

# A novel protocol to measure safe eel passage through pumping stations.

*Insides from case studies in Belgium*

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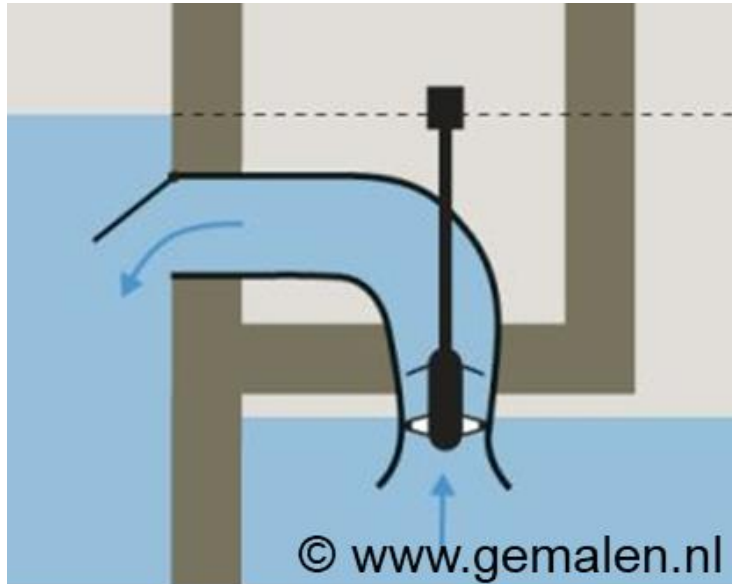


TAL  
TECH

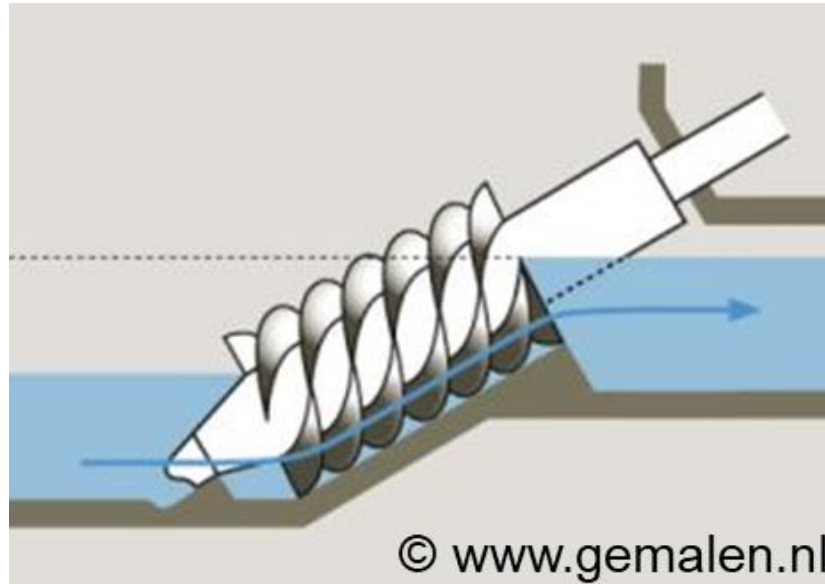


# Pumps aim to quickly move water against gravity

Axial flow pump



Archimedean screw pump



Centrifugal pump



Agriculture



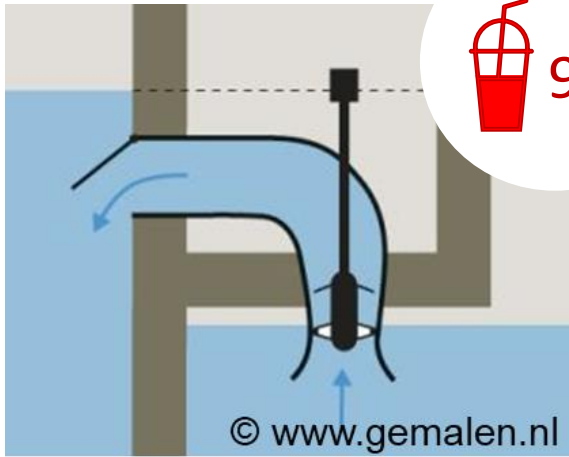
Waste & drink water



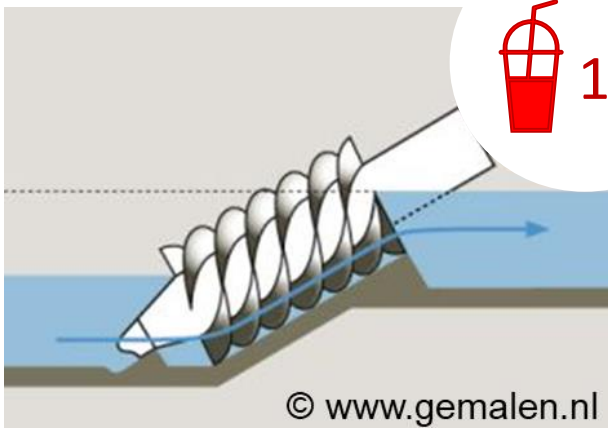
Water level control



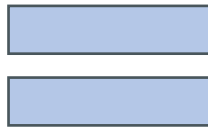
# Pumps are fish mixers



97%



19%



Buyse et al. 2014

# Pumping stations in Flanders (Belgium)

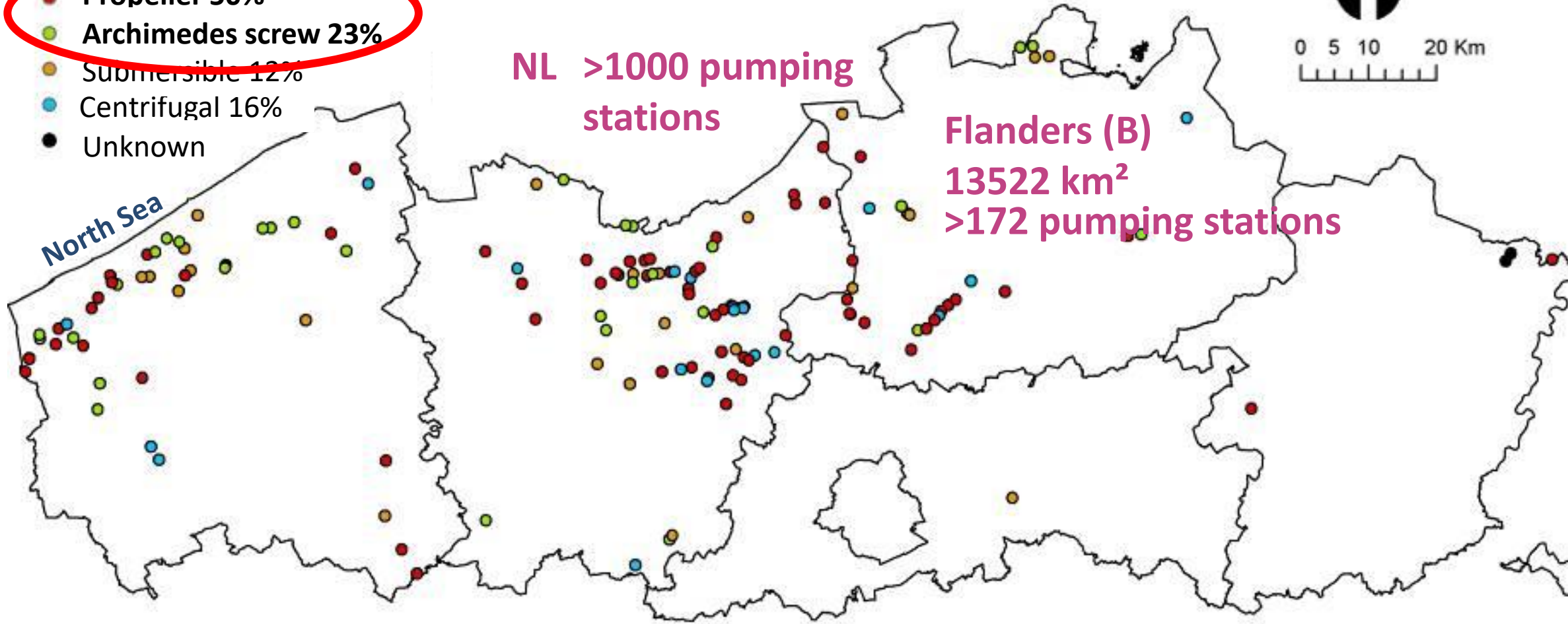
- Propeller 50%
- Archimedes screw 23%
- Submersible 12%
- Centrifugal 16%
- Unknown

NL >1000 pumping stations

Flanders (B)  
13522 km<sup>2</sup>  
>172 pumping stations



0 5 10 20 Km



# Increase in pump use due to climate change

## Sea level rise



Gravitational drainage  
less possible

## Extreme precipitation

*Even more rain: extra pumps  
should save Westhoek from  
even worse flooding*



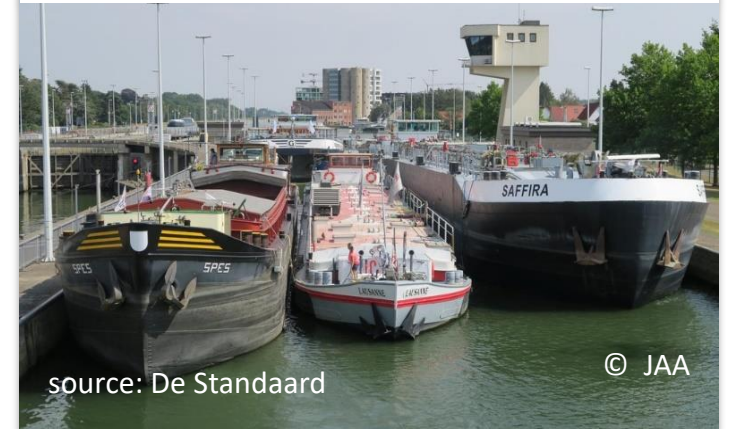
source: vrtnws

© Thijs Pattyn

Need for quick water  
drainage

## Extreme drought

*Long traffic jam on Albert  
canal due to ongoing drought*

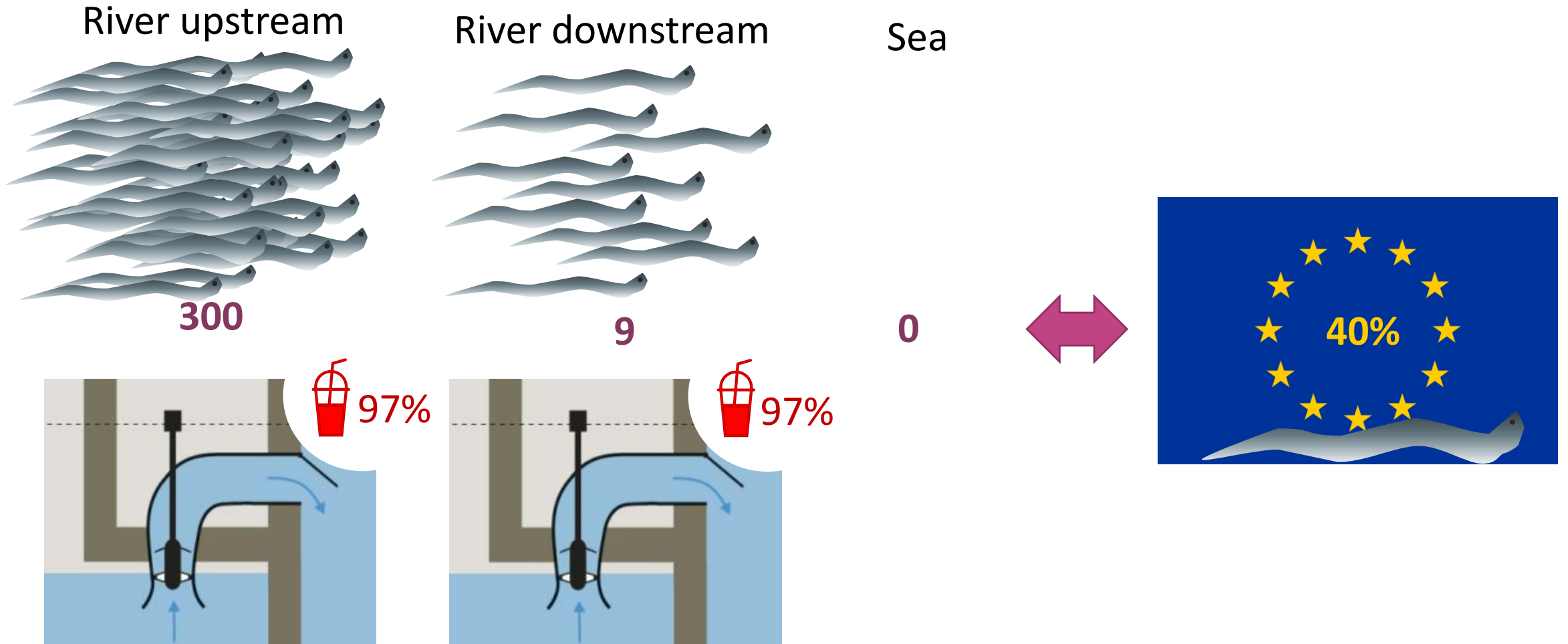


source: De Standaard

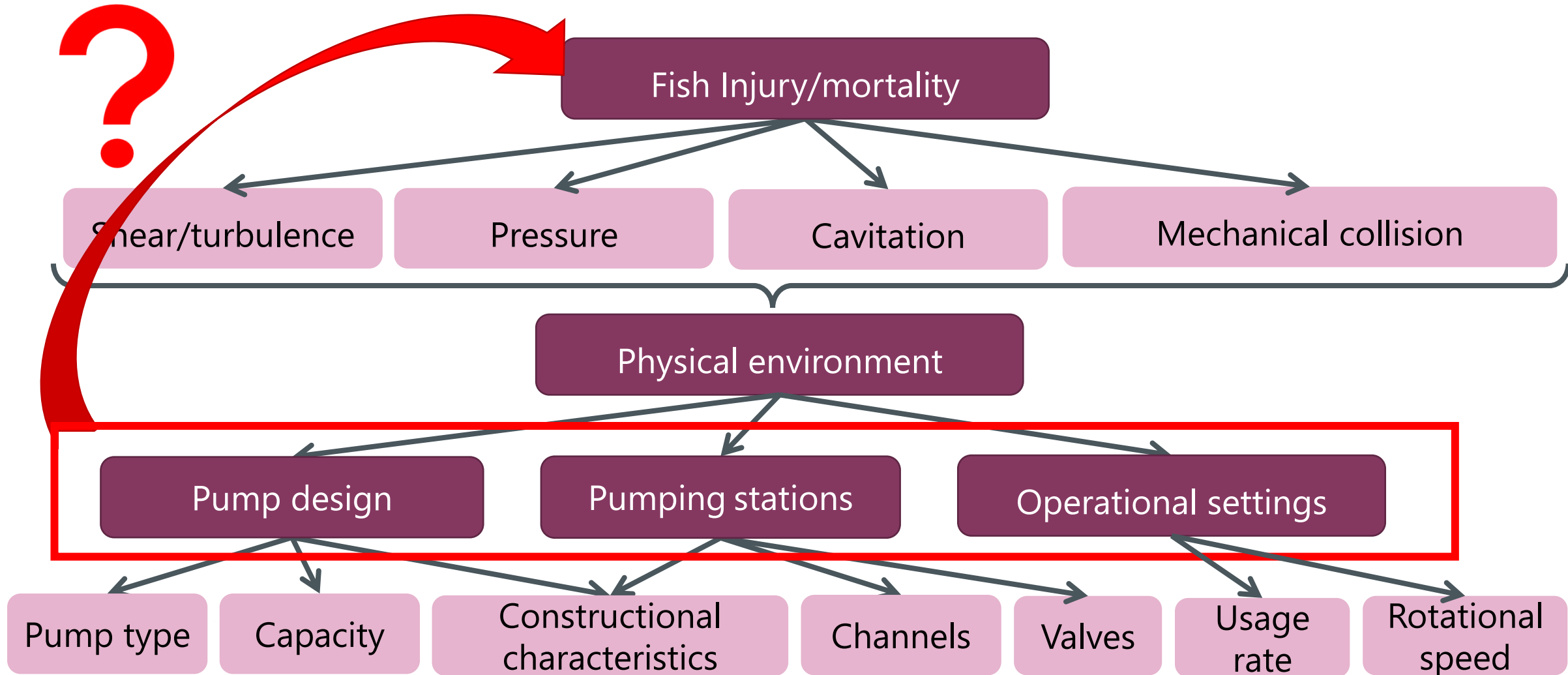
© JAA

Water recovery at locks

# Fish mixers vs EU eel regulation



# Factors that influence the fish safety



# A novel protocol

## Live fish tests

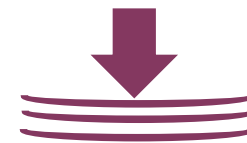


- At least 200 farmed eels
- Control: 50 eels
- Length: 70-90 cm
- Forced passages
- Fish safe: <5% mortality
- Adapted from Dutch standard (NEN)

## Passive sensor (BDS)



- Measures physical environment



Pressure



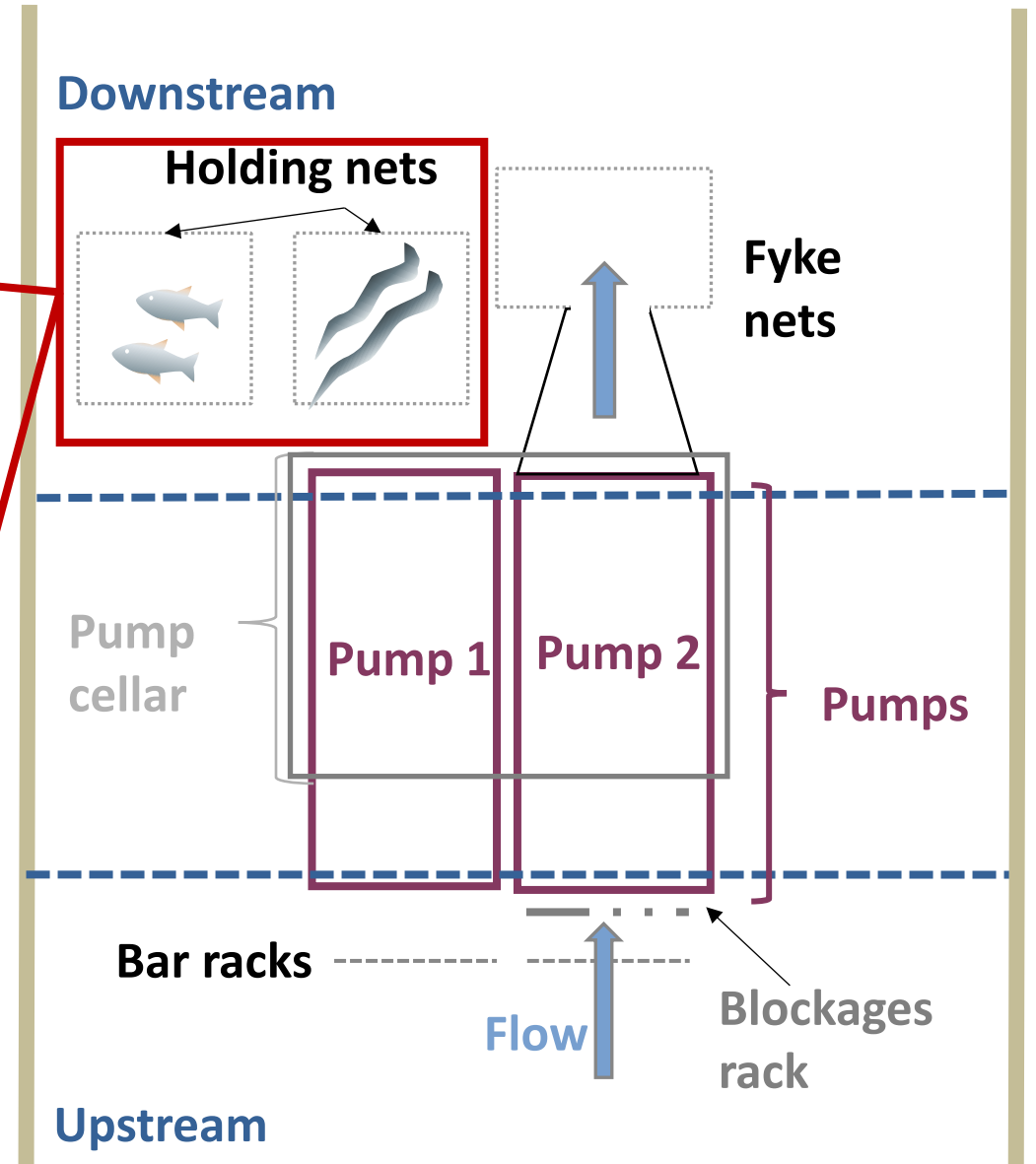
Acceleration



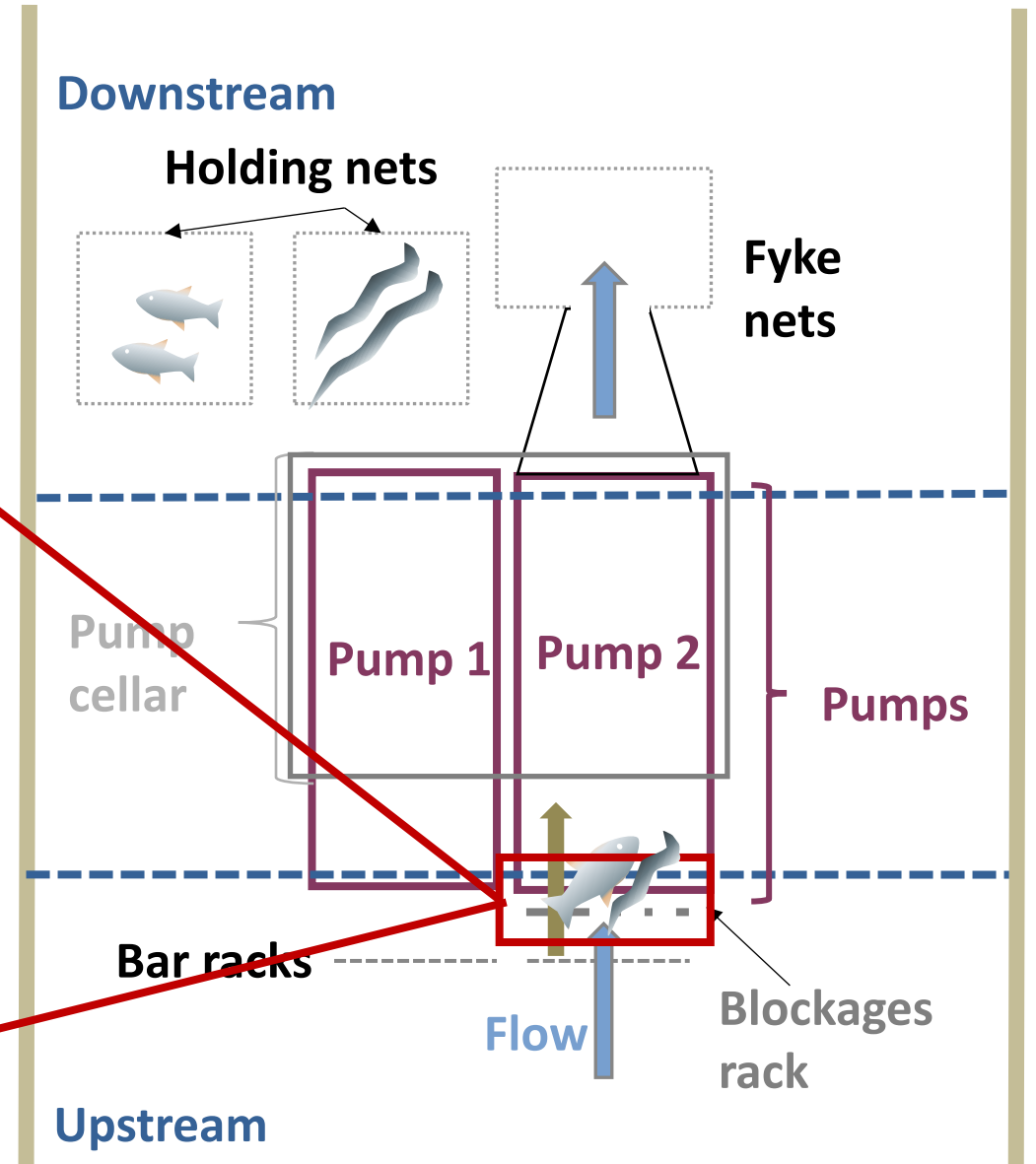
Rotation



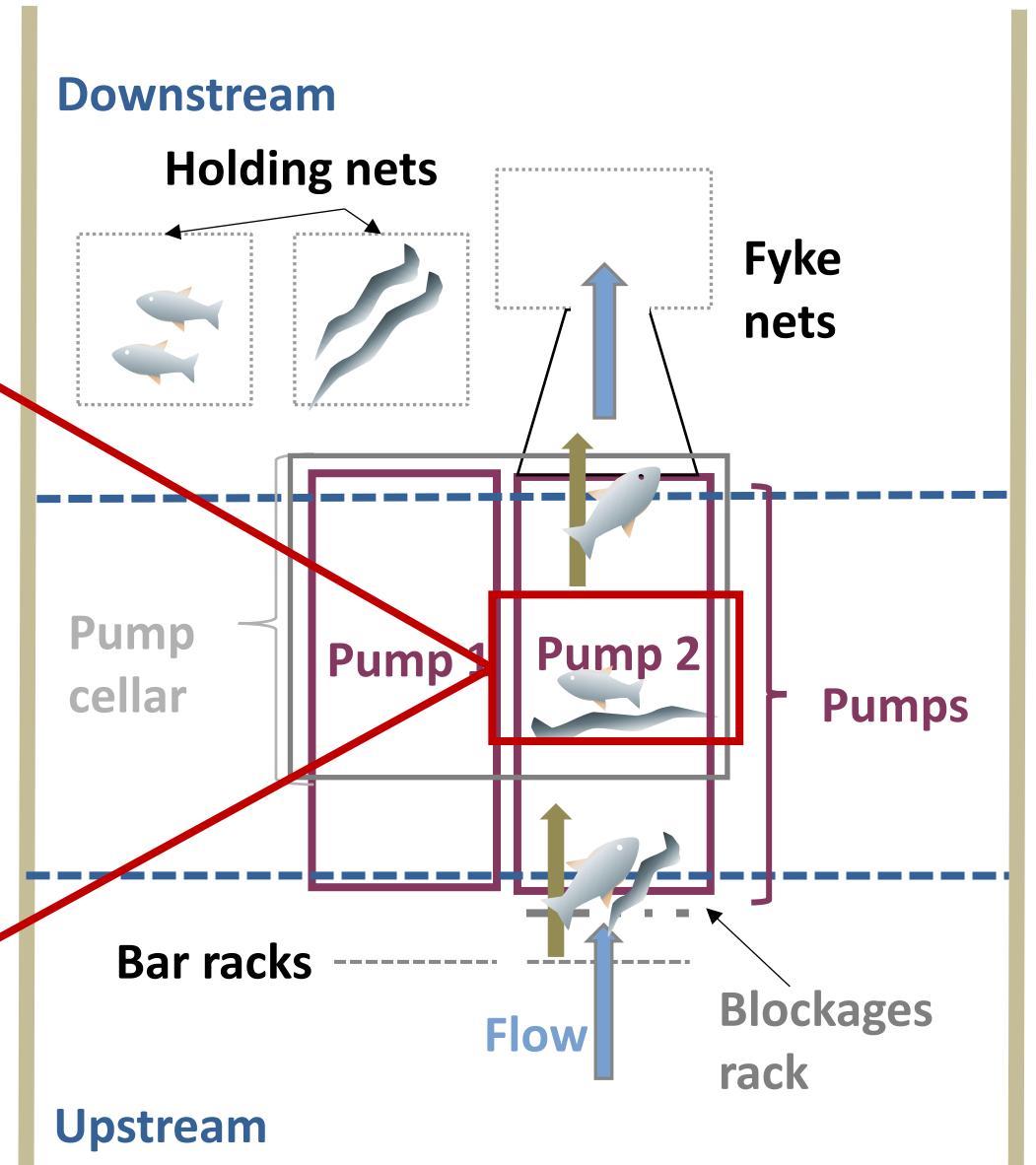
# Experimental setup



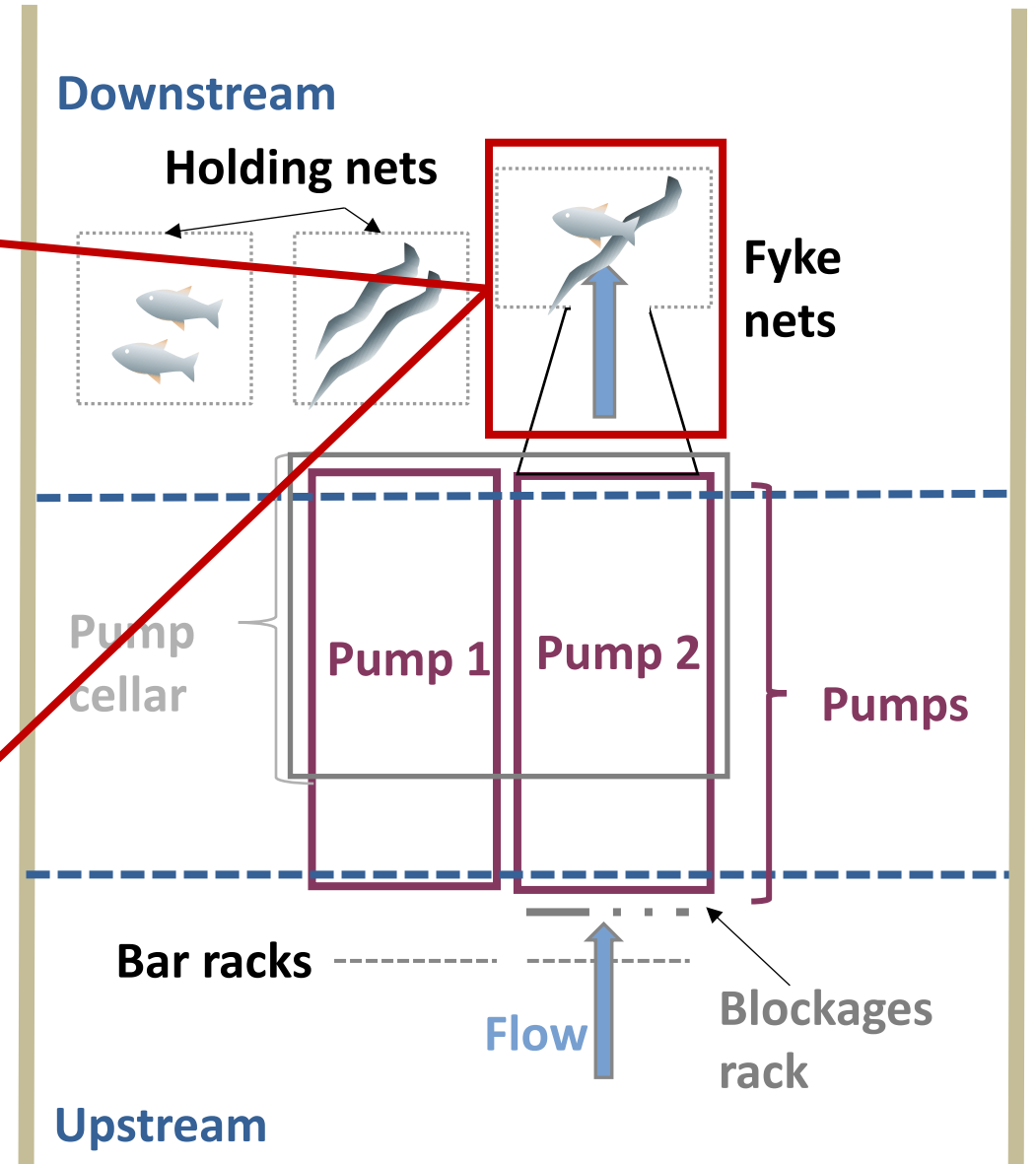
# Experimental setup



# Experimental setup



# Experimental setup

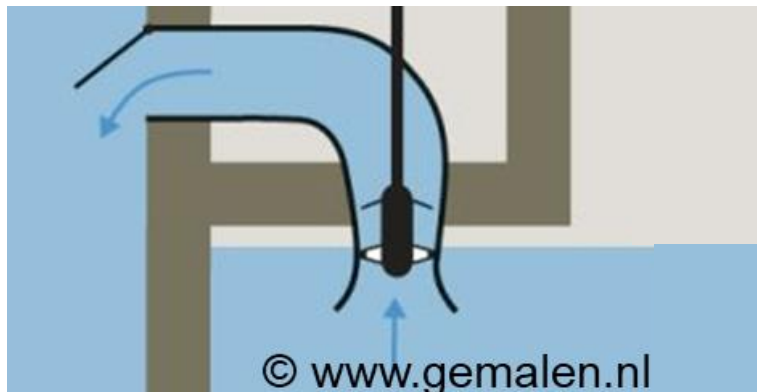


# Applying the protocol to 2 pumping stations

## Devils Hole



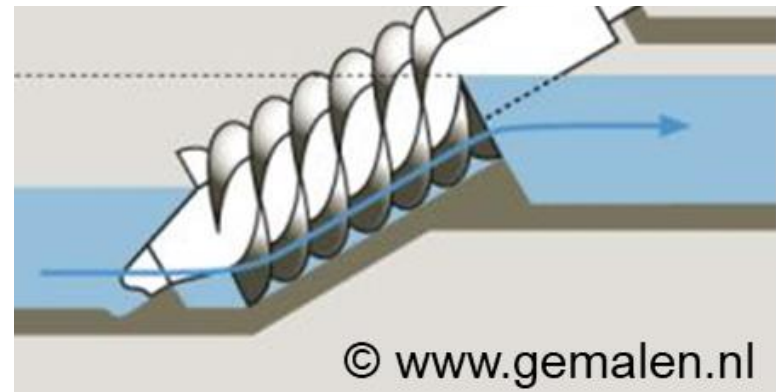
### Axial flow pumps



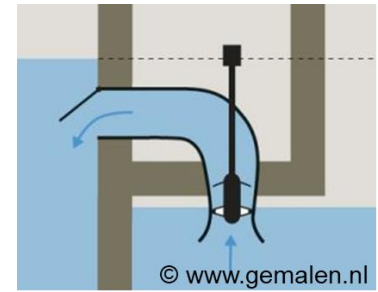
## Groot Schijn



### Archimedean screw pumps



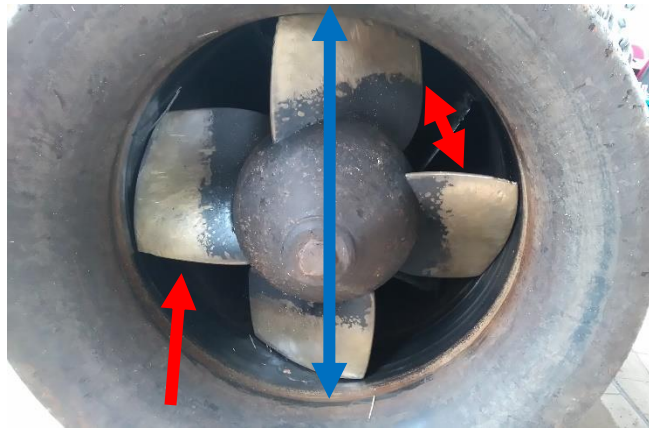
# Eel safe axial flow pumps?



Devils Hole



Classic axial flow pump



- Fixed speed
- 4 blades = less spaces
- Same diameter

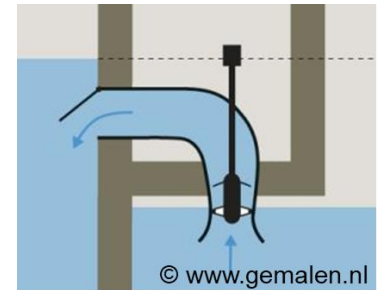
Pentair Fairbanks Nijhuis pump

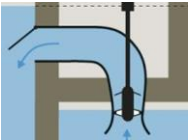









- Variable rotation speed
- Rounded blades
- 2 blades = more spaces
- Same diameter

Blade strike  
reduction?

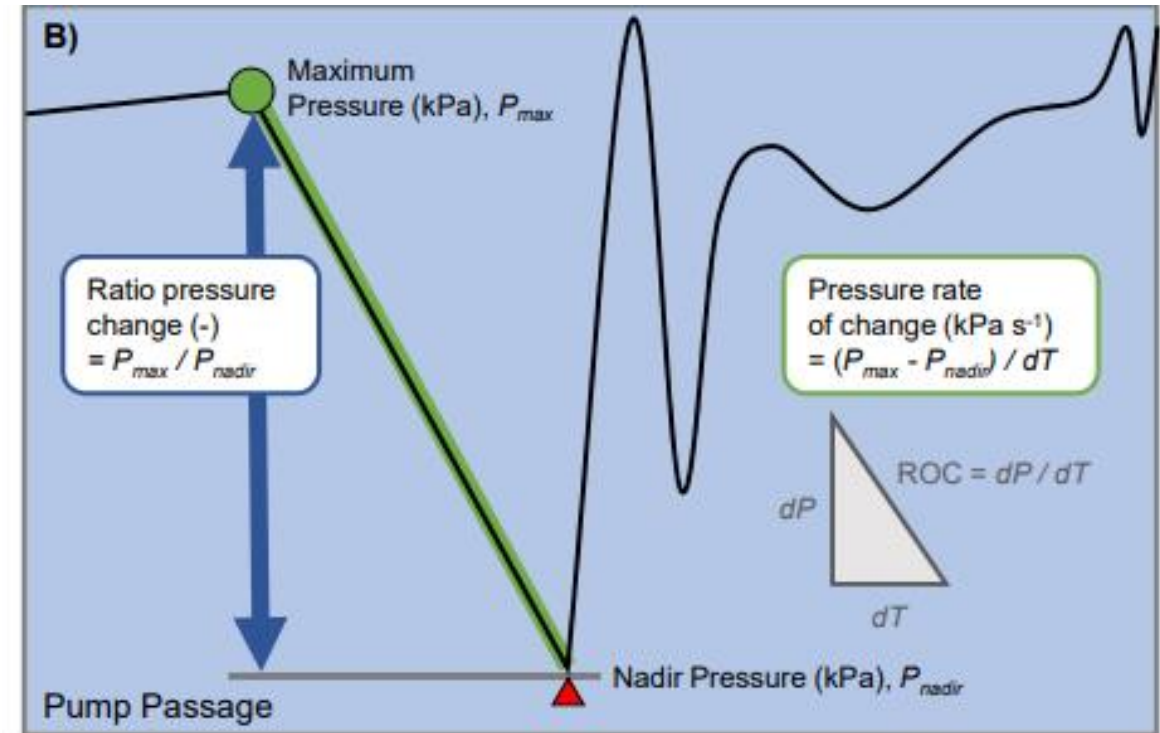
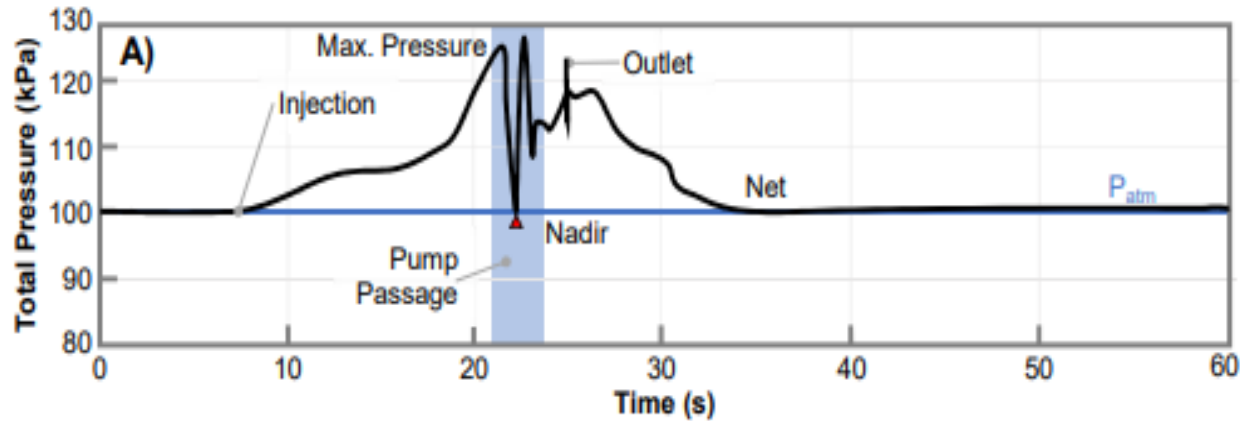
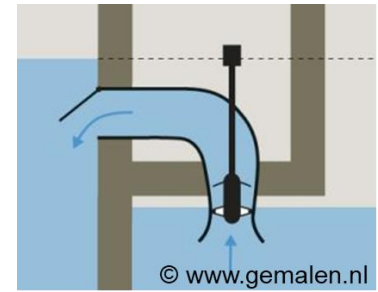
# Eel safe axial flow pumps?



| Pump type  | rpm   | control  | (re)captured  | mean length (mm)  | mortality   |
|--|---|--|---|---|---|
|   |  |  |  |  |   |
|   | 585   | /  | 1   | /   |  97% |
|  | 468   | 50   | 256   | 633   |   |
|  | 550   | 50   | 267   | 631   |   |

**Pentair Fairbanks Nijhuis pump = eel safe**

# Eel safe axial flow pumps?



Barotrauma risk high if:



Nadir = low



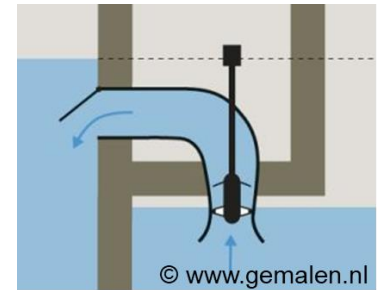
Log RP = high



ROC = high



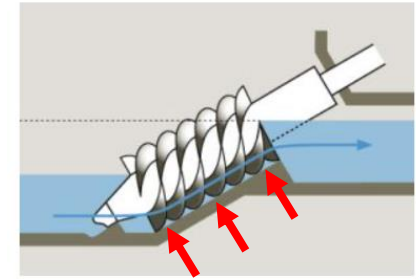
# Eel safe axial flow pumps?



| Pump type | rpm | useful data | nadir (hPa)   | Log ratio P       | ROC (hPa/s)     |
|-----------|-----|-------------|---------------|-------------------|-----------------|
|           |     |             |               |                   |                 |
|           | 585 | 6           | $854 \pm 164$ | $0,174 \pm 0,210$ | $4008 \pm 4118$ |
|           | 468 | 64          | $964 \pm 137$ | $0,048 \pm 0,155$ | $2657 \pm 7604$ |
|           | 550 | 51          | $933 \pm 126$ | $0,079 \pm 0,147$ | $2501 \pm 5248$ |

**no statistical differences between pumps!**

# Eel safe Archimedean screw pumps?



Archimedean screw



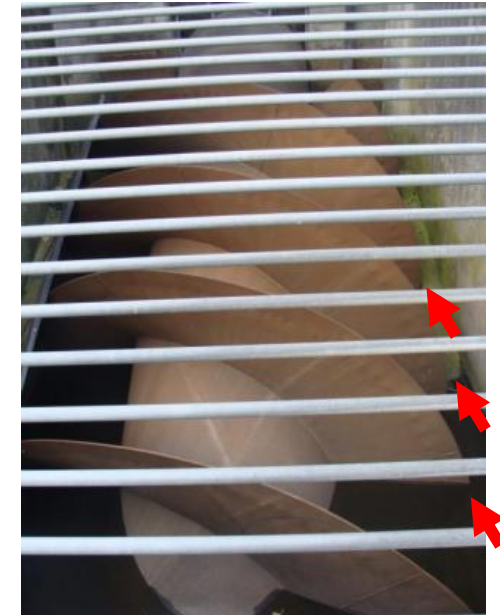
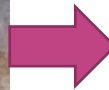
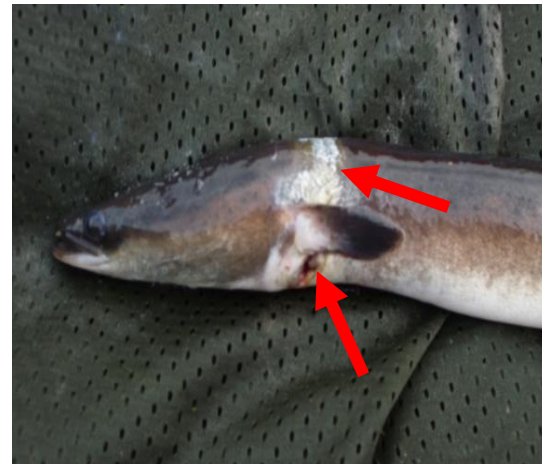
19%

De Wit adaptation

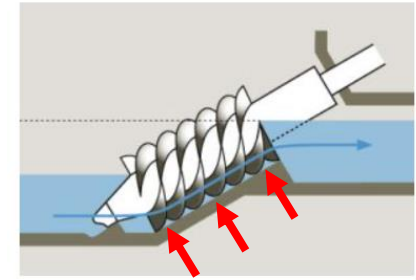


17%

Pinch damage in gully?

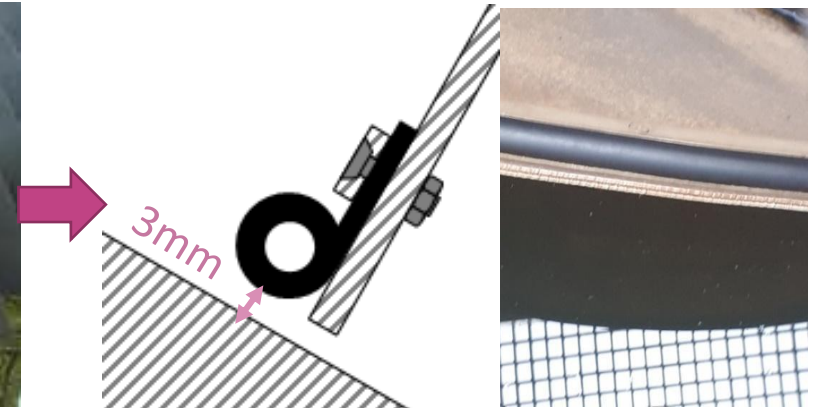
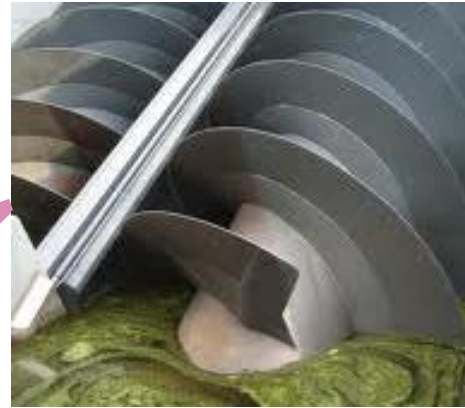


# Eel safe Archimedean screw pumps?



Open screw

Elst adaptation



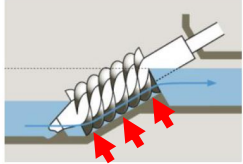





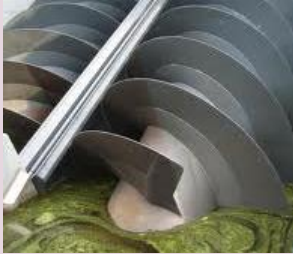
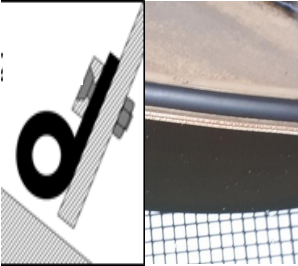

Groot Schijn



Enclosed screw

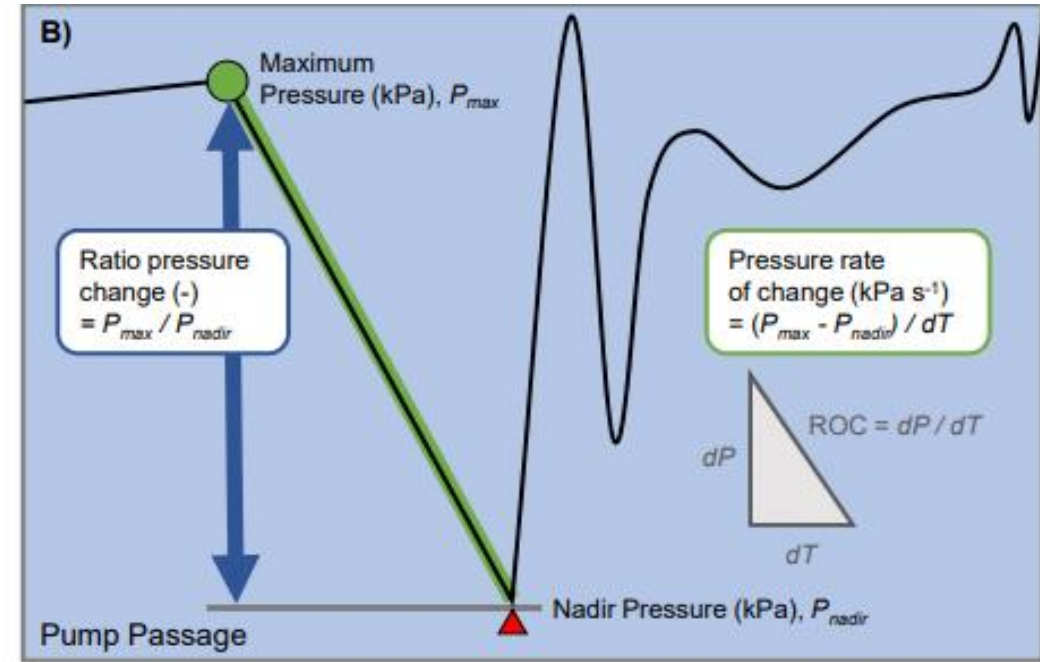
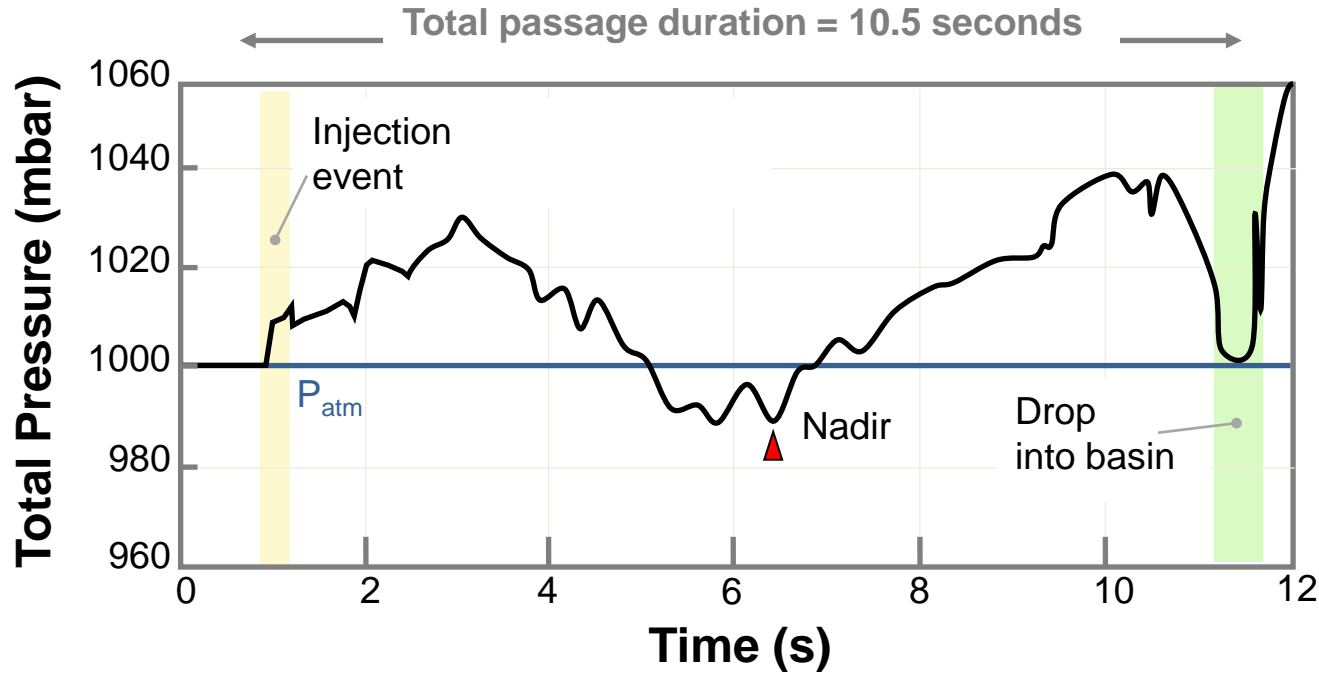
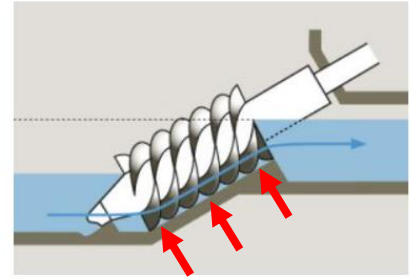


# Eel safe Archimedean screw pumps?

| Pump type   | rpm   | control  | recaptured  | mean length<br>(mm)*  | mortality   |
|---|---|--|---|---|---|
|    |  |  |  |  |  |
|    | 14,63   | 52   | 181   | 640   |   |
|   | 22,52   | 34   | 210   | 650   |   |
|   | 14,63   | 47   | 179   | 620   |   |
|   | 22,52   | 50   | 216   | 630   |   |
|  | 19,08   | 52   | 153   | 630   |   |
|   | 29,36   | 50   | 221   | 630   |   |

Broos et al.  
in  
preparation

# Eel safe Archimedean screw pumps?



Barotrauma risk high if:



Nadir = low

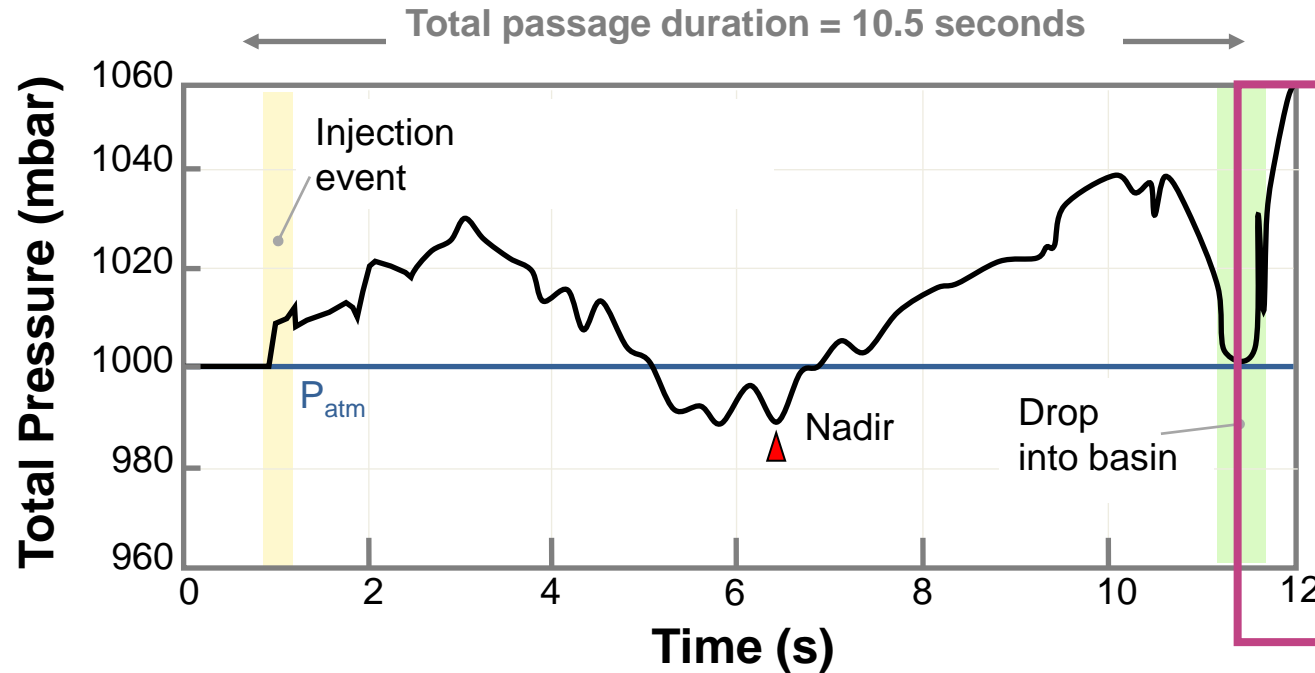
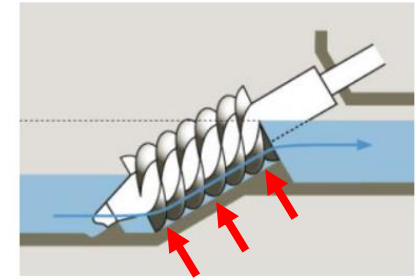


Log RP = high



ROC = high

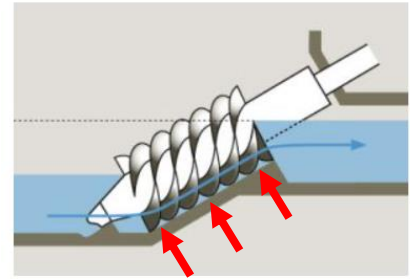
# Eel safe Archimedean screw pumps?

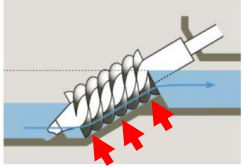








**Chaotic process**





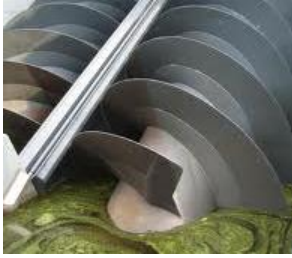

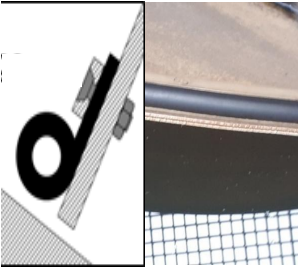









# Eel safe Archimedean screw pumps?

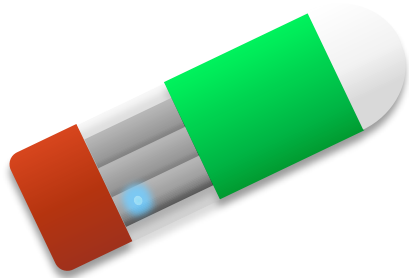


| Pump type  | rpm   | useful data  | nadir (hPa)   | ROC (hPa/s)   |
|--|---|--|---|---|
|   |  |  |  |  |
|   | 14,63   | 22   | 1141  | 252   |
|  | 22,52   | 48   | 1130  | 340   |
|  | 19,08   | 22   | 1121  | 153   |
|  | 29,36   | 19   | 1118  | 163   |

**no statistical differences!**

# Conclusion: decrease in eel smoothies



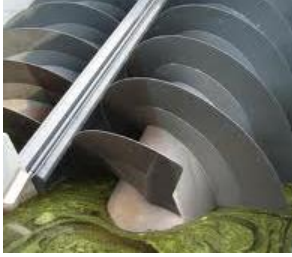

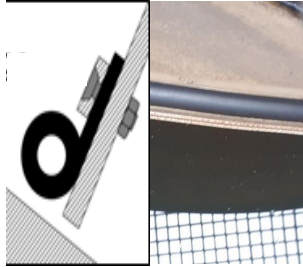

























|                          | Classic axial flow pump   | Pentair Fairbanks Nijhuis  | Open screw  | Enclosed screw   | Elst adaptation  |
|--------------------------|---|--|---|--|--|
| Operational mode         |      |     |      |     |     |
| Minimal                  | /   |  0% |  6%  |  5% |  5% |
| Maximal (or fixed speed) |  97% |  0% |  13% |  4% |  5% |



- Provided insights beyond fish-only observations.
- No direct link to improved fish safety (blade-strike/pinch damages)

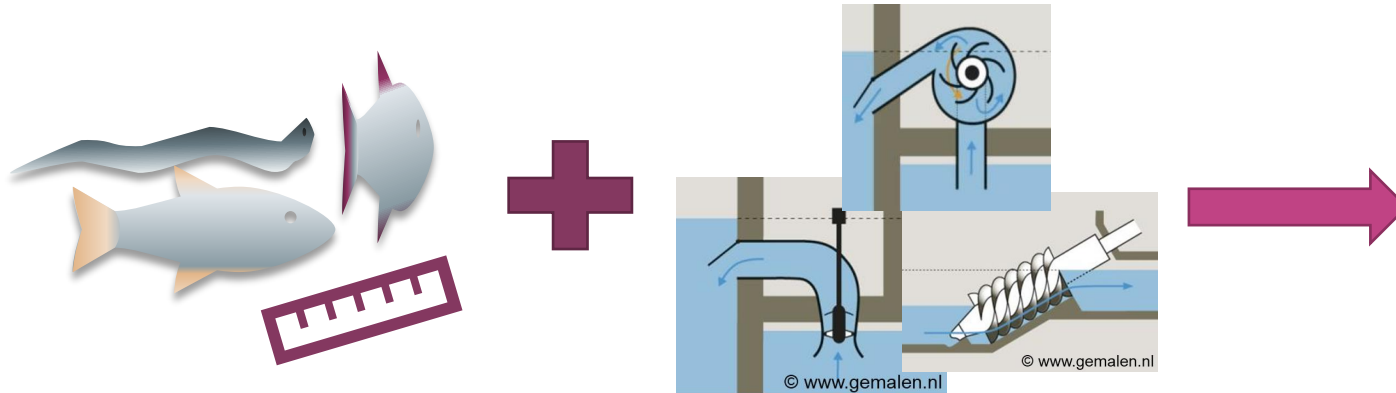


# Smoothie matrix: eel safe ≠ fish safe!

|  |   | Classic axial flow pump   | Pentair Fairbanks Nijhuis   | Open screw  | Enclosed screw   | Elst adaptation   |
|--|---|---|---|---|--|---|
| Operational mode   |   |          |        |        |       |  |
|  Minimal                    | /   |  0%    |  6%    |  5%    |  5%   |   |
|  Maximal (or fixed speed)   |  97%   |  0%    |  13%   |  4%    |  5%   |   |
|  Minimal                    | /   |  30%  |  18%  |  17%* |  7%  |   |
|  Maximal (or fixed speed) |  60% |  30% |  30% |  7%  |  9% |   |
|  Maximum and minimum      |  60% |  82% | /   | /   | /  |   |

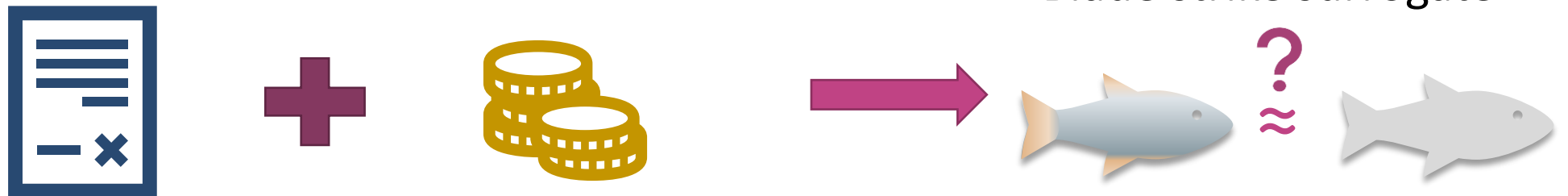
# Future research: my PhD

## 1. Pump and Species Characteristics



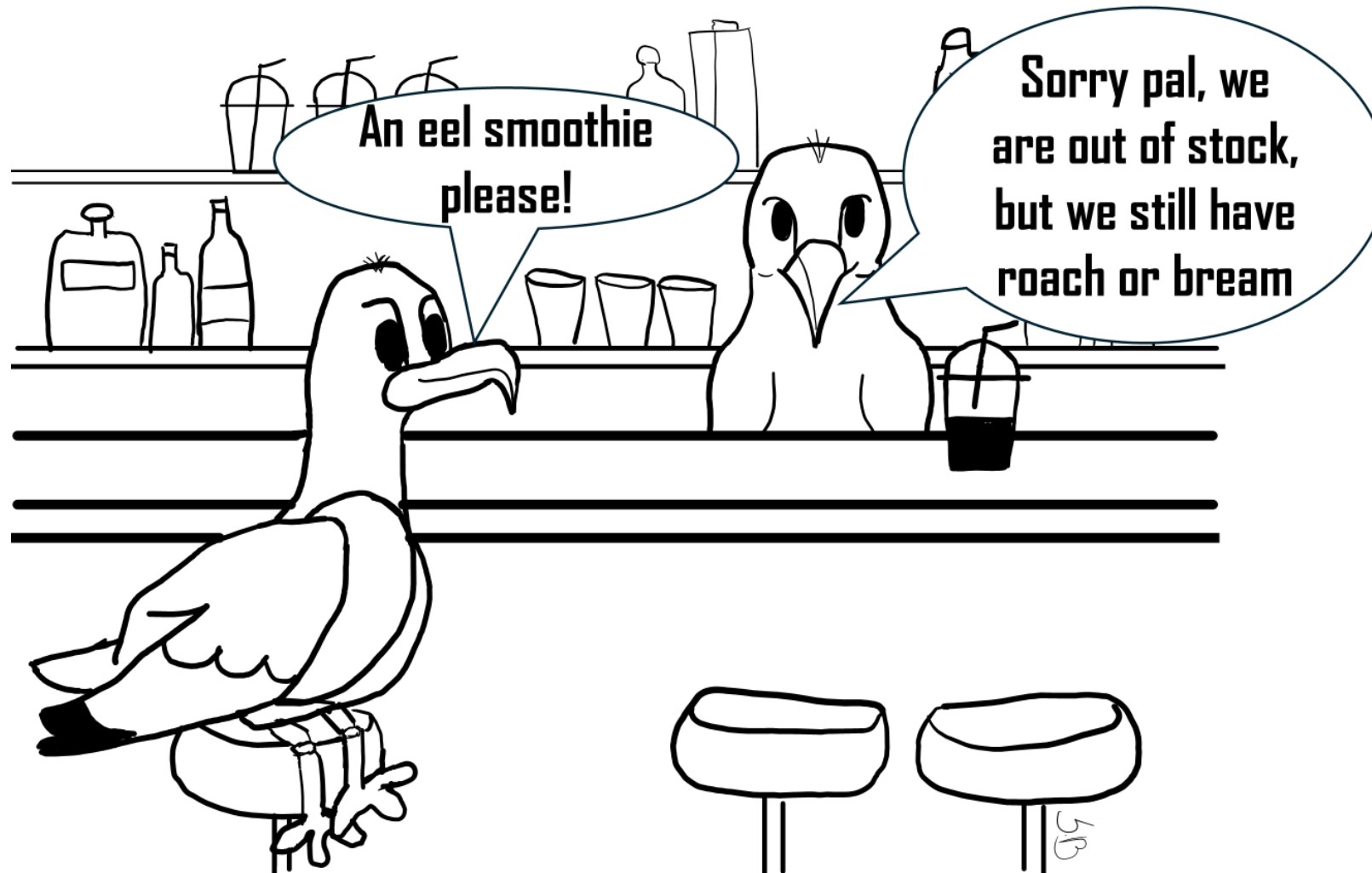
- Statistical inference
- variables correlated to particular injury
  - Cross- compare
  - Estimate risk

## 2. Use of surrogates

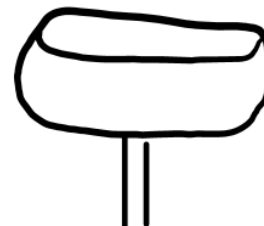


Blade strike surrogate

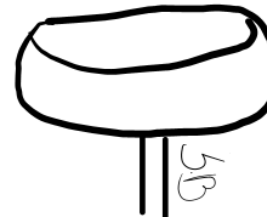
# Thank you for your attention!



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