ECOBIOP LAB UMR INRAE-UPPA 1224

Internship from 03-01-2025 to 08-29-2025

Detecting evolutionary changes in dispersal during range expansion of brown trout

Presented by Marion BUJ (Master 2 student, GREEN-EEAE)

Under the supervision of

Jacques LABONNE (Head of UMR ECOBIOP)
Gaëlle BRAHY (pHd student, UMR ECOBIOP)

Definitions

- **Dispersal** : 3 steps process

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Departure → **Transience** → **Settlement**

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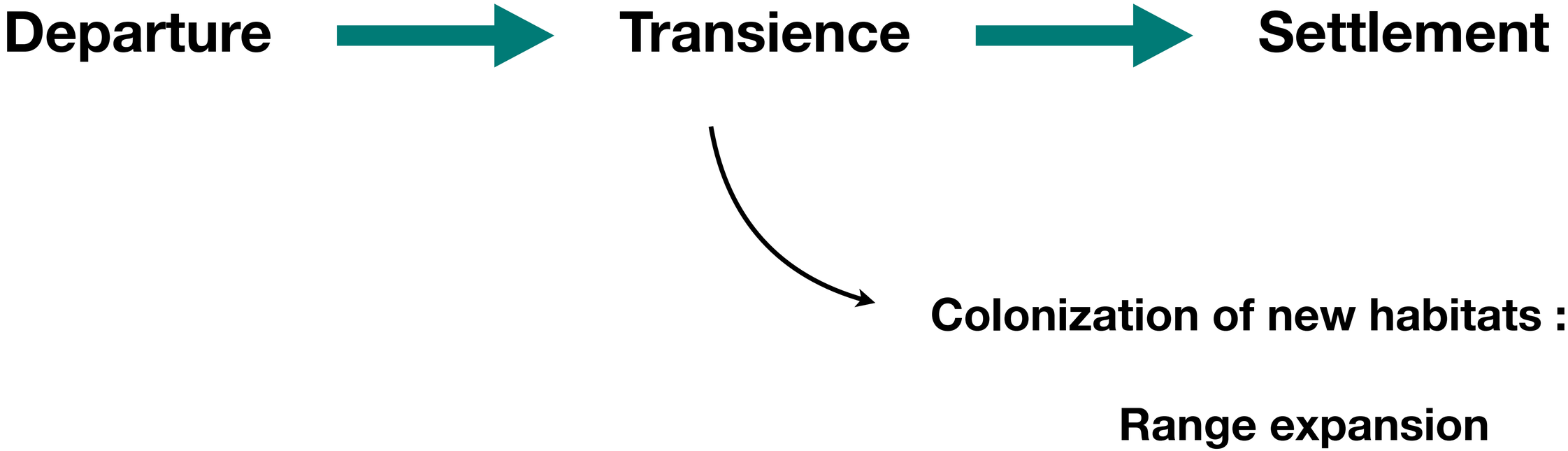
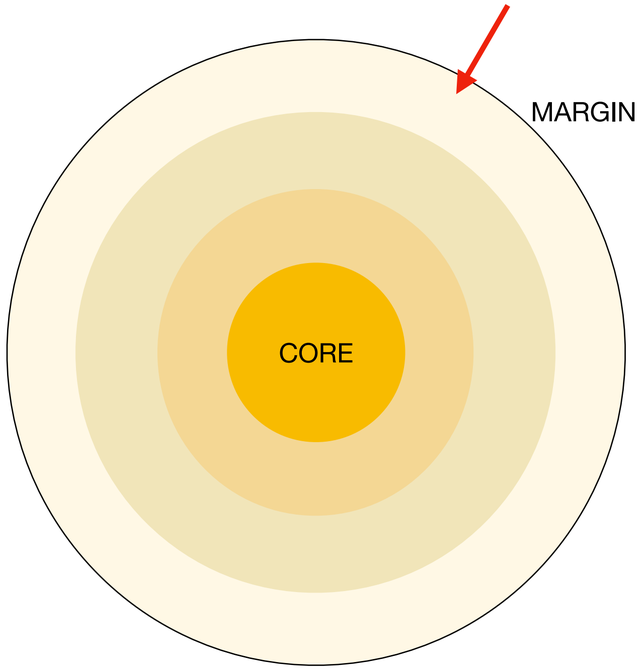
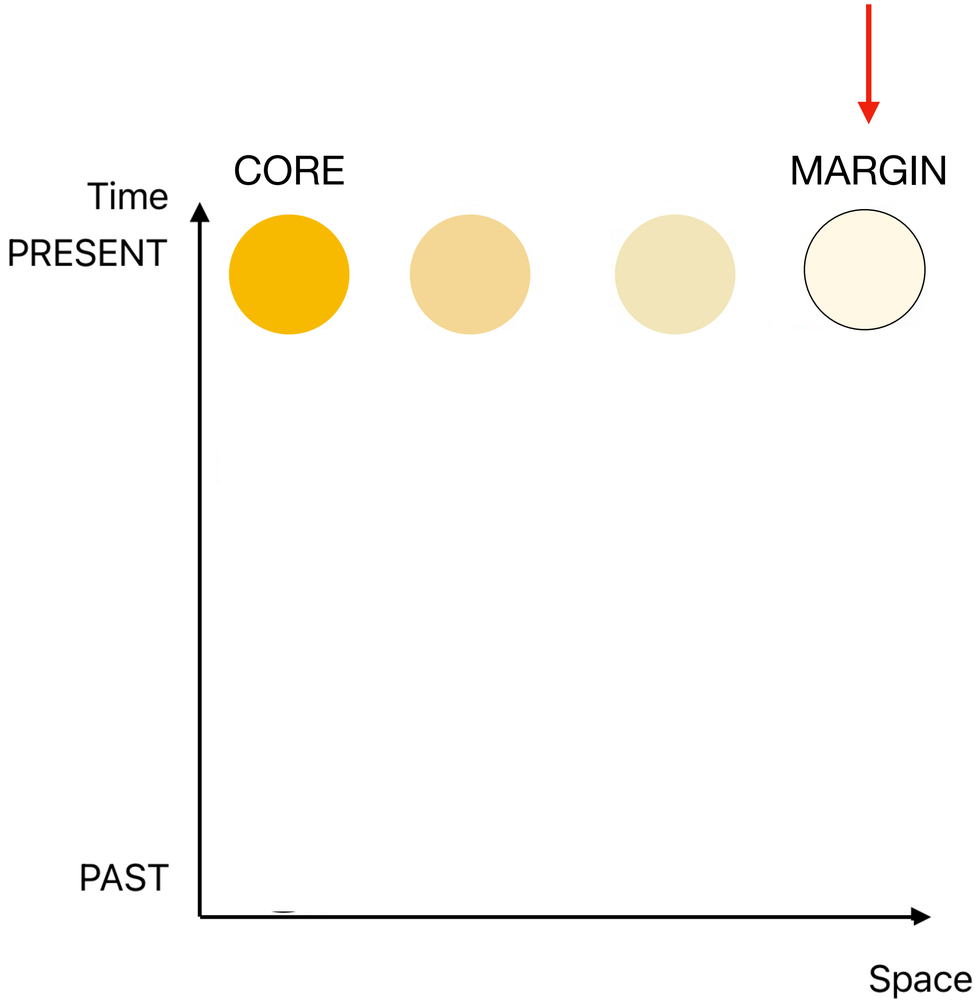
- **Dispersal** : 3 steps process



Context

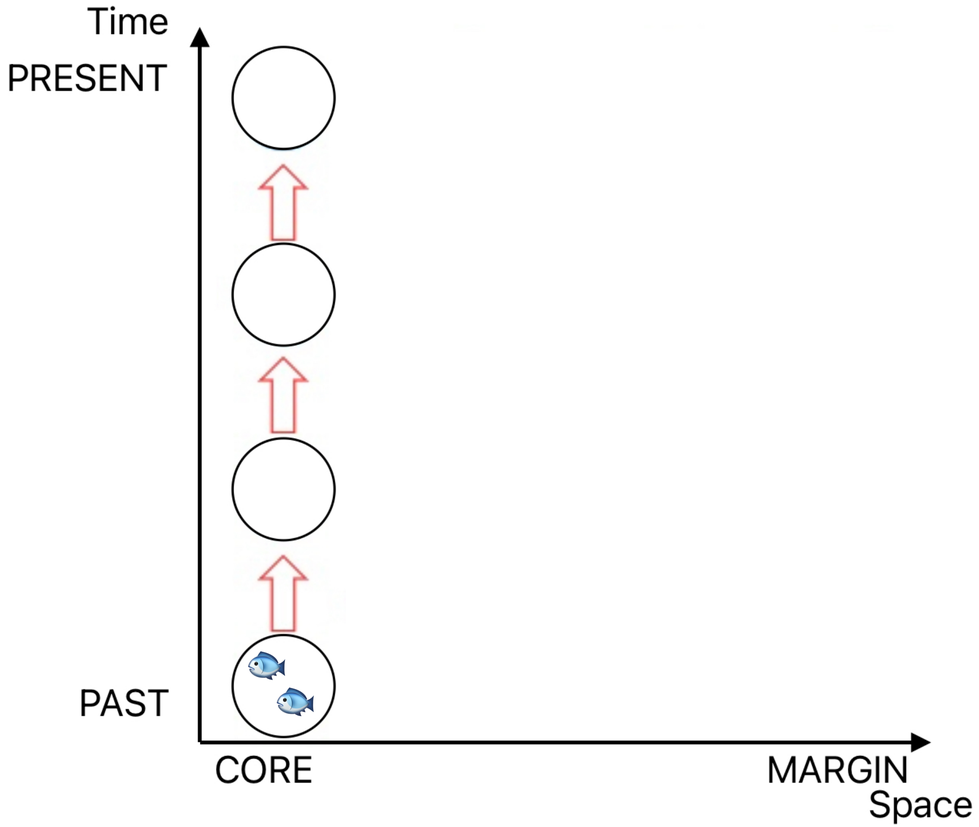
- **Expansion gradient** : transition from older, dense core populations to recently founded, low-density edge populations.





Context

- **Expansion range** : the succession in time of the expansion gradients. It is all the recently founded, young populations across the years.



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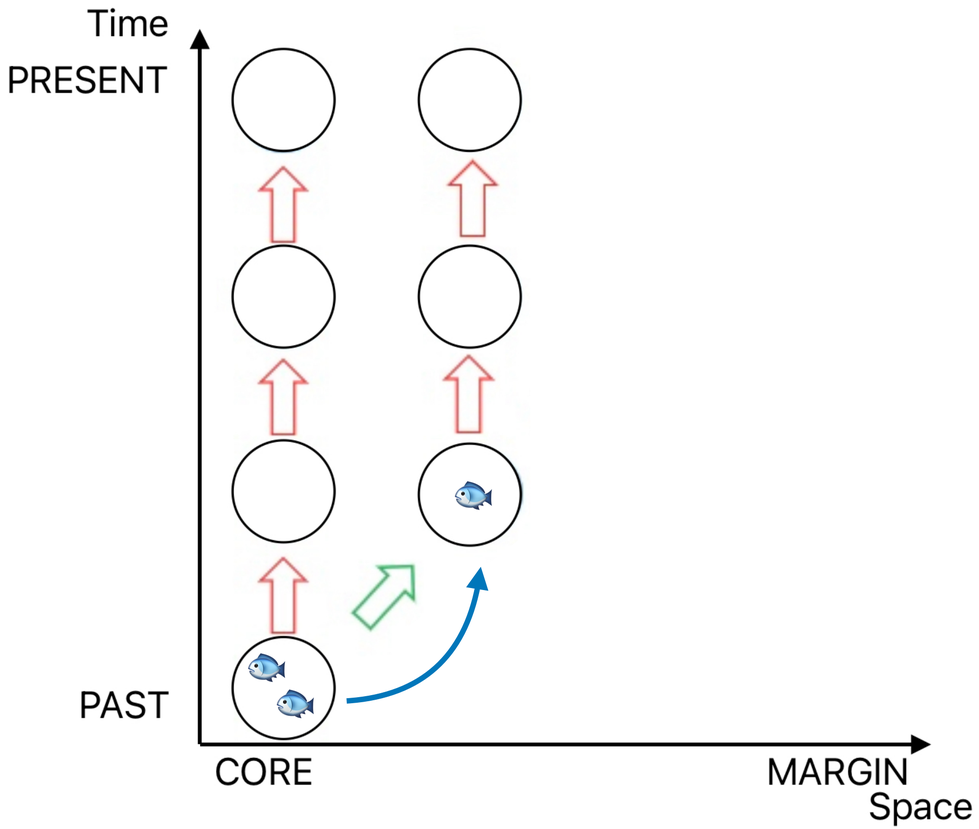

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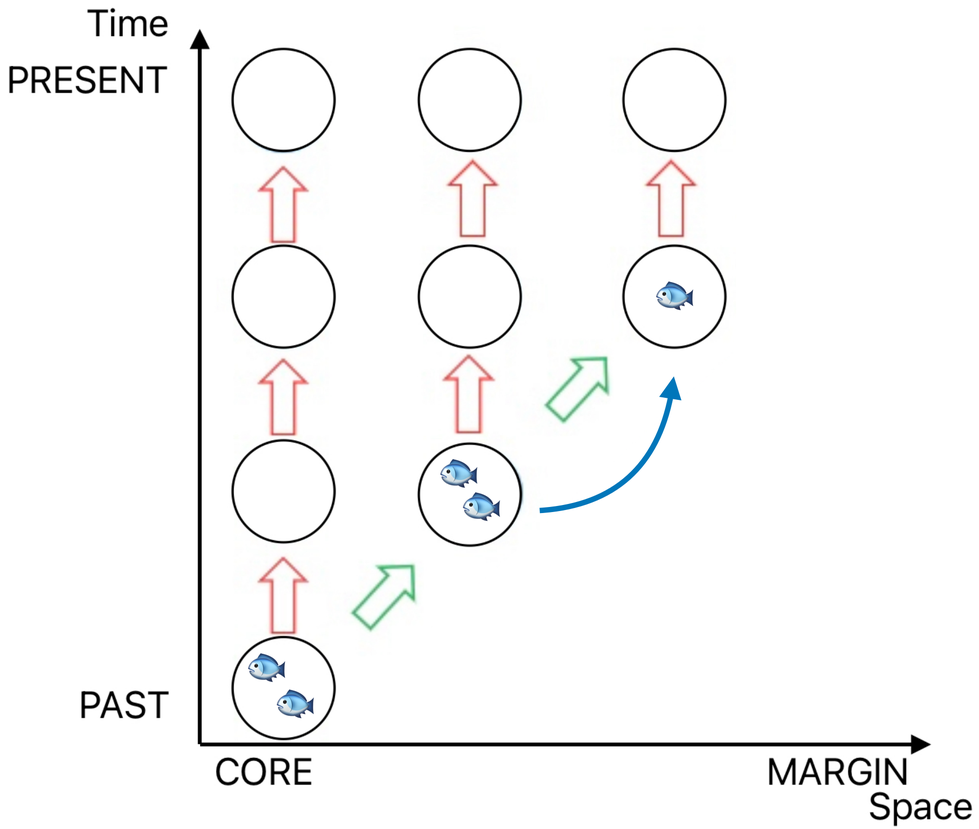

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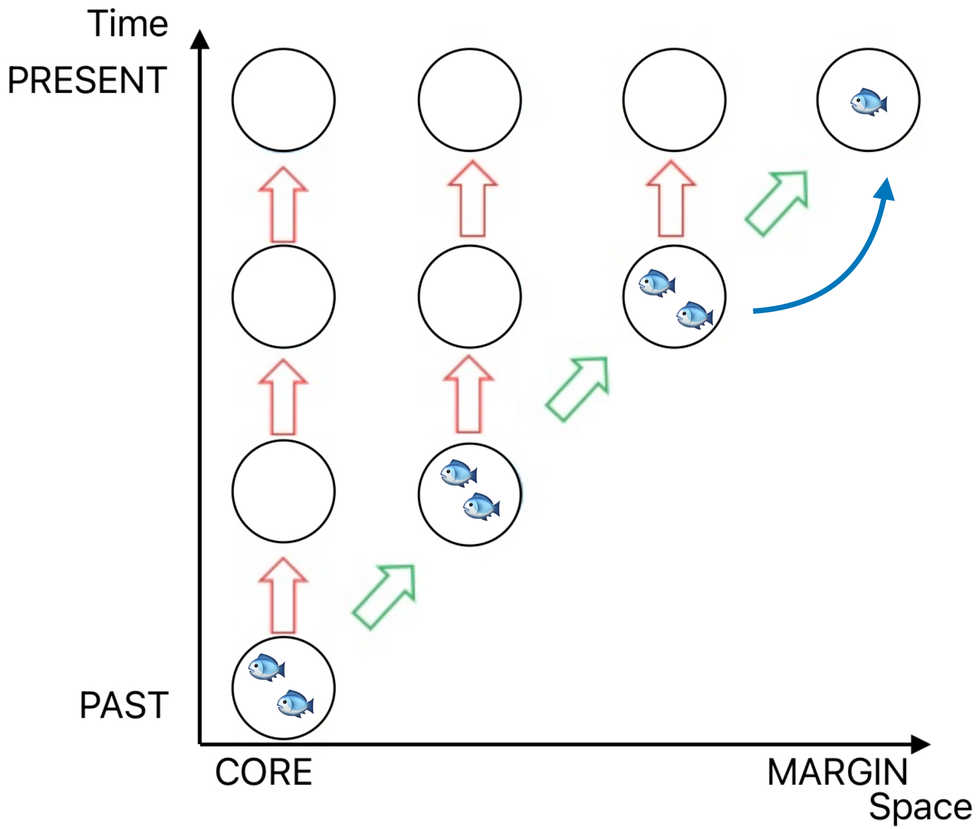

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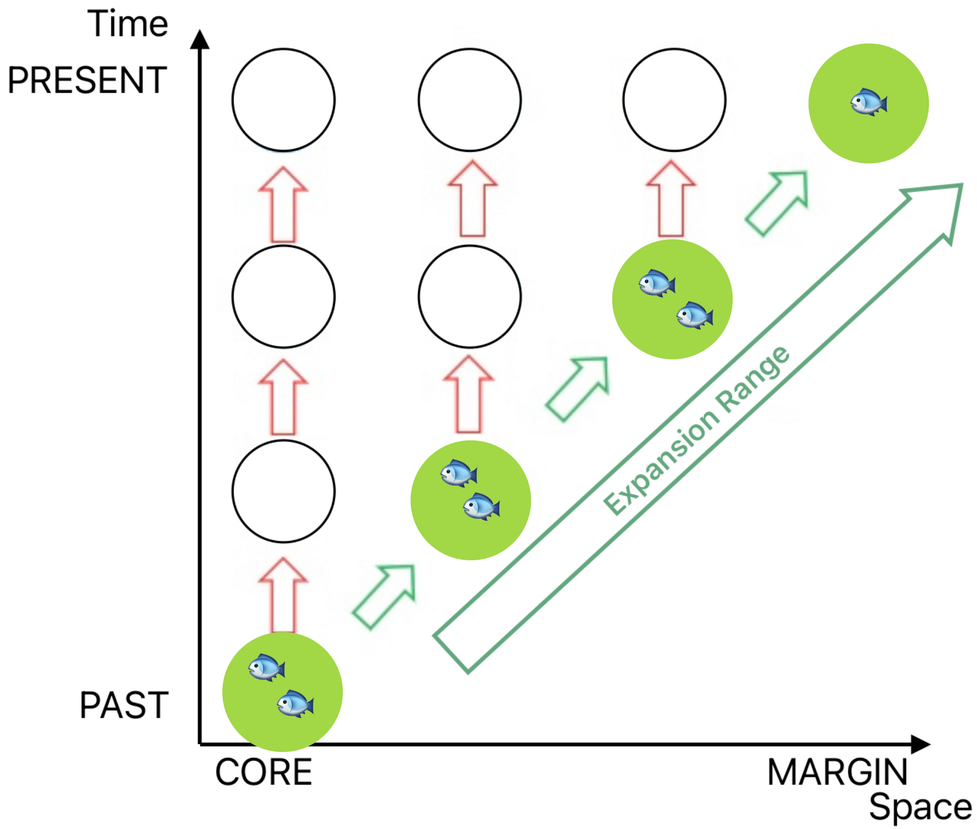


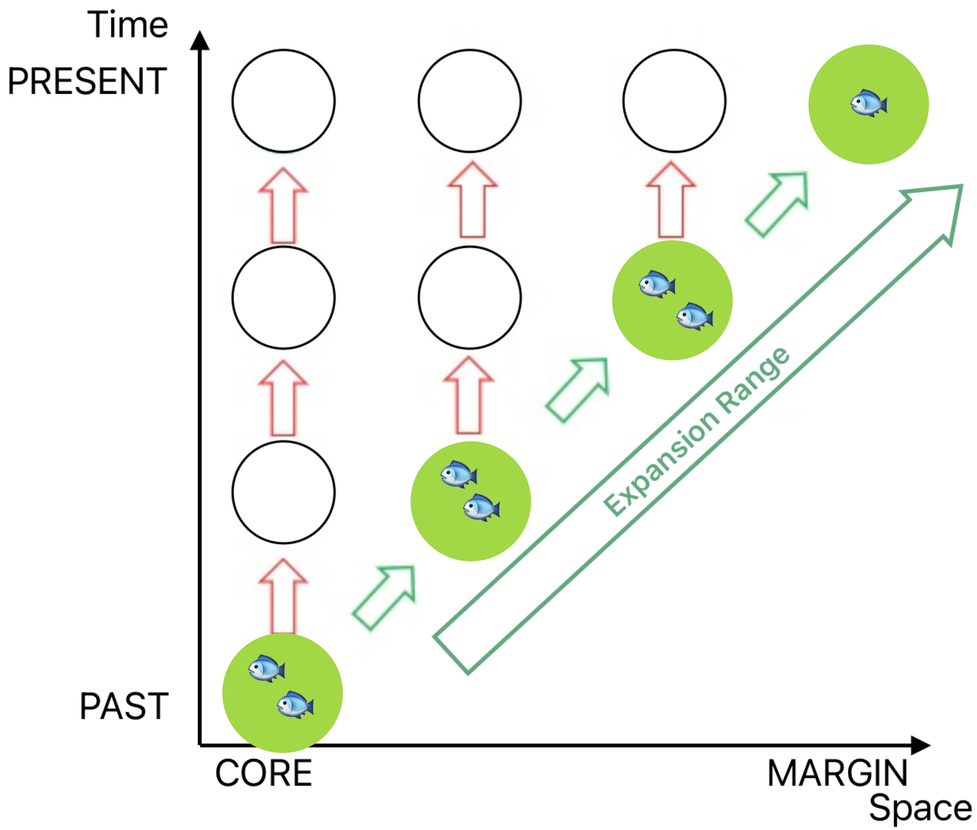
Context

- Expansion range : all the recently founded, young populations across the years.

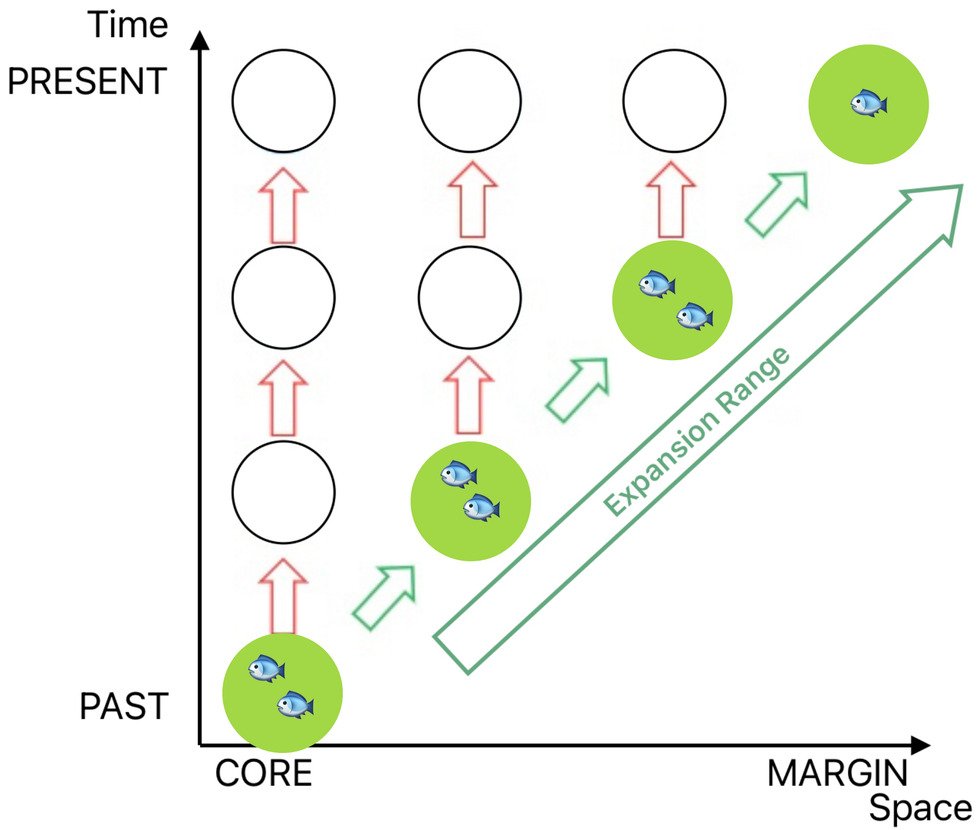
- Why are they special?

  - Low-density populations : low competition, high resource habitats (Travis & Dytham, 2002)

  - Spatial sorting : concentration of high disperal ability traits at the margins (Phillips et al., 2006)



Hypotheses



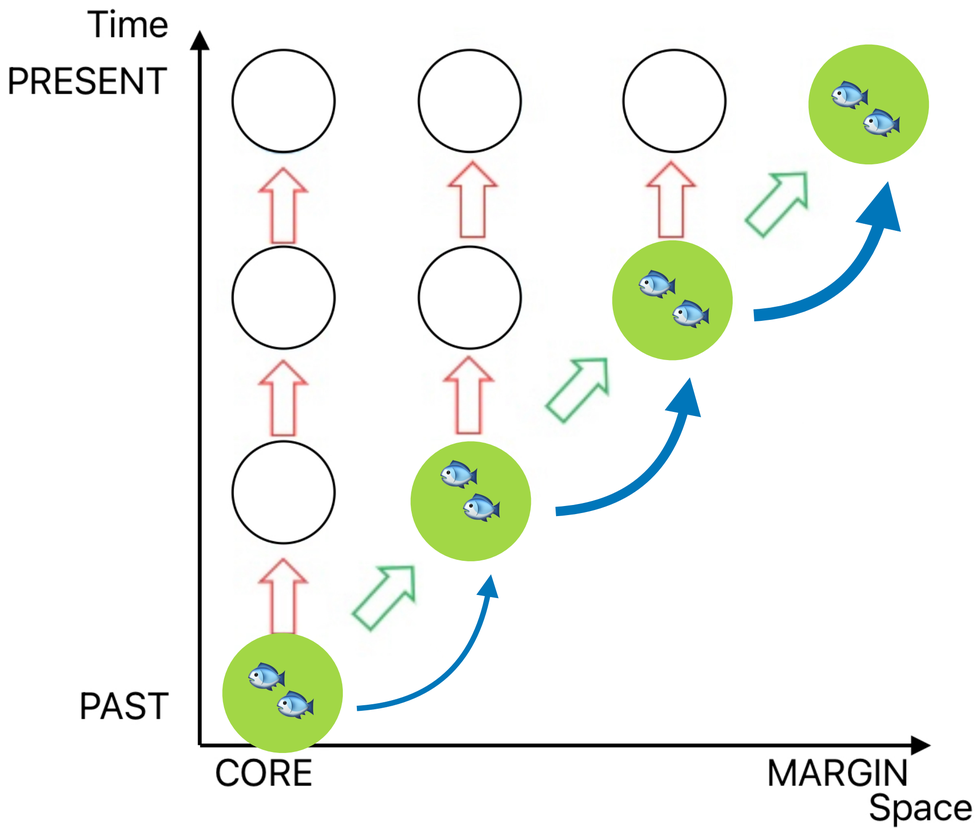
Hypotheses

- **H1** Emission

Selection for dispersal would translate into an increase in disperser emissions along the expansion range.

More dispersers = higher individual probability to leave

An increase in density would also translate into an increase of the probability to leave.



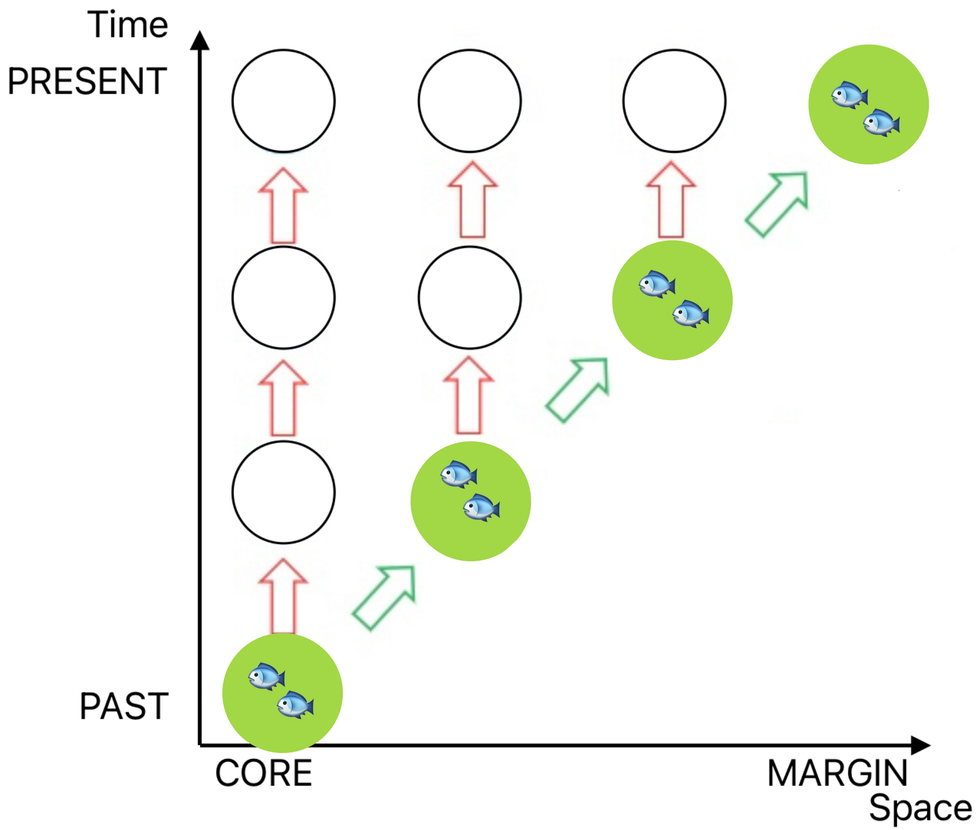
Hypotheses

- H1 Emission

AND / OR

- **H2** Distances

If there is an increase in dispersal distances : it is likely the core individuals are also participating in colonization



Study System

- Kerguelen Islands : subantarctic islands, low anthropization, limited interspecific competition

- Introduction of the brown trout in the 50’s

- Monitoring of the expansion since 1962

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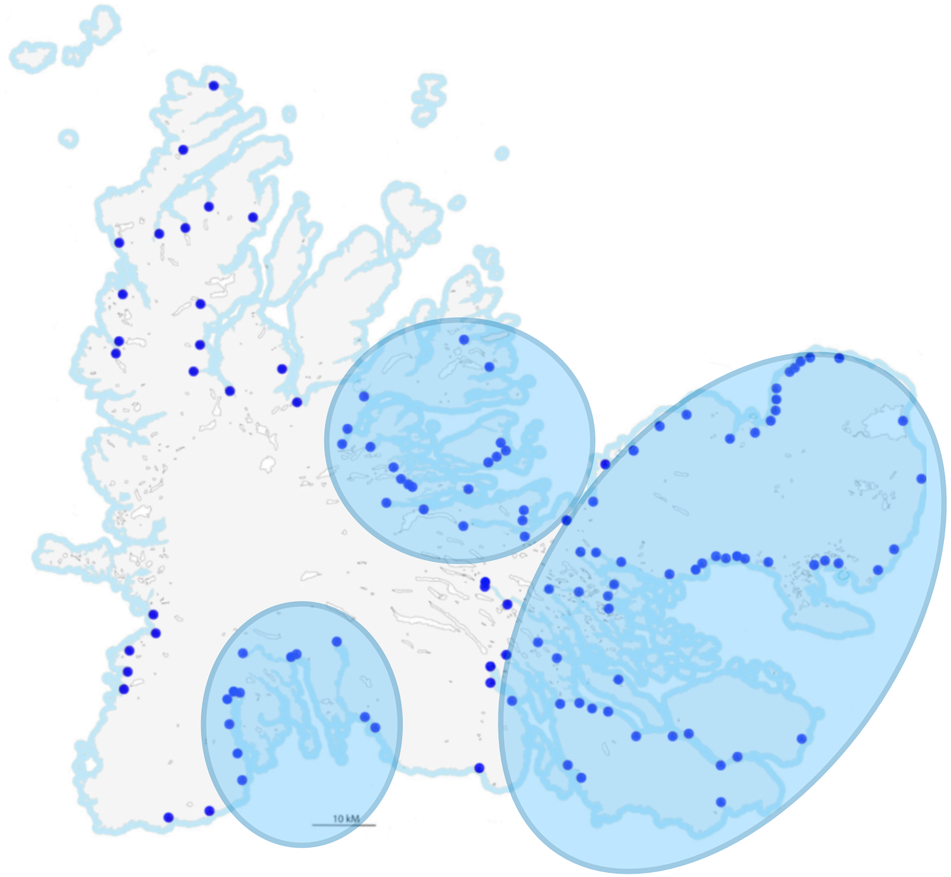
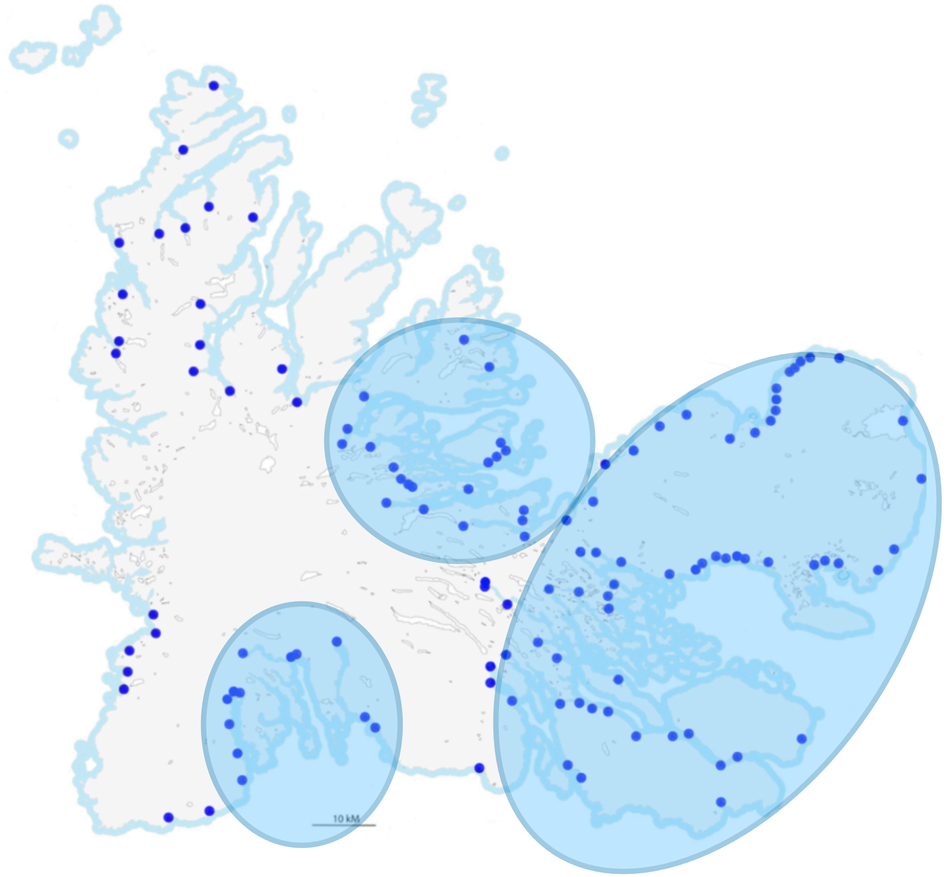
Map of Kerguelen Islands



Study System

- Kerguelen Islands : subantarctic islands, low anthropization, limited interspecific competition
- Introduction of the brown trout in the 50’s
- Monitoring of the expansion since 1962
- **Aim : Track footprints of evolution of dispersal in the expanding metapopulation**

Map of Kerguelen Islands



The data

A	B	C	D	E	F	G	H	I
Colisa/Sandre river code	**index**	**Long name**	**Short name**	**river length (km**	**catchment area (km²)**	**latitude**	**longitude**	**taille colonisable (km)**
S99-0001	1	Val des entrelacs (Arve)	Arve	17.4798	45.3	-49.182194	69.307014	17.4798
S99-0075	126	Rivière du Mont Ventoux	Ventoux	1.8226	12.8	-49.16894	69.308256	1.8226
S99-0076	125	Rivière du Mont Sinaï	Sinai	1.20455	4.4	-49.119014	69.347591	1.20455
S99-0002	2	Baie Chanzy	Chanzy	0.946177	11.4	-49.18949	69.358367	0.946177
S99-0003	3	Déversoir du Lac de la Croix du Sud	Croix_du_sud	0.473546	8	-49.225595	69.411015	0.473546
S99-0004	4	Déversoir du Lac Euphrosine	Euphrosine	0.627157	37.2	-49.237997	69.439026	0.627157
S99-0005	5	Rivière Ballon	Ballon	1.64777	0.25	-49.246523	69.440325	1.64777
S99-0006	6	Rivière Sans Nom (sud est de rivière ballon)	Sans_nom	0.817064	2.3	-49.248728	69.450693	0.817064
S99-0007	7	Ile aux Skuas (ruisseau sud)	Ile_aux_Skuas	0.586232	0.91	-49.251014	69.579299	0.586232
S99-0008	8	Ile du Port 1 (le plus au sud)	Port1	0.691247	4.8	-49.210209	69.619787	0.691247
S99-0009	9	Ile du Port 2	Port2	0.955927	2	-49.202859	69.632856	0.955927
S99-0010	10	Ile du Port 3	Port3	0.609906	6	-49.193861	69.651225	0.609906
S99-0011	11	Ile du Port 4 (le plus au nord)	Port4	0.603112	2.42	-49.185019	69.641048	0.603112
S99-0012	12	Val Froide - Merveilles	Merveilles	6.46228	108	-49.27218	69.405624	6.46228
S99-0013	13	Val Travers	Val_Travers	4.66732	93.6	-49.280067	69.478406	4.66732
S99-0014	14	Ruisseau de cabane POC (Port-Couvreux)	Couvreux	0.896501	0.19	-49.283493	69.695935	0.896501
S99-0015	15	Ruisseau sud de cabane POC	Couvreux_sud	1.21151	0.37	-49.292466	69.690518	1.21151
S99-0016	16	Ruisseau du fond du Havre du Beau Temps	Havre	0.69759	5.56	-49.301978	69.580646	0.69759
S99-0017	17	Ruisseau de l'Anse Sablonneuse (bras est)	Anse_Sablonneuse	0.59641	10	-49.316918	69.704593	0.59641
S99-0018	18	Port Kirk	Port_Kirk	2.84427	7.28	-49.293137	69.790788	2.84427
S99-0019	19	Val de l'Ouest	Val_de_l_Ouest	4.06589	22.6	-49.268241	69.85167	4.06589
S99-0020	20	Studer	Studer	8.73868	65	-49.213424	69.87083	4.91
S99-0021	21	Rivière du Doute	Doute	1.0365	9.8	-49.196494	69.925146	0.79
S99-0022	22	Rivière du charbon	Charbon	6.27974	9.42	-49.193868	69.932788	0.93
S99-0023	23	Rivière du Sérail	Serail	1.98751	10.1	-49.158679	69.98446	3.3
S99-0024	24	Rivière des Chasseurs	Chasseurs	4.45577	21.9	-49.142555	70.043304	3.23
S99-0025	25	Rivière du Nord	Nord	5.45175	50	-49.175094	70.137221	3.86
S99-0026	26	Rivière des Pépins	Pepins	3.09211	21.5	-49.166565	70.193741	3.09211
S99-0027	27	Rivière des Cataractes	Cataractes	0.672811	41.6	-49.150658	70.227875	0.672811
S99-0028	28	Rivière des Hautes mares Sud (alias Gorfous 1)	Gorfous_1	1.54016	7.725	-49.137358	70.233982	1.54016
S99-0029	29	Rivière des Hautes mares Nord (alias Gorfous 2)	Gorfous_2	2.94483	7.725	-49.135385	70.236086	2.94483
S99-0030	30	Rivière de la pointe des cabanes (alias Gorfous 4)	Gorfous_4	1.85768	7.725	-49.10621	70.234721	1.85768
S99-0031	31	Ruisseau sud du Cap Rouge (alias Gorfous 5)	Gorfous_5	1.68523	7.725	-49.079663	70.26749	1.68523
S99-0032	32	Ruisseau nor du Cap Rouge (alias Gorfous 6)	Gorfous_6	2.42446	7.725	-49.059097	70.372454	2.42446
S99-0033	33	Rivière de Rohan	Rohan	1.99377	9.1	-49.151387	70.512337	1.99377
S99-0034	34	Système du Lac Marville (Est)	Est	30.3429	226	-49.151387	70.512337	30.3429
S99-0035	35	Rivière des manchots	Manchots	9.19221	97.5	-49.229232	70.55493	9.19221
S99-0036	36	Rivière des Calcédoines	Calcedoines	1.31039	16.2	-49.328628	70.497528	1.31039
S99-0037	37	Rivière du Bungay	Bungay	18.9459	7.6	-49.358051	70.463652	18.9459
S99-0038	38	Rivière des Albatros	Albatros	18.1342	42.9	-49.350321	70.378048	18.1342

The data

	Short name	An	Ve	Sh	Ch	Cr	Eu	Ba	Sa	Ile	Po	Po	Po	Po	Mt	Va	Co	Co	Ha	An	Po	Va	Sh	Do	Ch	Se	Ch
	Code Sandre	S99-0001	S99-0075	S99-0076	S99-0002	S99-0003	S99-0004	S99-0005	S99-0006	S99-0007	S99-0008	S99-0009	S99-0010	S99-0011	S99-0012	S99-0013	S99-0014	S99-0015	S99-0016	S99-0017	S99-0018	S99-0019	S99-0020	S99-0021	S99-0022	S99-0023	S99-0024
		patch																									
	year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1962	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	1963	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
3	1964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
4	1965	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5	1966	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
6	1967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
7	1968	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
8	1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
9	1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
10	1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
11	1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
12	1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
13	1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
14	1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
15	1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
16	1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
17	1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
18	1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
19	1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
20	1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
21	1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
22	1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
23	1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
24	1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
25	1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	NA	0	1
26	1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	NA	0	1
27	1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	NA	NA	1
28	1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	NA	NA	1
29	1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	NA	NA	1
30	1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	NA	NA	1
31	1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
32	1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
33	1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
34	1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
35	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1
36	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
37	1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
38	1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
39	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
40	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
41	2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
42	2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
43	2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
44	2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
45	2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
46	2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
47	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
48	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
49	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1
50	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	1	0	0	0	0	1	1	1	1	1	1	1
51	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	1	0	0	0	0	1	1	1	1	1	1	1
52	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	1	0	0	0	0	1	1	1	1	1	1	1
53	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1
54	2015	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1
55	2016	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1
56	2017	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1
57	2018	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1
58	2019	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1
59	2020	NA	NA	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	NA	NA	NA	NA	1	1	1	1	1	1	1
60	2021	NA	NA	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	NA	NA	NA	NA	1	1	1	1	1	1	1
61	2022	1	NA	NA	0	NA	1	NA	NA	NA	NA	NA	NA	NA	1	1	NA	NA	NA	NA	1	1	1	1	1	1	1
62	2023	1	NA	NA	0	NA	1	NA	NA	NA	NA	NA	NA	NA	1	1	NA	NA	NA	NA	1	1	1	1	1	1	1
63	2024	1	NA	NA	0	NA	1	NA	NA	NA	NA	NA	NA	NA	1	1	NA	NA	NA	NA	1	1	1	1	1	1	1
64	2025	1	NA	NA	0	NA	1	NA	NA	NA	NA	NA	NA	NA	1	1	NA	NA	NA	NA	1	1	1	1	1	1	1

The model

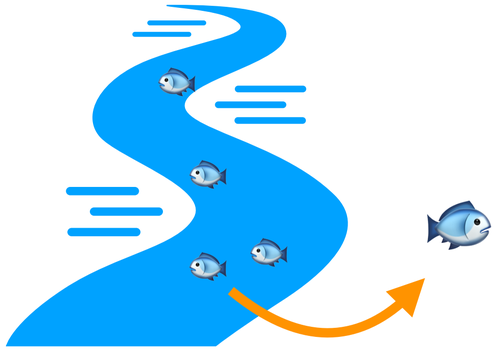
$$p_{t,i} = \left(1 - \exp\left[-cpar_t \cdot Acol_i^{\gamma} \cdot \left(\sum_{j \neq i} Y_{t-1,j} \cdot \left(Aem_j \cdot Dens_{t-1,j}\right)^{\theta} \cdot \exp\left(-\delta \cdot D_{i,j}\right)\right)\right]\right)^{(1-Y_{t-1,i}) \cdot V_{t,i}}$$

C E K

Probability to become colonized, at time *t*, for a patch *i*

The model

$$p_{t,i} = \left(1 - \exp\left[-cpar_t \cdot Acol_i^{\gamma} \cdot \left(\sum_{j \neq i} \underbrace{Y_{t-1,j} \cdot \left(Aem_j \cdot Dens_{t-1,j}\right)^{\theta}}_{\mathbf{E}} \cdot \exp\left(- \quad \cdot D_{i,j}\right)\right)\right]\right)^{(1-Y_{t-1,i}) \cdot V_{t,i}}$$



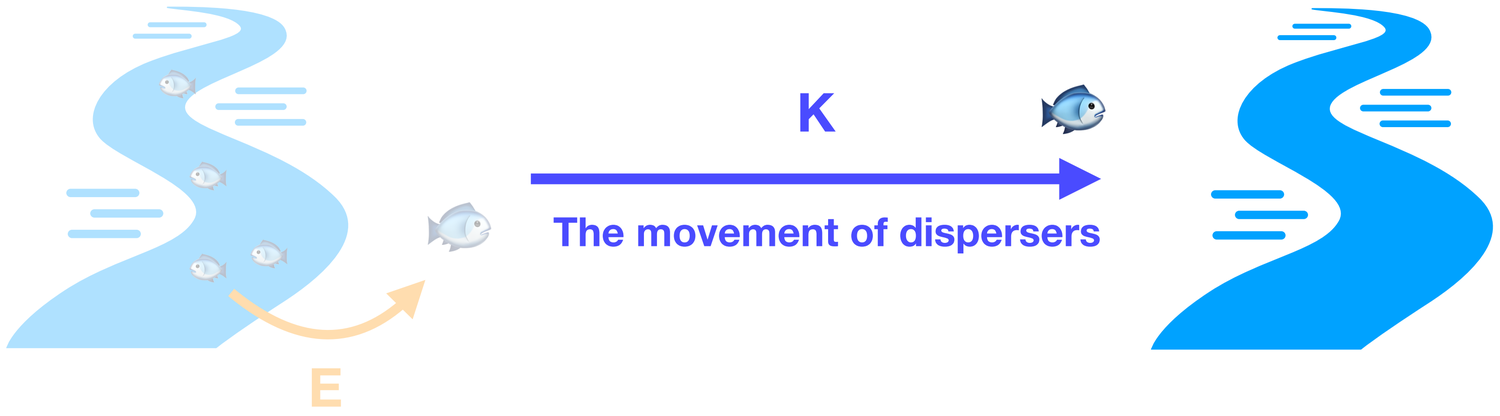
E

The quantity of dispersers

- how much fish leave a river?
- since we know population sizes, it translates into the individual probability to leave

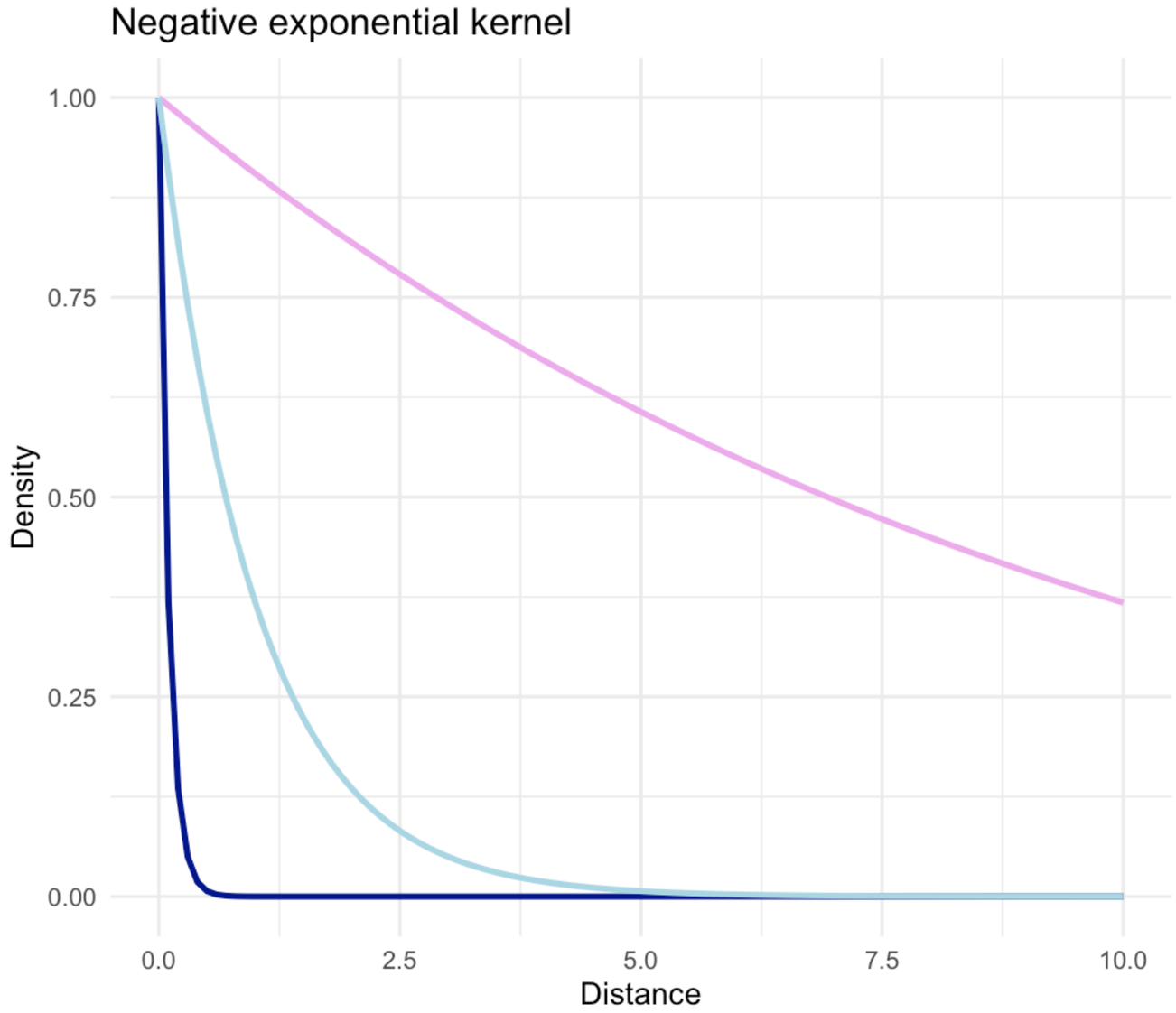
The model

$$p_{t,i} = \left(1 - \exp\left[-cpar_t \cdot Acol_i^{\gamma} \cdot \left(\sum_{j \neq i} \underbrace{Y_{t-1,j} \cdot \left(Aem_j \cdot Dens_{t-1,j}\right)^{\theta}}_{E} \cdot \underbrace{\exp\left(-\delta \cdot D_{i,j}\right)}_{K}\right)\right]\right)^{(1-Y_{t-1,i}) \cdot V_{t,i}}$$



- how far do they go?
- the kernel can give an information on the probability to migrate more or less far

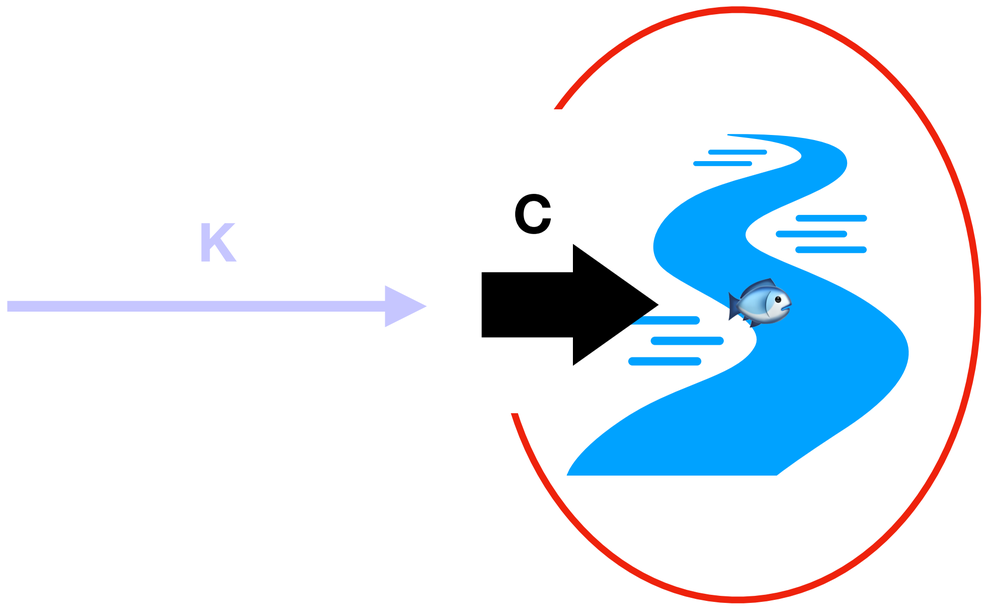
What does it look like?



The model

$$p_{t,i} = \left(1 - \exp\left[-cpar_t \cdot Acol_i^{\gamma} \left(\sum_{j \neq i} Y_{t-1,j} \cdot \left(Aem_j \cdot Dens_{t-1,j}\right)^{\theta} \cdot \exp\left(-\delta \cdot D_{i,j}\right)\right)\right]\right)^{(1-Y_{t-1,i}) \cdot V_{t,i}}$$

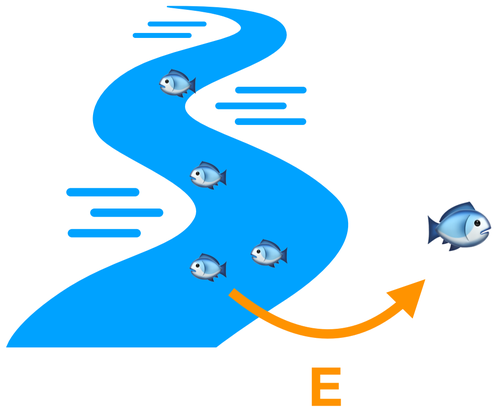
c



focal, uncolonized river

- how « easily » is this river colonized?
- describes the chances that the fish will **settle** and successfully colonize this new river

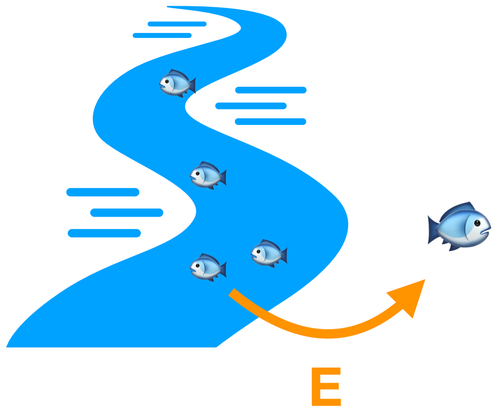
Results - Emission



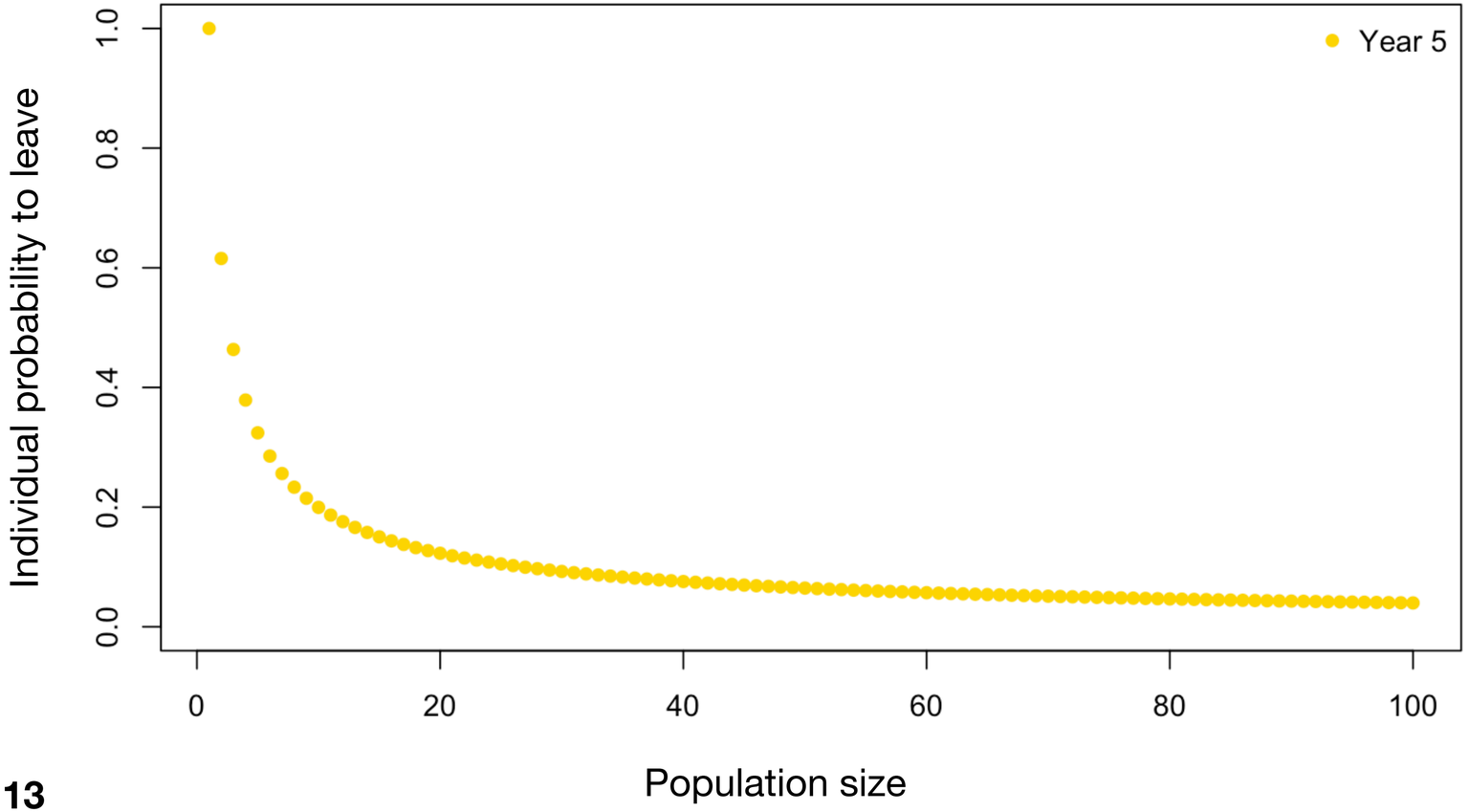
The quantity of dispersers

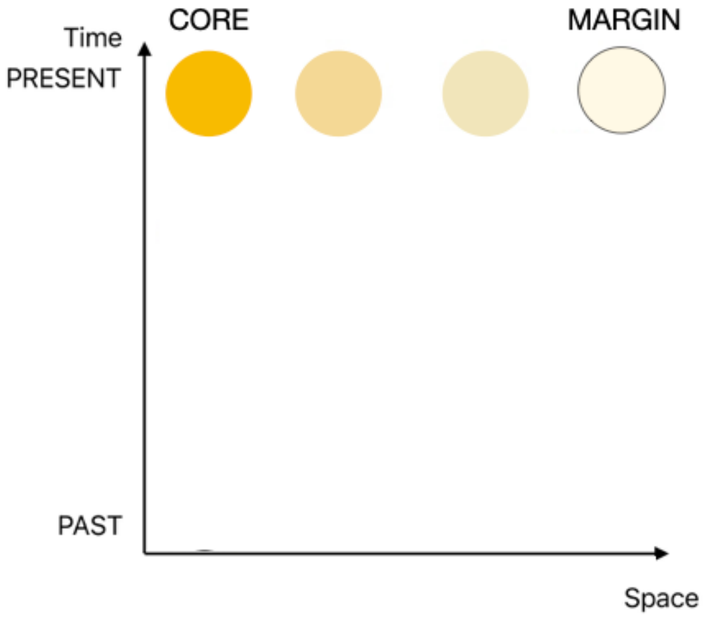
Results - Emission

The results indicate that for a time t, the probability to disperse is **higher in a small population** than in a large one



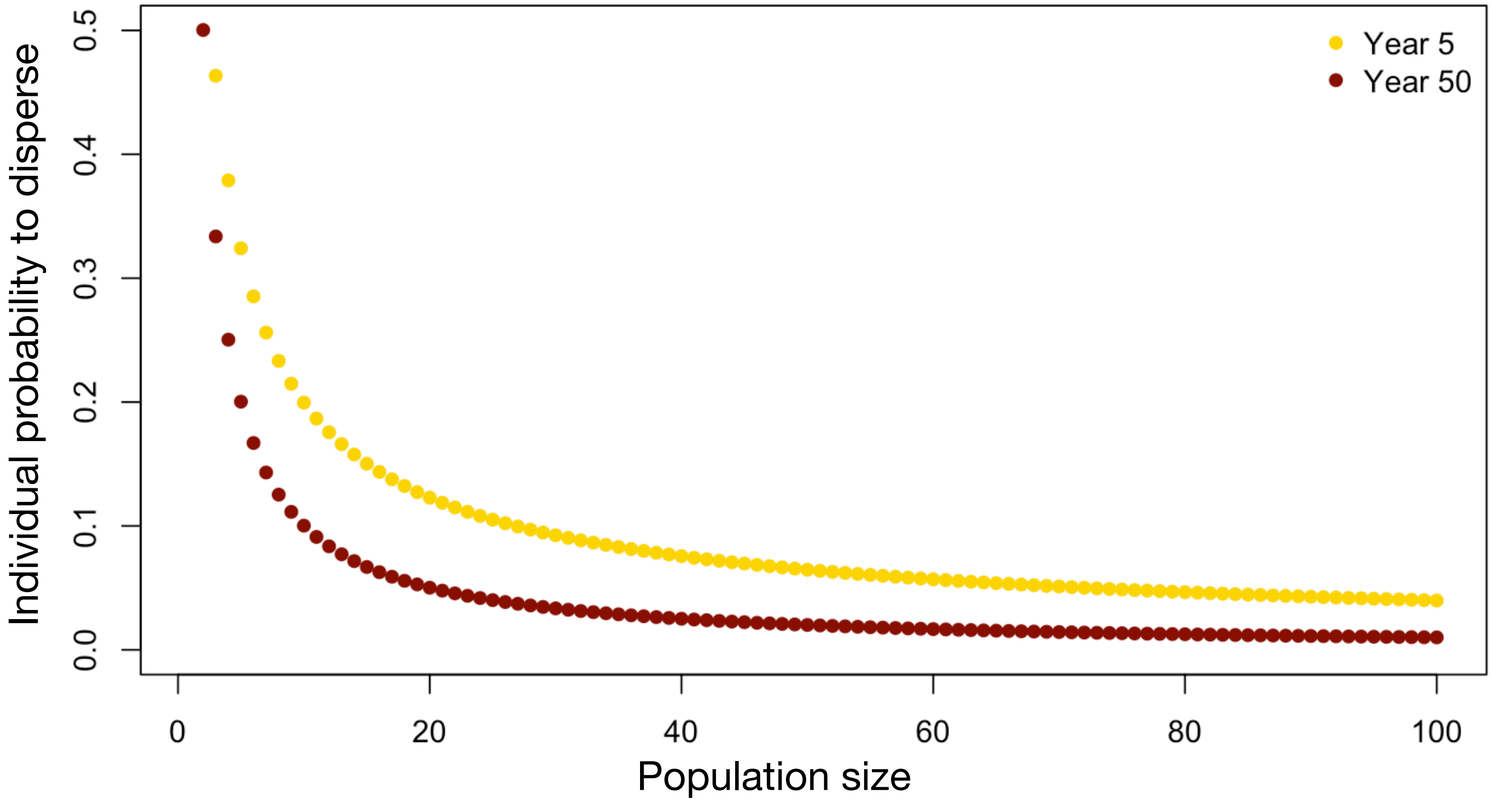
The quantity of dispersers

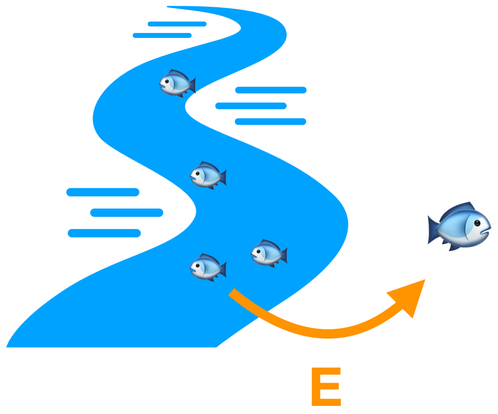




Results - Emission

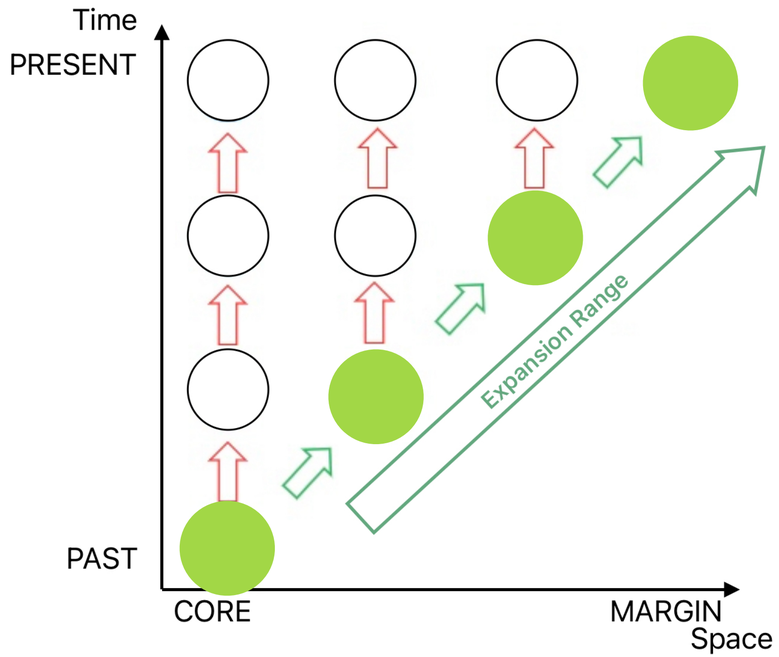
But accross the years, the probability to disperse, for a same population size, is decreasing.



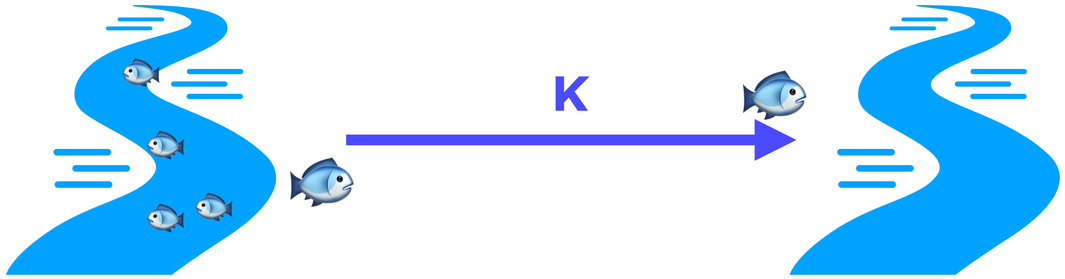


E

The quantity of dispersers



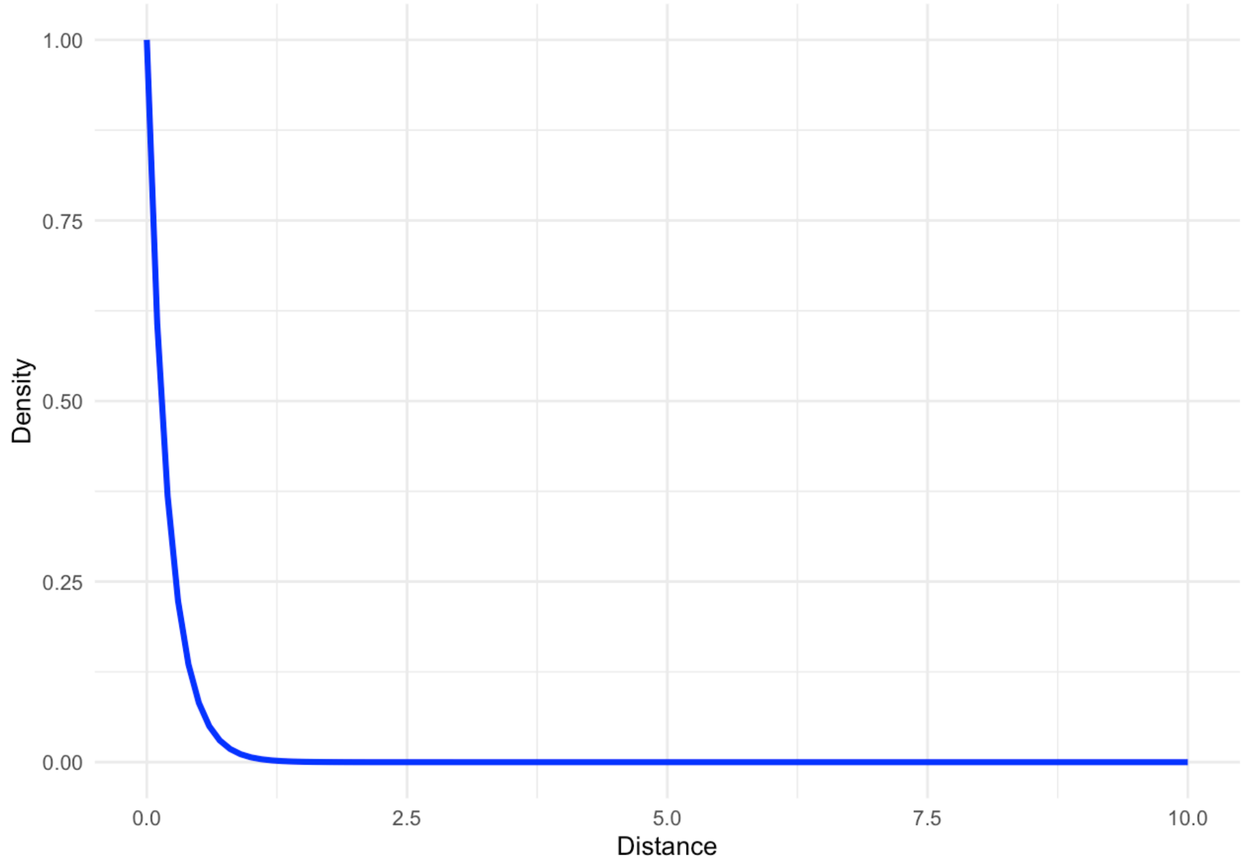
Results - dispersal kernel



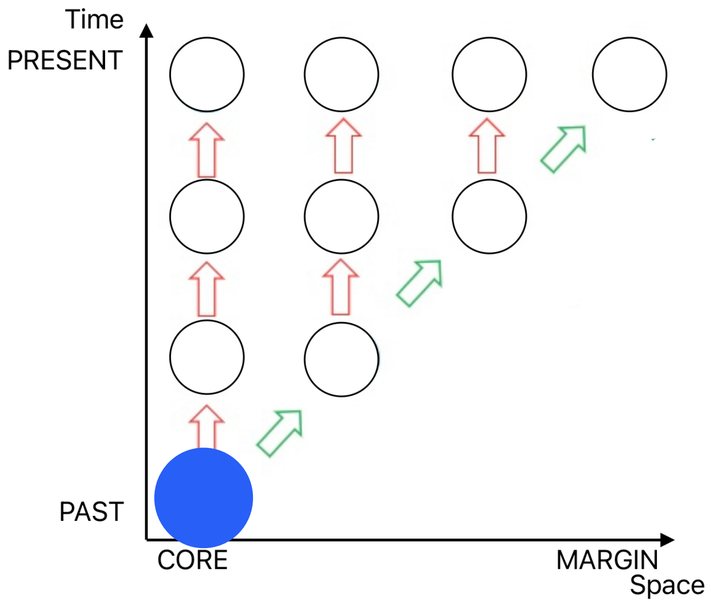
- It’s an indicator of how far the fish tend to disperse

Results - dispersal kernel

Shape of the dispersal kernel after 5 years

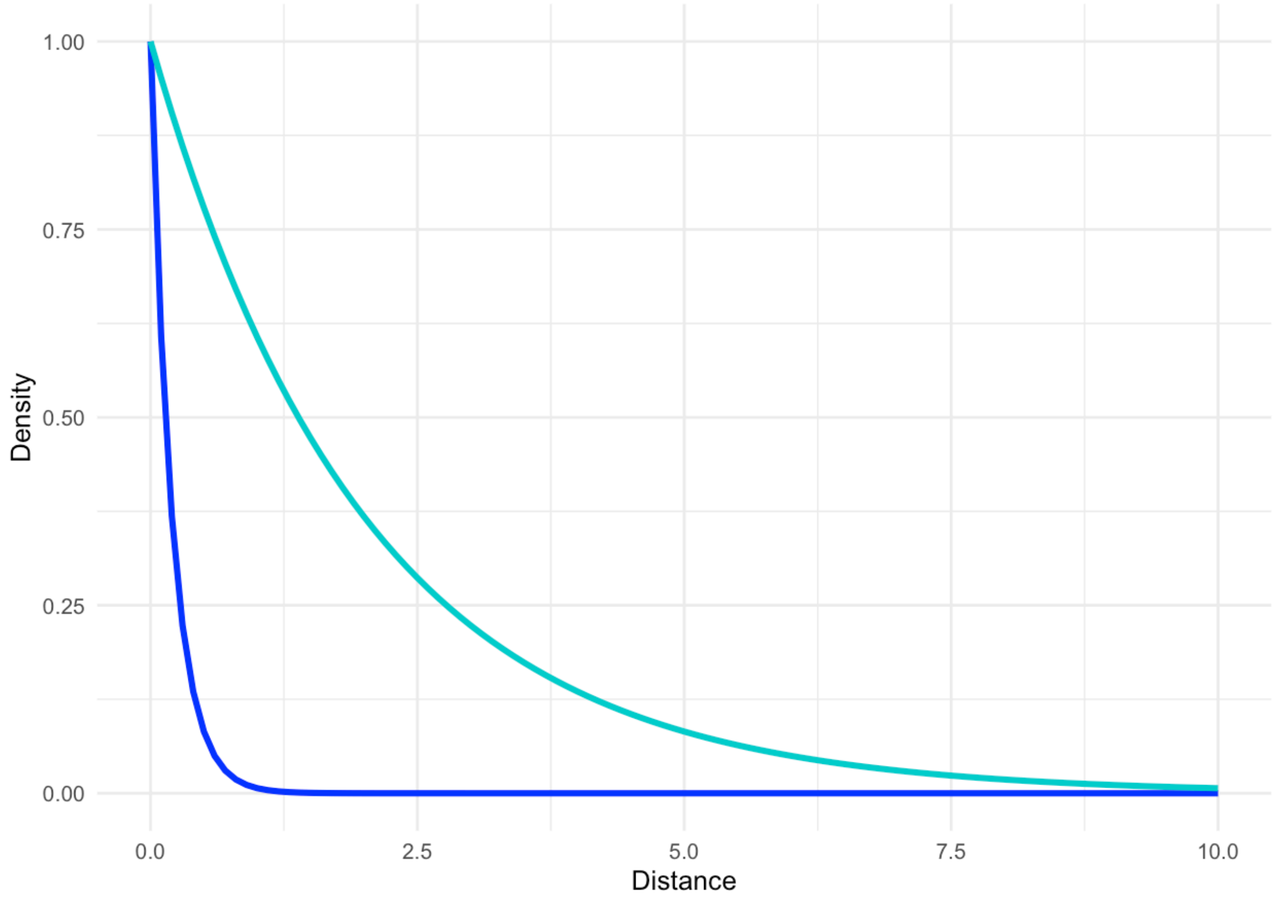


- It’s an indicator of how far the fish tend to disperse

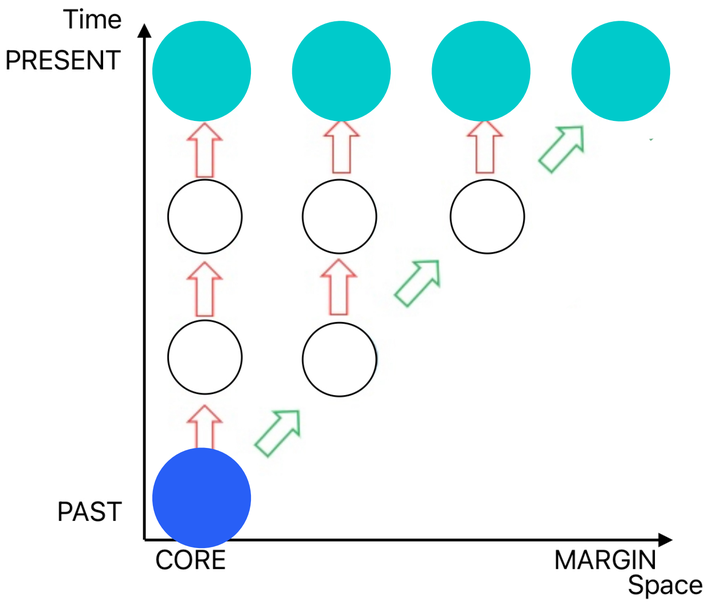


Results - dispersal kernel

Shape of the dispersal kernel after 50 years

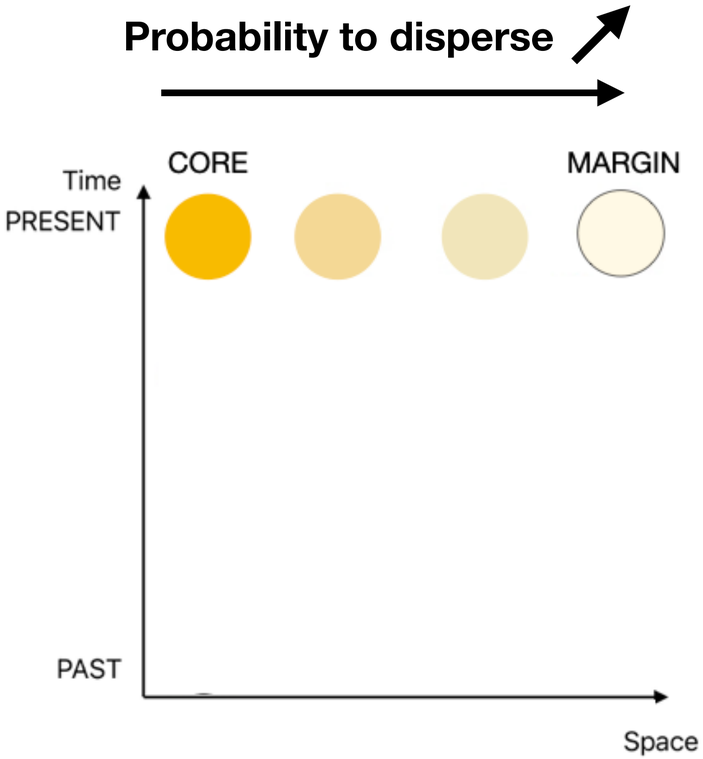


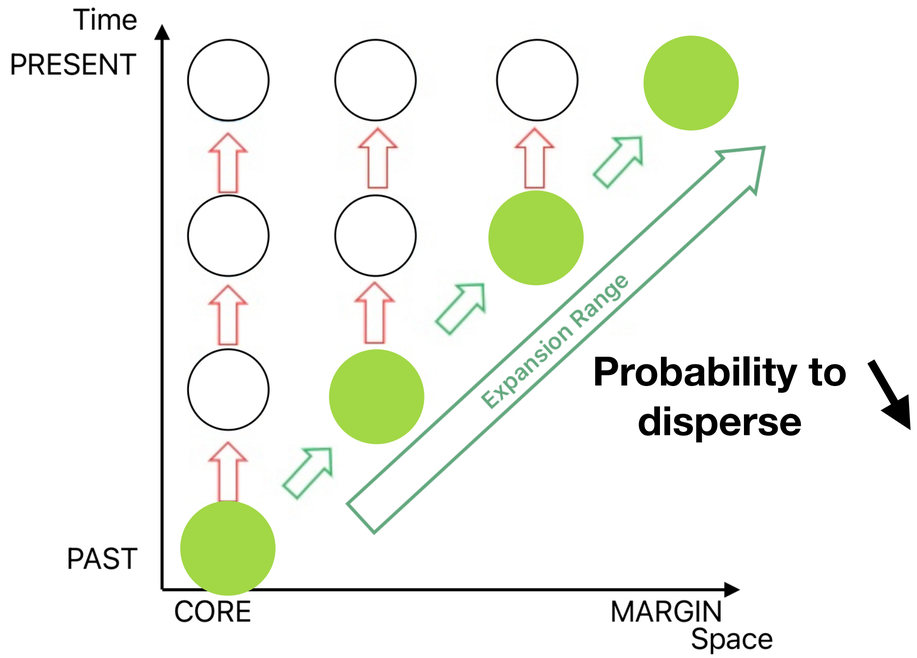
= Trouts disperse farther now than they did at the start of the colonization process



In conclusion,

- Contrary to our expectations, the individual probability to disperse decreases with high densities, but also decreases along the expansion range.

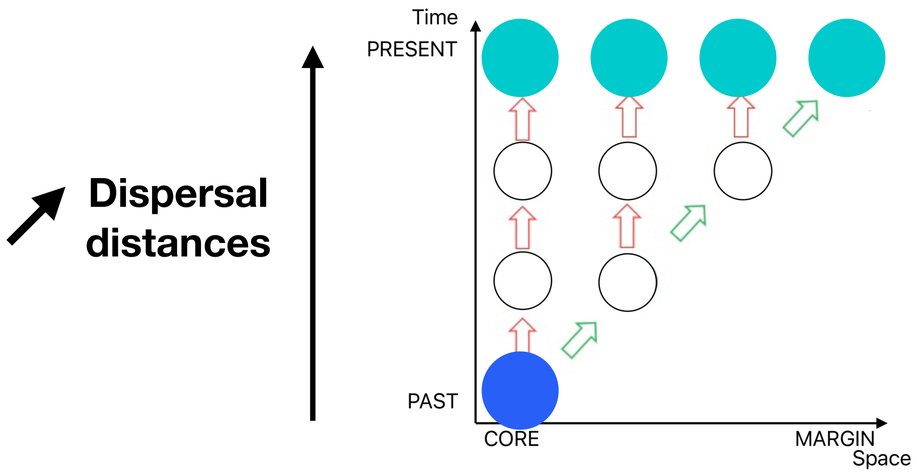




In conclusion,

- Contrary to our expectations, the individual probability to disperse decreases with high densities, but also decreases along the expansion range.

- Propagules tend to disperse farther and farther. This change in the kernel's shape is generalized across the metapopulation. It also seems this pattern has persisted for many years.



Thank you !