Modelling Arctic oceanographic connectivity to further develop PAME's MPA toolbox – *Progress report*

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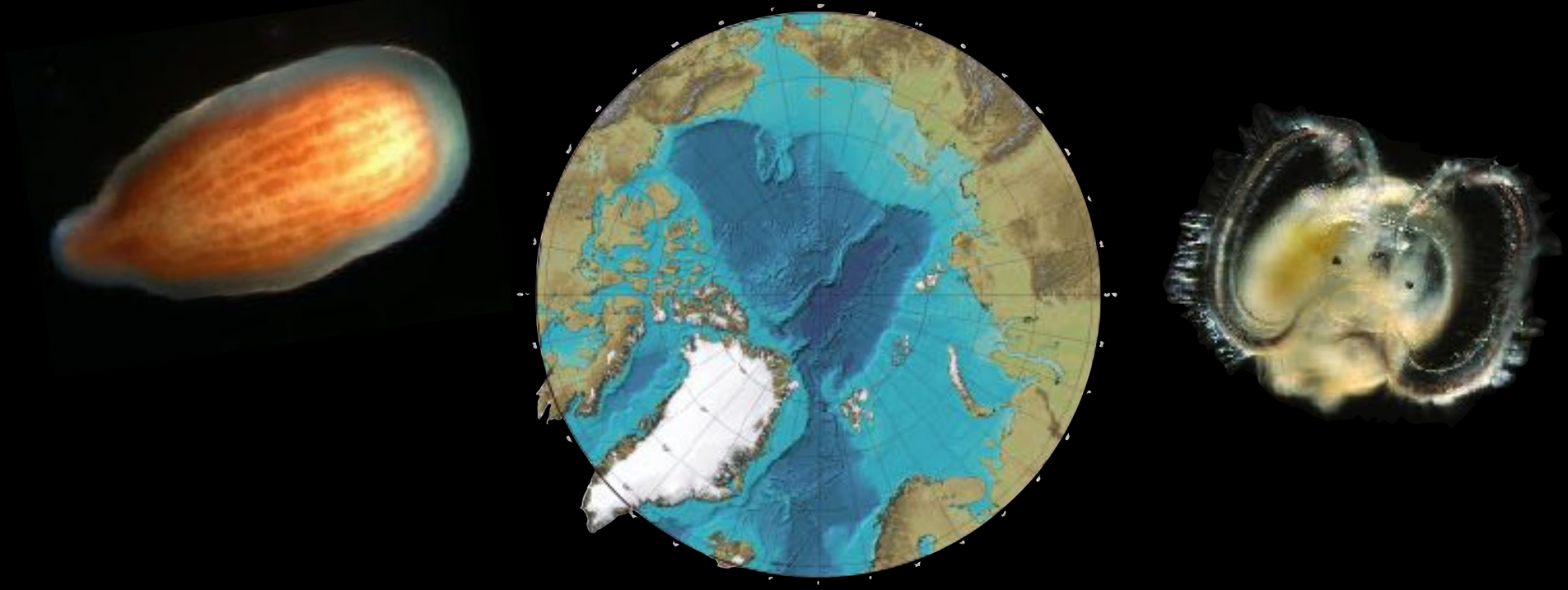
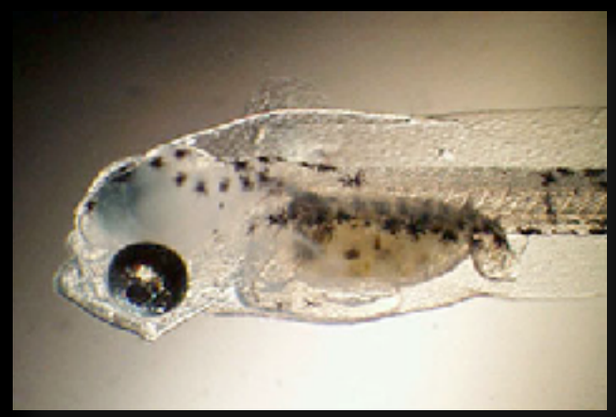
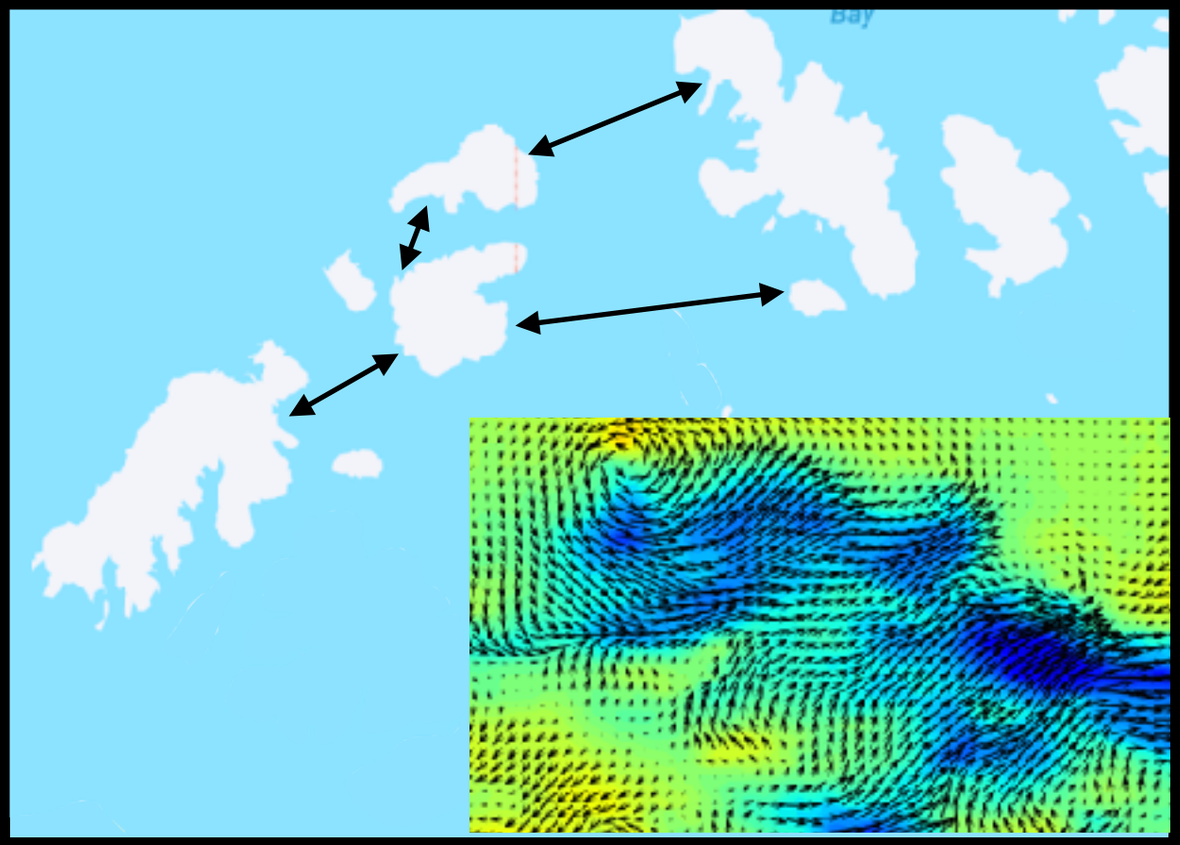
Sweden



Protection of the Arctic Marine Environment (PAME)
Oslo February 4, 2020

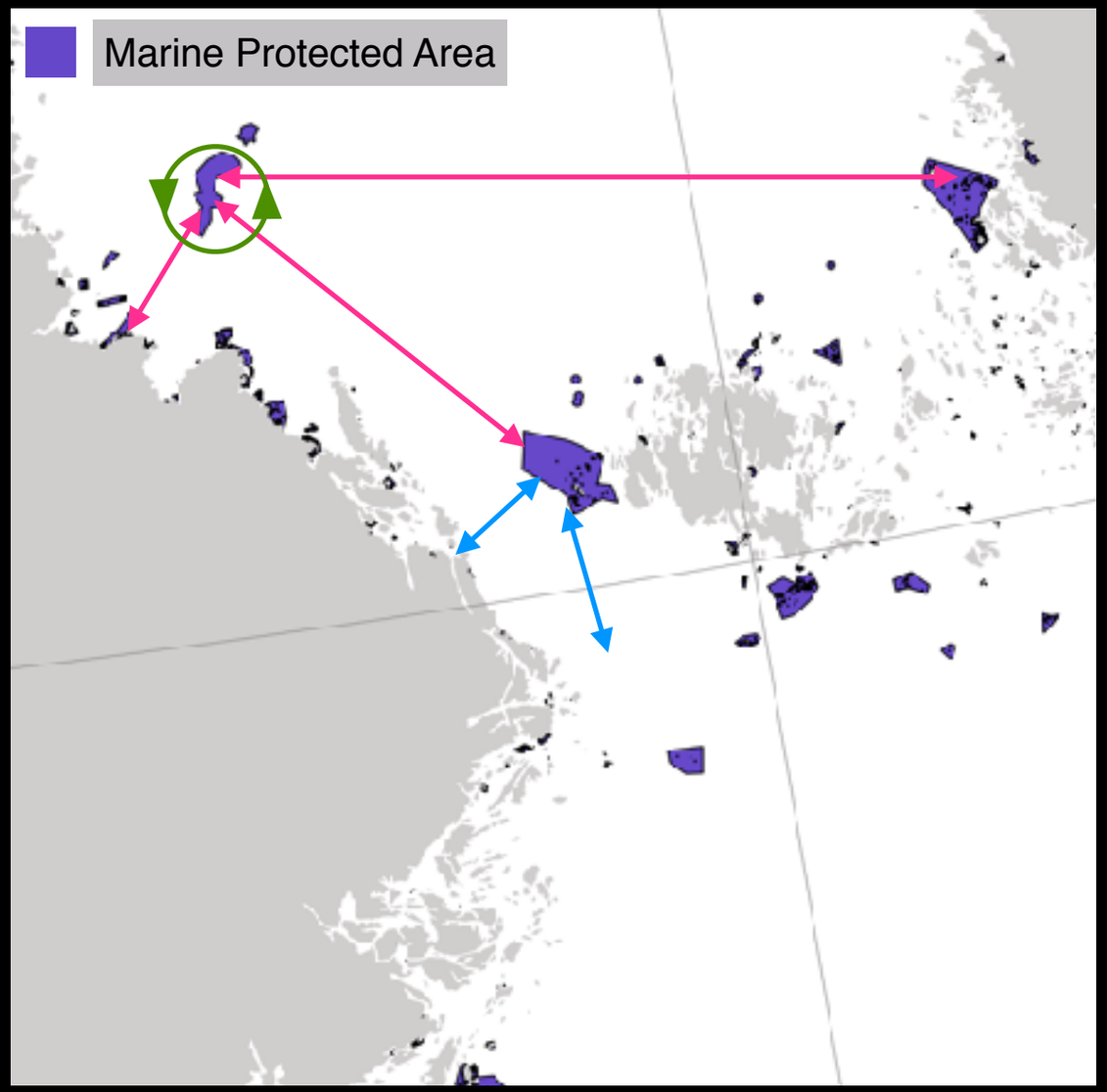
Dispersal & Connectivity





How can *connectivity* information aid in design & management of MPAs?

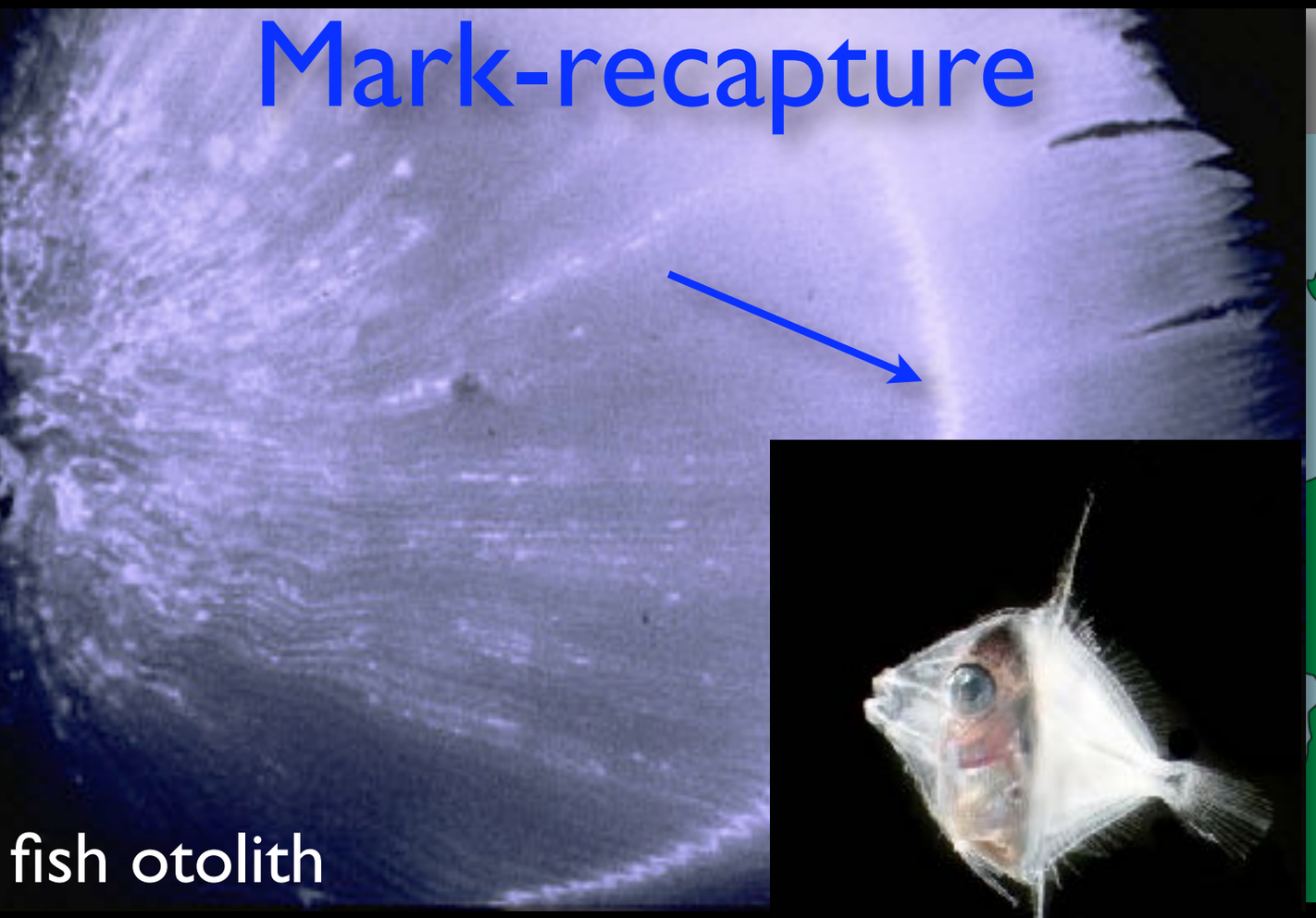
- Self-recruitment within an MPA
- Import/export from other areas
- Design criterion for MPA networks



How to estimate connectivity?

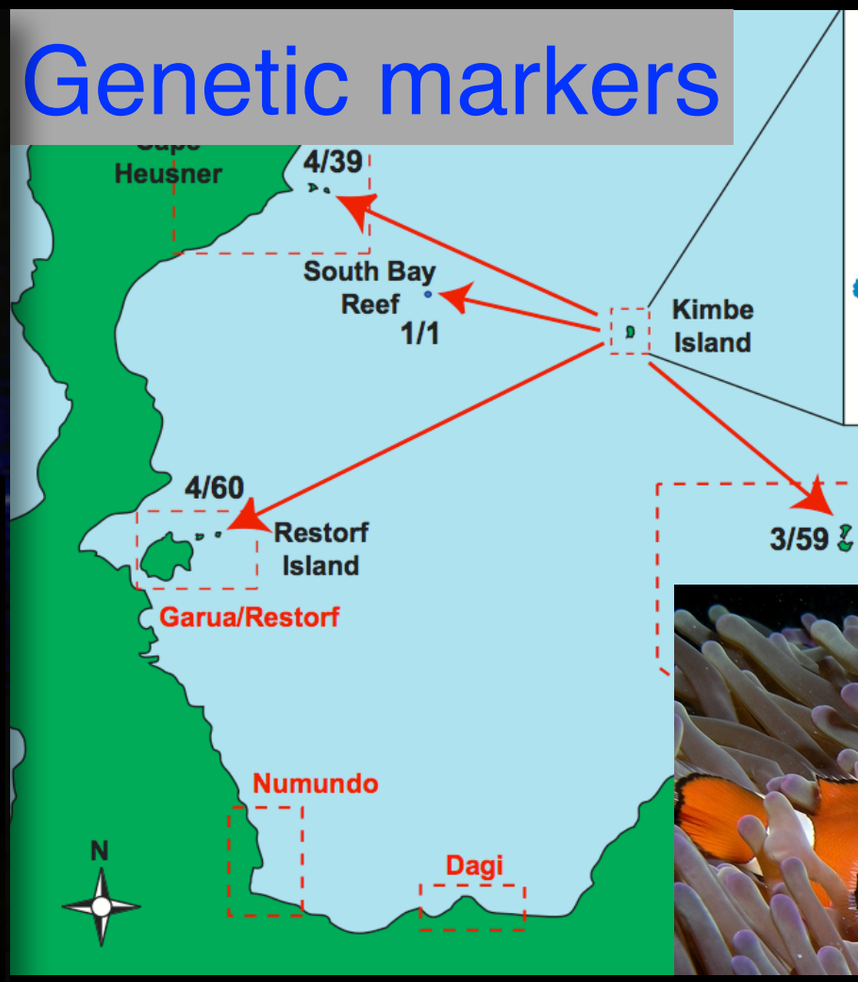
Direct measurements

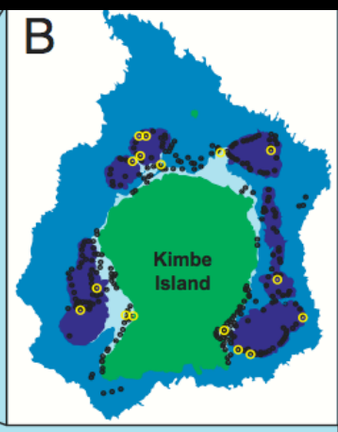
Mark-recapture



Jones et al. 1999

Genetic markers



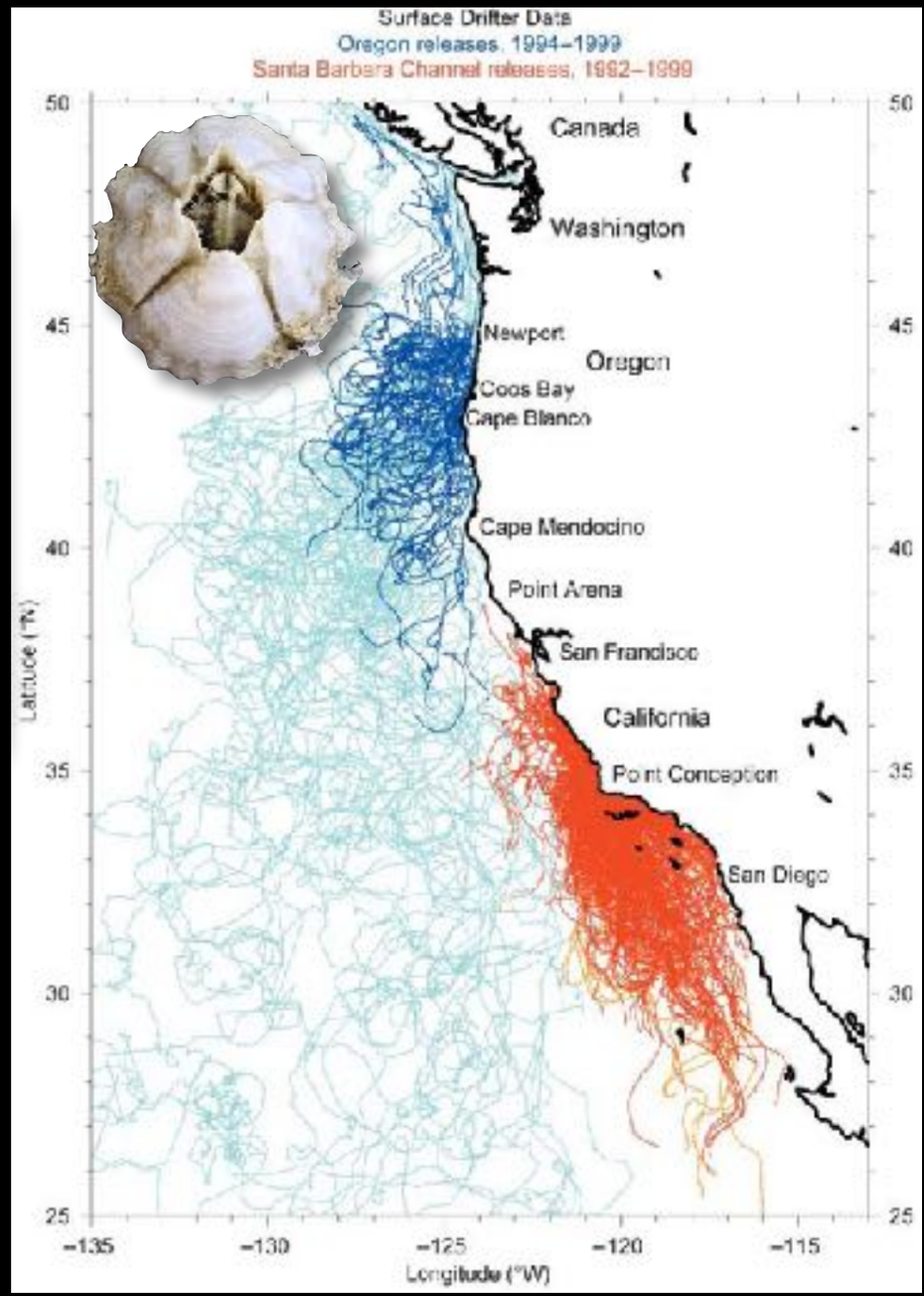


Planes et al. 2009

How to estimate connectivity?

Indirect measurements

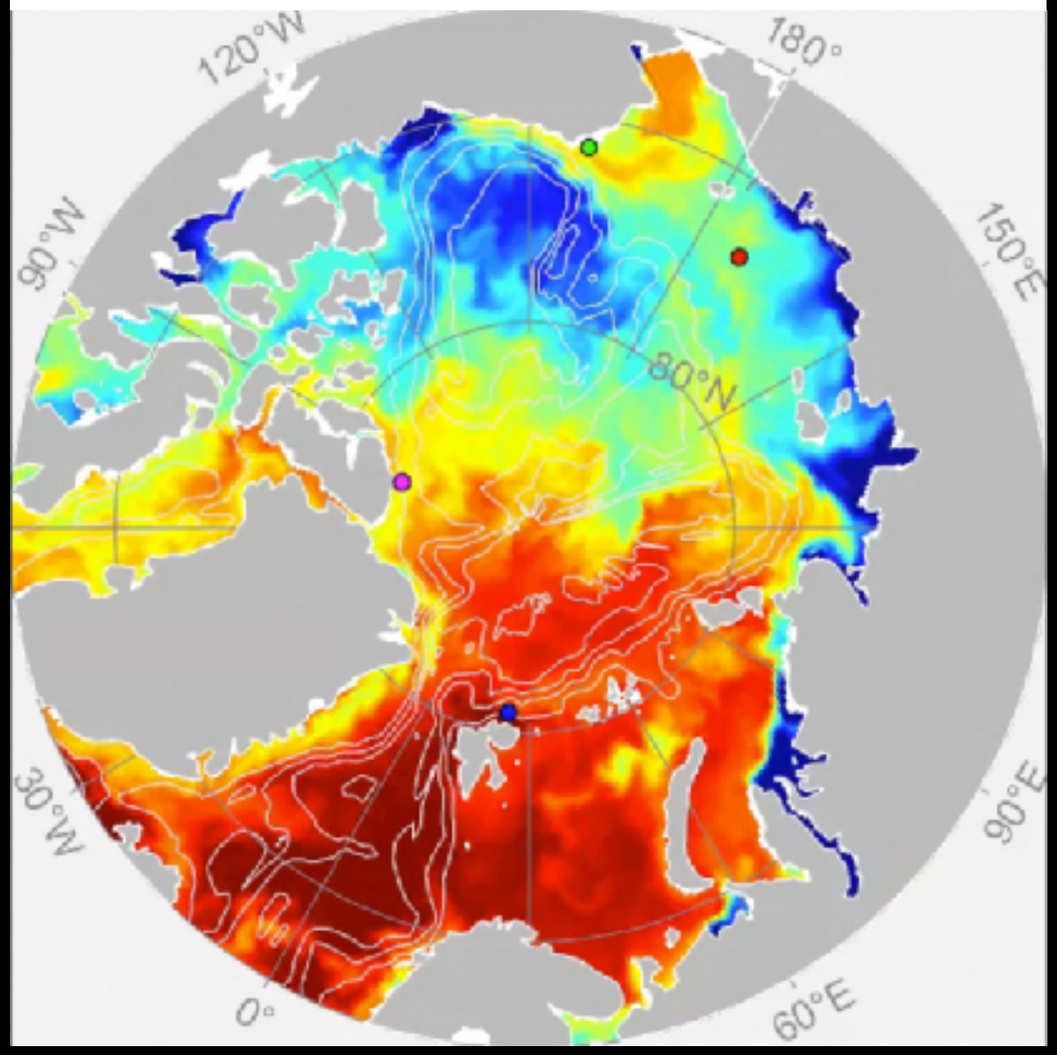
Drift buoys

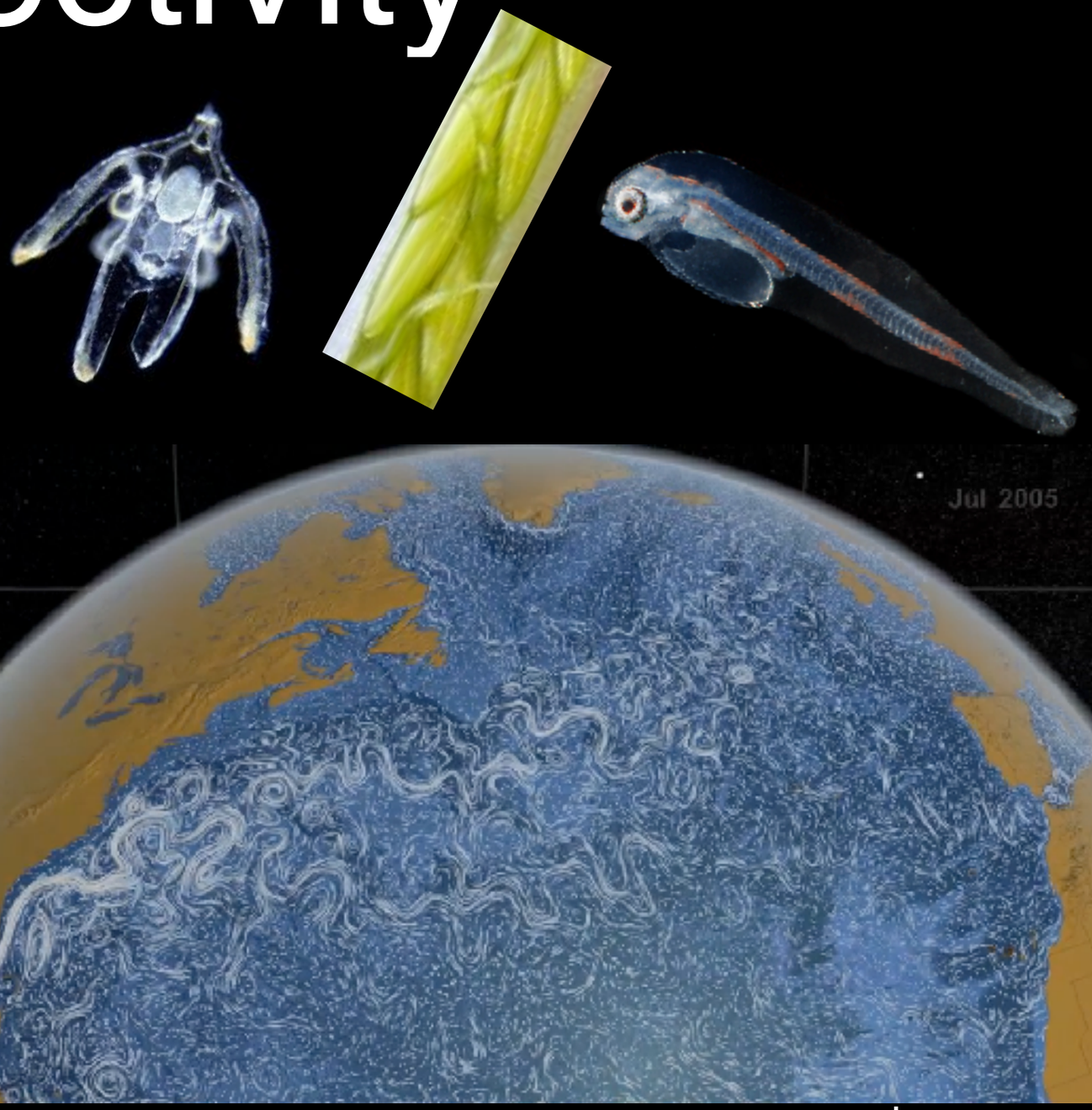


Sotka et al. 2004

Modelling oceanographic connectivity

Circulation model

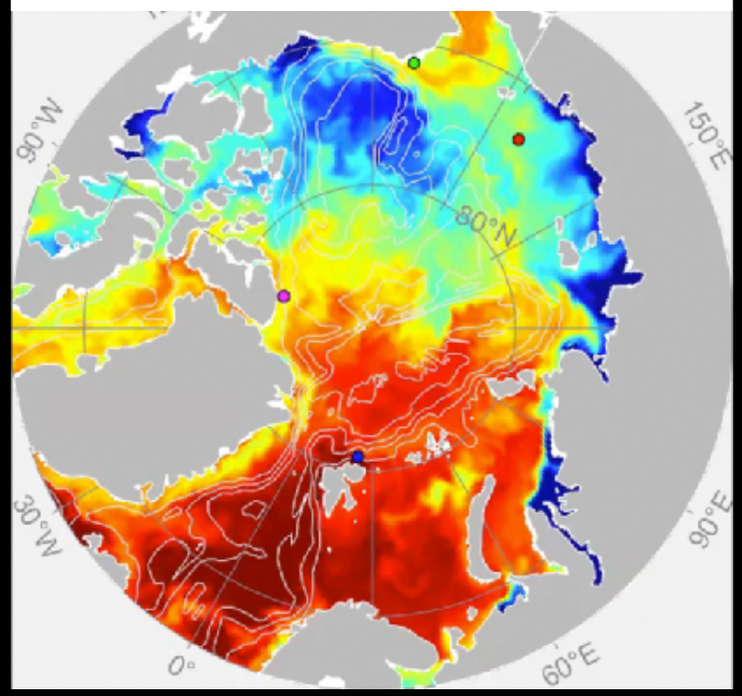




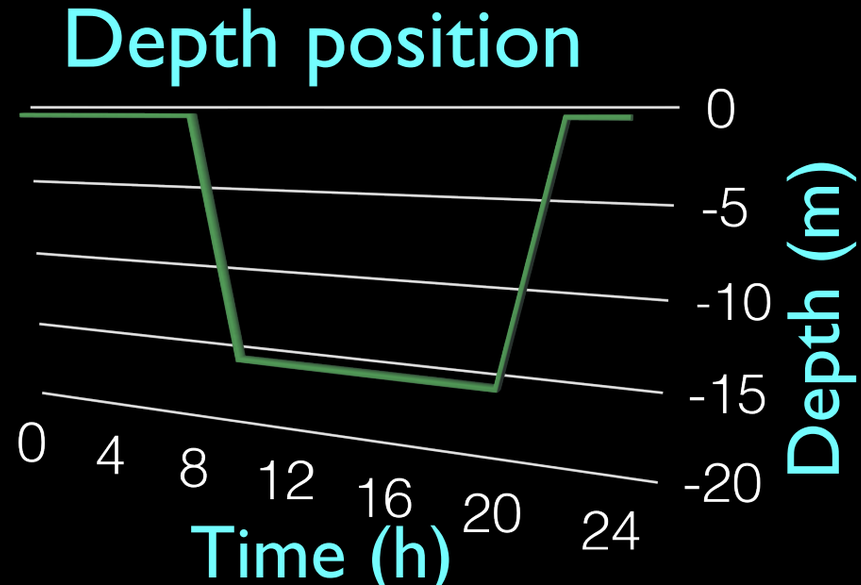
www.aoml.noaa.gov

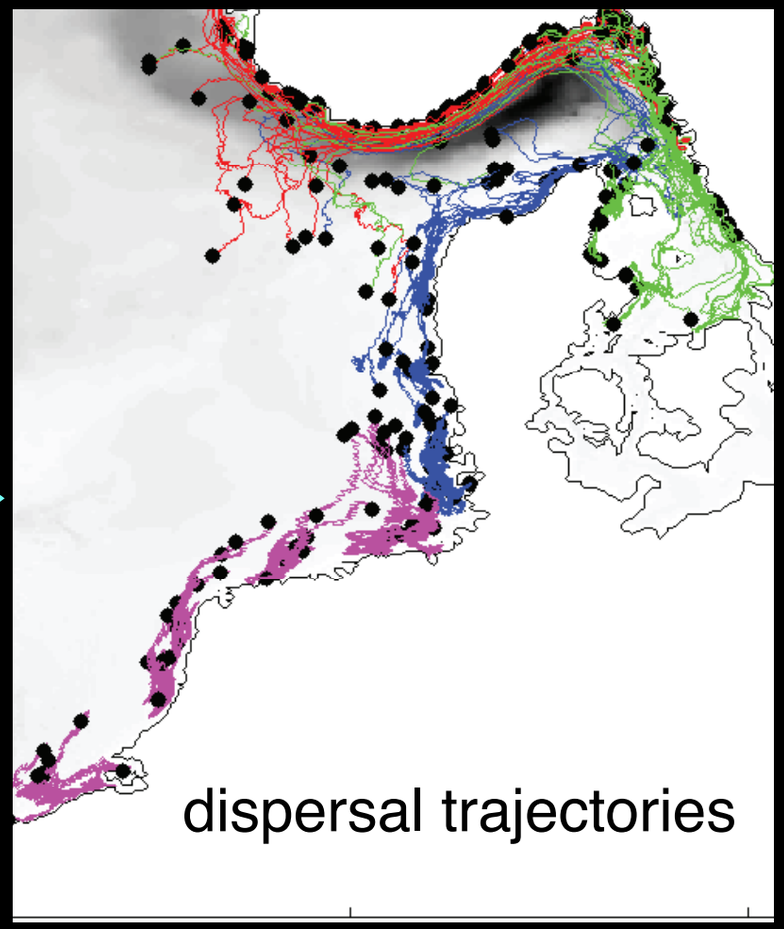
Biophysical model

Circulation model



- Spawning time
- Larval duration
- Vertical behavior

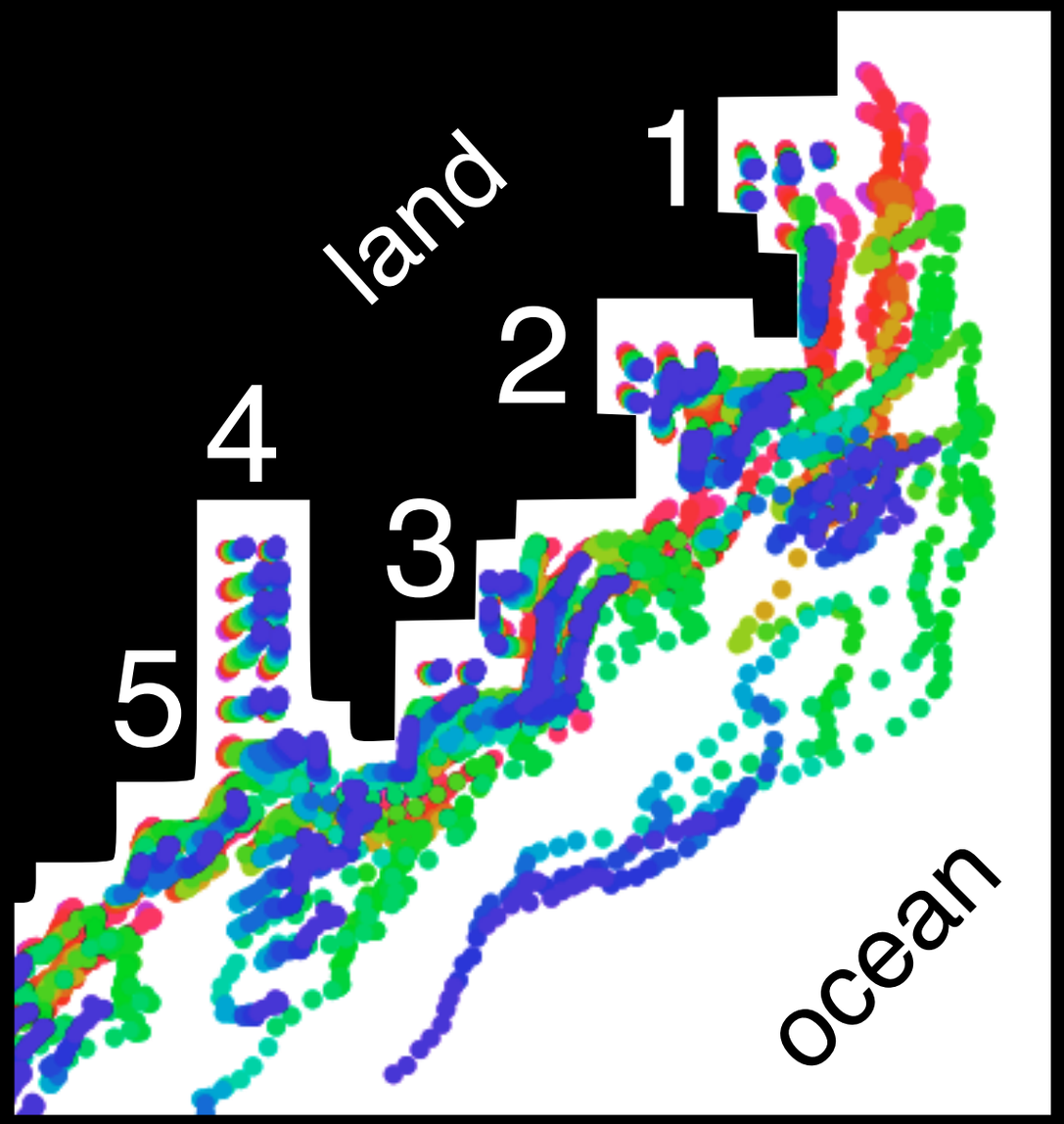




The Connectivity Matrix

The probability to disperse:

to area \ from area	1	2	3	4	5
1	40	0	0	0	0
2	0	0	52	0	10
3	9	27	0	22	0
4	0	17	0	0	20
5	45	47	42	63	0



Limitations with biophysical modelling

- Only relevant for species with free-drifting larvae (ca 70% of all marine species)
- Circulation models only approximate water transport
- Knowledge of larval behaviour often poor
- Estimating only potential connectivity, especially if habitat is not well mapped

Why choosing this approach?

- High coverage in space & time
- Can cover a broad range of species
- Inexpensive if circulation model is available
- Results can suggest areas for more detailed investigations, *e.g.* genetic studies

Progress of project

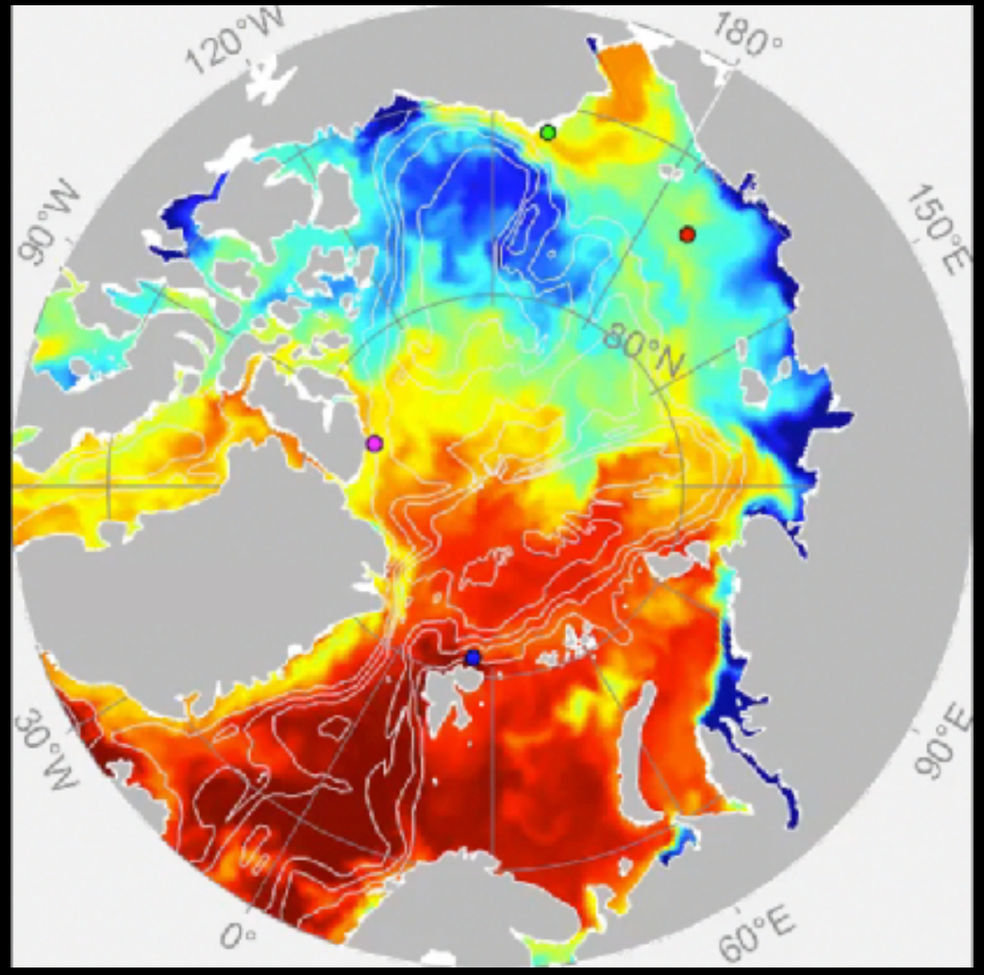
Modelling Arctic oceanographic connectivity to further develop PAME's MPA toolbox

Start: January 2019

End: July 2020

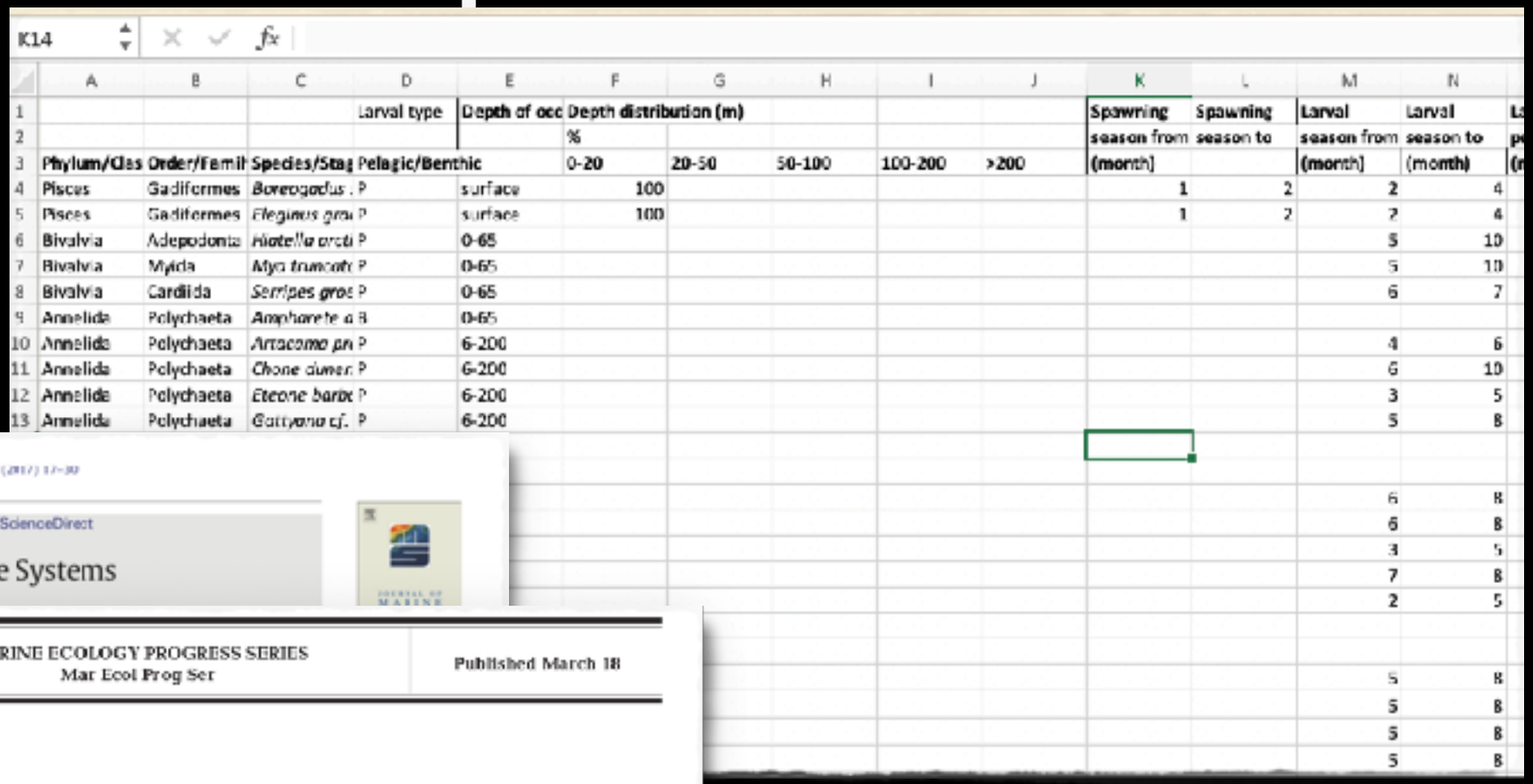
Selection of circulation model

- TOPAZ 4 (official model in Copernicus)
- ROMS ARCTIC 4



Review of dispersal traits

- Spawning season?
- Larval duration?
- Vertical behaviour?



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1				Larval type	Depth of occ	Depth distribution (m)					Spawning	Spawning	Larval	Larval
2						%					season from	season to	season from	season to
3	Phylum/Clas	Order/Famil	Species/Stag	Pelagic/Benthic		0-20	20-50	50-100	100-200	>200	(month)		(month)	(month)
4	Pisces	Gadiformes	*Boreogadus* .	P	surface	100					1	2	2	4
5	Pisces	Gadiformes	*Eleginus gra*	P	surface	100					1	2	2	4
6	Bivalvia	Adepodonta	*Hiatella arcti*	P	0-65								5	10
7	Bivalvia	Myida	*Mya truncata*	P	0-65								5	10
8	Bivalvia	Cardiida	*Serripes gros*	P	0-65								6	7
9	Annelida	Polychaeta	*Ampharete a*	B	0-65									
10	Annelida	Polychaeta	*Artacama pr*	P	6-200								4	6
11	Annelida	Polychaeta	*Chone dimer*	P	6-200								6	10
12	Annelida	Polychaeta	*Eteone barbo*	P	6-200								3	5
13	Annelida	Polychaeta	*Gattyana cf.*	P	6-200								5	8
													6	8
													6	8
													3	5
													7	8
													2	5
													5	8
													5	8
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Journal of Marine Systems 168 (2017) 17–30

Contents lists available at ScienceDirect

Journal of Marine Systems

ELSEVIER

Seasonal dyn

Helena Kling M

Department of Arctic and M

ARTICLE I

Article history:
Received 22 March 2016
Received in revised form
Accepted 7 December 201
Available online 9 Decem

Vol. 356: 189–202, 2008
doi: 10.3354/meps07271

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published March 18

Reproductive strategies of benthic invertebrates in the Kara Sea (Russian Arctic): adaptation of reproduction modes to cold water

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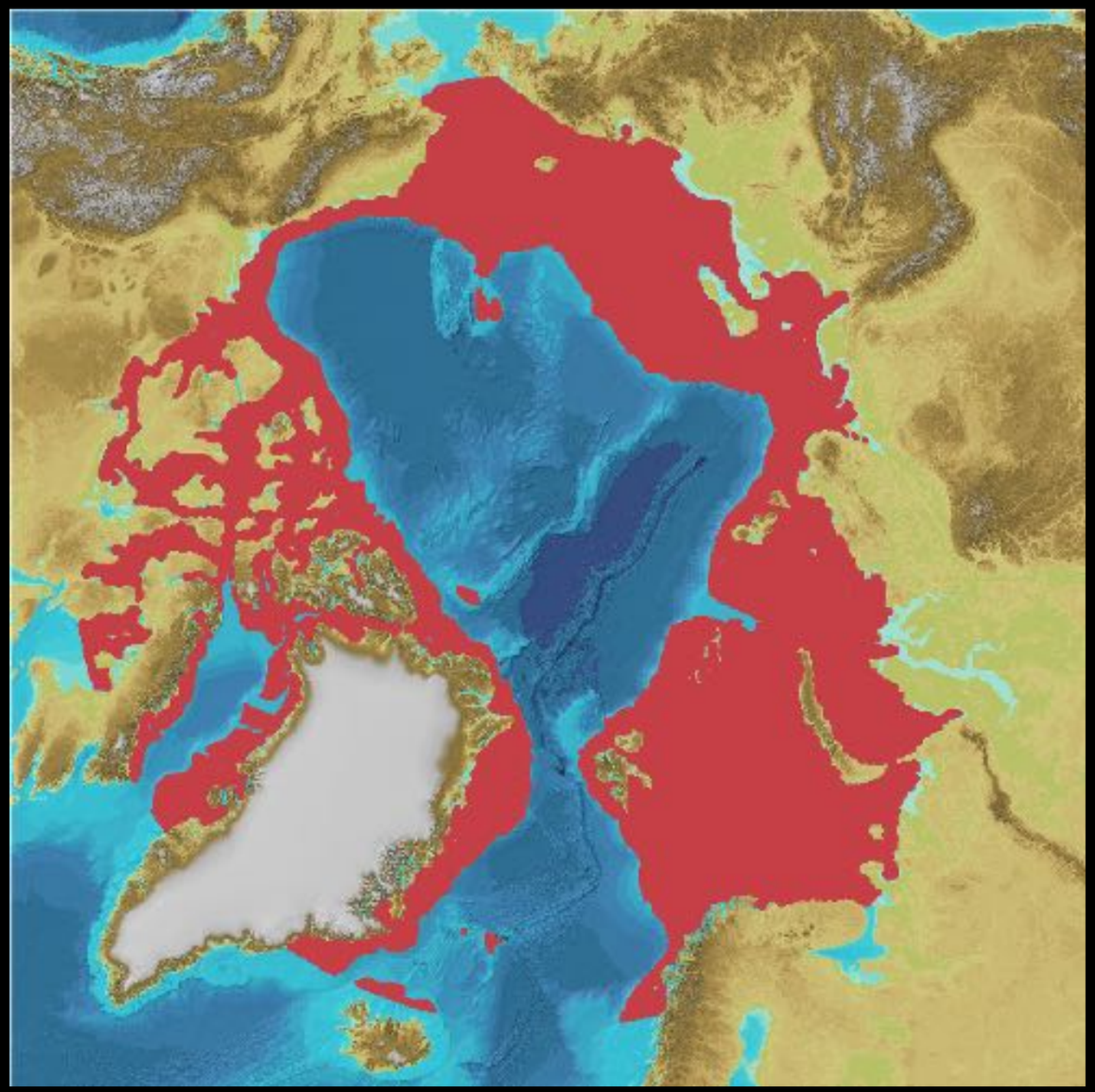
ABSTRACT: Many benthic invertebrates in the boreo-Atlantic region reproduce via pelagic larvae. Past investigations in polar areas suggested a greater predominance of species lacking a pelagic

Input from, *e.g.* CAFF and WWF

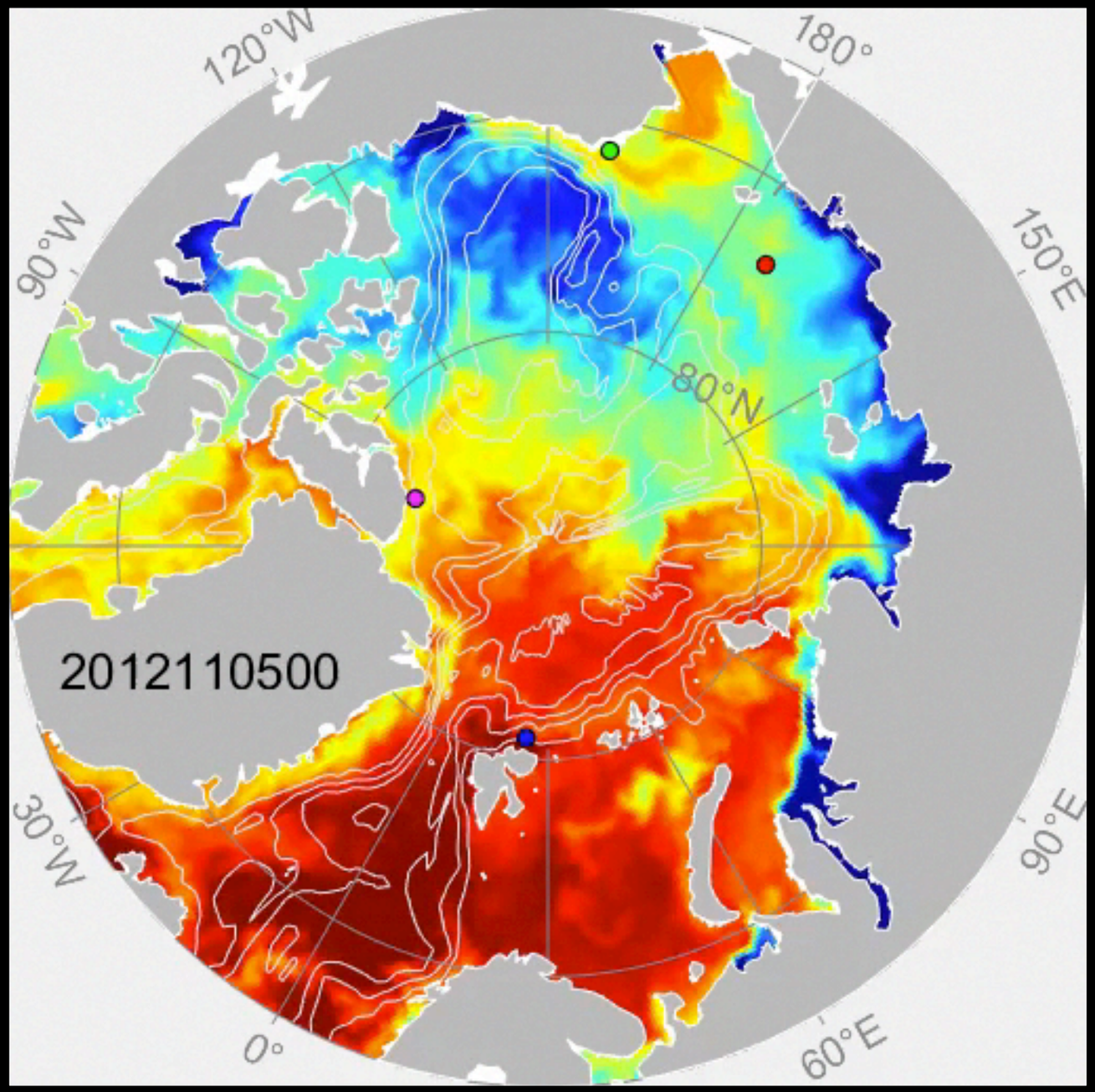
Poorly known!!

Setting up particle tracking model



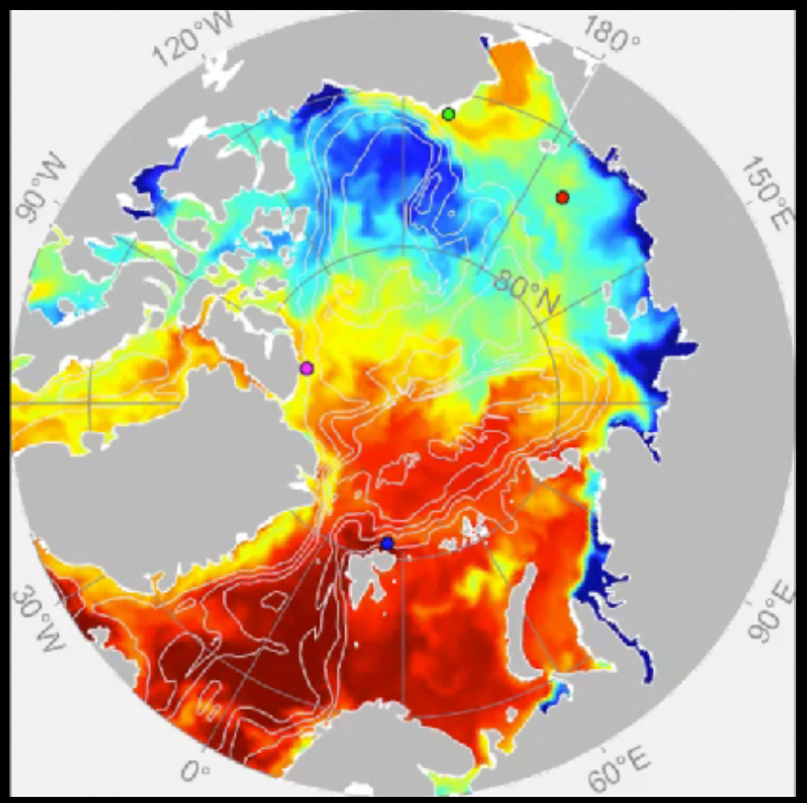
- Particle sources covering the entire area with a depth above 500 m
  40893 release points

Production of particle trajectories



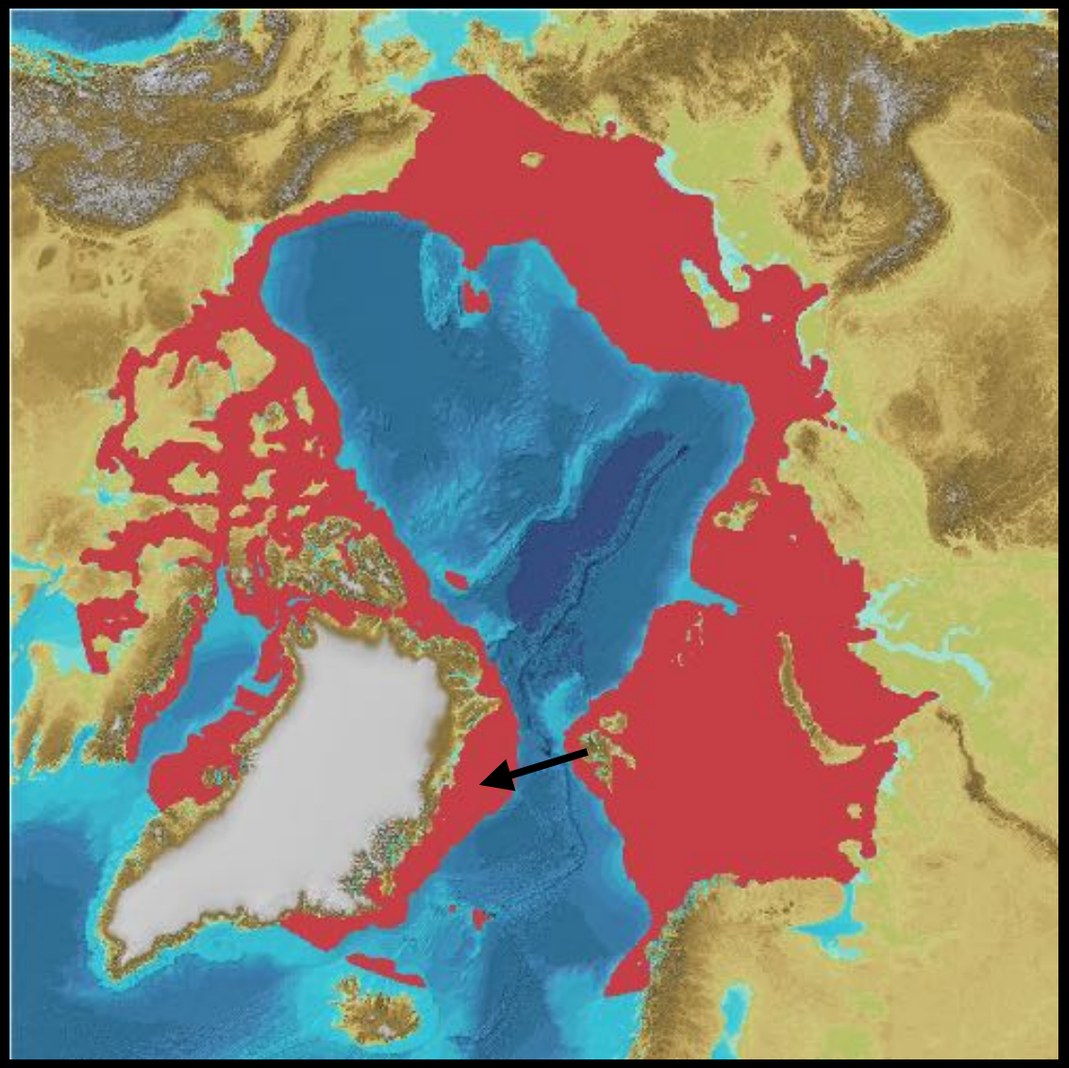
Production of particle trajectories

- Particle release every day and summarised every month
- Larval positions after 5, 10, 20, 30, 50, 70,100 days
- Larval drift depth: 0, 5, 10, 15, 20, 30, 50, 100, 150, 200 & 300 m
- Repeated for 10 (25) years
- Model simulations performed on a computer cluster



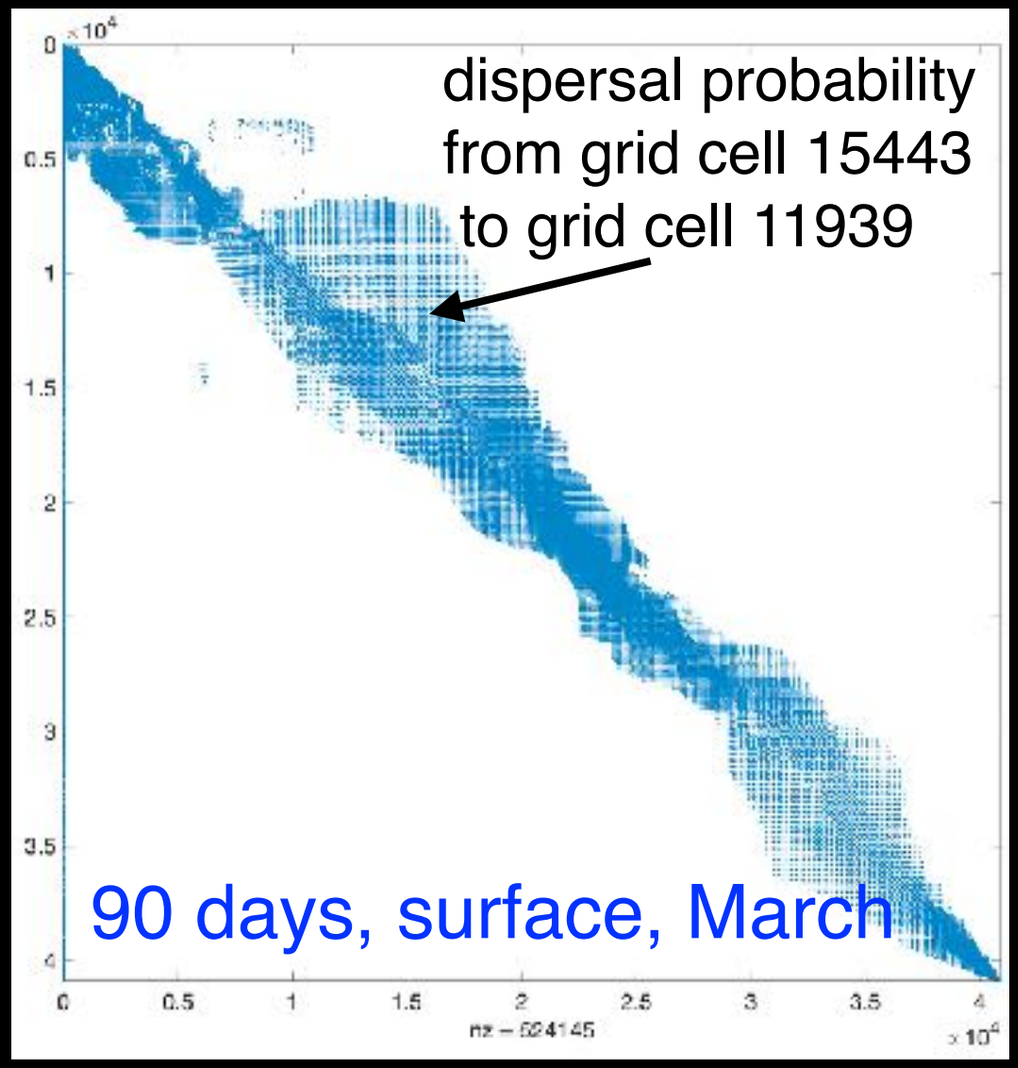
The connectivity matrix

- Calculating connectivity matrices (trait and habitat dependent)



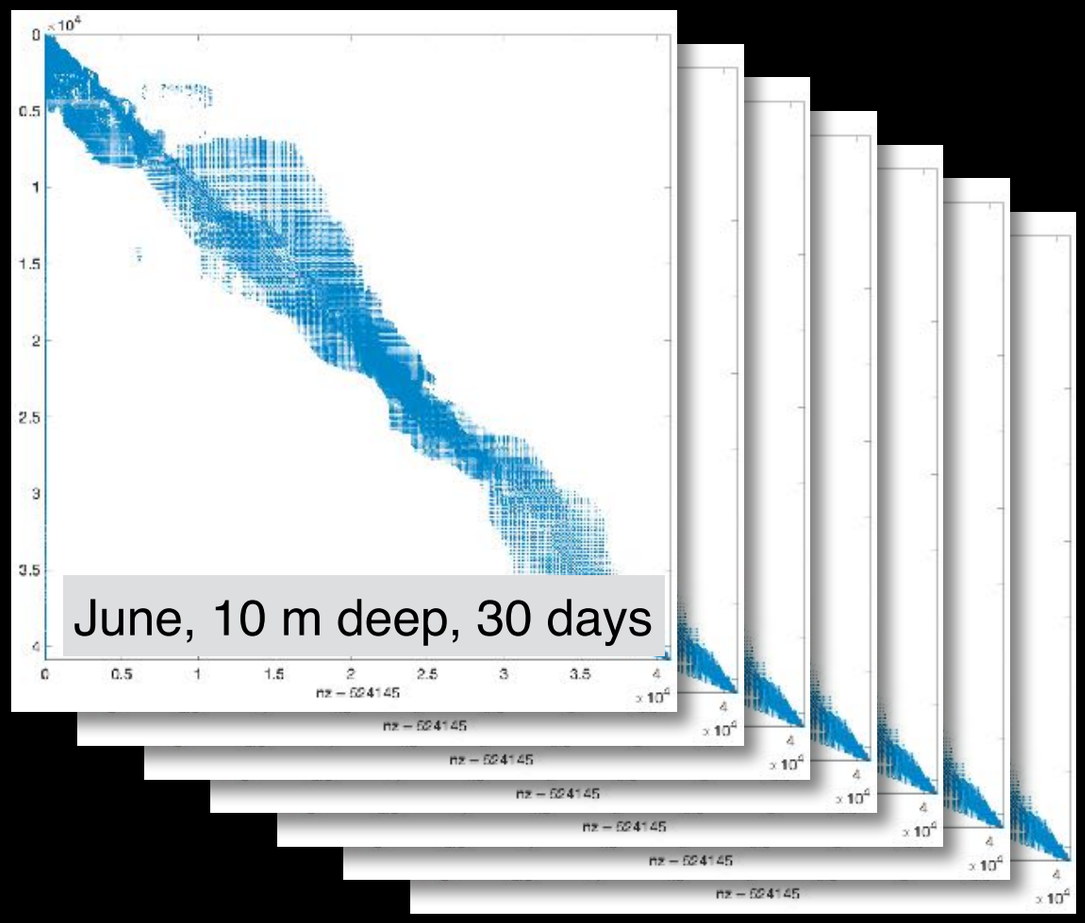
40893 sites

One connectivity matrix



A database of connectivity matrices

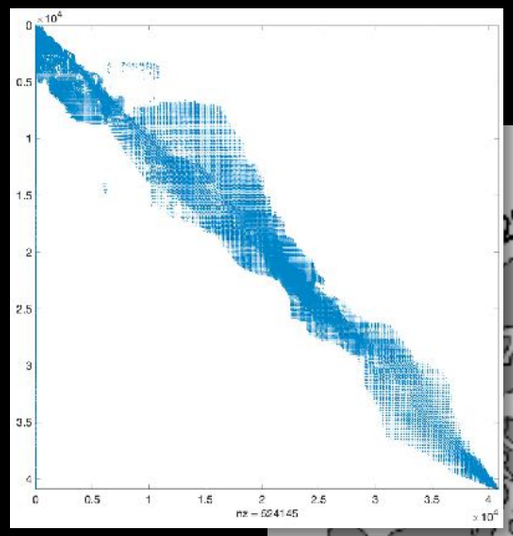
- Every month
- Larval positions after 5, 10, 20, 30, 50, 70,100 days
- Larval drift depth: 0, 5, 10, 15, 20, 30, 50, 100, 150, 200 & 300 m
- Averaged over all years

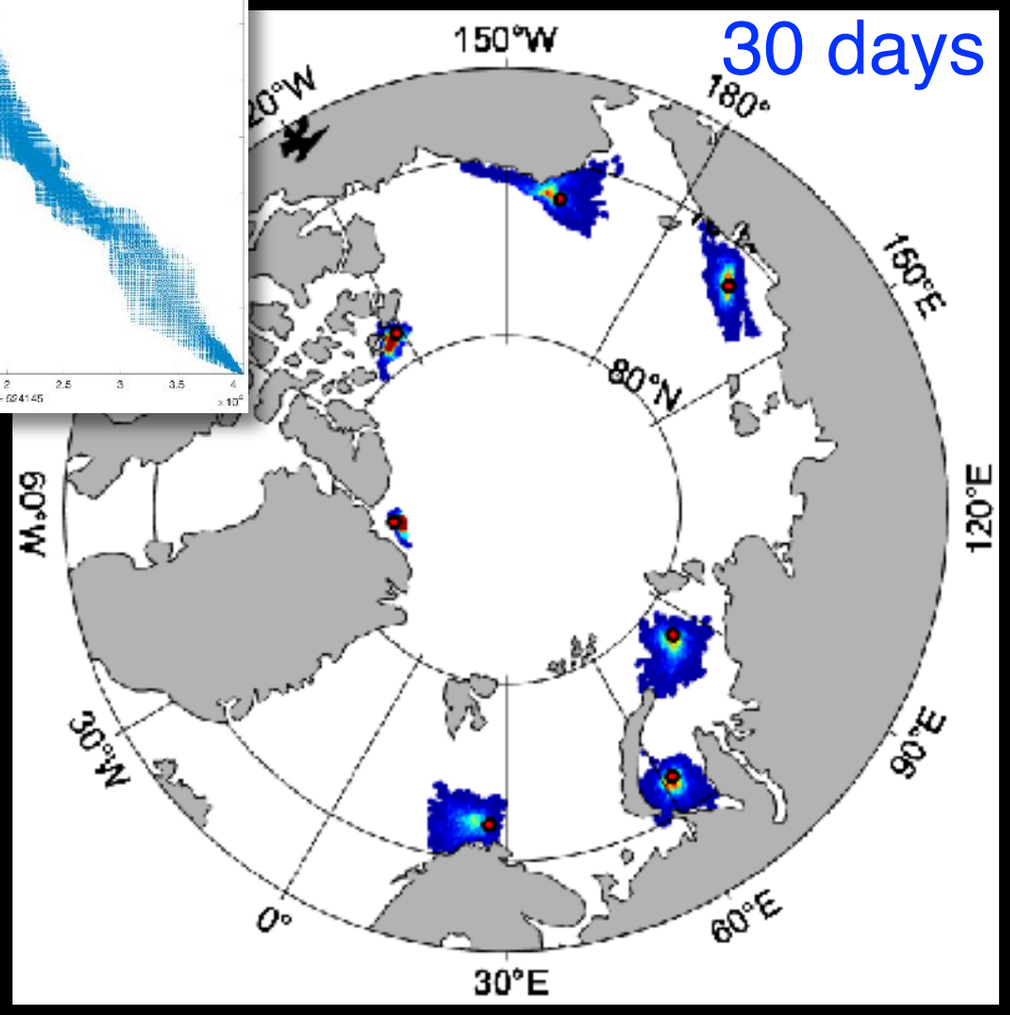


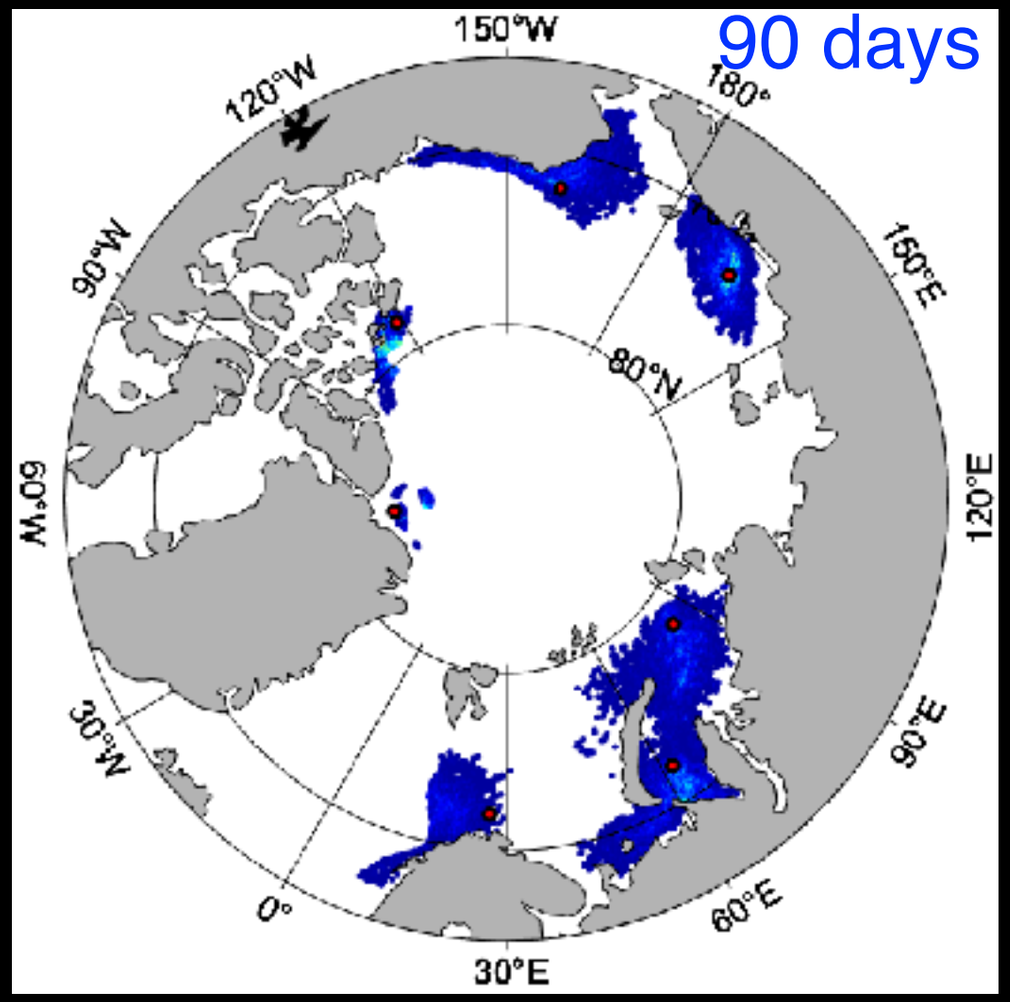
12 x 7 x 11 = 924 matrices

Examples of results

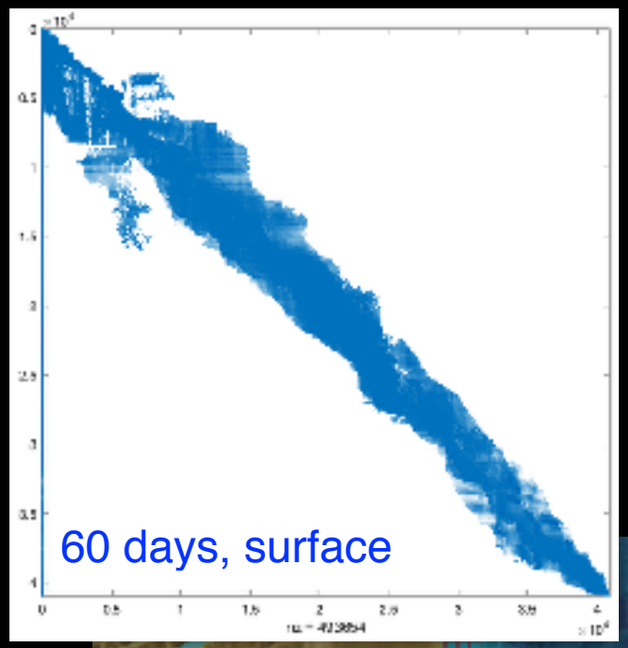
Heat-maps of dispersal probability from 7 release points

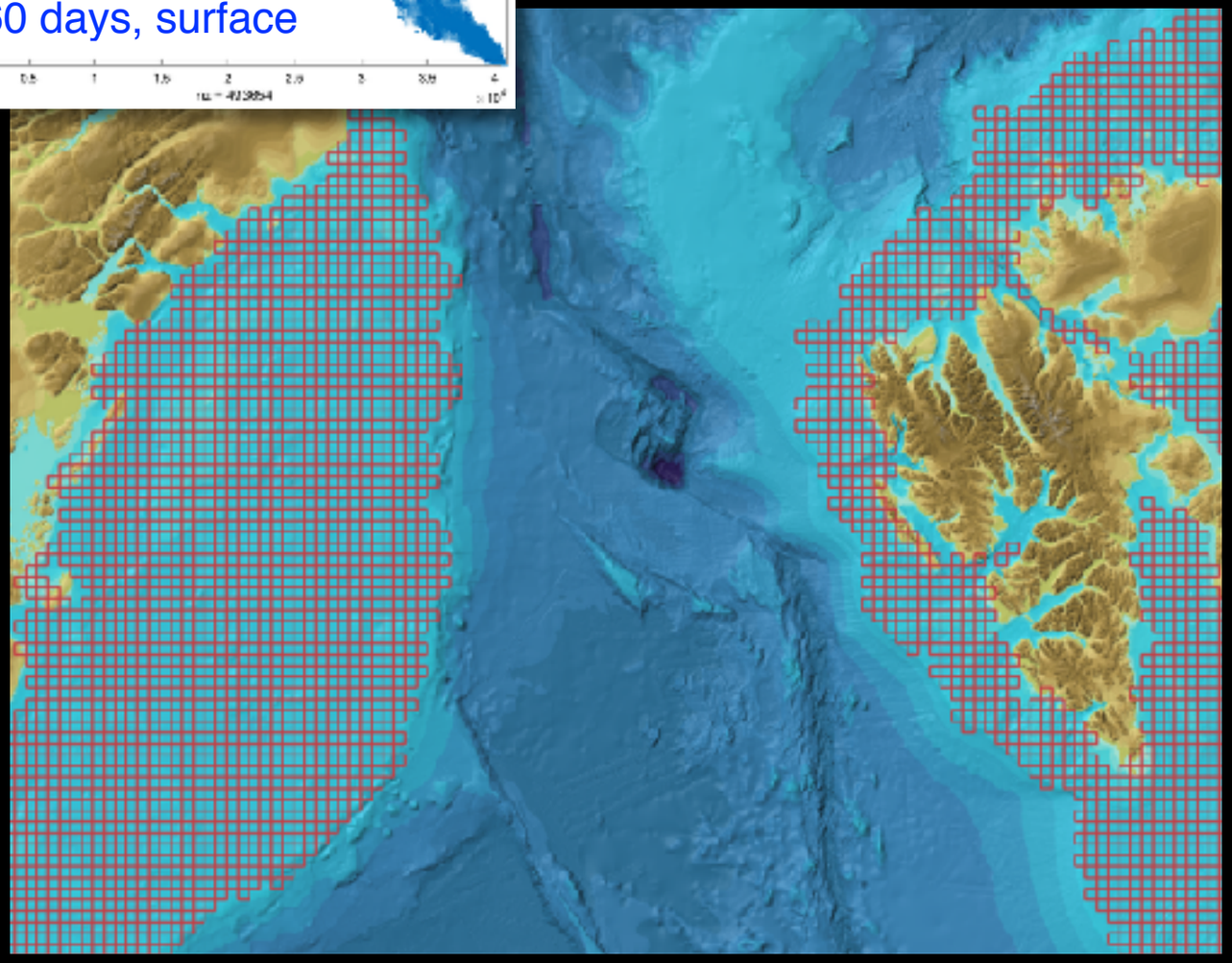


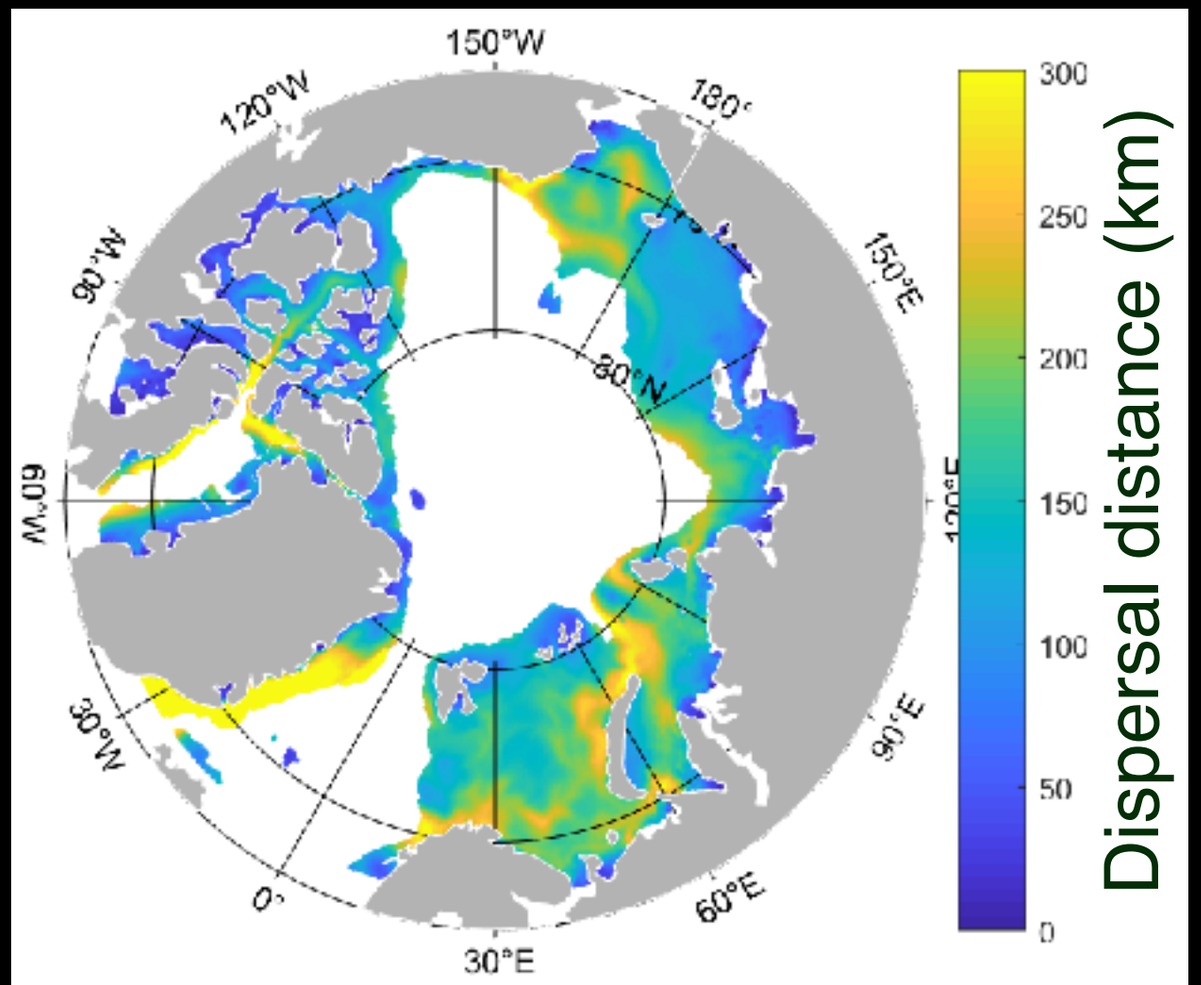




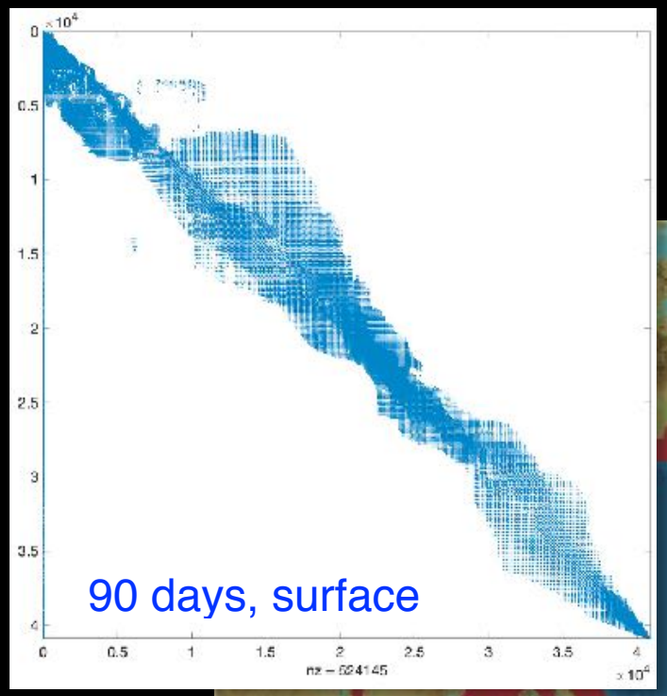
Maps of dispersal distance and direction

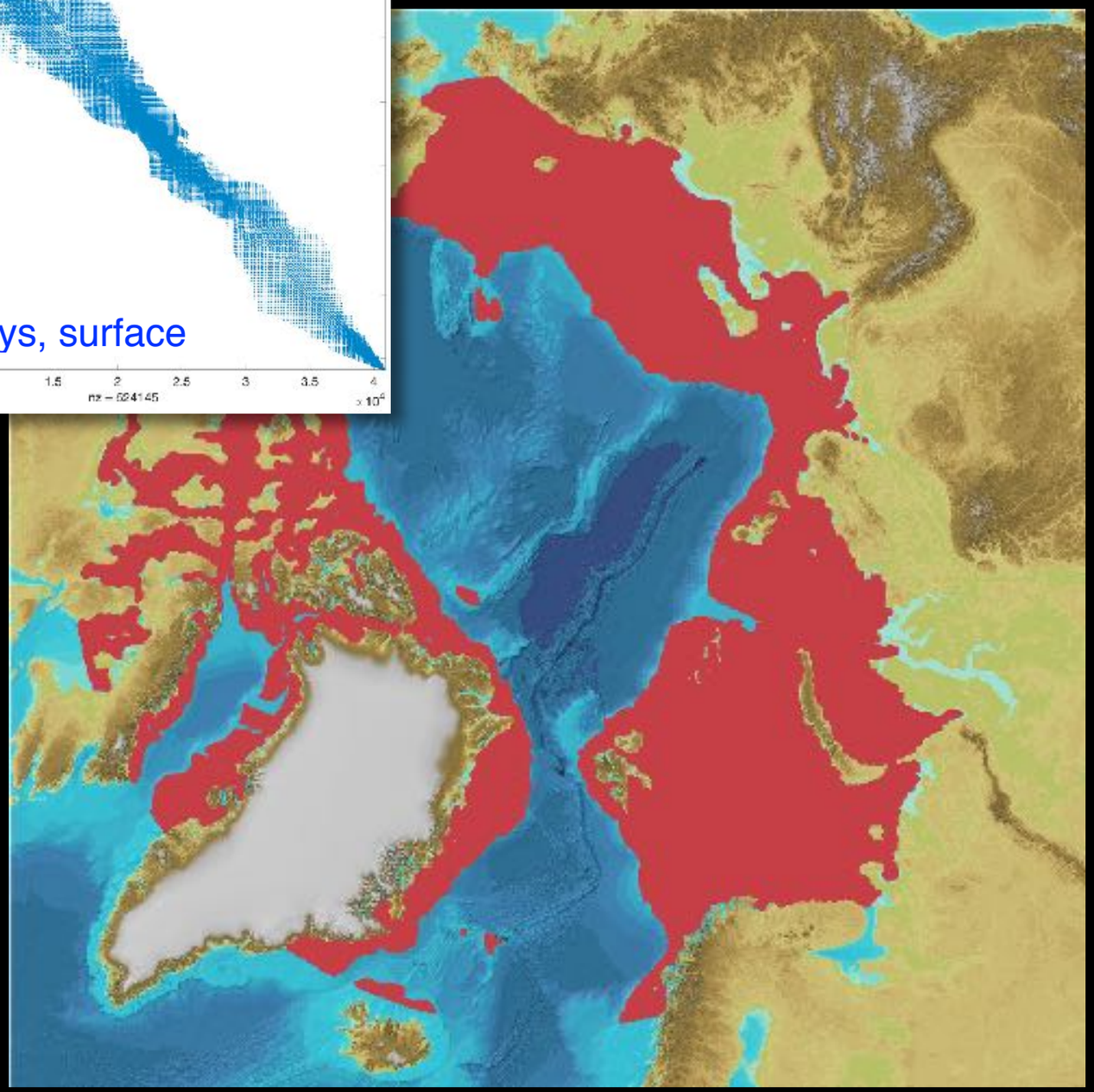


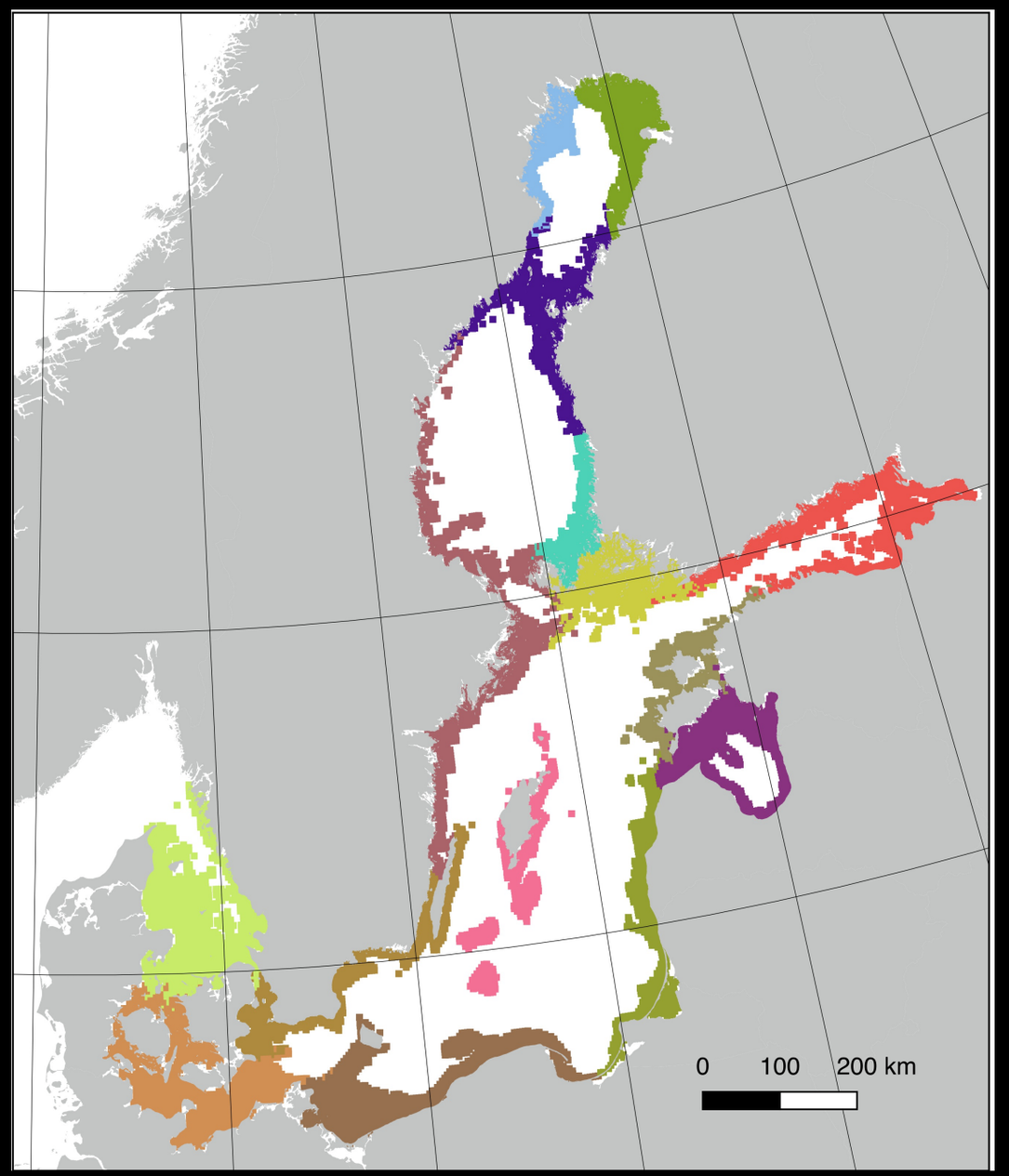




Mapping dispersal barriers



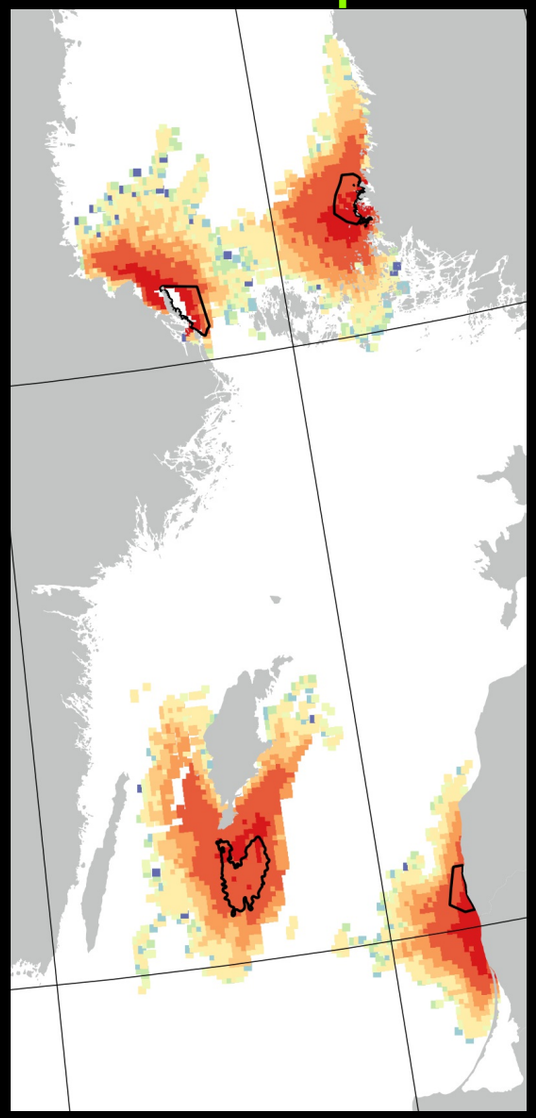


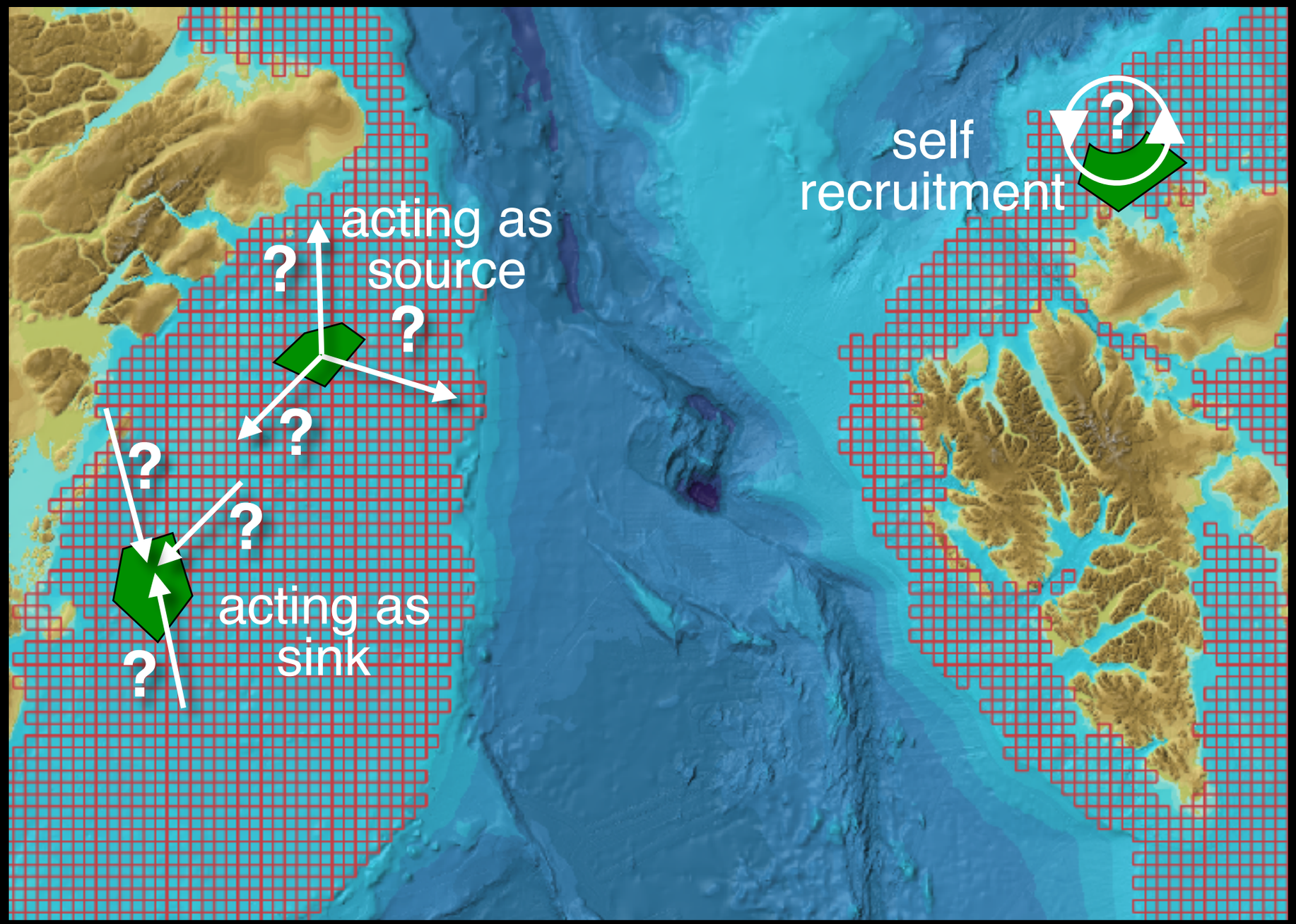


Nilsson Jacobi et al. (2012)

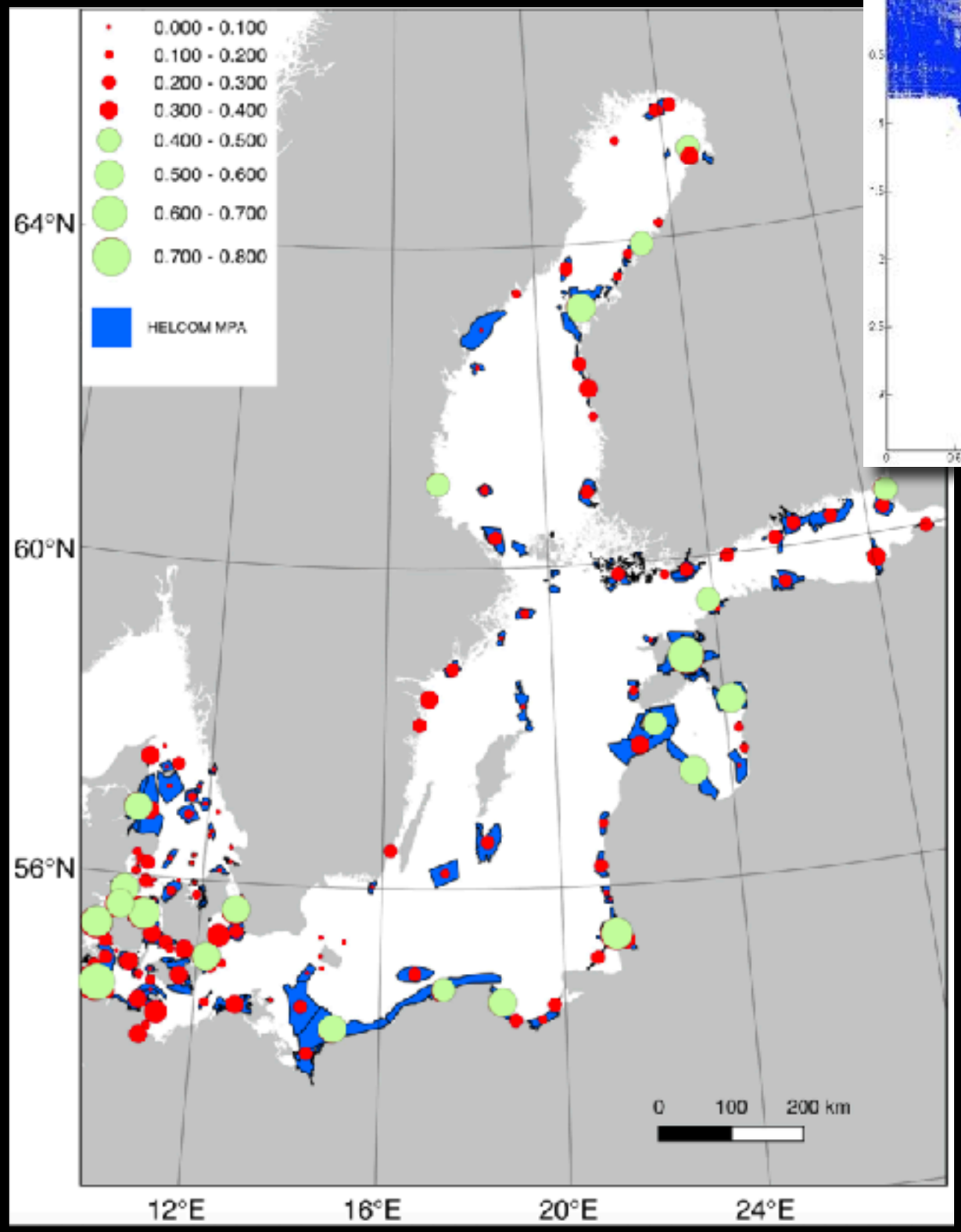
How can connectivity contribute to MPA design?

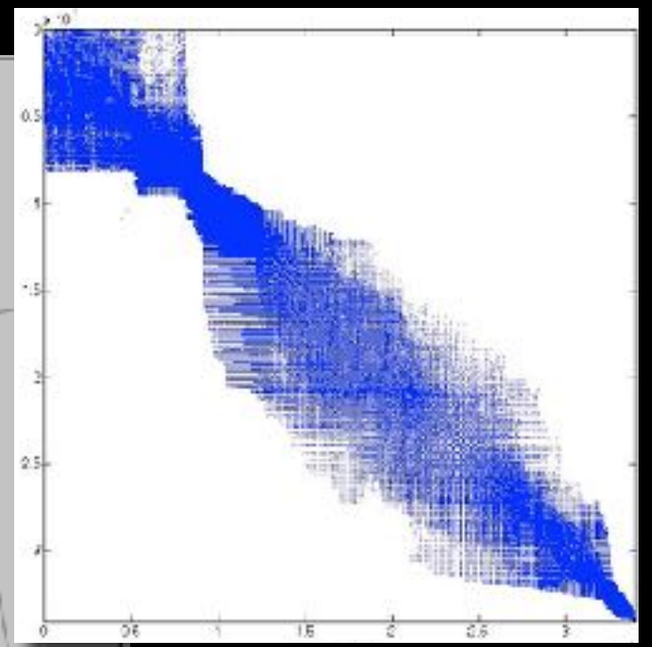
Area of influence after 10 days of transport





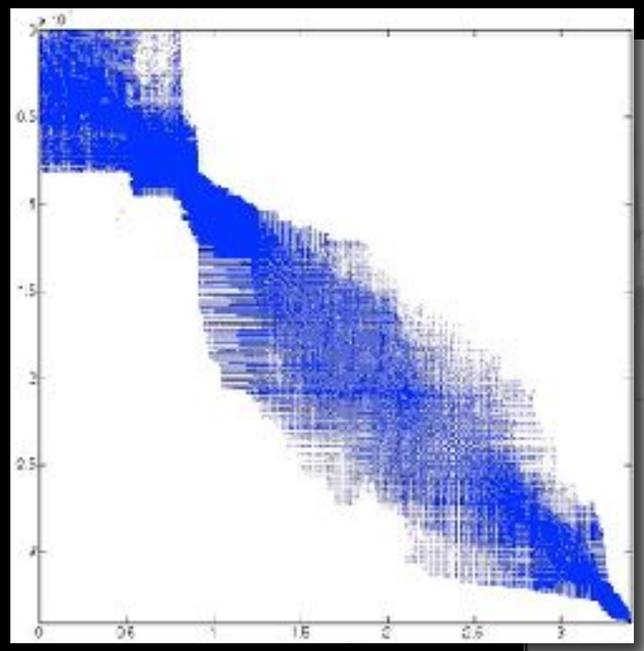
Self recruitment in MPAs

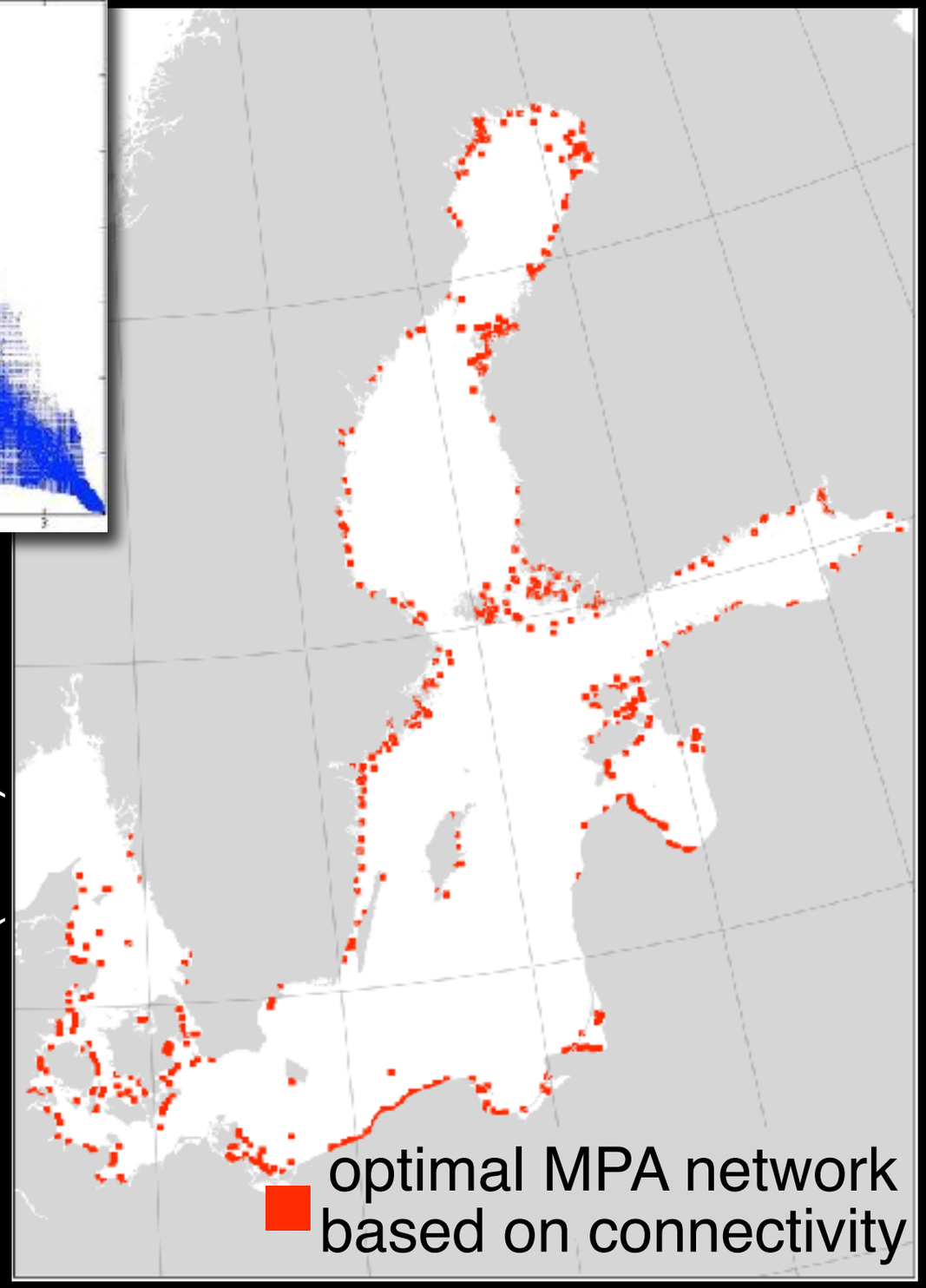




Jonsson et al. (2020)

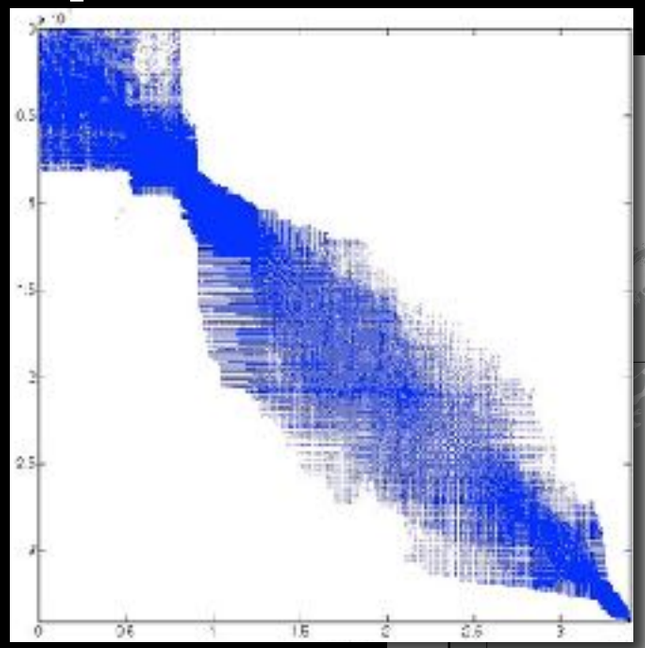
Identification of optimal MPA networks

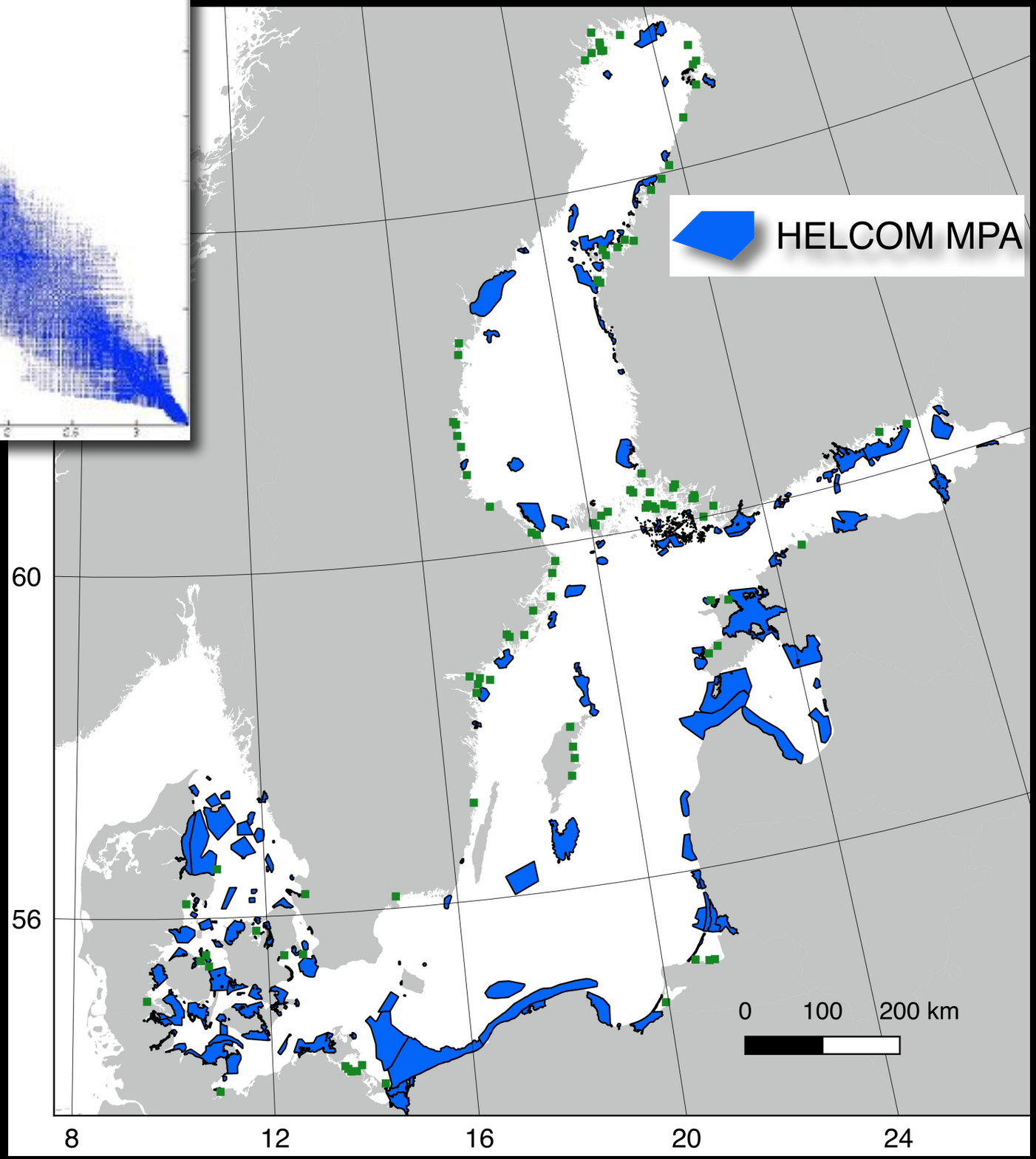




Jonsson et al. (2020)

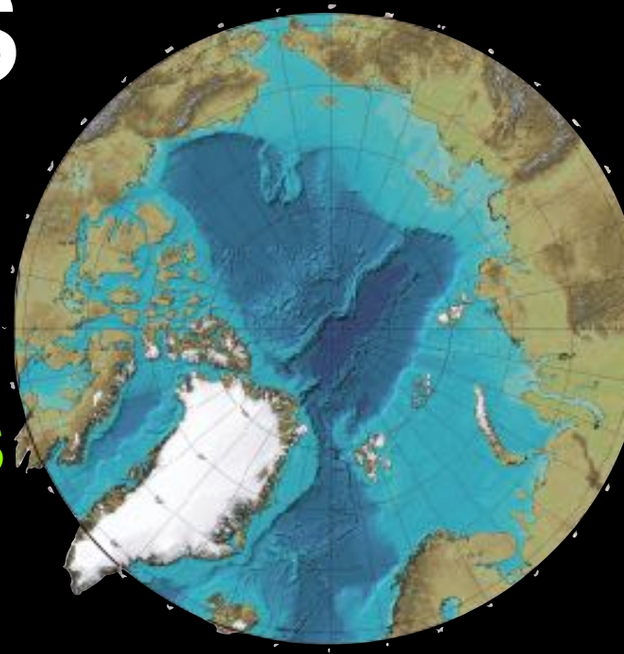
Optimal extension of MPA networks





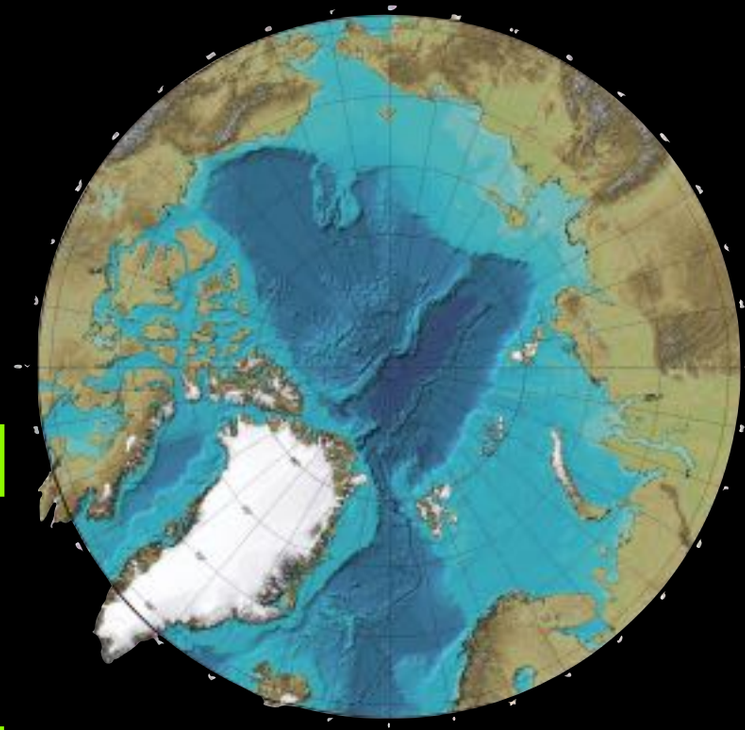
Jonsson et al. (2020)

Remaining tasks



- Quality control of dispersal simulations
- Continue to summarise dispersal simulations into connectivity matrices
- Initial analysis of connectivity patterns and identification of barriers
- Technical report (July 2020)
- Scientific report

Discussions with Marine Protected Areas Expert Group



- A general interest to include connectivity in the MPA toolbox
- A test case as demonstration would be useful
- Limited availability of habitat maps is a bottleneck
- This approach is not suitable for most migratory species, e.g. some fish & marine mammals

Thank you!