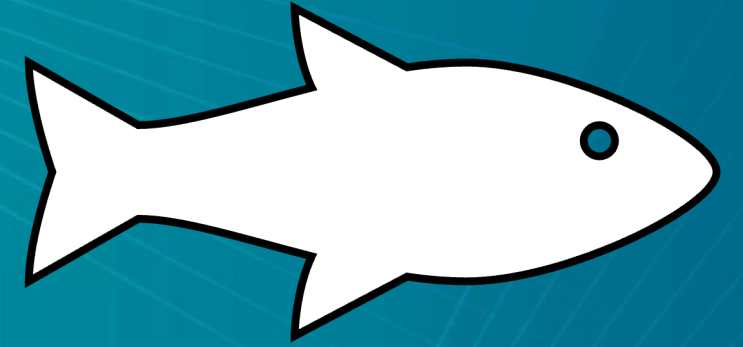


Not just the pump; broader considerations for downstream migrating silver eels at a 'fish-friendly' pumping station



Oliver Evans, Thomas Hutchinson,
Liam Carter, Stephen Collier, Andrew
Don, Rosalind M. Wright, Jeffrey A.
Tuhtan, Gert Toming and Jonathan D.
Bolland

The problem...

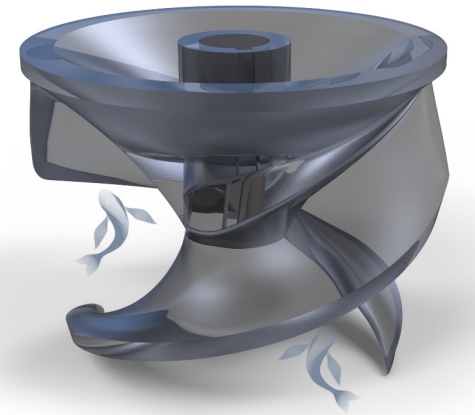
- Traditional style pumps can have extremely high mortality rates, especially for eels
- Mortality rates of up to 97%
- Delayed mortality and sub lethal injuries such as cuts, abrasion and internal bleeding can also occur
- All would reduce the chance of successful migration!



Developing 'fish-friendly' pumping stations

Key design features:

- Curved edges to reduce chance of blade mutilation
- Reduced number of blades
- Reduced pump running speed and reduced water velocity to limit the probability of blade strike



But...

- The pump must be operating to provide a downstream passage route!
- An eel must enter the pump to pass it!
- Safe route through the entire pumping station

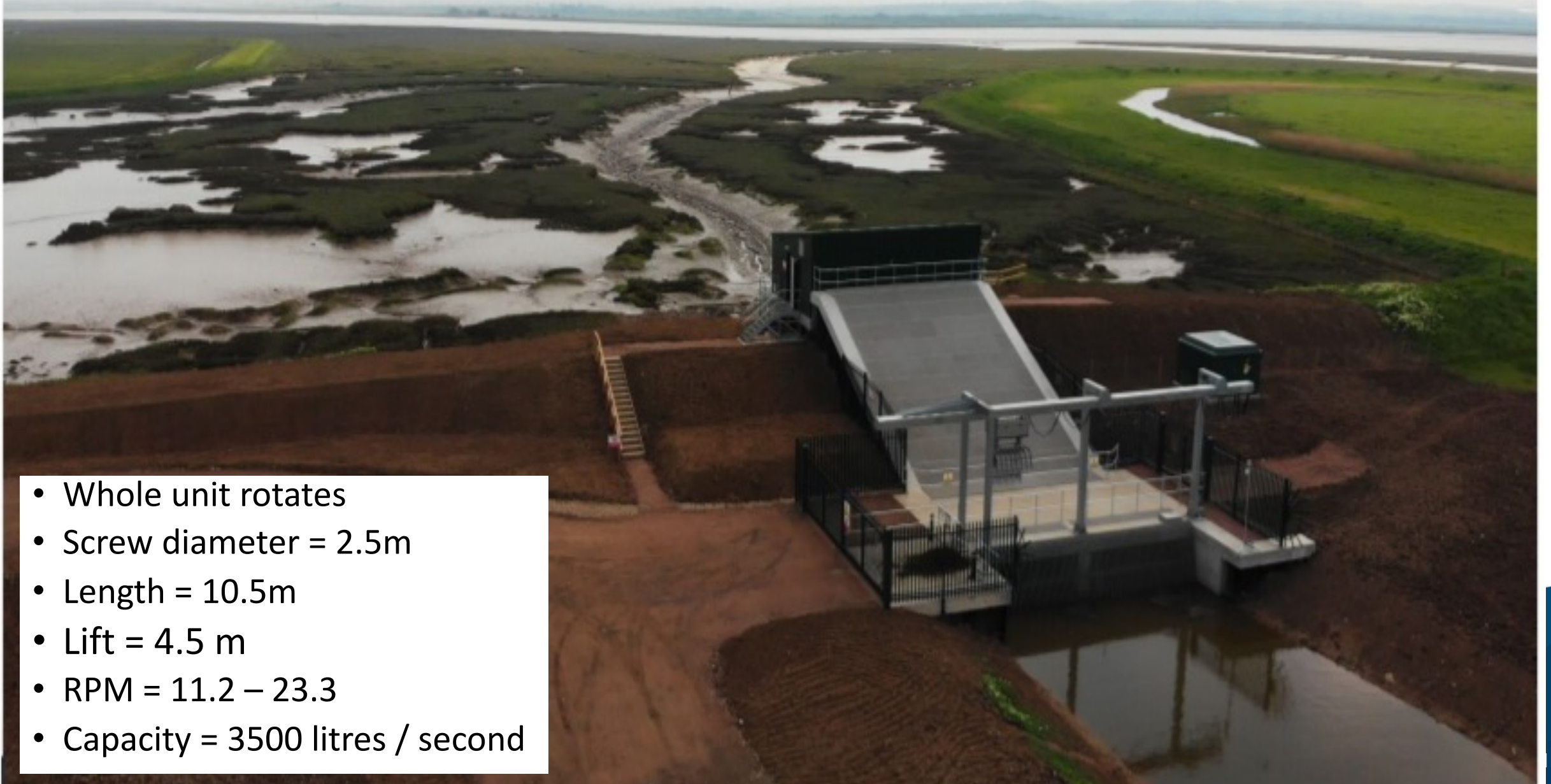
Aims and objectives

Aim: Understand the movements of downstream migrating silver eels at a fish-friendly pumping station

Specific objectives were to assess:

1. The timing of when eels approached the pumping station
2. The behavior of eels as they approached the pumping station weedscreen
3. The conditions experienced during movement through the entire pumping station

'True' Archimedean screw pump



- Whole unit rotates
- Screw diameter = 2.5m
- Length = 10.5m
- Lift = 4.5 m
- RPM = 11.2 – 23.3
- Capacity = 3500 litres / second



Study design



ARIS used to image eels approaching the pumping station weedscreen



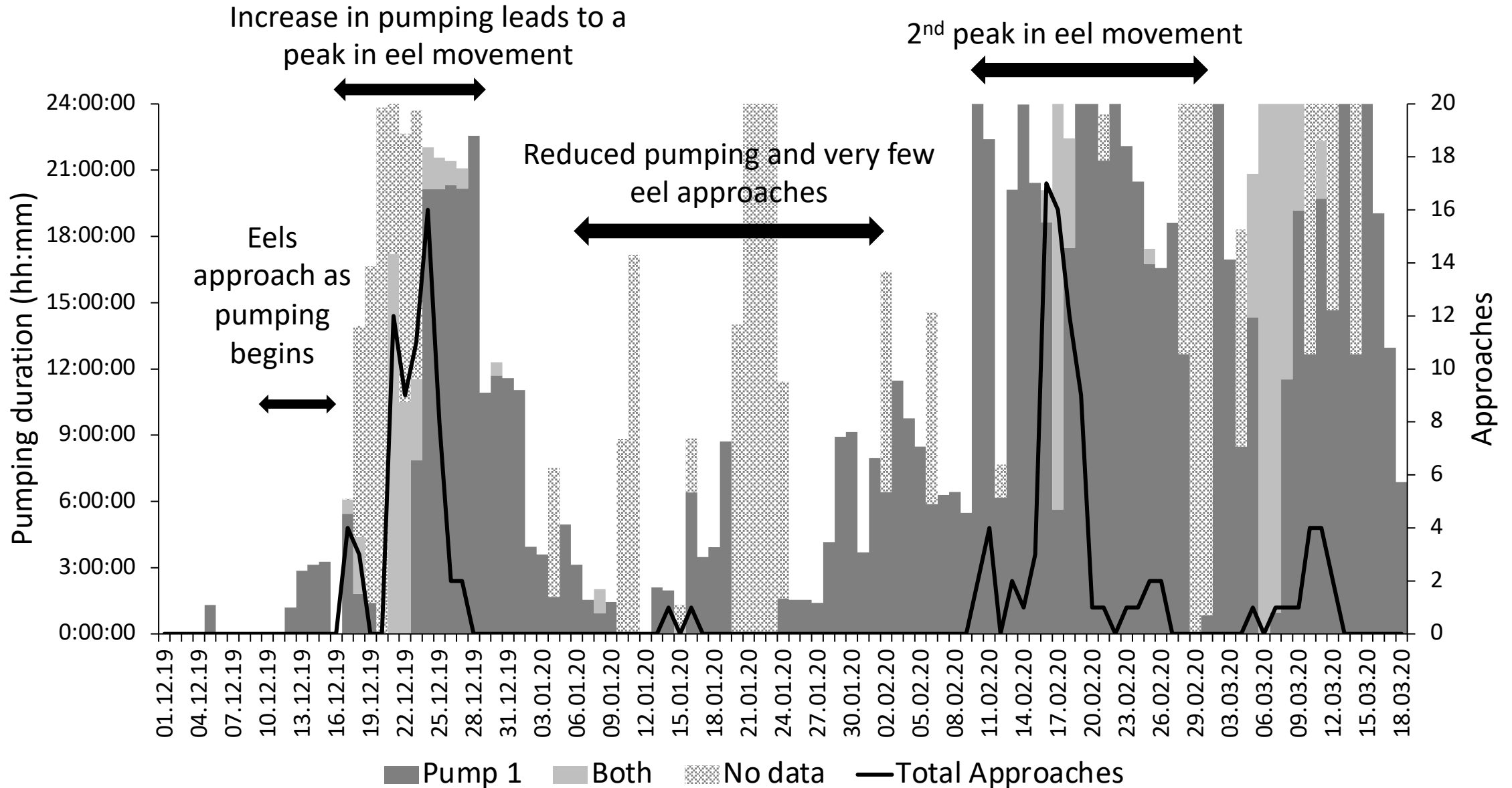
Study year	Start date	End date
1	08.10.19	18.03.20
2	04.11.20	30.03.21
3	09.12.21	24.02.22



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Movement of eels

Pump operation and eel approaches (Year 1)



Pump start date and operation

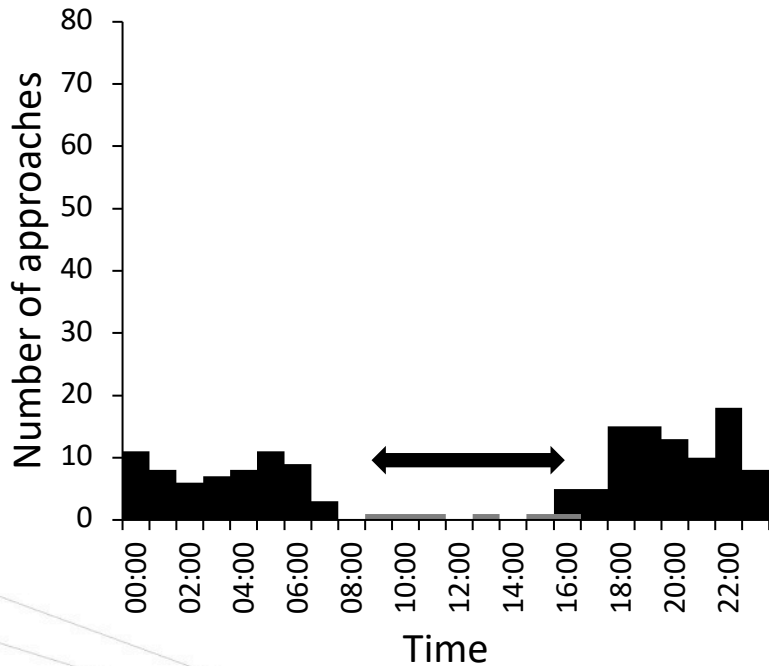
Eels would typically migrate in the UK from Autumn

Year	Pump first operated	Pumped >4 hours in one day	Total hours pumping	Mean \pm S.D. pump hours per day
1	05.12.19	17.12.19	1125:53	10:20 \pm 0.38
2	11.12.20	12.12.20	1287:59	11:56 \pm 0.38
3	21.12.21	27.12.21	90:19	01:23 \pm 0.06

Eel approach by hour

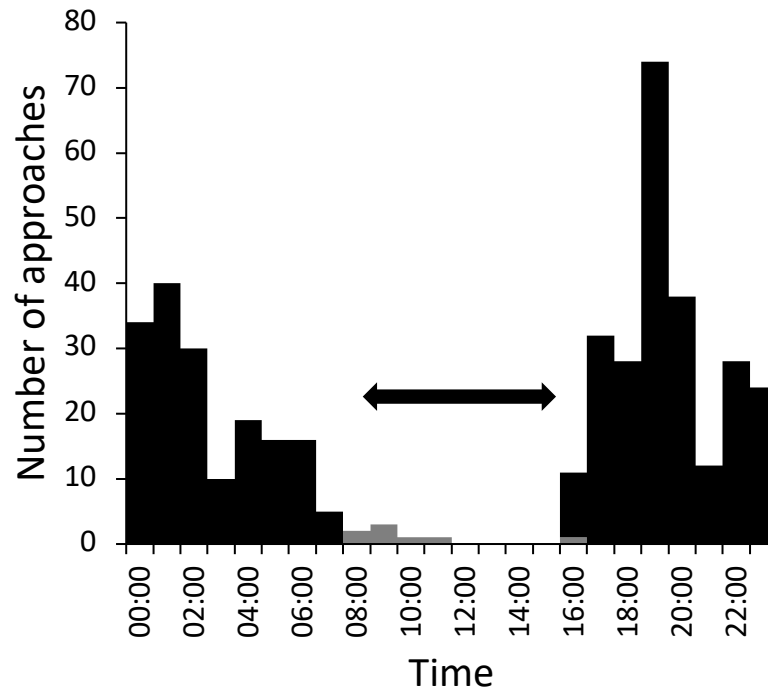
Year 1 (n = 157)

3.82%



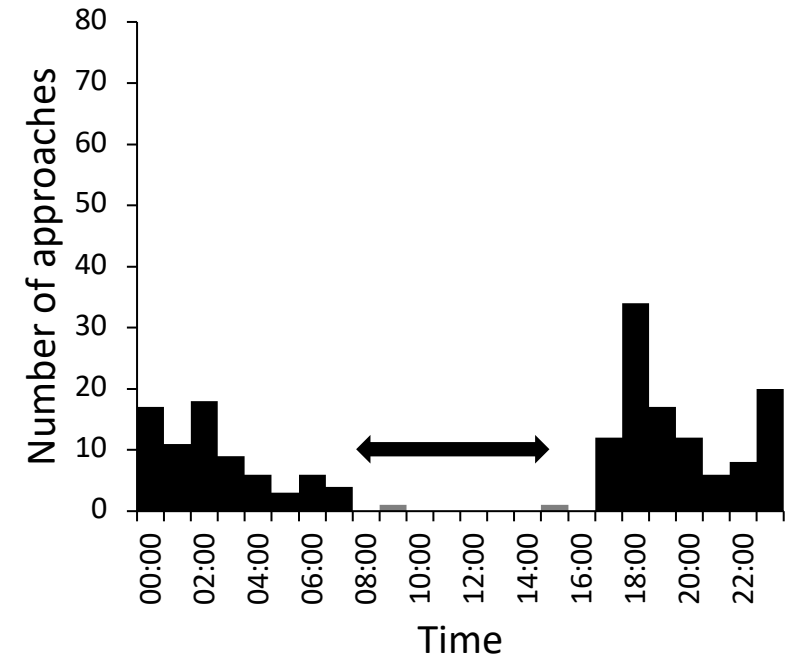
Year 2 (n = 424)

1.89%



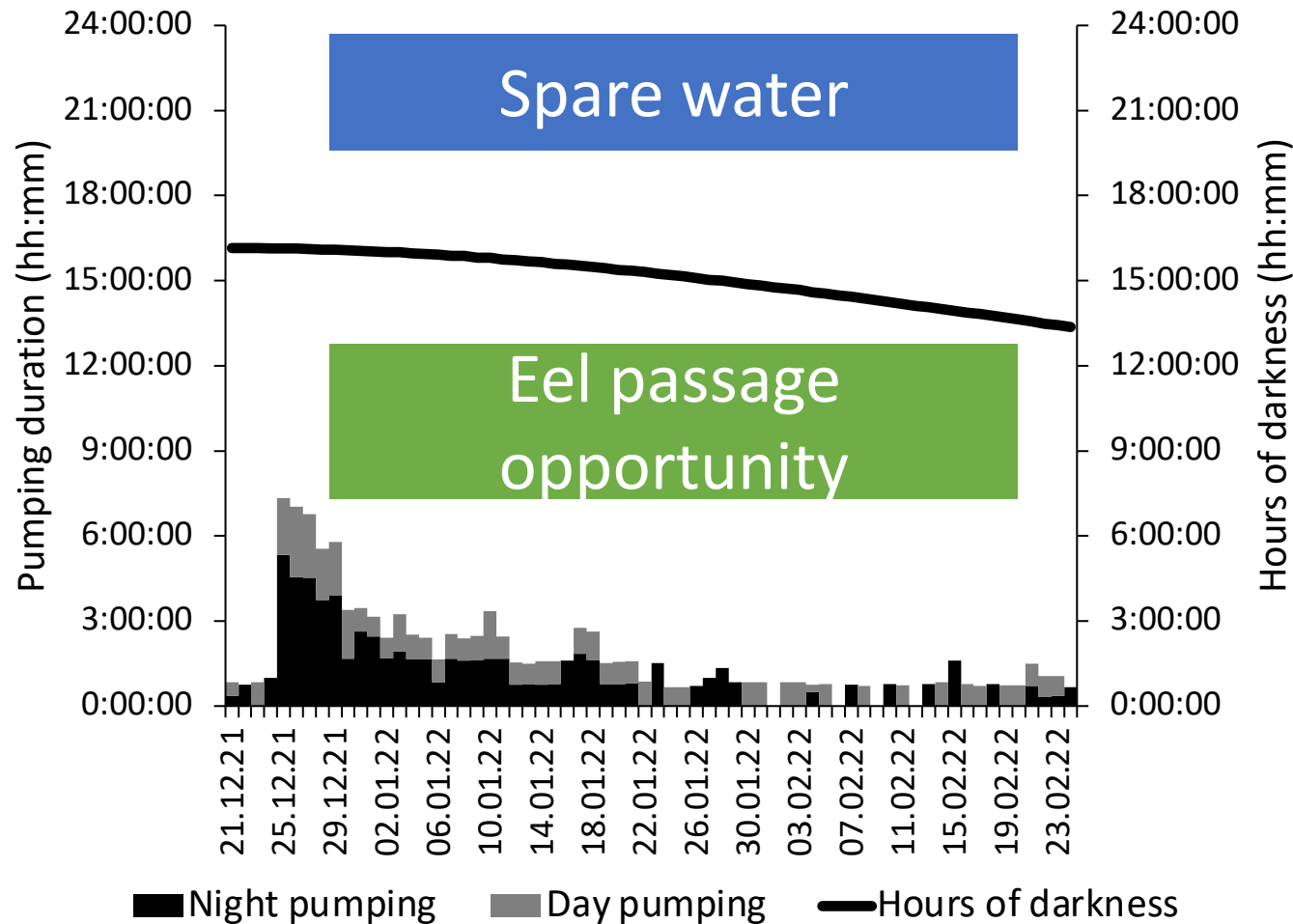
Year 3 (n = 185)

1.08%



■ Day ■ Night

Missed passage opportunities in dry years



Since first operation:

- 4 days with no pump operation (6.2%)
- 16 days with only daytime pump operation (24.6%)

30.8% of days had no night pumping

- Day pumping = 34:13 (hh:mm)
- Night pumping = 56:06 (hh:mm)

37.9% of the pumping during daylight but only 1.08% of eels approached



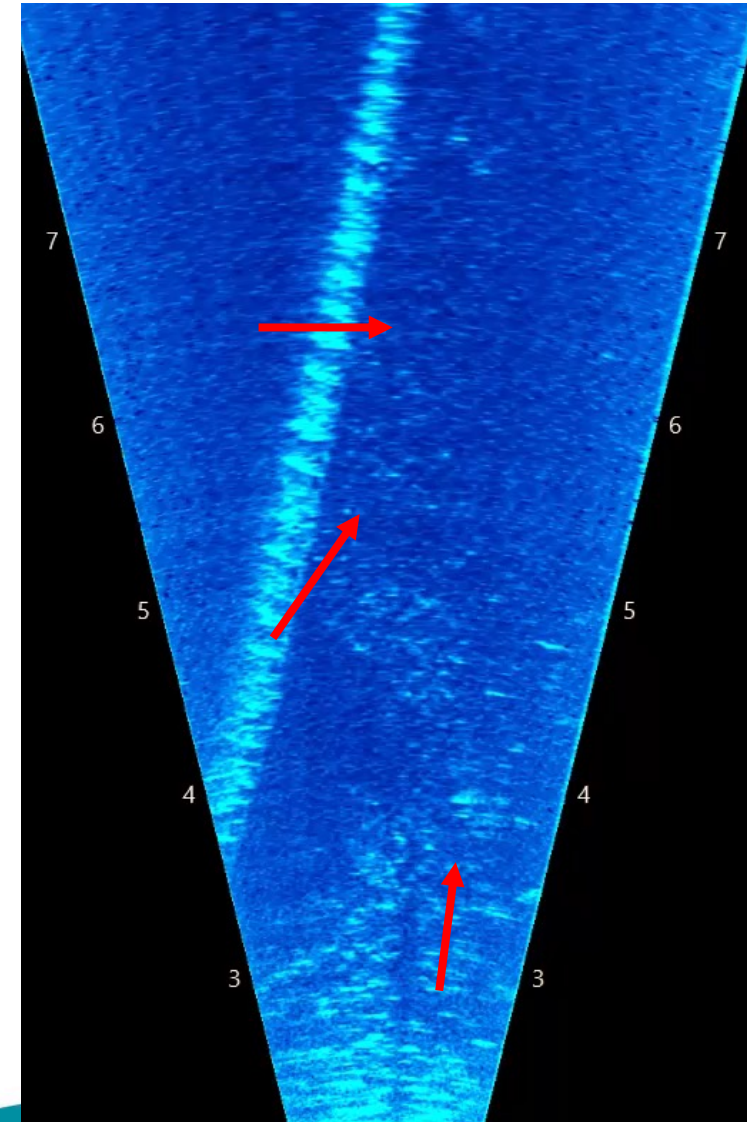
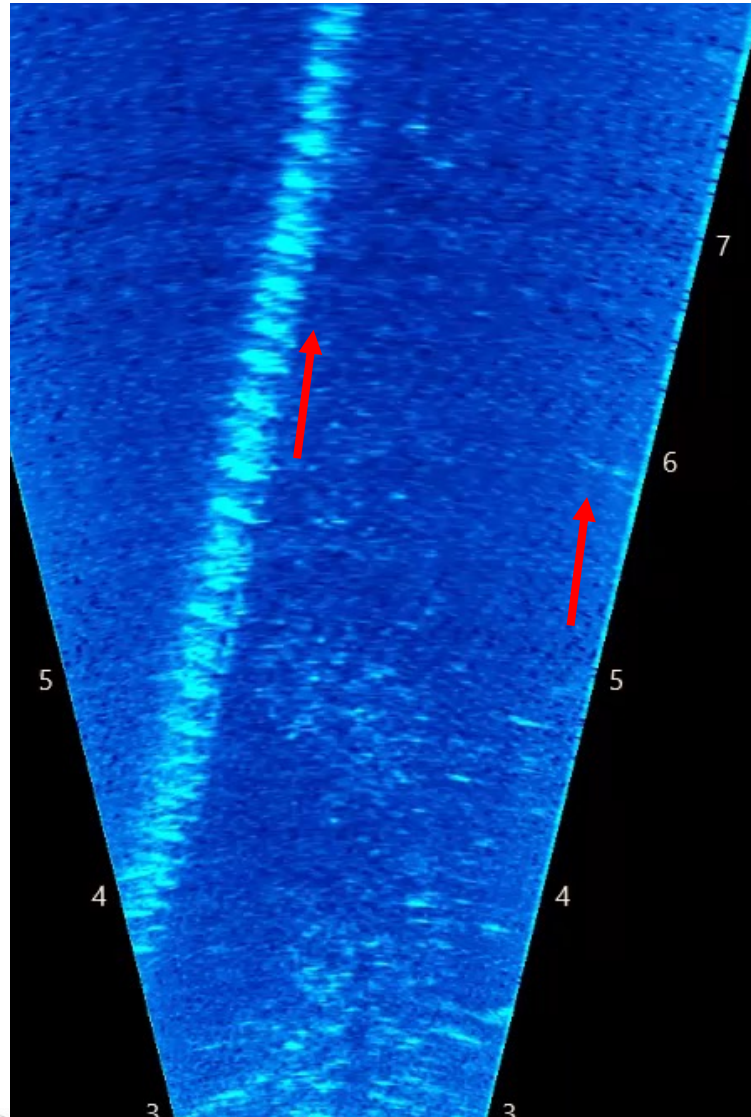
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Response of eels

Eel response at Bells pumping station

3 behaviors
observed:

- Tactile
- Non-Tactile
- No response



Weedscreen changes

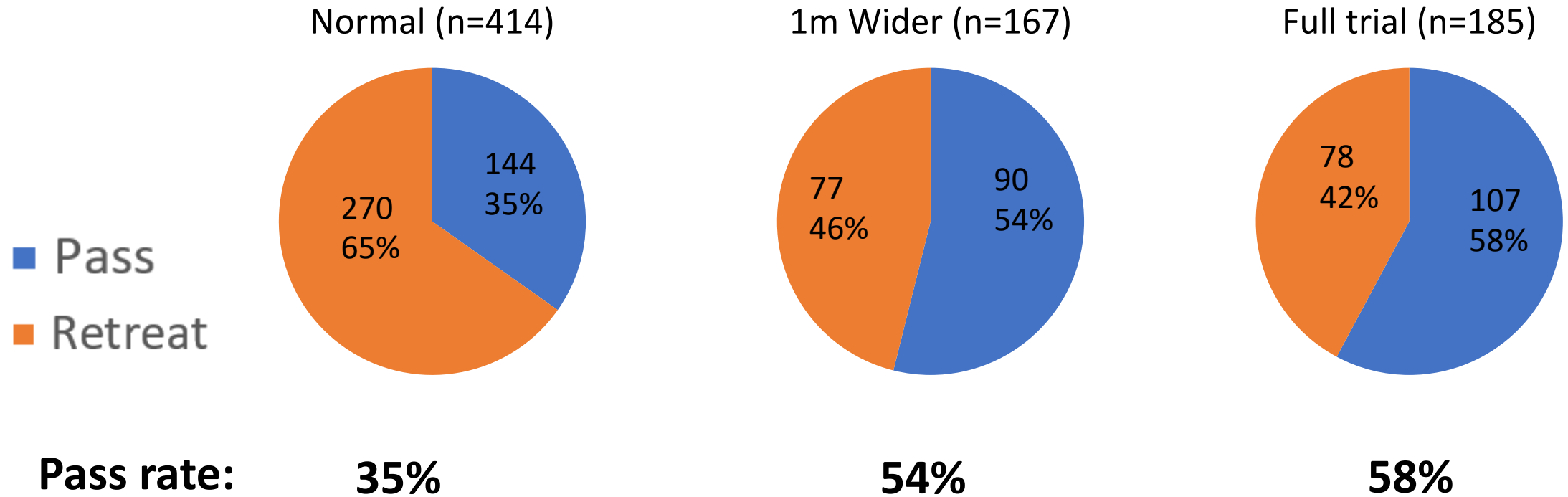
Original: 100mm spacing

Trial: 1m of wider spacing

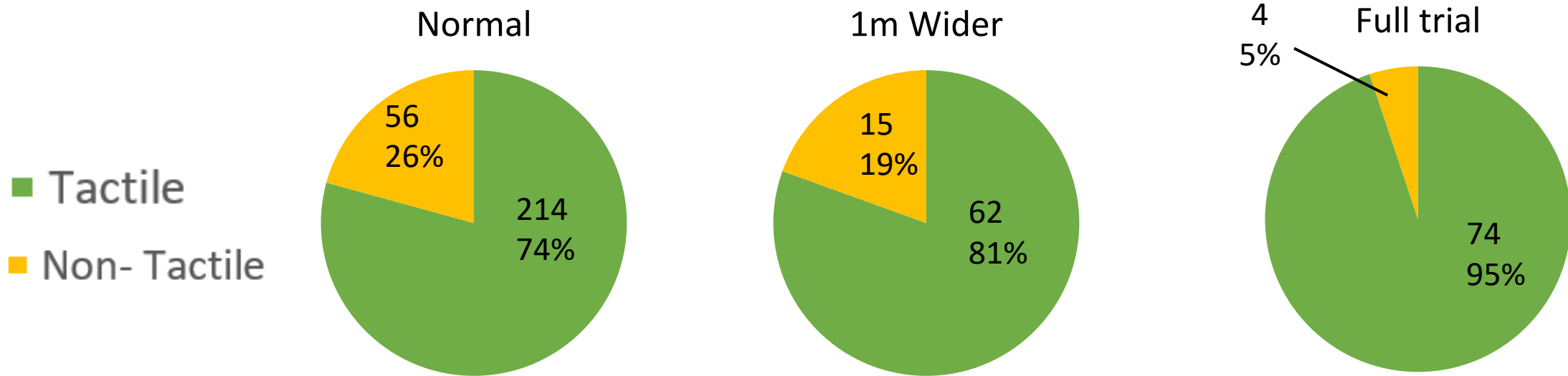
Full trial: All wider spacing



Eel fate at weedscreen



Eel response



Percentage of non-tactile responses decreased with wider weedscreen



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Assessing fish-friendliness

Assessing 'fish friendliness' of the pump

Due to the nature of the site live fish trials were not possible (this year):

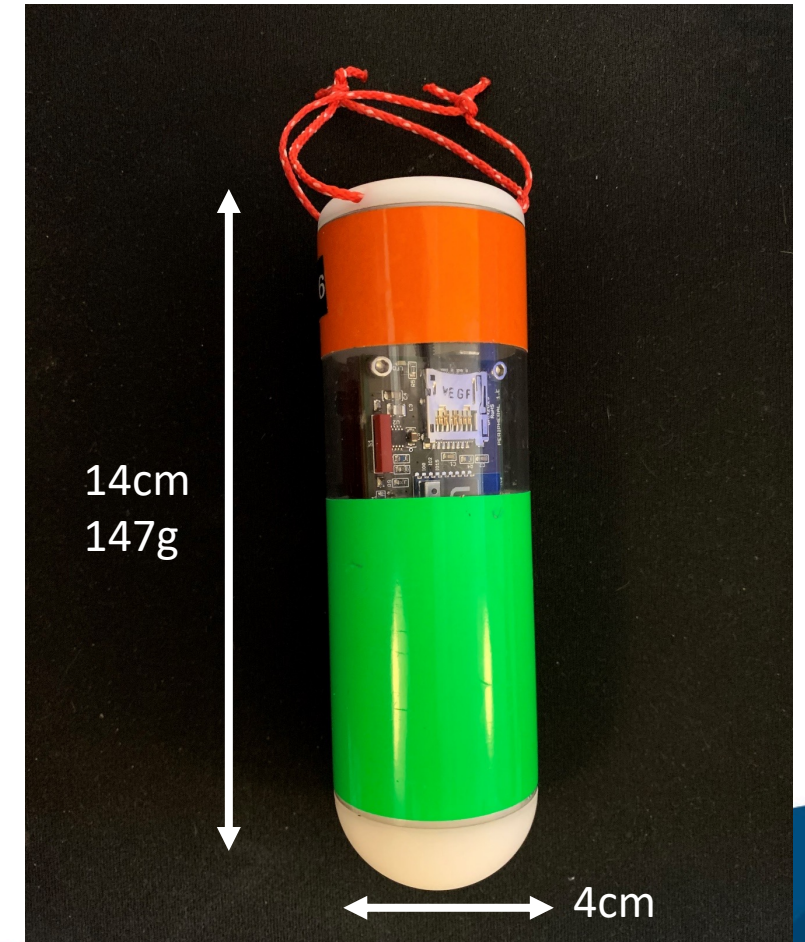
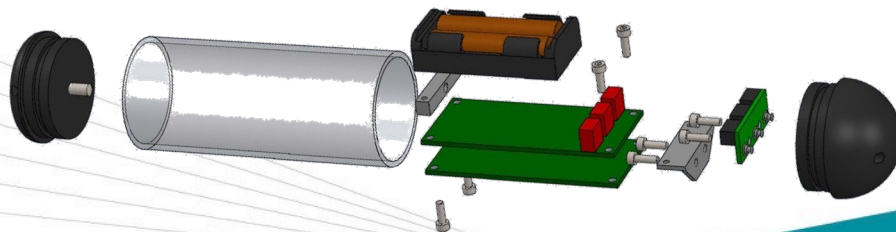
- Too few high tides
- Downstream environment unsafe
- Metalwork and obstructions could damage nets and recaptured eels
- ***Therefore...***

Sensors were used as a surrogate for eels and to record the conditions that would be experienced



Barotrauma Detection System (BDS)

Sensor sampling rate	400 kHz (digital) Saved at 100 or 250 Hz
Maximum sampling time	240 min
3D acceleration	+/- 16 g
3D rotational velocity	+/- 2067 °/s
Pressure	0 - 2941 kPa (3 sensors) Resolution: 0.028 kPa



Recapture of BDS

- One pump was run under normal operating conditions
- 18 BDS devices were successfully recovered



Typical pump passage:

Three main causes of injury:

Nadir pressure

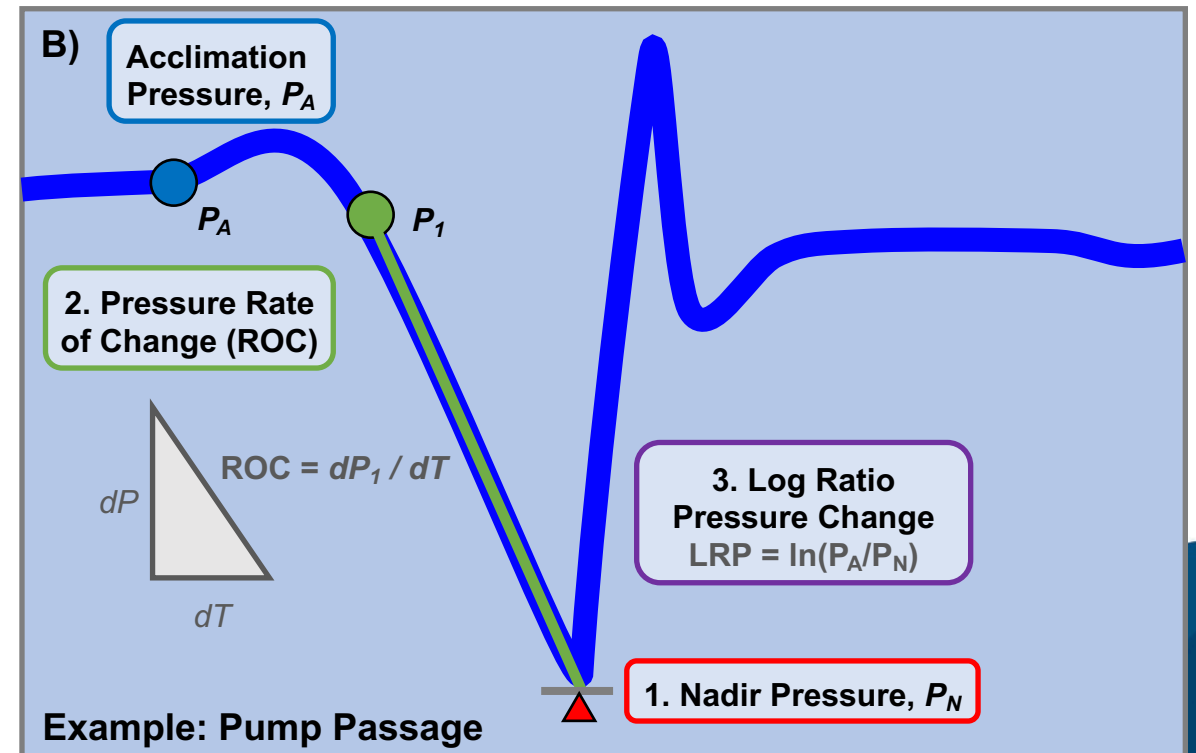
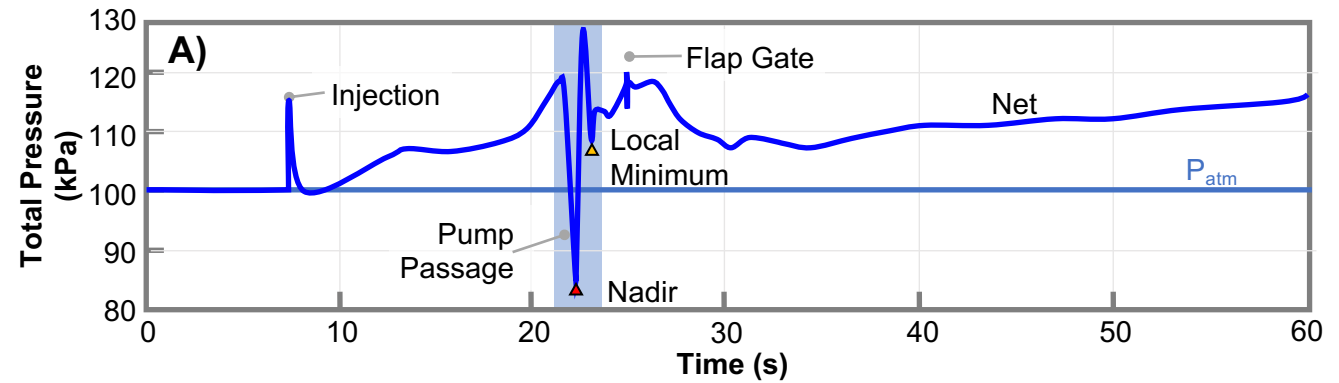
Lowest point of pressure during passage

Pressure rate of change

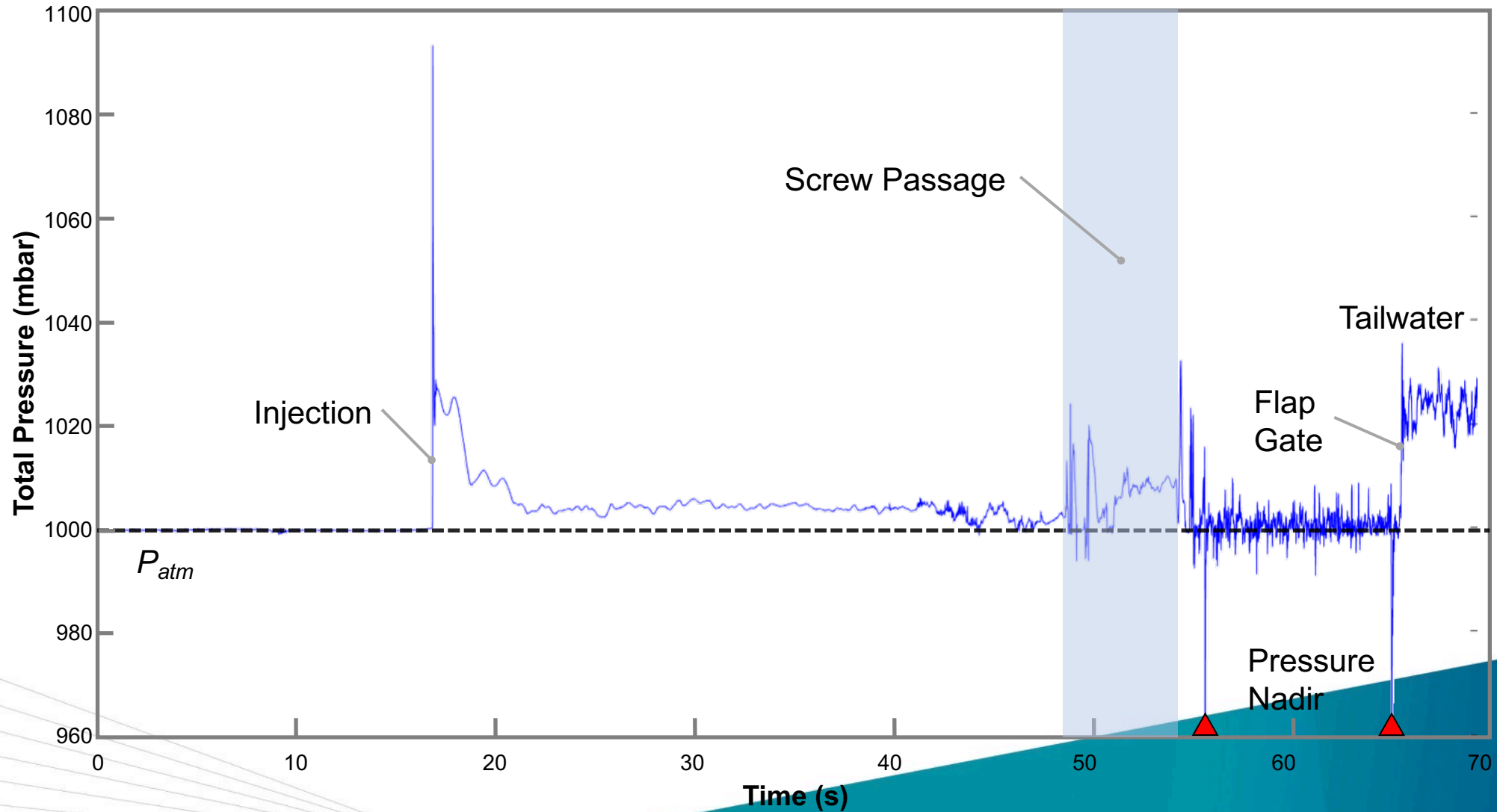
Difference between nadir value and highest point within previous 0.5 seconds

Log ratio pressure change

Variation in pressure during passage



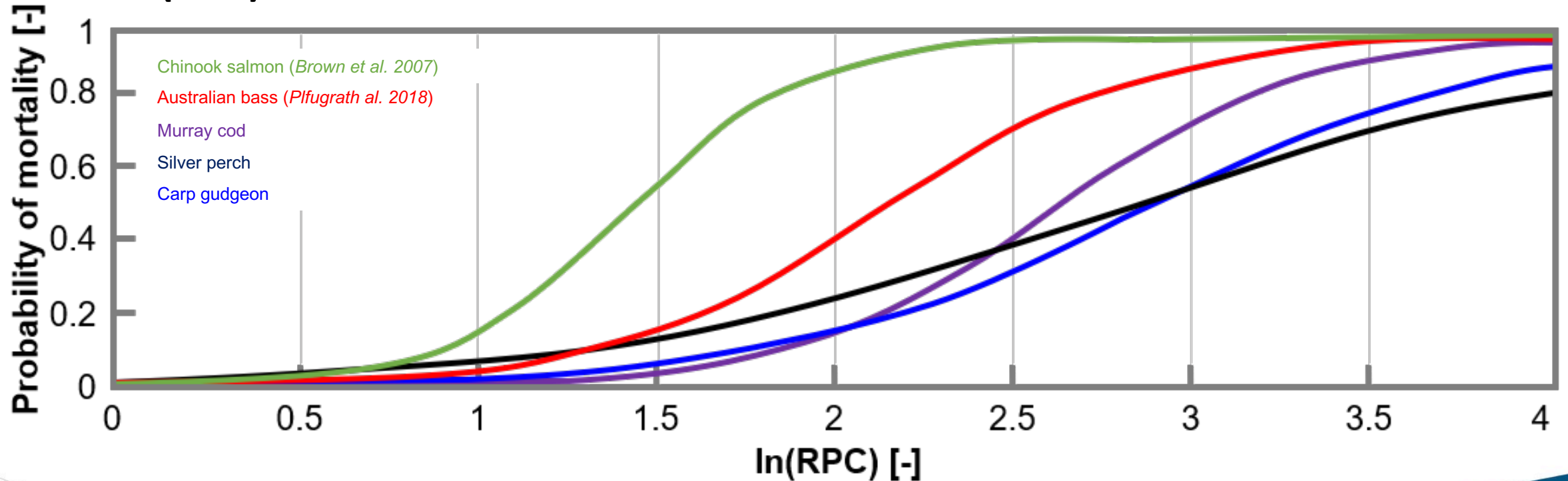
Typical Sensor Pressure at ASP ($n = 18$)



Very Low Expectation of Barotrauma Risk

Sensors in this study

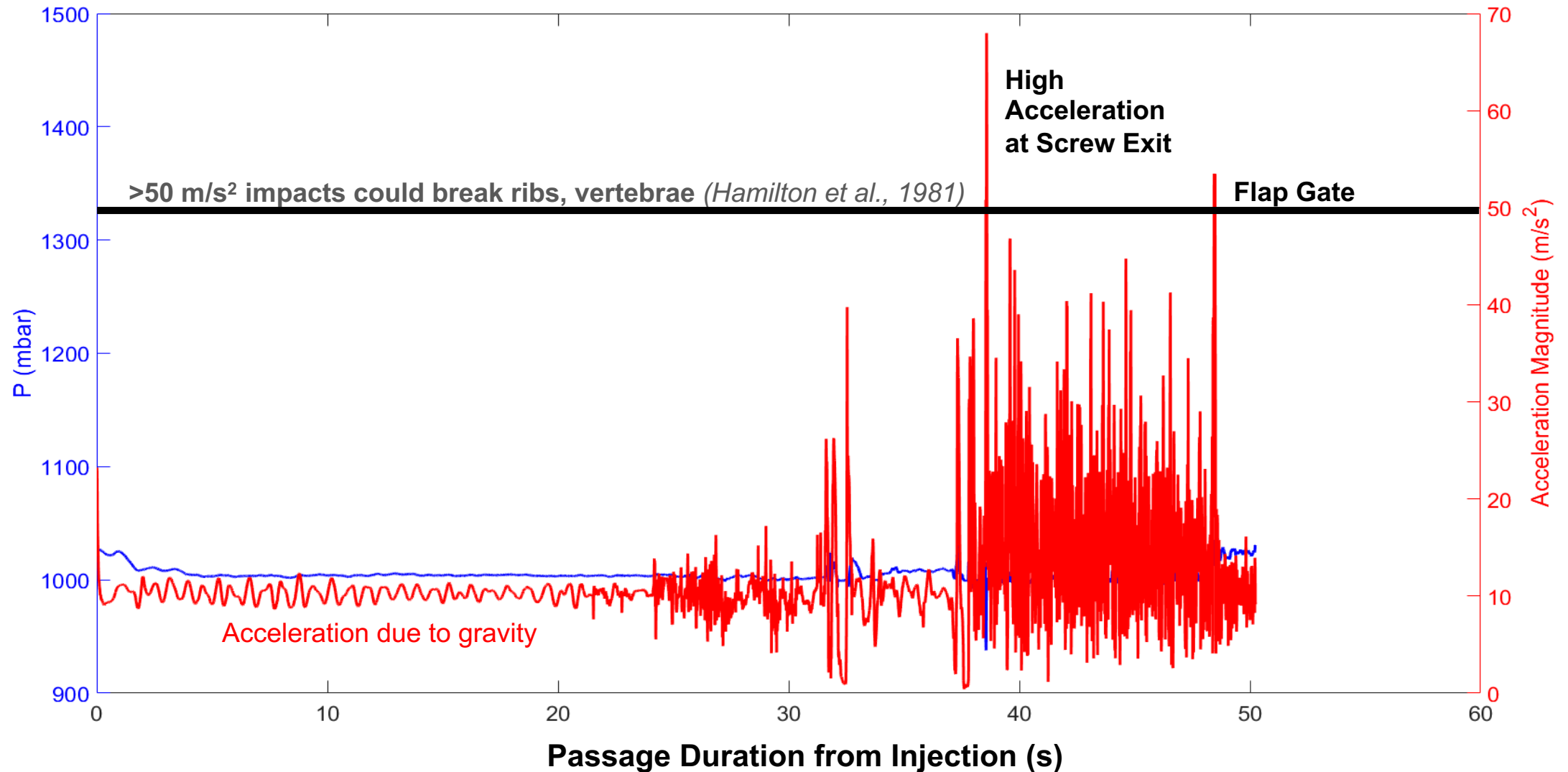
$\ln(\text{RPC}) = 0.02 - 0.04$



Therefore, extremely low risk of barotrauma occurring

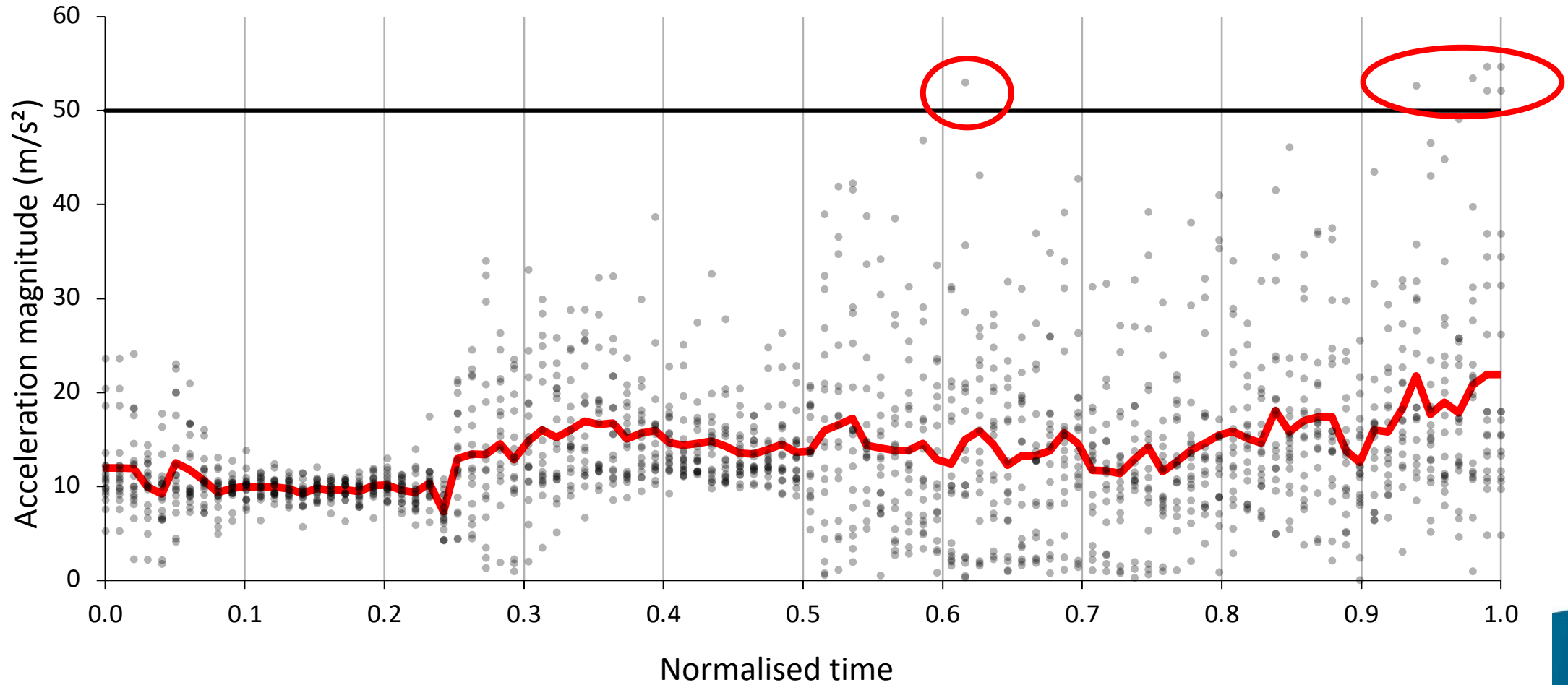


Flap Gate as a Potential Source of Injury?





Sources of injury



In summary: BDS

- **Pressure**

- **Observations:** High nadir, low LRPC and PRC
- **Outcome:** Very low risk to pressure-based injury and mortality

- **Acceleration**

- **Observations:** < 5 g over the passage duration, strike events at exit, flap gate
- **Outcome:** Some risk of impact related injury and mortality for eel

- **Note: the flap gate** provides a high-acceleration region!

Potential for injury, requires live fish testing when possible

Summary and management implications

1. Eels almost exclusively nocturnal and pumping during daylight represents missed passage opportunities
 - Operational changes recommended
2. Eels were reluctant to pass through original weedscreen but passage rate improved with wider bar spacing
 - Note - Health and safety must be considered when adapting screens
3. Very low risk of pressure-based injury and mortality but strike events at exit (i.e. flap gate) which could cause impact related injury and mortality for eel
 - Live fish testing to be performed where / when possible

Thank you for listening

For more information:

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