Migration in the fragmented Dronne River. Alas silver eels don't fly like drones!

Frédérique BAU[1,2], Nicolas DELIGNE[1,2], Alain ALRIC[2], Peggy GOMES[2], Philippe BARAN[2], Pierre SAGNES[2] and Hilaire DROUINEAU[1,2]

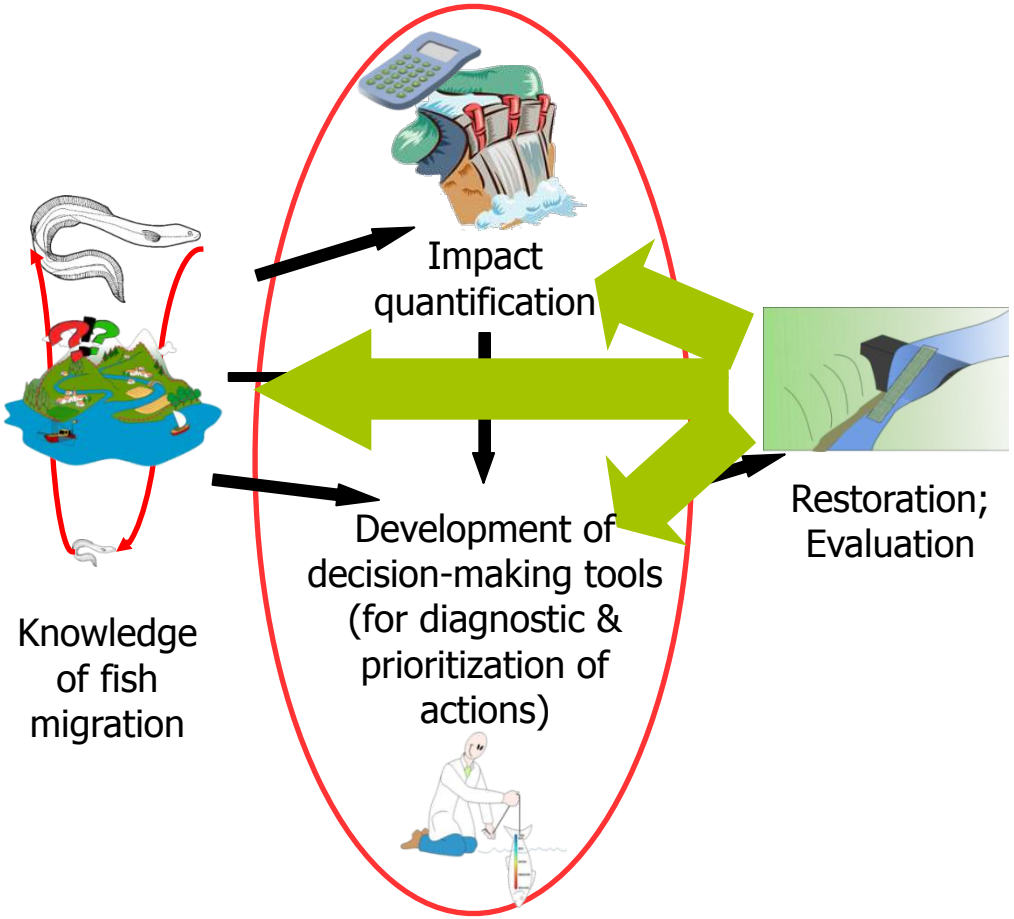
1: Irstea UR EABX – 50 avenue de Verdun, 33612 Cestas cedex – France *(frederique.bau@irstea.fr)*
2: Pôle Écohydraulique ONEMA-Irstea-INP – Allée du professeur Camille Soula, 31400 Toulouse – France

General context

- A decline of European eel stocks that required the implementation of management plans (EU Reg. 1100/2007) to reduce all the anthropogenic mortalities, including those related to hydroelectric facilities

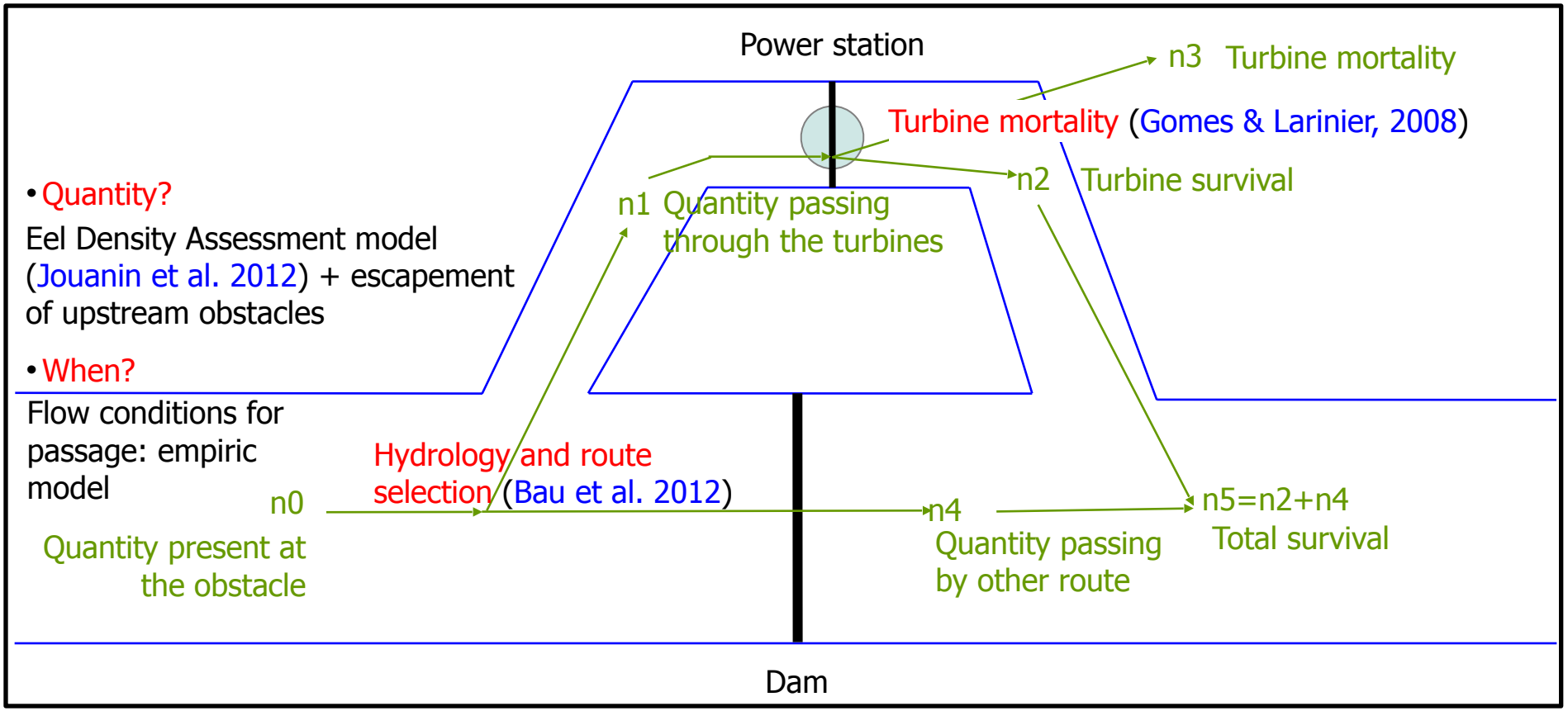
- First reporting of the French Eel Management Plan (2008/2012):

→ quantification of the impacts of hydroelectric facilities to downstream-migrating silver eels by using the Sea-Hope approach (Jouanin et al. 2012) based on the coupling of **four predictive sub-models**



The French Sea-Hope approach

(i) Yellow eel distribution and yearly proportion of downstream migrants
(ii) Hydrology and downstream migration dynamics
(iii) Hydrology and alternative passage routes at hydro facilities
(iv) Turbine characteristics and passage survival rate



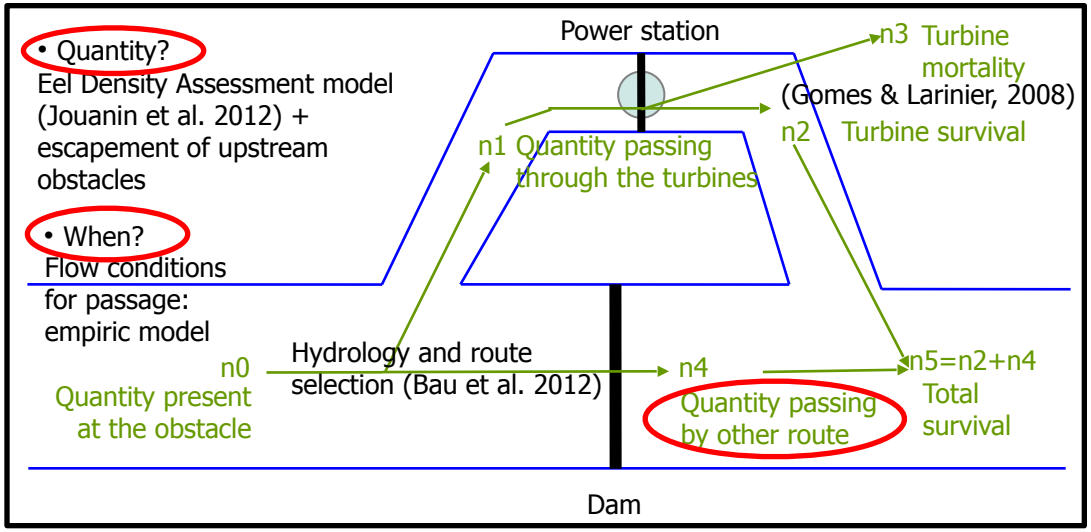
New objective: refine Sea Hope

- When do they move?

→ Test the transferability of model (ii) for other river flow patterns
→ Further radio telemetry experiment on the Dronne river, one of the 10 "index rivers" identified in the French Eel Management Plan

- How do they move?

→ Refine model (iv) "obstacle characteristics and survival rate"
→ Impact? of non-hydroelectric river obstructions and indirect effects (energy costs) by using electromyogram radio transmitter



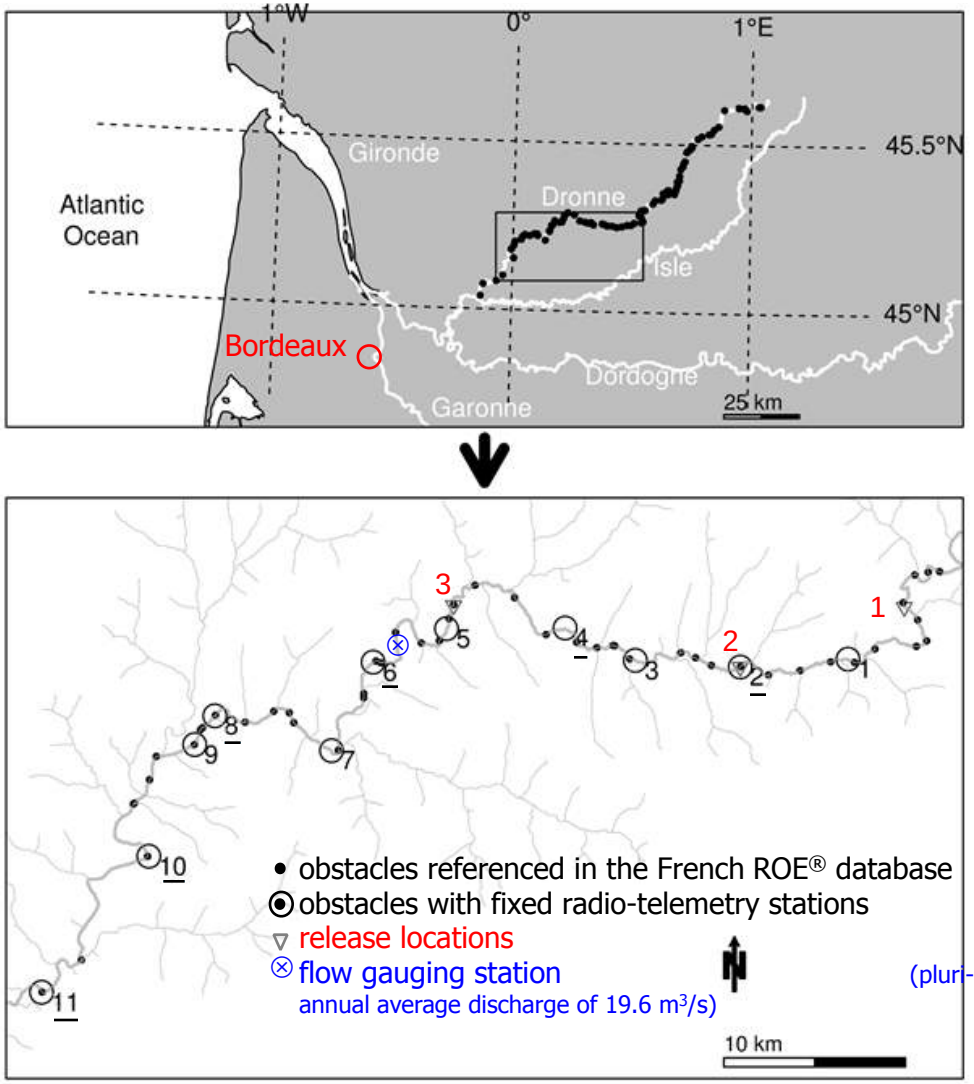
- How many?

→ Refine model (i) by working on the link between yellow and silver stages by using a new PIT-tag methodological approach

When & how do they move?

Study site: the Dronne

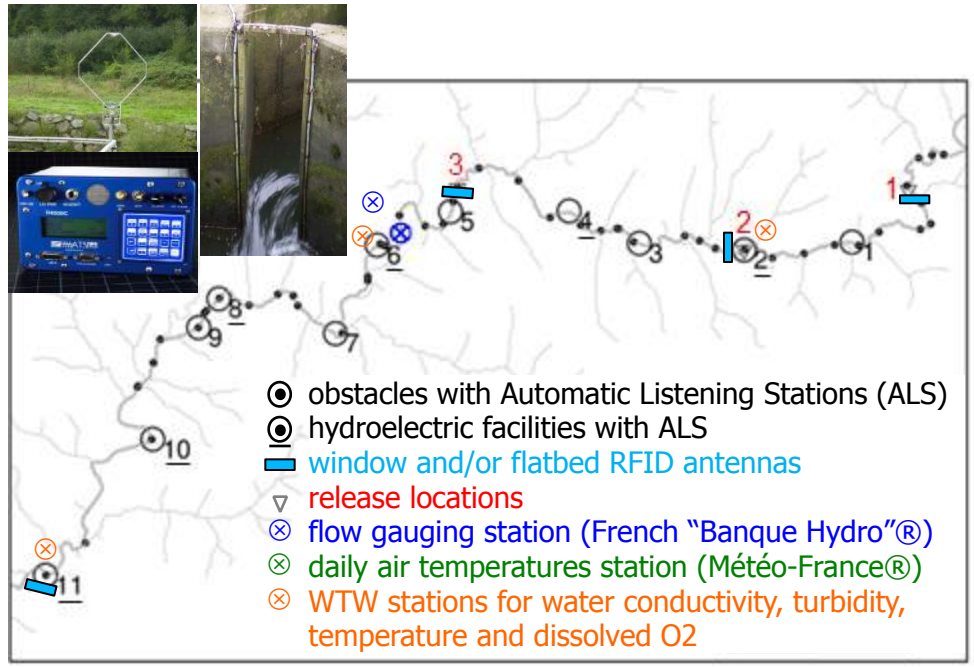
- A 200-km long low land plain river (SW France) with a pluvial flow regime representative of the hydrographic contexts of the Atlantic coast
- Study area: 90 km along the highly fragmented downstream section (one obstacle every 2.1 km)
- 7 of the 43 obstacles located in the study area are still used for hydroelectricity production



When & how do they move?

Methods: telemetry

- Fixed and mobile radio & RFID telemetry monitoring during three consecutive seasons of migration (2011/2012 to 2013/2014)
- 11 obstacles with R4500C ATS® ALS + environmental monitoring
- Double tagging (radio & PIT-tag) of 97 silver eels (mean TL 790mm)



When & how do they move?

Global results

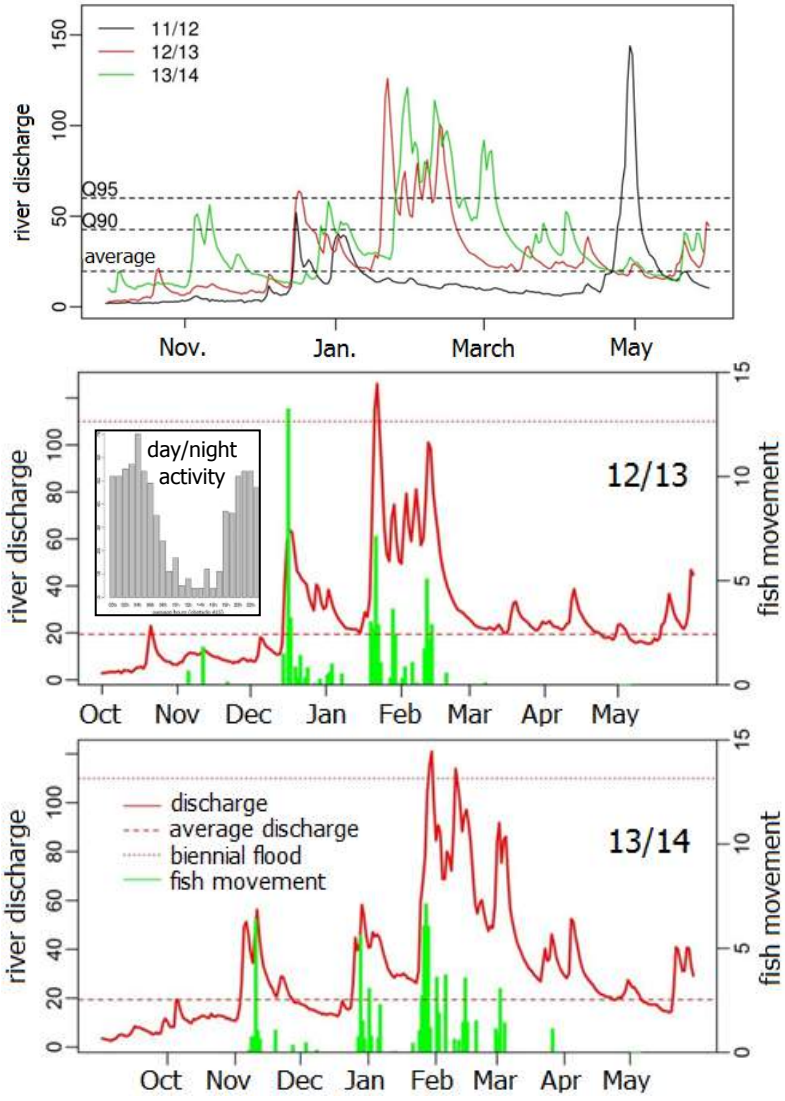
An hydrological contrast resulting in:

- Variable rates of global escapement

  (0% in 11/12 vs. 54%-59% in the next 2 seasons)

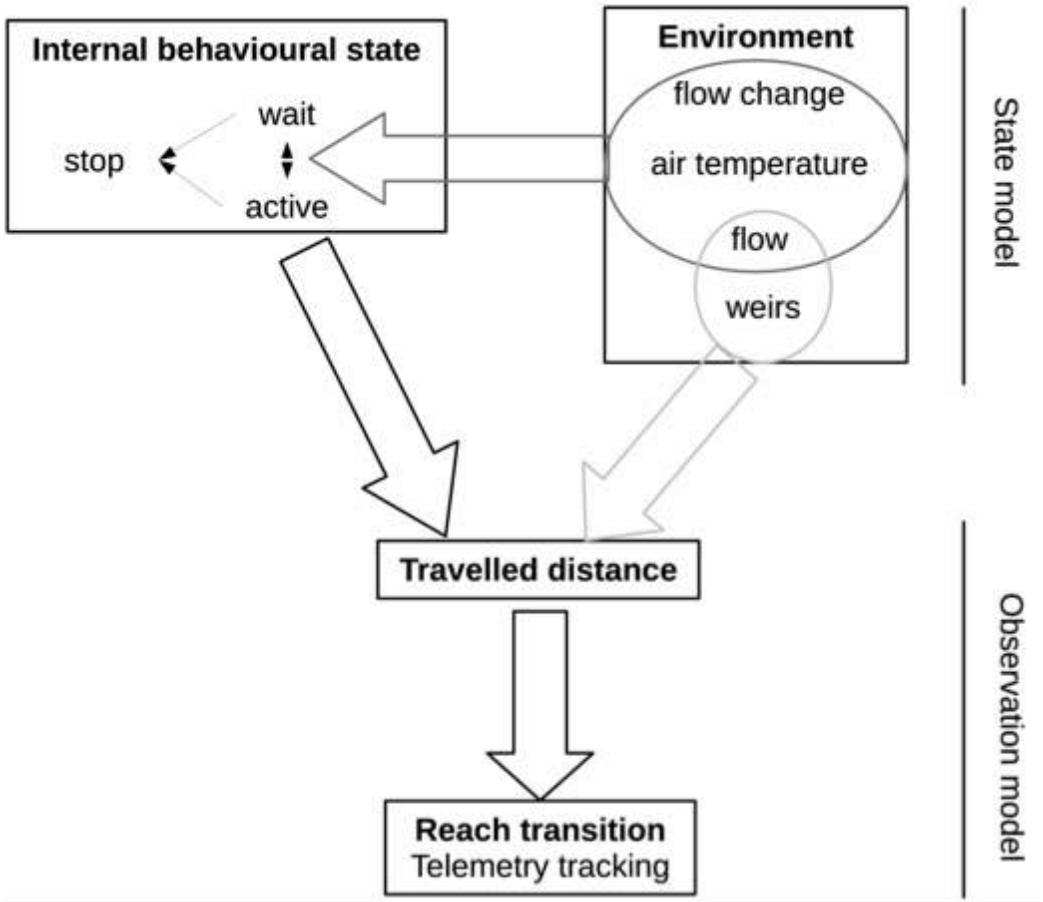
- Higher rates of migratory activity (speed and travelled distance) especially during rising flows in the 2 high-flow seasons

- Much more disruptions in migration (blockage, delay) under unfavorable environmental conditions and others after a few kilometers following passage through hydroelectric facilities



When & how do they move?

- Development of a Bayesian state-space model to analyse **simultaneously** the effects of environmental factors on migration triggering, the influence of river runoff on distance travelled & the impact of obstacles on escapement



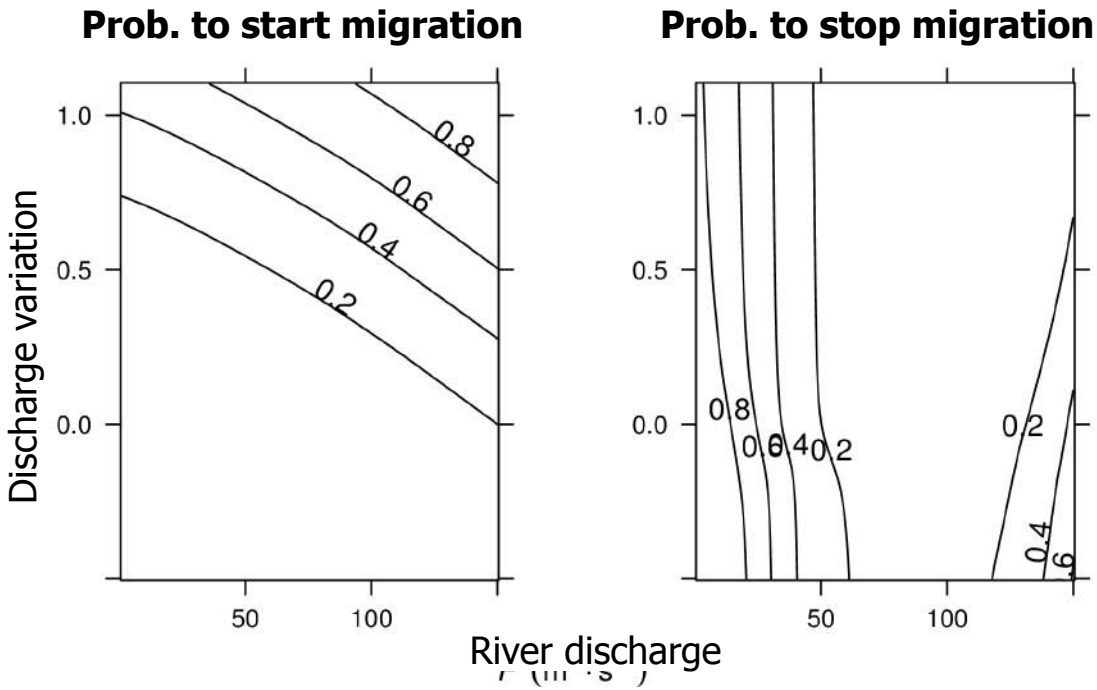
Interplay between individual internal state and environment addressed through movement analysis (Nathan et al., 2008)

Structure of the SSM illustrating the influence of environmental conditions on the internal behavioural state and their links with eel movements and resulting observations

When & how do they move?

SSM results

- Impact of river discharge & variations in discharge on migration triggering



States transition probabilities predicted by the model at different levels of average daily flow and relative variation of daily flow

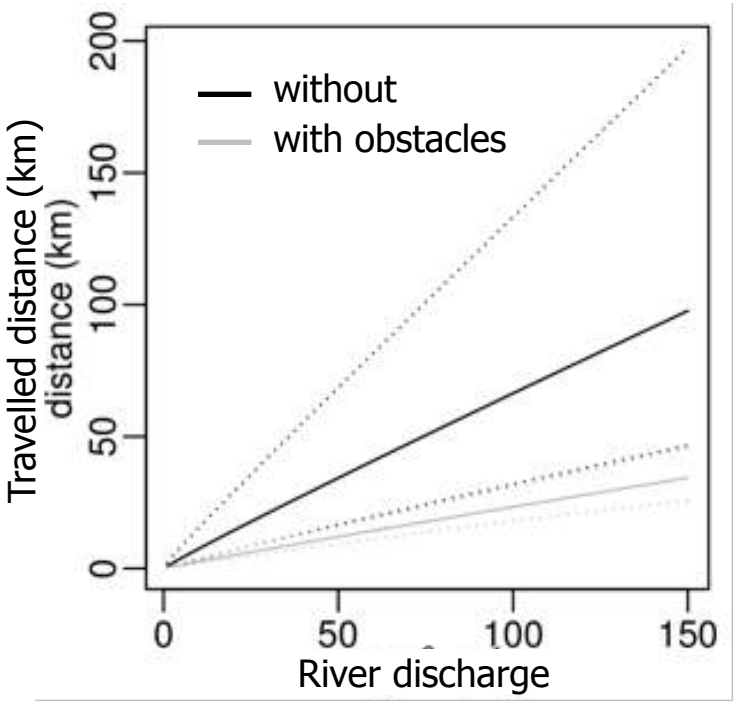
- Active eels tend to stop their migration below 40 m^3/s
- while a river flow higher than 50 m^3/s and a strong ΔF are required to trigger migration

Rather limited environmental window suitable for downstream migration in the system studied

When & how do they move?

SSM results

- Impact of river discharge and obstacles on travelled distance



Theoretical distance travelled by active eel in 24h without any obstacle (black line) and mean distance effectively travelled given the weirs density in the Dronne (grey line)

- Positive effect of discharge (and variations in discharge) on the distance travelled by fish
- Significant negative impact of obstacles on the distance travelled
  - each obstacle represents an additional 3.84 km
  - the distance covered by active migrant in 24 h is divided by 2.86 because of obstacles

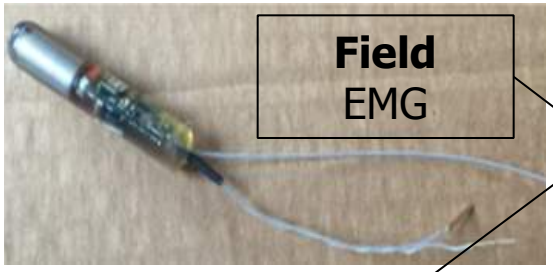
All kinds of obstacles can delay migration and impair escapement success given the limited environmental window suitable for migration

Is an eel escaped saved? Not necessarily!

Energy costs induced by river fragmentation

- Direct effects but also indirect
  disease or increased energy c
- Is that bad? Maybe, since ene
  costs related to successive ob

Feasibility test for implantation of Lotek CEMG2-R11-18 transmitter



Example of ID + EMG data

DATE	TIME	PWR	ANT	CODE	SENSOR TYPE	VALUE
18/03/15	14:35:57	239	AH0	12	EMG	2
18/03/15	14:36:02	235	AH0	12	EMG	1
18/03/15	14:36:07	222	AH0	12	EMG	1
18/03/15	14:36:12	255	AH0	12	EMG	1
18/03/15	14:36:17	205	AH0	12	EMG	2
18/03/15	14:36:22	255	AH0	12	EMG	2
18/03/15	14:36:27	255	AH0	12	EMG	2
18/03/15	14:36:32	220	AH0	12	EMG	3
18/03/15	14:36:37	218	AH0	12	EMG	4
18/03/15	14:36:42	222	AH0	12	EMG	4
18/03/15	14:36:48	214	AH0	12	EMG	3
18/03/15	14:36:53	247	AH0	12	EMG	17
18/03/15	14:36:58	233	AH0	12	EMG	12
18/03/15	14:37:03	233	AH0	12	EMG	19
18/03/15	14:37:08	253	AH0	12	EMG	37
18/03/15	14:37:14	254	AH0	12	EMG	46
18/03/15	14:37:19	251	AH0	12	EMG	45
18/03/15	14:37:24	226	AH0	12	EMG	26
18/03/15	14:37:29	227	AH0	12	EMG	10
18/03/15	14:37:34	140	AH0	12	EMG	44
18/03/15	14:37:40	121	AH0	12	EMG	25
18/03/15	14:37:45	137	AH0	12	EMG	5
18/03/15	14:37:50	178	AH0	12	EMG	4
18/03/15	14:37:55	170	AH0	12	EMG	1
18/03/15	14:38:00	173	AH0	12	EMG	1
18/03/15	14:38:06	118	AH0	12	EMG	1
18/03/15	14:38:11	131	AH0	12	EMG	1

Baseline EMG values after release in still water zone

Increased EMG values during movements in running water zone

How many?

Yellow to silver eel transition: silvering acquisition and yearly proportion of downstream migrants

- Long-term tracking up to silvering implies a change in methodology (current limits in radio telemetry, i.e. transmitter size and lifetime)
- Use of Radio Frequency IDentification (i.e. PIT) technology in HDX system
- Need for the development of large RFID flatbed antennas easy to install across a river and with sufficient detection capacity to track fish migration by successive RFID barriers
- Technical feasibility tests based on the Norwegian experience
- Installation of 2 flatbed antennas of 18m long in operation in the Dronne river for over a year

NIVA
Norwegian Institute for Water Research

How many? An RFID solution…

- 81% of the time in operation
  (stopped by power failure)
- Detection distance
  75-90cm (32-mm pit)
  50-60cm (23-mm pit)
- Detection efficiency
  100% of tagged silver eels
  75% of tagged yellow eels (at least)

How many? An RFID solution…

- Downstream site

  A1 : 18 m x 1.2 m
  A2 : 23 m x 1.2 m

- Detection distance

  A1: 93-110cm, A2: 75-90cm
  A1: 60-68cm, A2: 45-55cm

  Only A1 installed

- 71% of the time in operation (stopped by power failure)

- Detection efficiency
  100% of tagged silver eels

Conclusions & prospects

Eel migration in fragmented rivers. When obstacles appear.
Drouineau H., Bau F., Alric A., Deligne N., Gomes P., Sagnes P.
(submitted to Hydrobiologia)

- The study confirms that in systems where migration processes are comparable to those observed here, temporary turbine shutdowns could potentially have a positive effect on mitigating the impacts of hydroelectric facilities

  → our SSM can be a first step to determine appropriate river flow thresholds for targeted turbine shutdowns and to generate yearly indices of escapement success

- Carrying out meta-analysis of the different radio telemetry experiments on silver eel migration would be a relevant way of identifying invariants between rivers

- Continuation of EMG experiment with further records of passage at different kinds of obstacles and calibration tests to relate to energy expenditure

- Continuation of ongoing RFID experiments in the Dronne by multiplying much larger flatbed detection barriers (along with mass tagging)

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