Modelling the transport of important fishery species in the Mozambique Channel and Agulhas Bank (South Africa)

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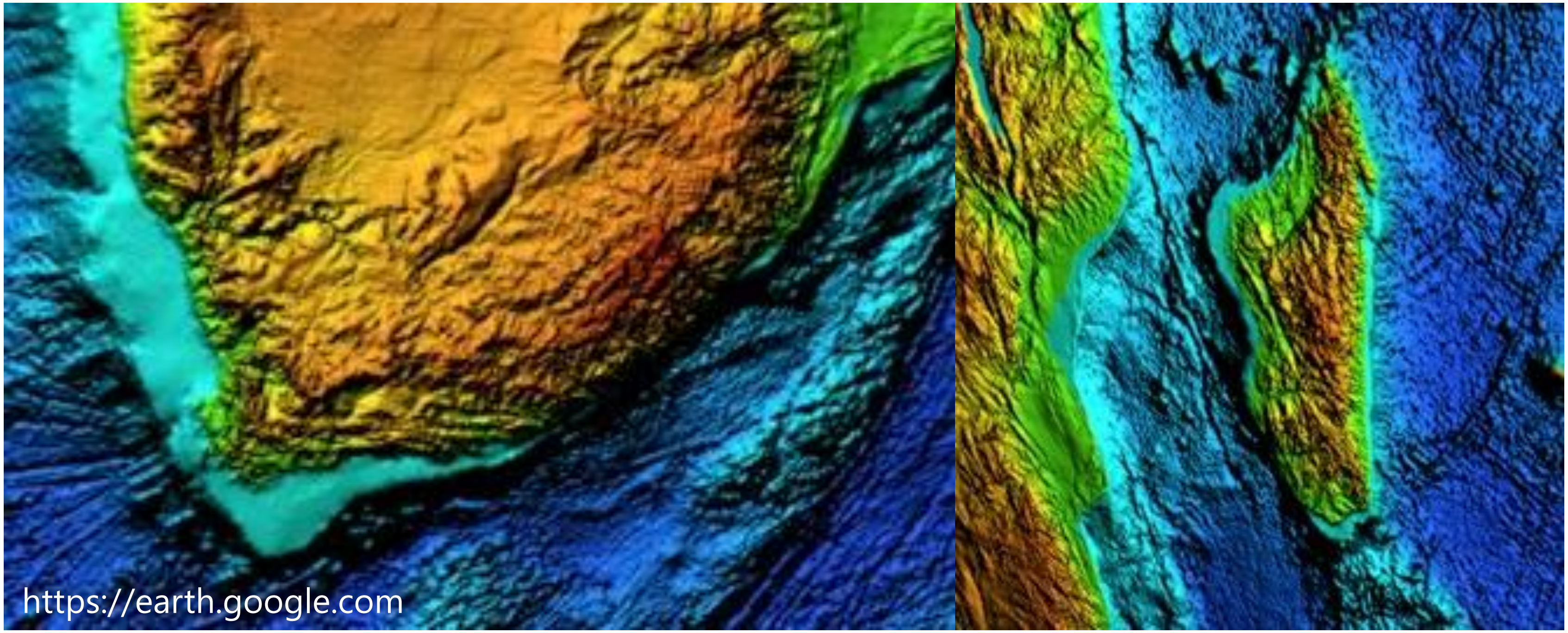
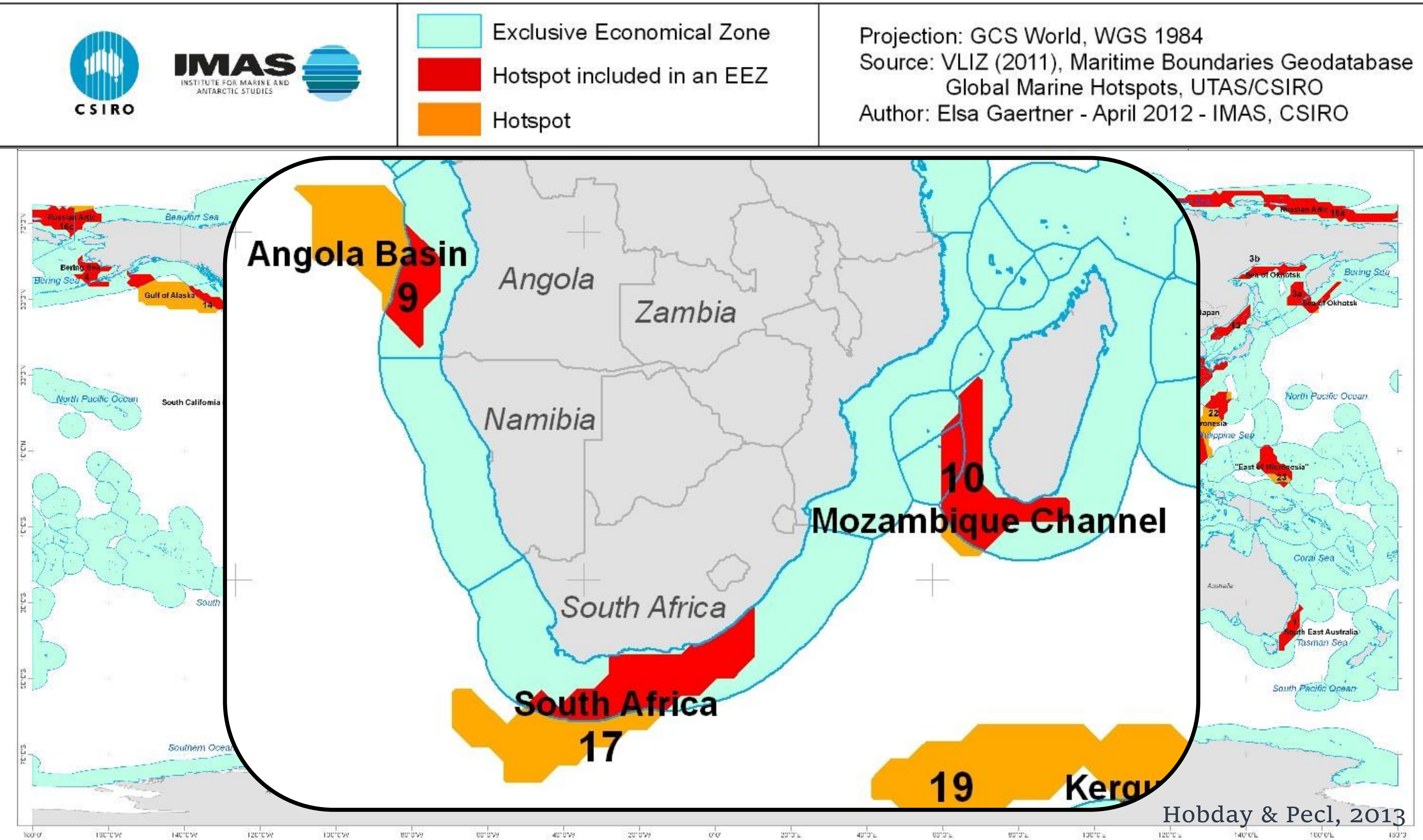


Global Marine **HOTSPOTS**

Areas warming faster than 90% of the worlds oceans.



Hobday & Pecl, 2013

Climate change and larval dispersal

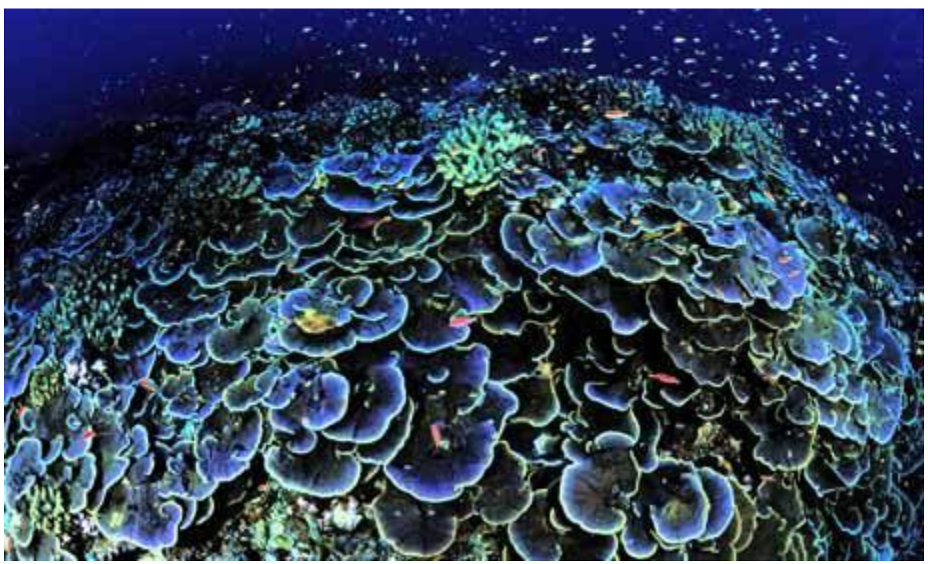
Although very little research on climate induced circulation changes exist, widespread changes can be expected.

Species with small dispersive larvae reliant on ocean currents could be transported to different areas creating shifts in the location of fisheries.

Alternatively reproductive effort could be lost with larvae not able to find suitable settlement habitat.

The effect of shrinking and/or shifting spawning habitat, and possible changes in spawning season, on larval dispersal and recruitment also need to be considered.

MPAs are being increasingly recognized as a key tool for maintaining and restoring ecosystem resilience in a changing climate, HOWEVER climate change can also threaten the intended outcomes of MPAs.



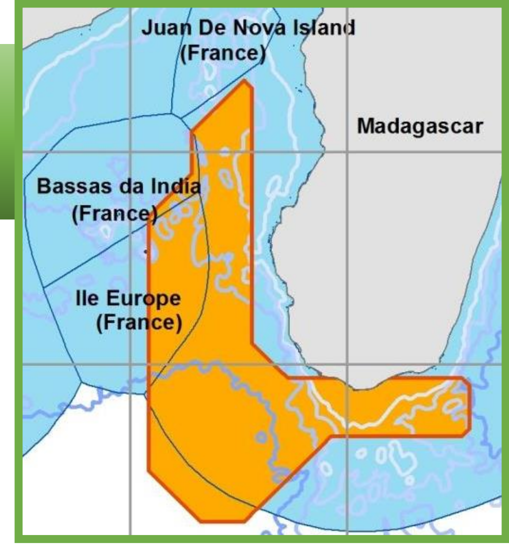
Spawning coral. Photo taken by Dr. Jim Maragos, U.S. Fish and Wildlife Service Coral Reef Biologist

This study uses an Individual-based Model coupled to a Regional Ocean Model to model the transport of planktonic stages of important fisheries species in the Mozambique Channel and Agulhas Bank (SA).

Model results are being used to determine:

1) Source and sink relationships
2) Larval distribution
3) Dispersal distance
4) Potential genetic connectivity between populations
5) Main drift routes

MOZAMBIQUE CHANNEL, Southern Madagascar



Octopus cyanea

Most economically important fishery in southwest region: contributing 60–70% of the value of marine resources purchased by collection and export companies

Also fished along Mozambique coast

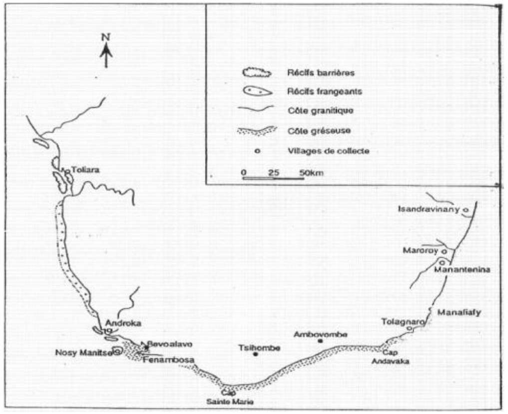
Paralarval duration of hatchlings before settlement ~30 days.

Panulirus spp

Found in southern Madagascar along ~ 500 km of coastline between Toliara and Isandravinany

Mostly fished by fishermen in the South

Long larval duration~months



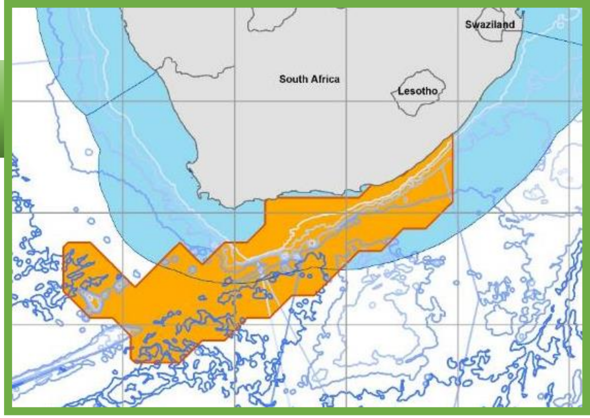
Penaeus indicus

Shrimp fisheries of Madagascar: Industrial trawl fishery, the artisanal trawl fishery and the traditional multi-gear fishery

P. indicus most abundant and distributed throughout Madagascar

Larval duration ~10-15 days

AGULHAS BANK, South Africa



Loligo reynaudi

Merluccius capensis (shallow) *and*
M. paradoxus (deep-water)

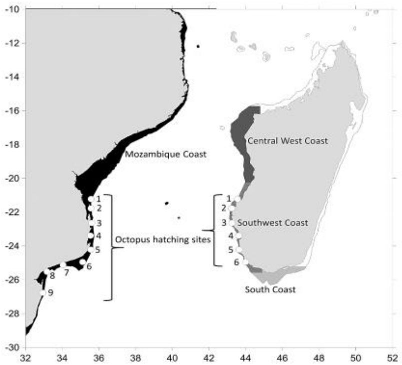
Both found in Southern Benguela Upwelling system and Agulhas Bank system

Both support commercial fisheries in South Africa:

- Chokka squid fishery off south coast
- Hake trawl and long-line fisheries off west and south coasts

Individual-based Models setup

Octopus cyanea



Hatching sites: Six hatching sites along southwest Madagascar & nine sites along southern Mozambique.

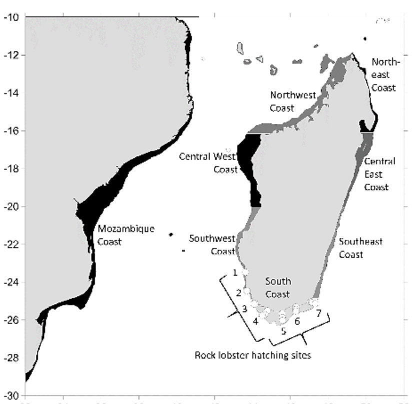
Release schedule: 500 paralarvae released every five days for one model year

Four transport scenarios: Passive and diel vertical migration (surface at night and depths 25/50/100 meters during day)

Transport duration: 30 days

Recruitment determined by position on day 30 (settlement age)

Panulirus spp



Hatching sites: Seven hatching areas along southern Madgascar. Where the width of the shelf allowed, hatching sites were classed as Inner shelf, Mid shelf or Shelf edge.

Release schedule: 1000 phyllosoma released every five days during the warmer months (January-March & September-December)

Phyllosoma stages represented by specific size and diel vertical migration inputs

Transport duration: >270 days

Recruitment: All phyllosoma reaching (or on) the continental shelf at model day 270 are considered able to metamorphose into puerulus and begin the journey across the shelf to settle along the coast.

Penaeus indicus

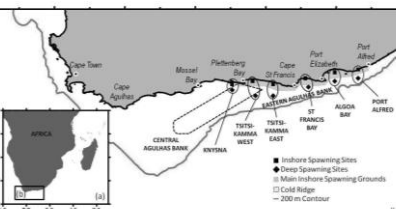
Hatching sites: Three main hatching ZONES – West coast, South coast, East Coast of Madagascar.

Release schedule: 10 000 larvae released every five days for one model year

Transport duration: 15 days

Recruitment determined by position on day 10–15

Loligo reynaudi



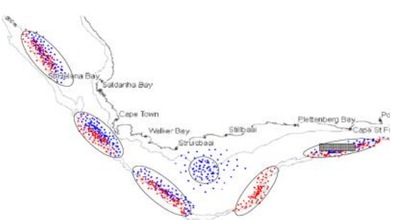
Hatching sites: Six from main spawning grounds, seven from "Fringe spawning" areas

Release schedule: 500 paralarvae released every five days for one model year

Transport duration: 40 days

Recruitment determined by position on shelf (day 40), or transport to nursery areas

Merluccius spp



Hatching sites: Five spawning hotspots for each species, and species specific release depths

Release schedule: 1000 eggs released every five days for one model year

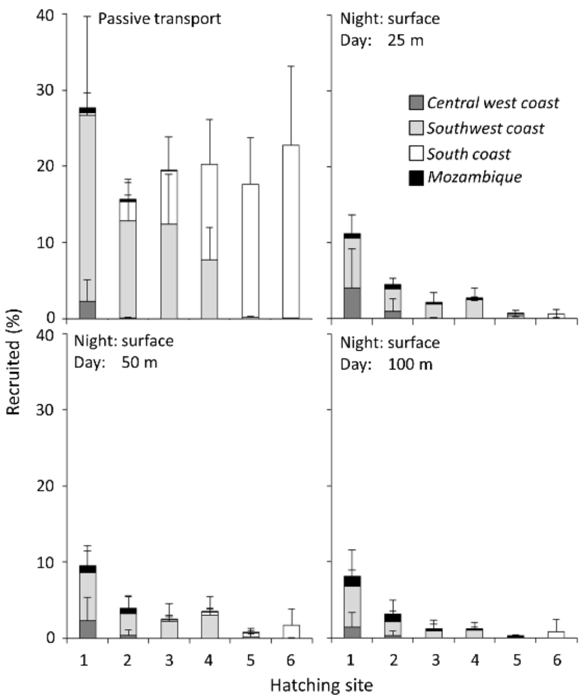
Transport duration: 40 days

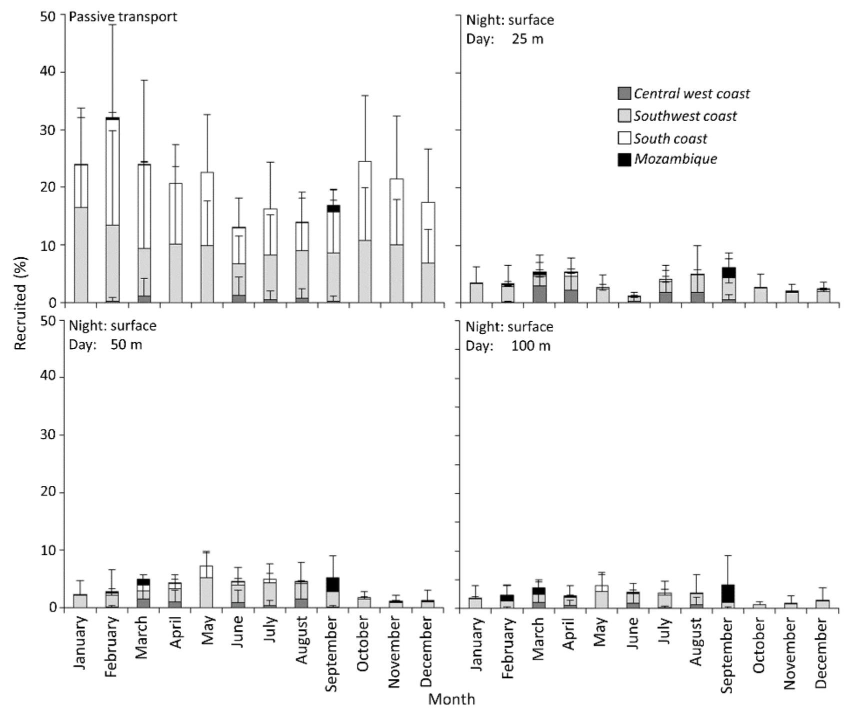
Recruitment to species specific nursery areas along coast

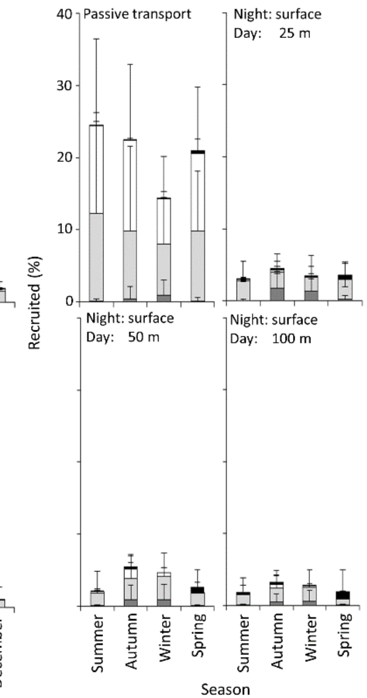
Results

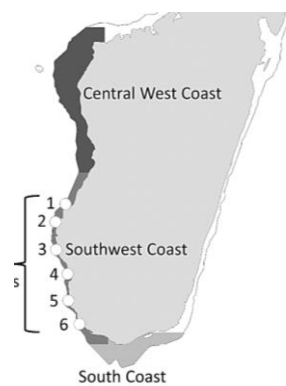
1) Source and sink relationships

Hatching site location significantly influences recruitment to specific areas, with season playing a more minor role.









Example 1: Octopus cyanea (Madagascar)

Other factors also influencing recruitment:

Diel vertical migration strategies

Hatching near shelf edge versus inshore

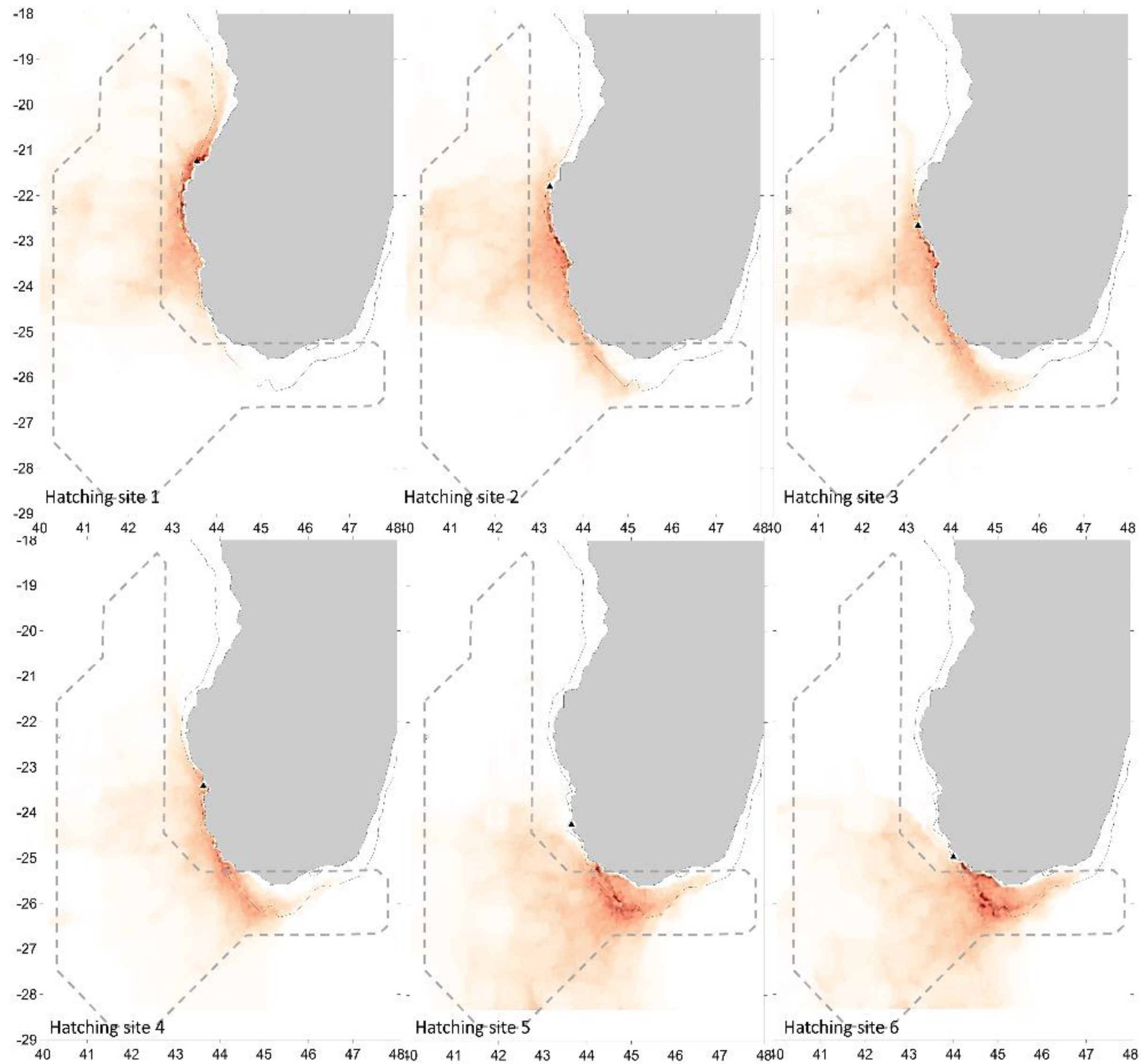
Results

2) Larval distribution

Analysing larval distribution (heat maps) further demonstrates the significant link between specific hatching sites and coastal areas.

In the given example of Octopus paralarvae distribution at settlement, it is clear spawning activity along the coast seeds local and adjacent reef populations, with paralarvae being retained and concentrated in certain areas.

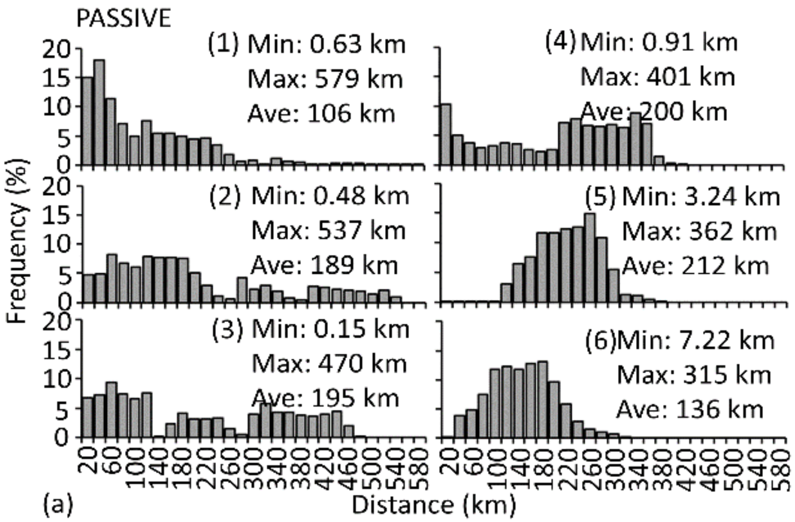
Seasonal variation in transport routes and distribution is also evident, as seen in this example of monthly shrimp larval distribution.



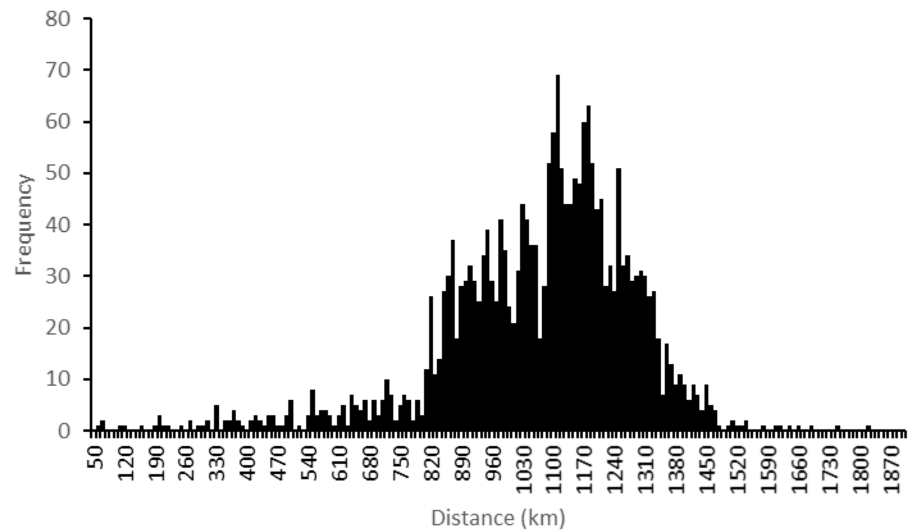
Results

3) Dispersal distance

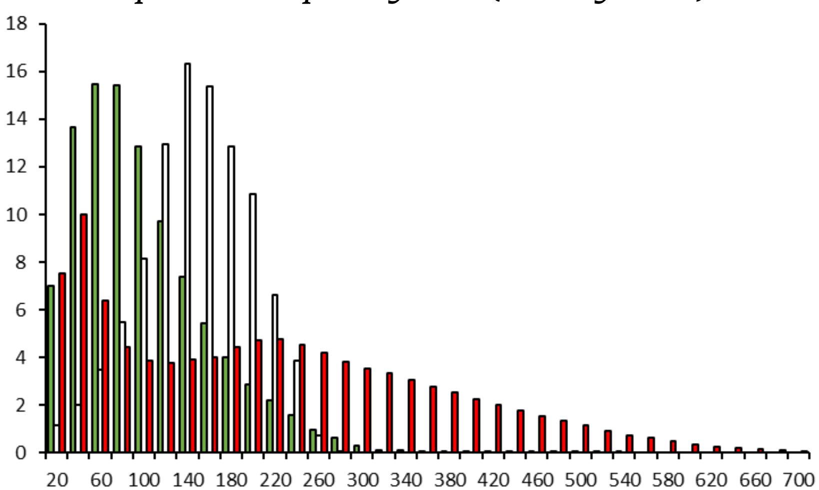
In addition to identifying areas of larval concentration in relation to origin or hatching site, it is also useful to analyse dispersal distance, particularly when considering the locality of Marine Protected Areas.



Example 1: Octopus cyanea (Madagascar)



Example 2: Rock lobster (Mozambique Channel)



Example 3: Shrimp (Madagascar)

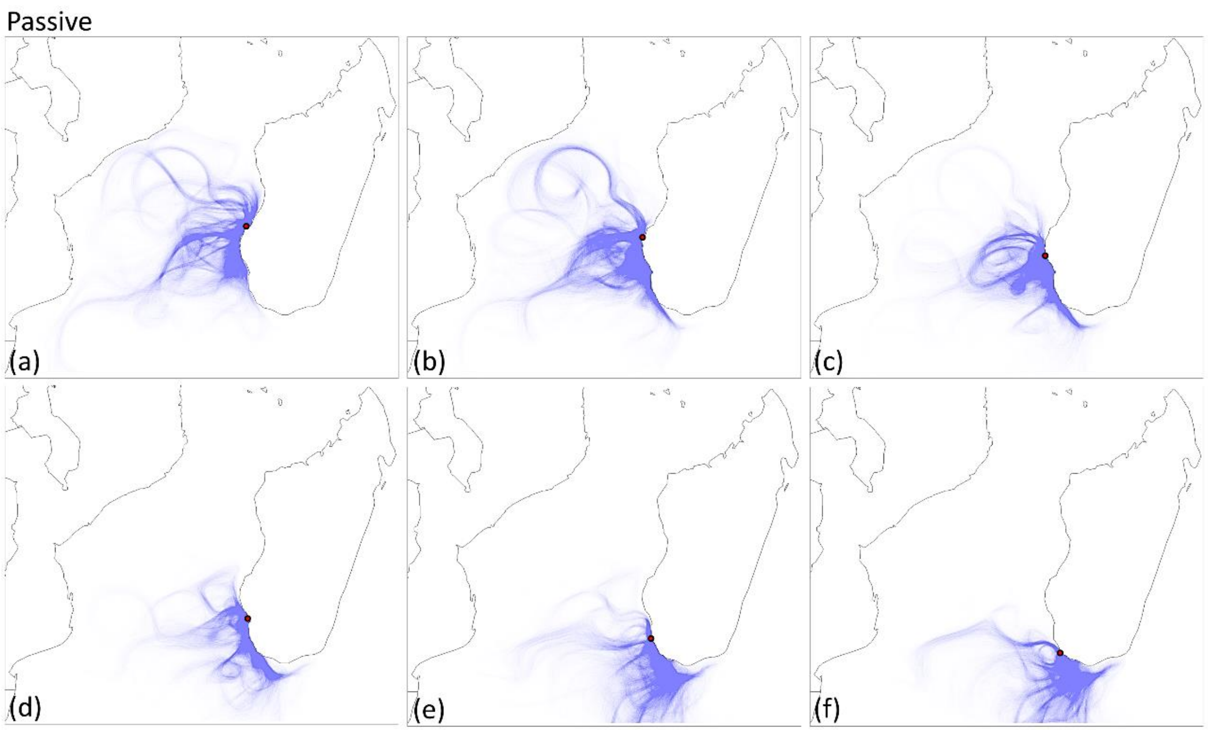
As show in examples 1 & 2, dispersal distance is largely determined by larval duration (30 days vs >270 days).

Also important however, is the locality of the hatching site. In example 3, dispersal distance for shrimp larvae for the **WEST**, SOUTH and **EAST** coasts of Madagascar are compared. Dispersal distance on the east coast is greatly increased by the strong Southern East Madagascar Current.

Results

4) Potential genetic connectivity between populations

The current results indicate some potential for gene flow between Malagasy and Mozambiquan marine species (Examples 1 &2). However for species with a larval duration of ~ 30 days, this is limited to hatching sites along central west coast of Madagascar. On the Agulhas Bank (South Africa), results indicate a barrier to gene flow exists off the west coast (Example 3), providing further evidence for separate Angolan and South African chokka squid populations.



4) Main drift routes

The main transport or larval drift routes from specific hatching sites identified using line density plots (darker lines).

Discussion

The coastal region of southwest Madagascar is recognised as one of Africa's most vulnerable areas to climate change.

Already experiencing severe droughts, down-scaled climate models predict the terrestrial region to become even hotter and drier.

In the future migration from inland villages to the coast is likely to increase, as farmers seek an alternative livelihood, placing even more pressure on coastal resources.

As evidenced by SST, southwest Madagascar is experiencing temperature increases of ~0.016°C per year. This is three times faster than in the northern regions (0.006°C yr^{-1}) and is above the global average (0.010°C yr^{-1}).

Changes in water temperature can have a number of detrimental effects including coral bleaching and mortality, and shifts in fish distribution and reproductive patterns.

In South Africa, shifts in the spatial distribution of several marine species; a result of changing SST, wind and upwelling patterns; have already been recorded.

In addition to these changes, which will have a cascading effect on existing spawning habitats and source and sink relationships, climate induced changes in circulation patterns will surely exacerbate these impacts.

By investigating larval source and sink relationships, distribution, dispersal distances and major drift routes, we aim to gain a deeper understanding of the potential impacts of climate change on the recruitment and early life history of important fishery species. By identifying major larval drift routes and comparing to climate model predicted changes in circulation patterns, we can further explore the impacts climate change may have.