Echange MMB / LNHE

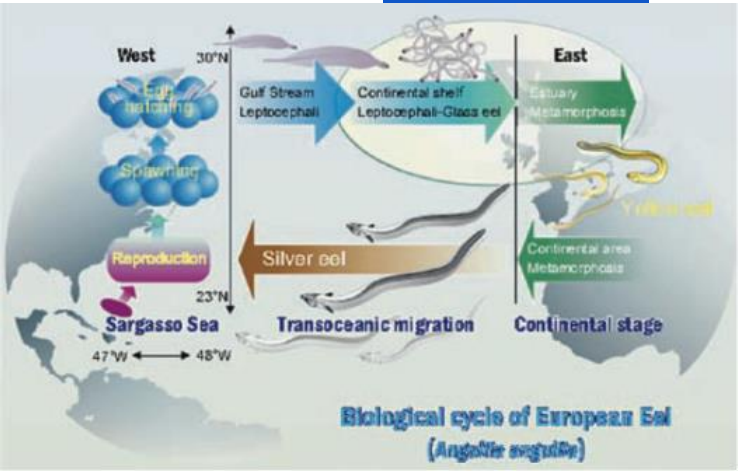
Modélisation de nage des poissons

Détection et identification des espèces de poissons à partir de vidéos acoustiques

Eric De Oliveira

Continuité écologique: ex. des poissons migrateurs

Garantir la libre circulation des espèces piscicoles, en particulier els espèces dîtes migratrices (saumon, anguille, alose, lamproie, …) mais aussi les holobiotiques (barbeau, brême, …)



Déclin généralisé lié en partie à la fragmentation des cours d'eau, mais de plus en plus d'autres facteurs (changement global, survie en mer (proies ?), hydrologie, Température (mer, rivière), pollution (survie œuf et larve), …

ICES Advice on fishing opportunities, catch, and effort *Published 5 May 2015*

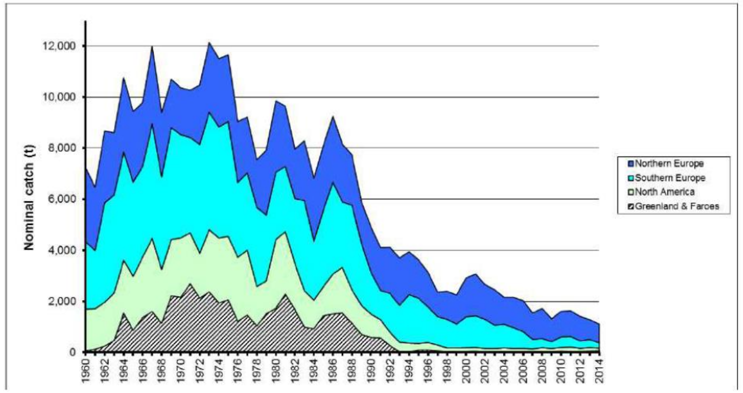
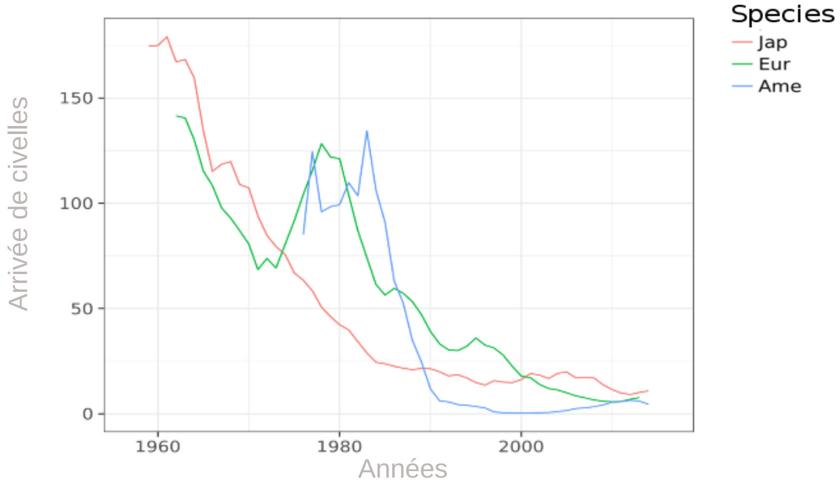
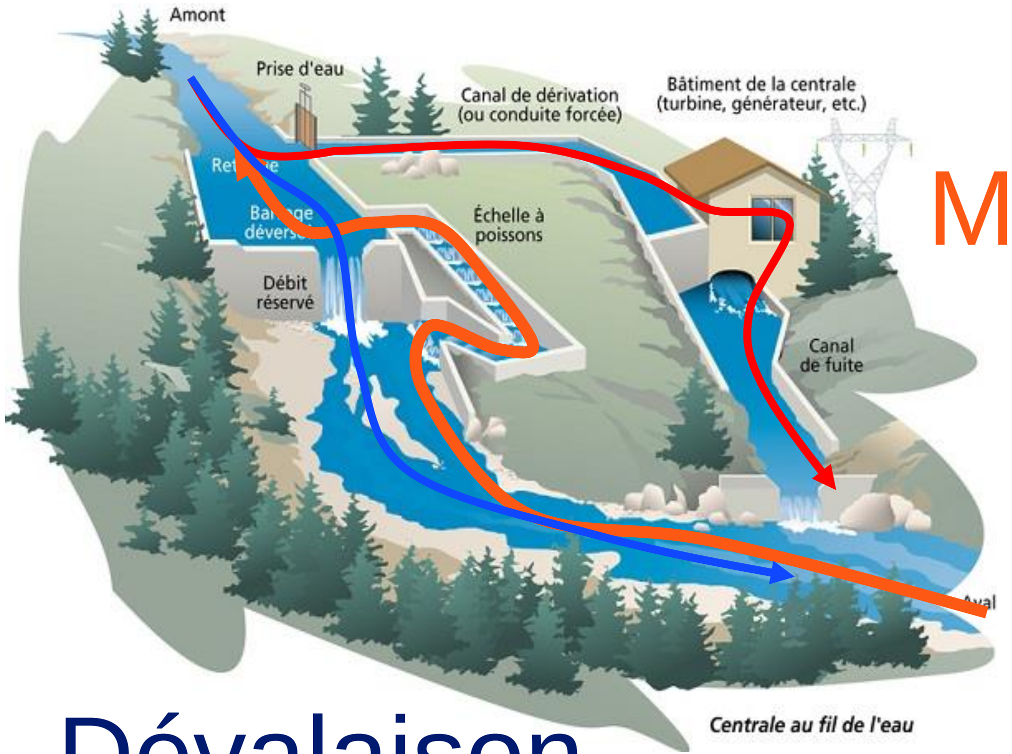


Figure 10.1.5.1 Reported total nominal catch of salmon (tonnes round fresh weight) in four North Atlantic regions, 1960 to 2014.

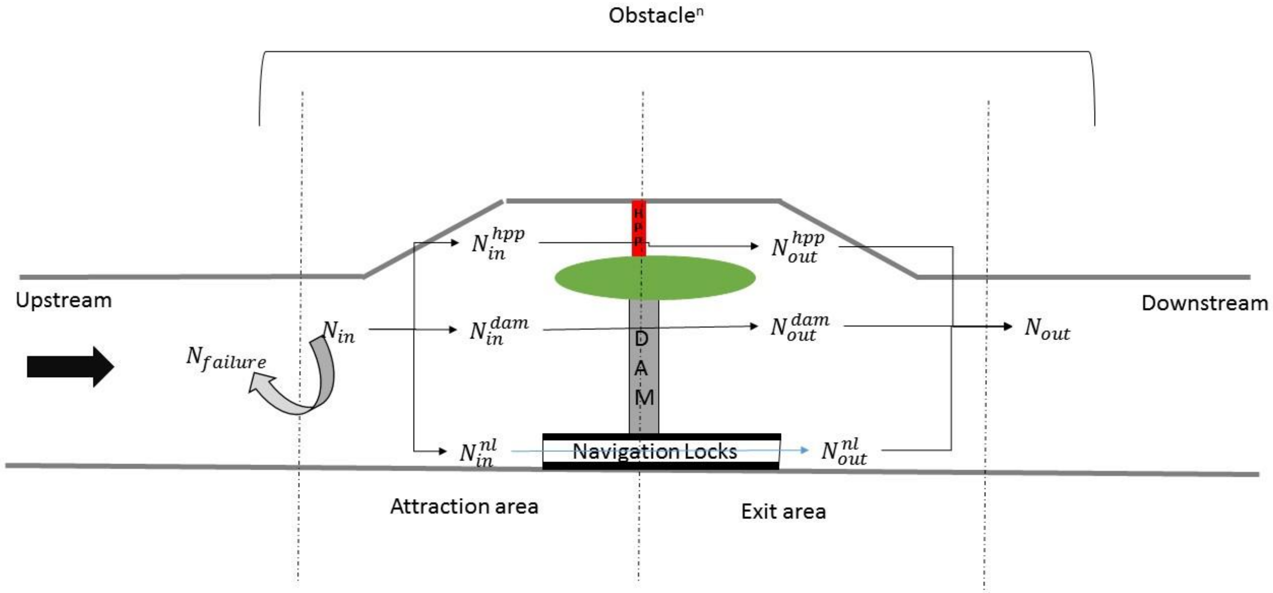


Adapté de Drouineau *et al.*,

Continuité écologique: ex. des poissons migrateurs



Montaison



Dévalaison

Enjeux pour EDF Hydro → Montaison

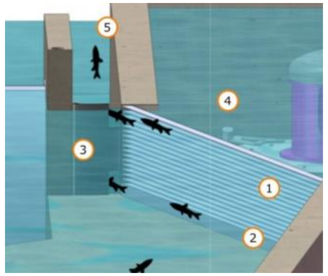
Grands Migrateurs
(saumon, alose, lamproie)

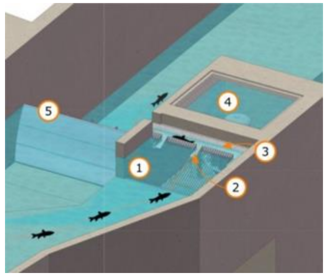
Anguilles

Augmenter l’attractivité et le franchissabilité pour toutes espèces

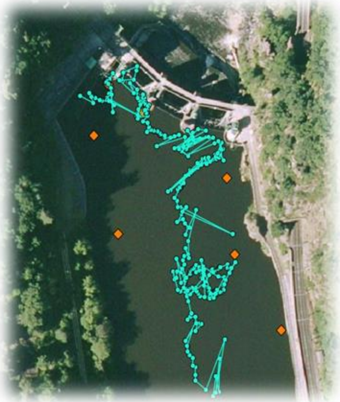
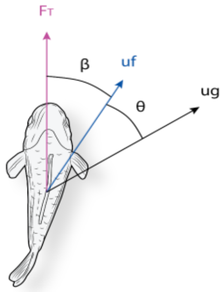
=> Modélisation comportement de montaison

Enjeux pour EDF Hydro → Dévalaison

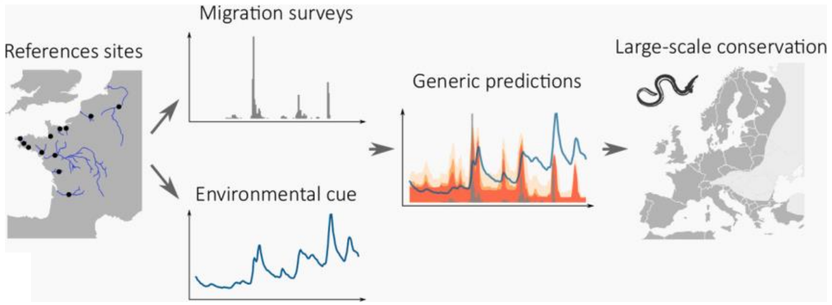


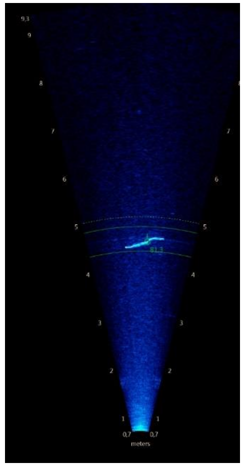
- Blocage physique et bypass

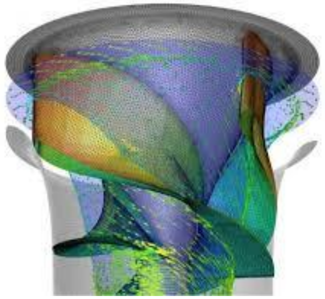



- Guidage et bypass
- Barrière comportementale

- Manoeuvre usine: Turbines et Vannes
  ⇒ périodes/pics de migration

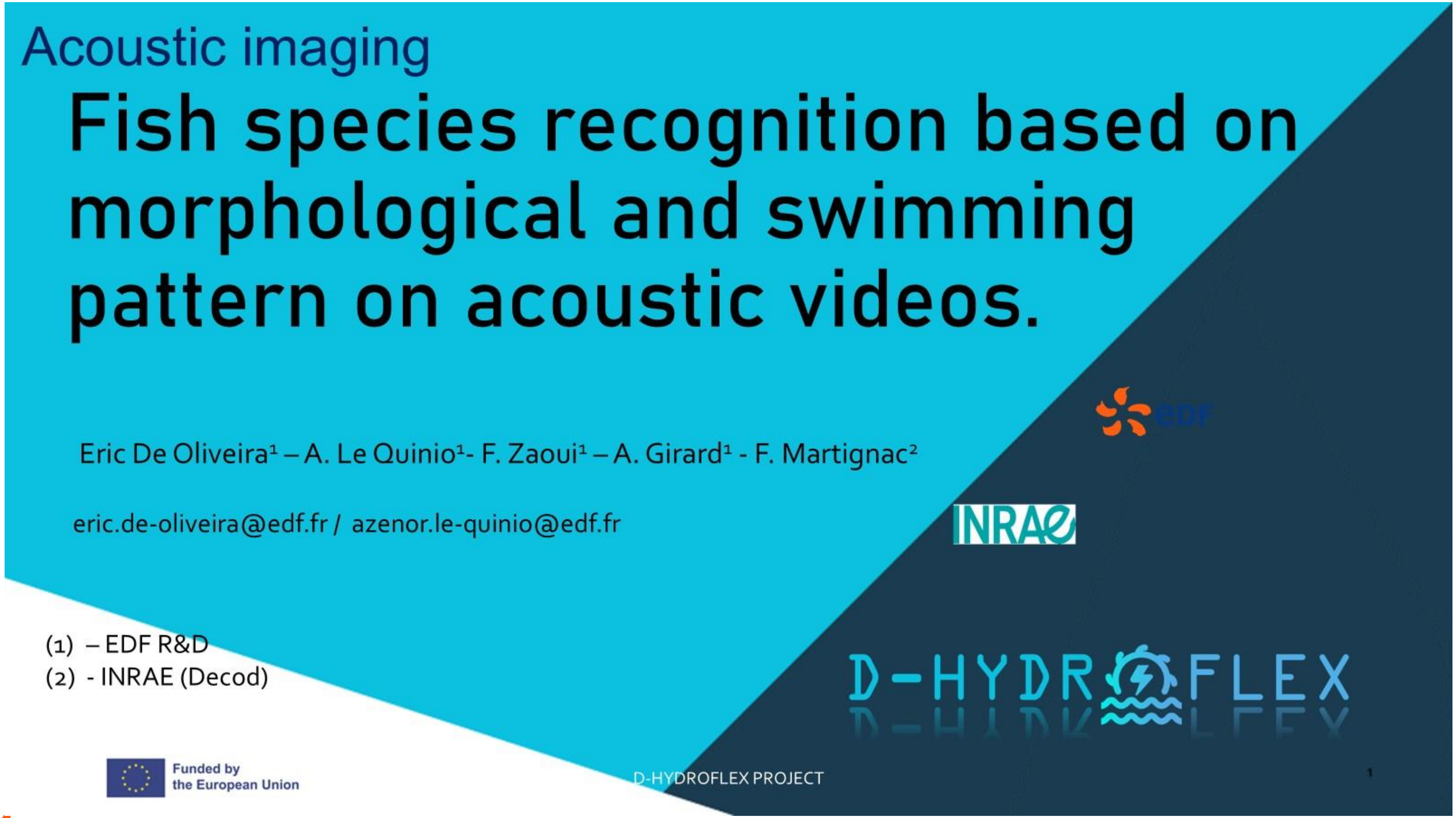






- Turbine Ichtyocompatible

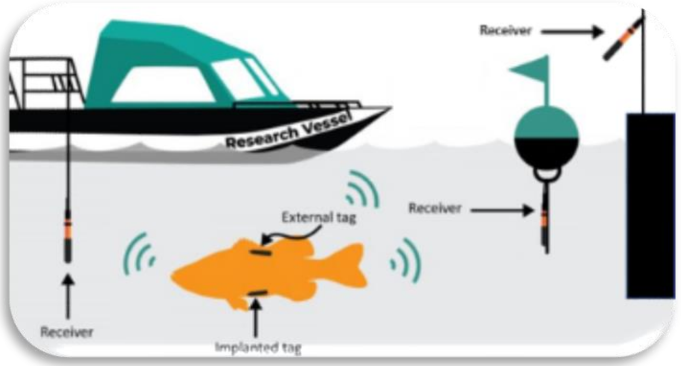
Fish migration monitoring: Acoustic videos



Fish Population monitoring *by hydroacoustic*

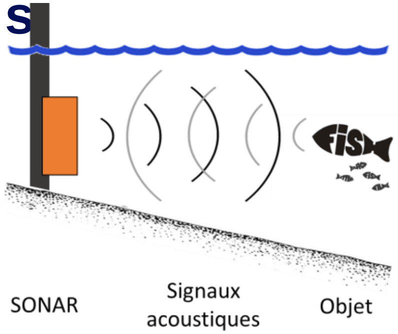
Captures

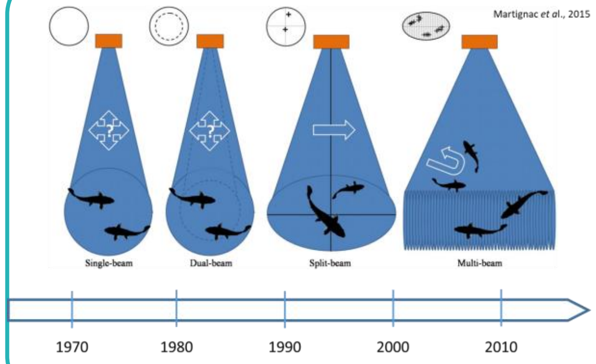
Telemetry



Optical cameras

Hydroacoustics





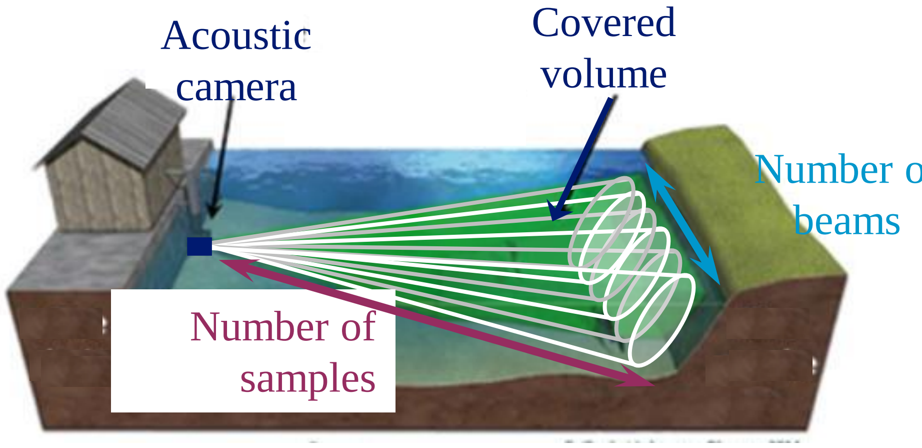
Several manufacturers

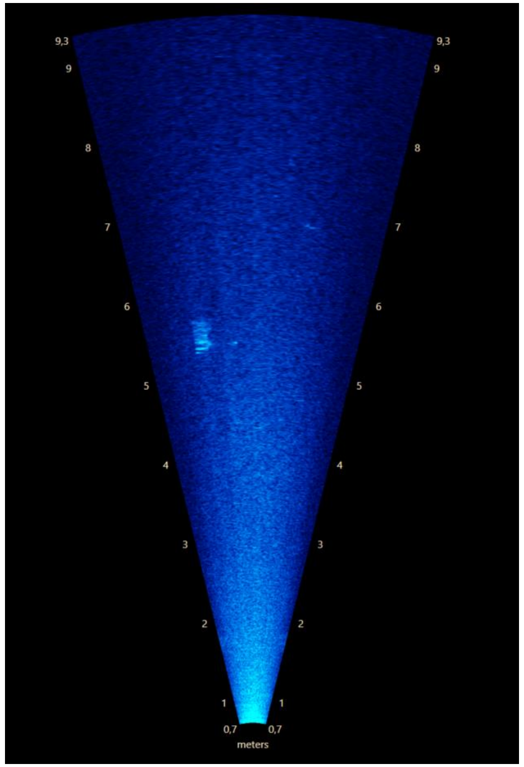
(Didson, ARIS, Bluewiew, Occulus)

Current limitations of acoustic cameras

- Many advantages of the acoustic cameras:

  - Non-intrusive
  - Low dependency to environmental conditions
  - Continuous recording over long period of time
  - Record fish morphology, swimming and behaviour





- But limitations to overcome:

  - Continuous recording generate high amount of data → need storage
  - Time consuming for the operatros
  - Analysis through species identification need expertise by operator + might be source of bias

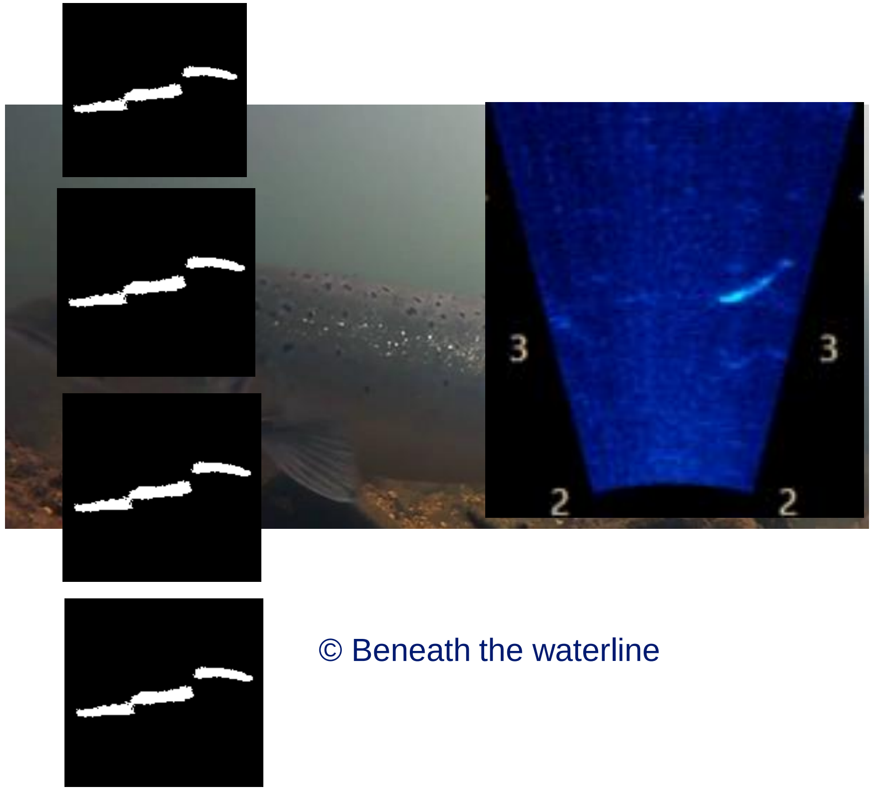
➢ **Need to automate acoustic videos analysis**

What information is available for fish species identification?

- Fish species identification widely explore on **optical devices**: **high level of detail** available
- **Less details** available from acoustic videos:

Colour and scales patterns

Overall morphology



© Beneath the waterline

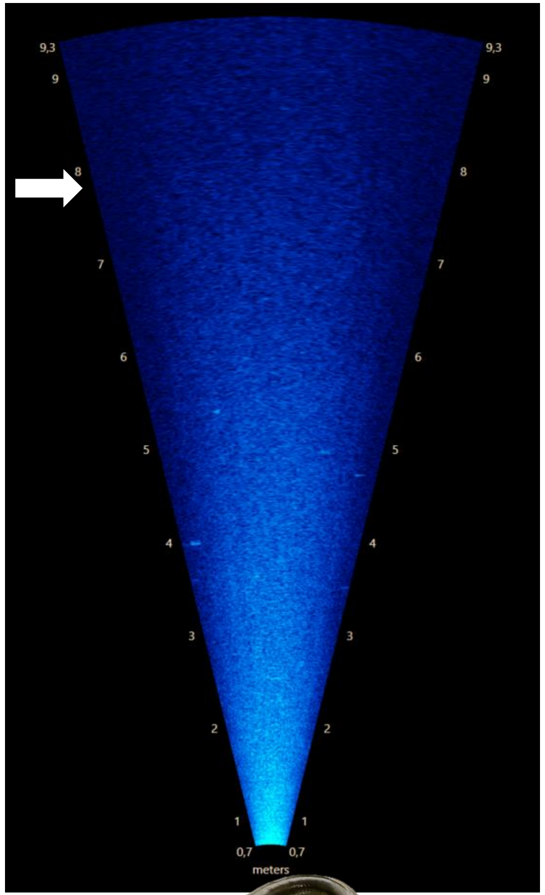
Number and positions of fins

Swimming locomotion

- Identification much **more complex without details of fish**: challenge of analysing acoustic videos

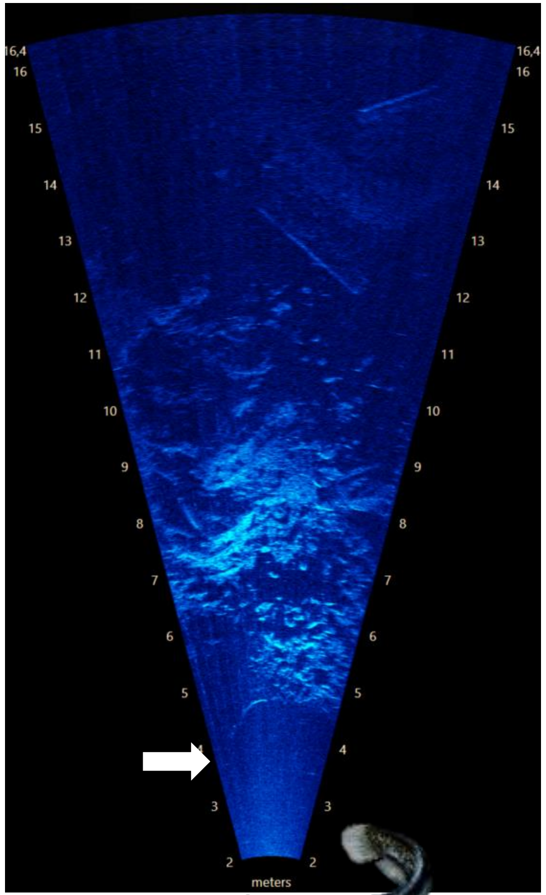
Presentation of the groups of species

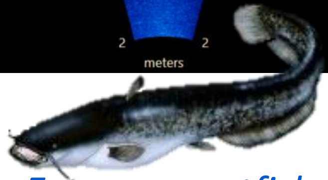
EEL



European eel

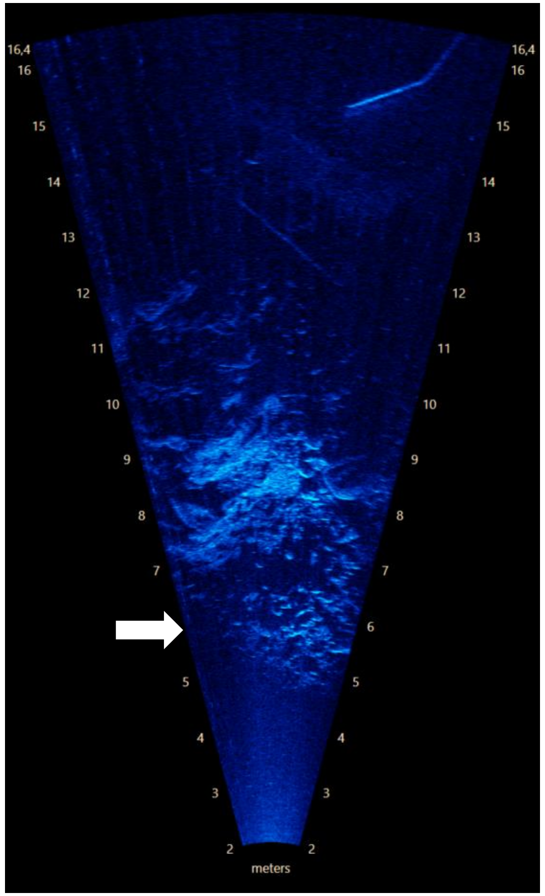
SIL





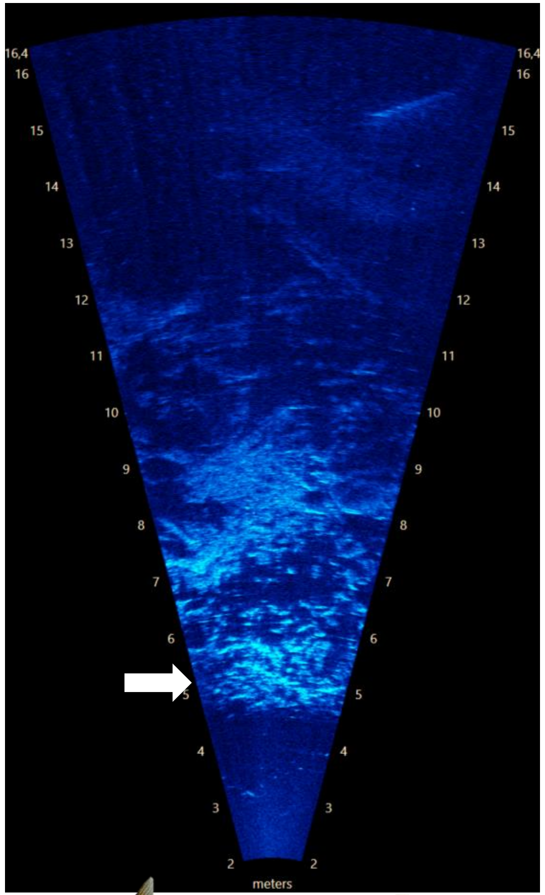
European catfish

SAT



Atlantic salmon

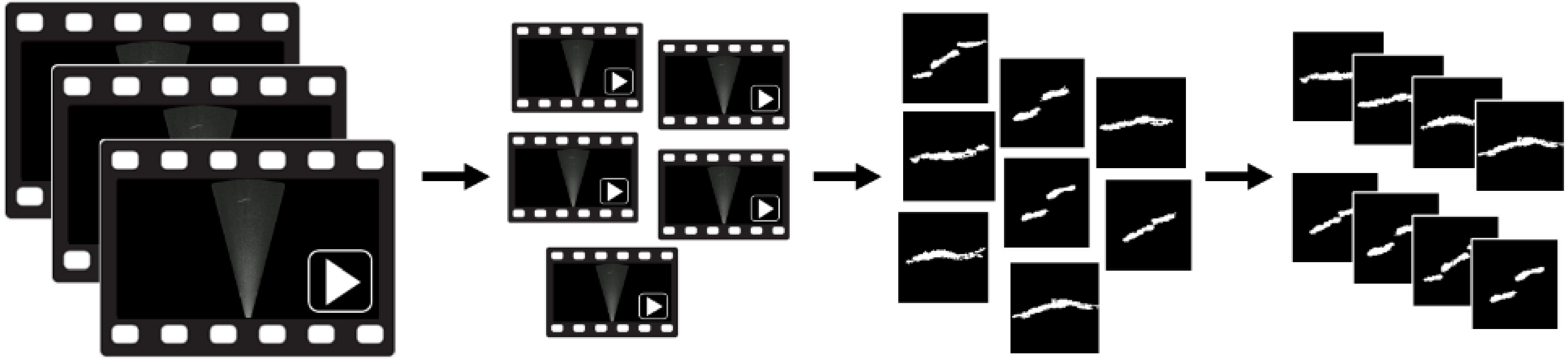
CYP



Common bream

Common carp

2- Detect and track => EELS



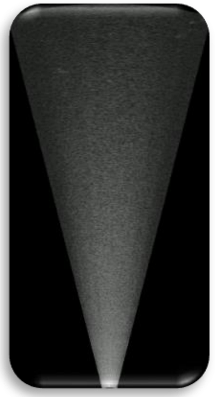
Acoustic videos | Sequences of interest | Images of objects of interest | Target's detection

- Sorting of the data of interest among the high amount of acoustic videos
- Pre-process the acoustic videos for species identification

Morphological & Motion analysis

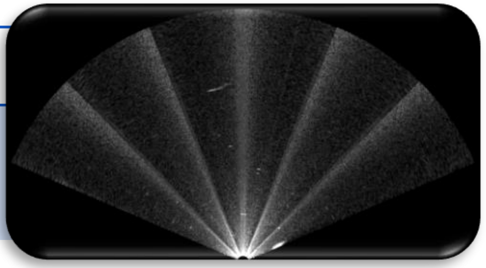
- Performance obtained on the **whole anguilliform-specific dataset of Mauzac** using ARIS camera:

Number of eels	Recall	Precision
753	73.8%	83.5%



- Comparison of the method performance on **4 common days of records** from the ARIS and the BlueView cameras of Mauzac, at the **same location and similar covered range**:

	ARIS	BlueView
Number of eels (Operator truth)	56	197
Recall	67.9%	70.1%
Precision	74.5%	72.6%



PLOS ONE

RESEARCH ARTICLE

Automatic detection, identification and counting of anguilliform fish using *in situ* acoustic camera data: Development of a cross-camera morphological analysis approach

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Data Availability Statement: Data recorded on the site of Mauzac are EDF property and are available on request at retd-lnhe-assistantes@edf.fr. The

Abstract

Acoustic cameras are increasingly used in monitoring studies of diadromous fish populations, even though analyzing them is time-consuming. In complex *in situ* contexts, anguilliform fish may be especially difficult to identify automatically using acoustic camera data because the undulation of their body frequently results in fragmented targets. Our study aimed to develop a method based on a succession of computer vision techniques, in order to automatically detect, identify and count anguilliform fish using data from multiple models of acoustic cameras. Indeed, several models of cameras, owning specific technical characteristics, are used to monitor fish populations, causing major differences in the recorded data shapes and resolutions. The method was applied to two large datasets recorded at two distinct monitoring sites with populations of European eels with different length distributions. The method yielded promising results for large eels, with more than 75% of eels automatically identified successfully using datasets from ARIS and BlueView cameras. However, only 42% of eels shorter than 60 cm were detected, with the best model performances observed for detection ranges of 4–9 m. Although improvements are required to compensate for fish-length limitations, our cross-camera method is promising for automatically detecting and counting large eels in long-term monitoring studies in complex environments.

Introduction

Active acoustic methods are widely used to study and monitor fish in marine and freshwater ecosystems [1,2]. Acoustic devices emit acoustic waves and record the echoes reflected by

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Published: February 24, 2023
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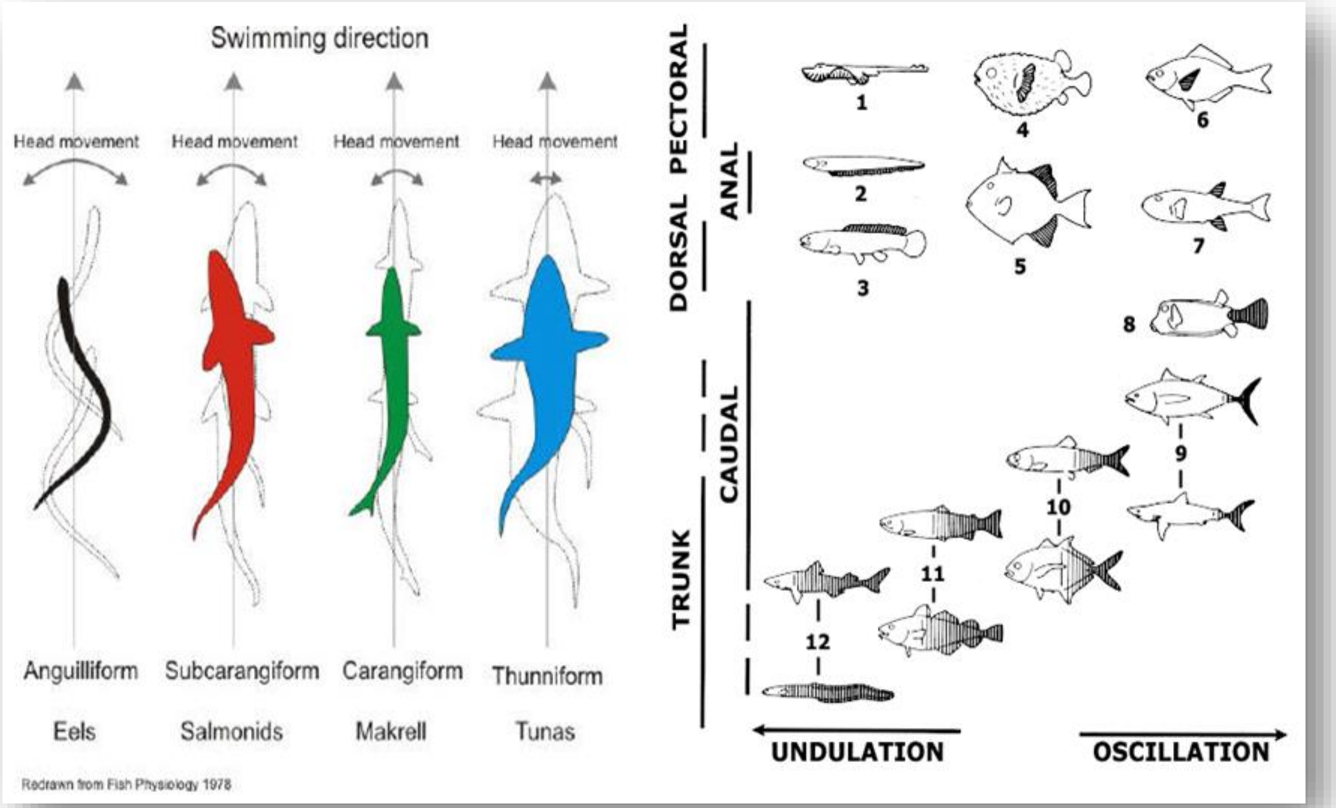
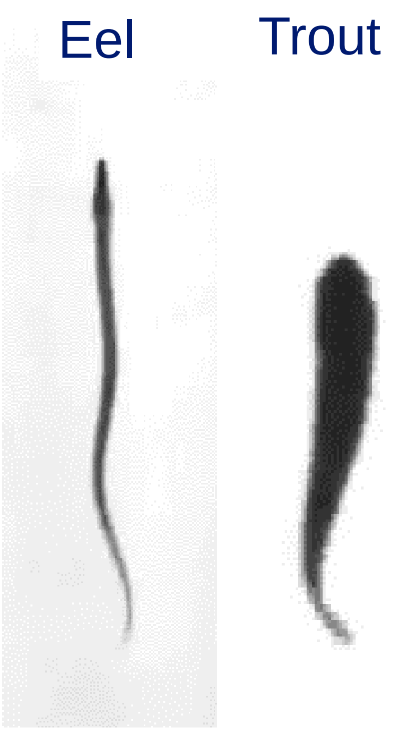
Focus on Swimming locomotion

- Swimming locomotion: how the fish deforms its body to swim



[Lindsey et al., 1978]



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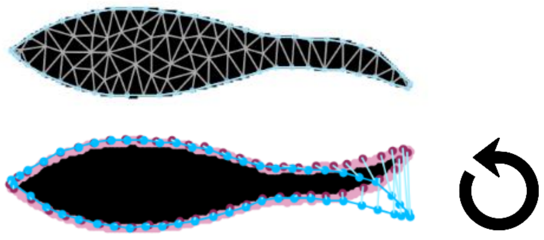
➢ Need to monitor and quantify the deformation over time

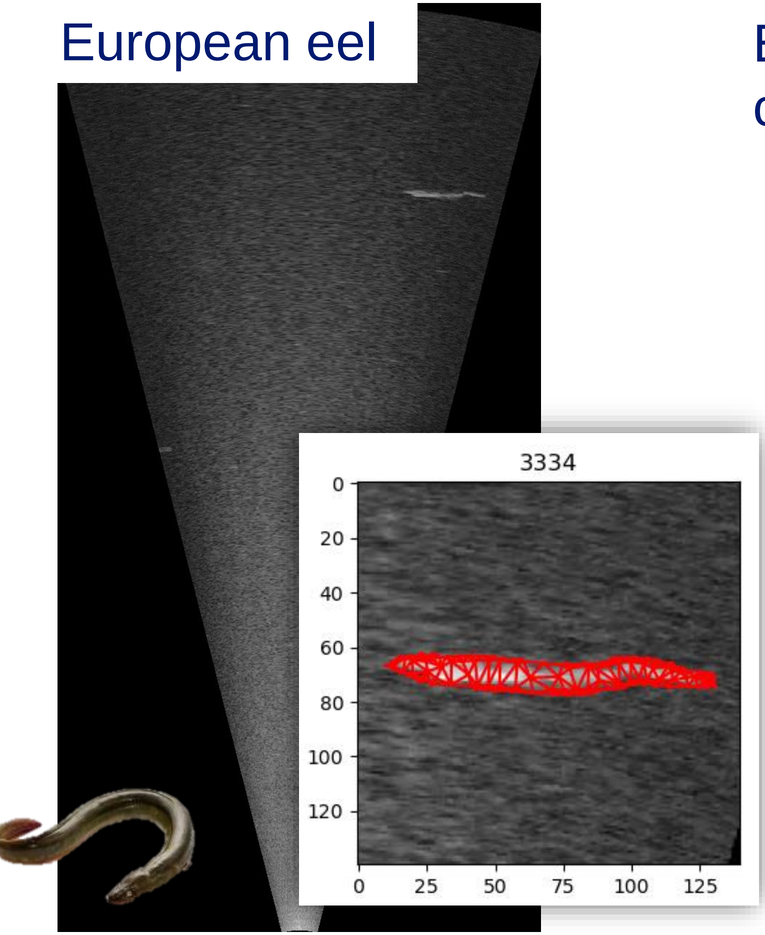
Deformable model on acoustic images

Mesh initialized for the target whole pasage

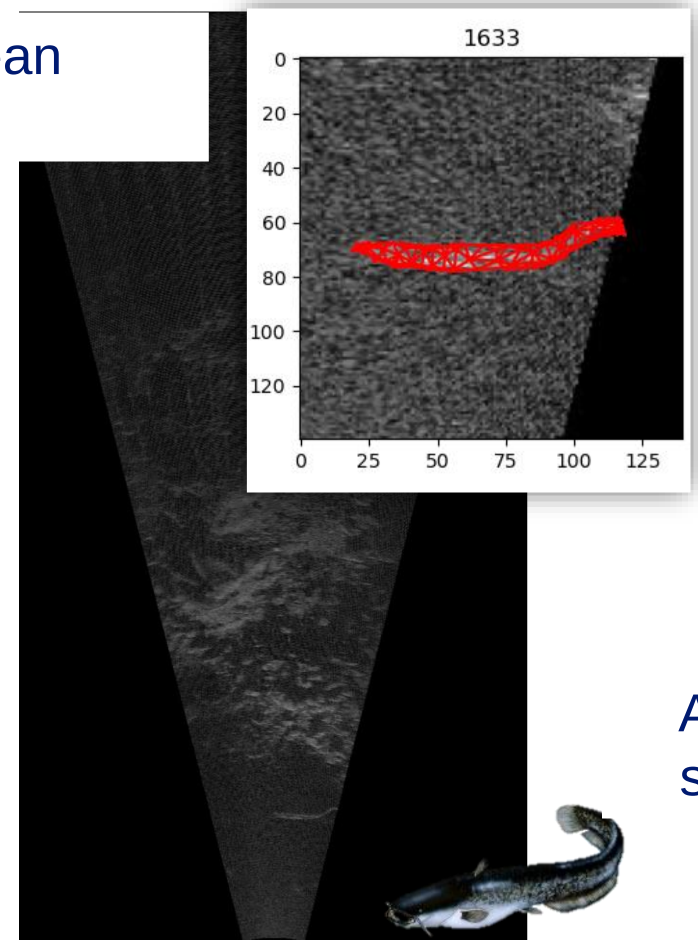
Deformation of the mesh from one detection to the next



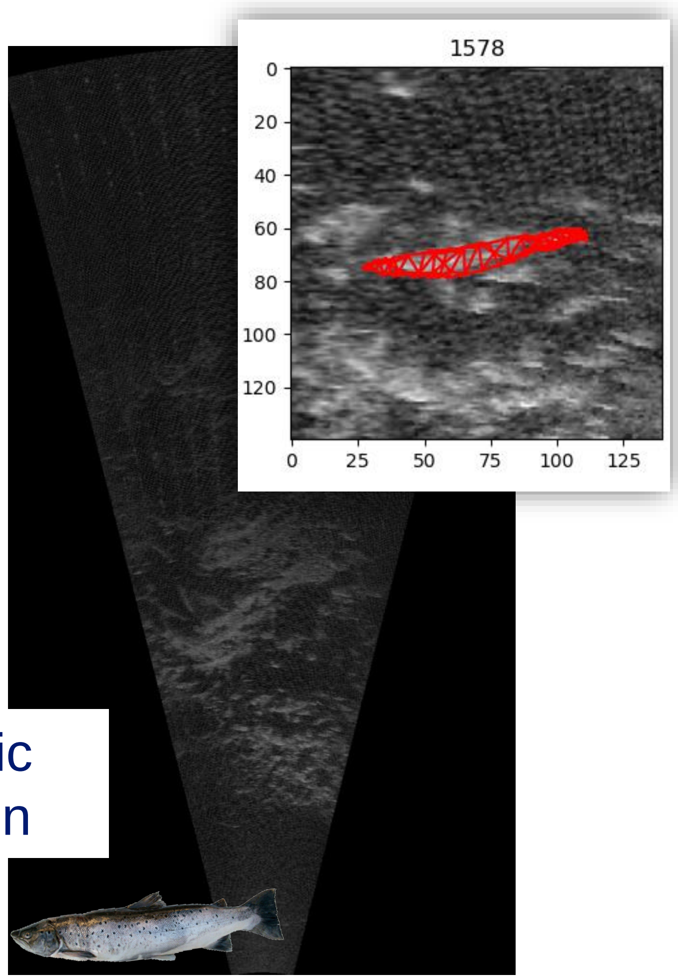
European eel



European catfish

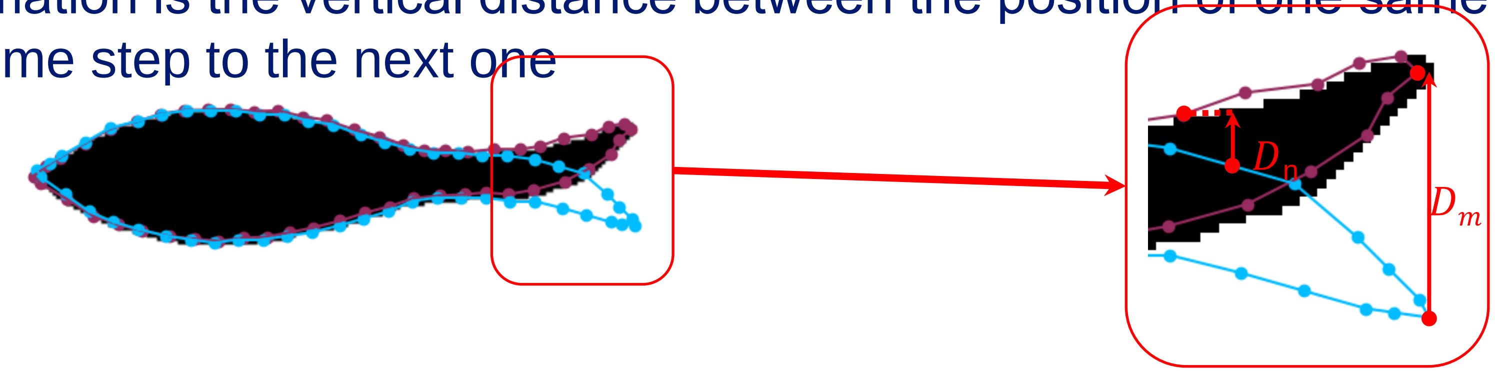


Atlantic salmon



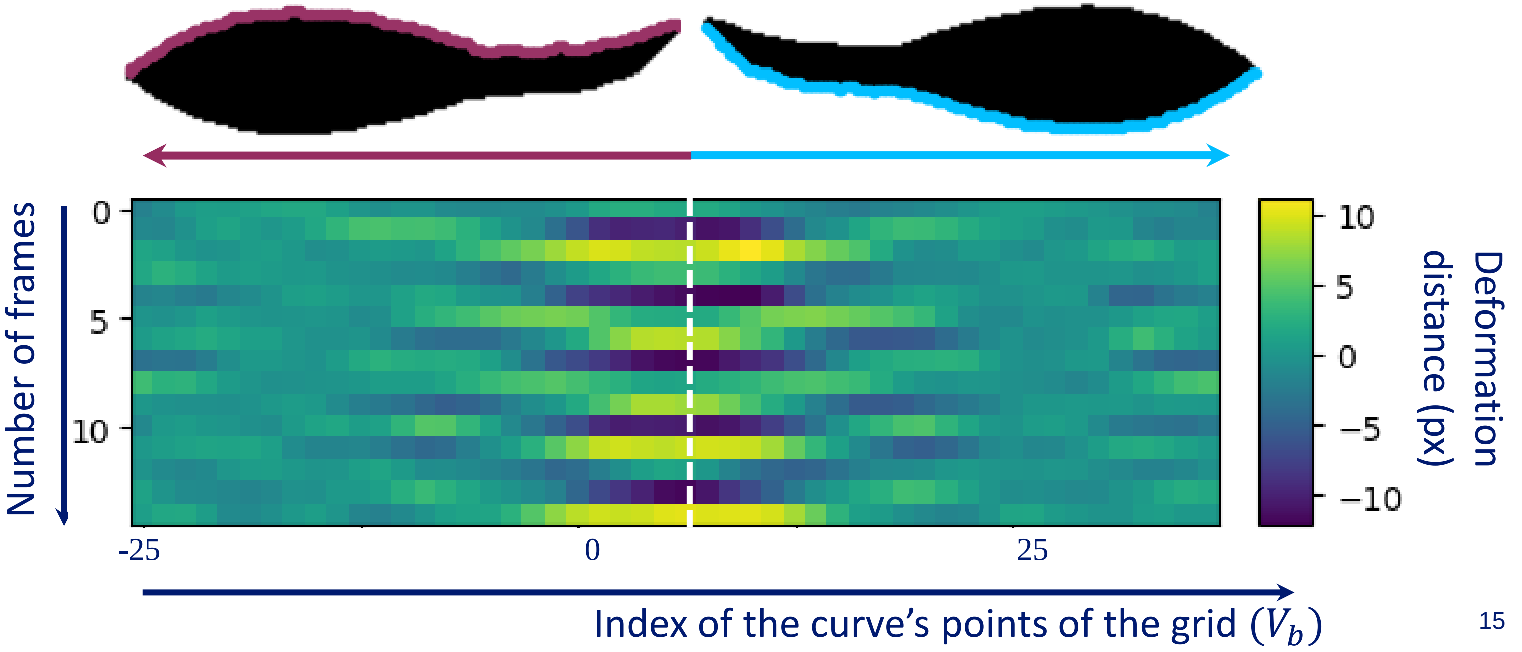
Calculation of deformation

- Rotation and translation carried out prior to the deformation calculation to get rid of the target's mouvement
- The deformation is the vertical distance between the position of one same point of the contour's mesh from one time step to the next one



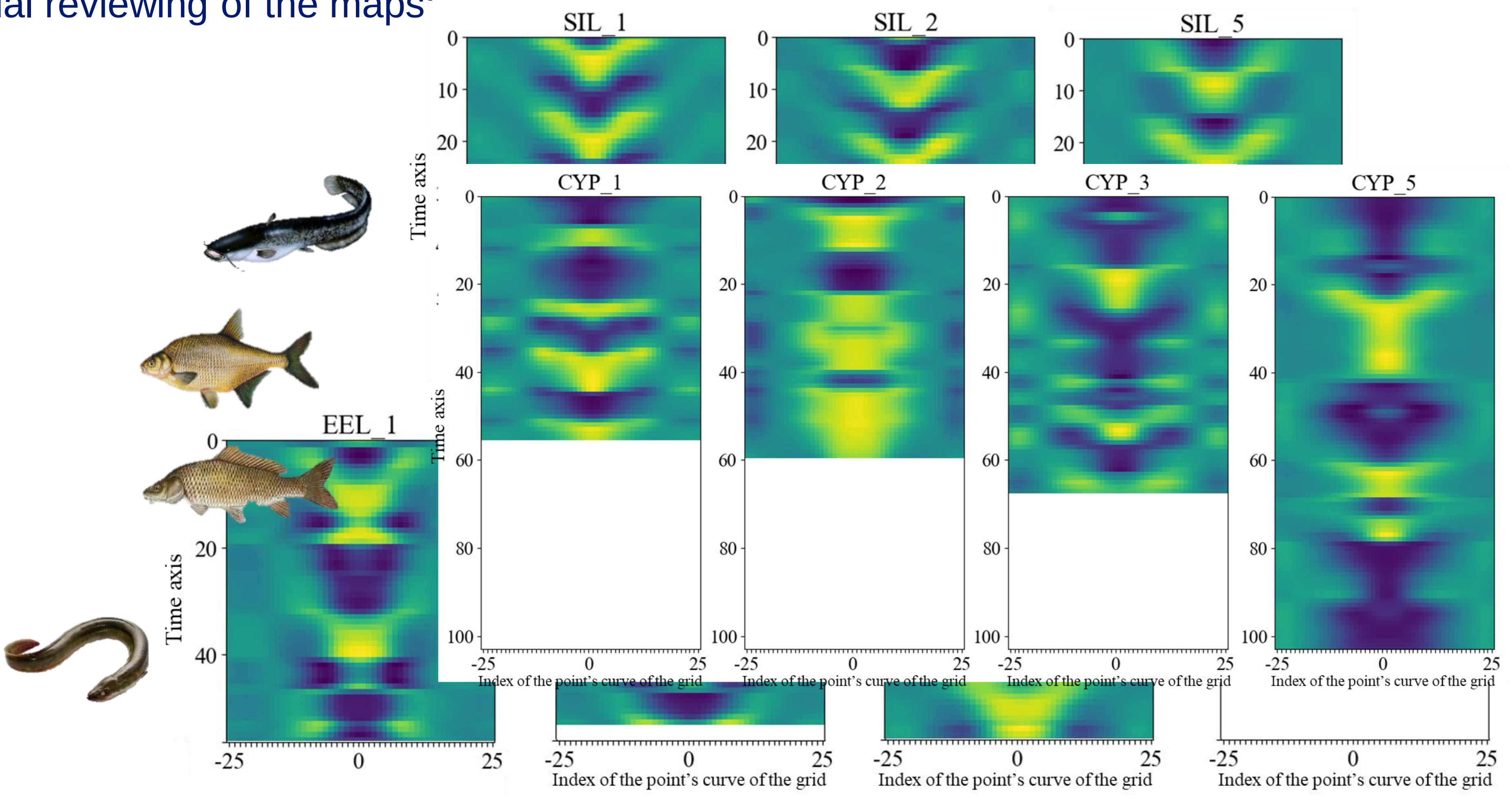
- Calculation of the deformation at each point of the contour's mesh, for each detection of the target

→ generation of map of deformation



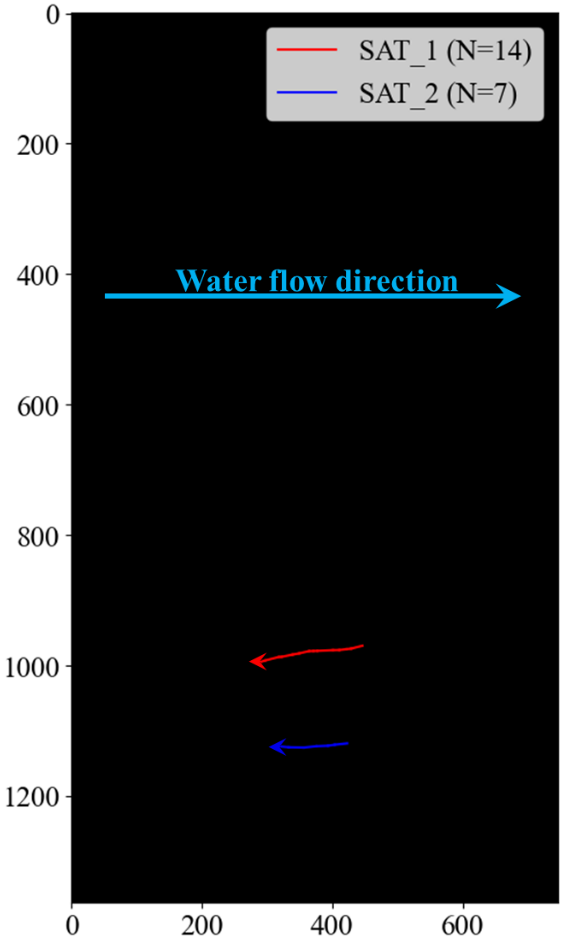
Comparison between individuals

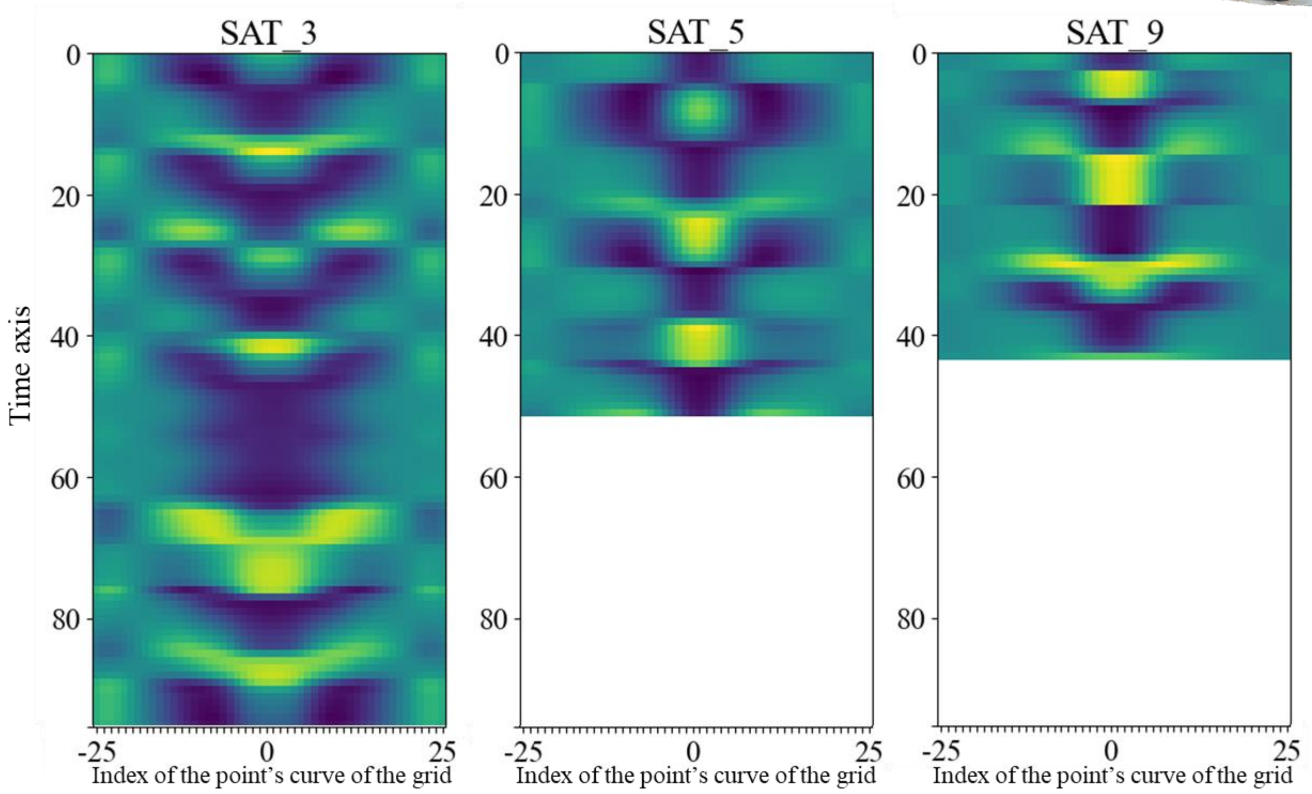
- Similarities between individuals of same species or group of species that can be observed with the visual reviewing of the maps:



Comparison between individuals

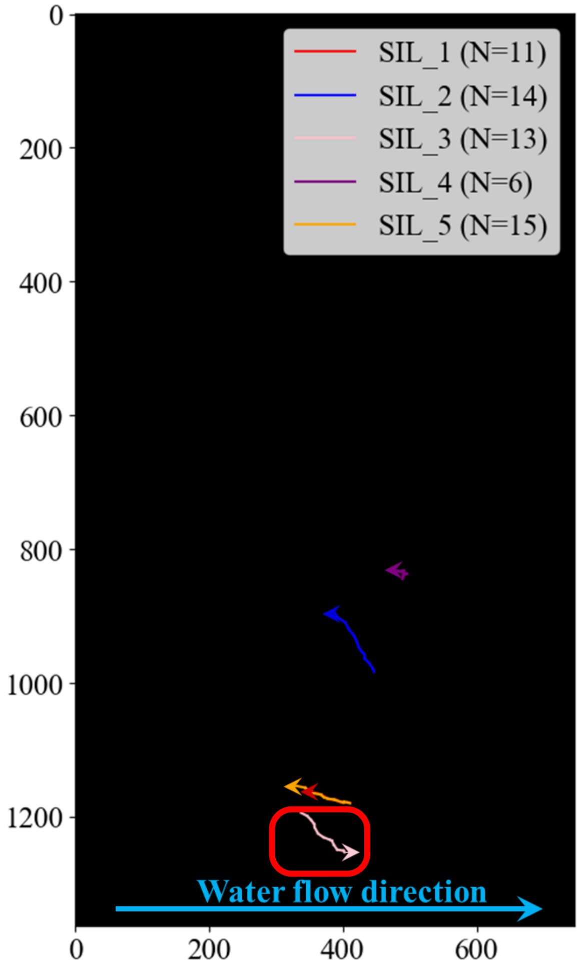
- Low similarities between the individuals of the species SAT: might be highly impact by the fish trajectories, much more heterogenous

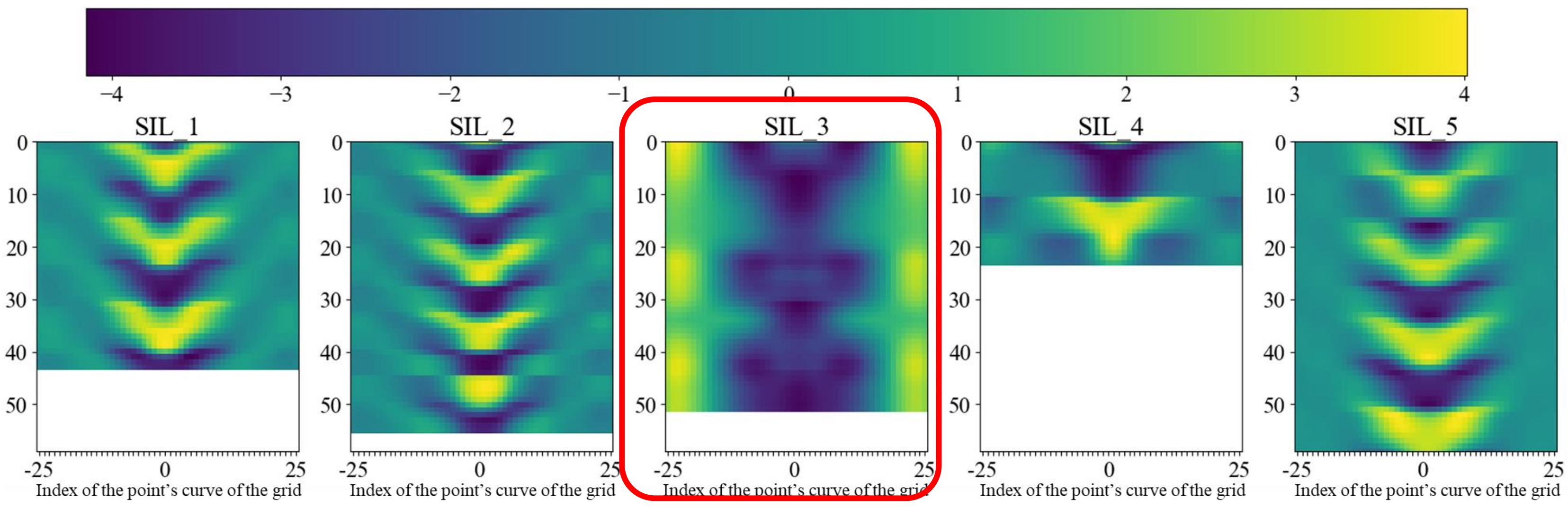




Impact of the fish’s direction

- High dissimilarity observed between individuals of the same species depending on their swimming direction:

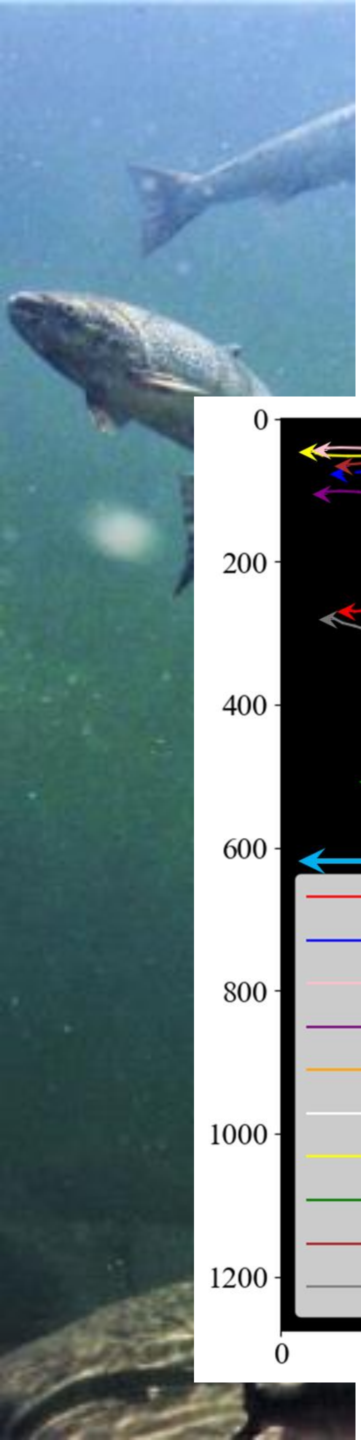


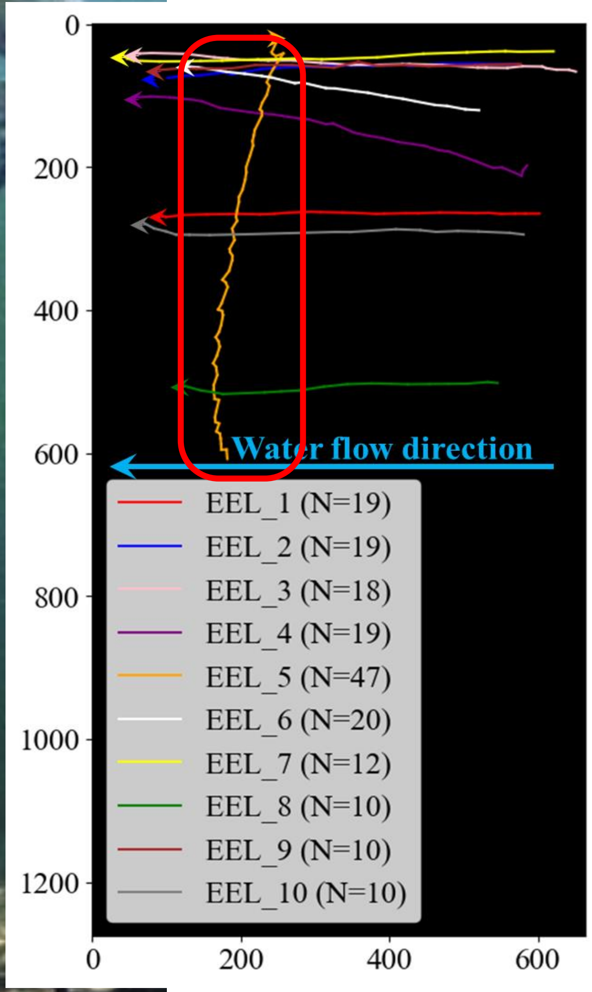


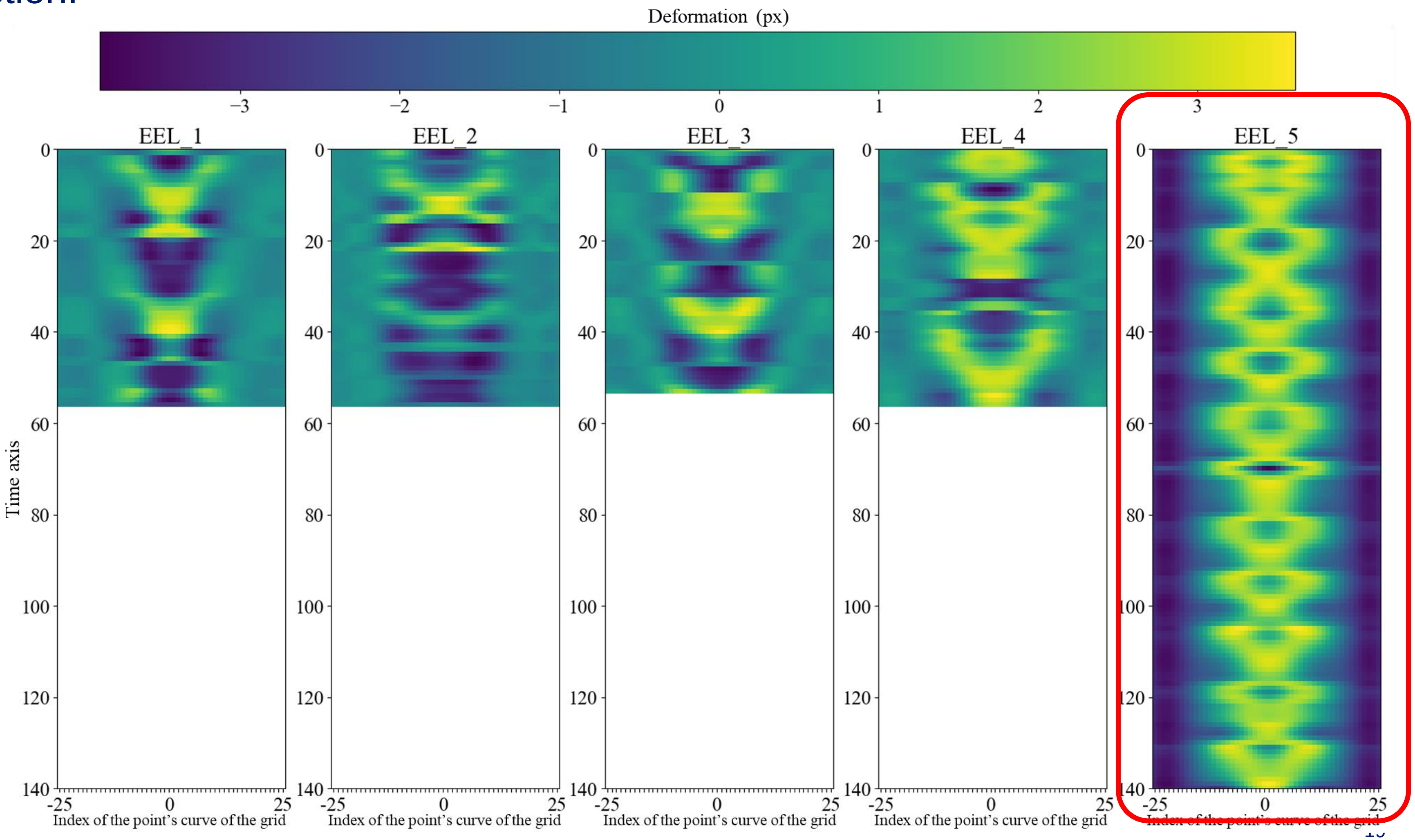
Downstream direction

Impact of the fish's direction

- High dissimilarity observed between individuals of the same species depending on their swimming direction:







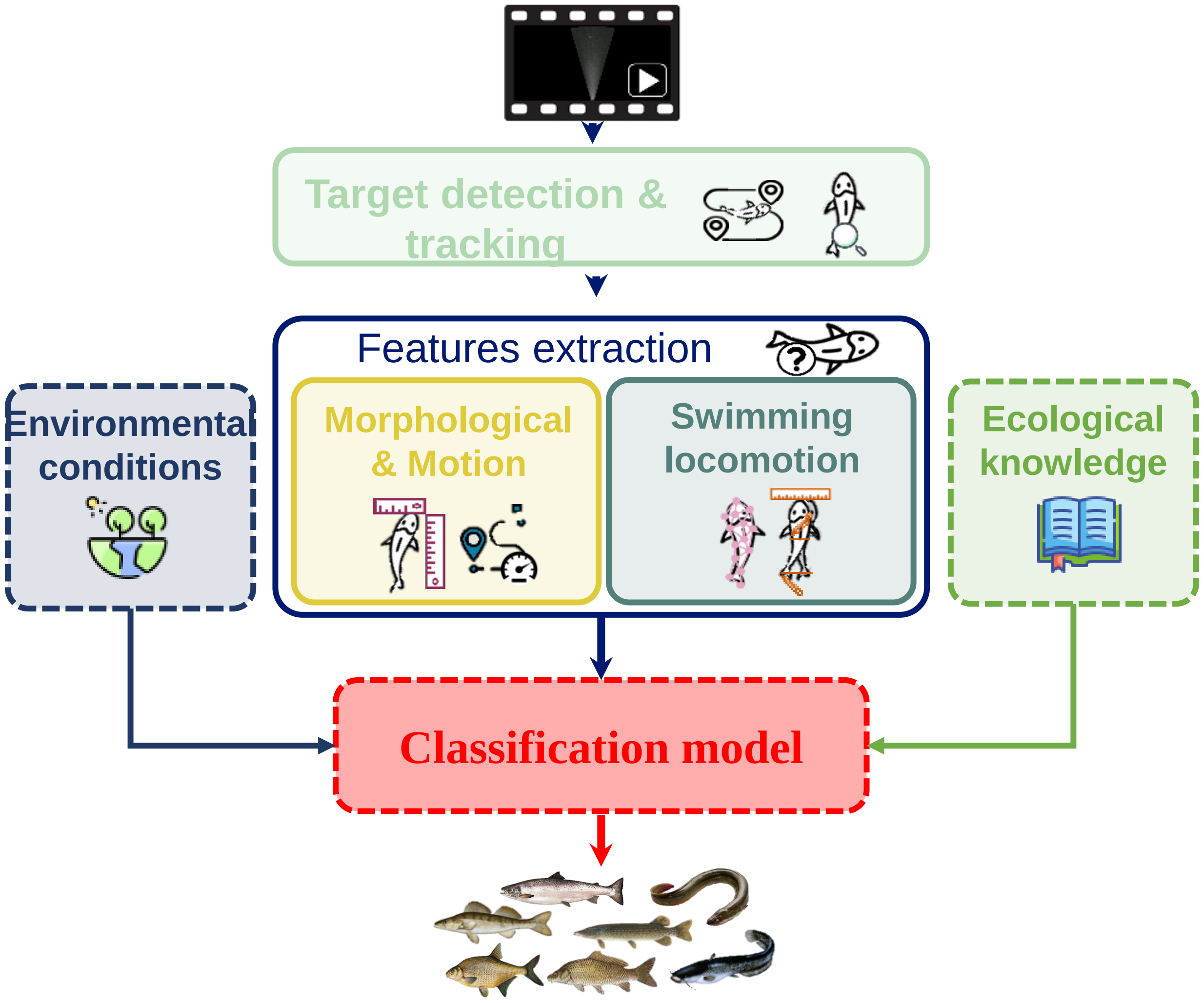
Downstream migration

Perspectives

- Design a classification model to automaticaly identify species from the whole set of information

- Consider **environmental conditions** (water flow…) and **ecological knowledge** (migration season, behaviour,…)

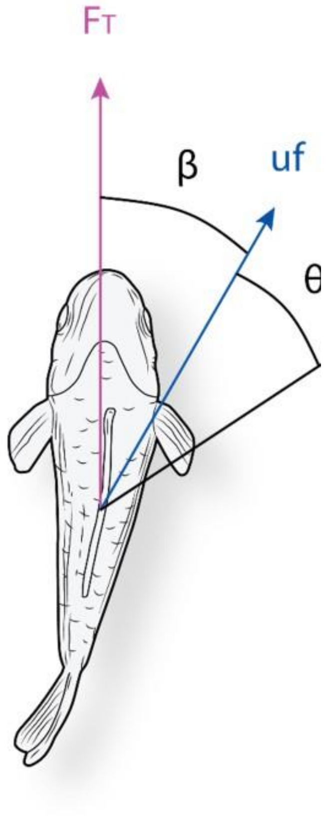
- Offer to go further in the analysis of fish passages with the study of swimming behaviour (predation, active swimming, …)



Modélisation trajectoire de nage

dévalaison des smolts

MODÉLISATION DU COMPORTEMENT DES SAUMONS ATLANTIQUES JUVÉNILES À L'APPROCHE D'UN OUVRAGE HYDROÉLECTRIQUE



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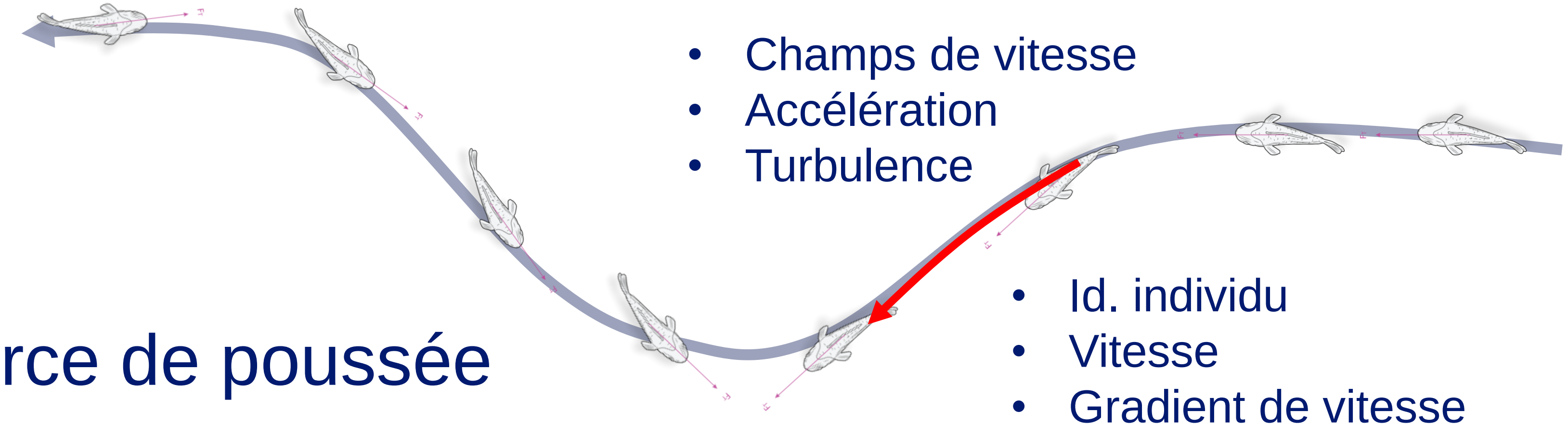
Funding
EDF R&D with CIFRE funding

Journées Télémétri

Hypothèse



- Champs de vitesse
- Accélération
- Turbulence

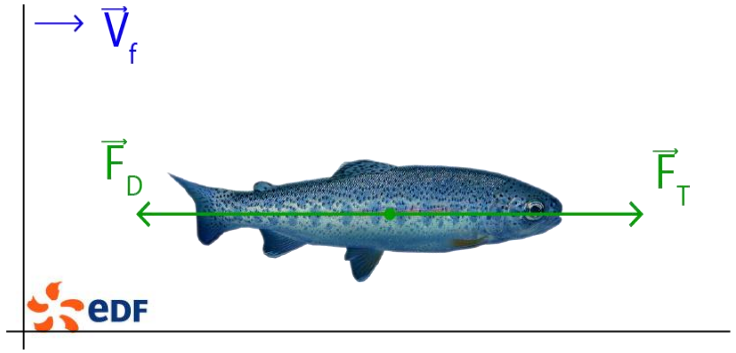
- Id. individu
- Vitesse
- Gradient de vitesse

=> La force de poussée

A partir du couplage entre CFD et télémetrie, nous cherchons à caractériser le comportement de nage des smolts => Force de poussée **(movement capacity)**

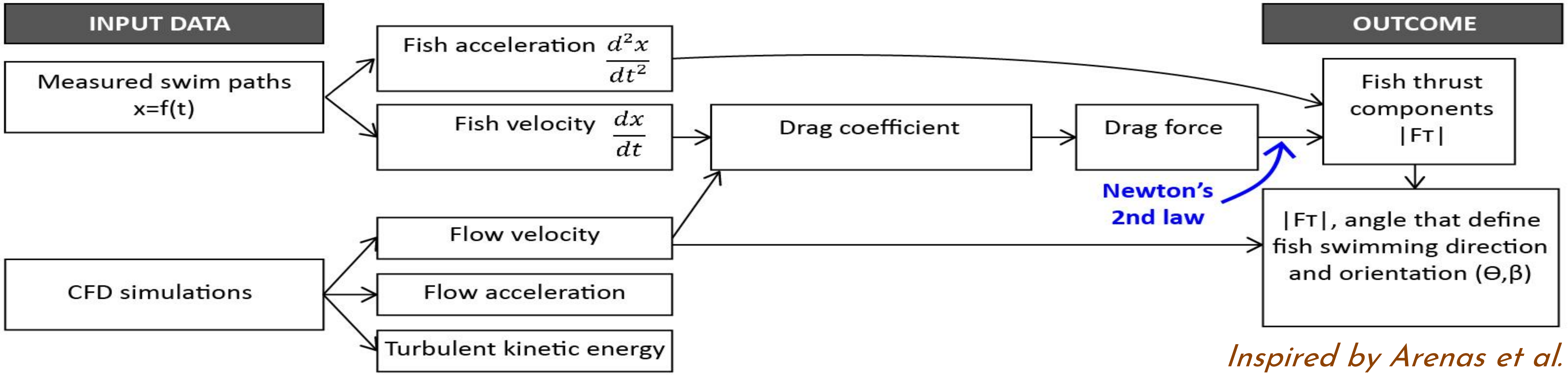
Résoudre la seconde loi de Newton: x(t) est la position à l'instant, t

$$m\frac{d\vec{x}(t)^2}{dt^2} = \vec{F}_T(t) + \vec{F}_D(t)$$

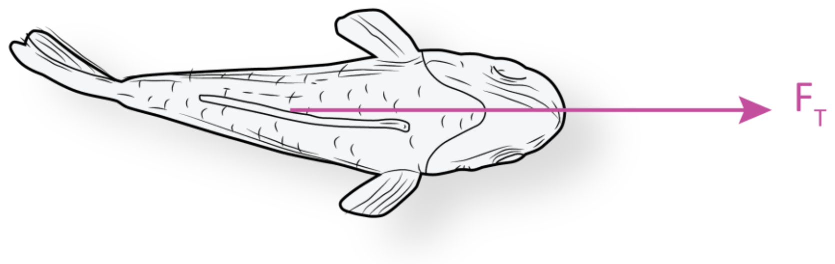


Où, m_f (kg) est le poids du poisson $\vec{F}_T$ (N) la force de poussée $\vec{F}_D$ et la force de trainée

Approche Méthodo.



Inspired by Arenas et al. 2015



- Une force de poussée

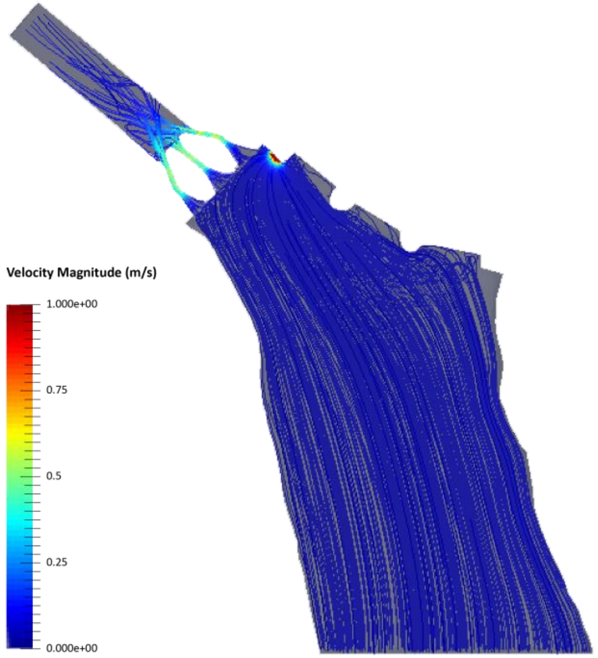
- Une orientation par rapport au sens de l'écoulement du fluide

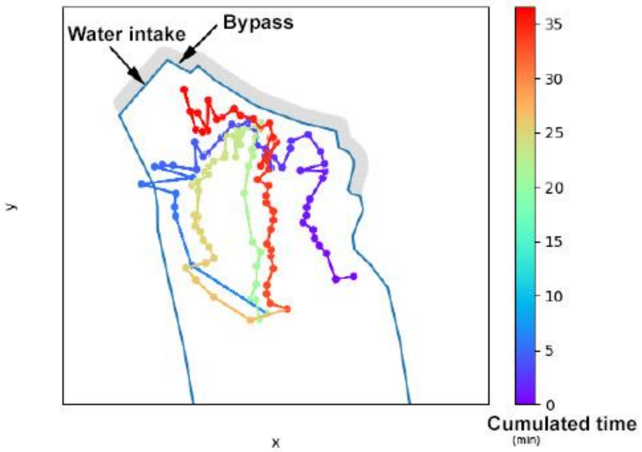
Simulation numérique CFD (Poutes 2017)

Contrasting intensities of hydraulic conditions

Low hydraulic conditions

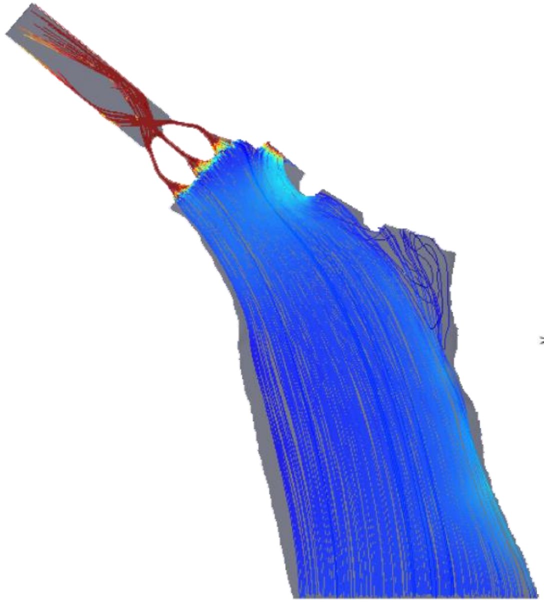
Q_{inflow} = 7, $Q_{turbined}$ = 2 m^3/s
Mean flow velocity = 1,6 cm/s

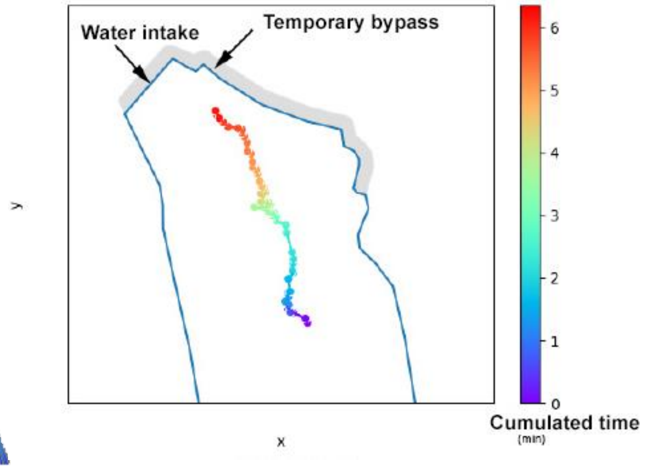




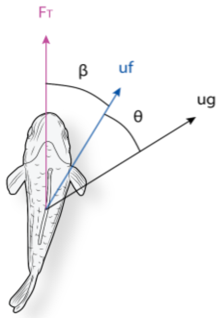
« High » hydraulic conditions

Q_{inflow} = 40, $Q_{turbined}$ = 27 m^3/s
Mean flow velocity = 17 cm/s





Analyse des comportements de nage



How do these hydraulic conditions intensities influence the smolt swimming behavior?

- **Low hydraulic conditions (uf, af, TKE)** :

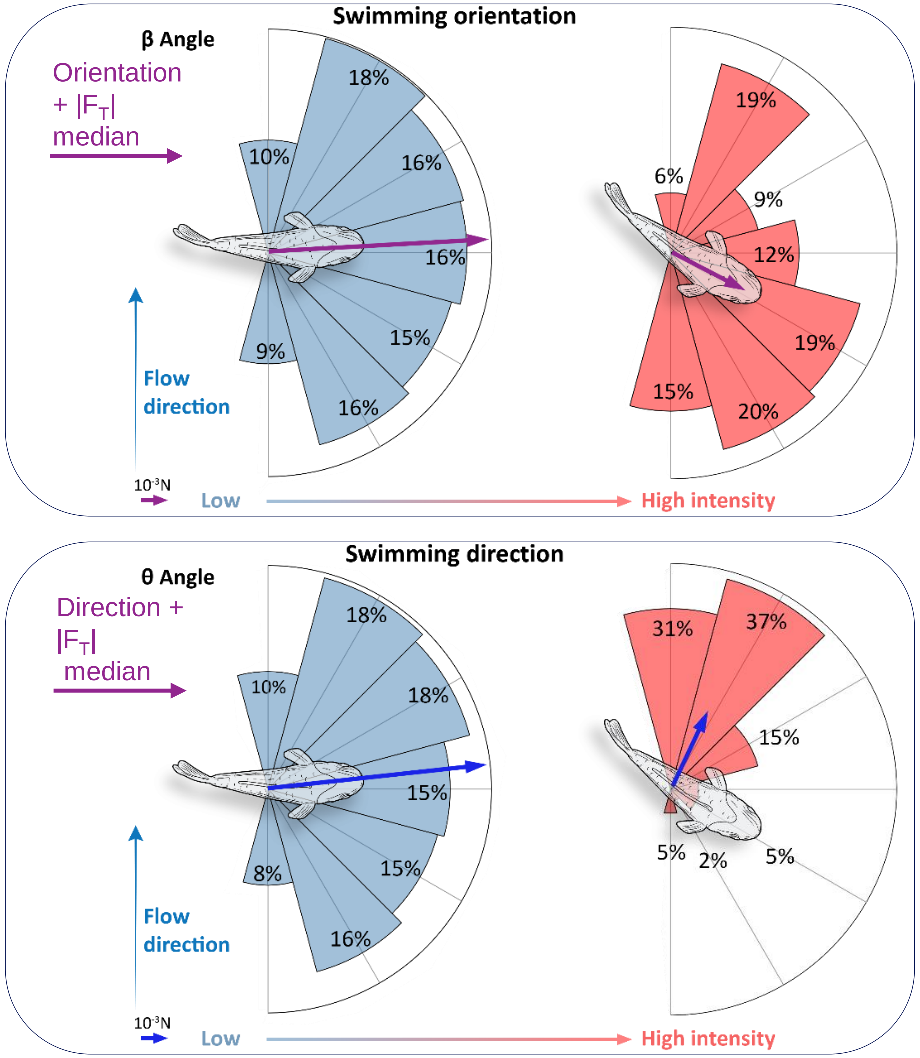
  The smolt has no preferred orientation or swimming direction.

  High intensity of thrust force **(burst)**.

- **High hydraulic conditions (uf, af, TKE) :**

  The smolt moves in the direction of the flow, head upstream: controlled drift.

  Low thrust force intensity **(endurance)**.

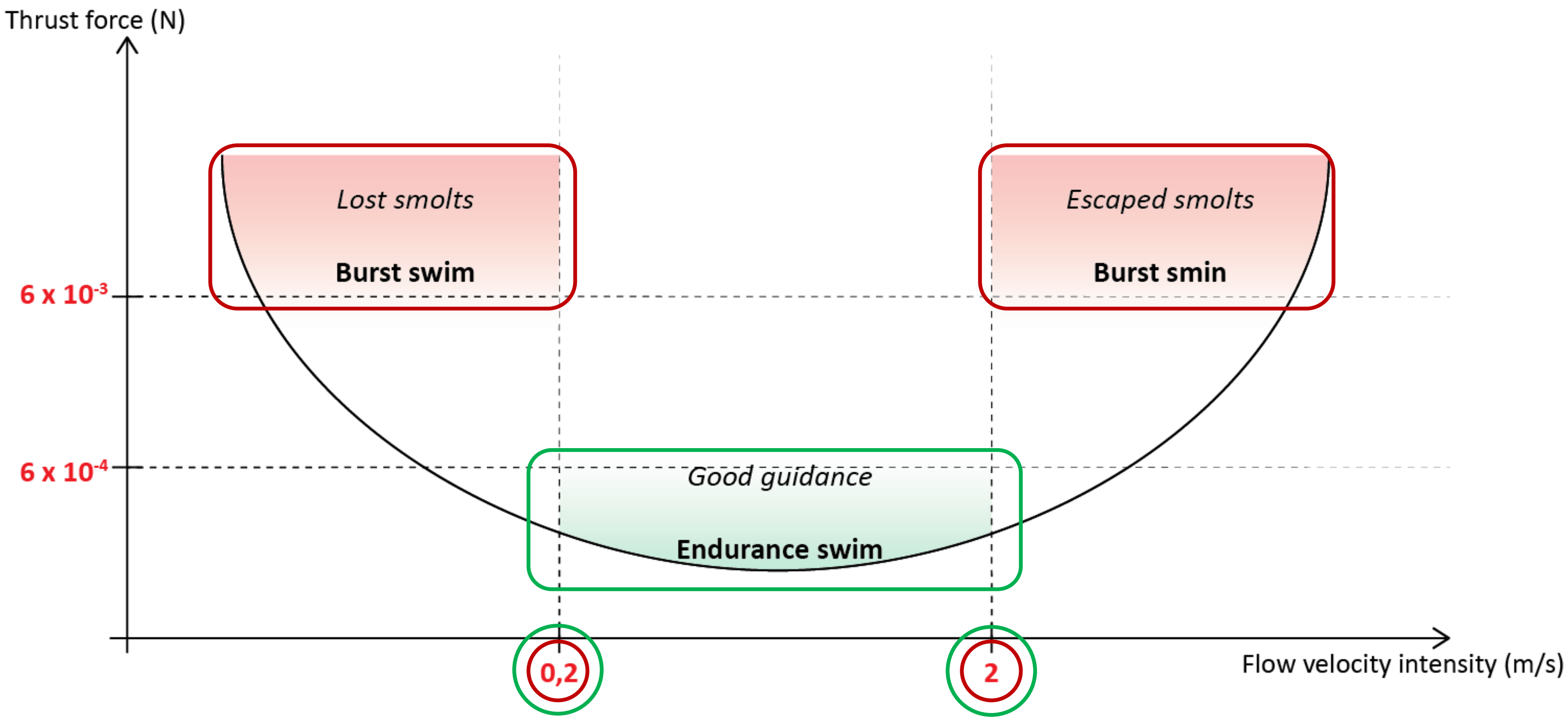


Ben Jebria et al., 2021

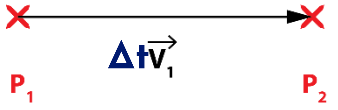
Analyse des comportements de nage

- Most studies analyzing smotls behavior are conducted in large structures with very high flows (Arenas et al., 2015; Enders et al. 2012; Johnson et al., 2009).

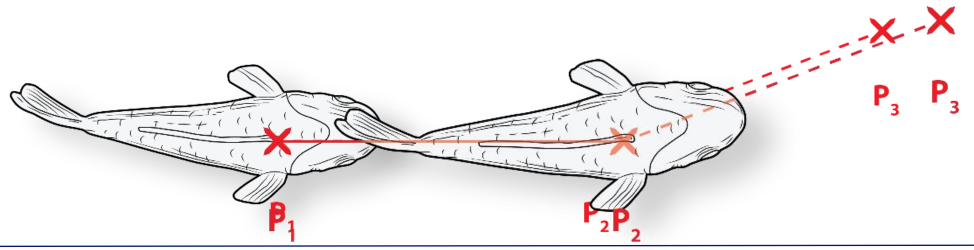
- **At Poutès, the flows are of very low intensity. Even for our high flow velocities.**



Modélisation des comportements de nage



To calculate $\overrightarrow{V_1}$, we need to know :
$\|\overrightarrow{F_1}\|$ and swimming orientation at the position P_1.



$$\begin{cases} \vec{Z}_{t+\Delta_t} = \vec{Z}_t + \vec{V}(t)\Delta t & \textit{(structural equation)} \\ \vec{Z}^*_t = \vec{Z}_t + \varepsilon_t & \textit{(observation equation)} \end{cases}$$

Bio-mechanical model of smolt behavior (Newton's 2nd law):

$$\vec{V}(t+\Delta_t) = \vec{V}(t) + \frac{\Delta_t}{m}\left(\vec{F}_T(t) + \vec{F}_D(t)\right)$$

Modélisation des comportements de nage

Thrust force model F_T

$$\vec{F}_T(t) = \begin{pmatrix} \|F_T(t)\| \cos(\gamma_t) \\ \|F_T(t)\| \sin(\gamma_t) \end{pmatrix}$$

γ_t : smolt swimming **directional variation**

- **The thrust force (F_T) and the directional variation γ are conditioned by smolt swimming behavior**

3 swimming behavior : passive (C_1), endurance (C_2) et burst (C_3).

$$\|F_T(t)\| | C(t) = C_i \sim \mathcal{U}(F_{i-1}, F_i) \forall i \in \{1,2,3\}$$

$$\gamma_t | C_{t-1} \sim \mathcal{WC}\left(\mu_t, \rho_t\right)$$

Modélisation des comportements de nage

1- A model on the smolt behavioral swimming state : linking the probability of being in one of the 3 behavioral swimming states with the flow velocity

Bézier regression model

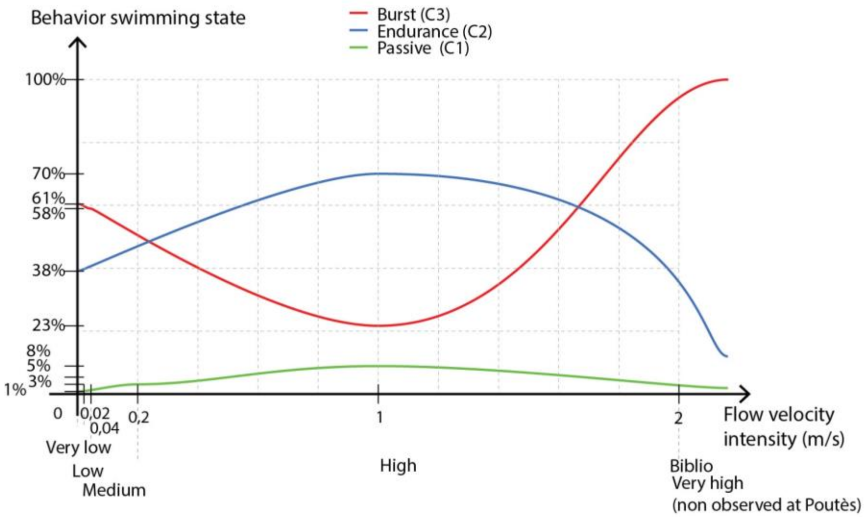
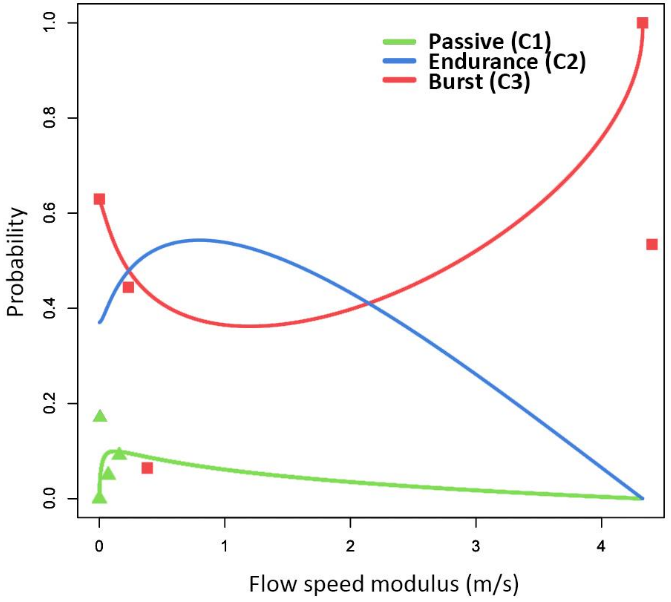


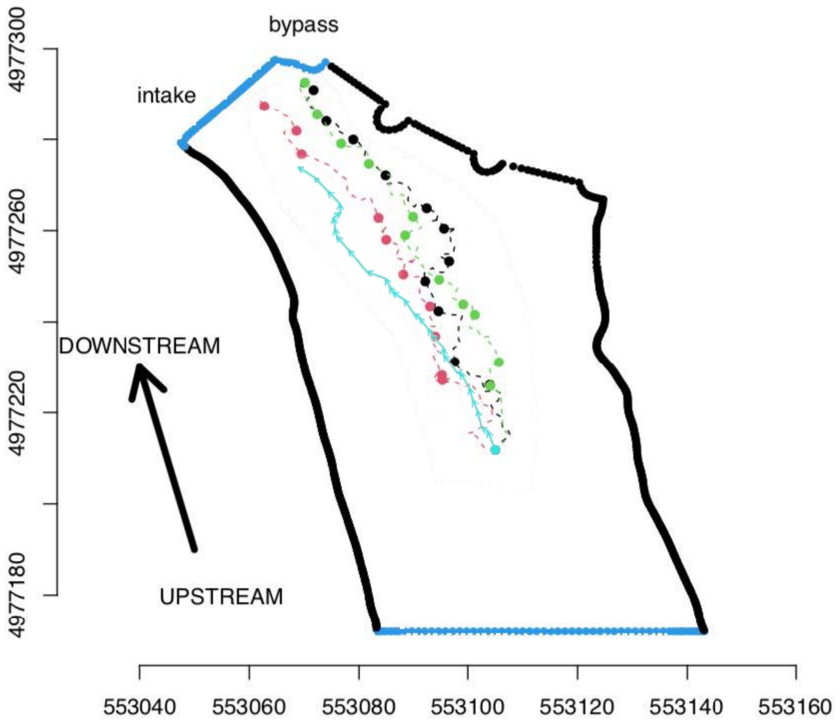
Figure showing the a priori knowledge of the probability of being in a behavioral swimming state as a function of flow velocity intensity



Example of Bézier curves with several random parameters: calibrate the model

Modélisation des comportements de nage

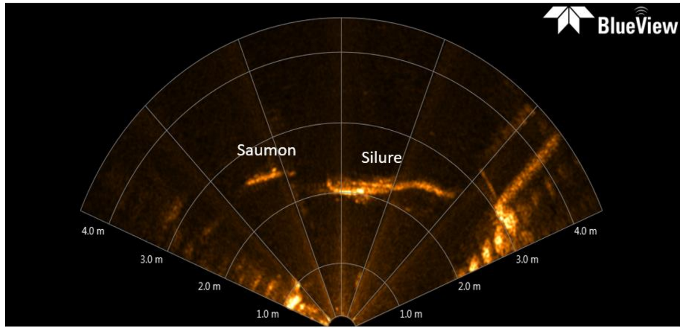
Test on real case: Simulation of 2D movements in Poutès

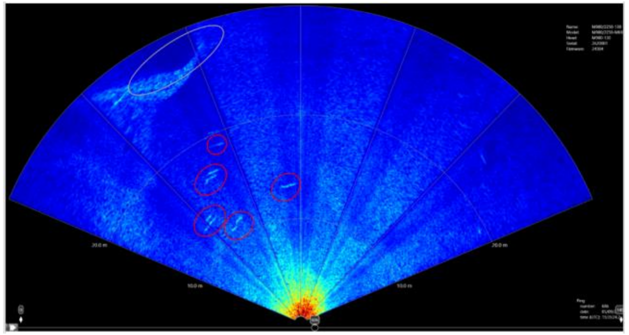


Example of trajectories measured (solid arrows) and simulated from random input parameters following the a priori distribution

Autres applications

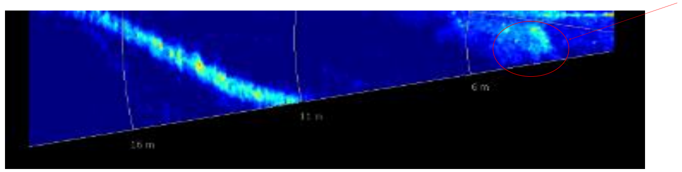
Biodiversité: dynamique de migration, présence du silure à proximité des sites hydroélectriques





Arrivées massive de colmatant au niveau des prises de centrales nucléaires

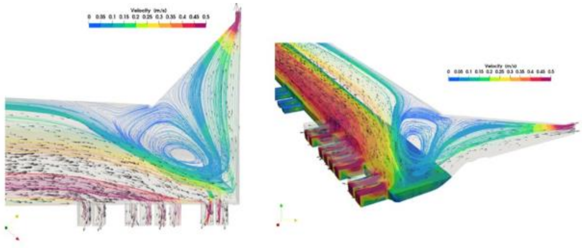
- Poissons
- Méduses
- Débris végétaux



Vision sonar des algues

Réduire l'entrainement des poisons dans les prises d'eau

Modélisation des nages en dérive



(a) Vue de dessus. (b) Vue 3D.


Merci