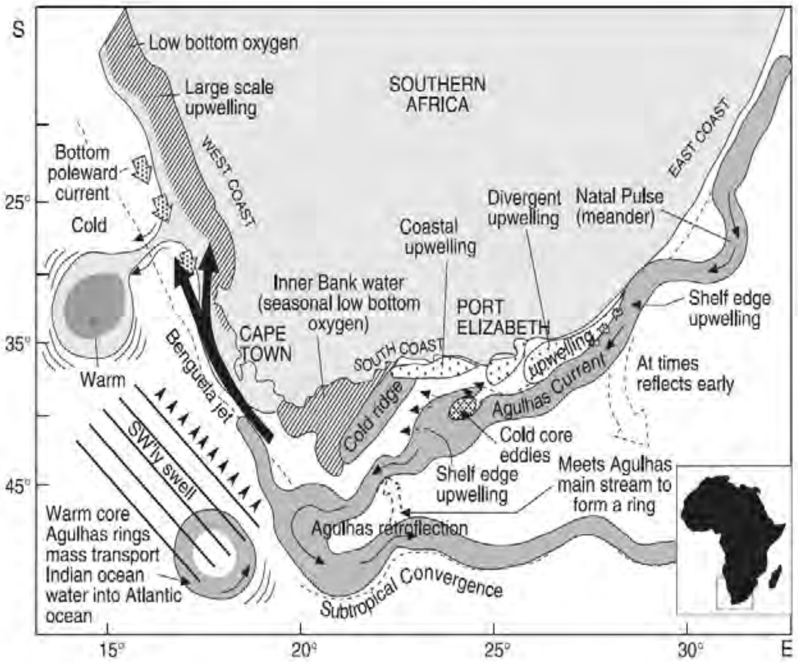
General patterns

SBB



Modified from Matsuura, 1975;
Bakun, 1996 and Mazzini, 2009

Agulhas Bank



Roberts, 2005

Studies carried out thus far…

First Lagrangian ROMS-IBM simulations indicate large losses of chokka squid *Loligo reynaudii* paralarvae from South Africa's Agulhas Bank

DOI: 10.2989/18142321003714518

M J Roberts[a] & C Mullon[b]

pages 71-84

African Journal of Marine Science

Volume 32, Issue 1, 2010

Effect of yolk utilization on the specific gravity of chokka squid (*Loligo reynaudii*) paralarvae: implications for dispersal on the Agulhas Bank, South Africa

Rodrigo S. Martins, Michael J. Roberts, Nicolette Chang, Philippe Verley, Coleen L. Moloney, and Erica A. G. Vidal

Martins, R. S., Roberts, M. J., Chang, N., Verley, P., Moloney, C. L., and Vidal, E. A. G. 2010. Effect of yolk utilization on the specific gravity of chokka squid (*Loligo reynaudii*) paralarvae: implications for dispersal on the Agulhas Bank, South Africa. – ICES Journal of Marine Science, 67: 1323–1335.

FISHERIES OCEANOGRAPHY

FISHERIES OCEANOGRAPHY Fish. Oceanogr. 23:2, 116–131, 2014

Modelling transport of chokka squid (*Loligo reynaudii*) paralarvae off South Africa: reviewing, testing and extending the 'Westward Transport Hypothesis'

RODRIGO S. MARTINS,[1,2,†,*]
MICHAEL J. ROBERTS,[1] CHRISTOPHE LETT,[3]
NICOLETTE CHANG,[4] COLEEN L. MOLONEY,[2]
MAURÍCIO G. CAMARGO[5] AND
ERICA A. G. VIDAL[5]

The role of the deep spawning grounds in chokka squid (*Loligo reynaudi*, d'Orbigny, 1845) recruitment

Nicola Downey, PhD thesis, 2014

Hydrobiologia (2014) 725:57–68
DOI 10.1007/s10750-013-1519-4

CEPHALOPOD BIOLOGY AND EVOLUTION

The São Paulo shelf (SE Brazil) as a nursery ground for *Doryteuthis plei* (Blainville, 1823) (Cephalopoda, Loliginidae) paralarvae: a Lagrangian particle-tracking Individual-Based Model approach

Rodrigo Silvestre Martins · Ricardo de Camargo · Maria A. Gasalla

Dispersal and retention potential for loliginid paralarvae in the Southeastern Brazilian Bight (23–29°S), Brazil, and the Agulhas Bank (18–27°E), South Africa, on the basis of passive Lagrangian transport

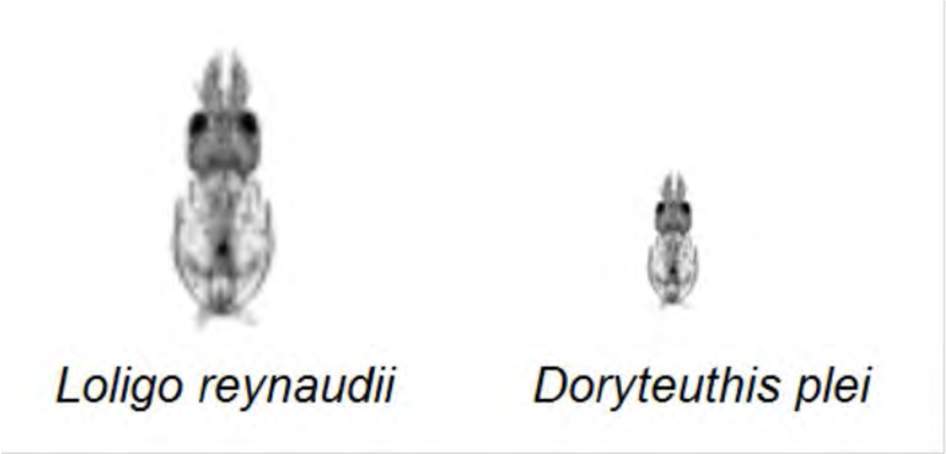
Martins, Camargo & Gasalla, 2014 – submitted to Journal of Marine Systems

Is the recruitment of the tropical arrow squid *Doryteuthis plei* (Cephalopoda: Loliginidae) linked to retention processes? An Individual-based modelling case study off southeastern Brazil

Martins, Camargo & Gasalla, 2014 – manuscript

Patterns found thus far…

- … the SBB shelf would be a “near-perfect” nursery ground for *D. plei* paralarvae (high likelihood of retention) whereas life would not be easy for *L. reynaudii* paralarvae on the Agulhas Bank (high likelihood of offshore losses) → reason underlying differences in paralarval sizes (Vecchione, 1987)?



- ….from the circulation-driven dispersal/retention viewpoint, recruitment fluctuations in the SBB may be related to other factors affecting the paralarvae, whereas on the Agulhas Bank losses from circulation patterns may play a more important role (Roberts and Mullon, 2010)

Circulation models used thus far…

Regional Ocean Model System (ROMS) (PLUME, Penven, 2000) for the Agulhas Bank (Roberts & Mullon, 2010)

- grid resolution : ~ 8 km horizontal dimension inshore, ~ 16 km horizontal dimension offshore
- 20 sigma levels (bottom following layers)
- meteorological forcing given by climatological atmospheric and oceanographic datasets from COADS and AGAPE (1991–1999; da Silva et al., 1994, Bentamy et al. 1996, Biastoch and Krauβ 1999)

Regional Ocean Model System (ROMS) (SAfE, Penven et al. et al., 2006) for the Agulhas Bank (Martins et al., 2010, 2014)

- grid resolution 1/12° (~ 8 km horizontal dimension)
- 22 sigma levels (bottom following layers)
- meteorological forcing given by climatological atmospheric datasets from COADS (1945–1993; da Silva et al., 1994)

Circulation models used thus far…

Princeton Ocean Model (POM) for SBB (Martins et al., 2014)

- grid resolution 1/12° (~ 8 km horizontal dimension)
- 22 sigma levels (bottom following layers)
- in situ wind data obtained from the Global Forecast System (GFS) 1° x 1° analysis available four times daily

Princeton Ocean Model (POM) for SBB (Martins et al., manuscript)

- grid resolution 1/12° (~ 8 km horizontal dimension)
- 22 sigma levels (bottom following layers)
- averaged meteorological forcing given by averaged wind data obtained from 1960 to 1970 [National Center for Environmental Prediction (NCEP) reanalysis I]

Princeton Ocean Model (POM) for SBB (Martins et al., manuscript)

- grid resolution of 1 km in the horizontal dimension (HIGH RESOLUTION!!!)
- 22 sigma levels (bottom following layers)
- In situ temperature and salinity data obtained from Simple Ocean Data Assimilation (SODA; ttp://www.atmos.umd.edu/~ocean/data.html) reanalysis

Circulation models used thus far…

Limitations:

PLUME ROMS (Roberts and Mullon, 2010)

- uses averaged data
- grid resolution too coarse (do not resolve small scale oceanographic phenomena)
- grid does not cover the whole Agulhas Bank

SAfE ROMS (Martins et al. 2010, 2014, Downley, 2014)

- grid resolution too coarse (do not resolve small scale oceanographic phenomena)

Circulation models used thus far…

Limitations:

Princeton Ocean Model (POM) for SBB (coarse, in situ data model)

- not fully validated
- grid resolution too coarse (do not resolve small scale oceanographic phenomena)

Princeton Ocean Model (POM) for SBB (coarse, averaged data model)

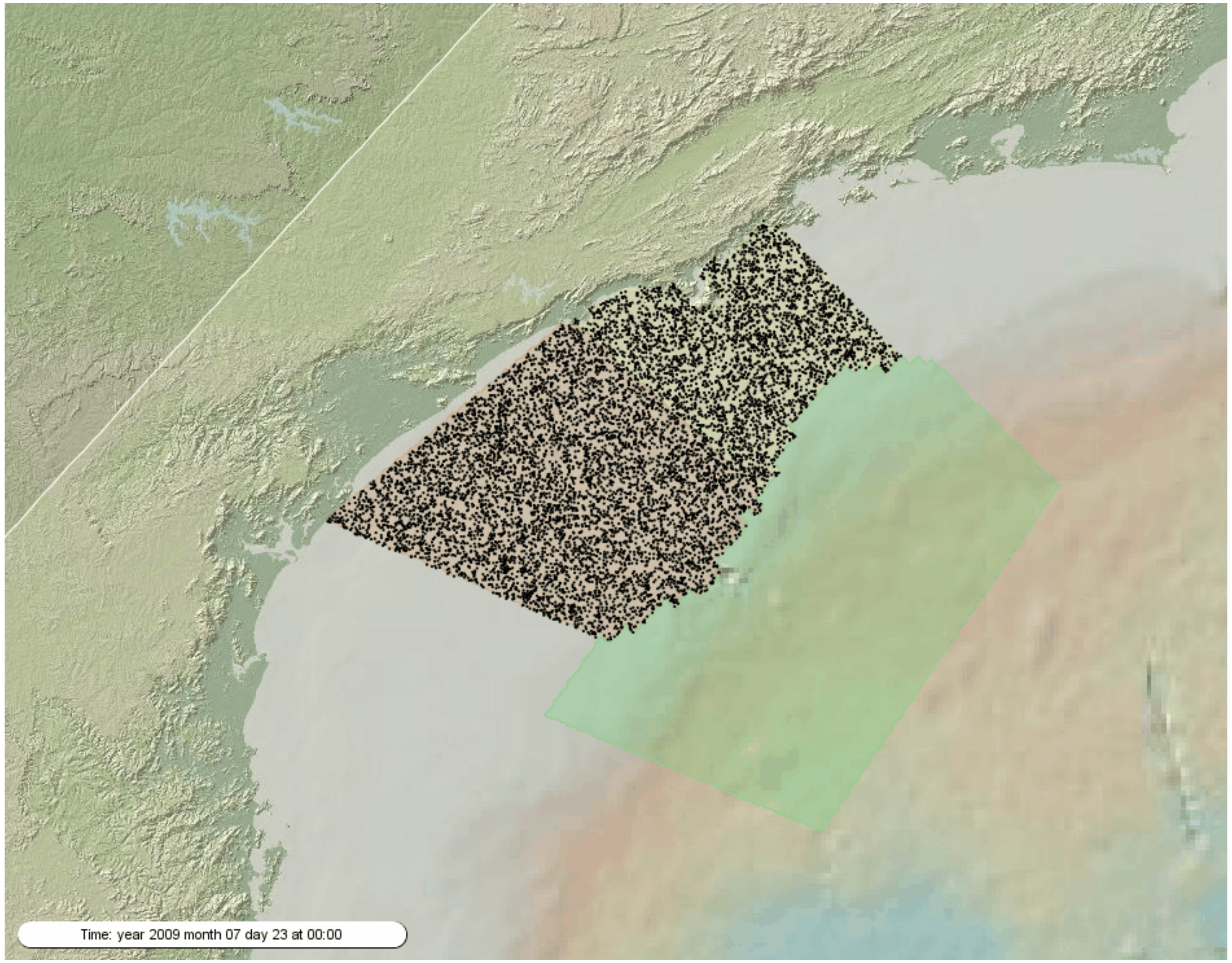
- not validated
- uses averaged data
- grid resolution too coarse (do not resolve small scale oceanographic phenomena)

Princeton Ocean Model (POM) for SBB (high resolution, in situ data model)

- not validated
- computer and space demanding

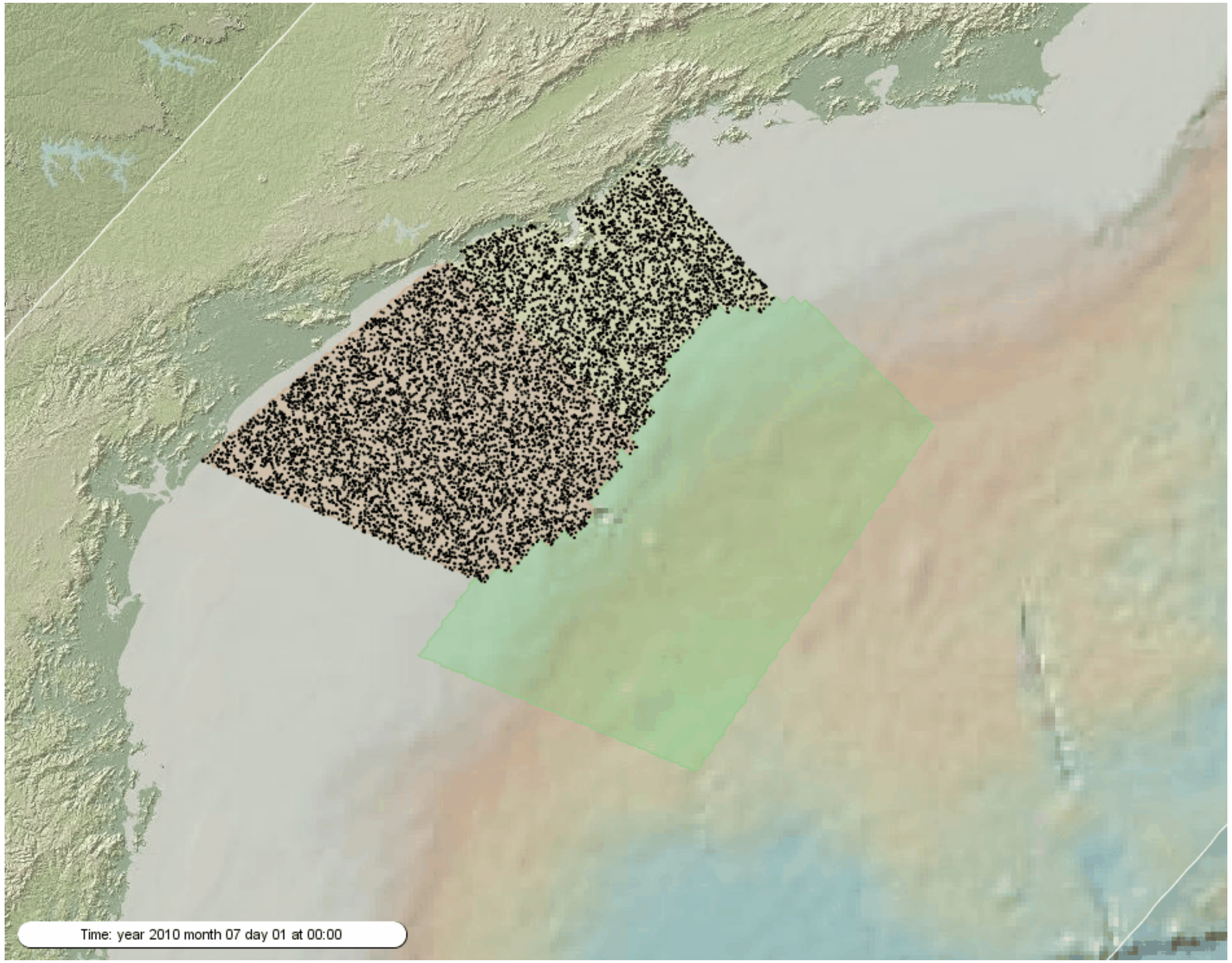
In situ vs. averaged data

Offshore losses – July 2009
Martins et al. 2010

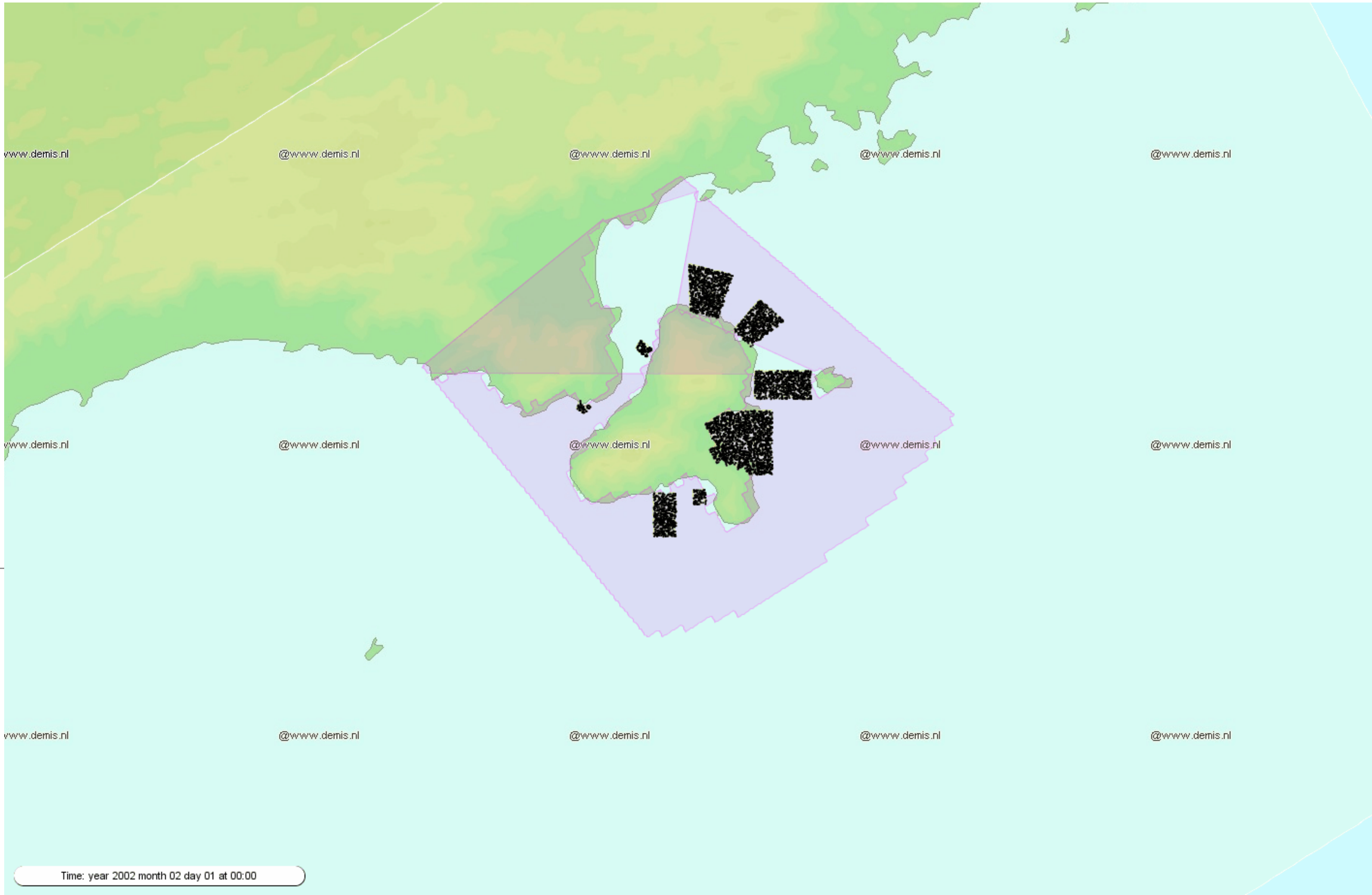


In situ vs. averaged data

Offshore losses – July 2010
Martins et al. 2010



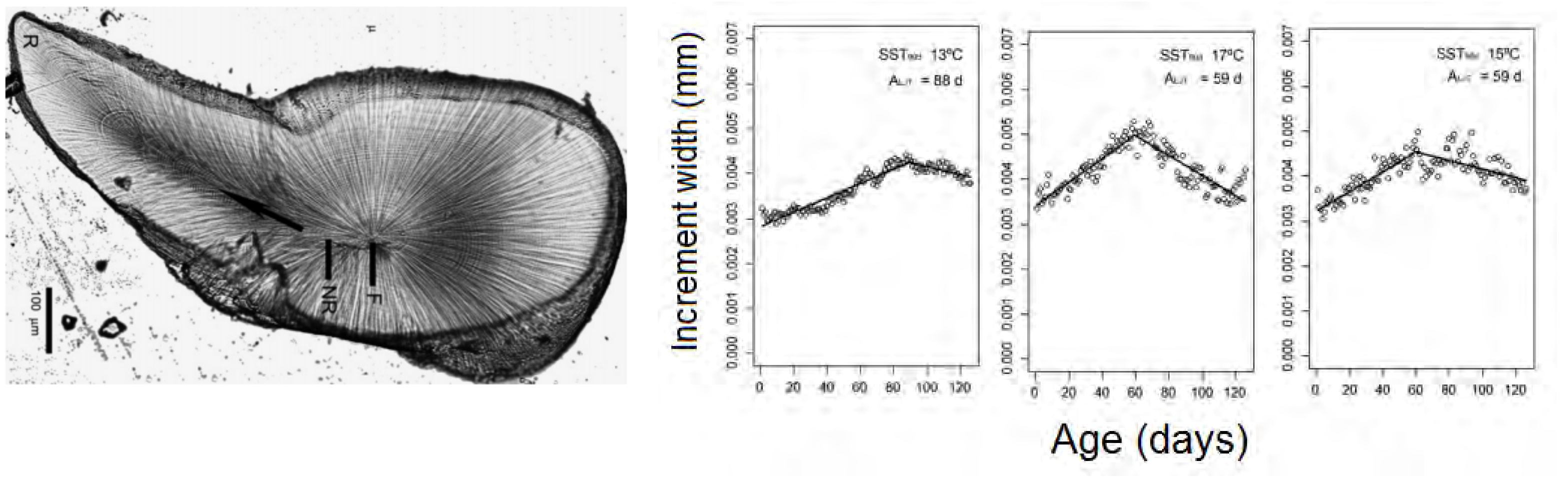
Circulation model grid size



Information on the squid spawning sites and behavior

- *Loligo reynaudii* is known to spawn in shallow (20-40 m) and deep (> 60 m) bottoms
- different transport patterns were found by Martins et al. (1014) and Downey (2014) for shallow and deep spawning grounds (retention close to the shore, westward transport offshore)
- *Doryteuthis plei* spawning grounds were unknown until 2010
- because the high retention on the whole shelf, spawning is possible anywhere from the coast to the slope on the SBB
- now its know that they spawn in very shallow waters (Gasalla et al., 2010)
- there is evidence for deep water spawning grounds too

- pelagic larval duration (PLD): PLD is poorly known for most loliginid squid species
- rearing is not indicated in this case, because it is laborious, time-consuming and may be biased by laboratory conditions
- solution: analysis of accretion pattern (i.e. difference of the thickness of growth rings during the would-be pelagic phase) on statoliths of adult squid (e.g. Moreno et al., 2012)



Analysis of accretion pattern in *Loligo vulgaris* (modified from Moreno et al., 2012)

Biological aspects of squid paralarvae biology & ecology: ***growth***

- growth is a better criteria for recruitment than age
- rearing studies of loliginid paralarvae is time and laborious consuming
- data avaliable for *Doryteuthis opalecens*, *Sepioteuthis* spp. and *Loligo reynaudii*
- problems: laboratory biases and the need of severale xperiments to account for several temperatures

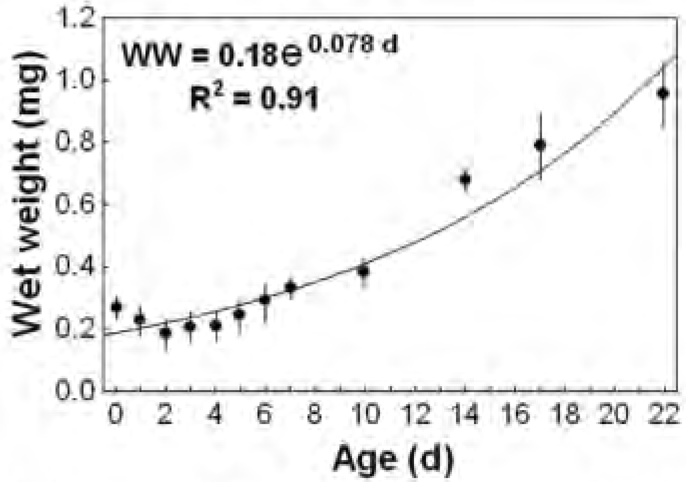


Fig. 4. *L. v. reynaudii*. Growth of fed paralarvae reared at 16 ± 1 °C expressed as wet weight (WW) versus age (in days post-hatching). Values are means of 15–51 paralarvae ± SD.

Vidal et al., 2005

Biological aspects of squid paralarvae biology & ecology: ***vertical distribution***

- vertical distribution of loliginid paralarvae is poorly known (best data for *Doryteuthis opalecens* and *Loligo vulgaris*)

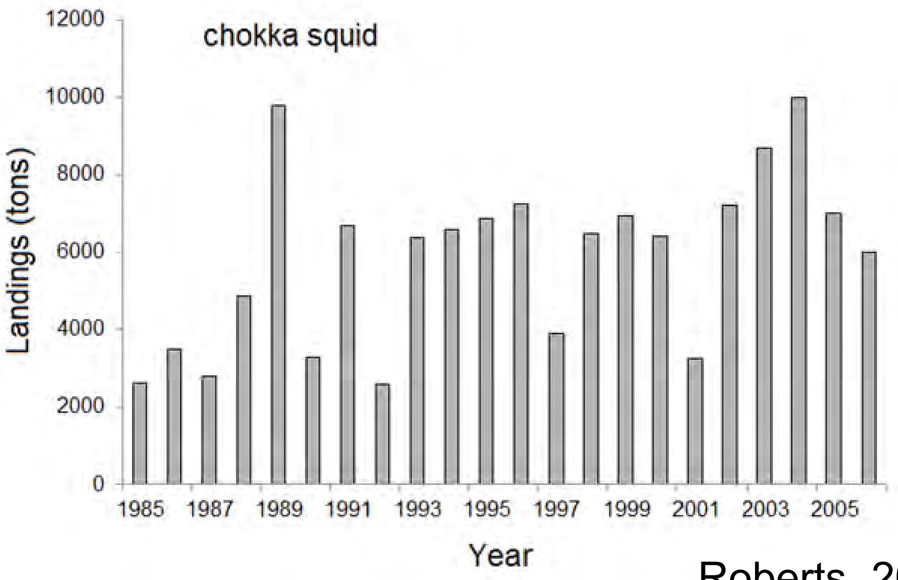
- this information is necessary to account for differential transport (vertical shear of currents in the water column)

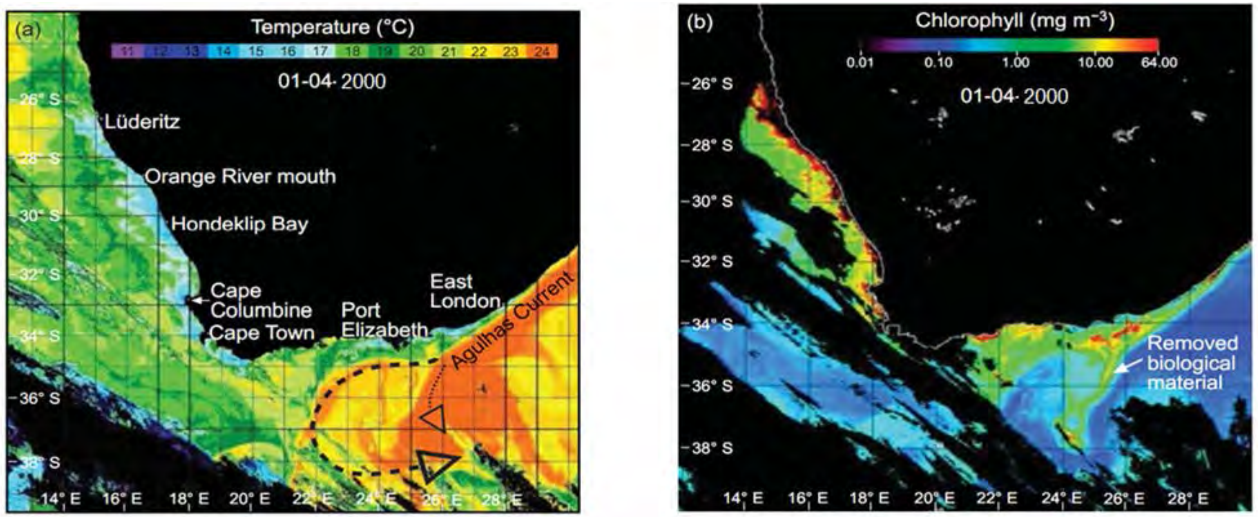
- no field data available for *Loligo reynaudii*

- good field data is now available for *Doryteuthis plei* (Araújo, 2013): 10 m during day and 20 m during night between RJ and Southern SP coast

Squid paralarvae IBM-circulation models vs. climate change…

- IBM-circulation modelling approach is used to gain insights to the most important “ingredient” in cephalopod recruitment: the early life stages
- oceanographic variability tend to increase and to be unpredictable in the future
- Warmer water temperature = smaller paralarvae (consequences for transport?)
- circulation anomalies may cause crashes in cephalopod fisheries





Roberts, 2005; Roberts and Mullon, 2010

Gaps to be fulfilled…

1. need of high resolution, validated circulation models built with in situ data for accounting natural oceanographic variability

2. clarify the PLD for the species studied using statolith increment analysis

3. need for paralarval rearing experiments at several temperatures (temperature-based growth submodels)

4. need for better field data on vertical distribution of paralarvae

5. need to think in ghe consequences of climate change on early life stages of squid

6. need to validate the IBM-circulation models in the field

The End
Thank you!
Obrigado!
☺