An Archimedes screw threesome: A study evaluating the fish friendliness of three Archimedes screw variants

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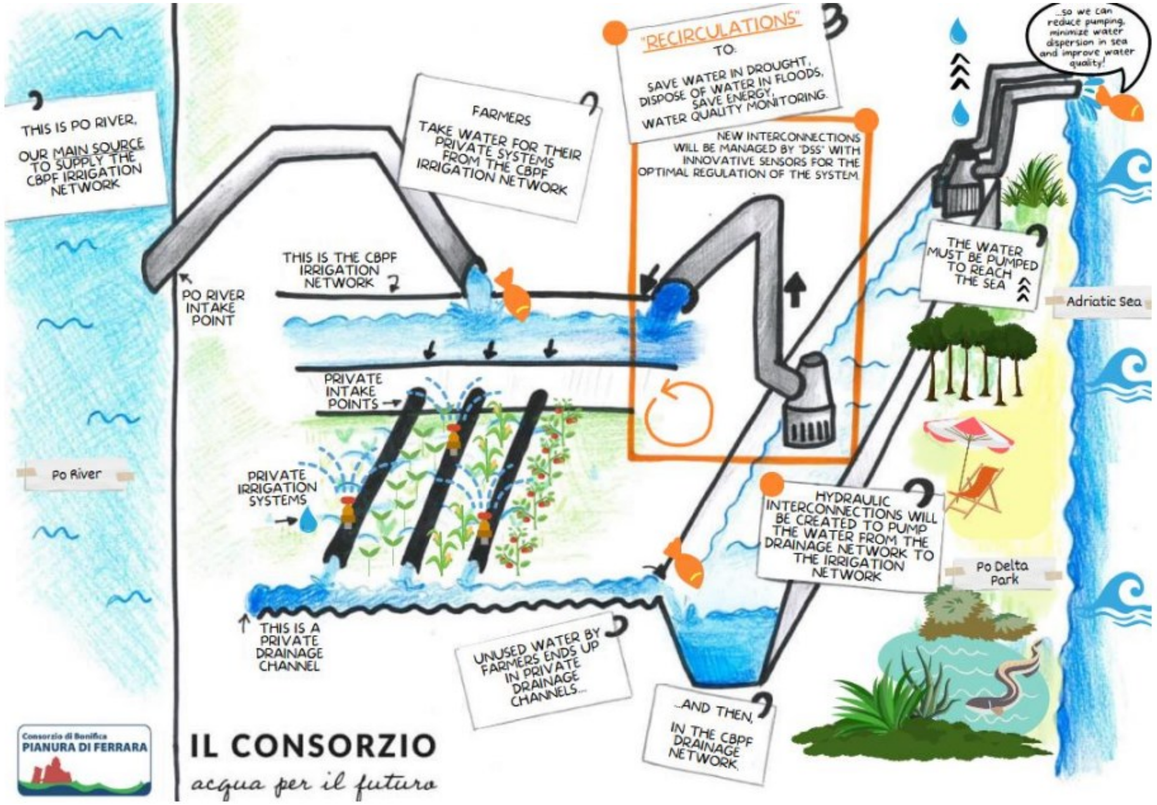
To pump or not to pump ?

- Pumps, screw pumps in particular, are used worldwide to transport water
  - → for flood control,
  - → irrigation,
  - → and water provisioning

- Due to
  - → the increase in salinization,
  - → the occurrence of droughts,
  - → and the intensity of heavy precipitation events

  the need for pumps is unfortunately increasing

- Thus, it is unlikely that pumping stations will be removed any time soon.



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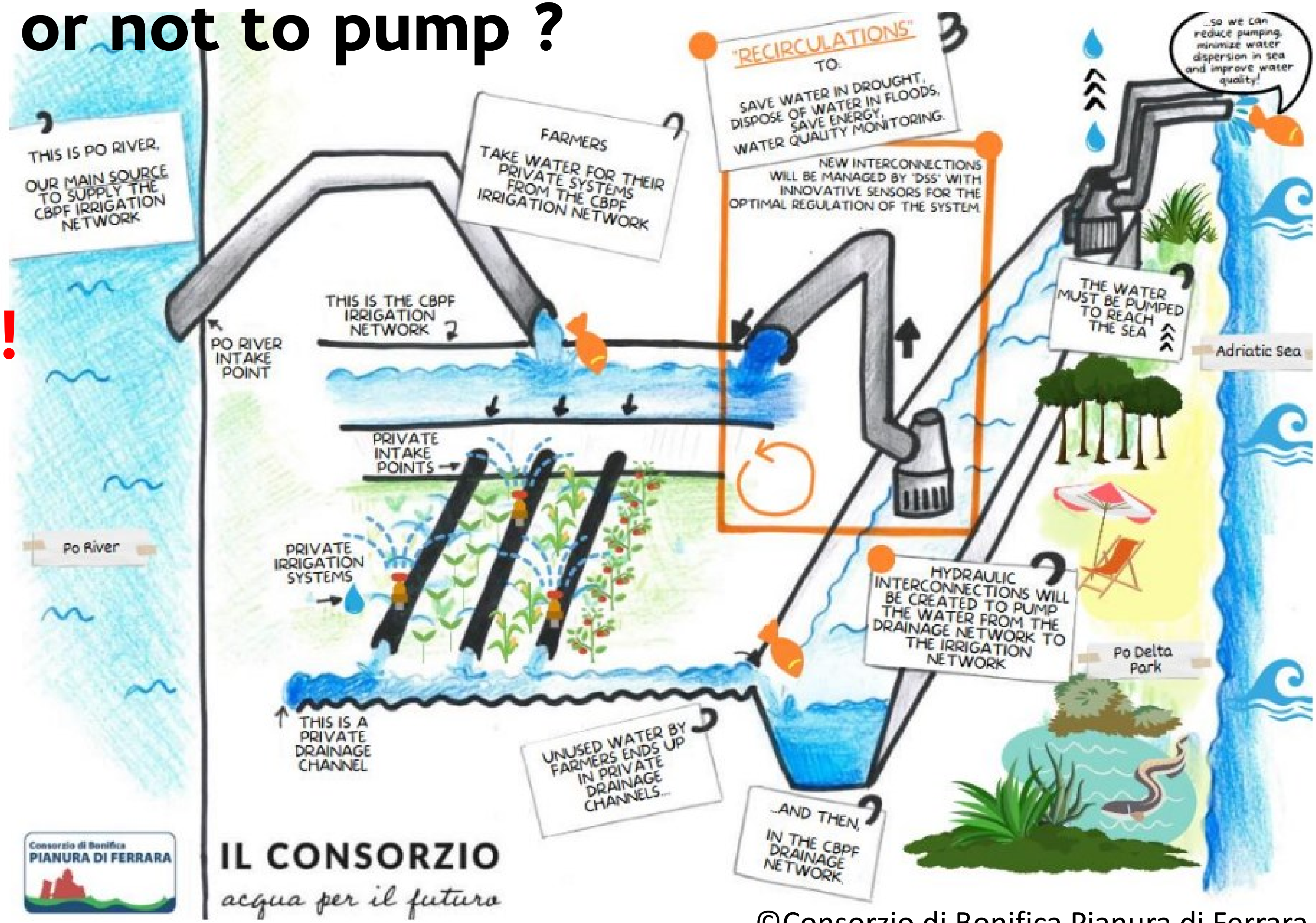
To pump or not to pump ?

To pump!



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To pump or not to pump ?

- Pumping installations will remain a constant threat to migrating fish as they block or hinder:
  - → Upstream fish migration
  - → Downstream fish migration

Pumping stations block upstream migration

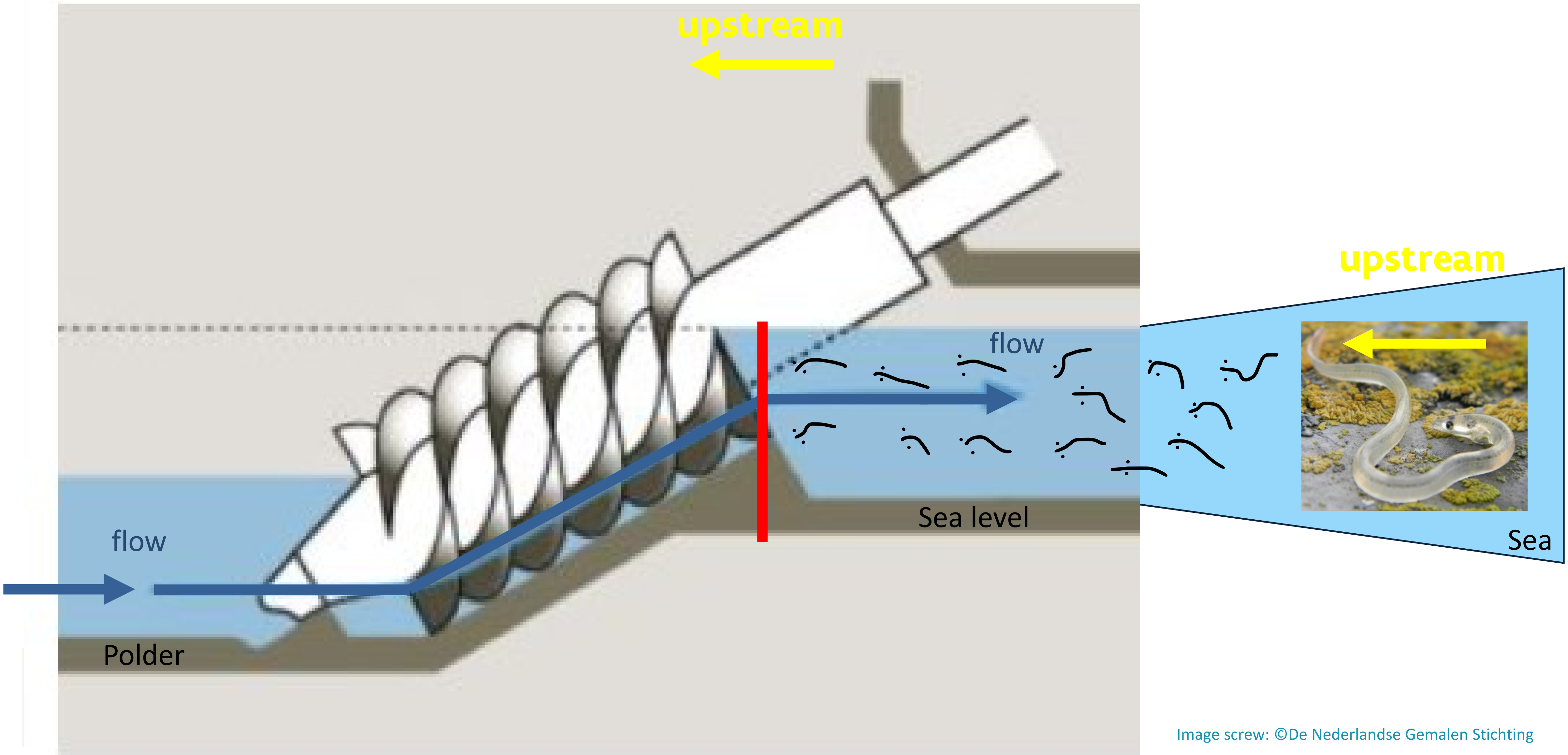
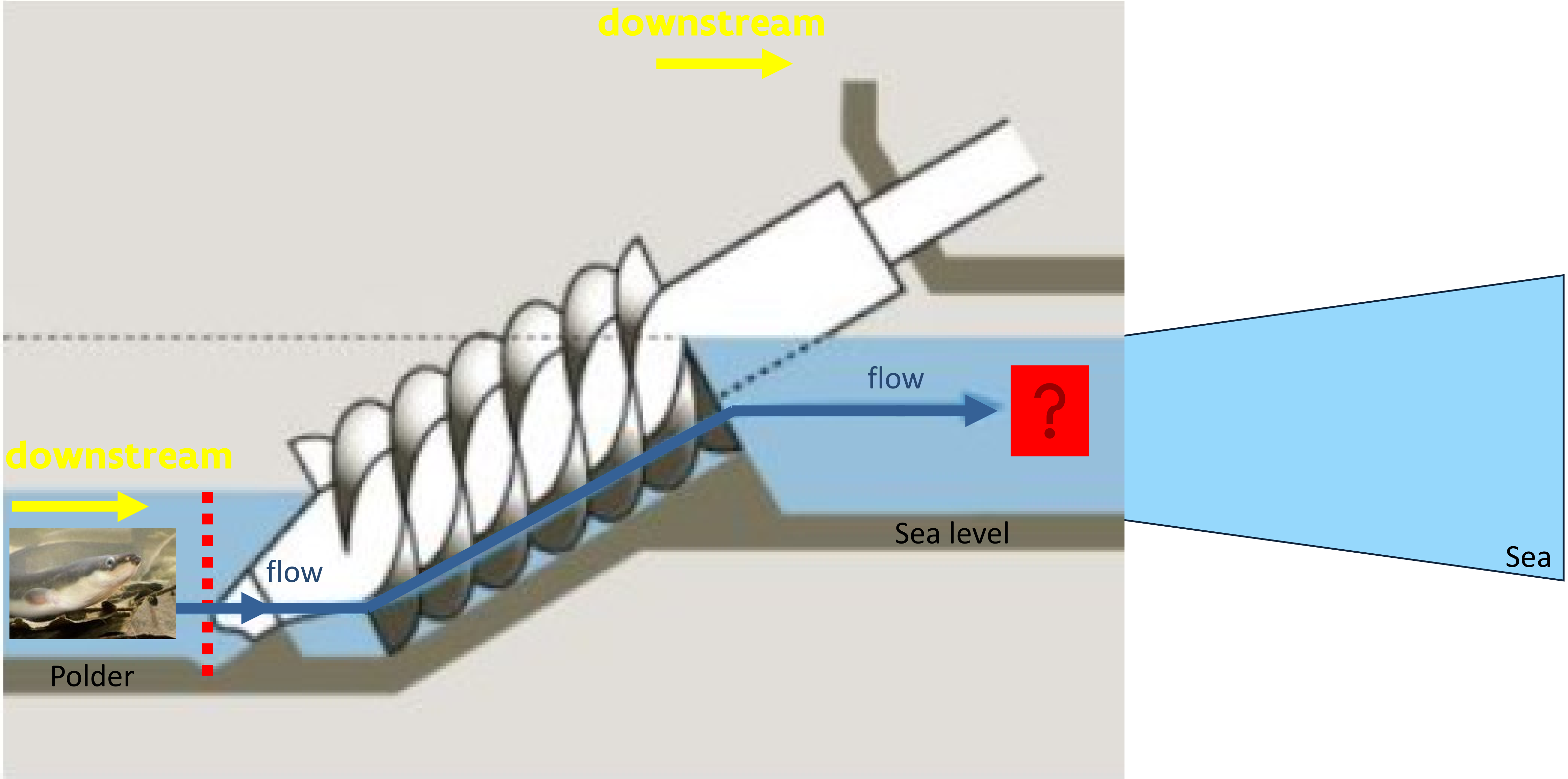


Image screw: ©De Nederlandse Gemalen Stichting

Pumping stations hinder and pose safety issues for downstream fish migration



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Research question:

What's the fish safety of 3 different screw types?

Pumping station ‘Groot Schijn’

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Pumping station ‘Groot Schijn’

Pumping station ‘Groot Schijn’

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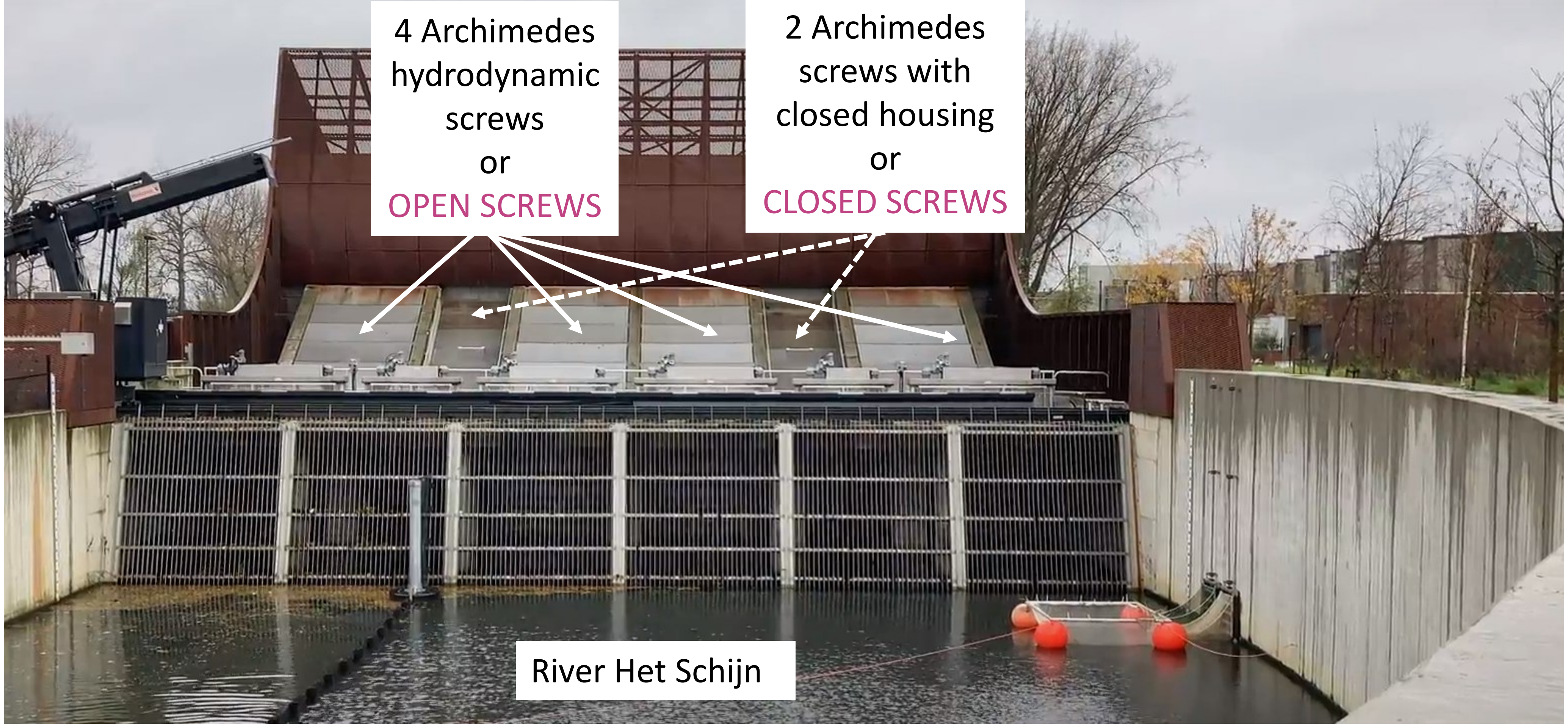
Pumping station ‘Groot Schijn’

Archimedes screw types



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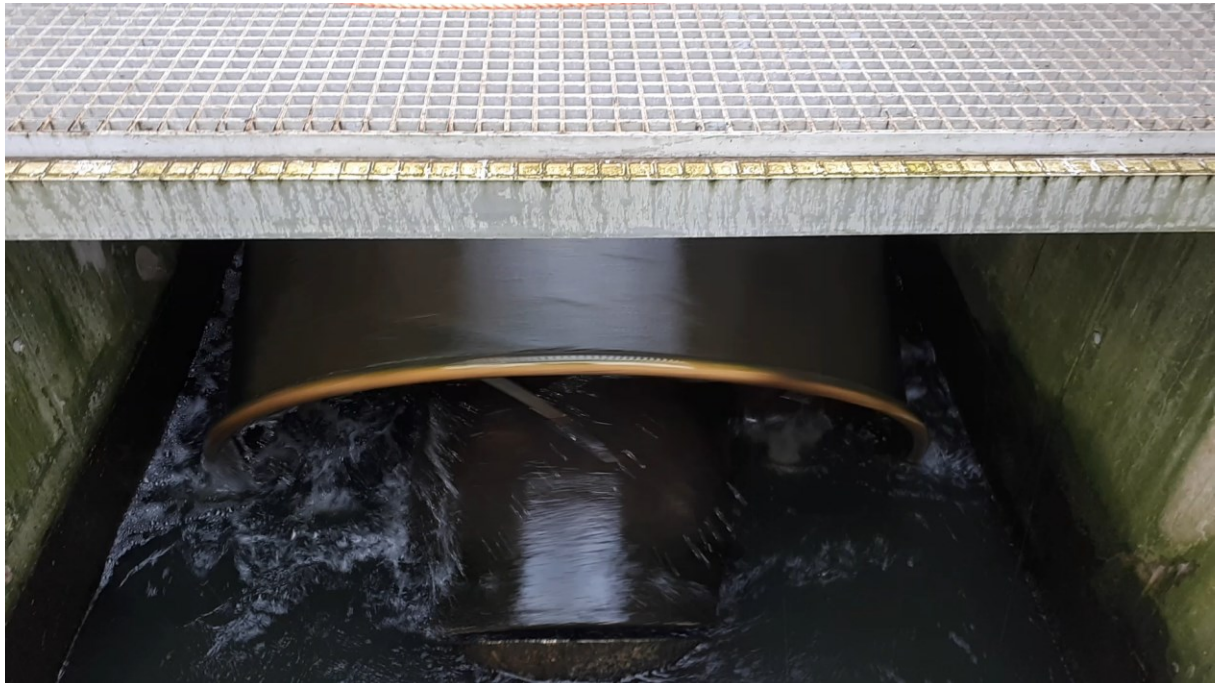
Pumping station 'Groot Schijn'

Archimedes screw types

Open screw

Closed screw



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Methods

Scenario's

Closed screw

Scenario 1: maximum rotation speed (100% or 29 rpm)
Scenario 2: reduced rotation speed (65% or 19 rpm)

Open screw

Scenario 3: maximum rotation speed (100% or 23 rpm)
Scenario 4: reduced rotation speed (65% or 15 rpm)

2021

Open screw with rubber strips

Scenario 5: maximum rotation speed (100% or 23 rpm)
Scenario 6: reduced rotation speed (65% or 15 rpm)

2022

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Three combined methods to test fish safety

1. Live fish tests

2. BDS sensors

3. Fish backpack sensors

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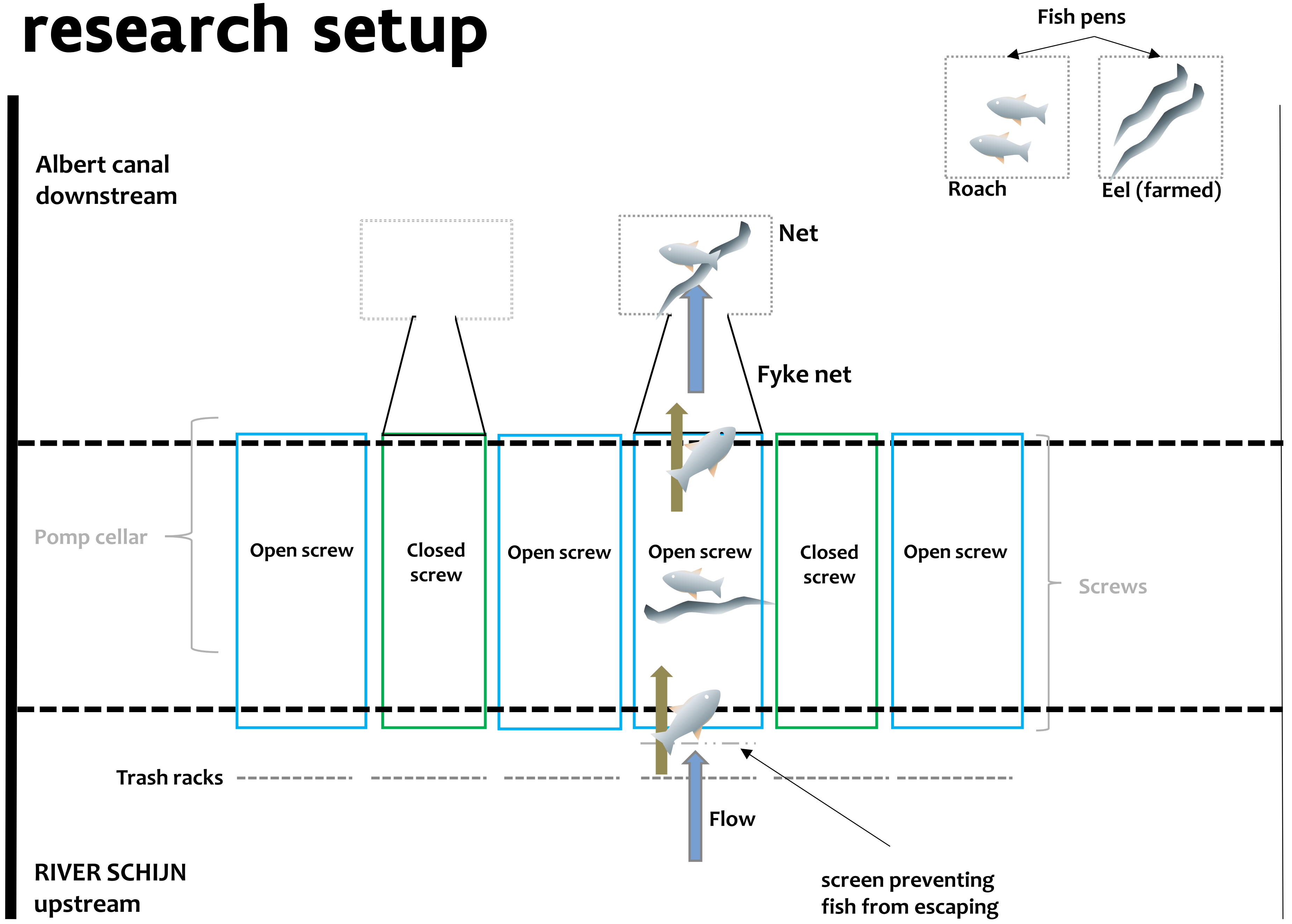
Pump and research setup



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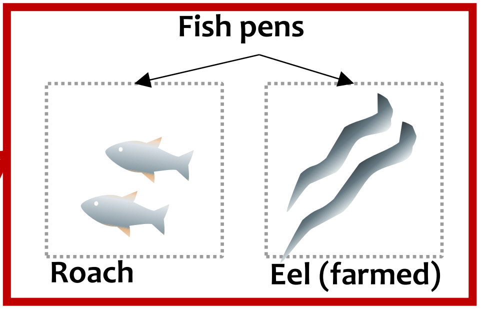

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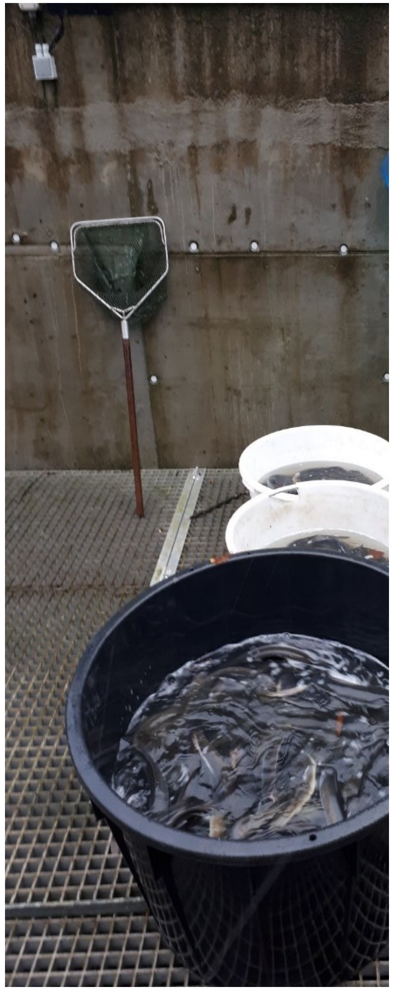

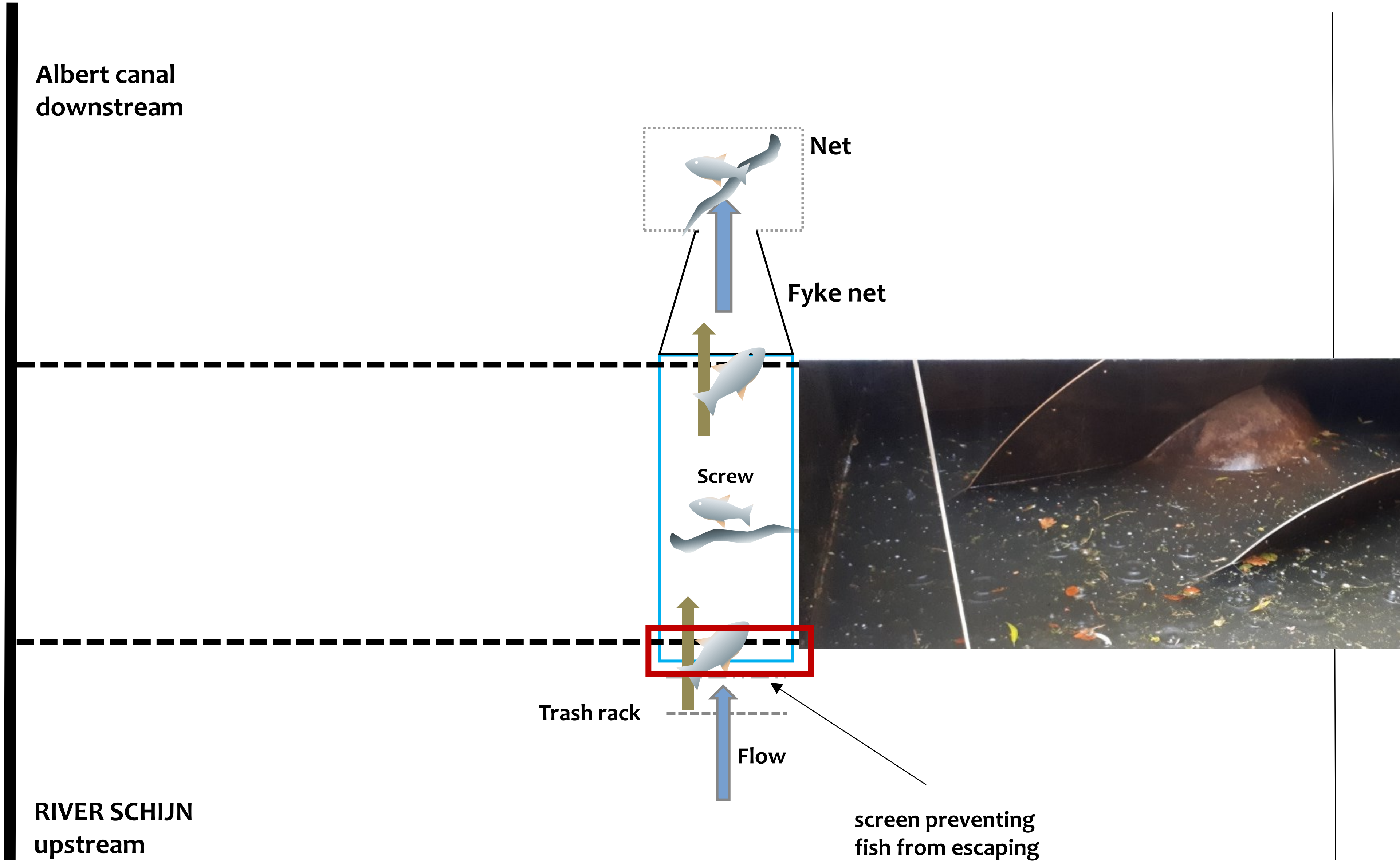

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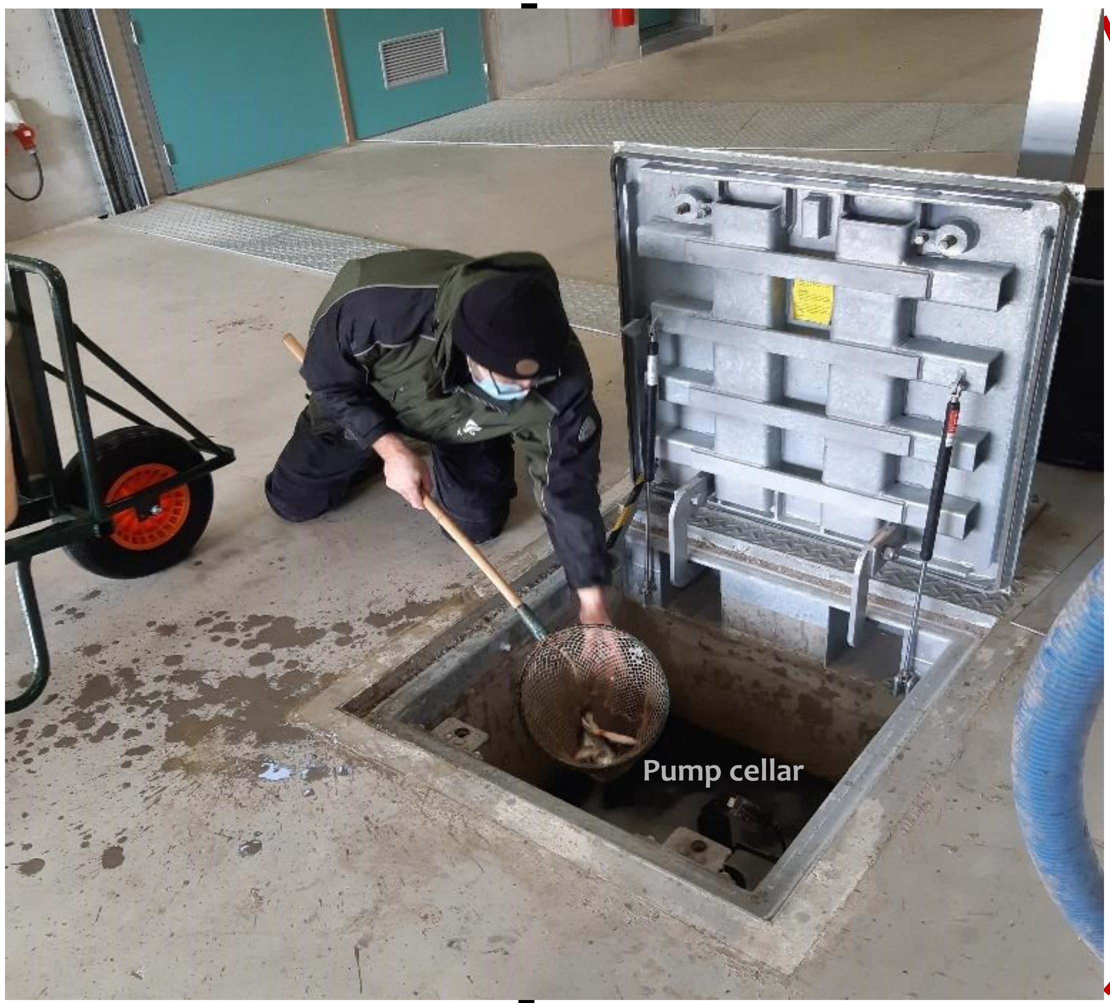
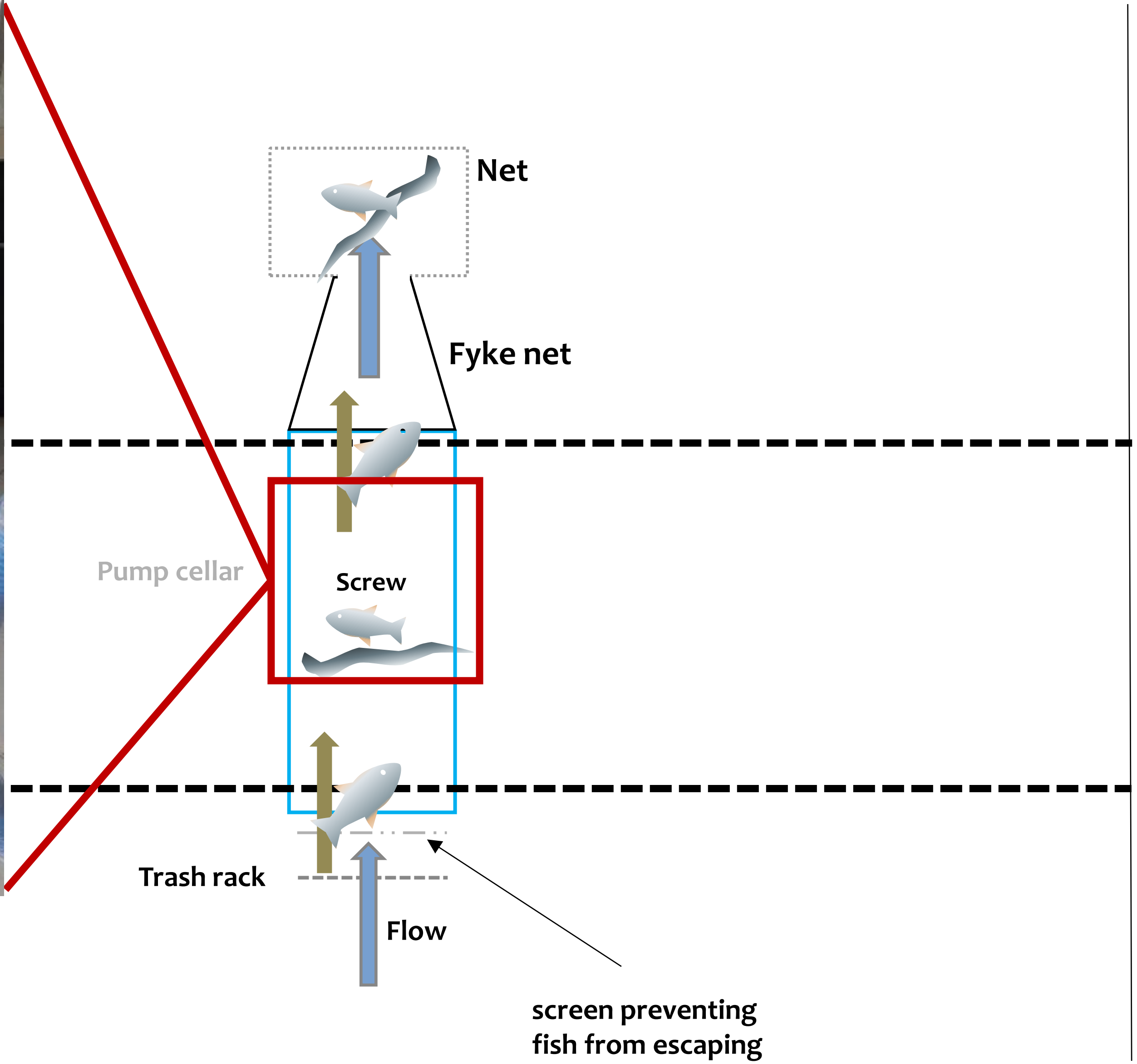
Pump and research setup





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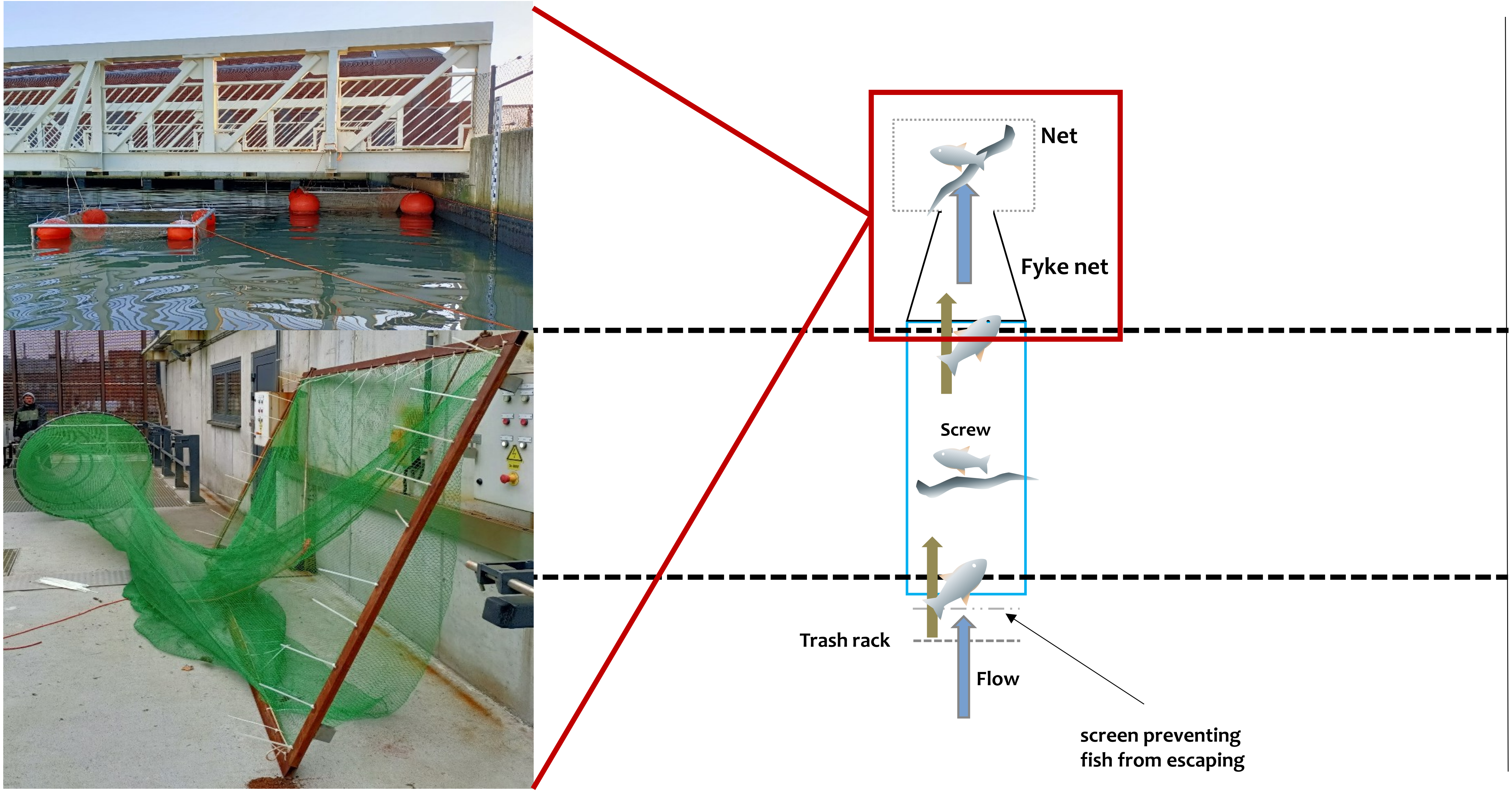
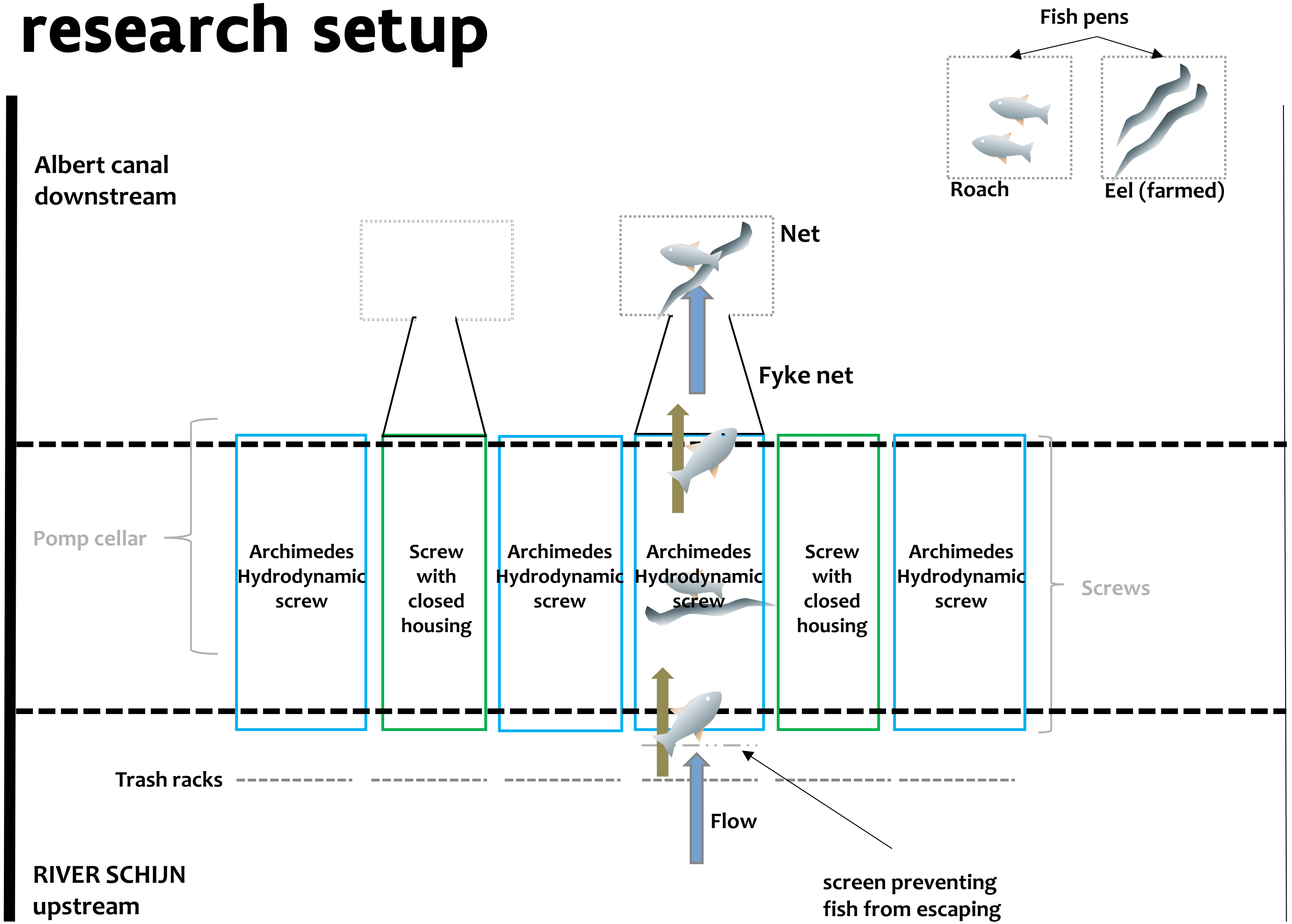
RIVER SCHIJN
upstream

Pump and research setup



Pump and research setup



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Pump and research setup

Sample sizes

- Based on a power analyses ‘sample size’ was calculated
  - → 5% fish safety norm
  - → 200 to 300 individuals / scenario
  - → We used the minimal number of 200 ind. / scenario
    - → First trial: 50 ind.
      - If mortality > 20% → STOP
      - If mortality < 20% → remaining 150 ind. Were used
  - → A control group / scenario
    - → 50 ind.

Pump and research setup

Determination of injuries

- NEN guideline 8775
  → Injury classes → subcategories + description

Injury class	Category	Description
1.		**Healthy, undamaged fish**
2.		**Slightly injured fish**
	2.1	Red and/or damaged eyes
	2.2	Red and/or damaged fins
	2.3	Light scratches, bruises and/or scale loss <20%
3.		**Heavily (terminal) injured fish**
	3.1	Significant scale loss >20%
	3.2	Cuts, cut through, severed body parts
	3.3	Breuken

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Results

Three combined methods to test fish safety

1. Live fish tests

Length frequency distribution Roach (Rutilus rutilus)

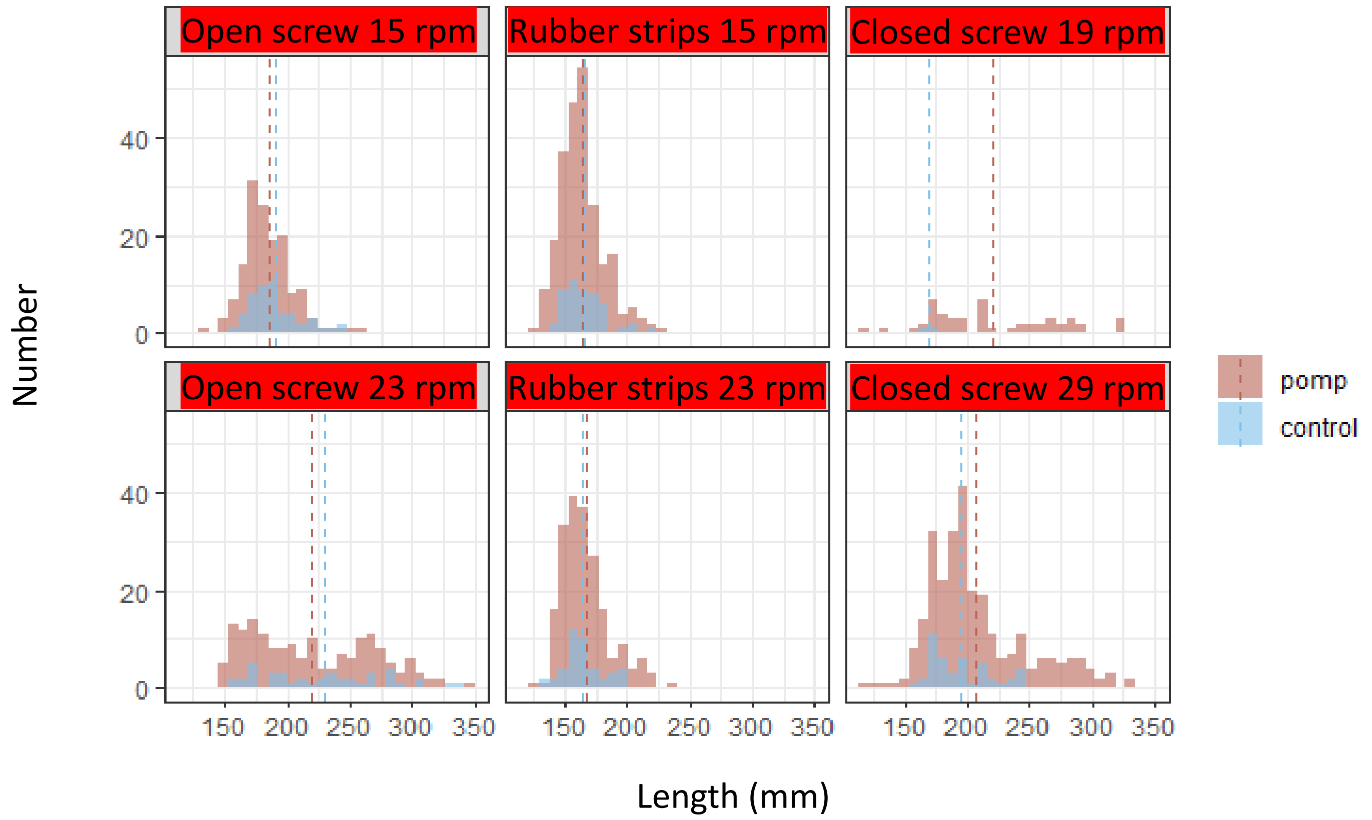

Photo: Rollin Verlinden / Vilda

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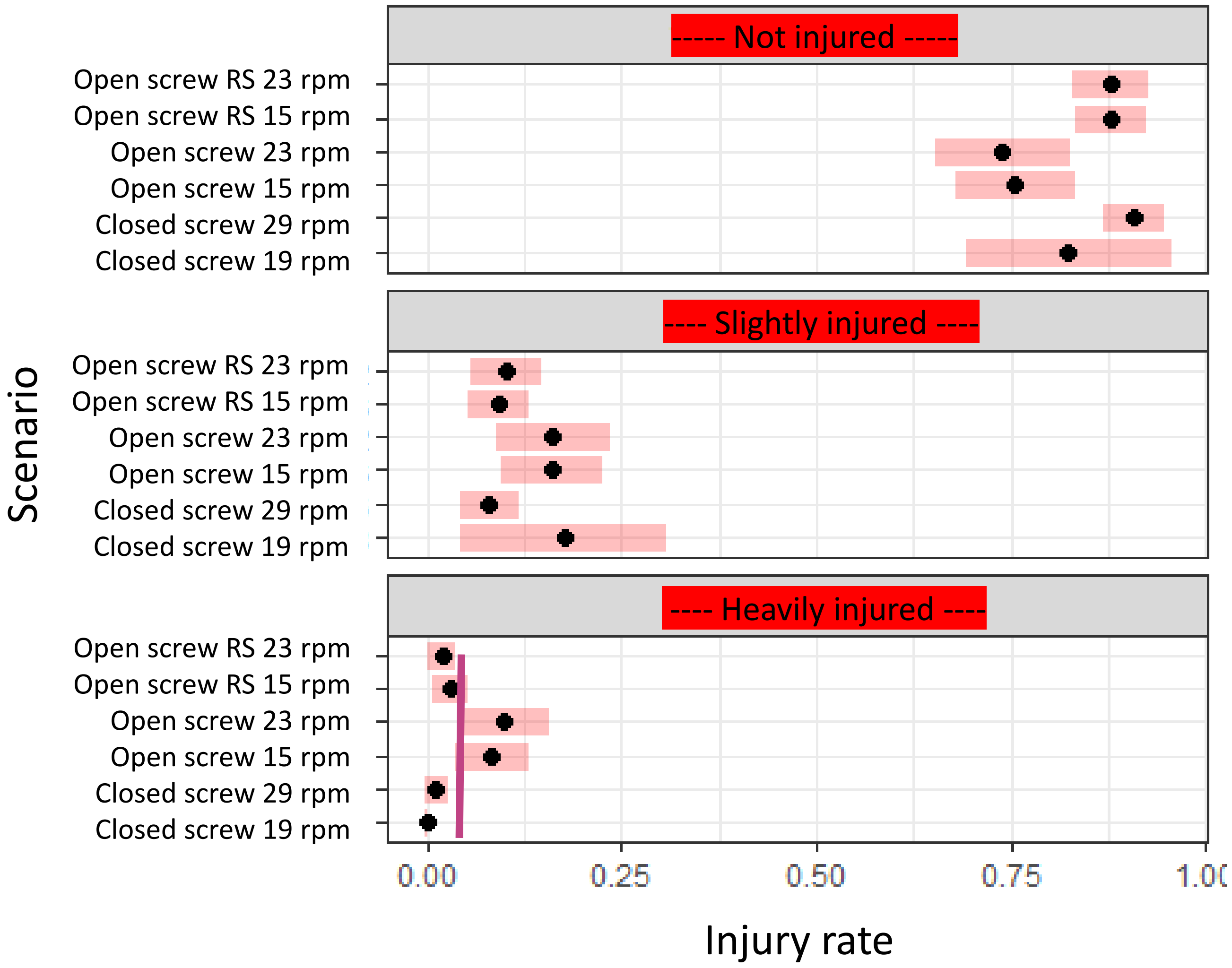
Injury rate for roach



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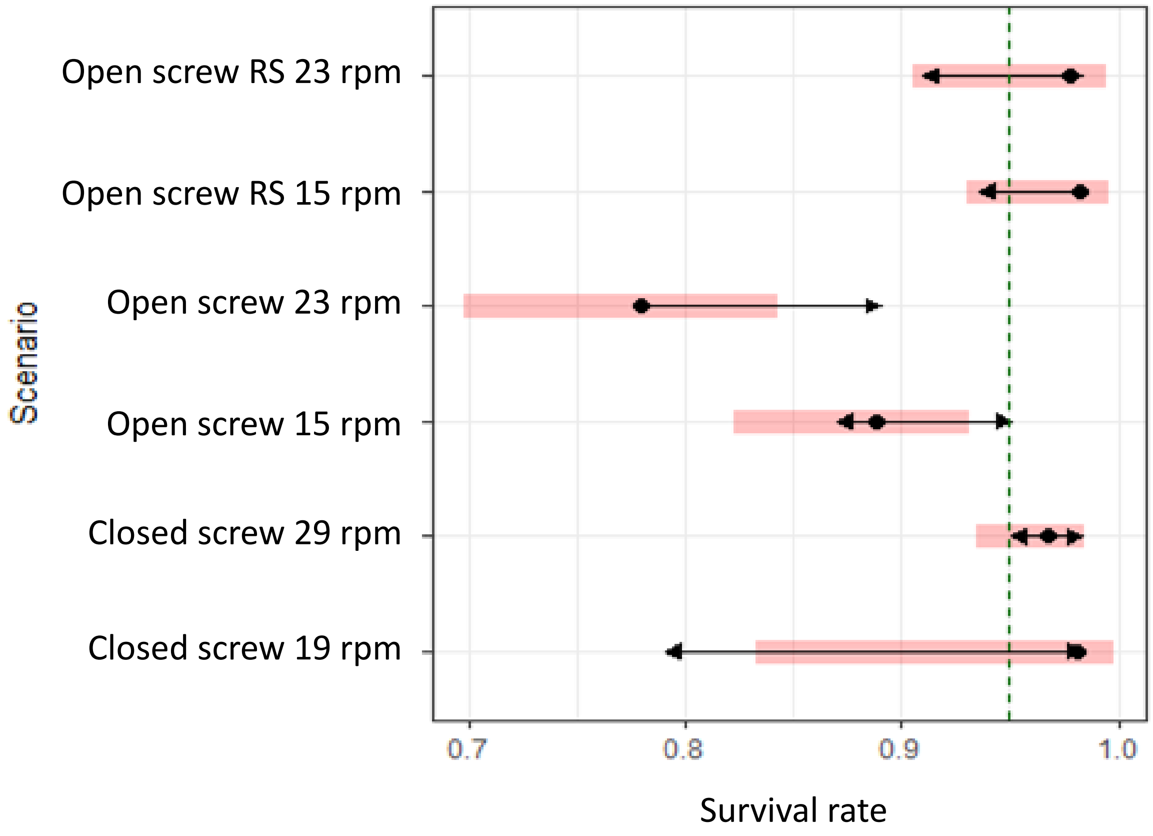
Survival rate of roach



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Examples of roach injuries

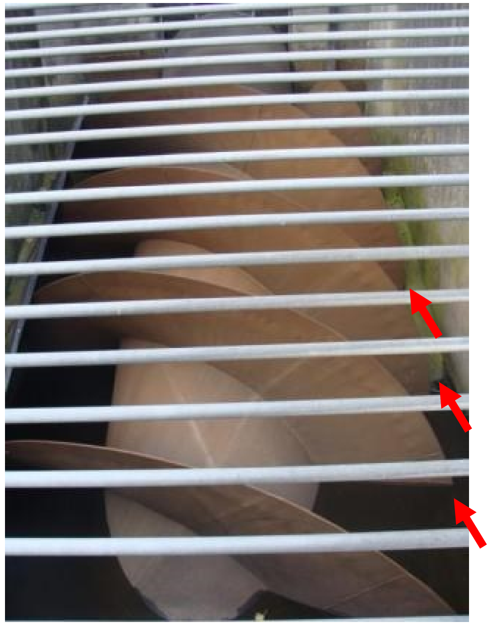
Determination of injuries

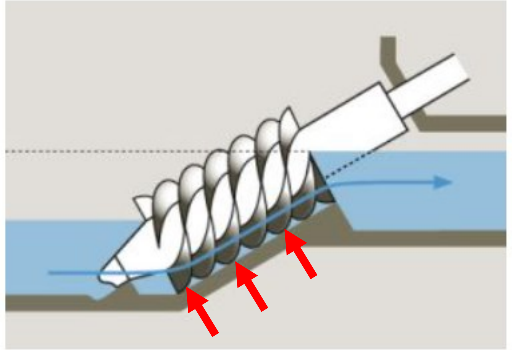
- Photo database with individual code

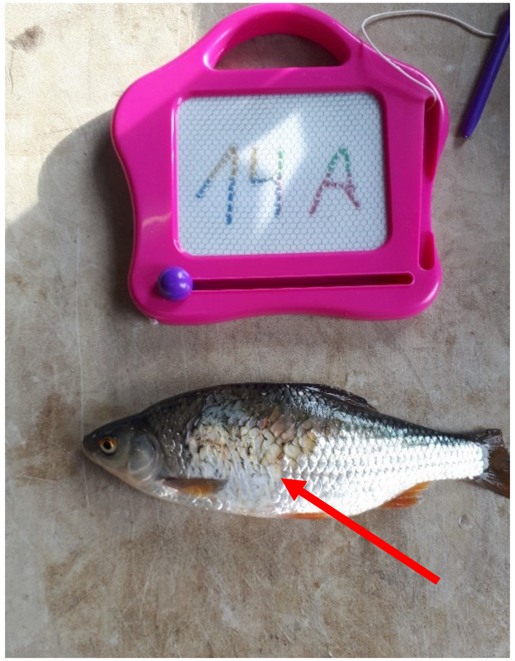
Photo's: INBO

Cause of injuries

- It is likely that the observed injuries are mainly caused by ‘pinching’







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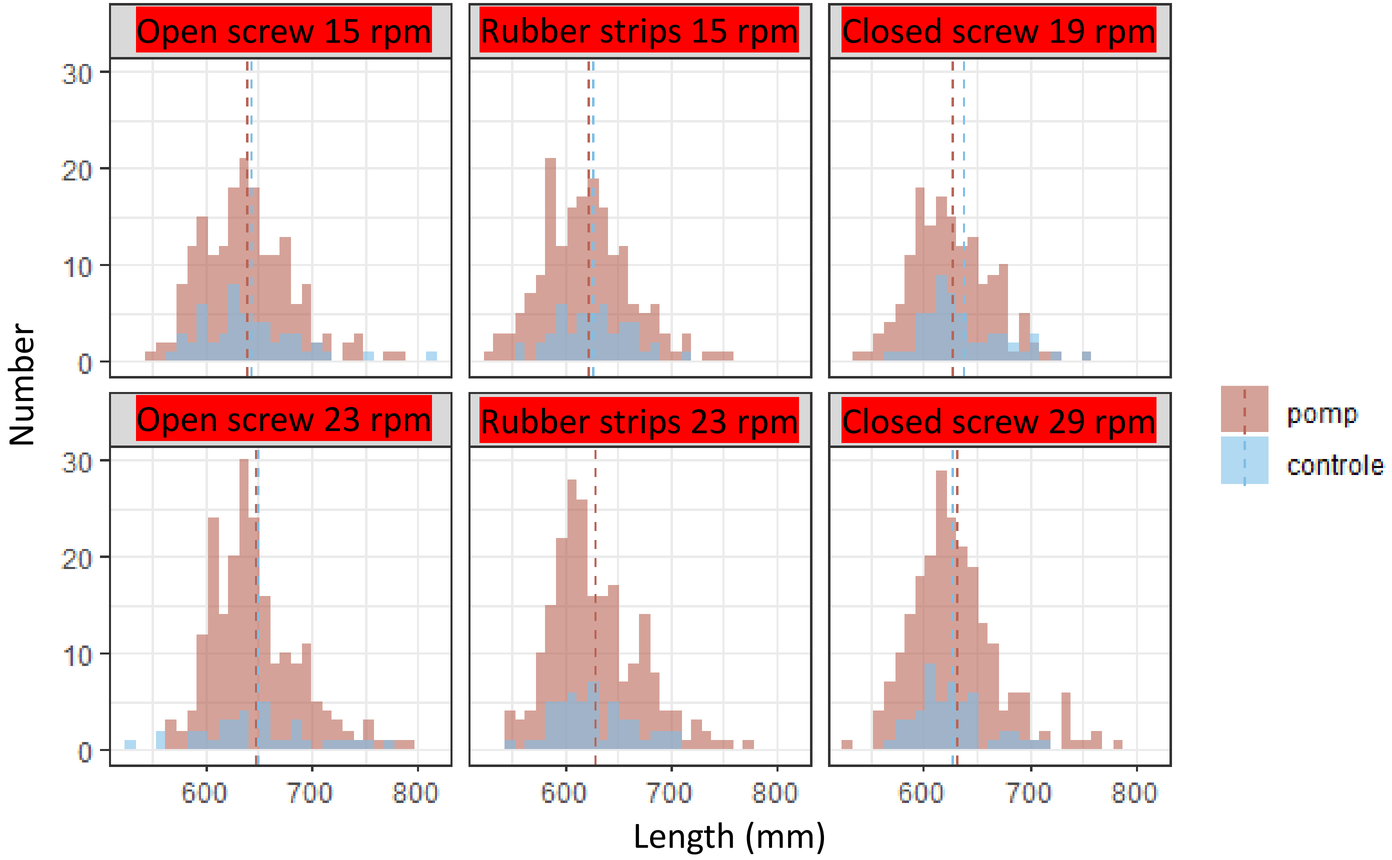
Length frequency distribution for European eel (Anguilla anguilla)



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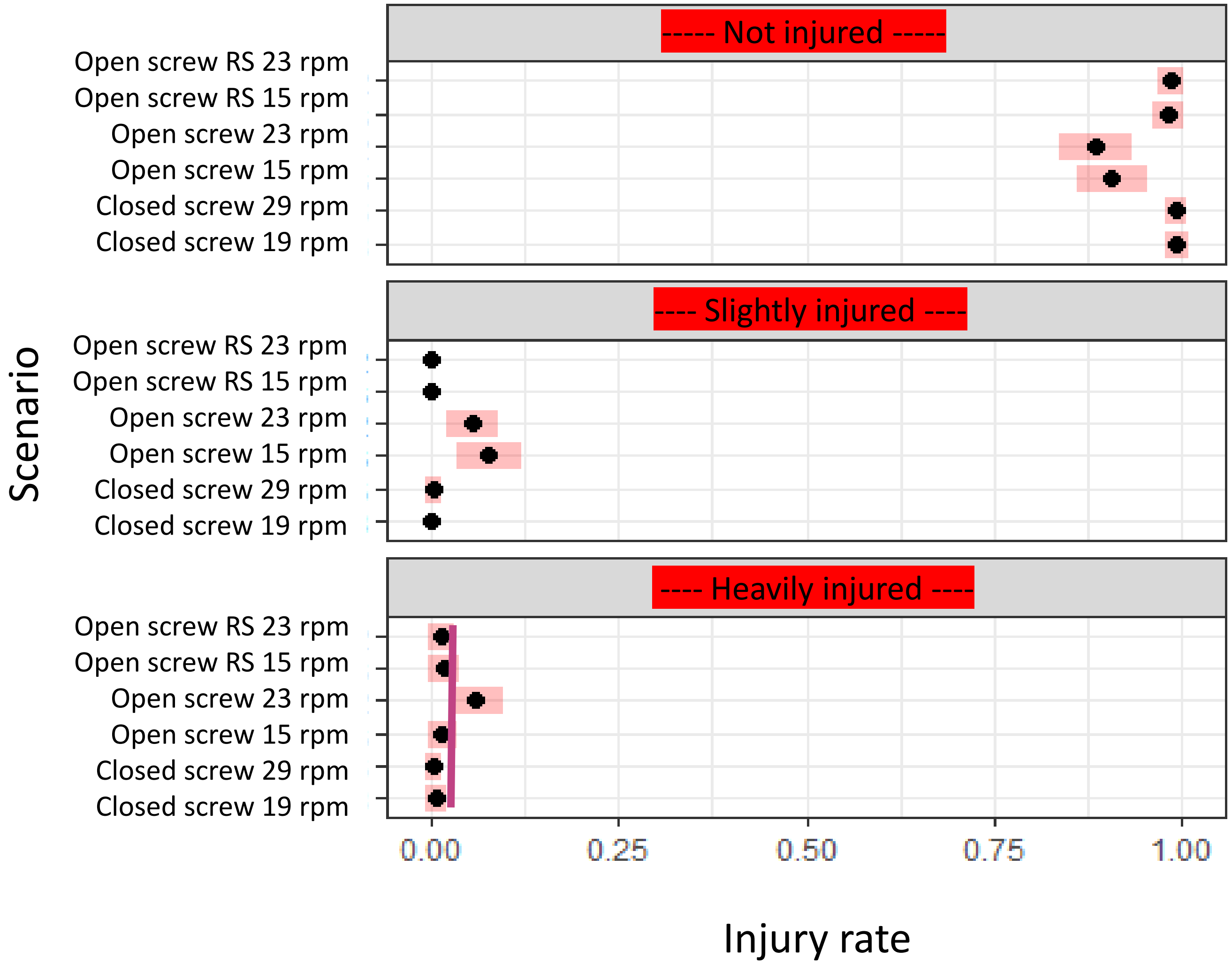
Injury rate eel



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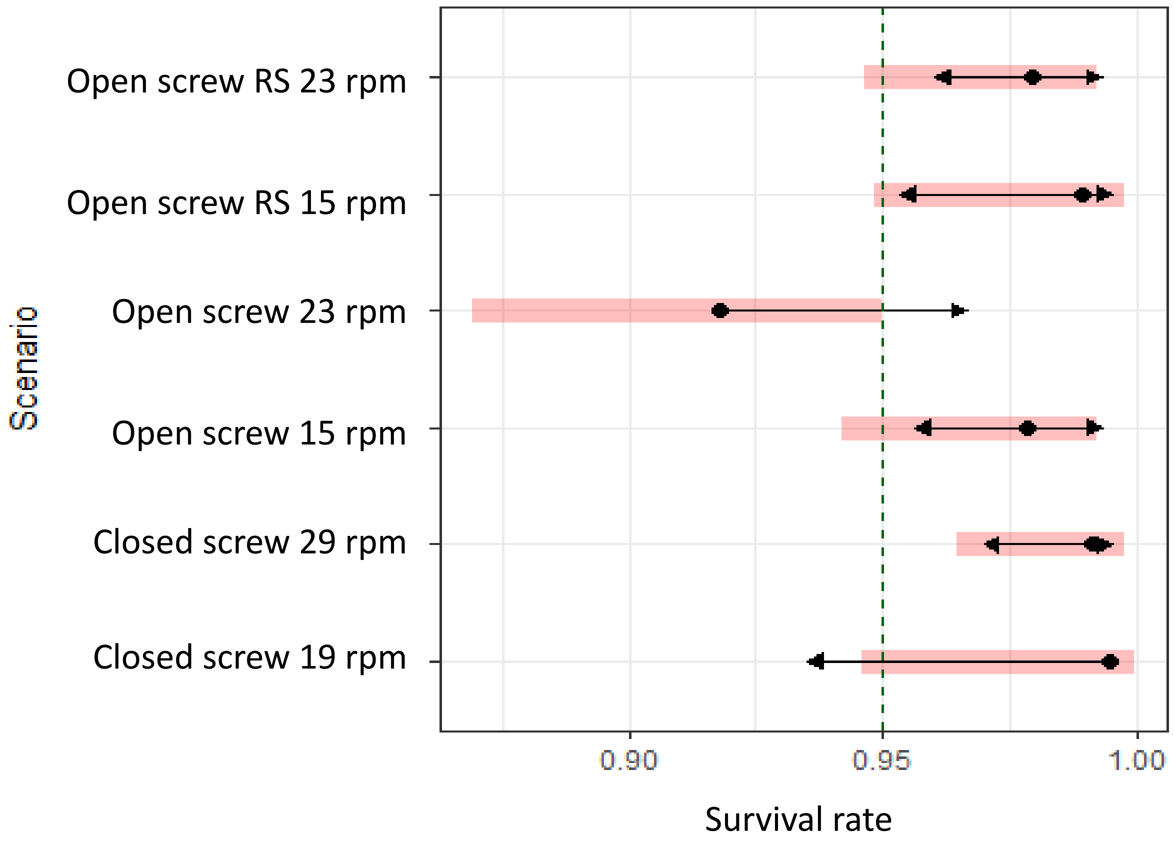
Survival rate of eel



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Examples of eel injuries

Determination of injuries ▶ Photo database with individual code

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Cause of injuries

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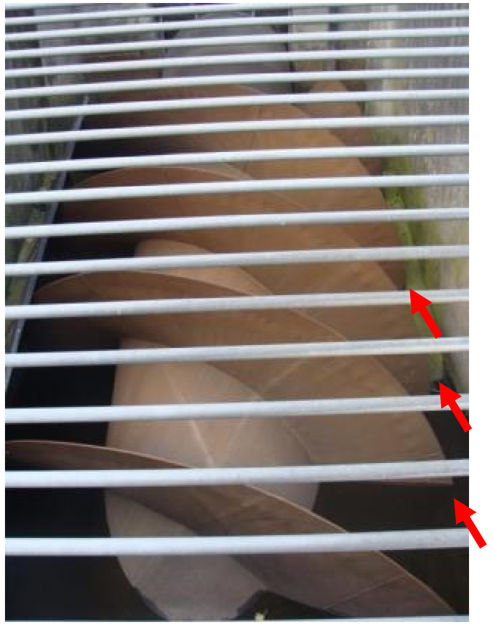

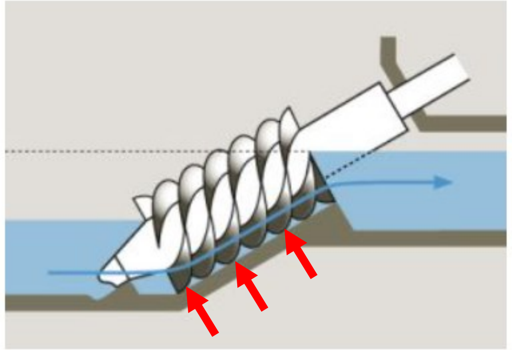

Vijzel

Three combined methods to test fish safety

2. BDS sensors

- To measure the physical conditions during pump passage
- The BDS is an underwater sensor that measures
  - → the total water pressure,
  - → linear acceleration,
  - → rotation rate,
  - → magnetic field intensity,
  - → and absolute orientation (roll, pitch, and yaw angles)
- identify exposure to events such as decompression, collisions, and severe turbulence
- Taltech Centre for Biorobotics

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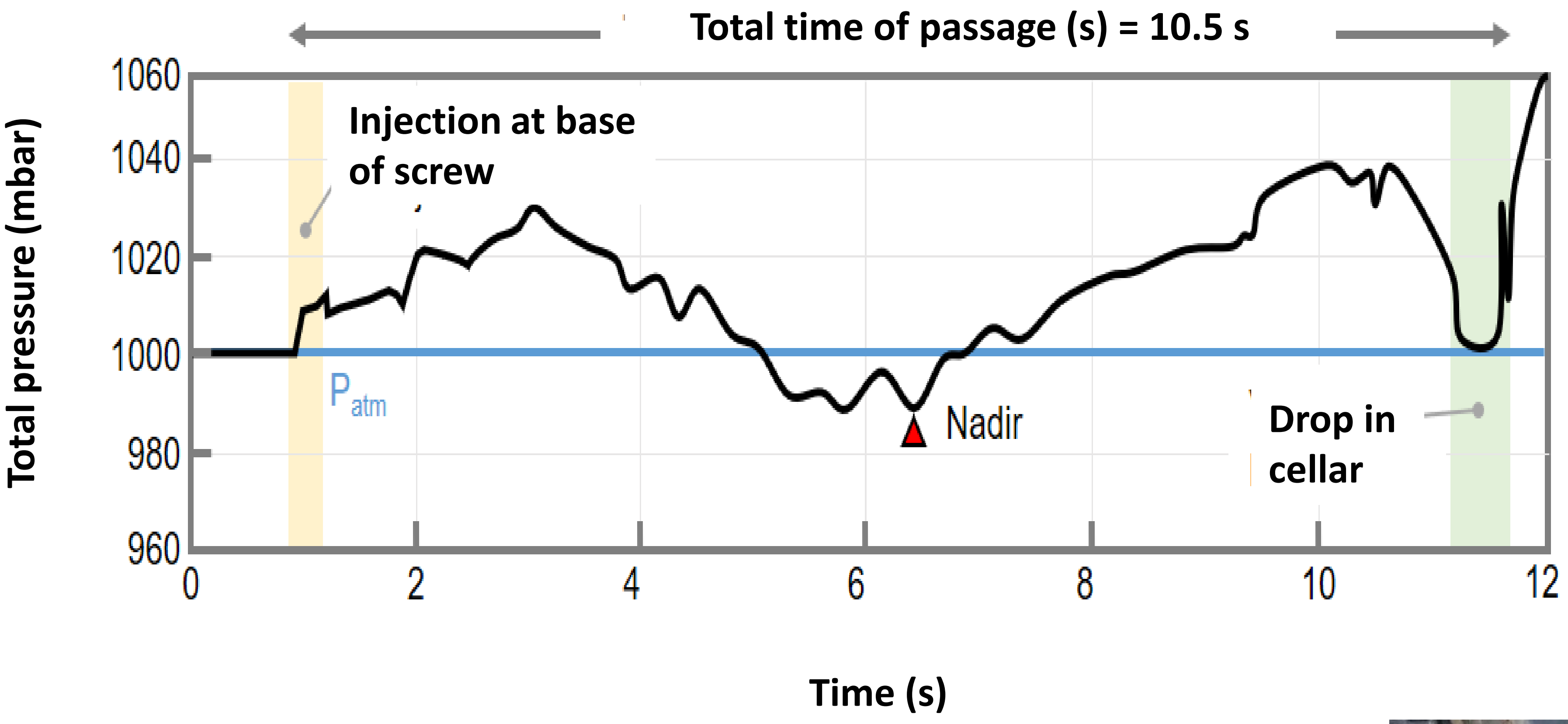
BDS sensor passage = a chaotic event



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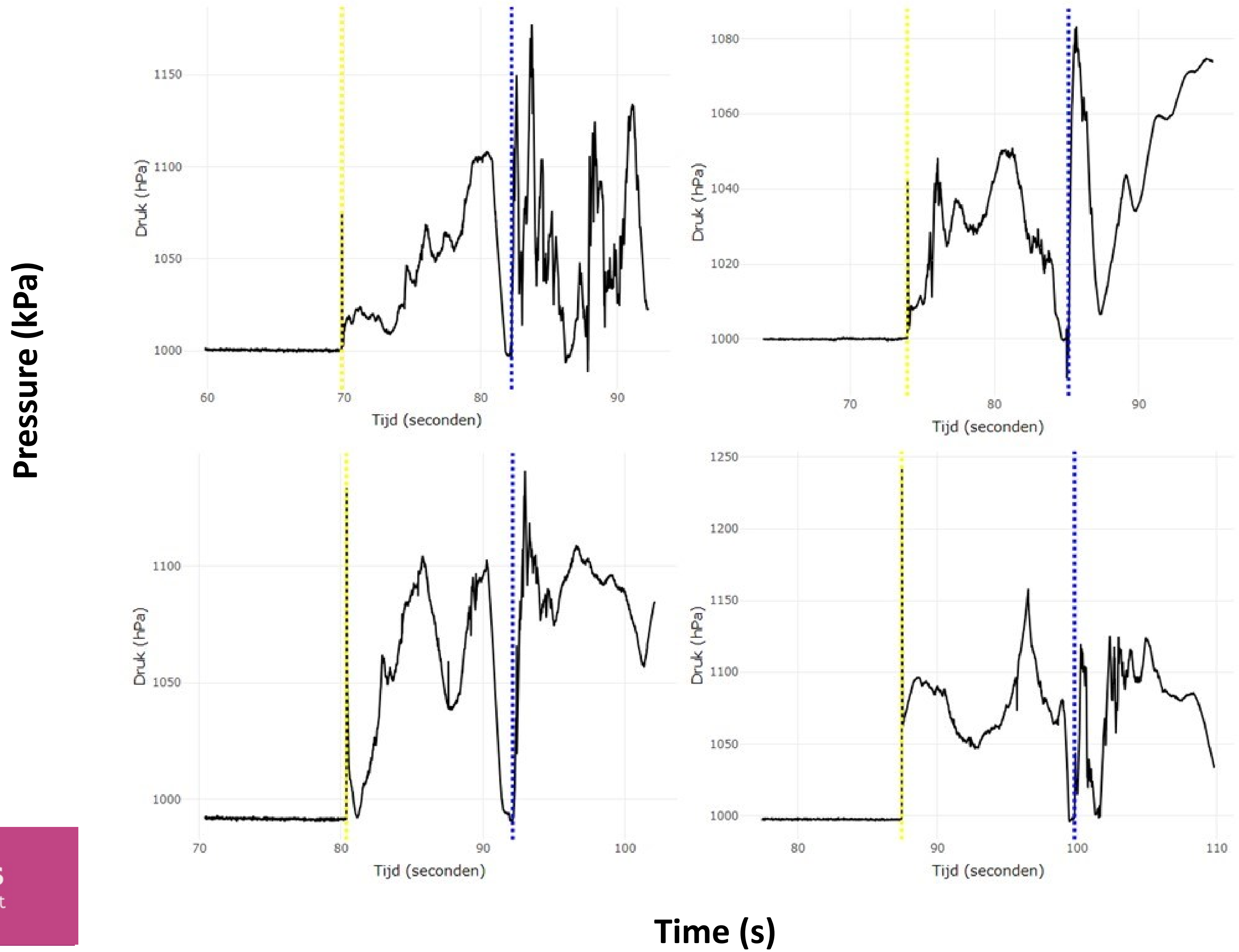
BDS sensor passage = chaotic event



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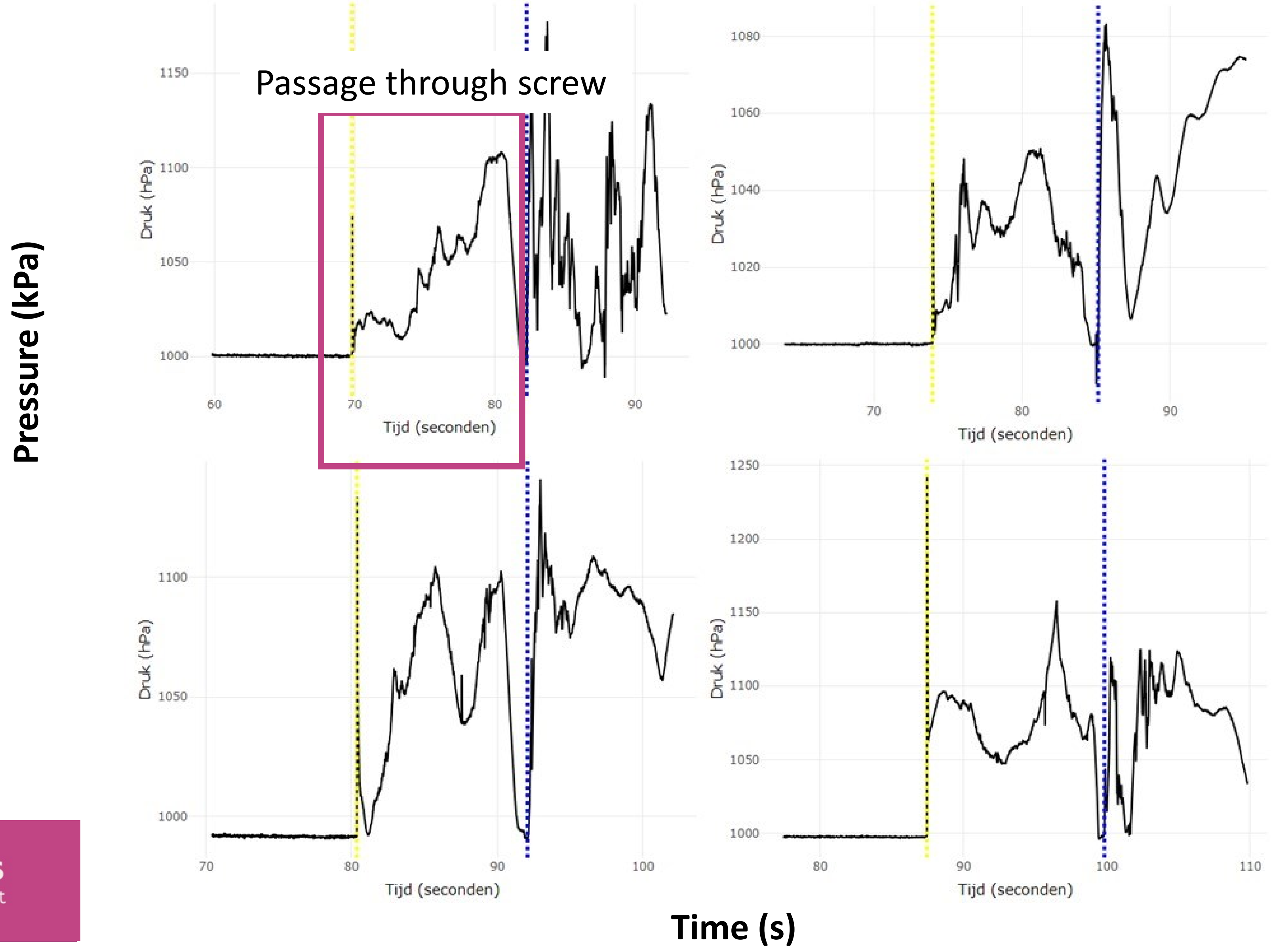
BDS sensor passage = chaotic event



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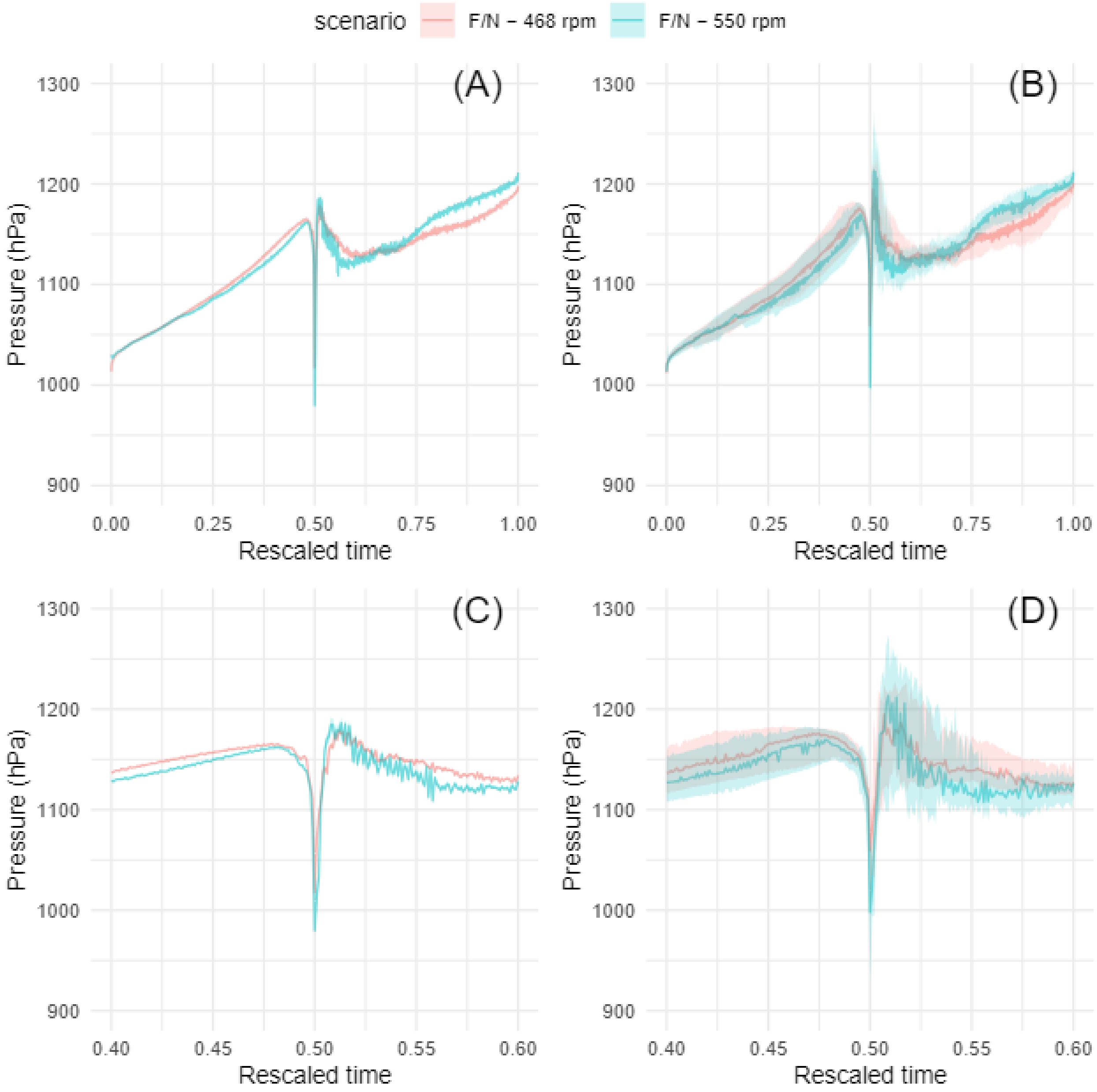
BDS sensor passage through an axial flow pump



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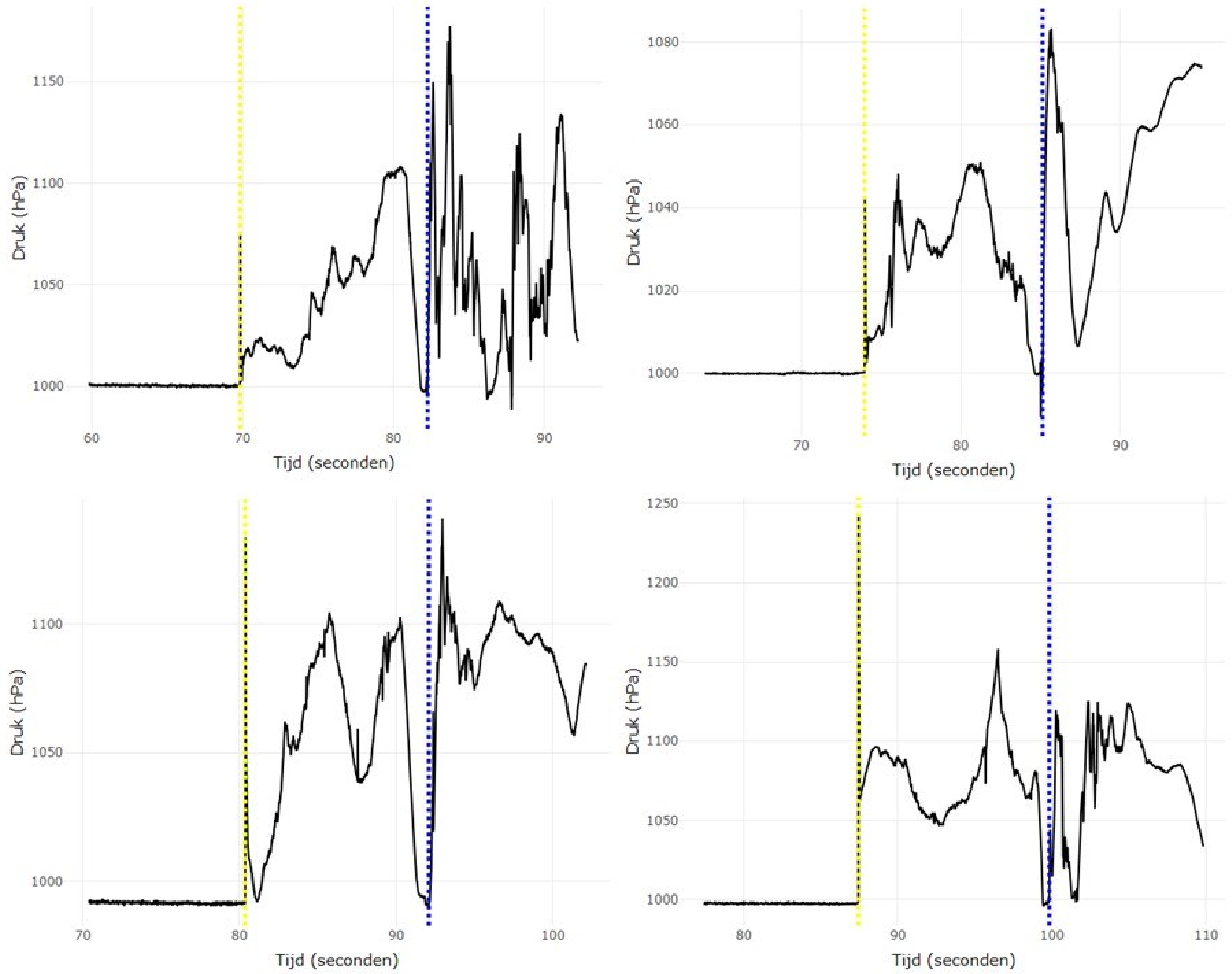
BDS sensor passage = chaotic event

Pressure (kPa)



Time (s)

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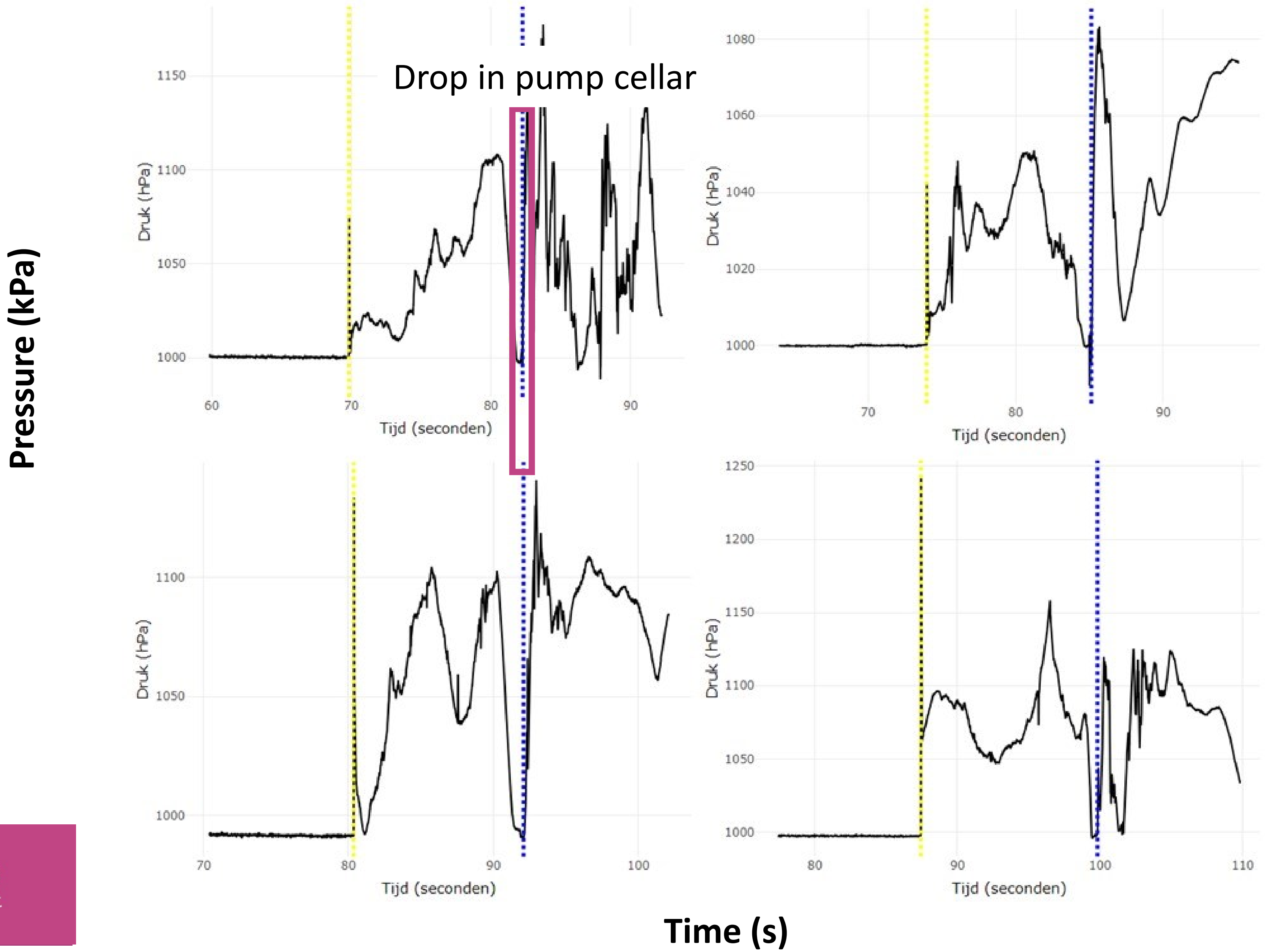
BDS sensor passage = importance of the surroundings



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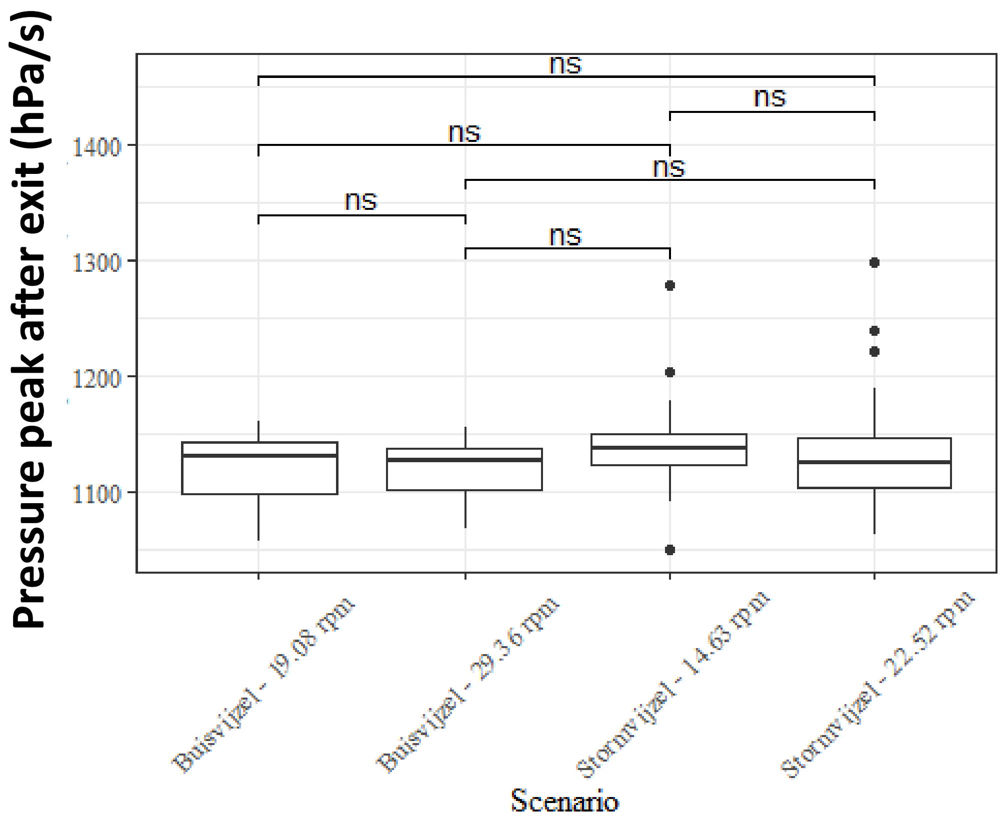

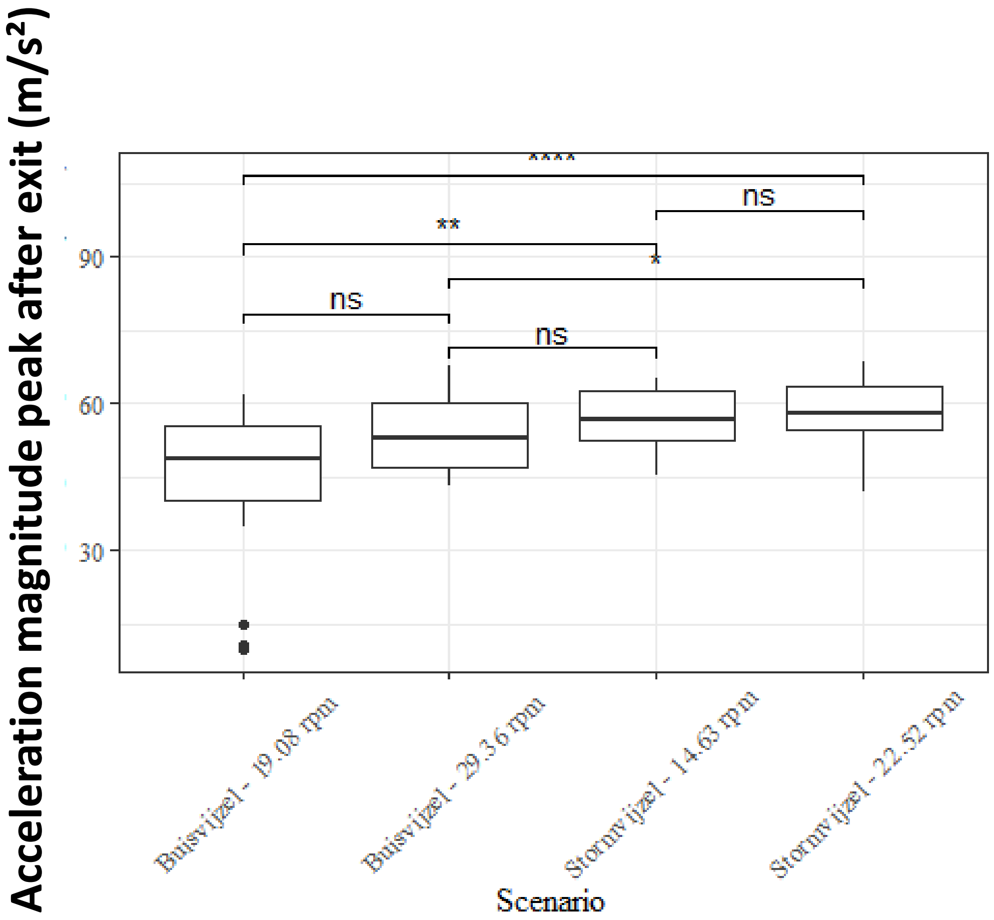

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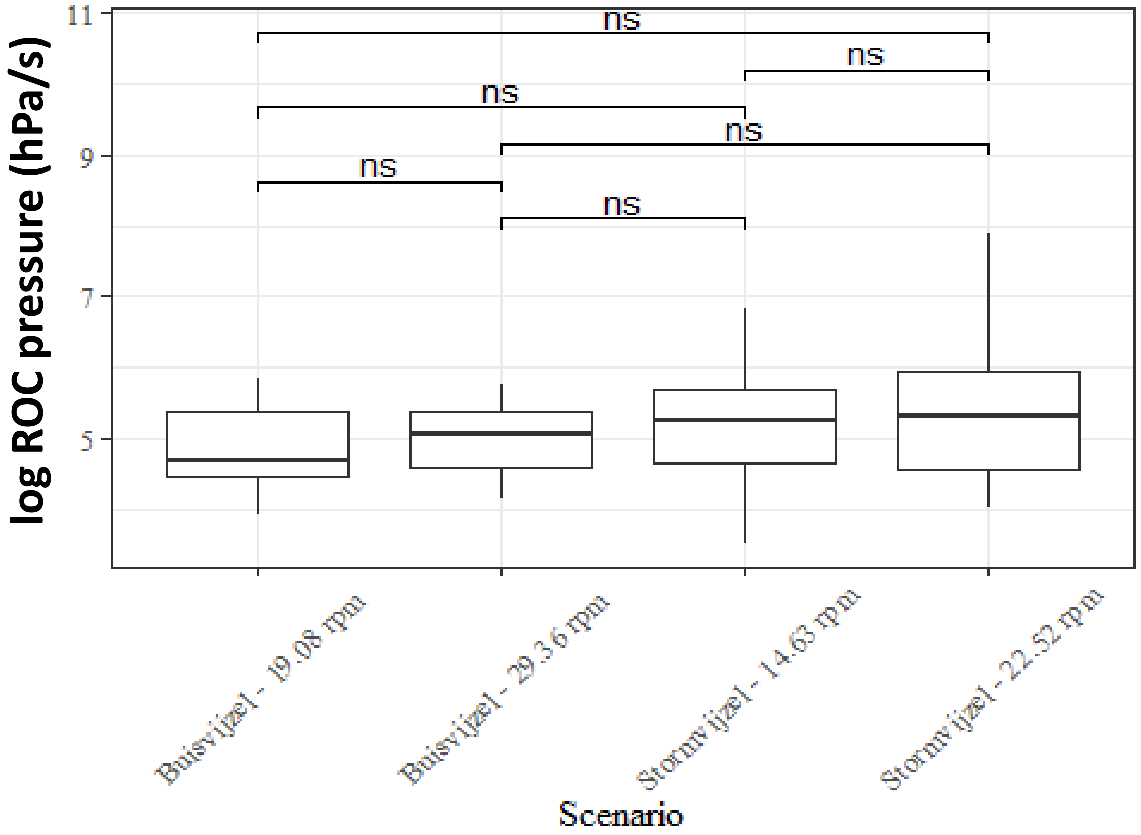
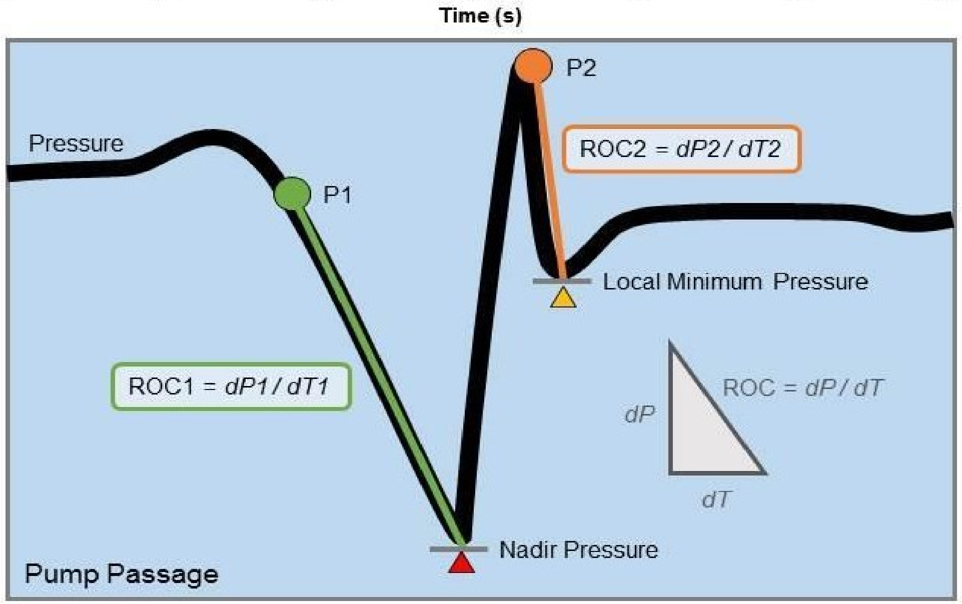
BDS sensor passage = importance of the surroundings





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Three combined methods to test fish safety

3. Fish backpack sensors

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Three combined methods to test fish safety

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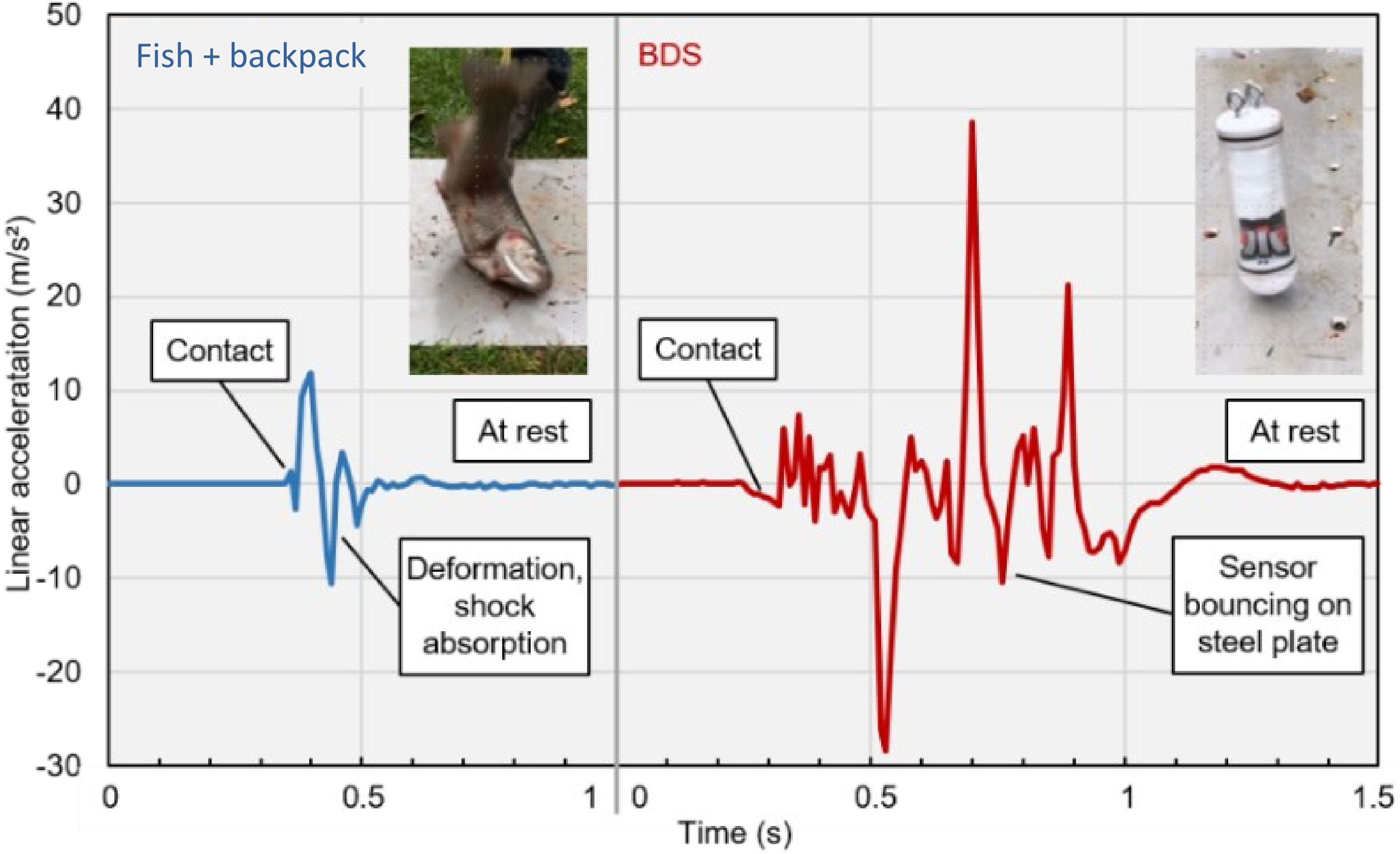

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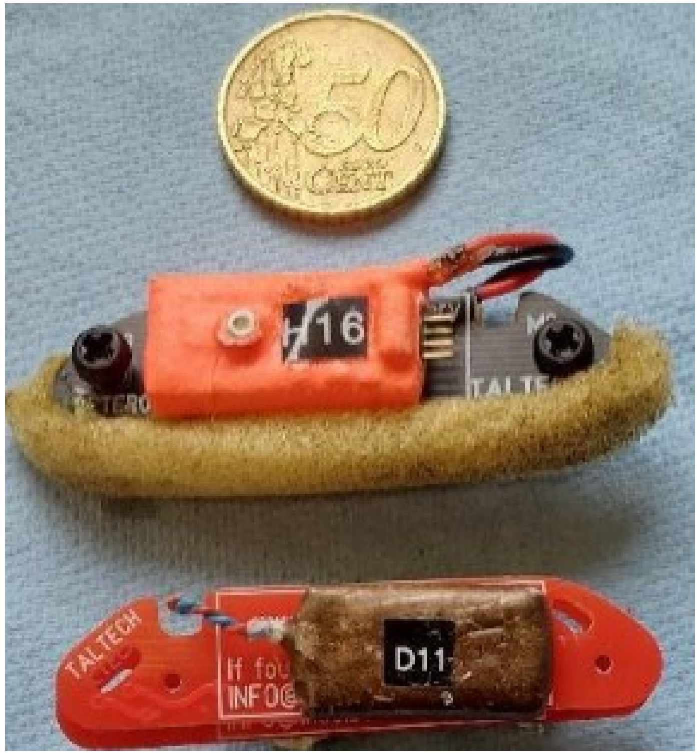

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Three combined methods to test fish safety

3. Fish backpack sensors

- The FB sensors showed similar pressure patterns as BDS
  - → a chaotic events in the screw
  - → and a consistent pressure peak at the exit of the screw
    - → corresponding to the fish falling into the pump cellar.
- As the FB measurements gave similar results as the BDS, they are not discussed further

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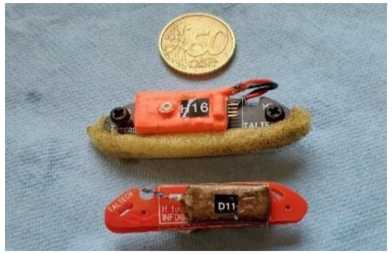
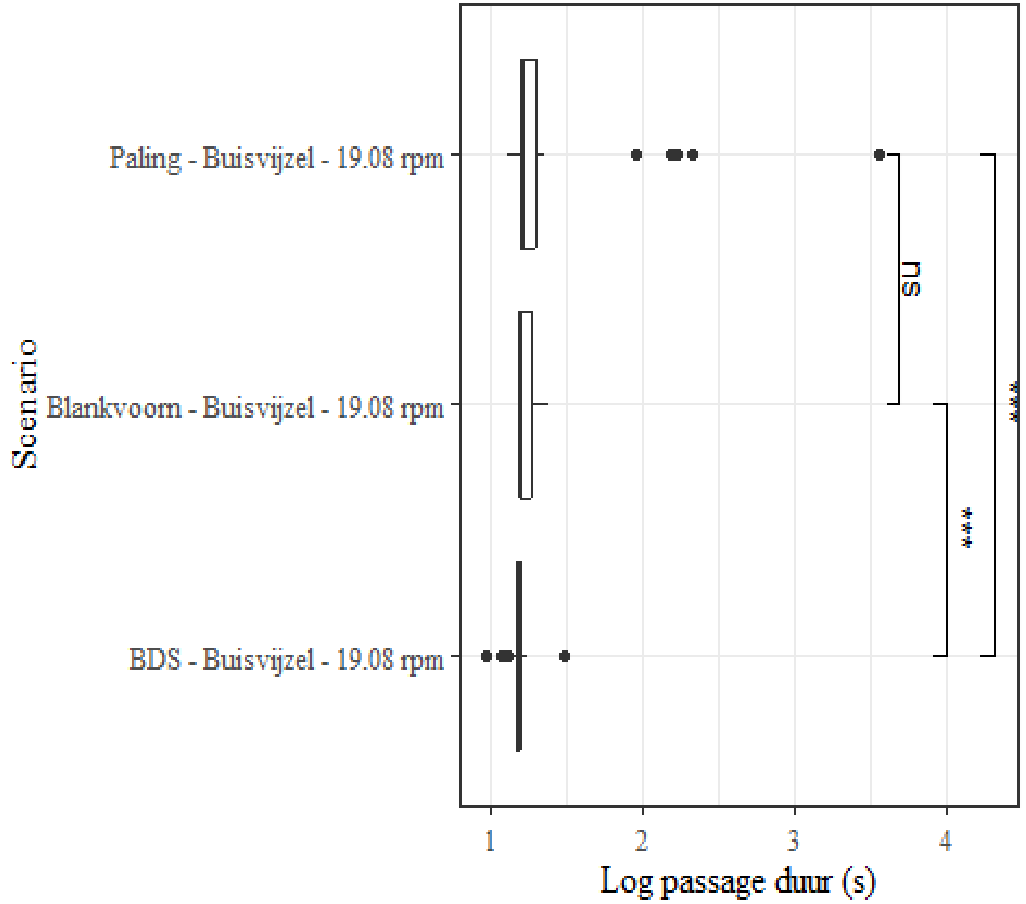
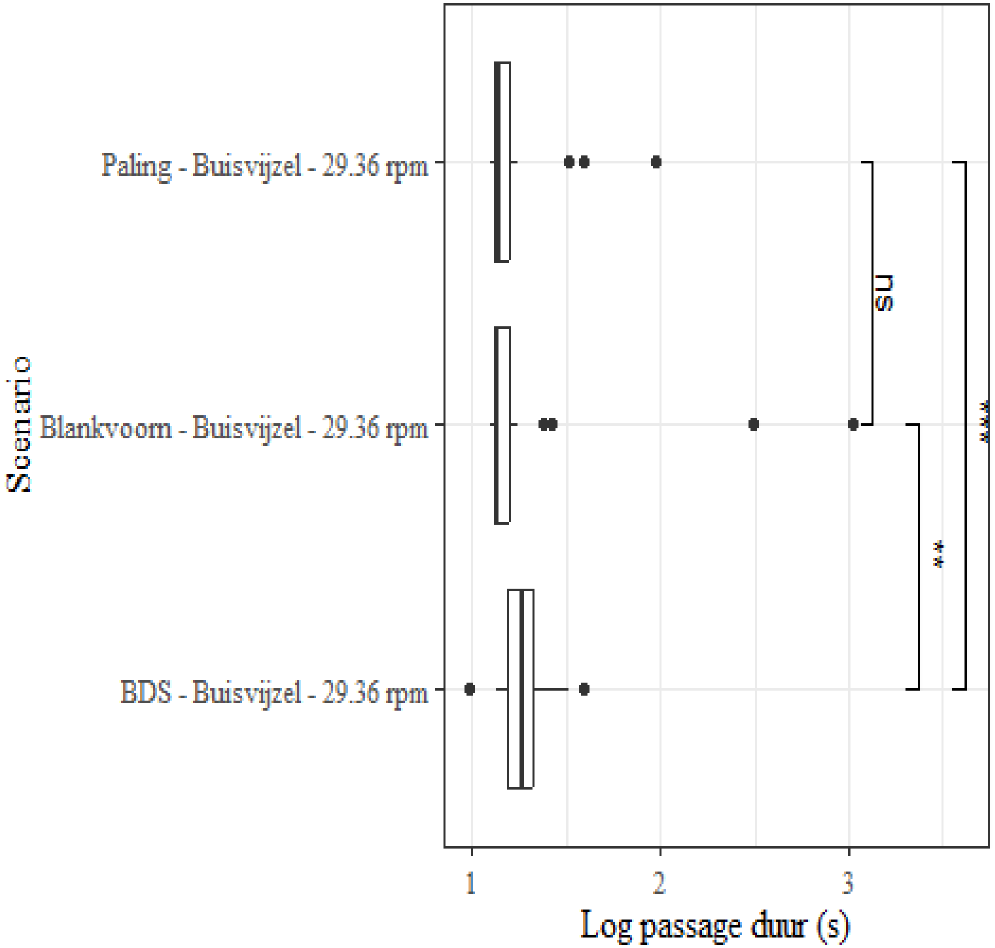
FB sensors: Variable passage time







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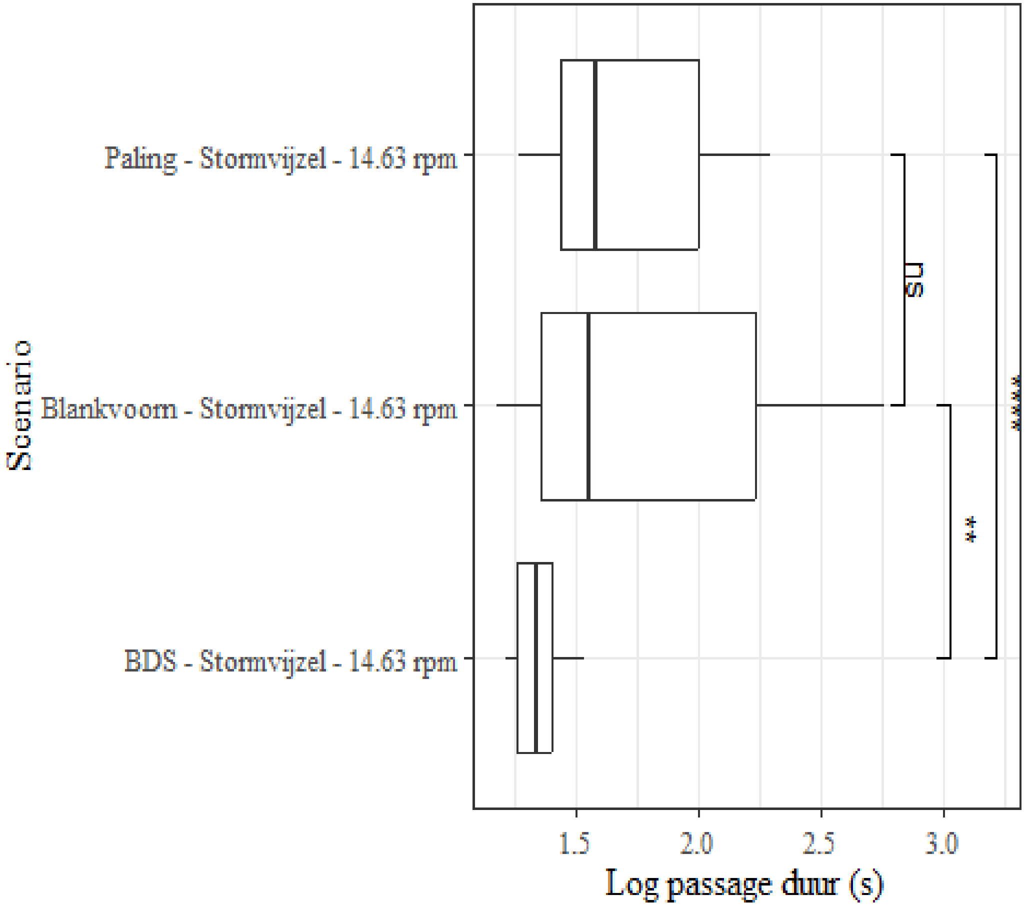
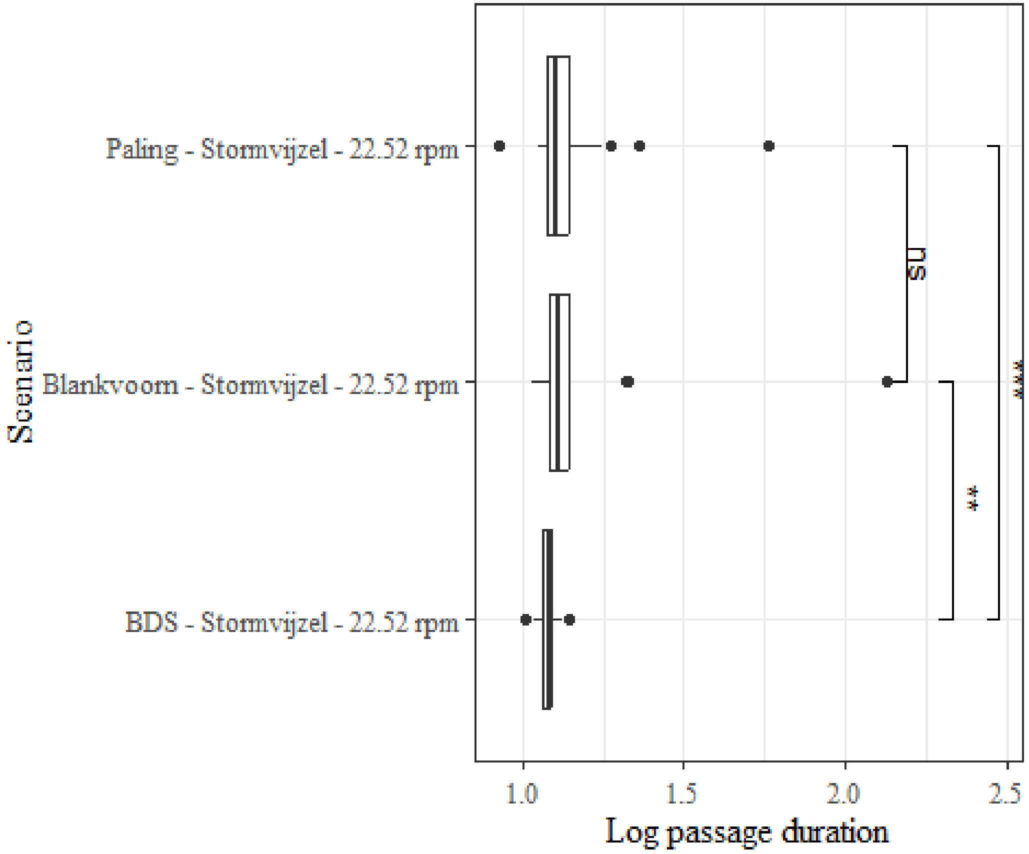




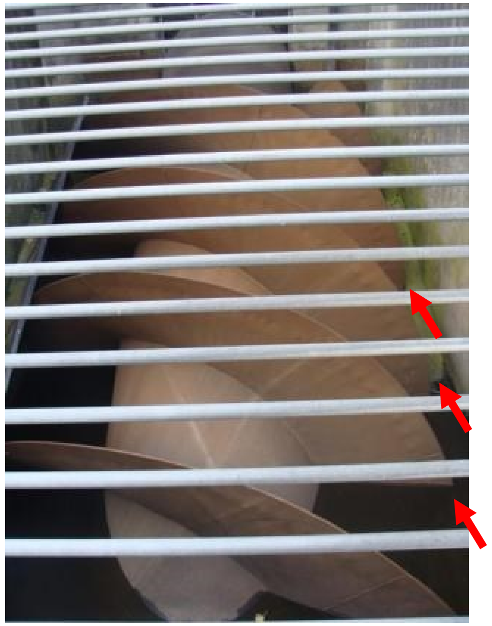
Sensor evaluations

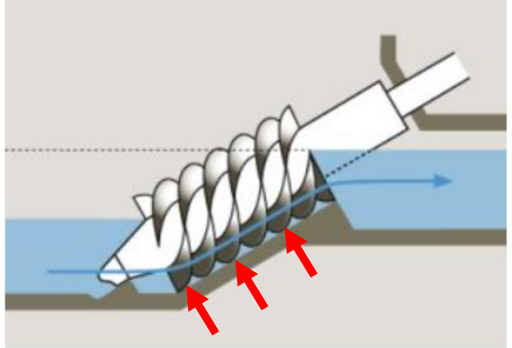
- No extreme pressure changes were measured in the screws

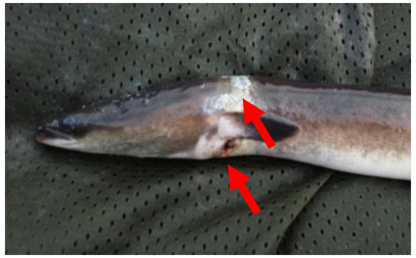
  → no external signs of barotrauma
  → unlikely that sudden decompression is a main source of injury at the three screw types

- It is likely that the observed injuries are mainly caused by 'pinching'

- Importance of the surroundings







Conclusions

Take home message

- **CLOSED SCREWS**: provides safest passage → NO PINCHING INJURIES
- **OPEN SCREWS WITH RUBBER STRIPS**: a good alternative → REDUCES PINCHING INJURIES
- **OPEN SCREWS:** cause biologically significant damage to roach and eel

- Importance of surroundings

Take home message

- CLOSED SCREWS: provides safest passage → NO PINCHING INJURIES
- OPEN SCREWS WITH RUBBER STRIPS: a good alternative → REDUCES PINCHING INJURIES
- OPEN SCREWS: cause biologically significant damage to roach and eel

Screw type	Rotation speed (rpm)	Eel survival rate (%)	Roach survival rate (%)
Closed screw	19*	95	83*
	29	96	93
Opens screw rubber strips	15	95	93
	23	95	91
Open screw	15	94	82
	23	87	70

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That’s all folks !
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