

# Reef-to-reef connectivity shapes metapopulation structure along the French Atlantic coastline & informs conservation priorities

**Martin Marzloff**

Raphaël Clément, Céline Cordier, Philippe Cugier, Carmen David, Stanislas Dubois, Louise Firth, Antony M Knights, Flavia Nunes

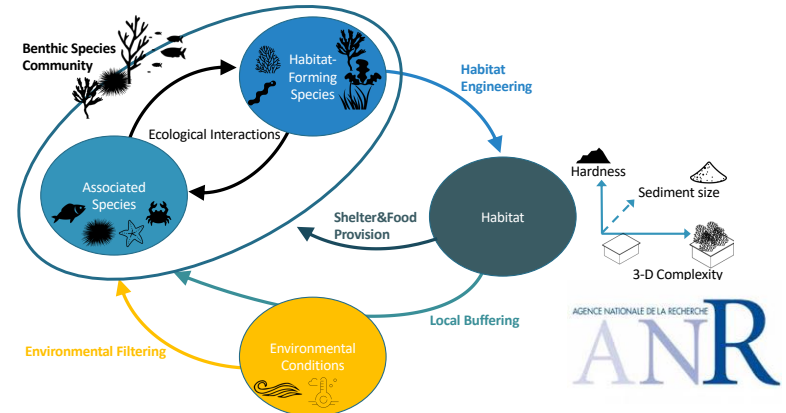


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# Marine Connectivity Of Benthic Species

Broad research interests in **modelling** to **understand & predict** coastal ecosystem structure and dynamics

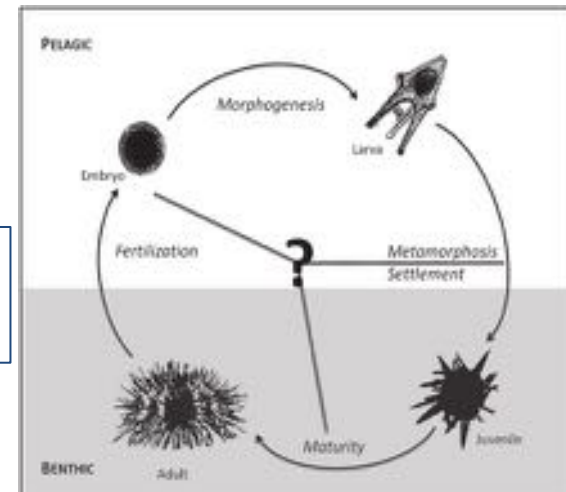


Summary figure of starting TRIDENT research project on development of trait—based models for benthic systems

**Modelling community dynamics of species with bentho-pelagic life cycle**



Critical role of **larval / propagule / seeds dispersal** to **population connectivity**



Dorey (2013). *PhD thesis*

# Marine Connectivity Of Benthic Species

## Ecologically- or commercially-important species

*P. maximus*



*O. edulis*



*M. varia*



*C. fornicata*



*O. nigra*



*C. gigas*

## Habitat-forming species

Honeycomb worm *Sabellaria alveolata*



Eelgrass *Zostera marina*



Parc naturel marin d'Iroise ©

# Two complementary lenses to study connectivity

## (1) Biophysical modelling of larval dispersal

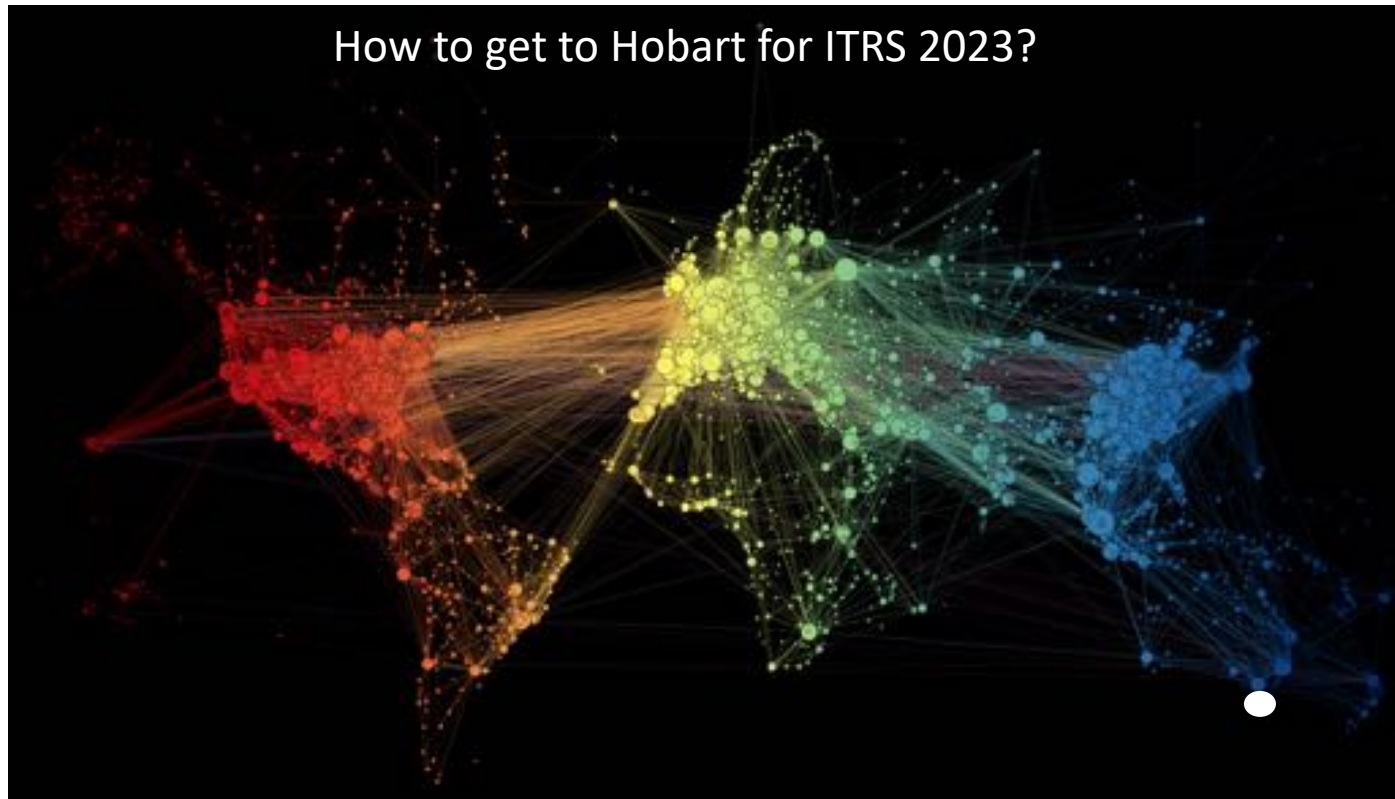
- PROS
- + Spatially-extensive assessment of **potential** connectivity routes
  - + Account for species specificities (e.g. larval duration, spawning period etc.)
- CONS
- Limited ability to finely capture ecological processes involved in connectivity



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Global maps of major airports and flights routes

Source: M GrandJean <https://www.martingrandjean.ch/connected-world-air-traffic-network/>

# Two complementary lenses to study connectivity

## (1) Biophysical modelling of larval dispersal

How to get to Hobart for the **actual first** ITRS in 1792?  
Van Dieman's land



Bruni D'Entrecasteaux



La Peyrouse



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How to get to Hobart for the **actual first** ITRS in 1792?

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La Pérouse



"Who cares about politics and revolution, to keep the wig competition going as long as possible, we'd better not get our heads chopped... So let's do some cool science stuff along the world's shores, then we meet in Van Dieman's land, check out the giant kelp, share some shellfish with the locals and discuss our findings."

Source: <http://www.ourtasmania.com.au/exploration-dentrecasteaux.html>

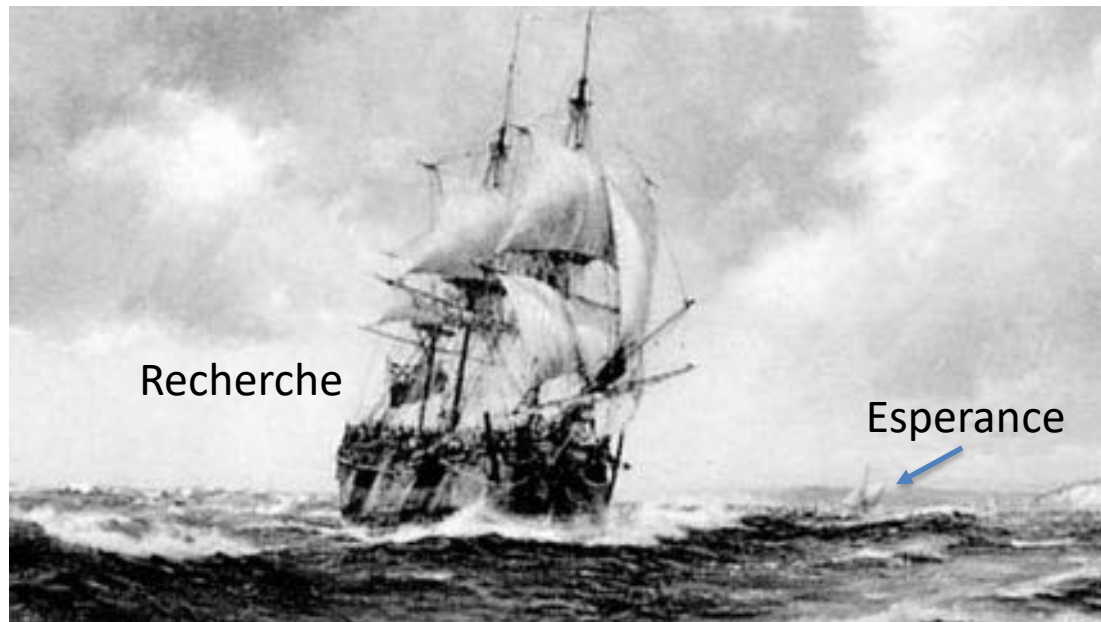
# Two complementary lenses to study connectivity

## (1) Biophysical modelling of larval dispersal



Bruni D'Entrecasteaux

How to get to Hobart for the **actual first** ITRS in 1792?  
Van Dieman's land



*Left Brest on Sept. 28<sup>th</sup> 1791 to arrive in Recherche Bay, Tasmania, on April 20<sup>th</sup> 1792*



# Two complementary lenses to study connectivity

(1) Biophysical modelling of larval dispersal

(2) Population genetics

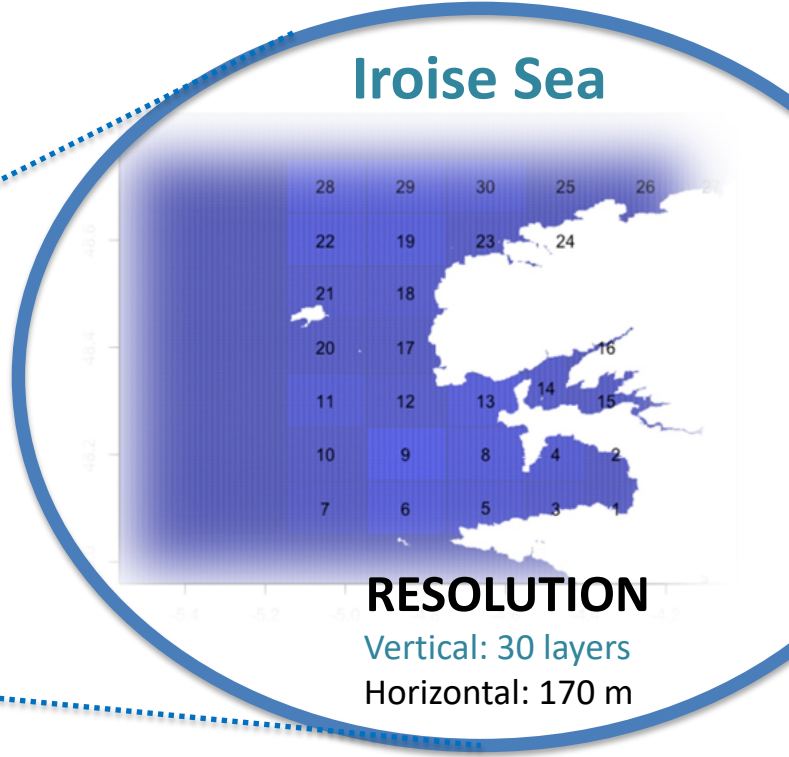
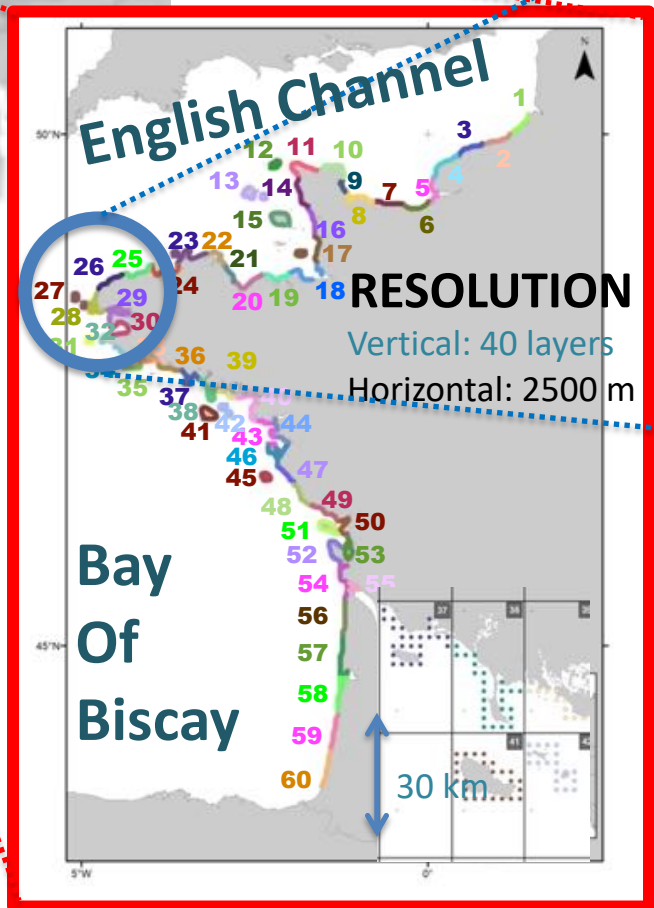


- PROS + Assessment of **effective** connectivity (gene flow) between distant populations
- CONS - Sparse and spatially-discrete sampling  
- Multiplicity of molecular approaches & indices



# Hydrodynamic modelling of larval dispersal

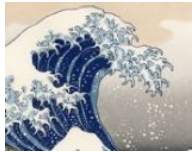
## Simulations using alternative MARS3D model configurations



# Hydrodynamic modelling of larval dispersal

Simulations using alternative MARS 3D configurations

## Realistic forcings in hydrodynamics simulations



- River outflows
- Wind
- Tides (spring Vs dead) and waves

## Larval dispersal

- Eulerian approach
- Passive tracers (i.e. no vertical swimming behaviour)
- Instantaneous zone-specific release in the bottom layer
- Release during spawning season (April to September for years 2012-2018)
- Different Dispersal Durations (10 days – 6 weeks)

# Hydrodynamic modelling of larval dispersal

Simulations using alternative MARS 3D configurations

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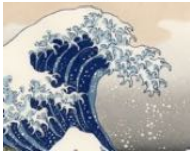


- River outflows

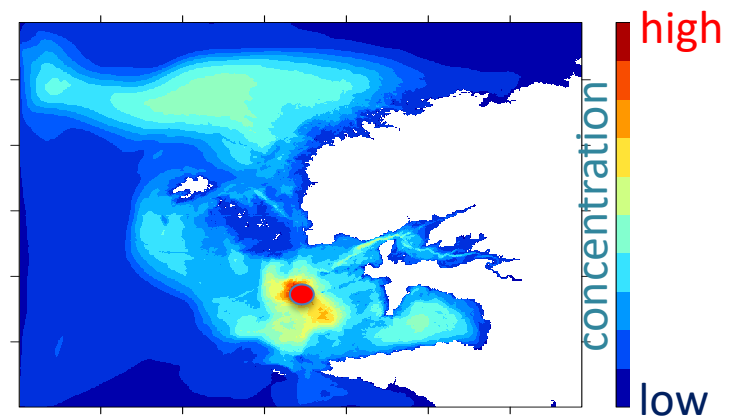


- Wind

- Tides (spring Vs dead) and waves



## Concentration in tracer (30 days after release)



## Larval dispersal

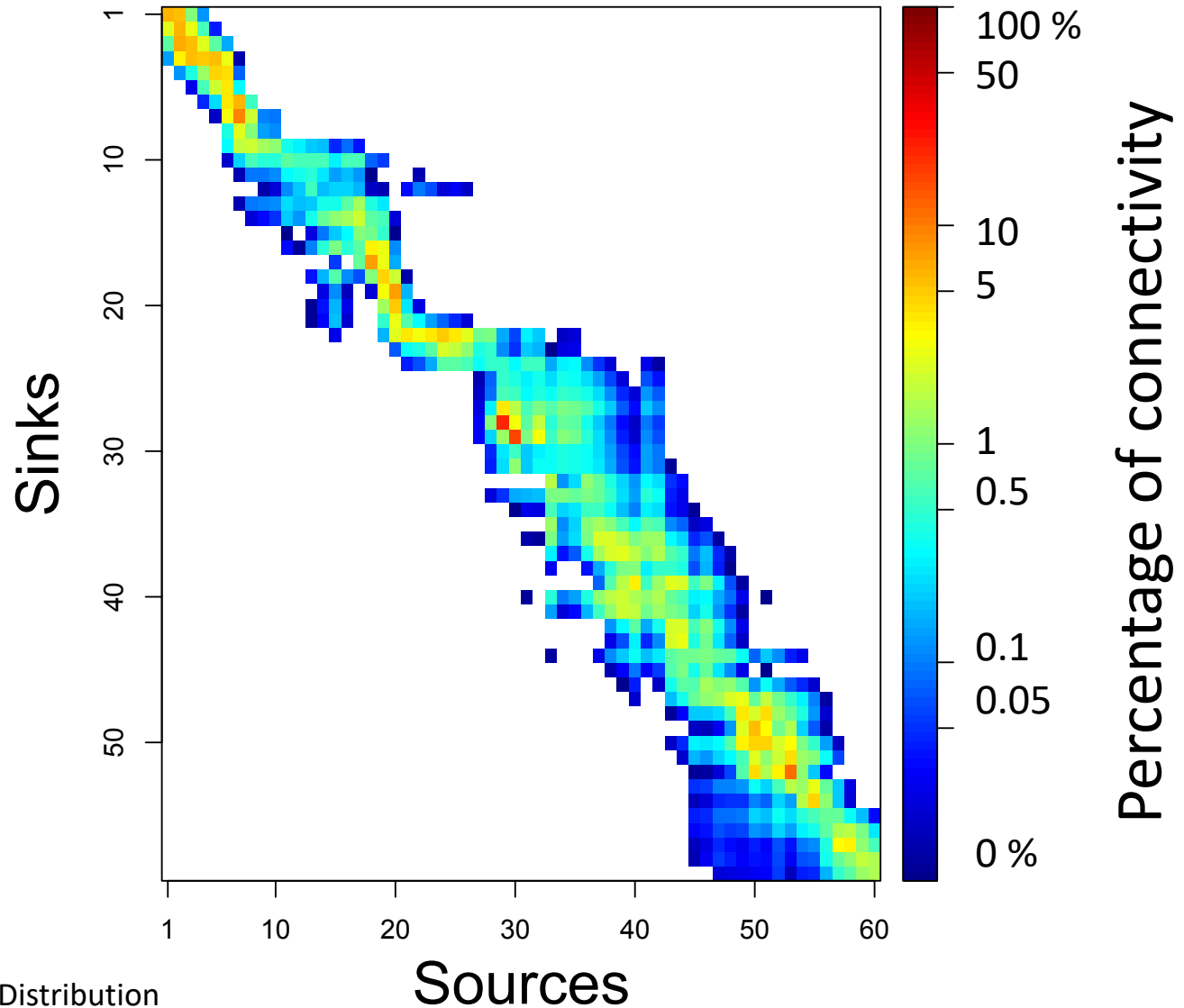
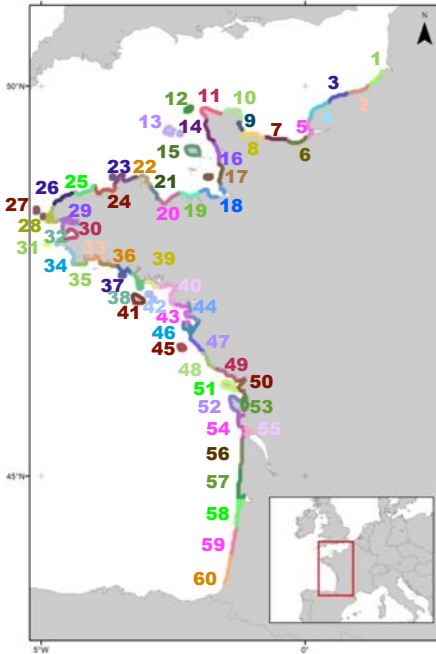
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# Simulated regional hydrodynamic connectivity

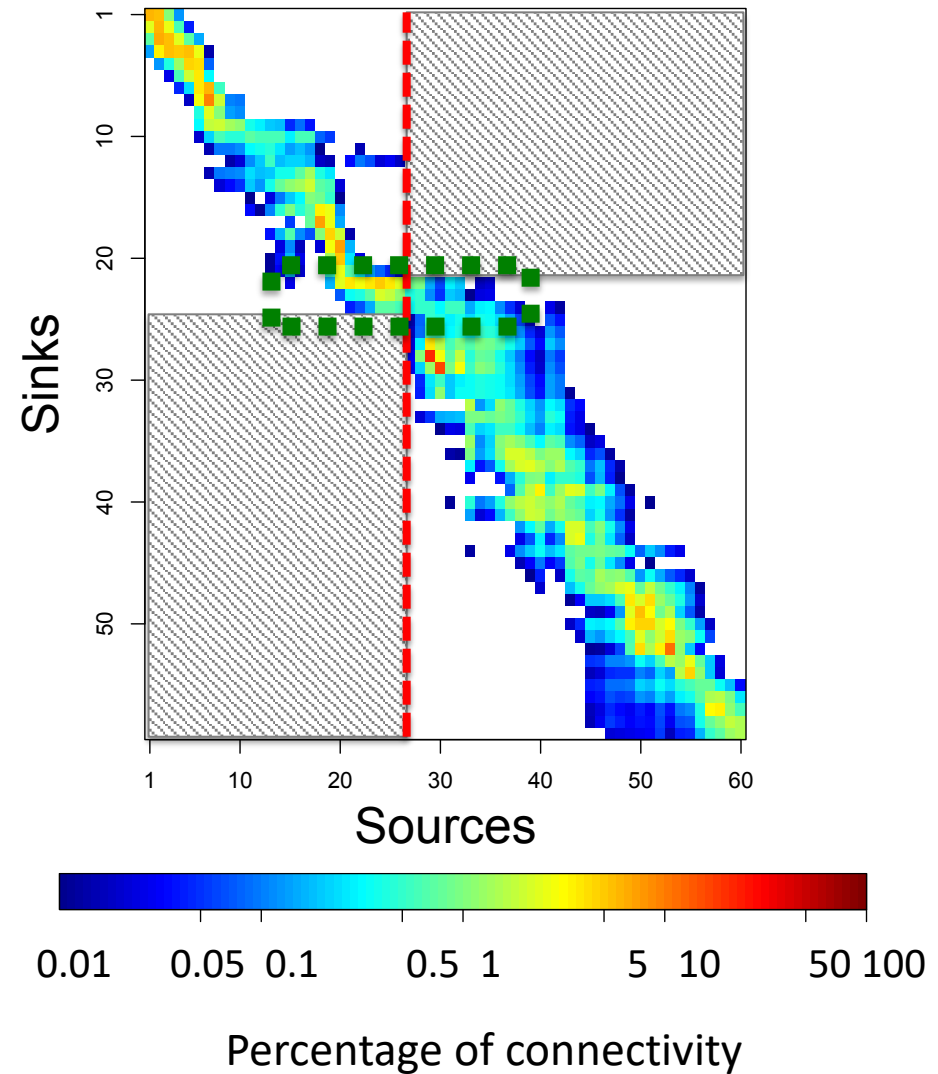
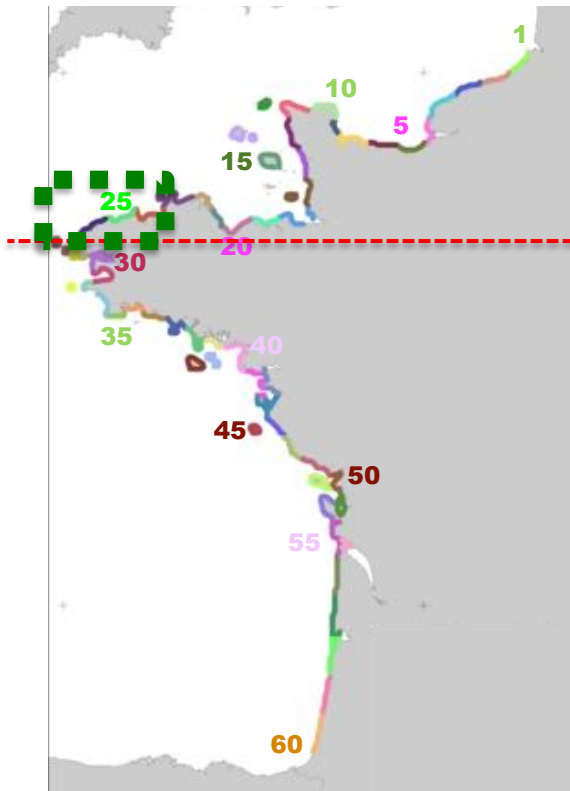
## Mean Connectivity Matrix

(Monthly mean / April-Sept. / 2012-2016 / 4-week dispersal)



# Simulated regional hydrodynamic connectivity

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# Species-specific hydrodynamic connectivity

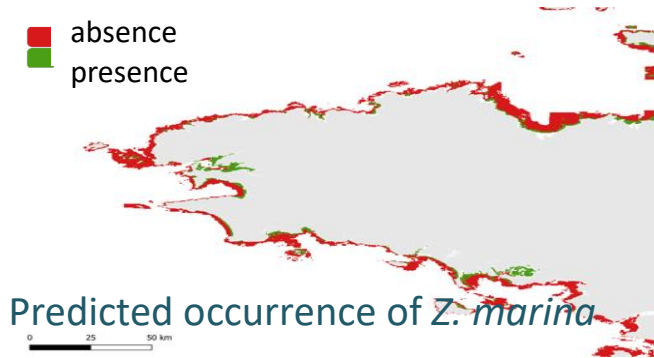


## Case of eelgrass (*Z. marina*)

### Species Distribution

(based on Modelling & expert knowledge)

■ absence  
■ presence



Predicted occurrence of *Z. marina*

(Romain Mouillard's MSc thesis - 2020)

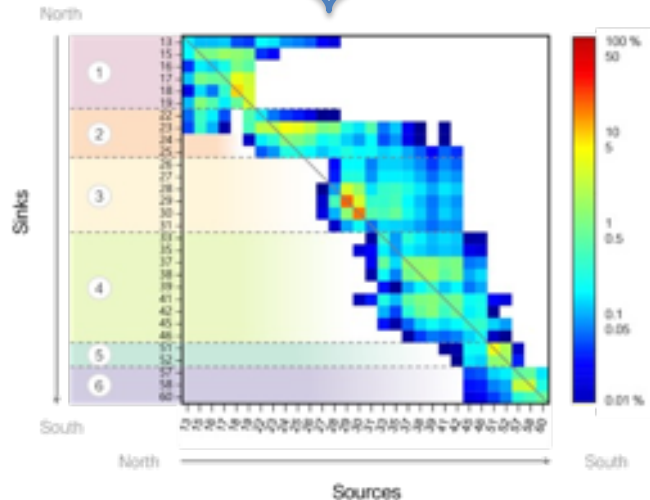


&

“Larval ecology” (i.e. dispersal duration)



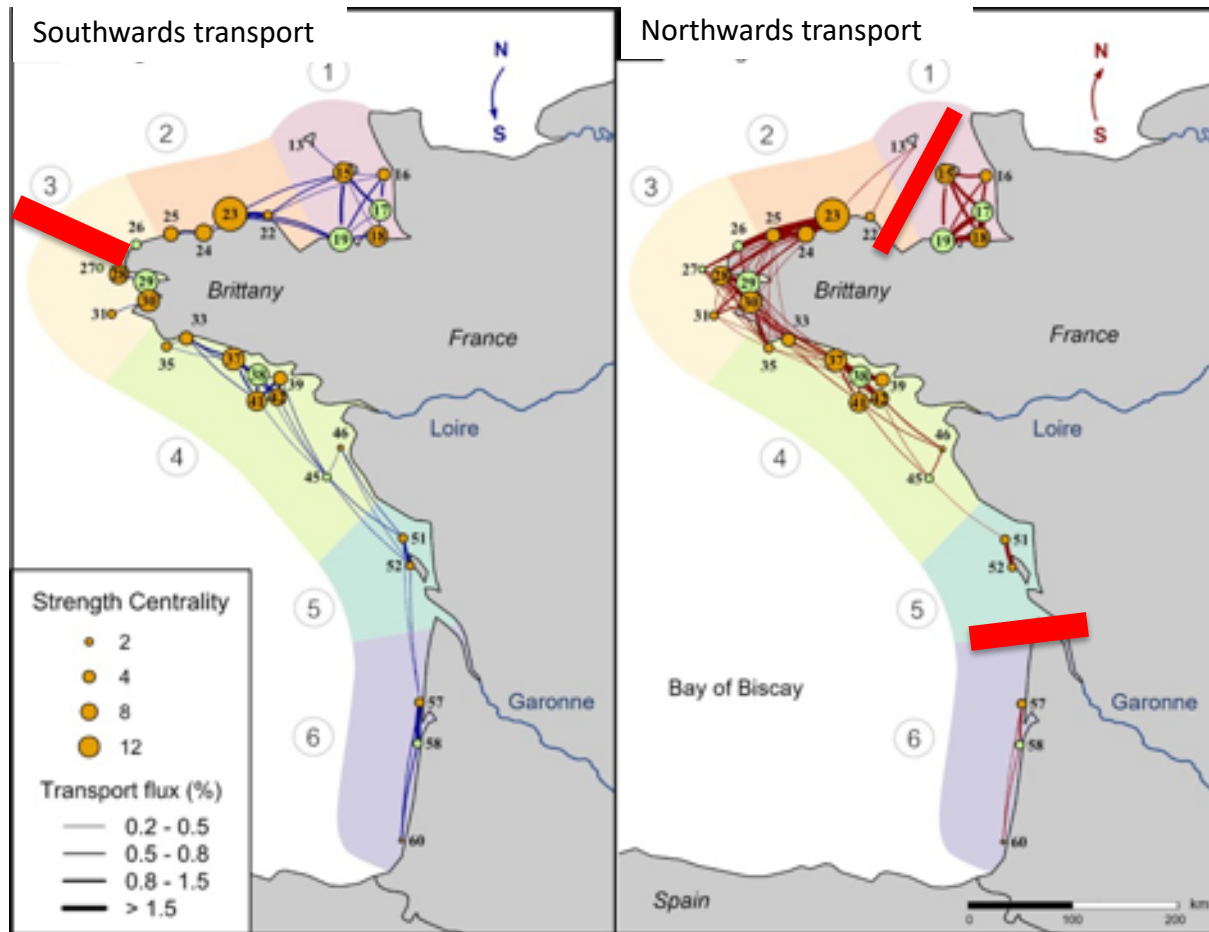
e.g. 6-week dispersal for eelgrass spath (Jankhe *et al.*, 2016)



Raphaël CLEMENT's MSc (2022) / Clément *et al.* (in prep.)

# Species-specific hydrodynamic connectivity

## Case of eelgrass (*Z. marina*)



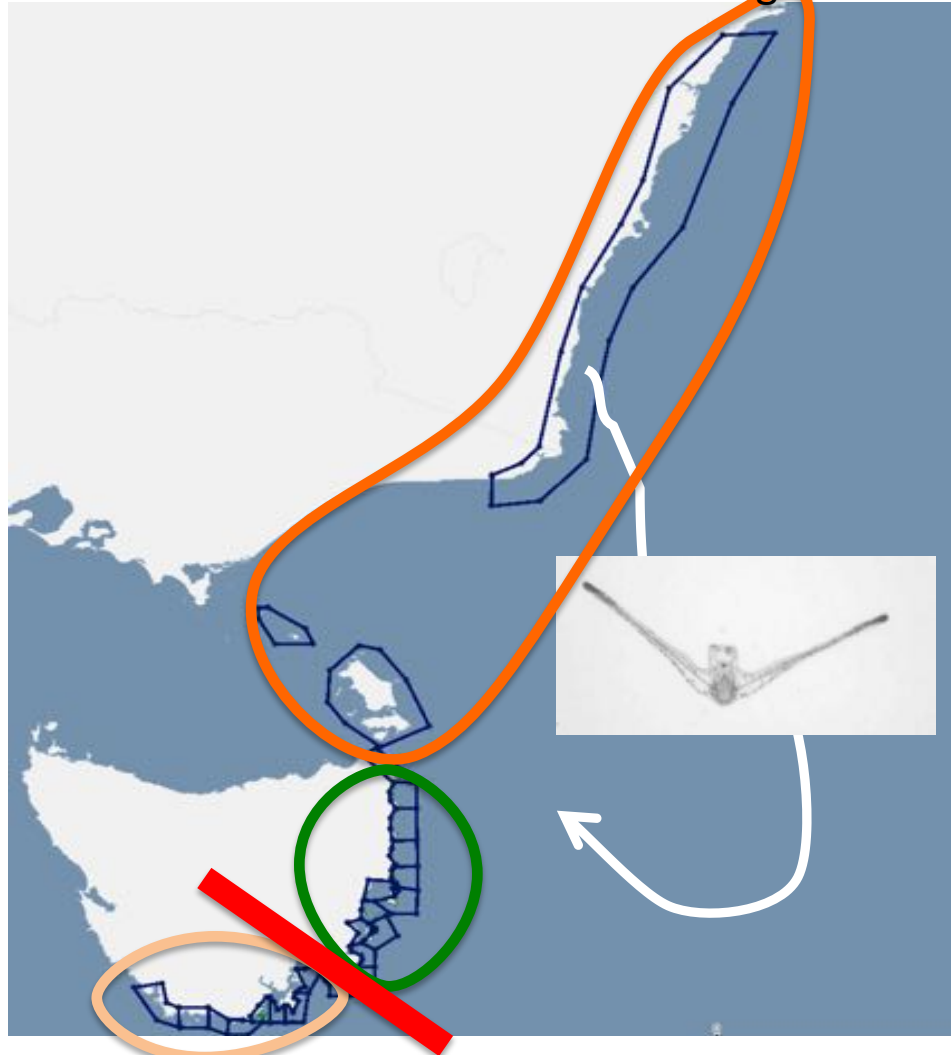


# Species-specific hydrodynamic connectivity

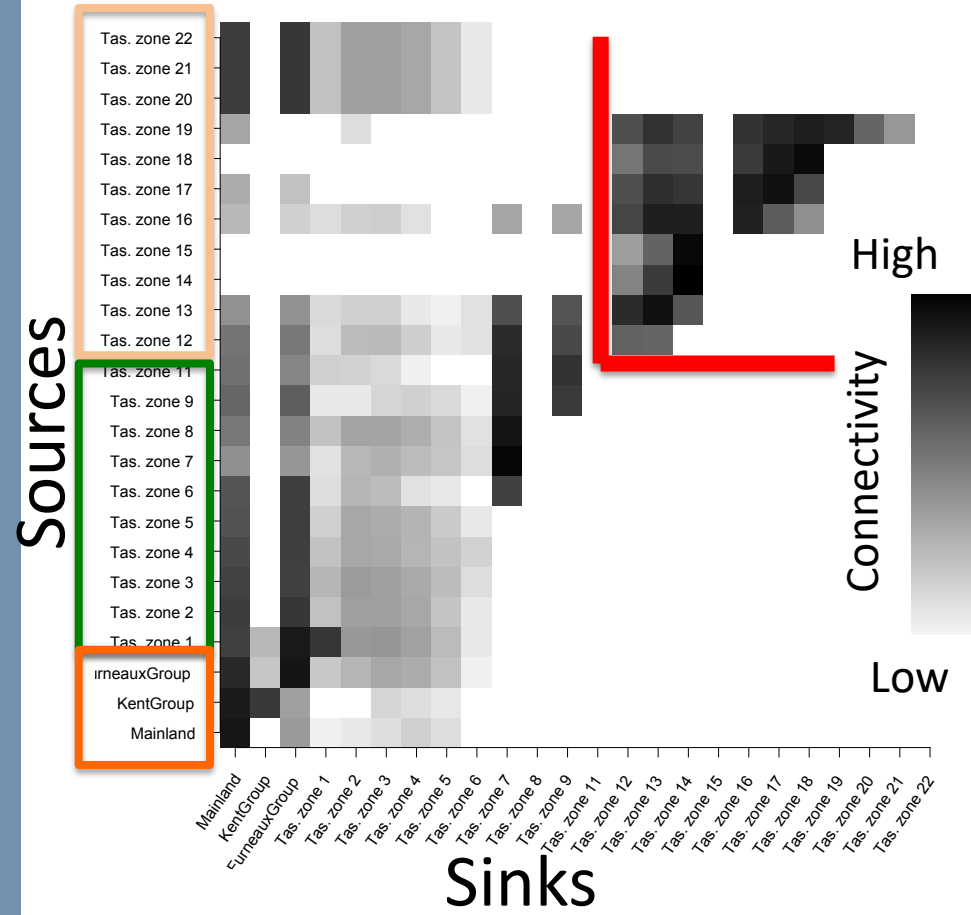
## Mean Connectivity Matrix for *C. rodgersii*



Coastal zones defined for modelling



Regional reef-to-reef connectivity



# Metapopulation network & connectivity metrics

Case of *Sabellaria* reefs

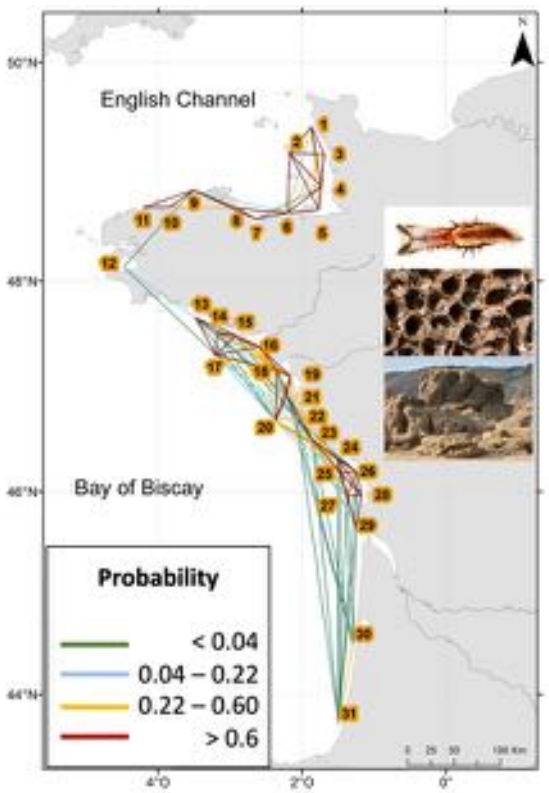


## Mean Connectivity

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# Metapopulation network & connectivity metrics

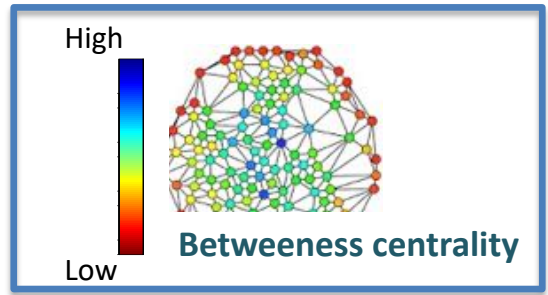
Case of *Sabellaria* reefs



## Sequential Node Removal Scenarios

Removal priority rules

- Random
- ▲ Endnodes
- Betweenness
- + Low reef abund.
- ⊠ High reef abund.

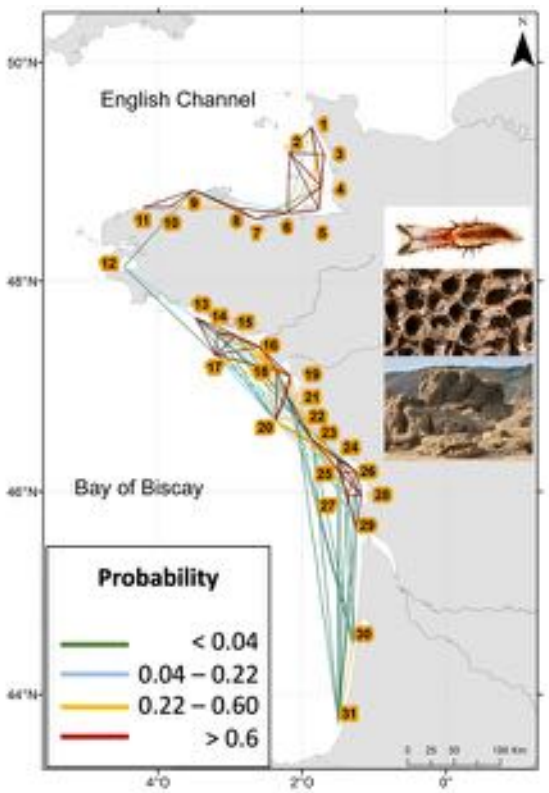


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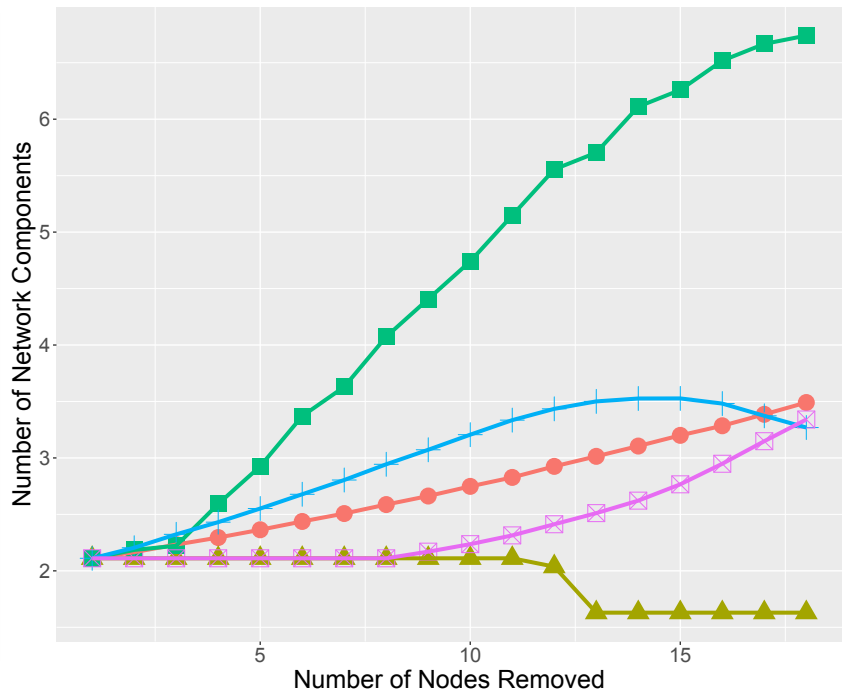
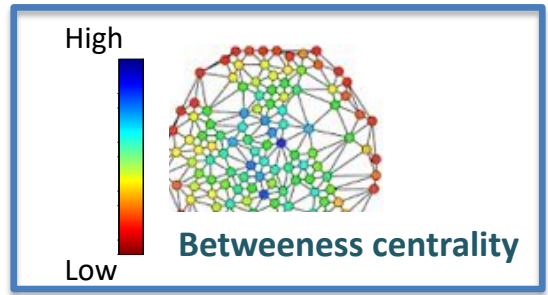
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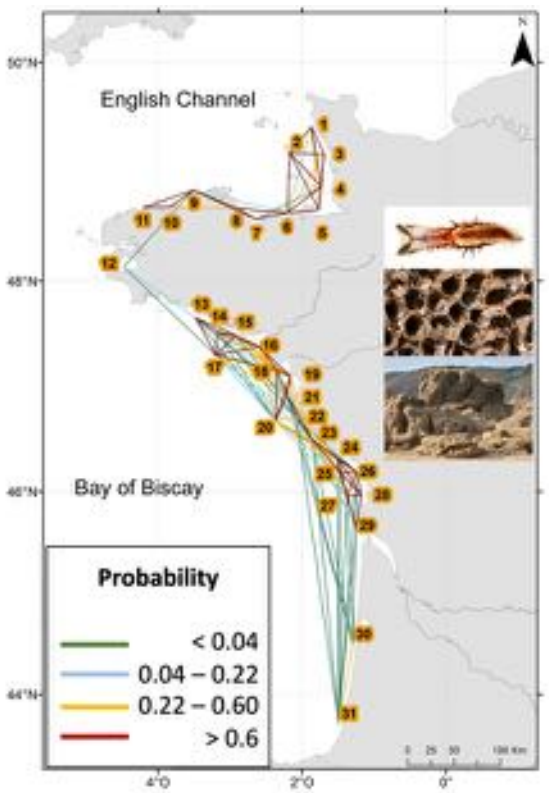
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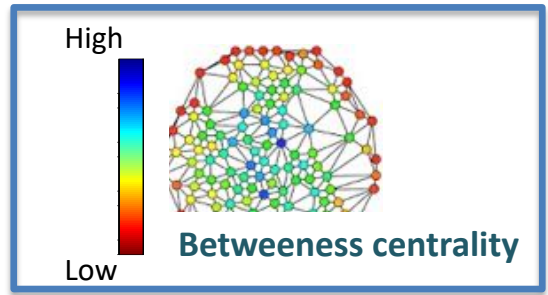
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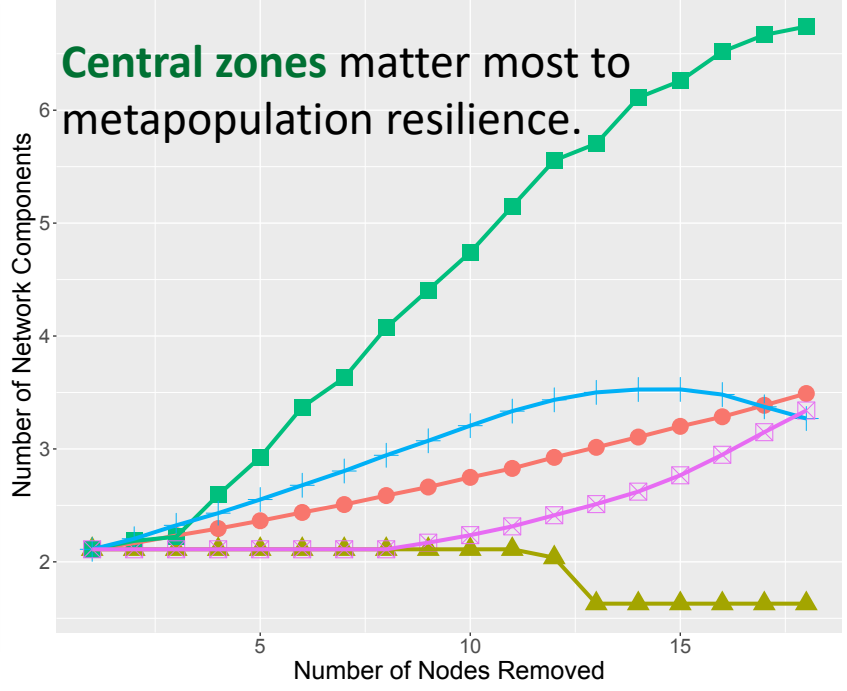
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**Central zones** matter most to metapopulation resilience.



### Mean Connectivity

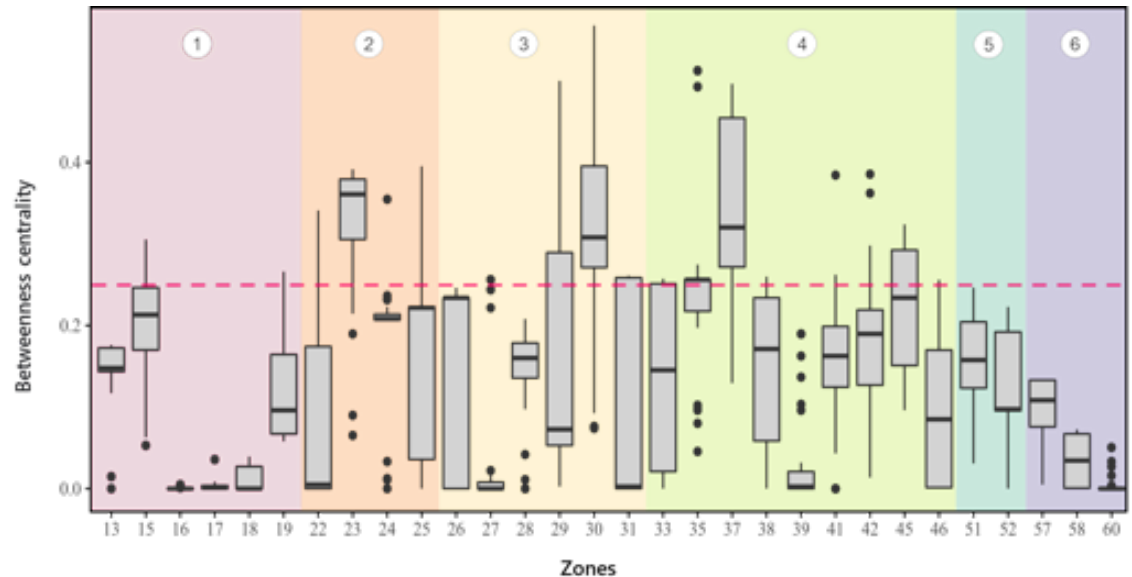
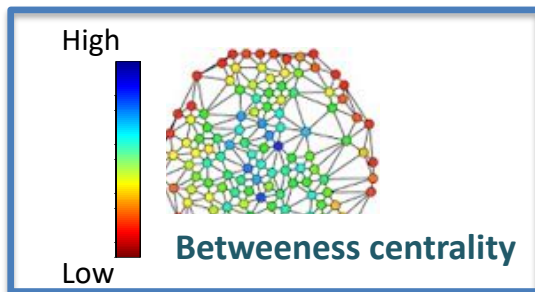
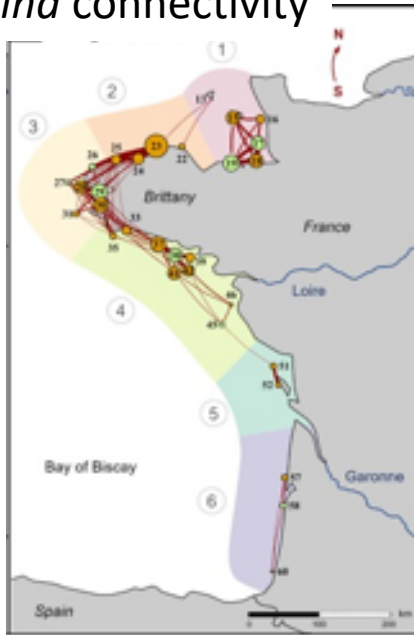
(April-Sept. / 2012-2016 / 4-week dispersal)

# Variability in zone-specific connectivity metrics

Case of eelgrass (*Z. marina*)



*Z. marina* connectivity

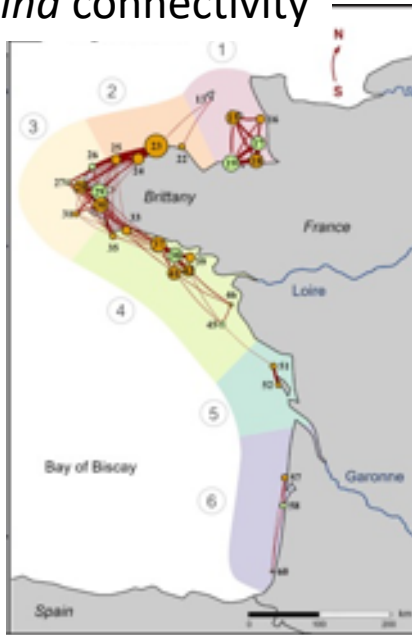


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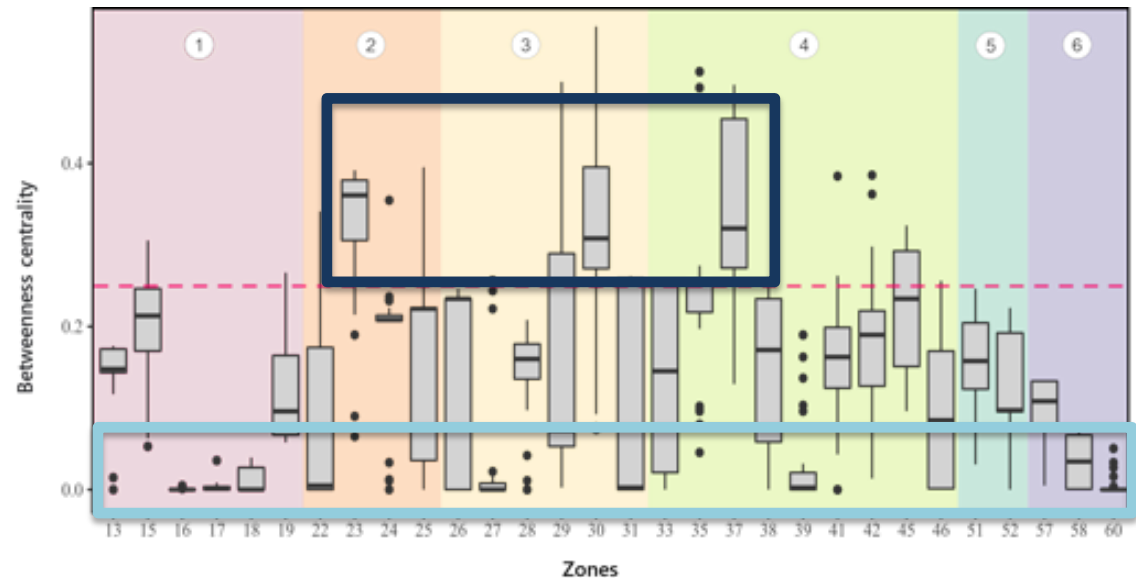
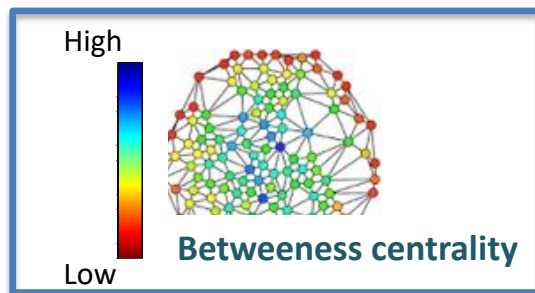
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*Z. marina* connectivity



- **Central Vs edge** zones in network

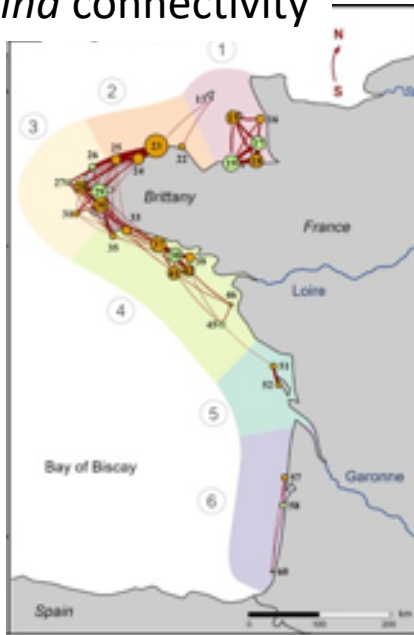


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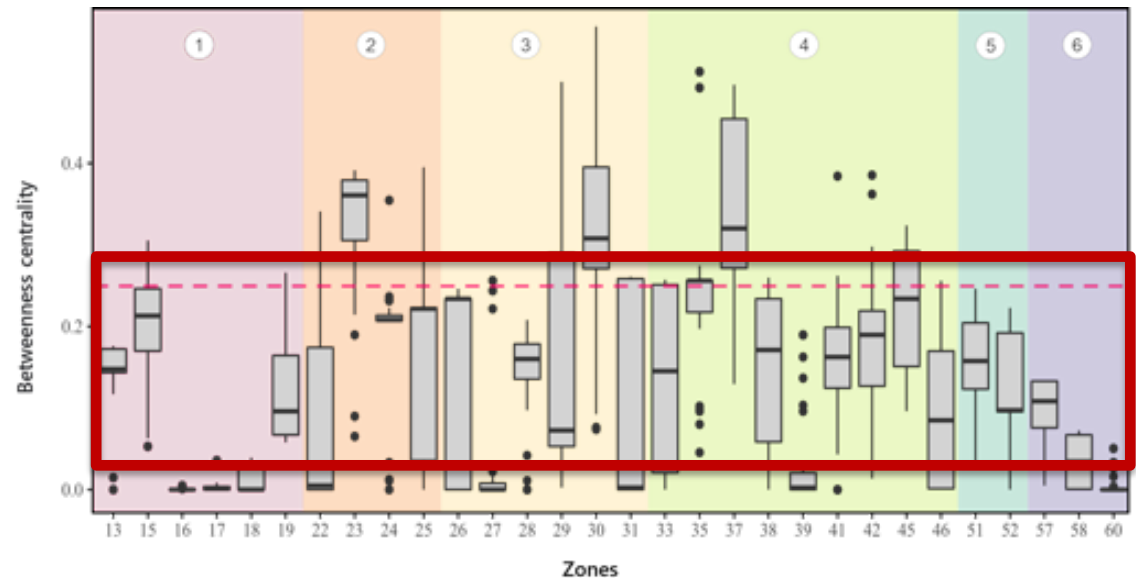
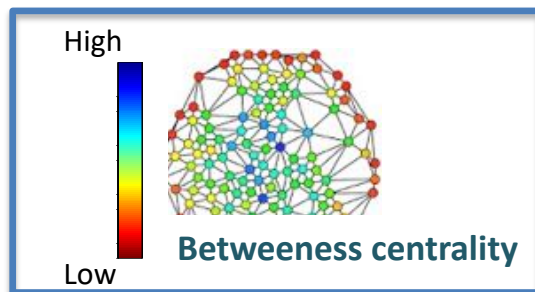
Case of eelgrass (*Z. marina*)



*Z. marina* connectivity



- **Central Vs edge** zones in network
- **Variability for intermediate zones**



# Variability in marine connectivity and extreme events

## Ecologically-relevant consequences of 'extreme' connectivity events

- Dramatic changes in **local retention**
- Significant **changes in dominant connectivity patterns**



# Variability in marine connectivity and extreme events

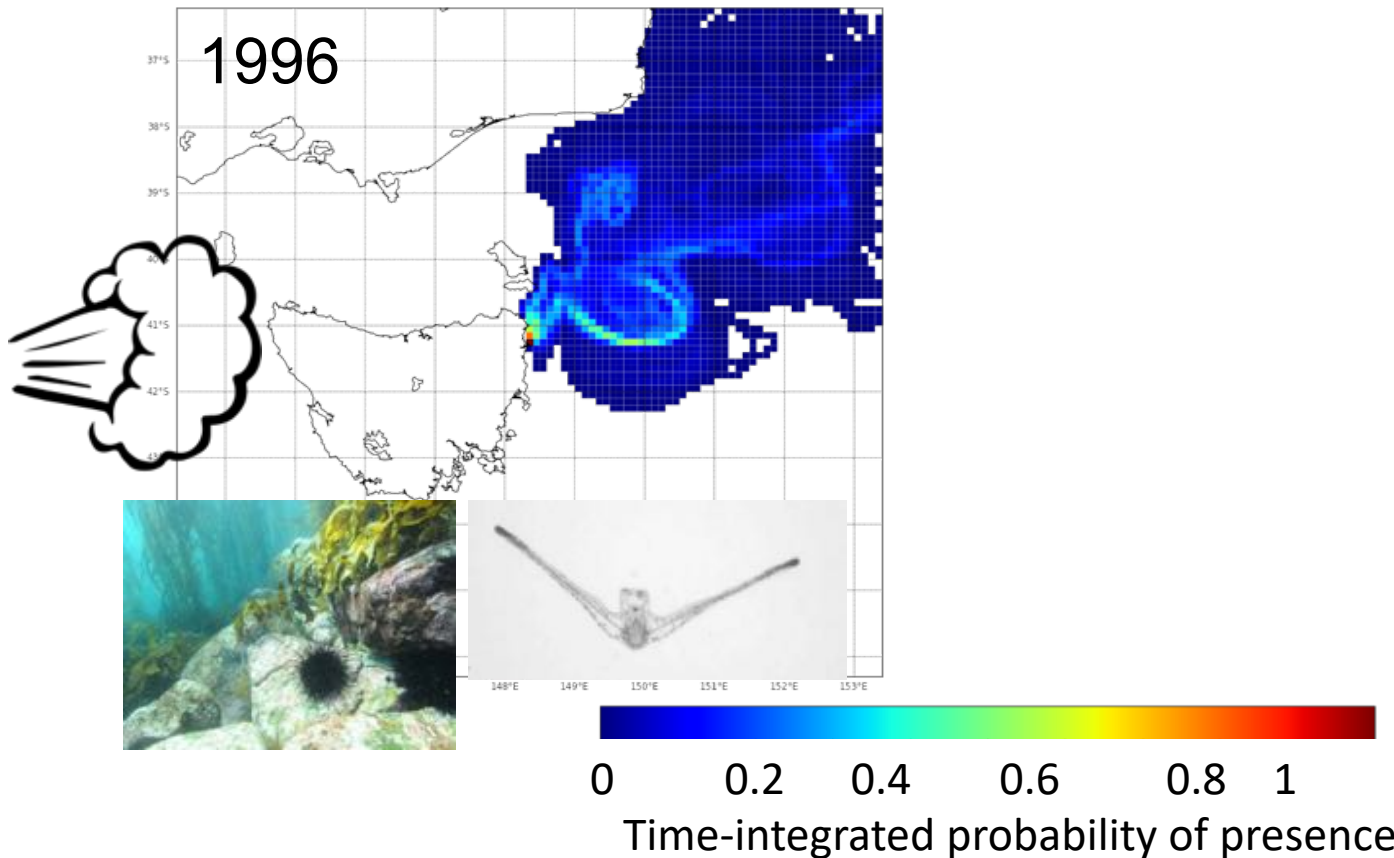
## Ecologically-relevant consequences of 'extreme' connectivity events

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- Significant **changes in dominant connectivity patterns**

### Example Of Larval Dispersal Of *C. Rodgersii*

#### Typical Southern Winter conditions

1996



0 0.2 0.4 0.6 0.8 1

Time-integrated probability of presence

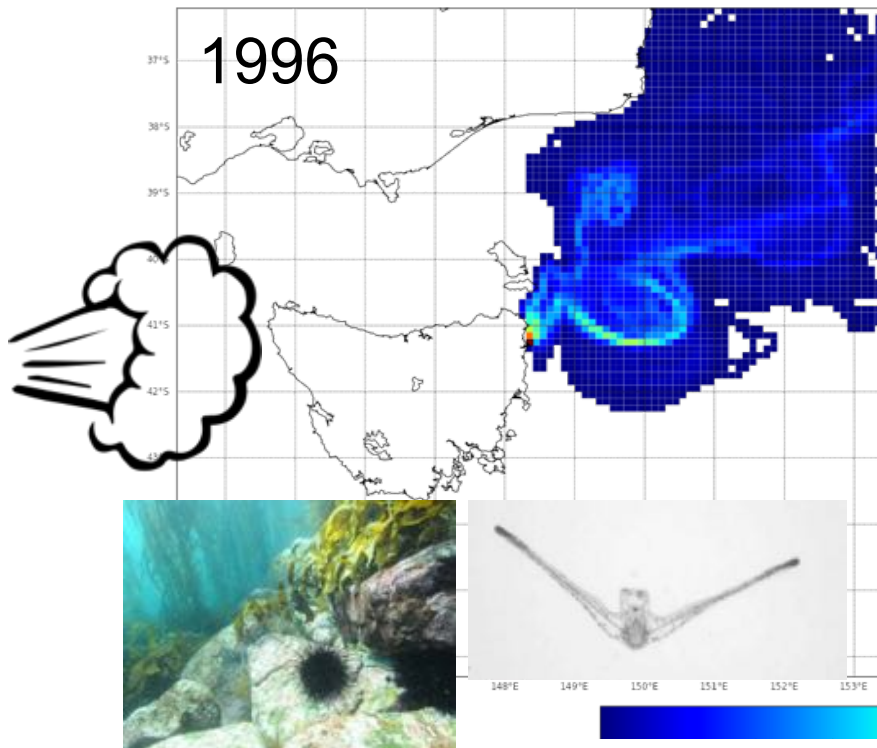
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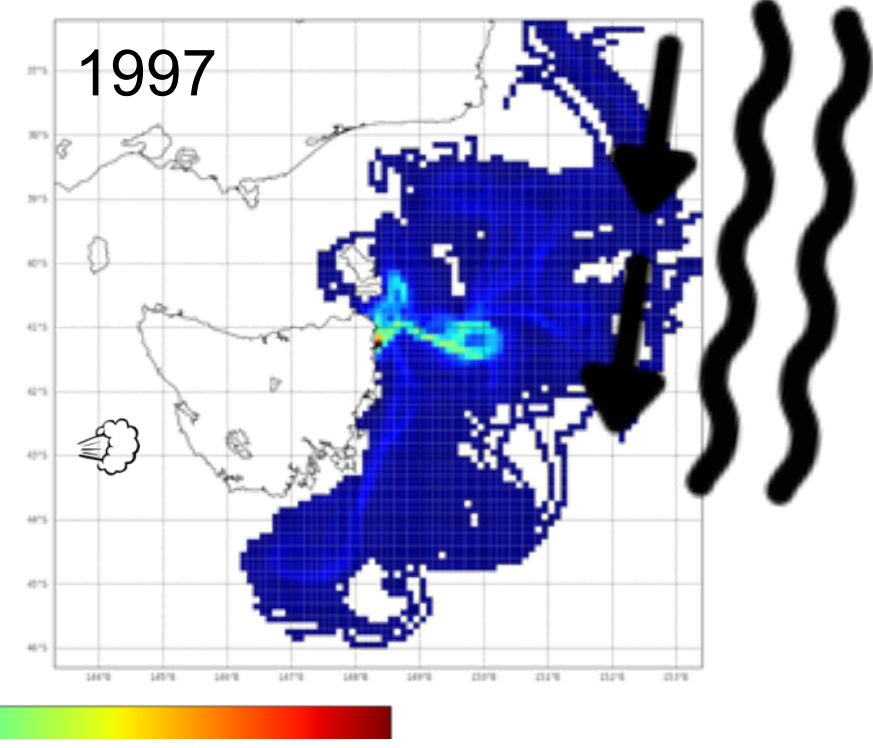
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### Example Of Larval Dispersal Of *C. Rodgersii*

Typical Southern Winter conditions



'Extreme' EAC-driven Southern Winter conditions



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Time-integrated probability of presence

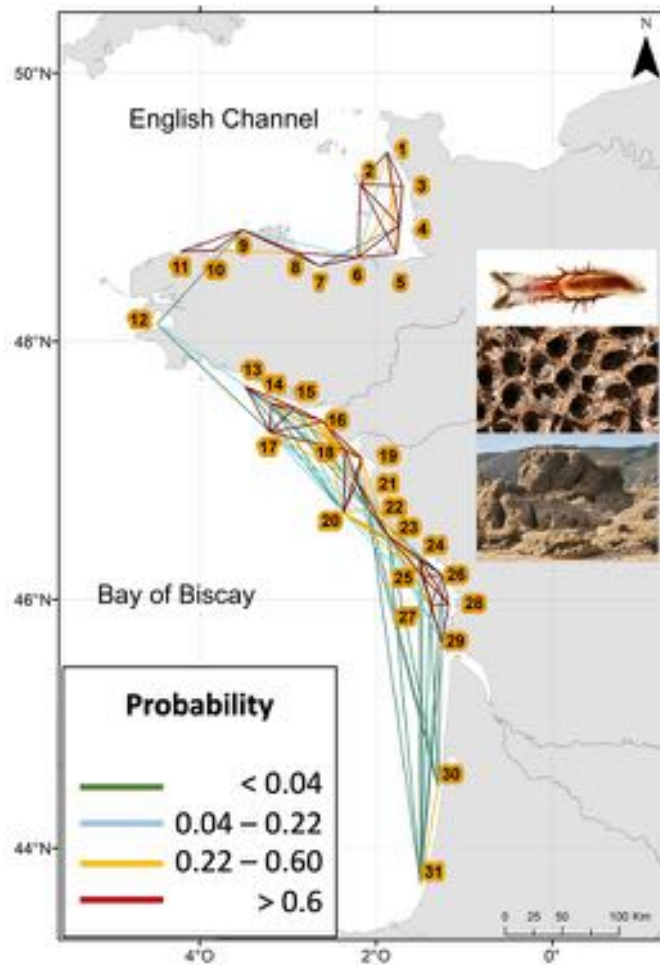
# Comparisons between hydrodynamics and genetics

Overall consistency between hydrodynamics and genetics for *Sabellaria* reefs

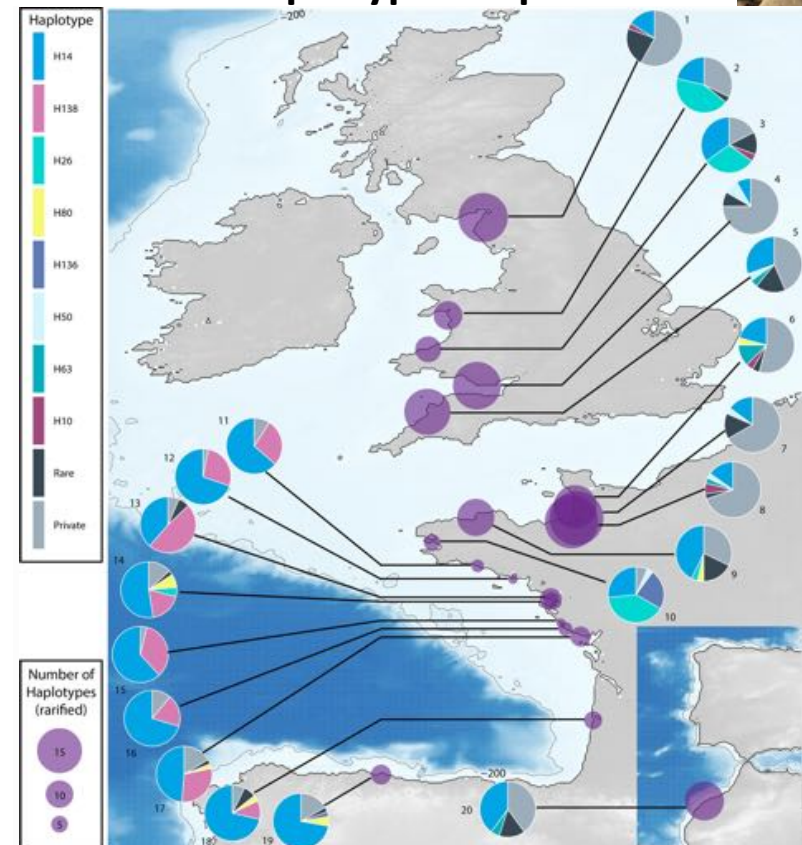
Hydrodynamics connectivity

&

Population genetics



Haplotype frequencies





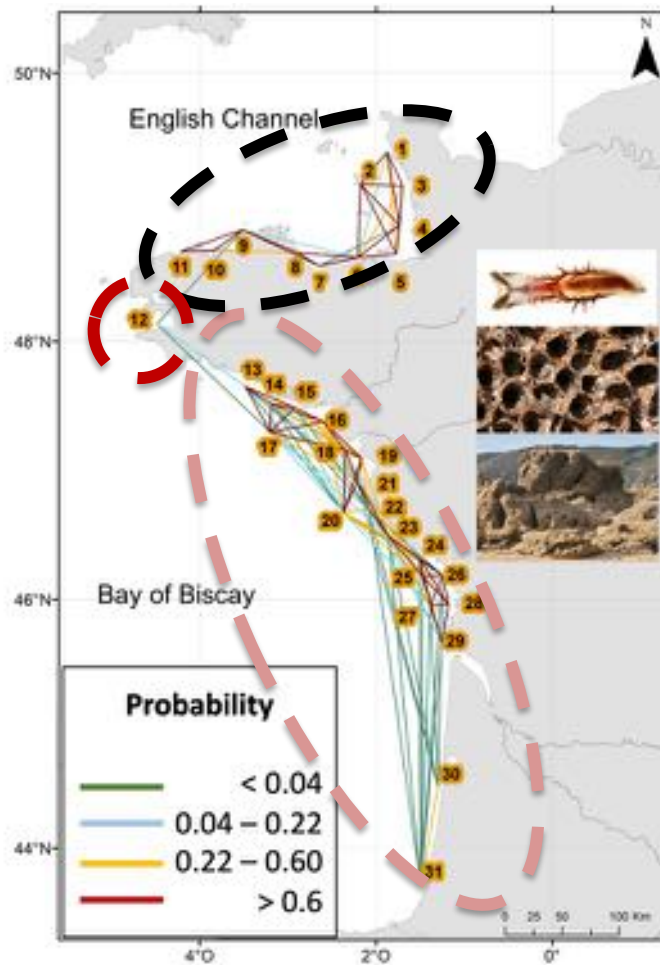
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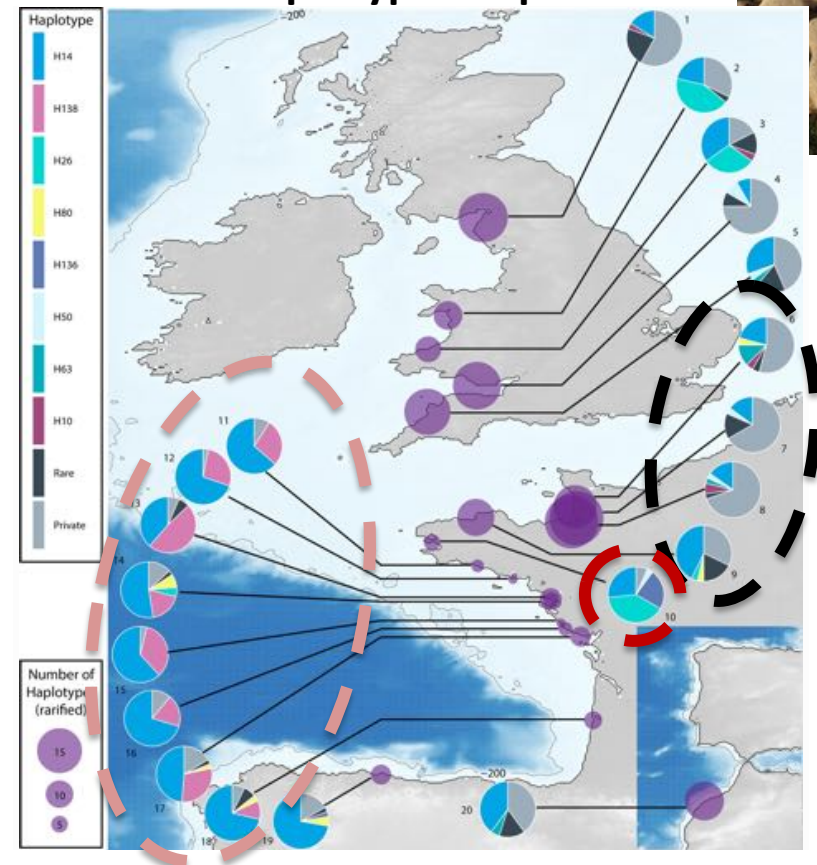
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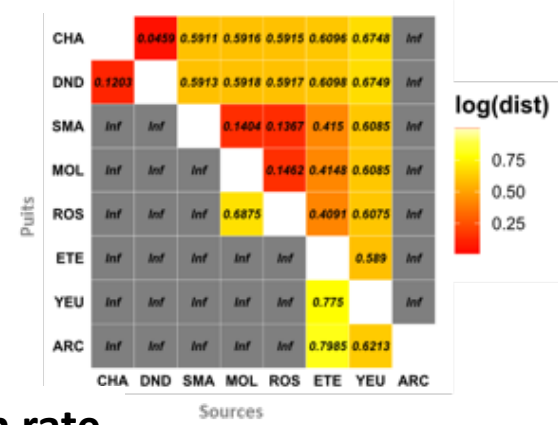


# Comparisons between hydrodynamics and genetics

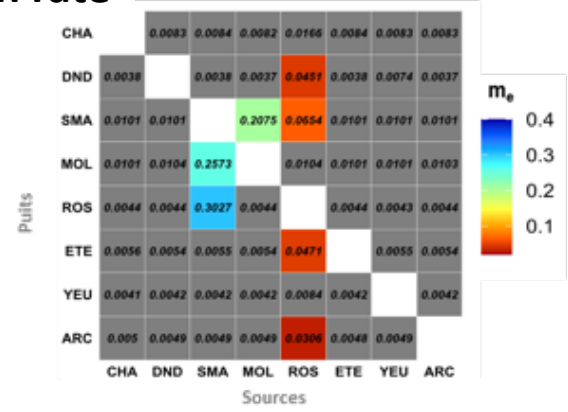


## Discrepancies between hydrodynamics & genetics connectivity for *Zostera marina*

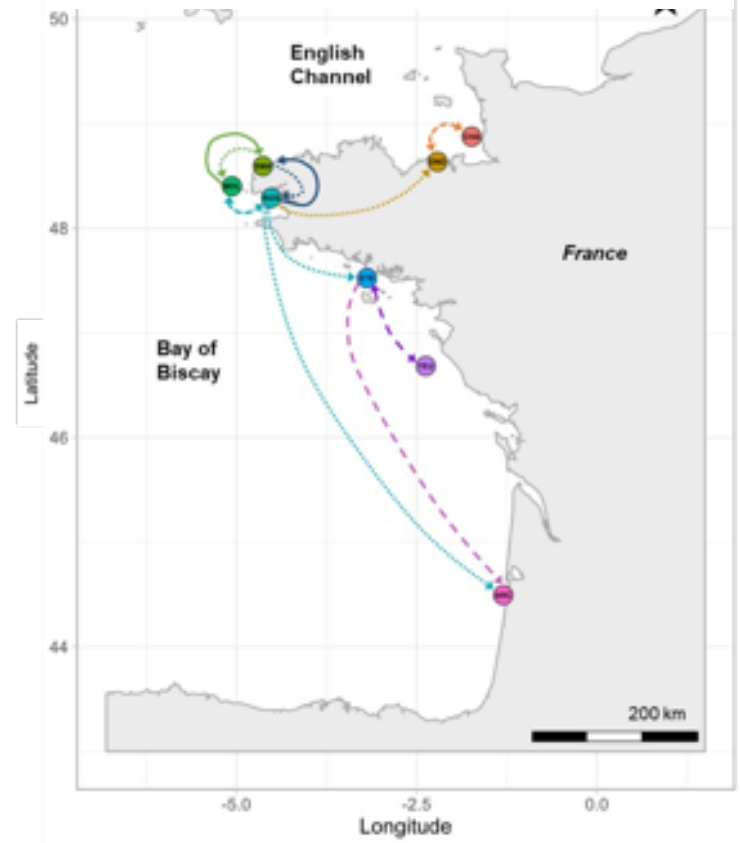
### Shortest hydrodynamic path



### Genetic migration rate



### Graphical synthetic comparison

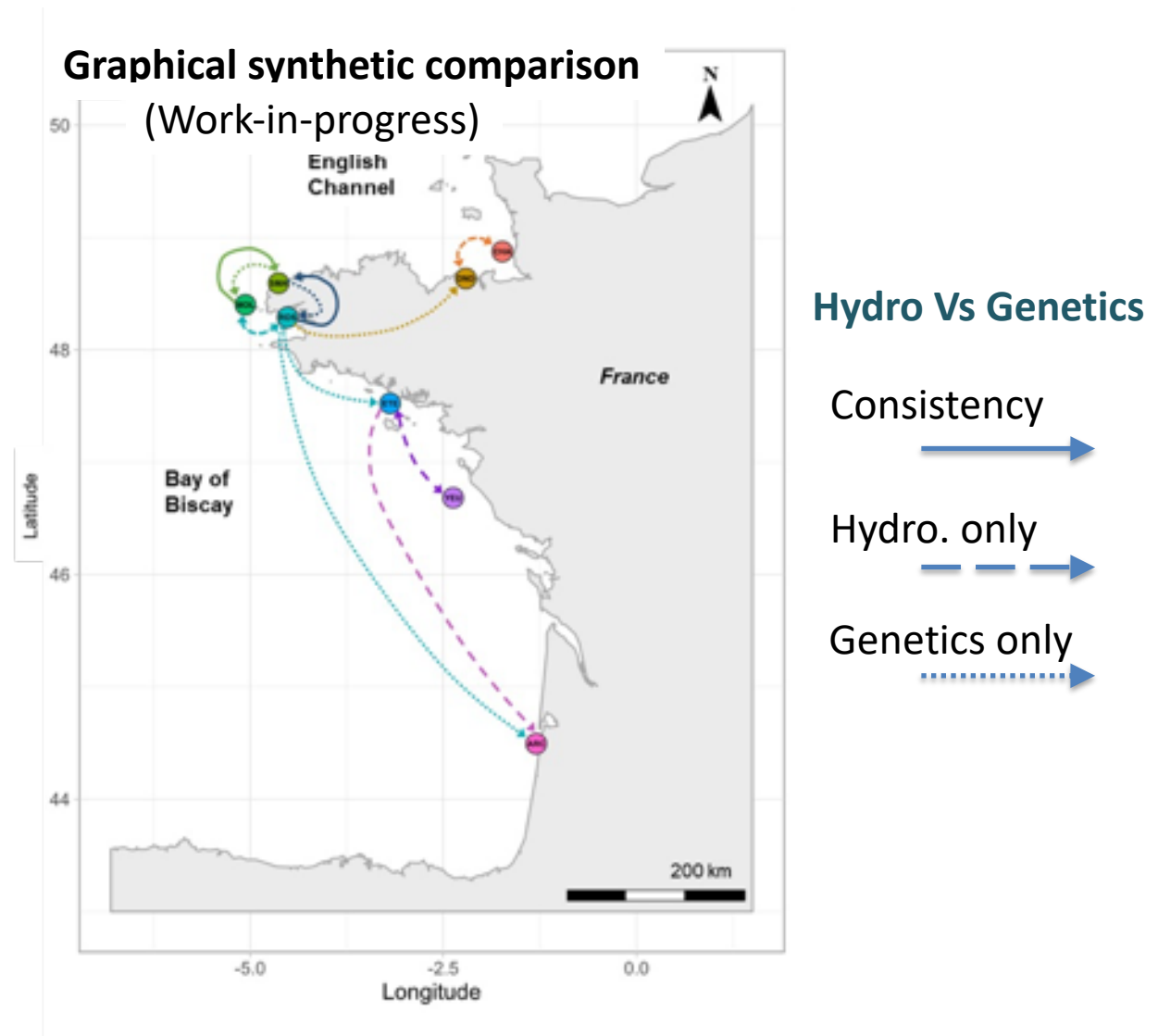




# Comparisons between hydrodynamics and genetics



## Discrepancies between hydrodynamics & genetics connectivity for *Zostera marina*

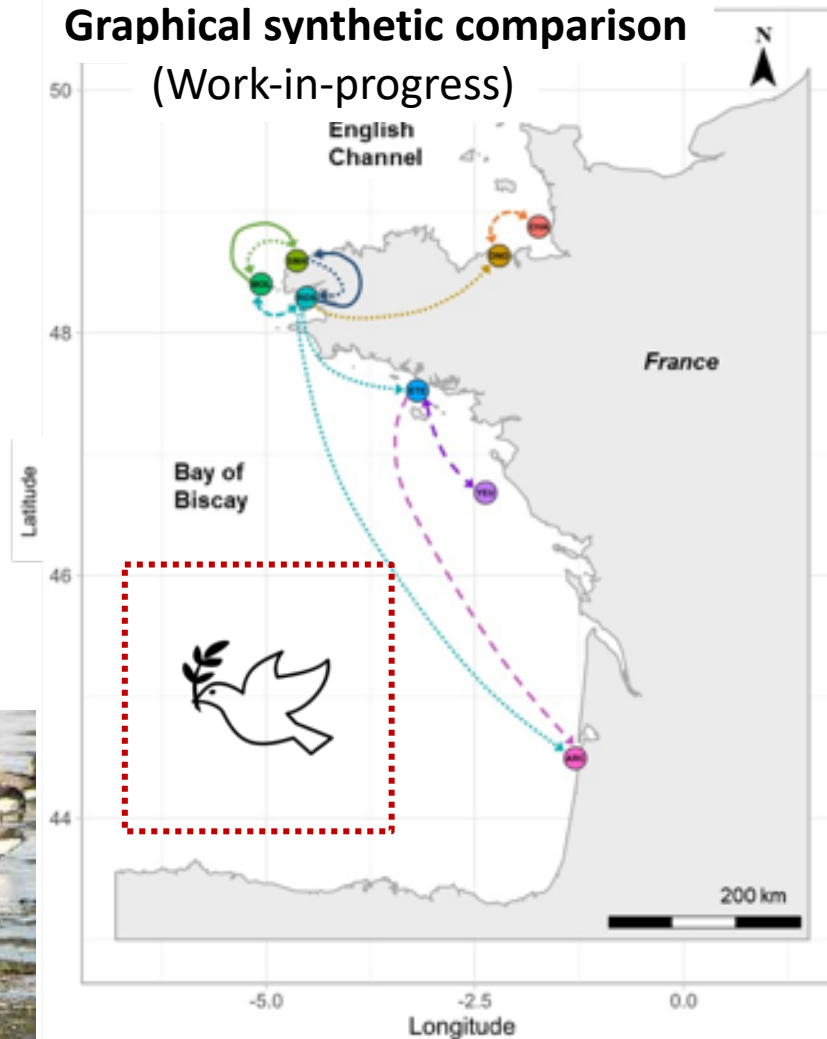


# Comparisons between hydrodynamics and genetics



Discrepancies between hydrodynamics & genetics connectivity for *Zostera marina*

## Graphical synthetic comparison (Work-in-progress)



### Hydro Vs Genetics

Consistency



Hydro. only



Genetics only



# Conclusion & Perspectives

- **From marine reserves patchwork**



- **to effective network**



- Importance of connectivity to inform MPA network design (30% MPAs by 2030 objective)
- Reliable graph metrics (e.g. betweenness centrality) as indicators of key hubs to network

# Conclusion & Perspectives



• From marine reserves patchwork

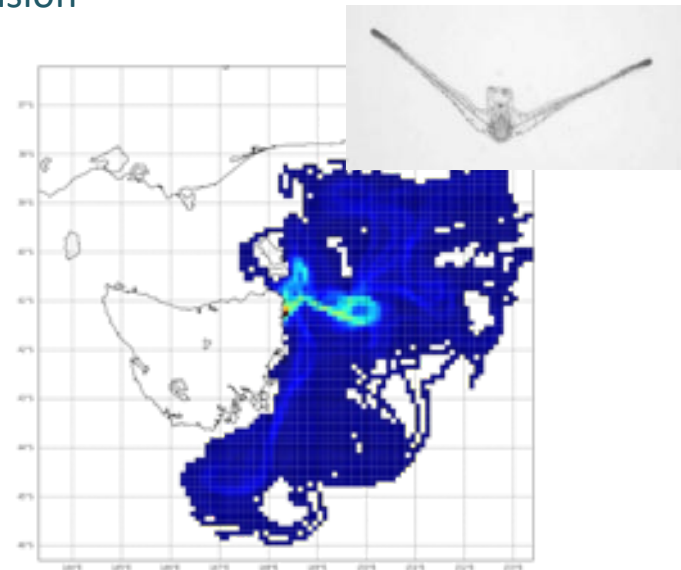
to effective network

• Influence of « **extreme** » **connectivity events** on metapopulation structure

- Maintain sporadic connectivity between distinct sub-populations

(e.g. Bay of Biscay Vs English Channel)

- Contribute to climate-driven range extension



# Conclusion & Perspectives

- From marine reserves patchwork



to effective network



- Influence of « extreme » connectivity events on metapopulation structure
- **Complementarity of population genetics & hydrodynamics modelling**
  - Valuable insights on ecological processes and population structure
  - Work-in-progress to overcome challenges related to quantitative comparison



# Conclusion & Perspectives

- From marine reserves patchwork

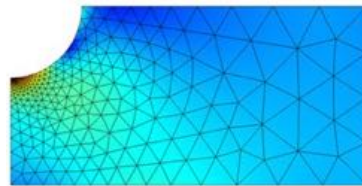


to effective network



- Influence of « extreme » connectivity events on metapopulation structure
- Complementarity of population genetics & hydrodynamics modelling
- Perspectives related to development of a hi.-res. coastal ocean model

(MEDIATION 2022-2026 project)



- Adaptive model grid
- Capturing larval behaviour as well as temperature- / food-dependent survival
- Assessing the effects on marine connectivity of artificial reefs (50 offshore windfarms planned!)
- Dynamics forecast of climate-driven changes in connectivity by 2100

# Thanks for your attention

RESEARCH ARTICLE

Diversity and Distributions WILEY

## Connectivity modelling informs metapopulation structure and conservation priorities for a reef-building species

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**Pictogrammes:** TheNounProject.org

**Photo credits:** S. Dubois, X. Caisey, O. Dugornay, Parc Naturel Marin d'Iroise

**Artwork:** Malou Zuidema

M. Marzloff is the recipient of the Agence National de Recherche early career grant ANR-21-CE02-0006.



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