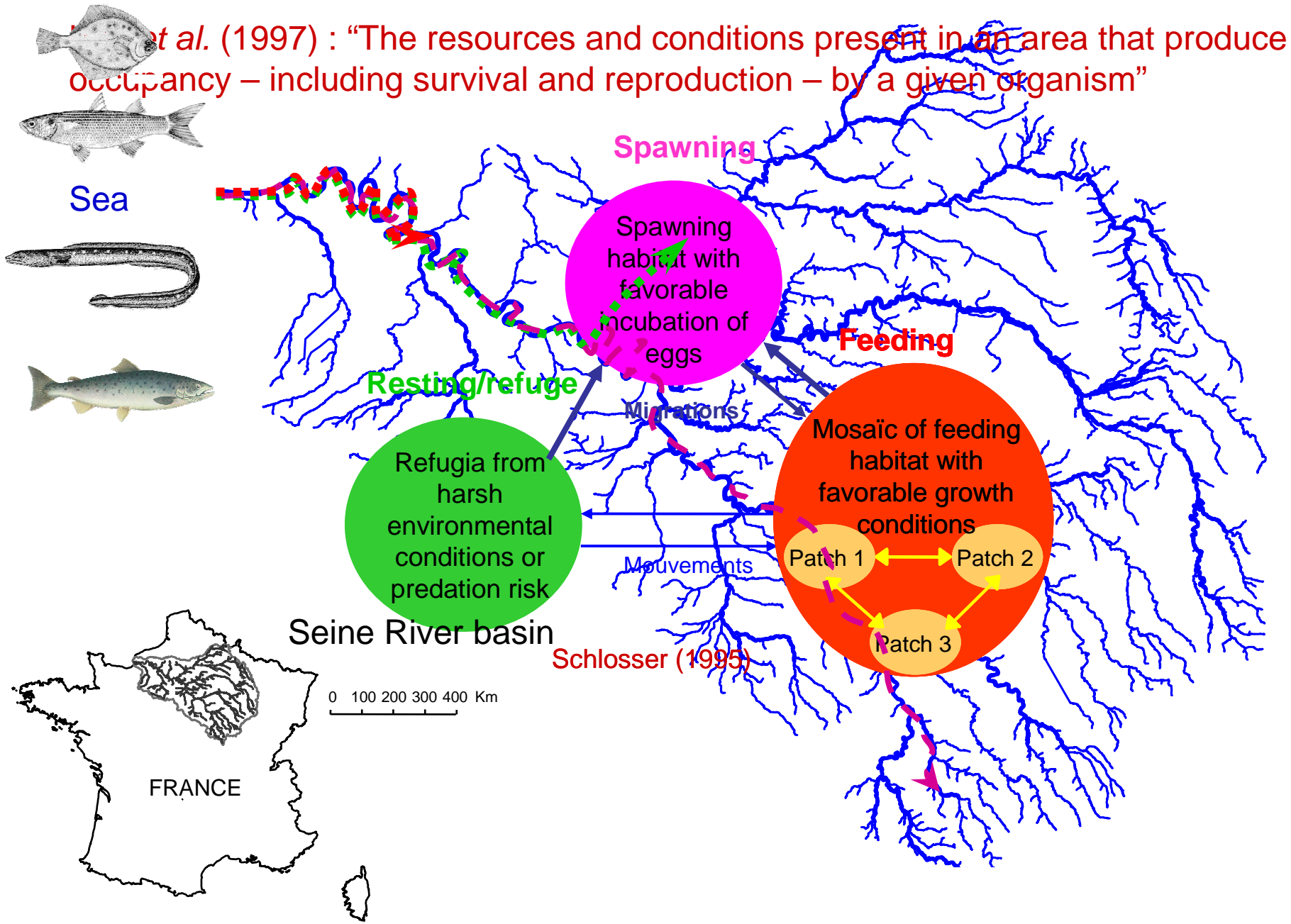# Evaluating ecological connectivity of aquatic corridors for fishes

Céline Le Pichon

Cemagref – HBAN, Parc de Tourvoie, BP44, 92163 Antony, France
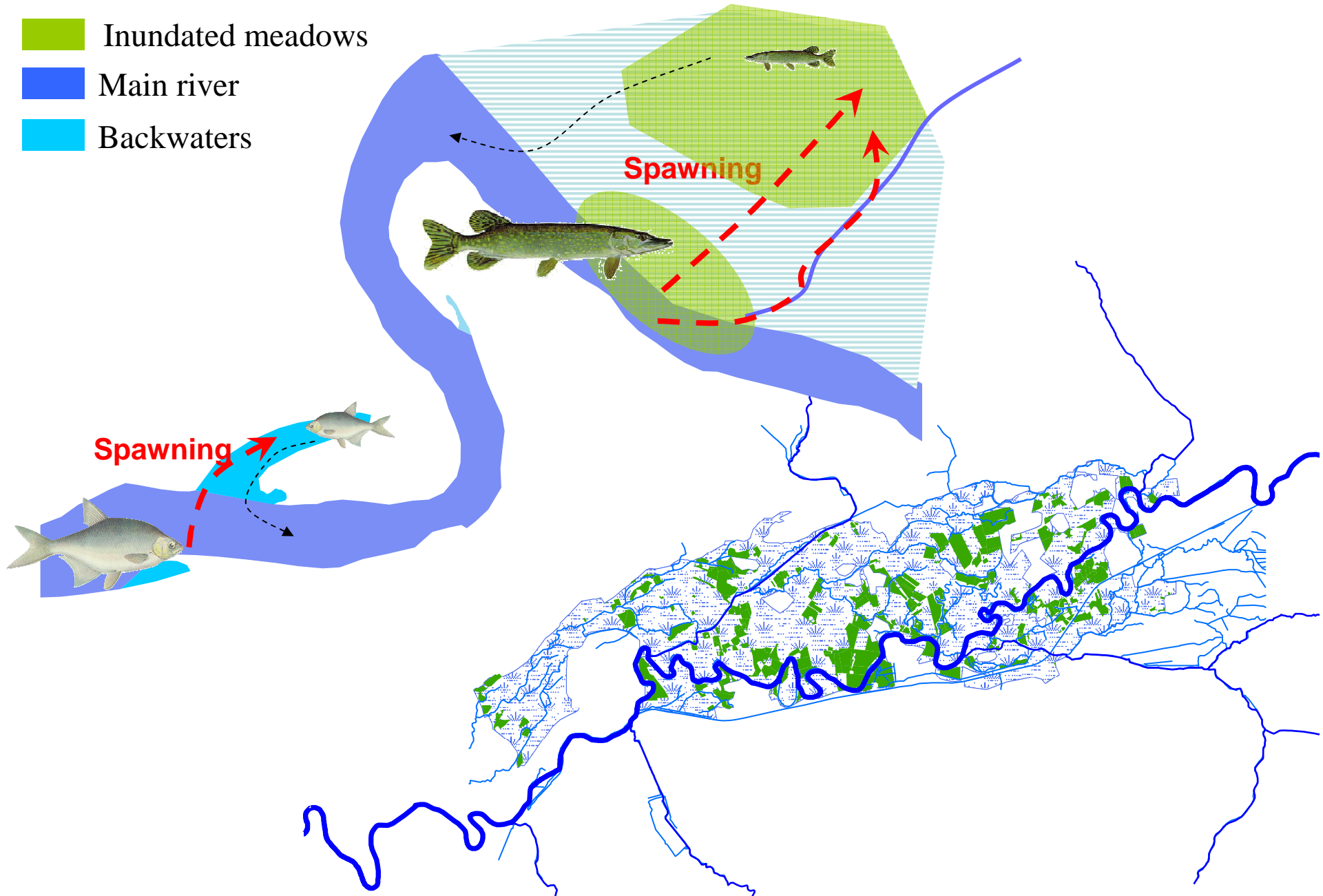
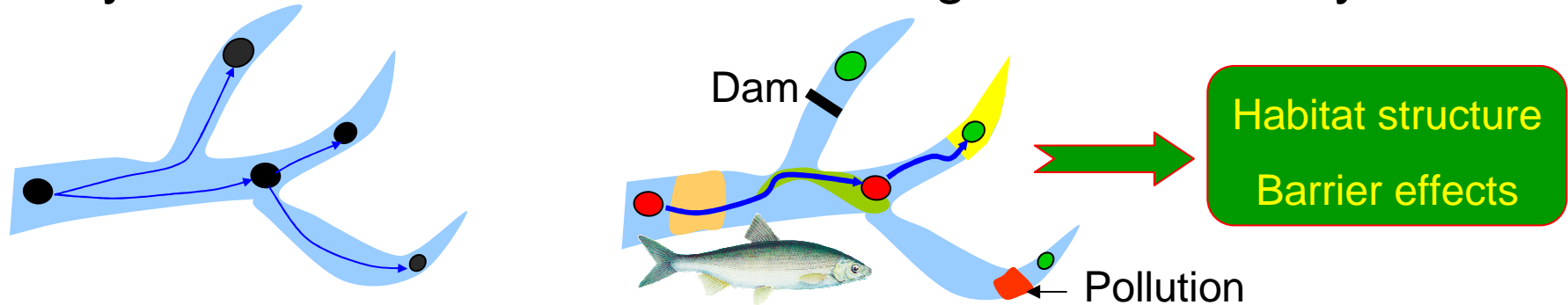# Longitudinal / lateral migrations and spatial scale

[...] et al. (1997) : "The resources and conditions present in an area that produce occupancy – including survival and reproduction – by a given organism"

Sea

Spawning

Spawning habitat with favorable incubation of eggs

Feeding

Resting/refuge

Migrations

Refugia from harsh environmental conditions or predation risk

Mosaïc of feeding habitat with favorable growth conditions

Patch 1 — Patch 2

Patch 3

Seine River basin

Schlosser (1995)

Mouvements

0 100 200 300 400 Km

FRANCE

Lateral connectivity to spawning habitats

Inundated meadows
Main river
Backwaters

Spawning

Spawning

River connectivity for fishes
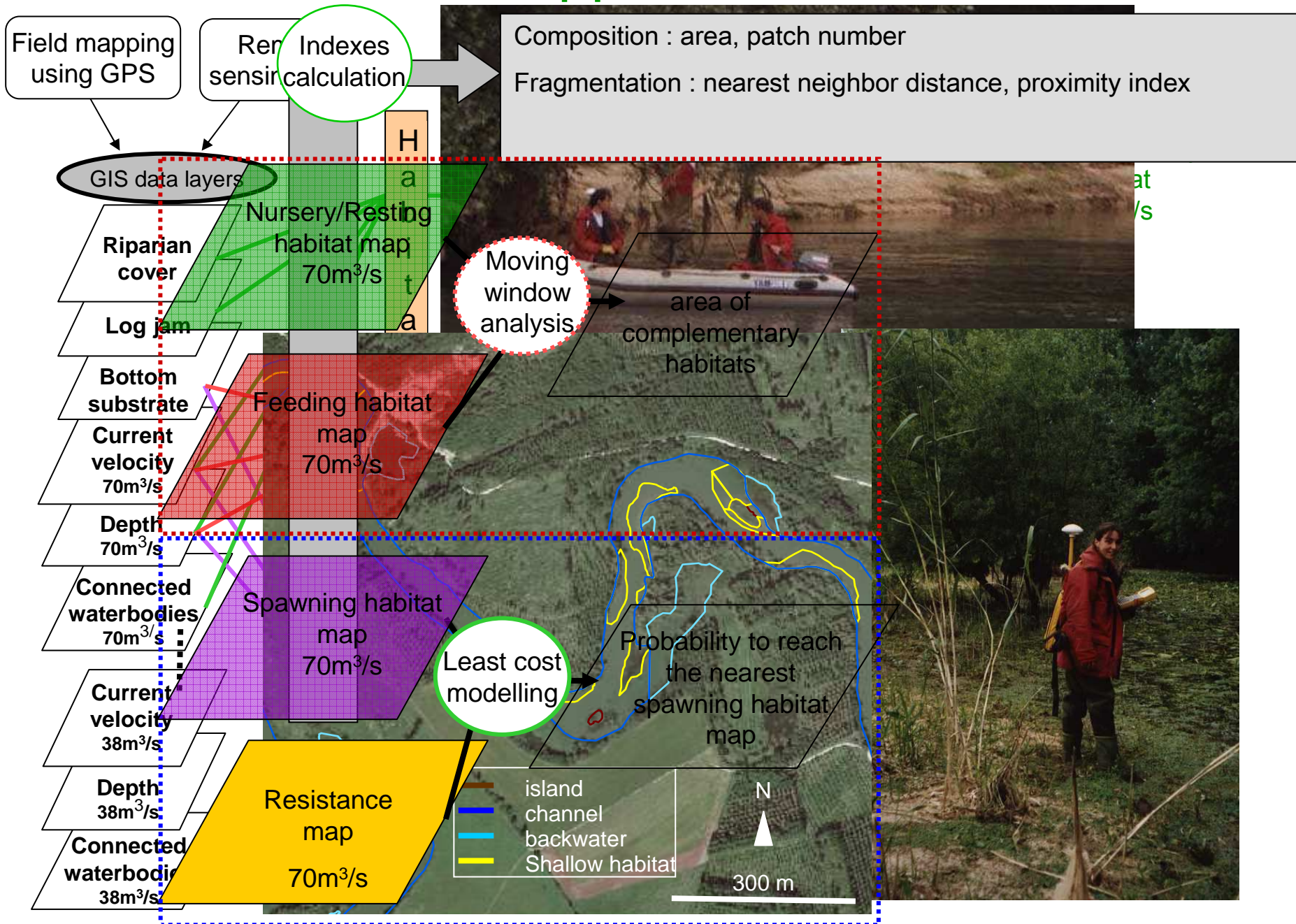
➢ Hydraulic connectedness and biological connectivity

Dam

Habitat structure

Barrier effects

Pollution

➢ Estimation with hydrographic and biological distances

■ Channel
■ Island
■ Feeding habitat
■ spawning habitat

100 m

B

d_{eucl}

d_{hydro}
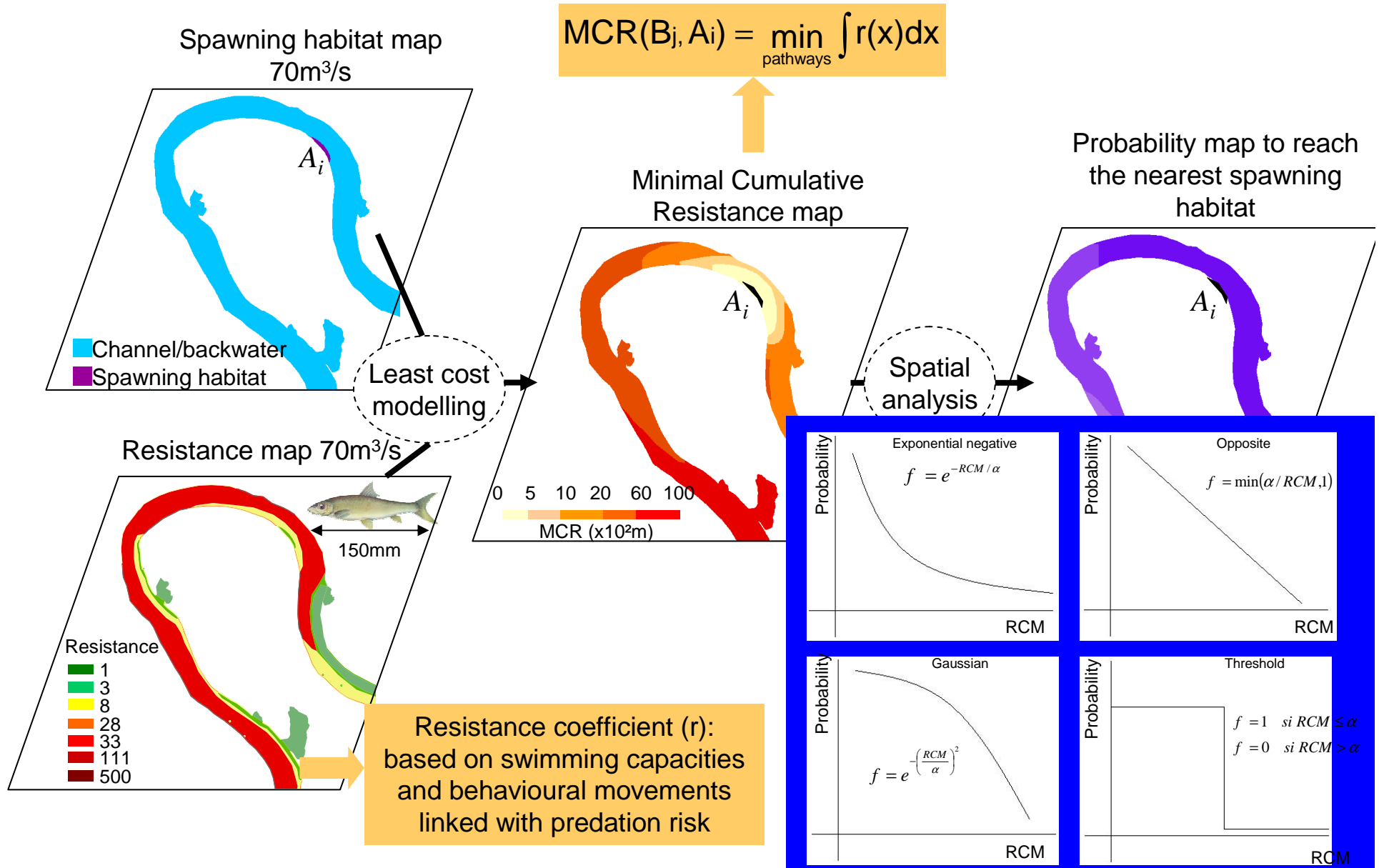d_{fonc}

A

Flow direction
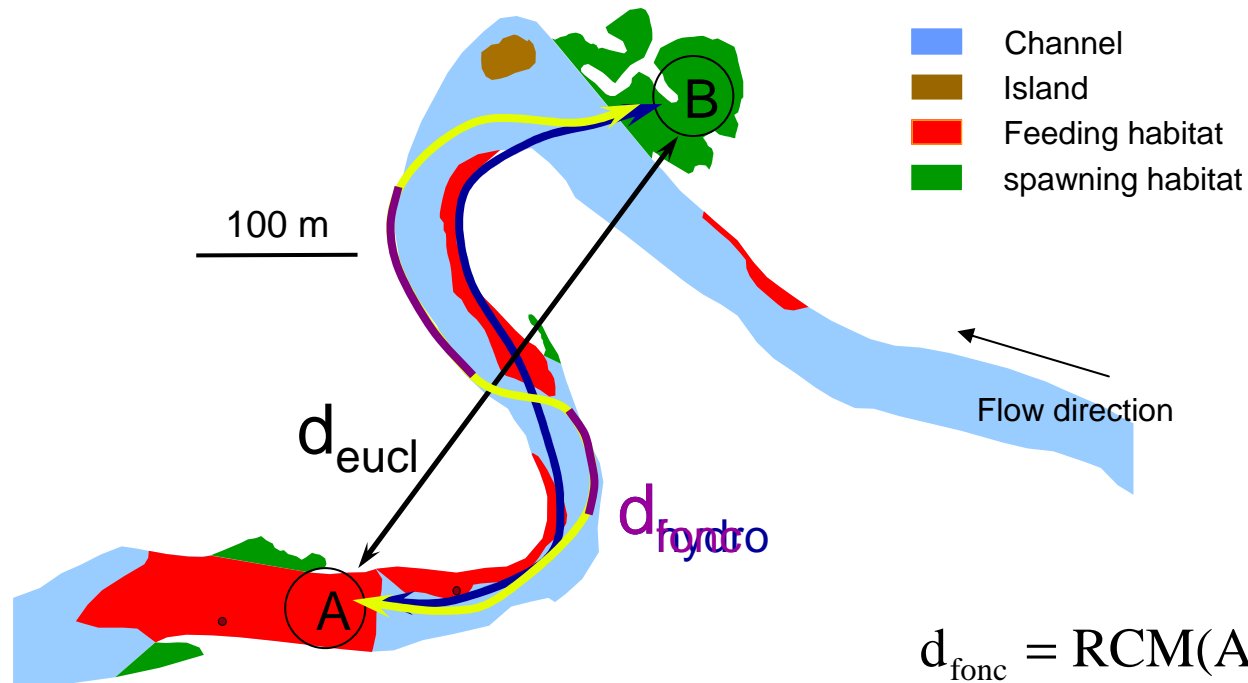
Integrating riverscape composition between patches using minimal cumulative resistance (MCR) from Knaapen *et al.* (1992) or least cost modelling

$$d_{fonc} = RCM(A, B) = \min_{\text{possible ways}} \int r(x)dx$$

Flowchart of the approach: methods and tools

Field mapping using GPS

Remote sensing

Indexes calculation

Composition : area, patch number

Fragmentation : nearest neighbor distance, proximity index

GIS data layers

Riparian cover

Log jam

Bottom substrate

Current velocity 70m³/s

Depth 70m³/s

Connected waterbodies 70m³/s

Current velocity 38m³/s

Depth 38m³/s

Connected waterbodies 38m³/s

Nursery/Resting habitat map 70m³/s

Feeding habitat map 70m³/s

Spawning habitat map 70m³/s

Resistance map 70m³/s

Moving window analysis

area of complementary habitats

Least cost modelling

Probability to reach the nearest spawning habitat map

island
channel
backwater
Shallow habitat

N

300 m

Example of connectivity to a spawning habitat

Spawning habitat map
70m³/s

A_i

Channel/backwater
Spawning habitat

$$MCR(B_j, A_i) = \min_{pathways} \int r(x)dx$$

Minimal Cumulative
Resistance map

A_i

0 5 10 20 60 100

MCR (x10²m)

Least cost
modelling

Resistance map 70m³/s

150mm

Resistance
1
3
8
28
33
111
500

Resistance coefficient (r):
based on swimming capacities
and behavioural movements
linked with predation risk

Spatial
analysis

Probability map to reach
the nearest spawning
habitat

A_i

Exponential negative

$f = e^{-RCM/\alpha}$

Opposite

$f = \min(\alpha/RCM, 1)$

Gaussian

$f = e^{-\left(\frac{RCM}{\alpha}\right)^2}$

Threshold

$f = 1 \quad si\ RCM \leq \alpha$
$f = 0 \quad si\ RCM > \alpha$

Probability

RCM

Probability

RCM

Probability

RCM

Probability

RCM

Impact of habitat structure on ecological connectivity

Exemple for:
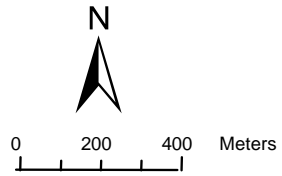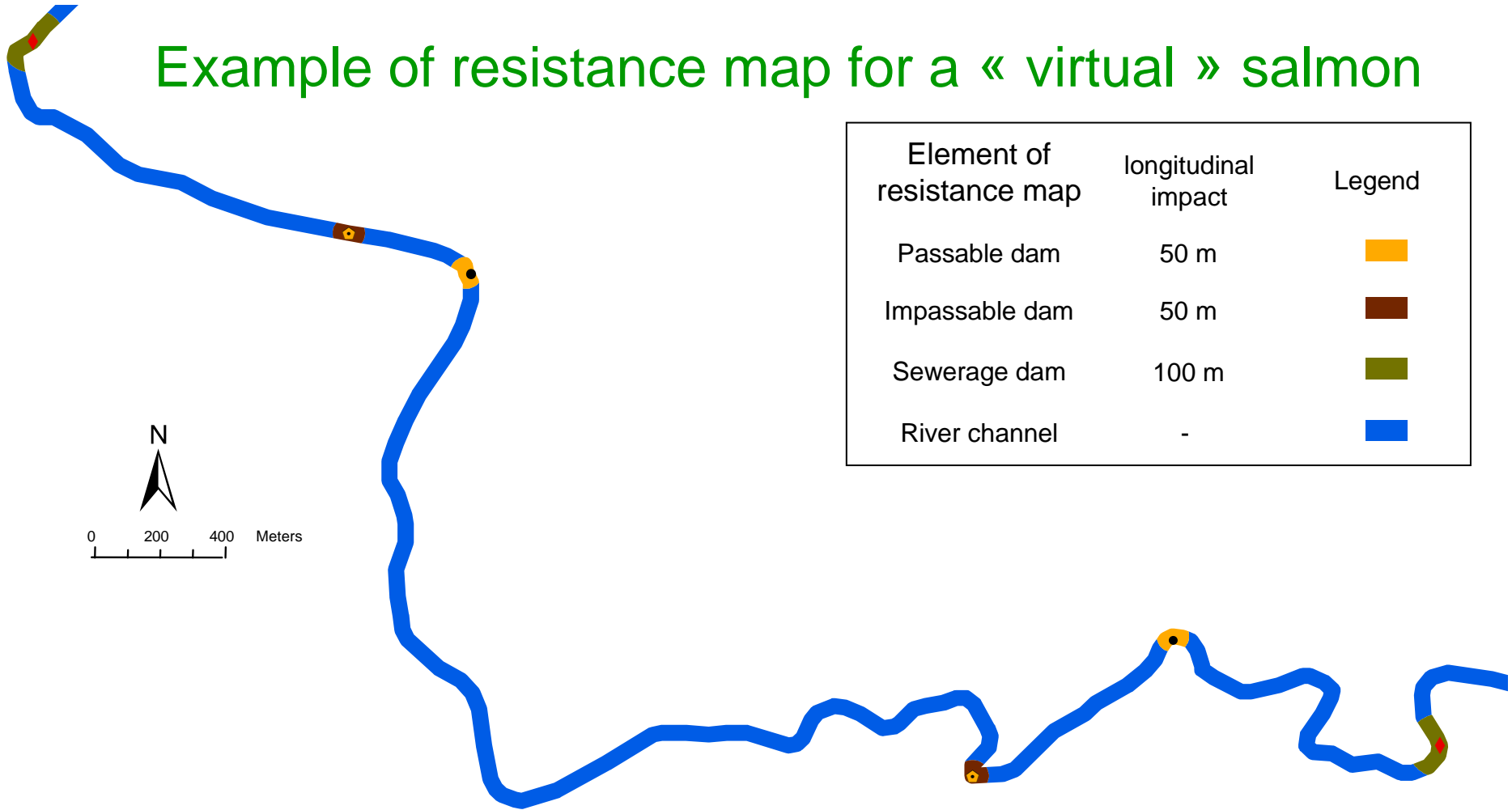Seine river segment of 25km, limited by navigation weirs
Barbel size 150mm
25 spawning habitat patches

Resistance variability to movement and some area with lower probabilities

1 km

0.2   0.5   0.75   0.8   0.9   1

Probability to reach the nearest spawning habitat
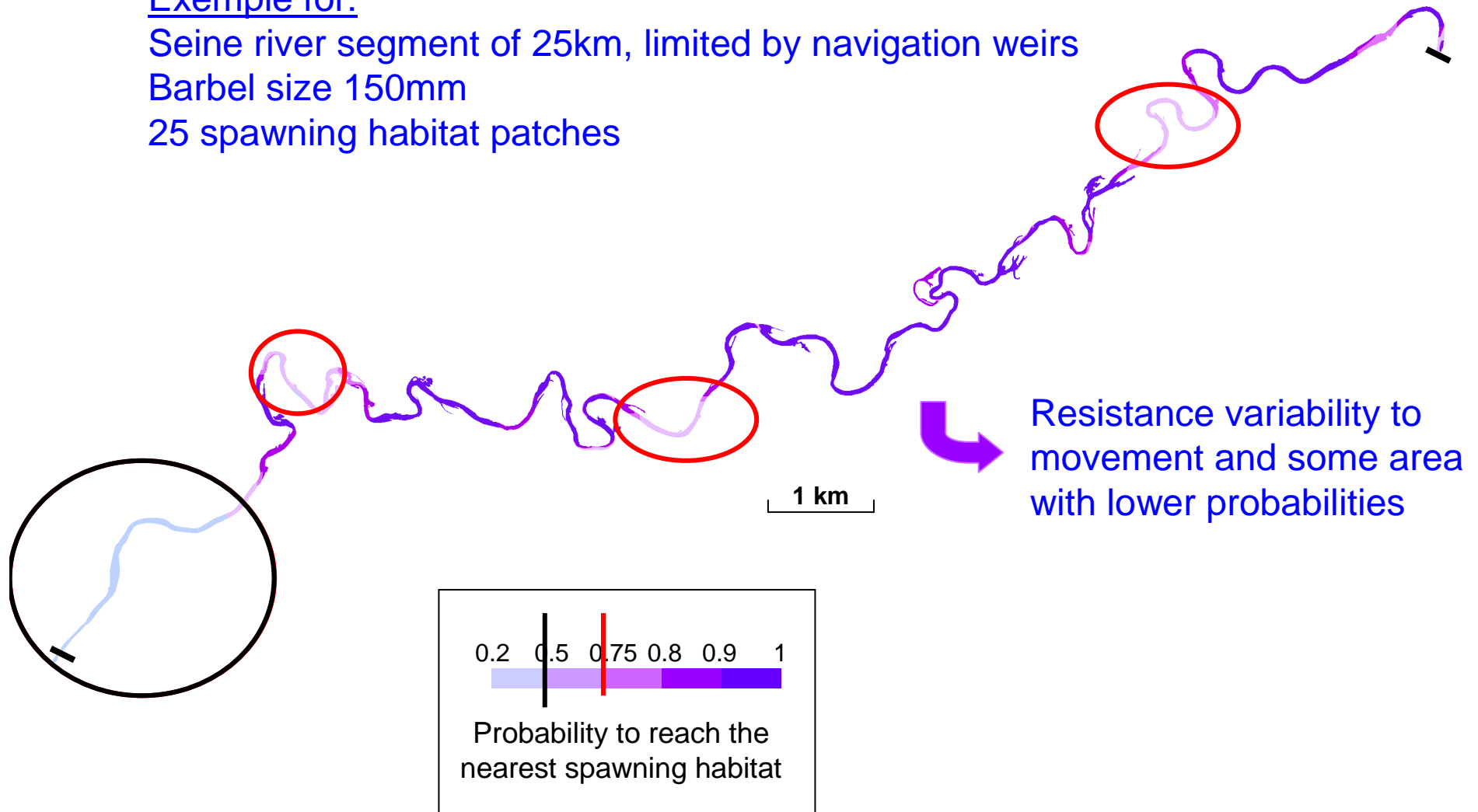
Cumulative Impact of physical and chemical barriers on ecological connectivity

Legend

- ♦ sewerage plant
- ⬠ impassable dam
- ● other dams
- ▬ Seine and Aube
- — hydrographic network

N

0   33   66   kilometers
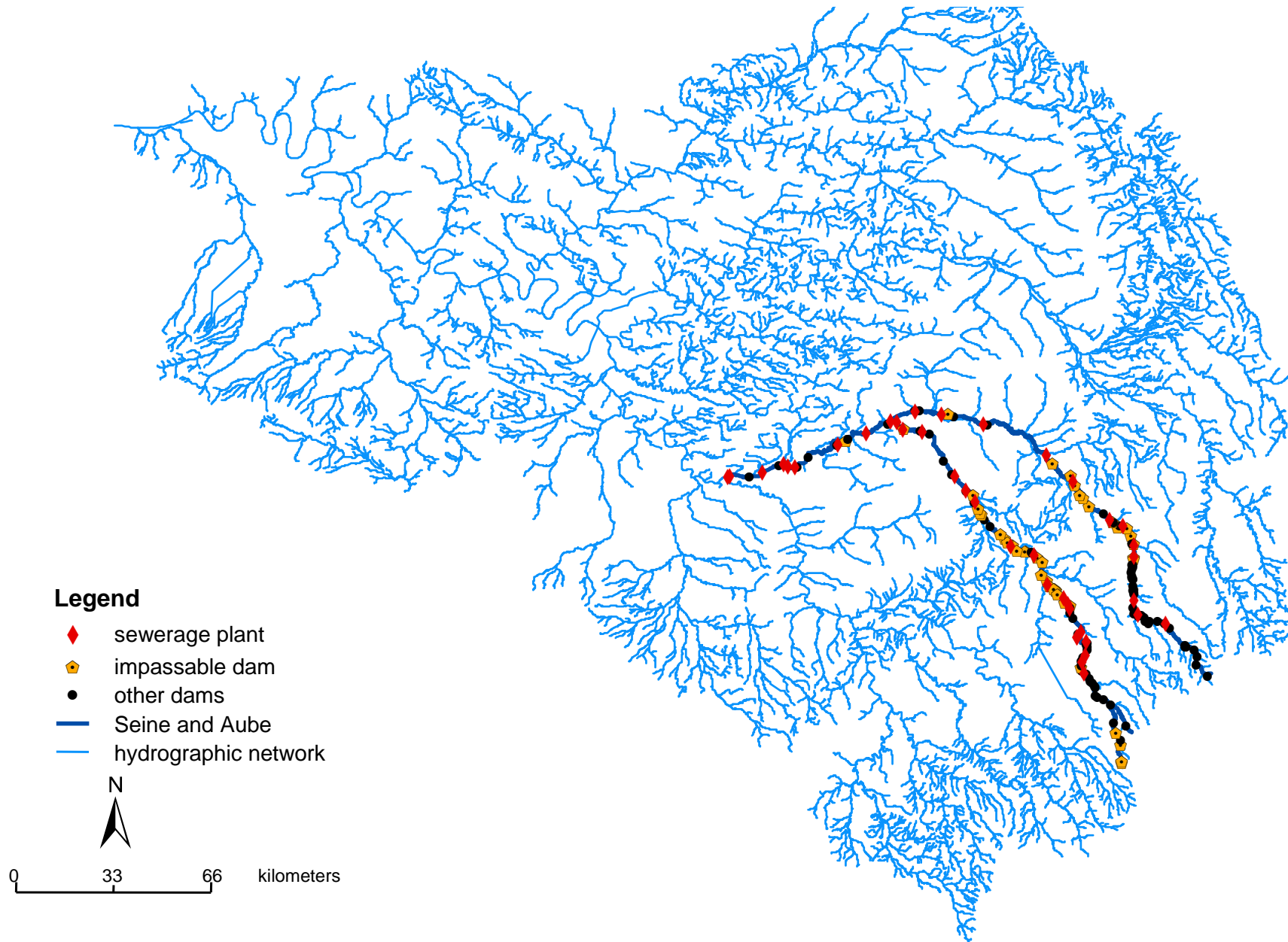
Example of resistance map for a « virtual » salmon

Element of resistance map	longitudinal impact	Legend
Passable dam	50 m	🟧
Impassable dam	50 m	🟫
Sewerage dam	100 m	🫒
River channel	-	🟦

N

| 0 | 200 | 400 | Meters |

Element of resistance map	Resistance coefficient for upstream movements
Passable dam	20
Impassable dam	500
Sewerage plant	10
River channel	2

Cumulative resistance for a « virtual » salmon to reach upstream spawning habitats
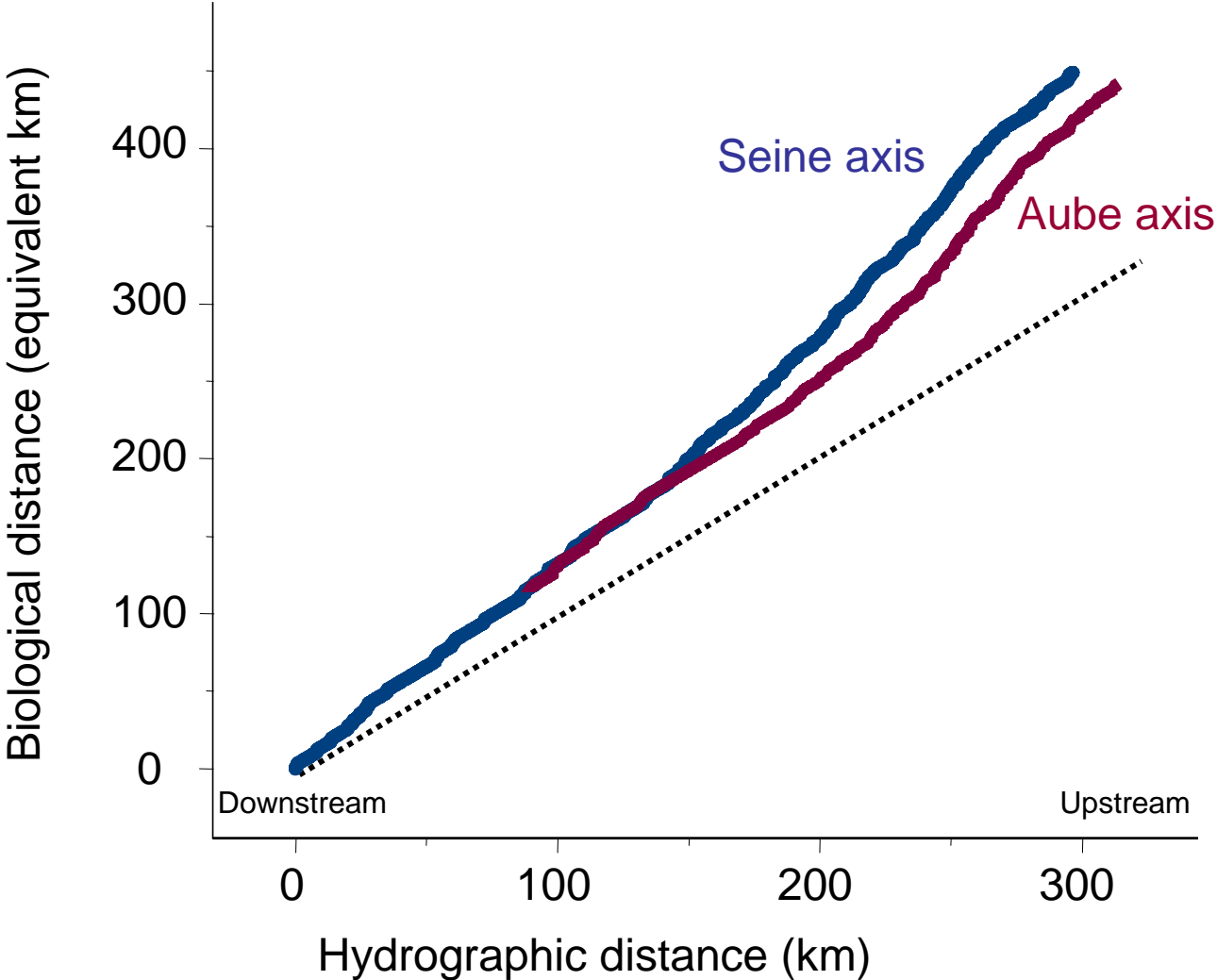
Example of lateral connectivity for pike (*esox lucius*)

Land use and hydrographic network

Legend

— Migration pathways

Potential land use for spawning

- Aquatic habitat
- Young poplar plantation
- Dense old poplar plantation
- Pasture or meadow
- Tall grasses
- Ripisylve

N

0   700   1 400   Meters
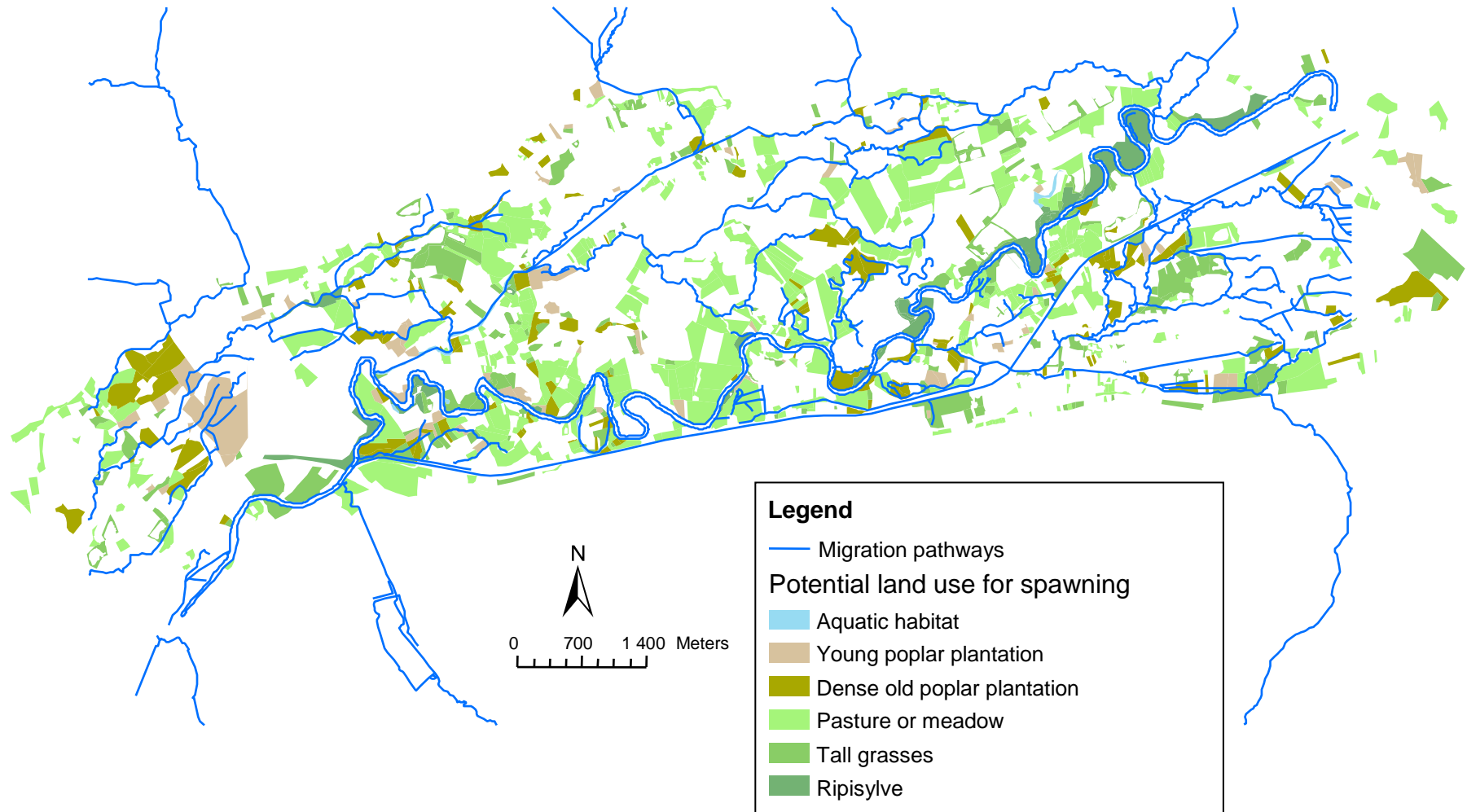
Spawning habitat quality and inondated area

Potential spawning habitat around 160 m³/s according to their distance to a migration pathway

Legend

	Flood 160 m³/s
	Migration pathways

Class distance to migration pathway	Rate of return for YOY
0-50 m	92,5%
50-100 m	80,0%
100-200 m	76,7%
200-300 m	61,8%
300-400 m	44,9%
400-500 m	30,0%

N

0   700   1 400   Meters
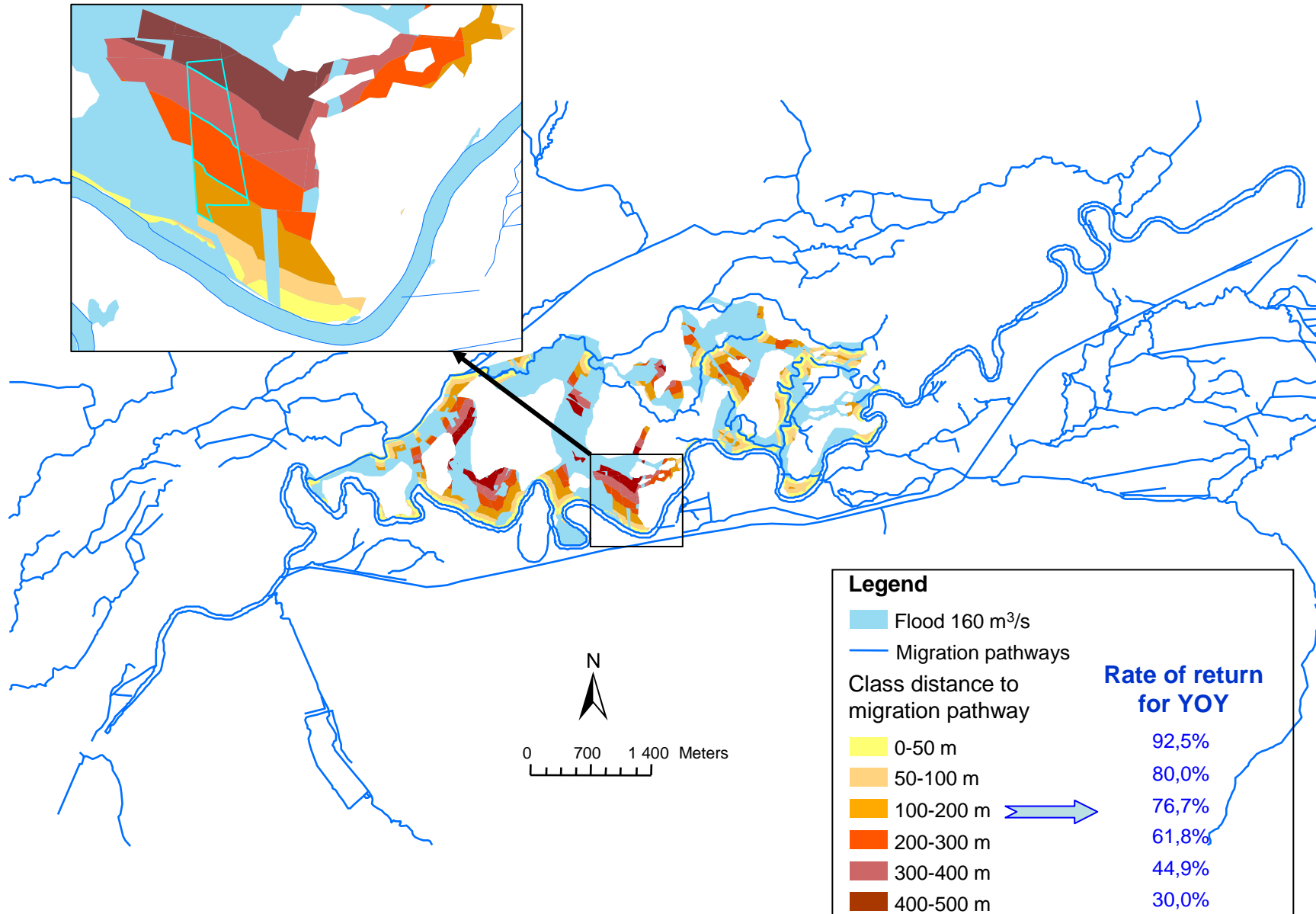
Barrier effects and habitat modification impacted bullhead presence

Presence of bullhead ● Absence of bullhead ○
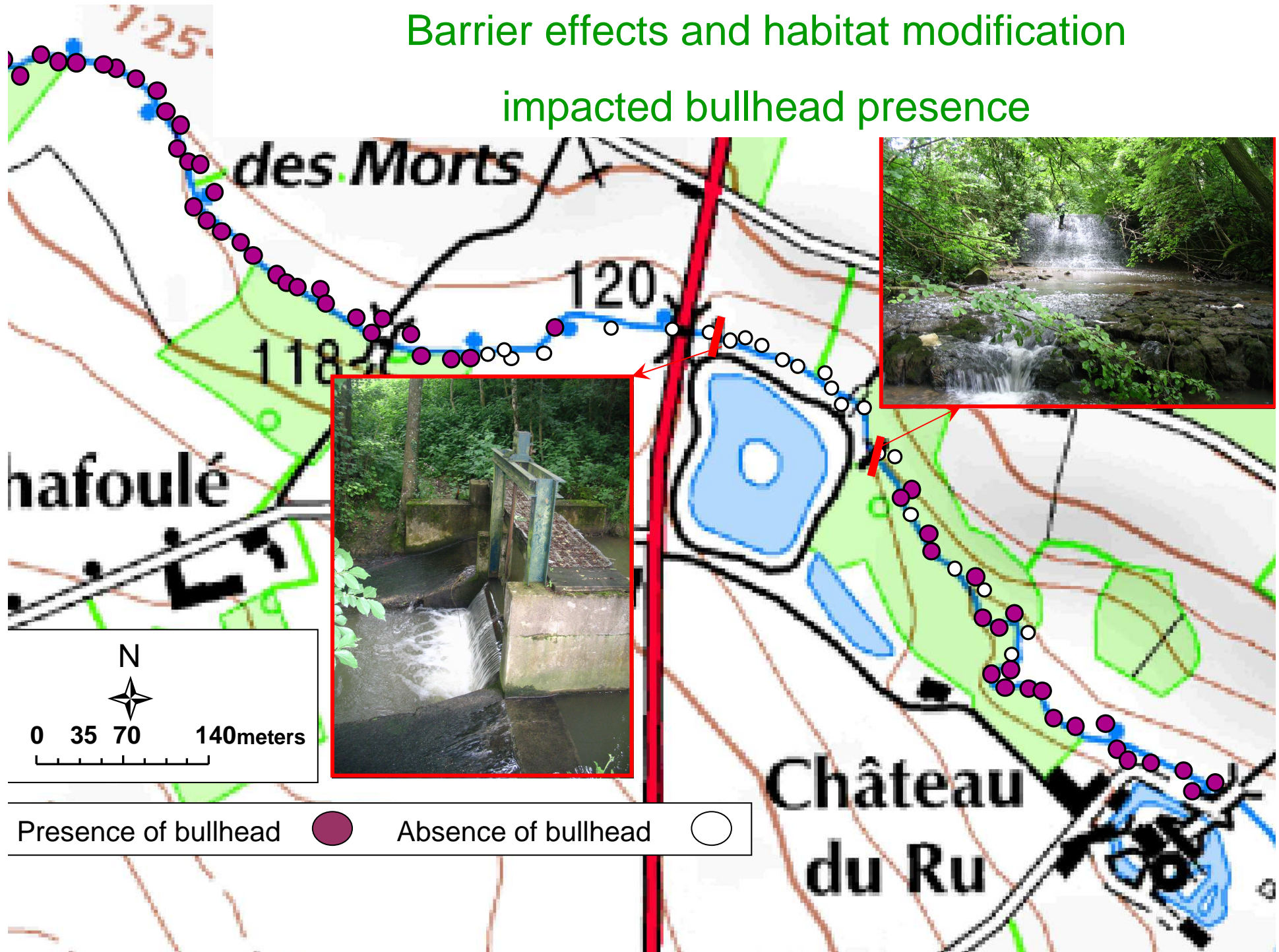
Evaluating connectivity for fish

✓ Indexes quantifying vital habitats quality

✓ Maps visualizing global connectivity of segments

✓ Freeware calculating oriented hydrographic and biological distances

Allowing:

✓ Identification of critical habitat

✓ Preservation of high quality patches

✓ Prioritization of restoration schemes

✓ Test of scenarios

Adding a patch of feeding habitat
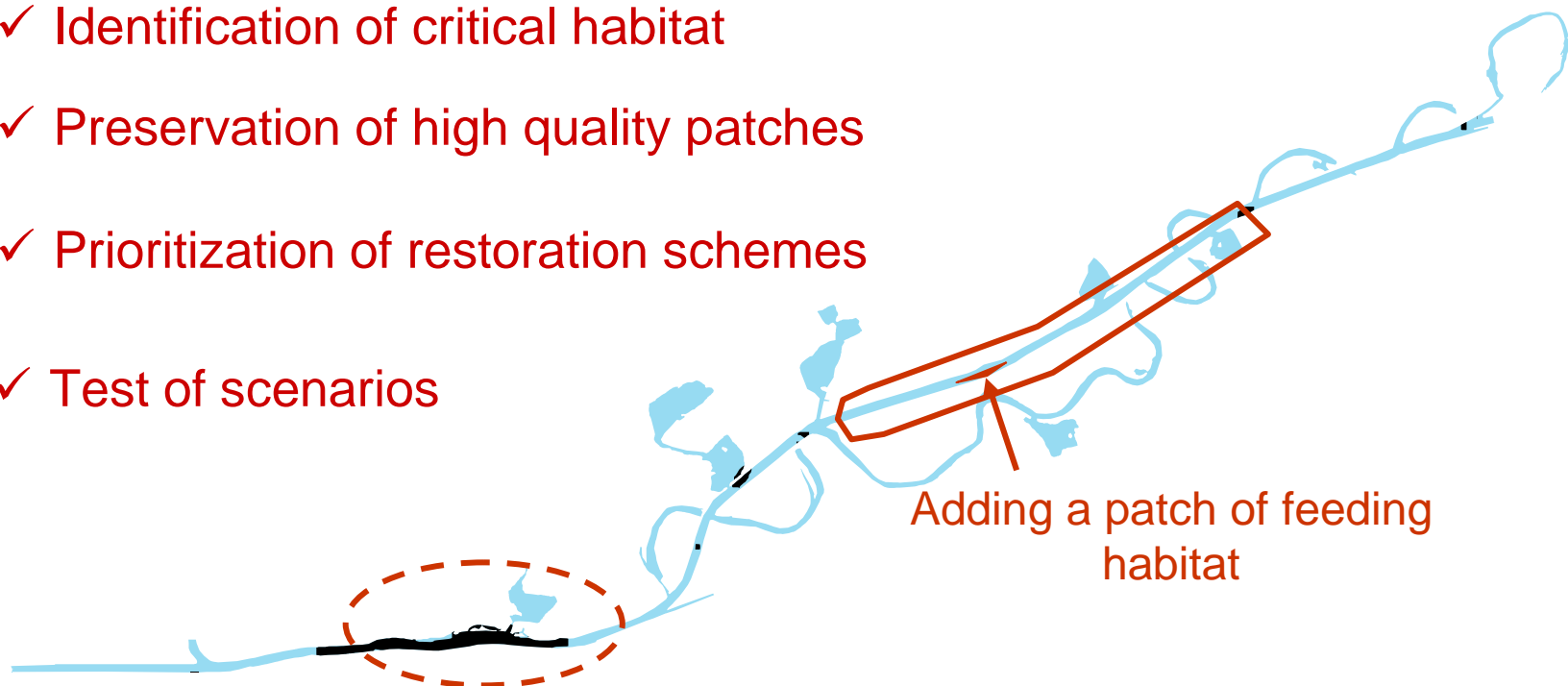
How it may help the definition of aquatic corridors?

➢ Increasing connectivity

▪ reduce fragmentation by the restoration of vital habitats

▪ decrease barrier effects by the equipment of impassable dams, reduce diffuse pollutions, better water treatment in sewerage plants,