Shads metapopulations, insight from microchemistry studies

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Local and global initiatives: How science supports management actions on diadromous species

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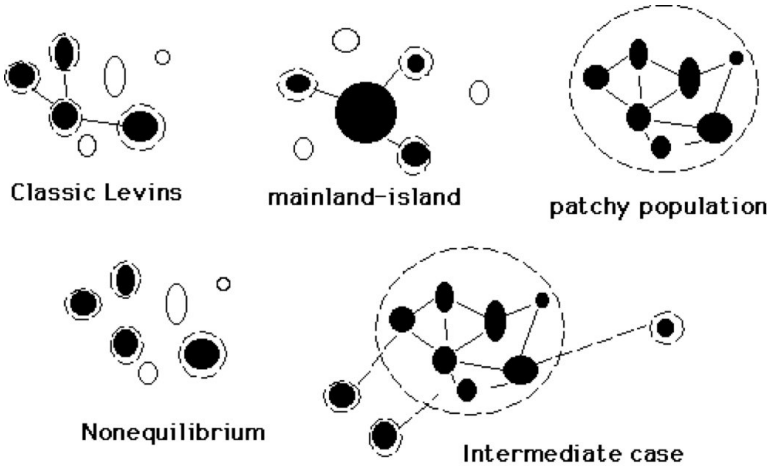
What is a metapopulation ?

why is it relevant to address shad ecology

A metapopulation : a population of populations (Levins, 1969)

- Connectivity between populations
- Interdependent dynamics
- Island-continent ?
- Source-sink ?



Applying metapopulation concept to shads ?

Shadspopulation dynamics to metapopulation dynamics

Anadromy, dispersal at sea

Large historical distribution area

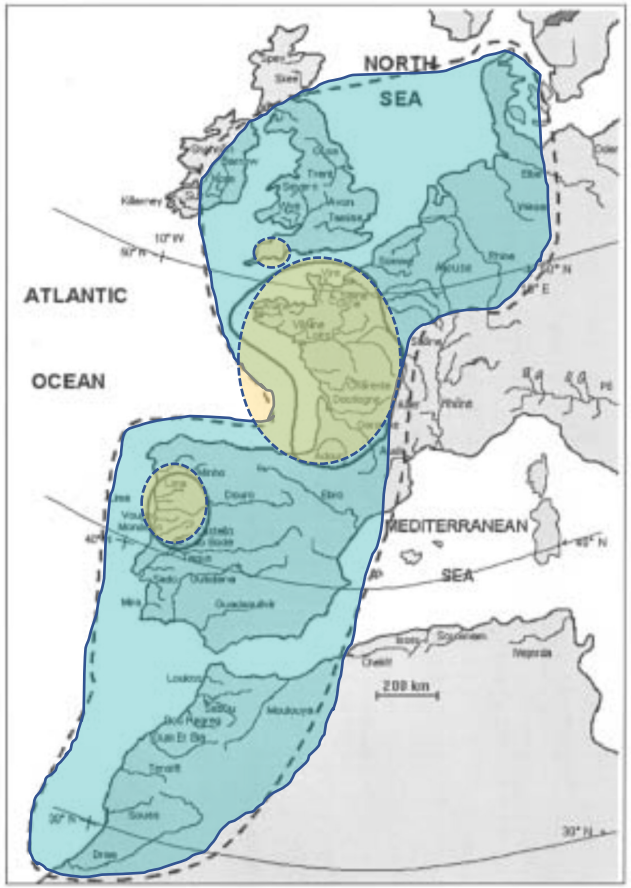
Reduced actual distribution area

Large variations of POP. Dynamics

-local extinctions (Morrocco, Portugal)

-recolonisation in Brittany and Normandy

-Population in Tamar (UK)



Adapated from Baglinière et al, 2003

How populations could be interdependant ?

Individual migrations and population dynamics

individual

Population
Group

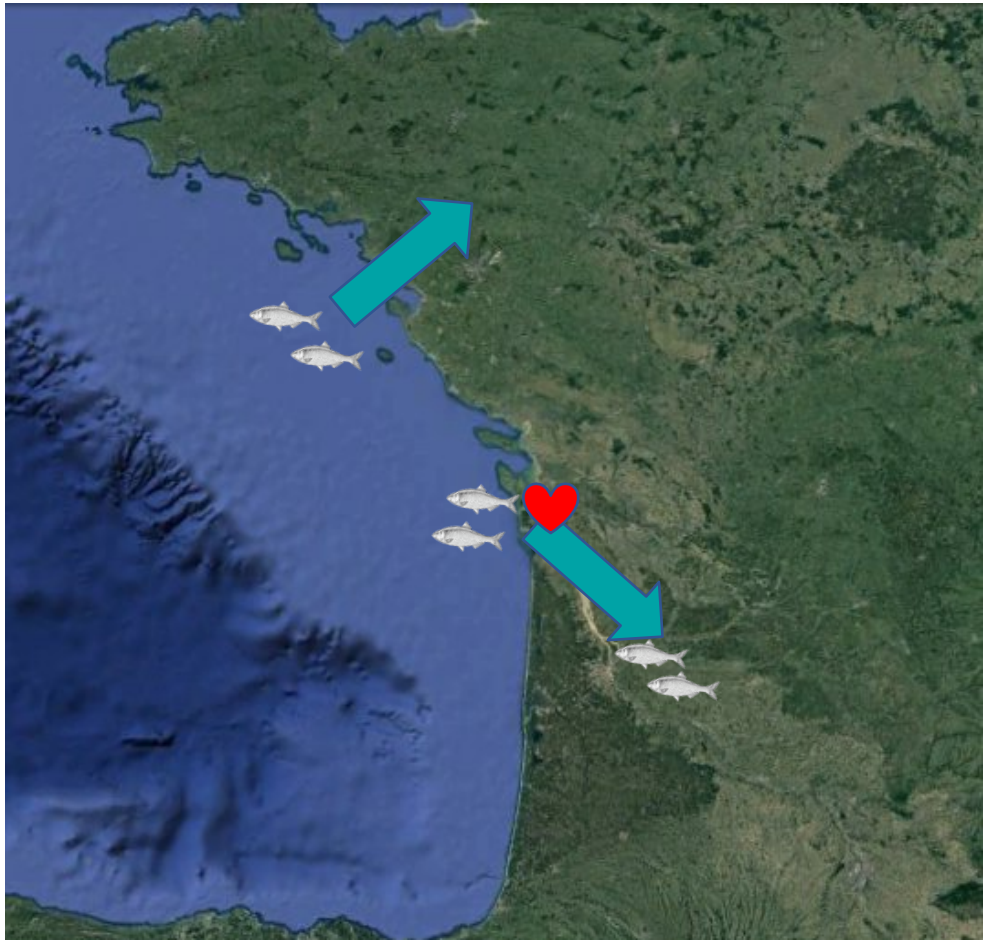
How populations could be interdependant ?

Individual migrations

Imprinting ?

Homing ?

Straying ?



How populations could be interdependant ?

Population dynamics

Density ?

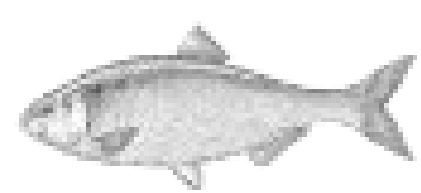
Abundance ?

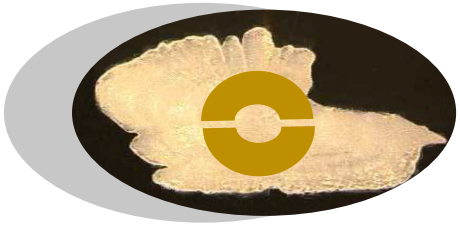
Social cues ?

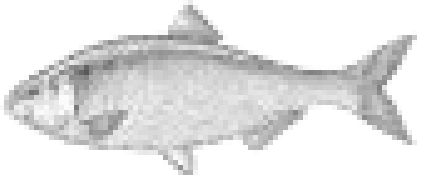
Connectivity

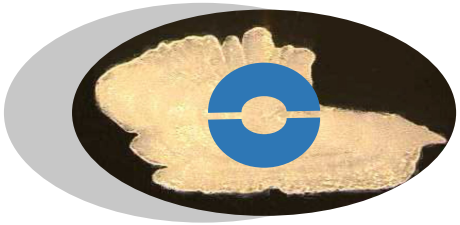
Metapopulations of shads

Insight from otolith microchemistry : Individual Movements









Composition of juvenile stage River 1

≠

Composition of juvenile stage River 2

Tracer of **natal origin** that can be retrieved at adult stage

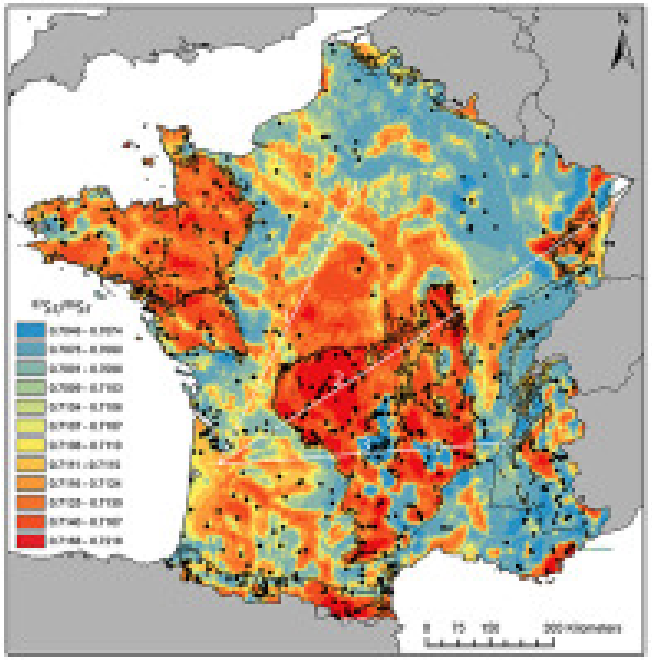
Robust tracer of location of River spawning grounds ?

Discrimination of different **rivers** ?

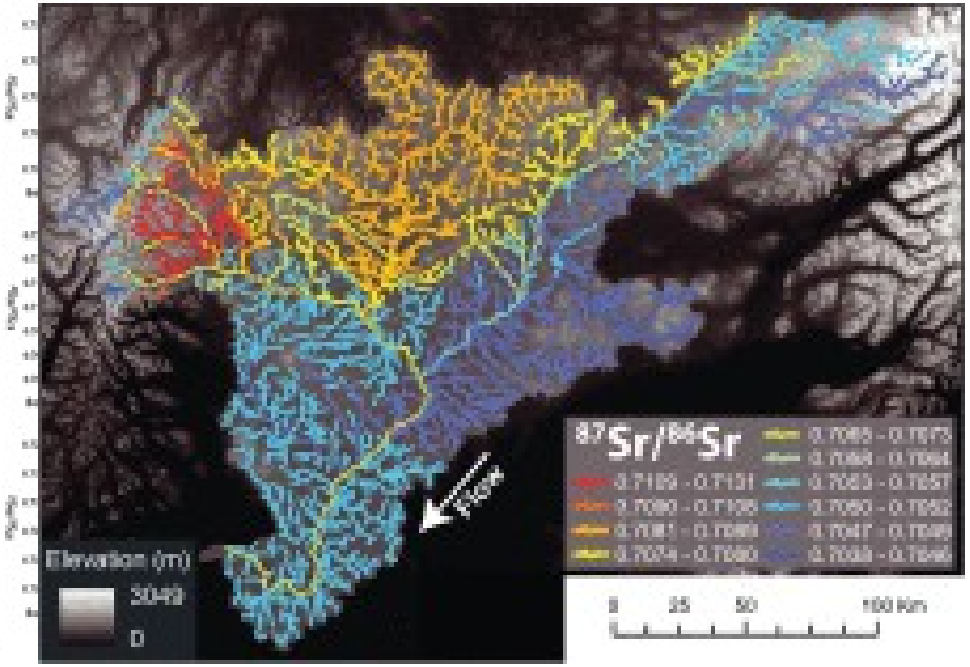
Set of **Reference values** for **fish location** (water/juveniles)

Robust and predictible tracers

Use of 87Sr/86Sr, Sr and Ba



87Sr/86Sr map of France from Wimes et al 2018 Geology



Holt et al 2021; A dendritic network model showing the non-Euclidean relationships among 87Sr/86Sr values across the hydrological system. Adapted from Brennan et al., 2016, Fig. 3, used with permission

Homing/straying of *A. alosa* (Martin et al.)

Rivers	Water samples (*n*)
Adour E.	—
Adour R.	3
Aulne	3
Blavet	3
Dordogne	3
Garonne	4
Lima	3
Loire	5
Minho	6
Mondego	3
Nivelle	4
Saison	3
Scorff	3
Vilaine	3
Vire	3
Charente	3
Oloron	5
Nive	4

Adults spawners

Rivers	2009	2010	2011	2012	2013	Total
Adour E.			2		29	31
Adour R.					6	6
Aulne					12	12
Blavet					7	7
Dordogne				5	66	71
Garonne				27	37	64
Lima					4	4
Loire			4		24	28
Minho	24	21	25		17	87
Mondego					15	15
Nivelle	16					16
Saison					6	6
Scorff					10	10
Vilaine		3	10		6	19
Vire			7		27	34
						410

Juveniles

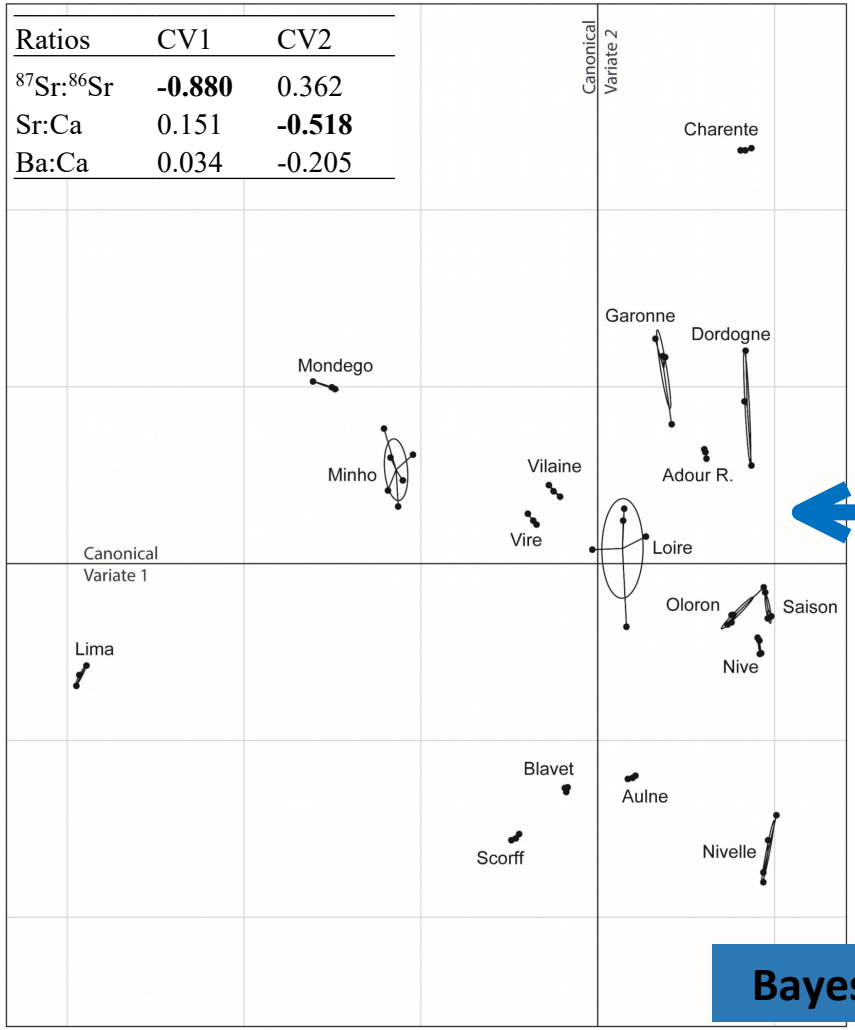
Rivers	2009	2011	2012	2013	Total
Adour E.					
Adour R.					
Aulne					
Blavet				16	16
Dordogne				3	3
Garonne					
Lima					
Loire				4	4
Minho	10	4	6		20
Mondego					
Nivelle					
Saison					
Scorff					
Vilaine				1	1
Vire					
					44

At each river, water samples were collected from late May to September 2013, close to historic spawning area of Allis shad.

Bayesian hierarchical mixture model

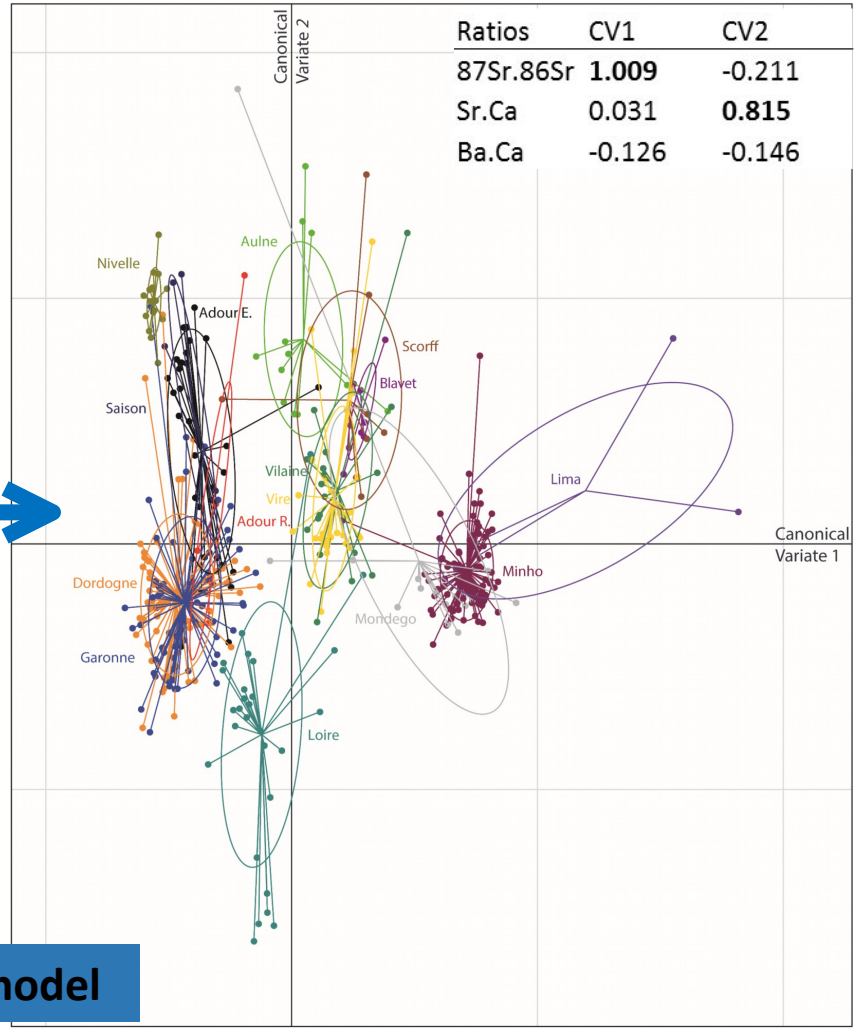
Spatial differences in water signatures

Ratios	CV1	CV2
$^{87}Sr:^{86}Sr$	**-0.880**	0.362
Sr:Ca	0.151	**-0.518**
Ba:Ca	0.034	-0.205



Otolith natal fingerprints: Adults+juveniles

Ratios	CV1	CV2
87Sr.86Sr	**1.009**	-0.211
Sr.Ca	0.031	**0.815**
Ba.Ca	-0.126	-0.146



Bayesian model

Determination of natal origin of individuals

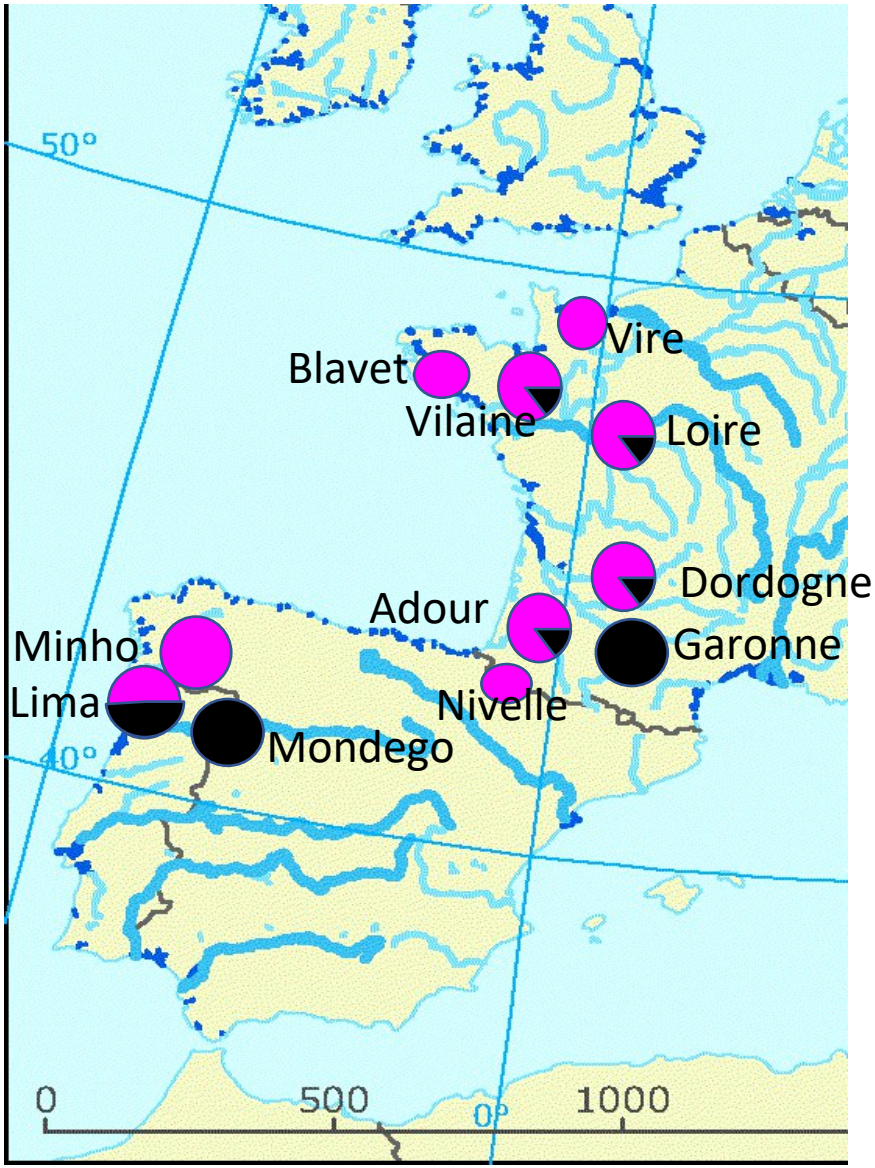
Large proportion of locals

Qualitative study

High proportion of homing fish

% of local origin

% of non local



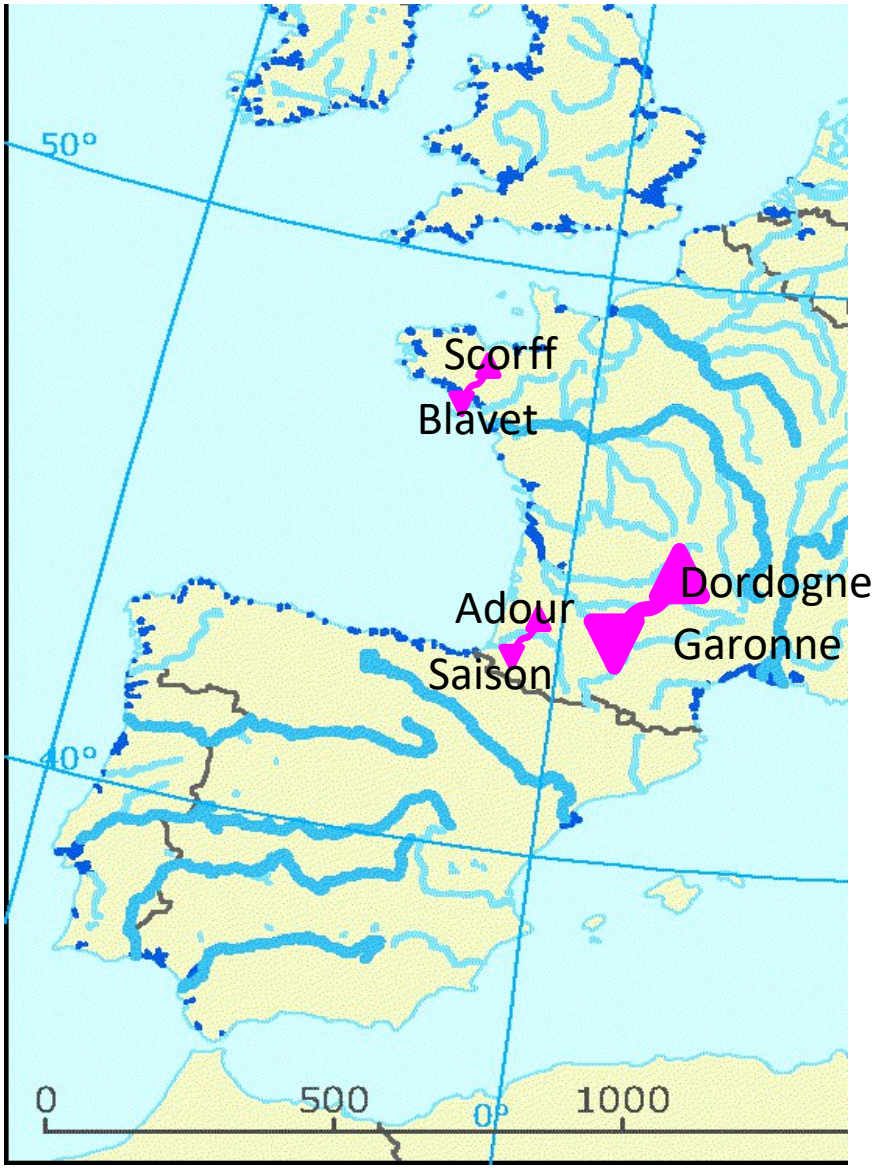
Exchanges within same catchment

Qualitative study

In Garonne 72% from Dordogne

In Saison 50 % of Adour

In Scorff, 90% of Blavet



Most exchanges between neighbour rivers

Qualitative study

- Blavet in Vilaine
- Vilaine in Loire
- Adour and Nivelle in Garonne
- Minho in Lima

long distances exchanges

Ex: A Garonne-Dordogne fish in Mondego

Preliminary results of Diades WP6

Qualitative study

Confusion Matrix (Naive Bayes)

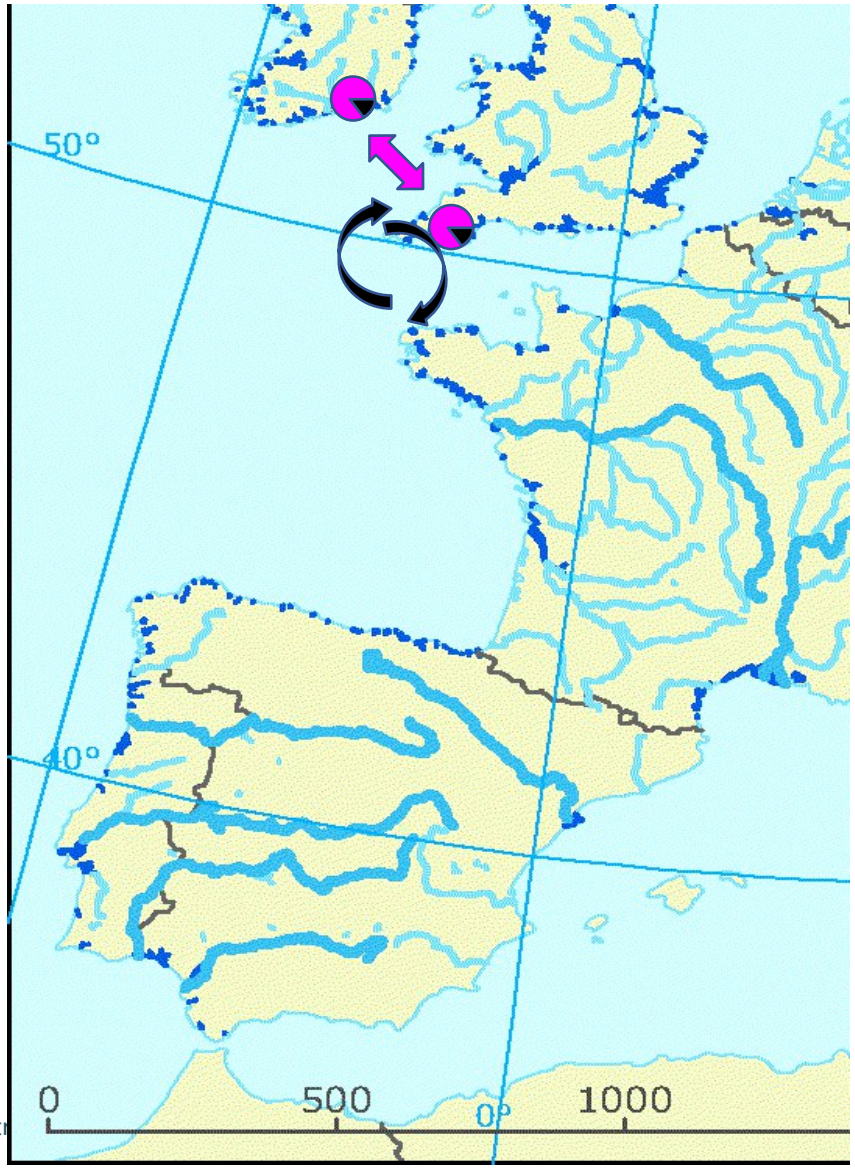
River/capture	Brittany	Tamar	Barrow
Brittany	67	2	1
Tamar	0	19	1
Barrow	3	12	22

Work in progress

for Spain/Portugal data

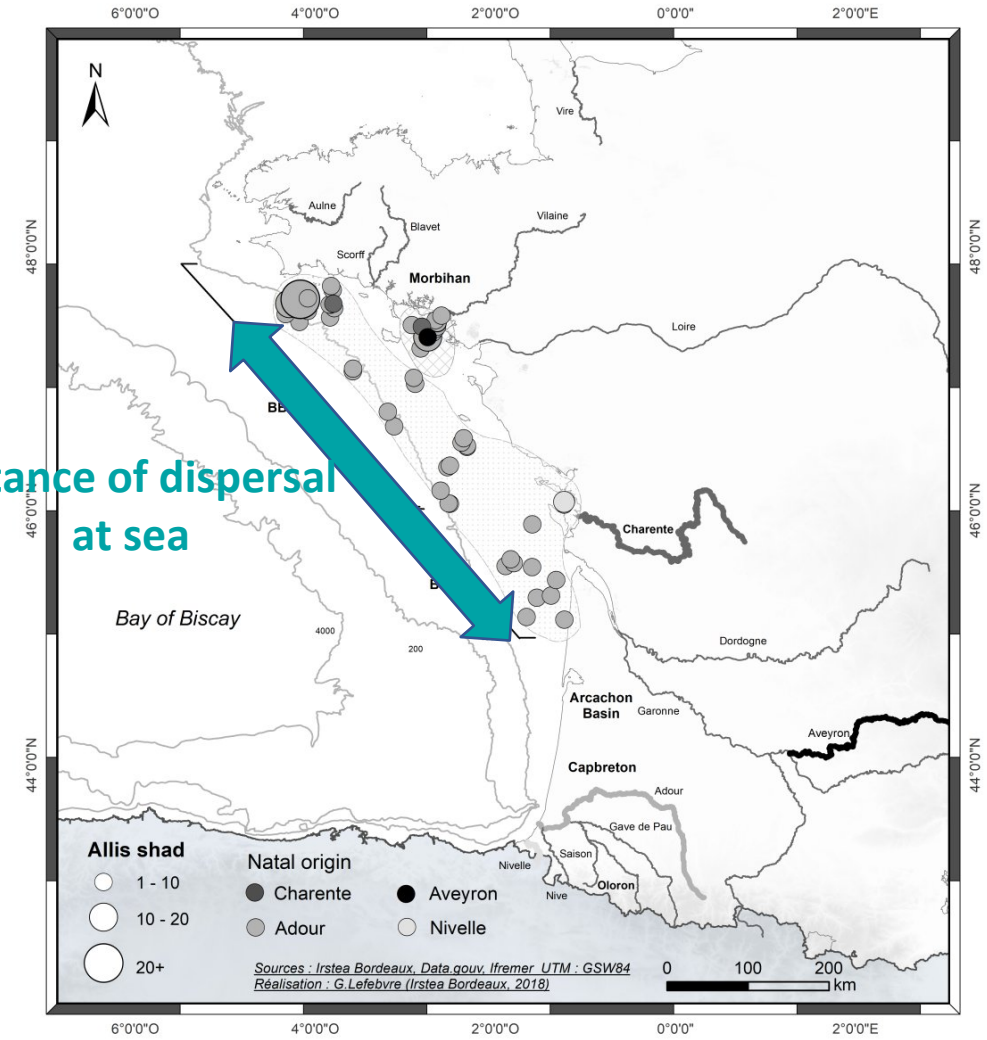
- Origin of Fish caught at sea ?
- Origin of Mondego adults with

Connectivity restored ?

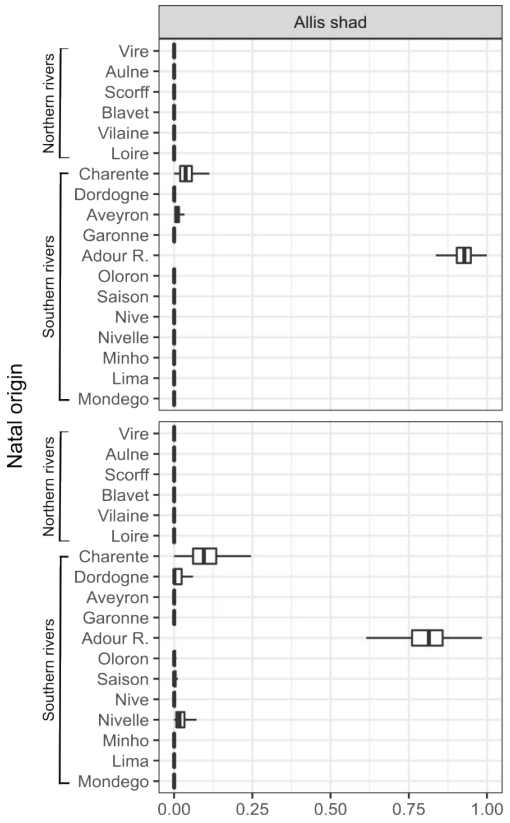


Dispersal capacity : connectivity at sea

Nachon et al, mixing at sea of A. Alosa in the 80's



Distance of dispersal at sea

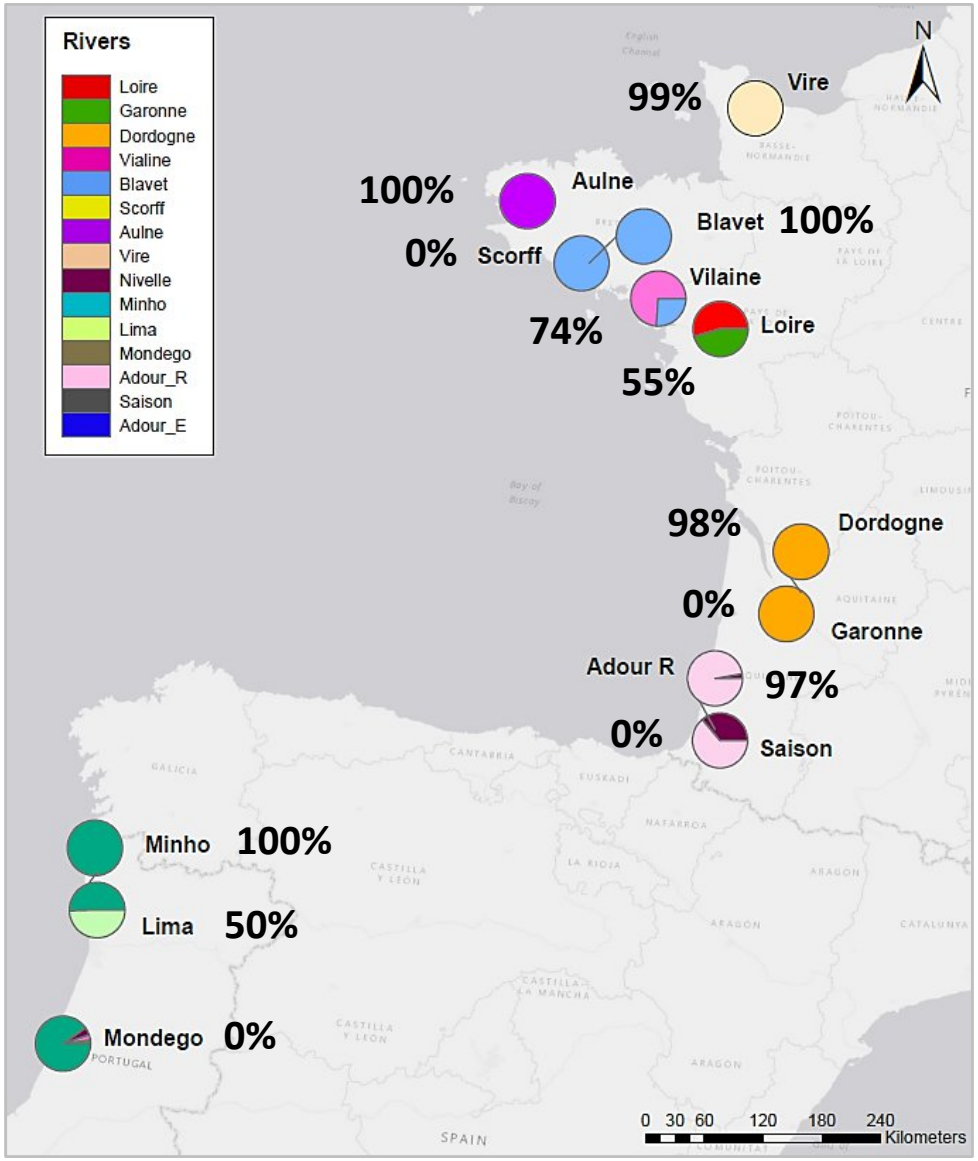


Quantifying fluxes of fish between populations

Randon et al; accounting for relative abundance of populations

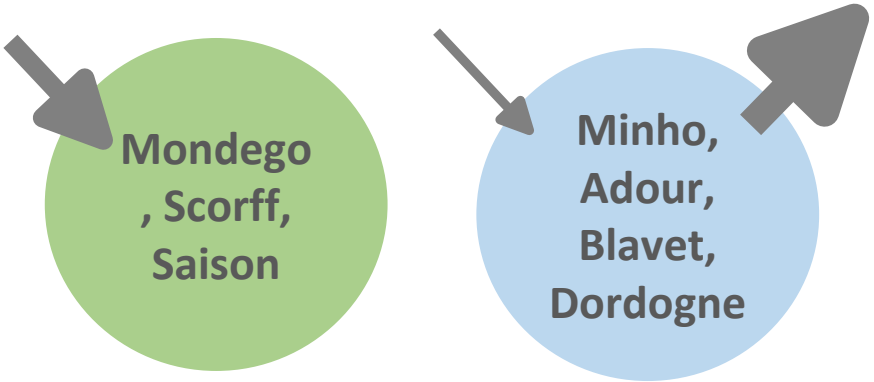
❖ ***Natal origin of fish by reproduction river?***

- Homing varying
- Vire et Aulne = closed pop
- Exchanges between neighbour rivers
- A few long distance rivers



• Metapopulation dynamics and conservation

❖ *Source sink dynamics?*



0%
Successful strayers (survival and straying)

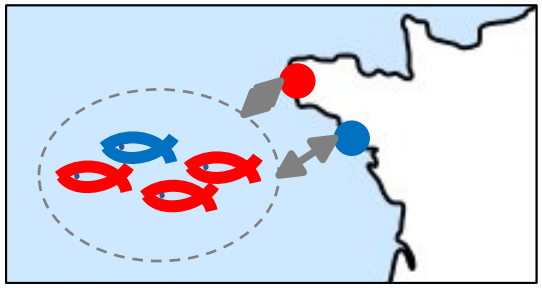
98-100%
Strayers abundance

- **Closed populations** in northern part (Vire, Aulne) → recent colonisation (few decades) response to global change ? Origin of first strayers ?

Implication for conservation ?

Isolation by distance → consistant with genetic studies (Alexandrino *et al.* (2006); Jolly *et al.* (2012)

Adverse effect of low abundance for dispersal ?



Connectivity and interdependence of population calls for large scale management

Thanks for your attention

Questions ?

Adult Allis shad allocations to natal rivers (Martin et al

Natal river

Posterior conditional assignment probabilities were higher than 0.80 for 85% of fish

Collection site	Vire	Aulne	Scorff	Blavet	Vilaine	Loire	Charente	Dordogne	Garonne	Adour R.	Oloron	Saison	Nive	Nivelle	Minho	Lima	Mondego	Undetermined
Vire (34)				3	31													
Aulne (12)		**11 (92%)**																1
Scorff (10)				**9 (90%)**														1
Blavet (7)				**7 (100%)**														
Vilaine (19)			1	2	**16 (84%)**													
Loire (28)					3	**24 (86%)**												1
Dordogne (71)								**61 (86%)**										10
Garonne (64)								**46 (72%)**		11				3				4
Adour R. (6)		1								**5 (83%)**								
Adour E. (31)		1								**13 (42%)**	**17 (55%)**							
Saison (6)										**3 (50%)**				3				
Nivelle (16)														**16 (100%)**				
Minho (87)					1										**86 (99%)**			
Lima (4)															2	**2 (50%)**		
Mondego (15)	2								1					1	11			

A great proportion of individuals hatched and grown in the watershed in which they were collected

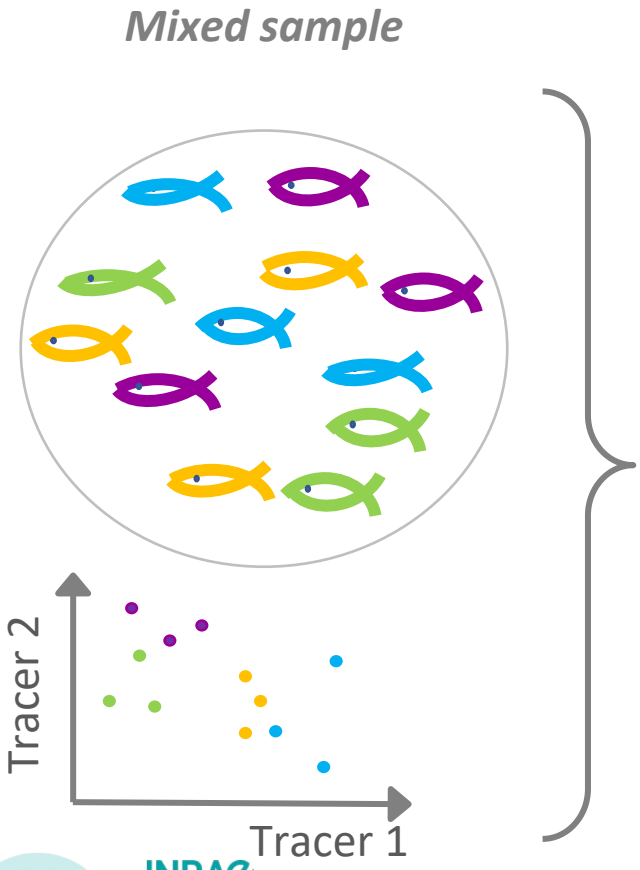
However, their fidelity to the natal river within the watershed of origin appeared less precise

Some individuals strayed into non-natal spawning rivers but originated from neighbouring watersheds

Some non-resident spawning adults travelled long and ultra-long distances between natal and spawning river

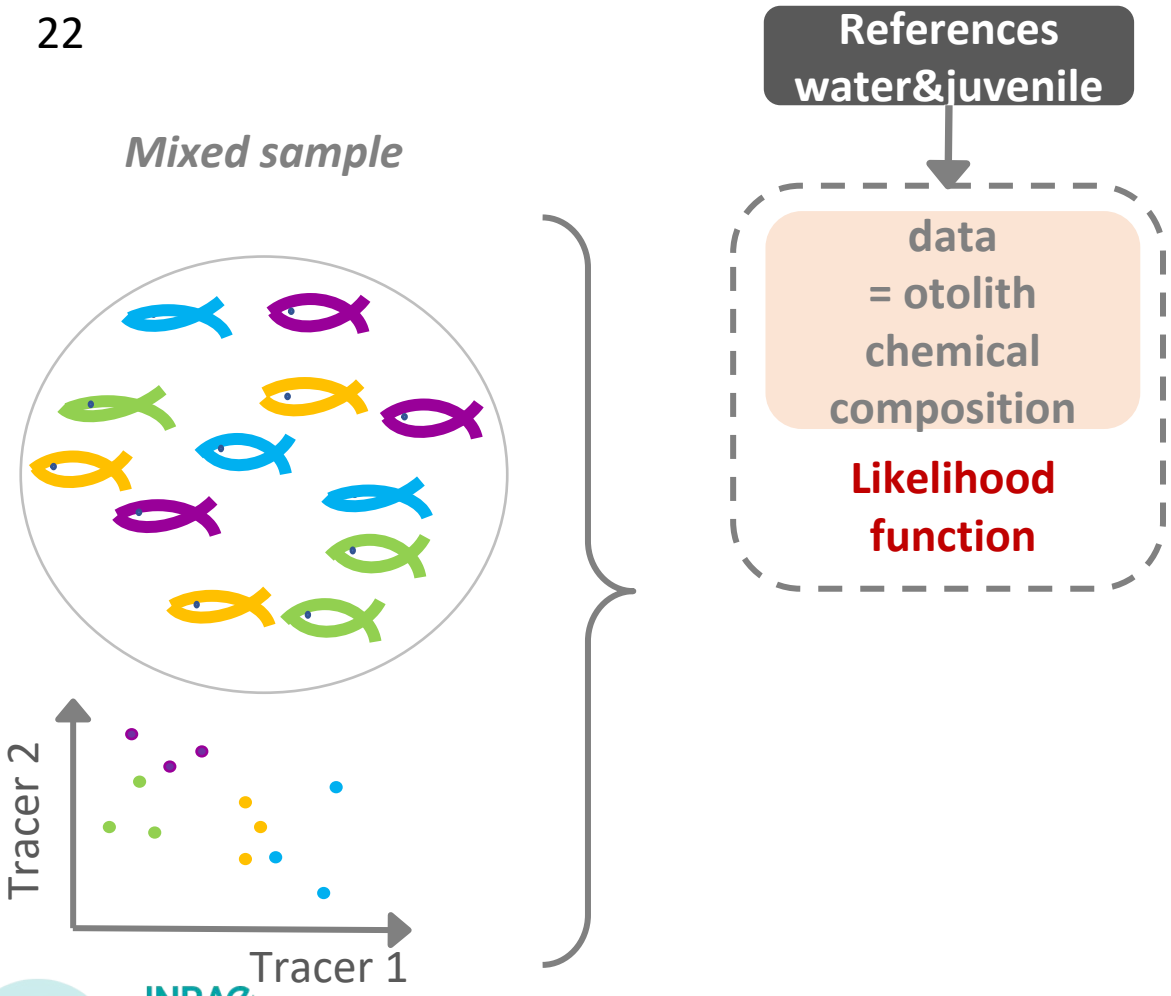
17 adults (4%) were classified as “undetermined” indicating that those individuals represent heterogeneous signatures not well represented in the training data

General principle of Bayesian models

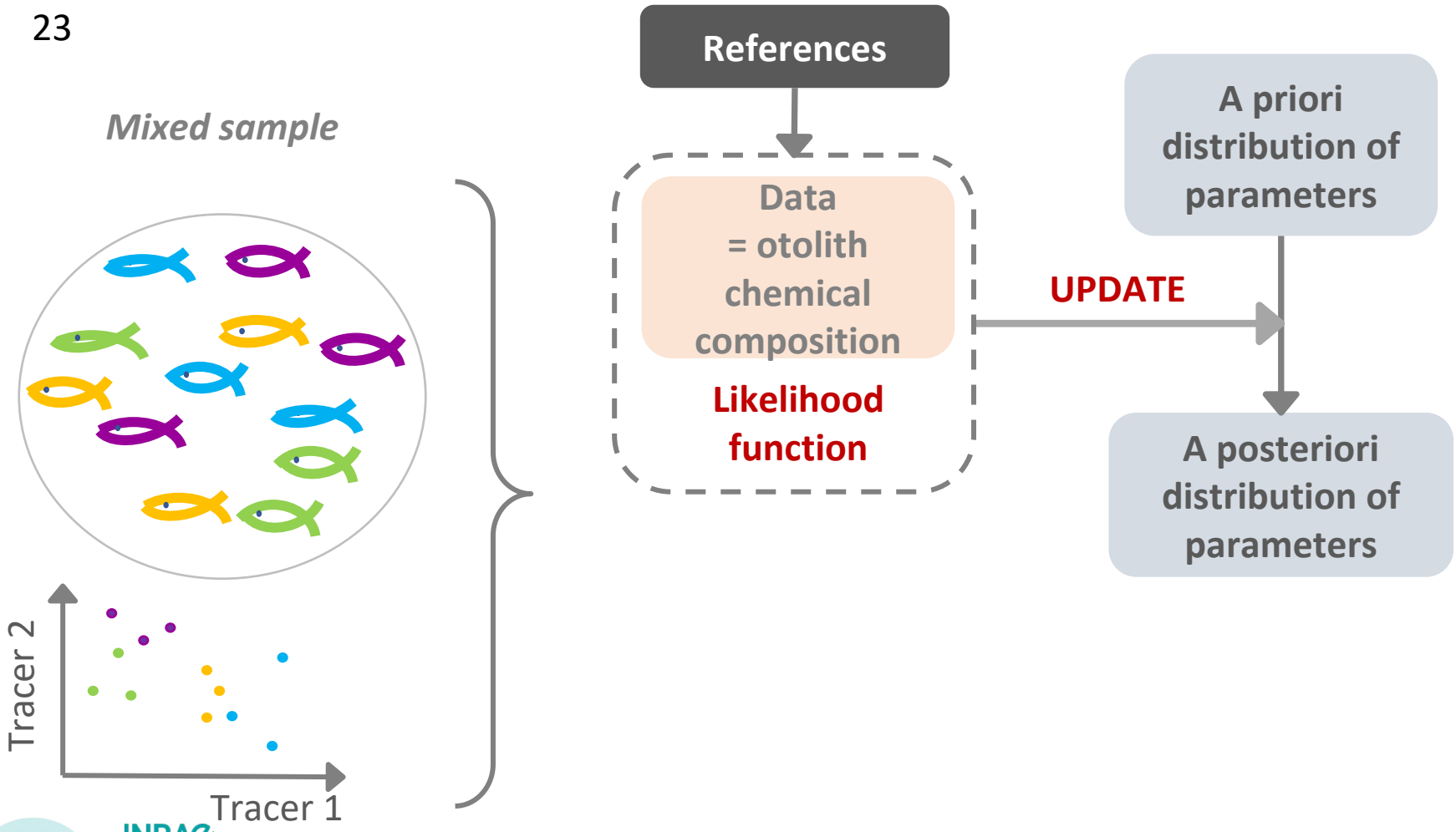


Data
= otolith chemical composition

General principle of Bayesian models



General principle of Bayesian models



Mix of otolith fingerprints

General principle of Bayesian models