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The influence of passive wedge-wire screen aperture and flow velocity on juvenile European eel exclusion, impingement and passage

Liam J. Carter [a], Stephen J. Collier [a b], Robert E. Thomas [b], Josh Norman [a], Rosalind M. Wright [c], Jonathan D. Bolland [a]

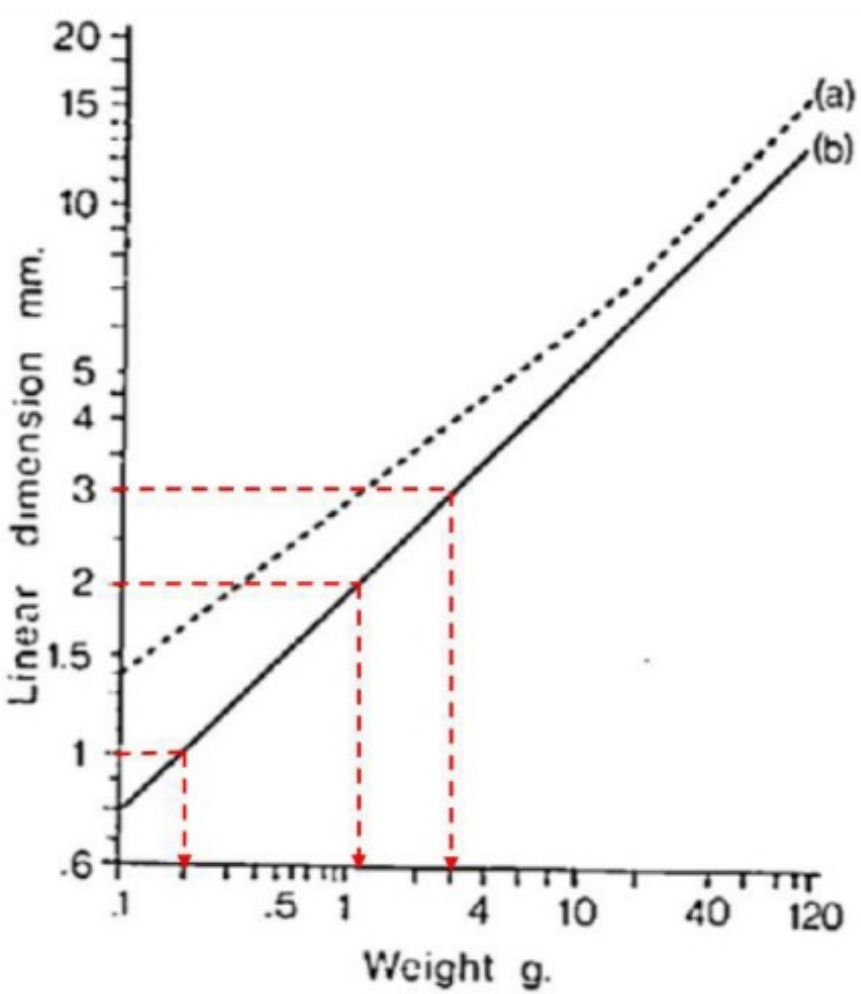
Liam Carter
Fish Ecology Specialist, Natural England
Liam.Carter@NaturalEngland.org.uk

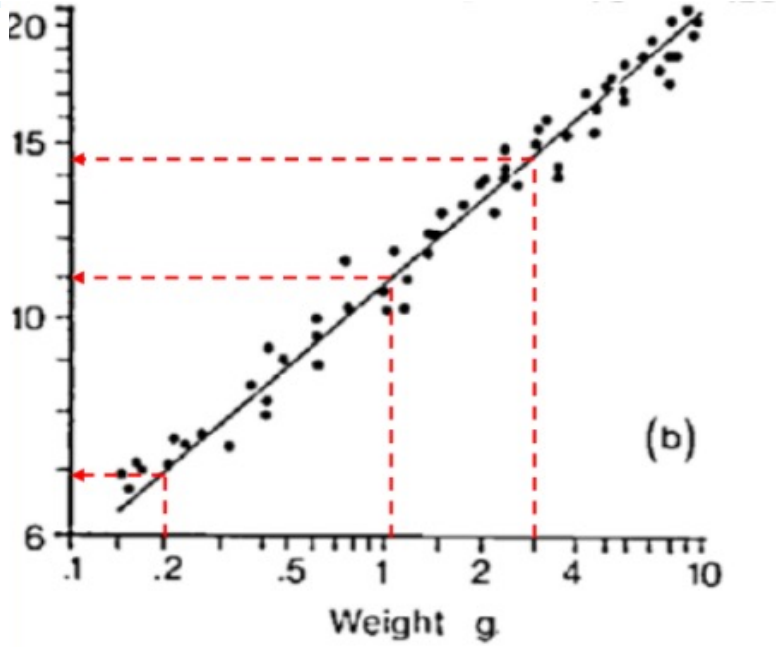
Background

- Screens are required to protect critically endangered European eel at hazardous intakes, such as power stations, potable water intakes and land drainage pumping stations as per EC Regulation No. 1100/2007 and UK Eel Regulations (2009) statutory instrument
- We know the impacts of intakes and screens on downstream migrating adult silver eels
- Knowledge of entrainment risk for upstream migrating glass eels and elvers lacking
- Little quantitative evidence of behaviour and exclusion of juvenile European eel at different screen apertures

Knights (1982)

- Former Environment Agency eel screening manual informed by Knights 1982 paper

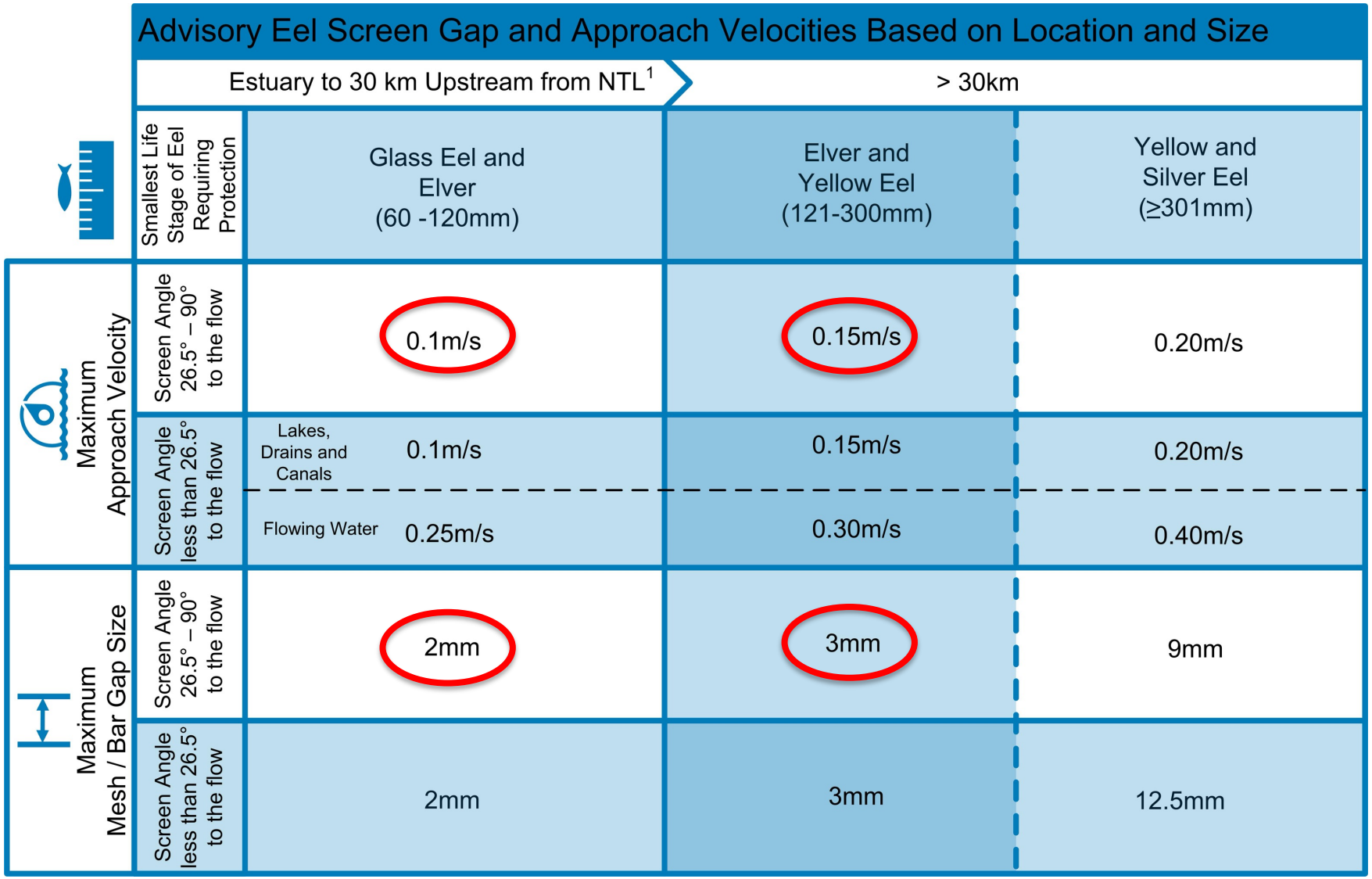




1, 2 and 3-mm grid bar spacing exclude eels larger than 7, 10.7 and 14.5 cm

Knights, B. (1982). Body dimensions of farmed eels (Anguilla anguilla L.) in relation to condition factor, grading, sex and feeding. Aquacultural Engineering 1, 297-310.

New EA guidance



Advisory Eel Screen Gap and Approach Velocities Based on Location and Size				
		Estuary to 30 km Upstream from NTL[1]	> 30km	
Smallest Life Stage of Eel Requiring Protection		Glass Eel and Elver (60 -120mm)	Elver and Yellow Eel (121-300mm)	Yellow and Silver Eel (≥301mm)
Maximum Approach Velocity	Screen Angle 26.5° – 90° to the flow	0.1m/s	0.15m/s	0.20m/s
	Screen Angle less than 26.5° to the flow	Lakes, Drains and Canals 0.1m/s	0.15m/s	0.20m/s
		Flowing Water 0.25m/s	0.30m/s	0.40m/s
Maximum Mesh / Bar Gap Size	Screen Angle 26.5° – 90° to the flow	2mm	3mm	9mm
	Screen Angle less than 26.5° to the flow	2mm	3mm	12.5mm

Overall aims and objectives

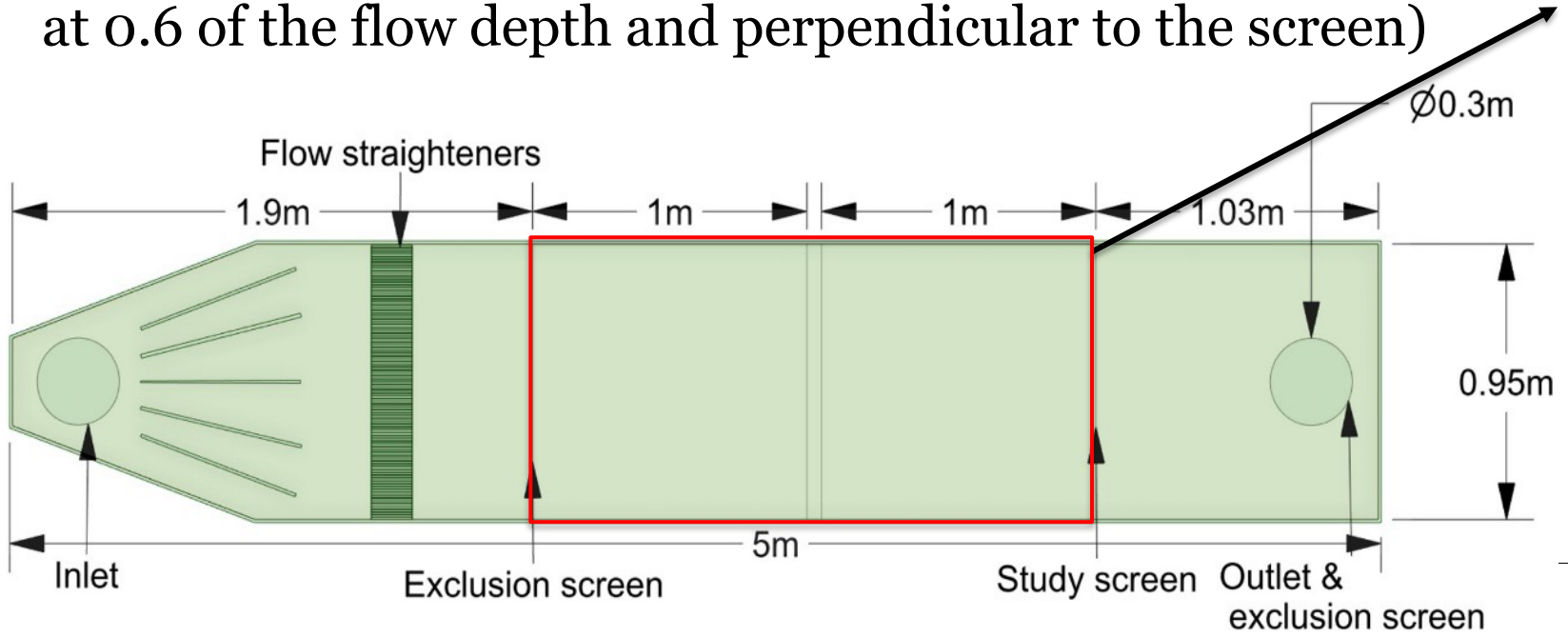
- Test four screen apertures (1, 2, 3, & 5-mm) & four flow velocities (0, 0.1, 0.15, & 0.2 ms-1) using two size classes of juvenile eels; 60-80 mm glass eels & 100-160 mm elvers. Ten eels per trial, 15 minutes max. considerations for (1) physical exclusion (2) migratory separation (positive rheotaxis) and (3) behavioural avoidance
- Investigate the influence of prevailing light (day vs night) on eel behaviour and fate; 60-80 mm eels using 2 mm aperture screen, 100-160 mm eels using 3 mm aperture screen across all approach velocities
- Morphometric measurements (head width, head height, length etc.) taken post trial

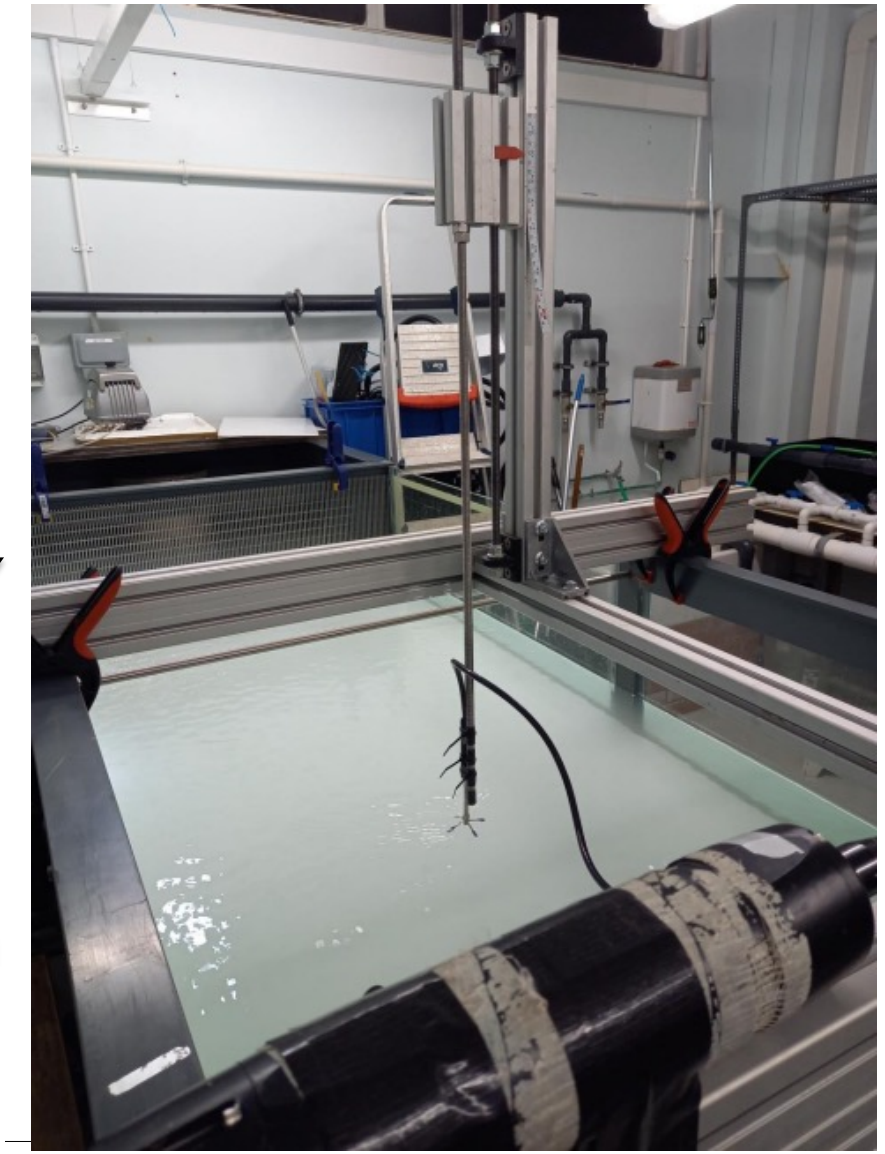
Methods and experimental setup

- Five Overhead infrared cameras used to record behaviour during trials; analysed post study.
- Trials conducted at night after 18:00 in a dark room. Only red LED strip lights floor level around walkways for safety purposes.
- Impingement (10 secs on screen), passage (through screen), behavioural avoidance (made contact with the screen during trial but remained free swimming after 15 mins elapsed), migratory separation (no contact with study screen during trial).
- Tank temperature kept constant through all trials at 10 degrees Celsius (same as river temperature initial glass eels were captured at in March 2021).
- Two sources of eels; 60-80 mm glass eels from River Parrett, Somerset. 100-160 from River Wensum, Norfolk.

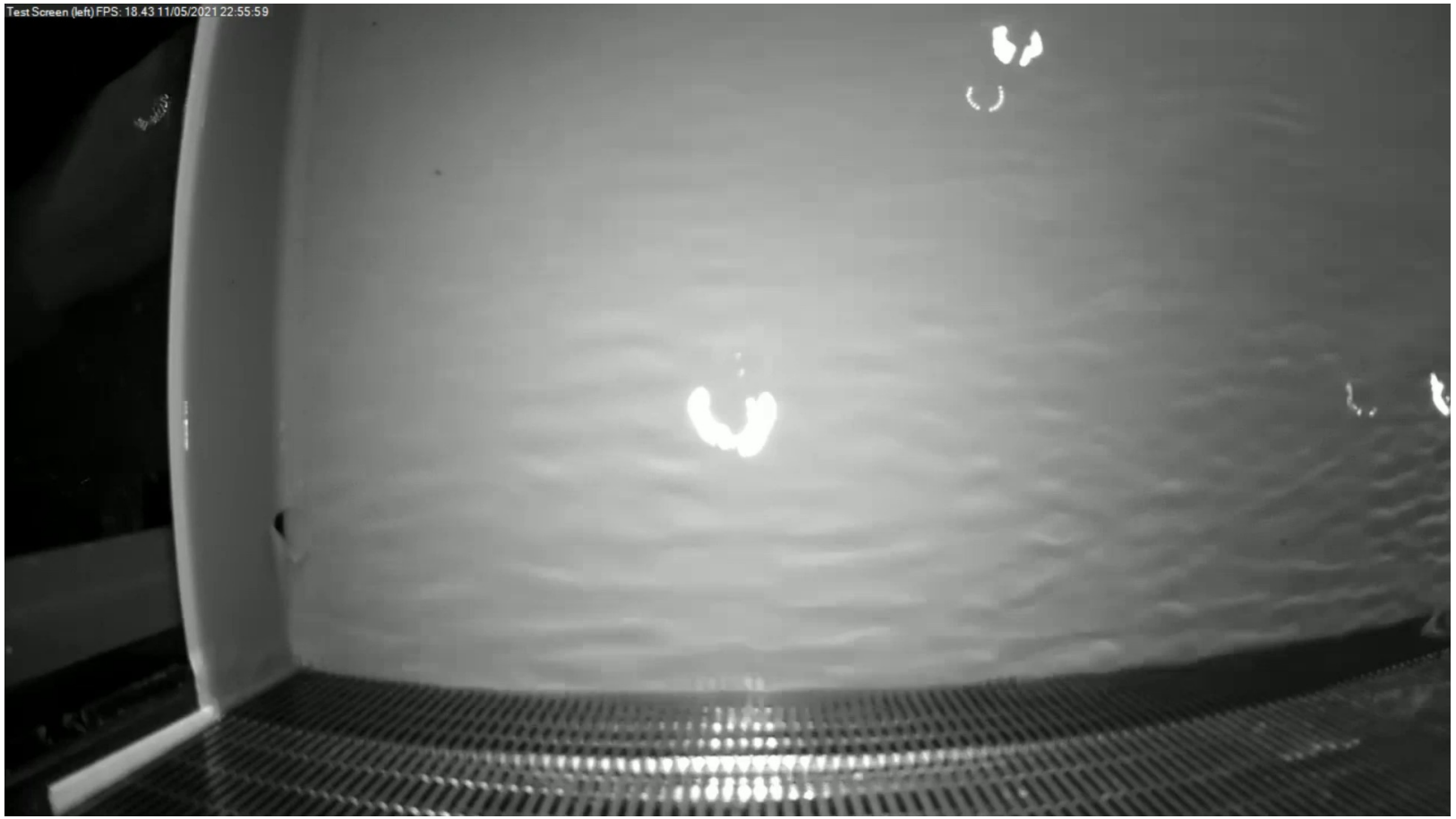
Methods and experimental setup

- Flume = 5m x 1m x 0.5m, water depth = 10cm
- Passive wedge wire = 34SB profile (2.8-mm wide x 5-mm deep), vertical slots and oriented at 90° to the flow
- Exclusion screen apertures = 1mm (open area = 26.5%), 2mm (41%), 3mm (51%) and 5mm (64%)
- Approach velocities = 0, 0.1, 0.15 and 0.2 (10 cm upstream, at 0.6 of the flow depth and perpendicular to the screen)

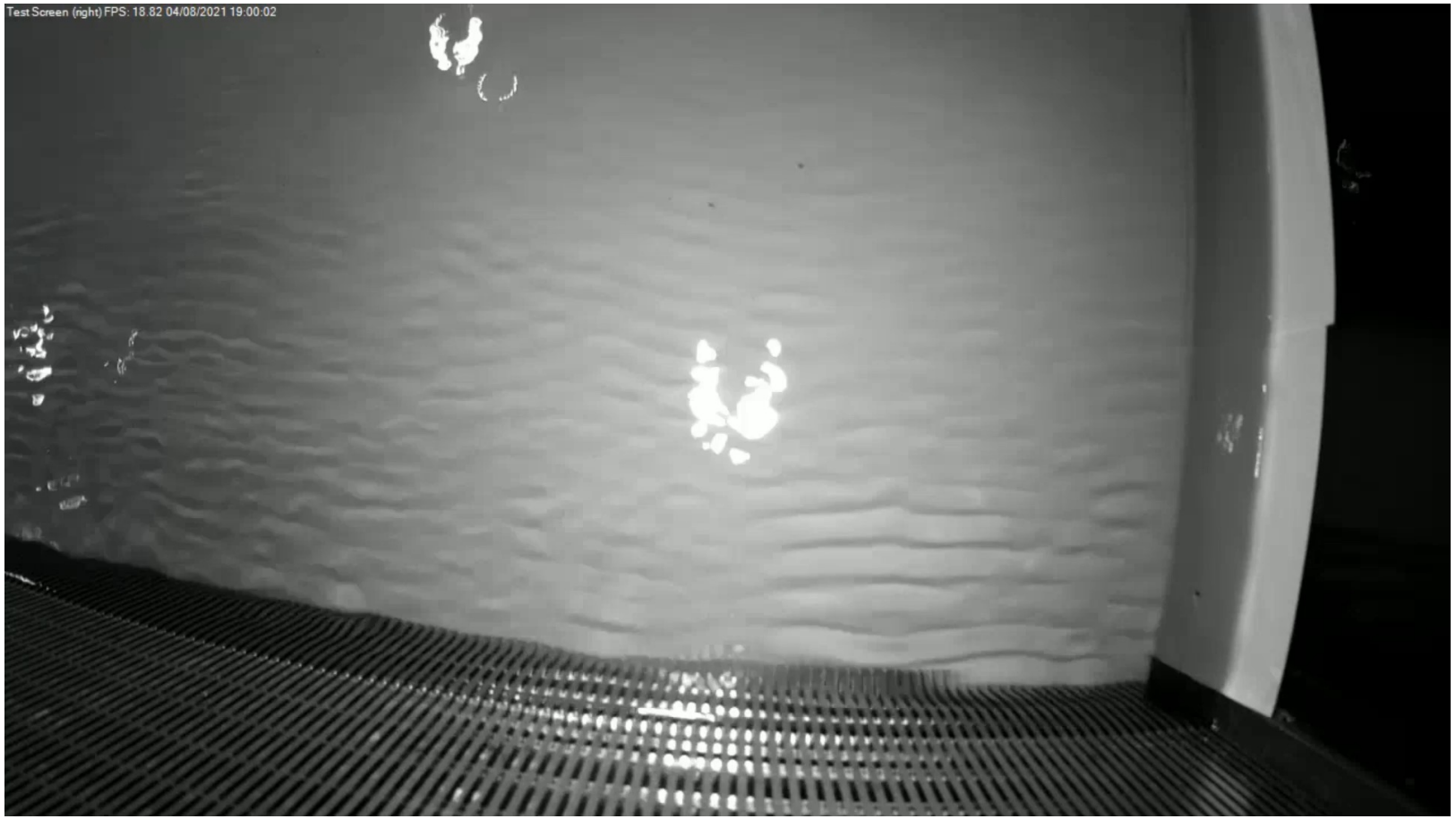




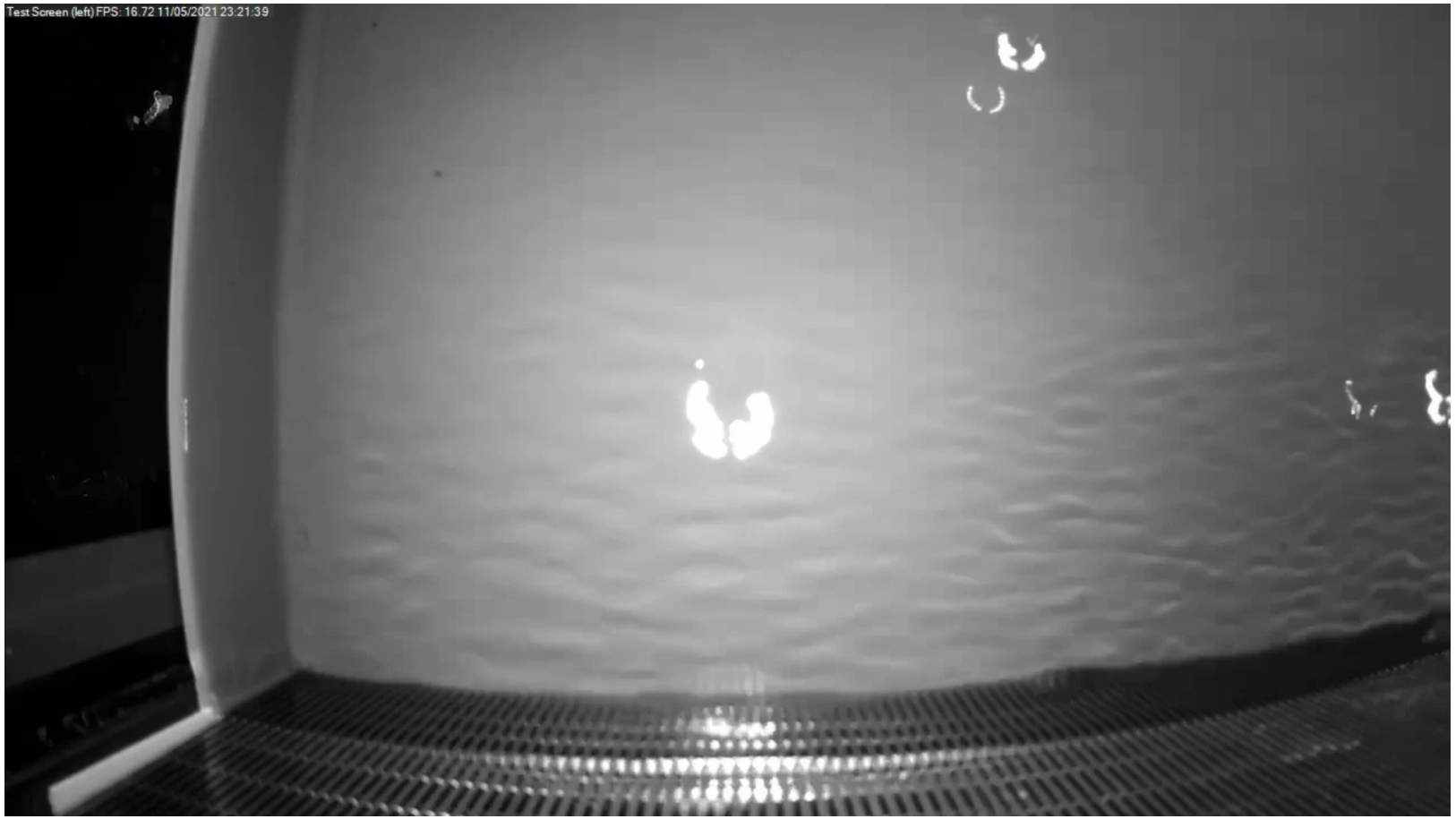
Impingement; 60 -80 mm
2 mm screen 0.2 ms flow



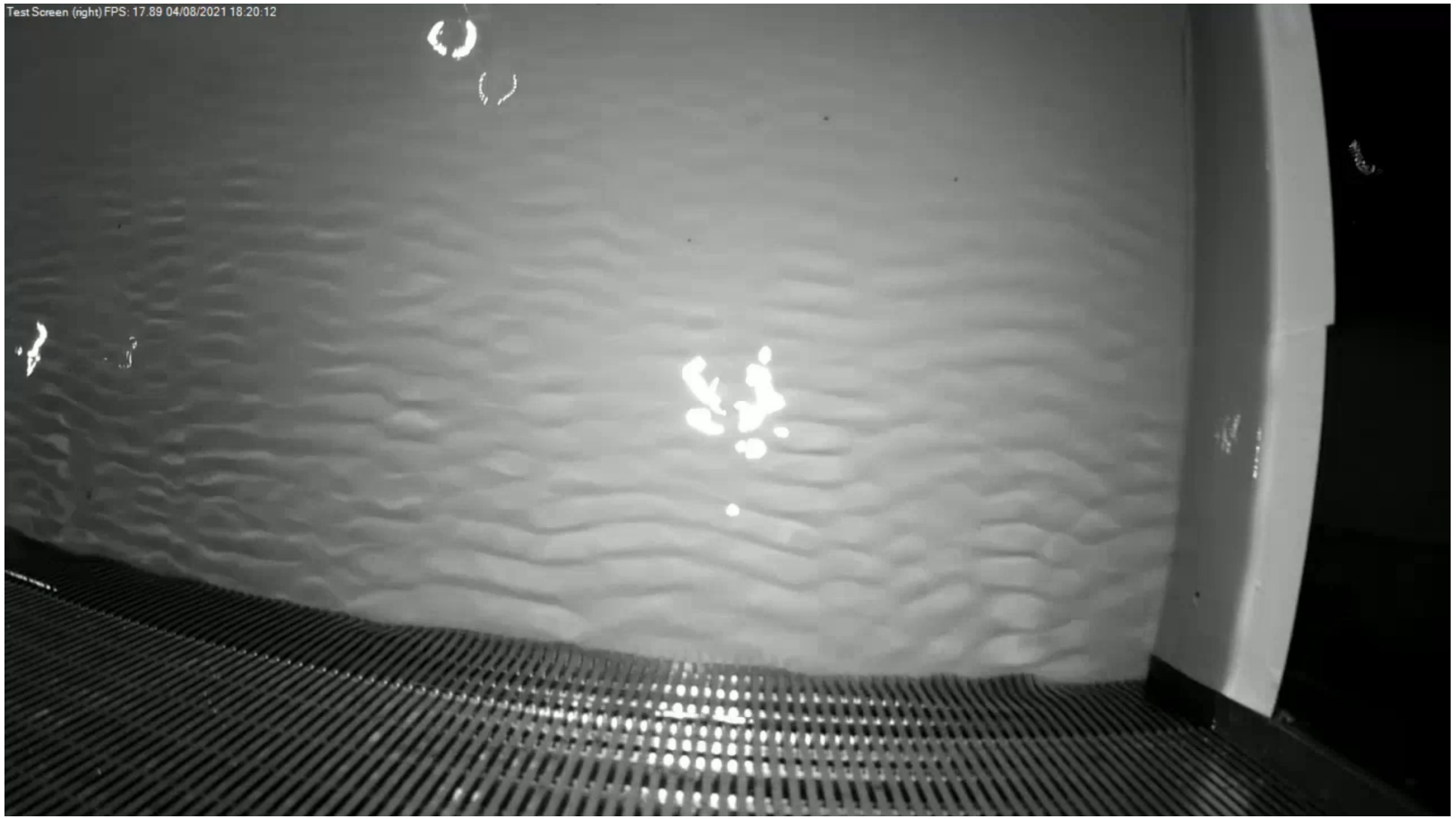
Impingement; 100-160 mm
2 mm screen 0.2 ms flow



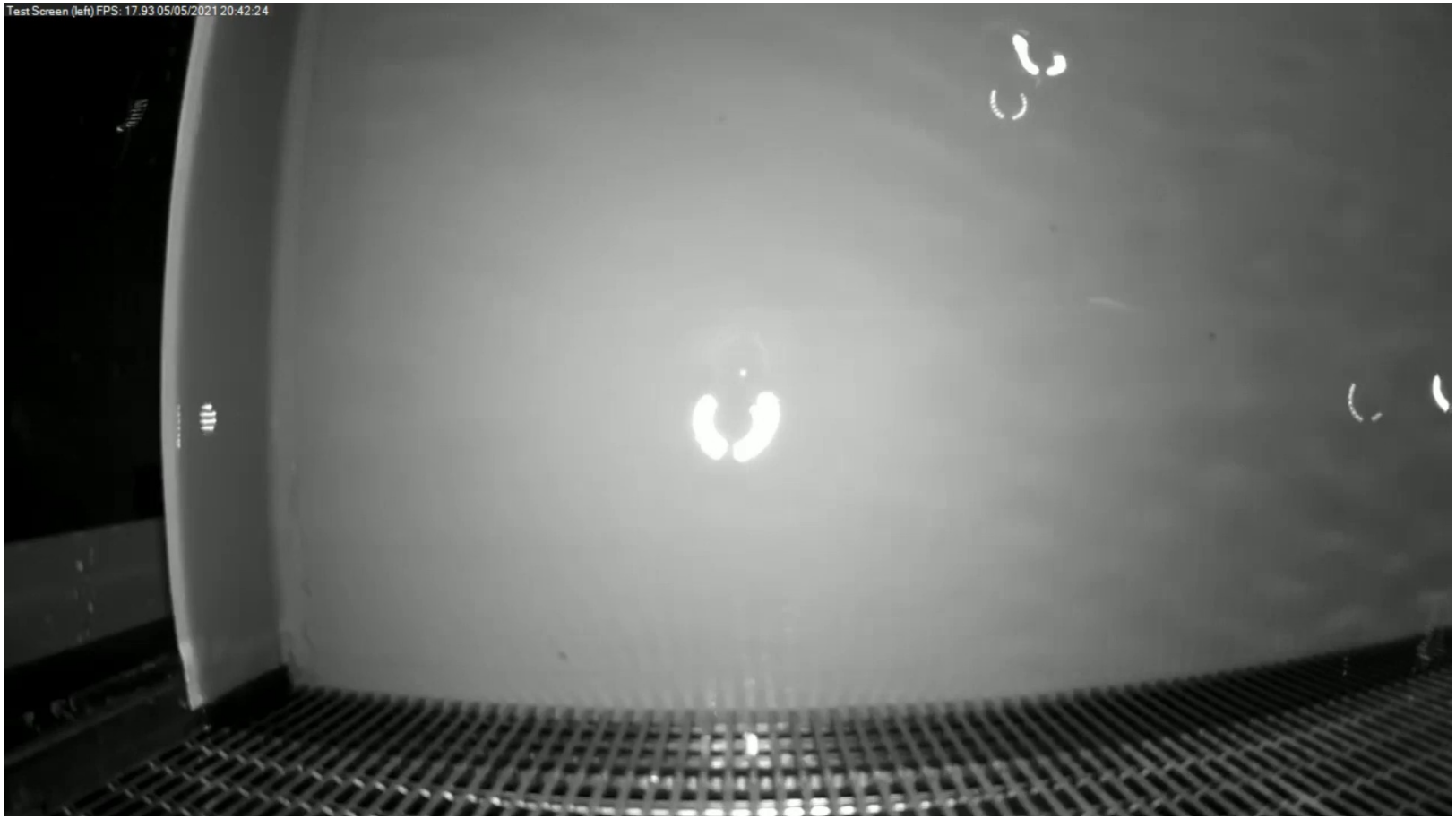
Behavioural avoidance; 60-80 mm
2 mm screen 0.2 ms flow



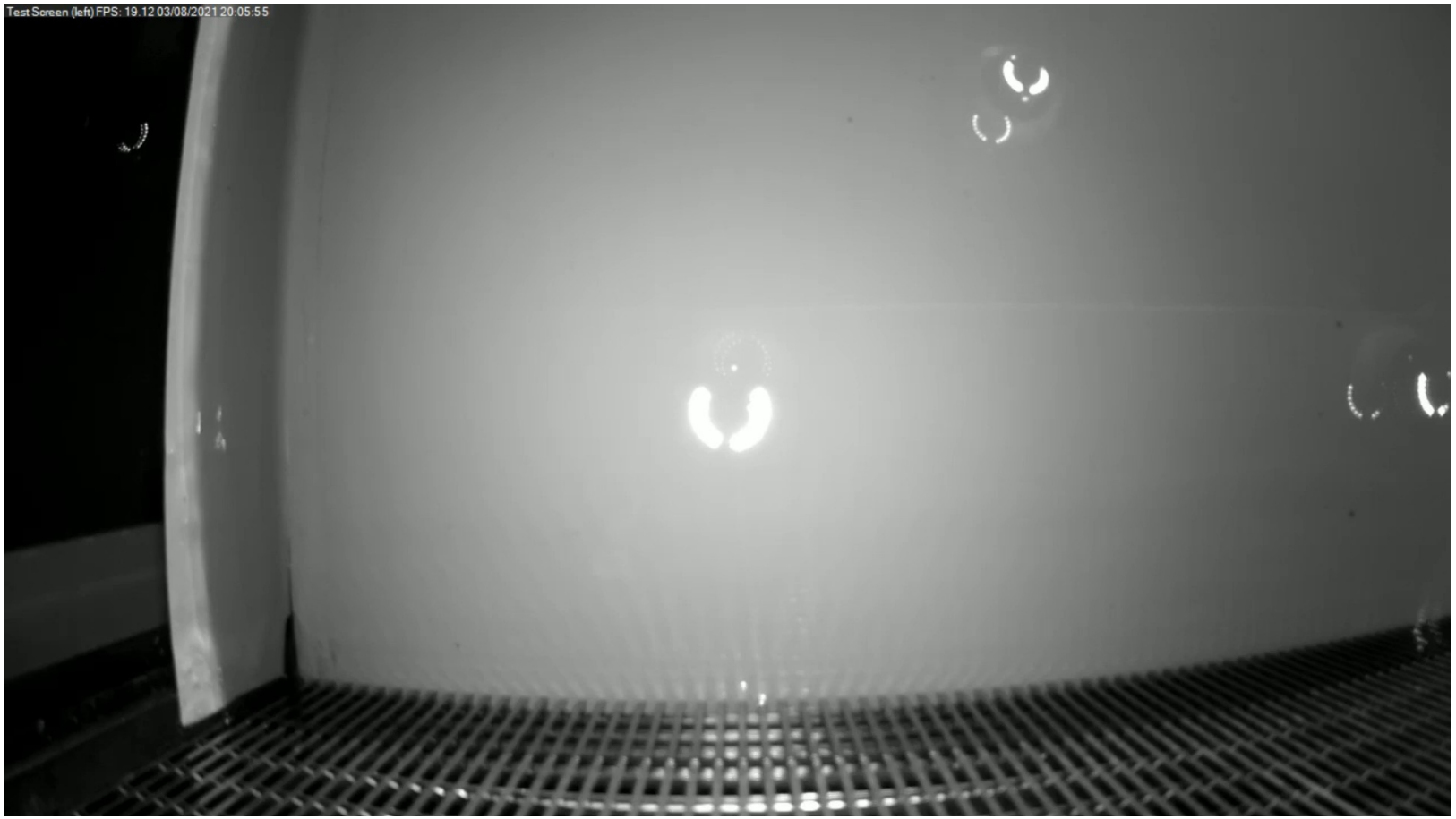
Behavioural avoidance; 100-160 mm
2 mm screen 0.2 ms flow



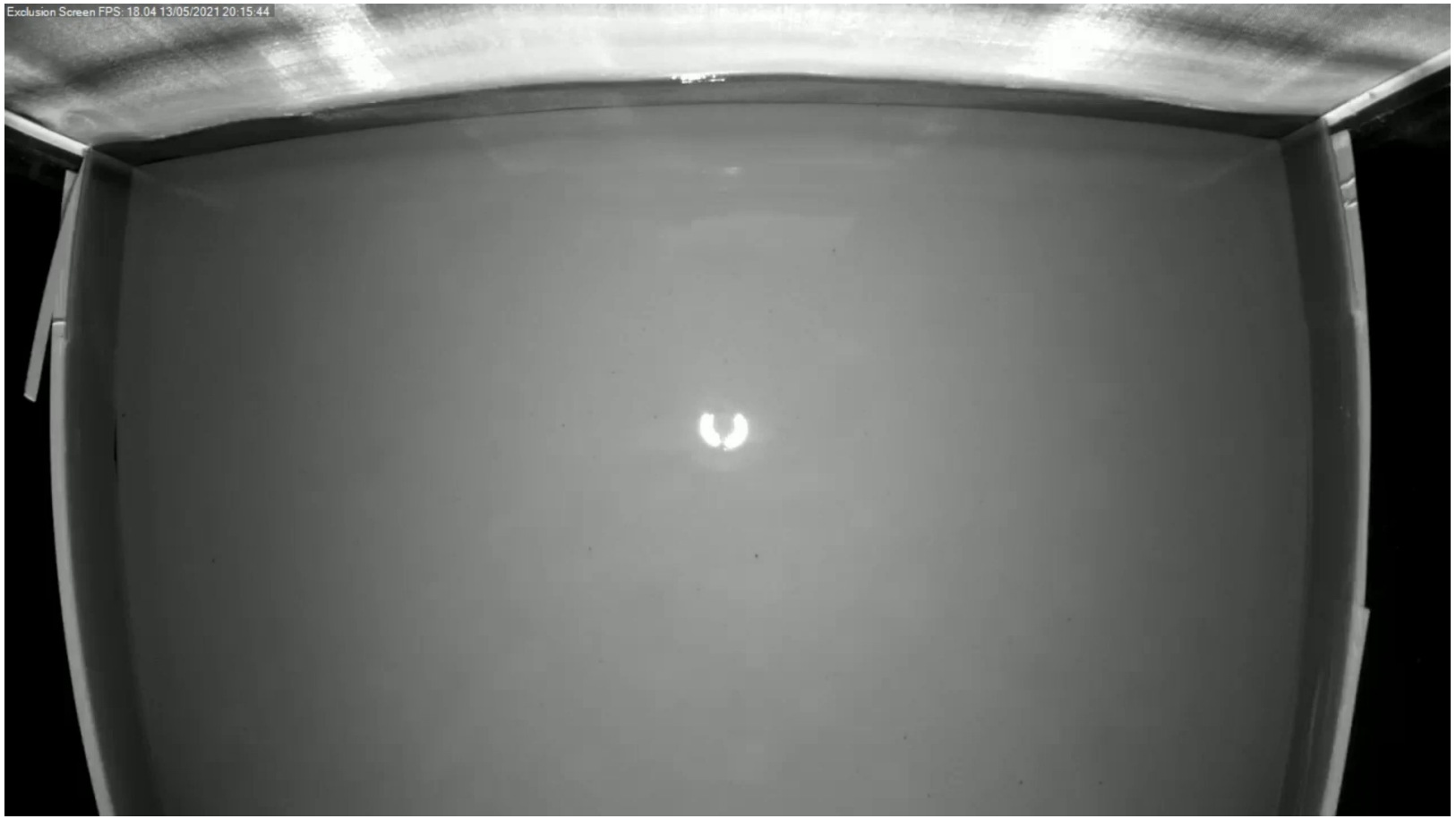
Passage through screen; 60-80 mm
5 mm 0.1 ms flow



Passage through screen; 100-160 mm
5 mm 0.1 ms flow

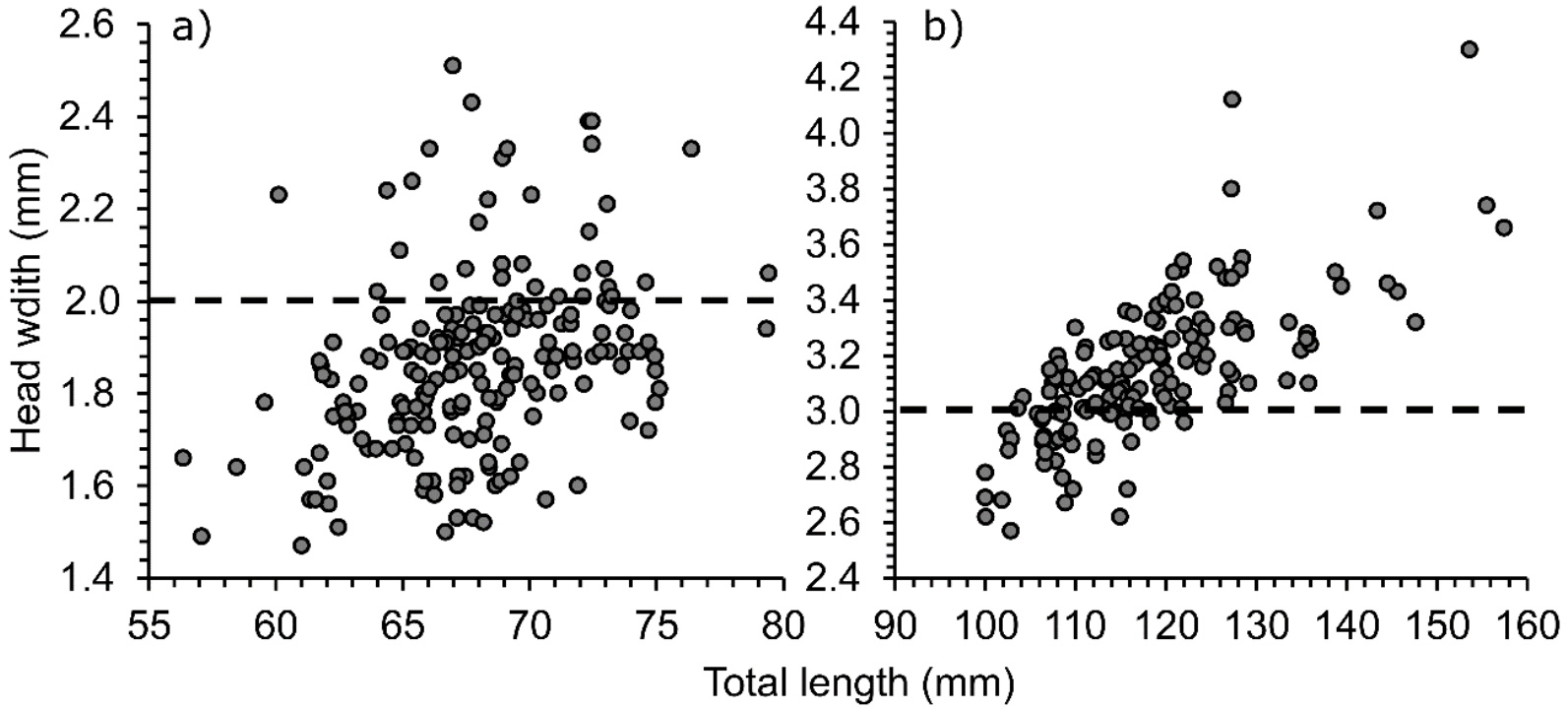


Migratory separation; 60-80 mm
2 mm 0.1 ms flow



Results – head width and exclusion

- 60 - 80mm eels = 0%, 60.5% (n = 121) and 100% had a head width <1, 2 and 3 mm
- 100 - 160 mm eels = 0%, 14.4% (n = 23), 85.6% (n = 137), and 100% had a head width <1, 2, 3, and 5 mm



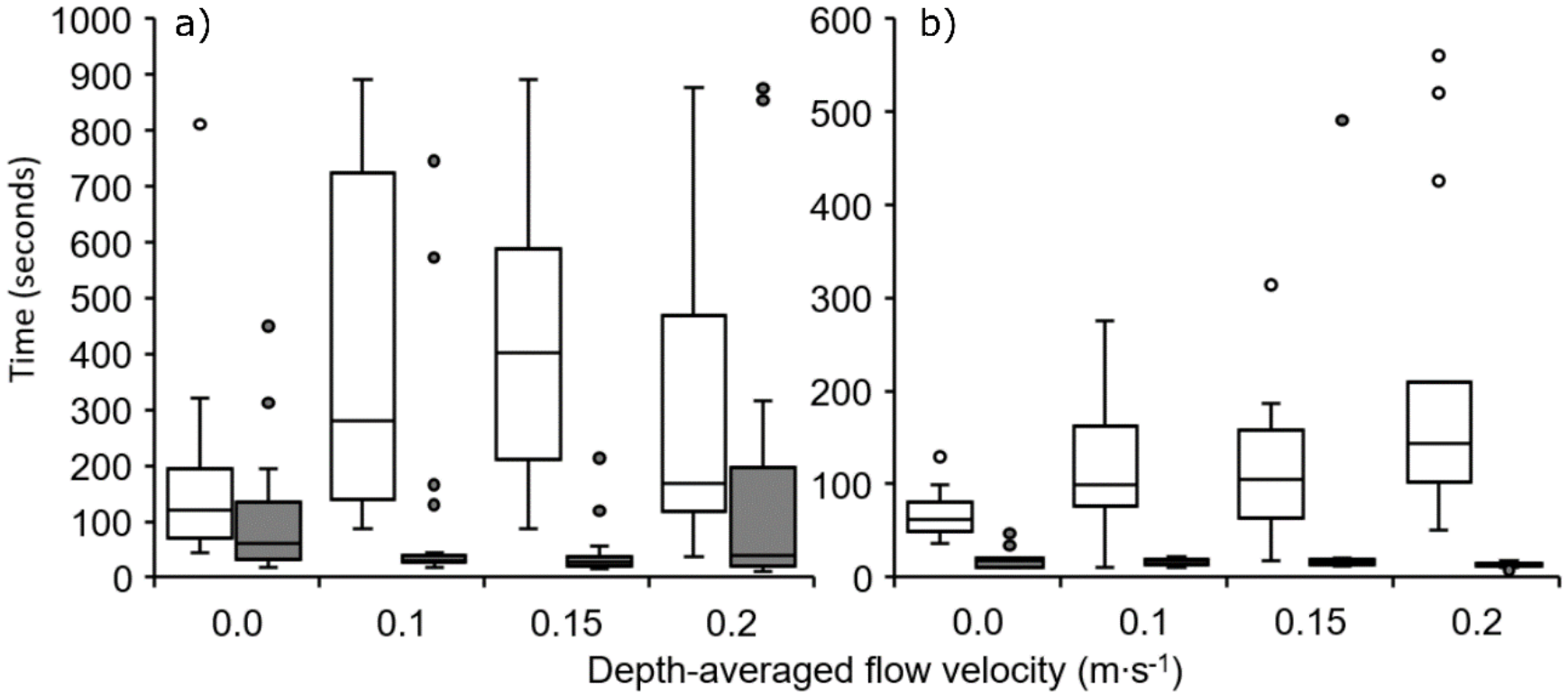
Results – eel fate

- Large proportion were impinged; up to 90% and 100% for 60–80 mm and 100–160-mm size classes at 0.2 m s -1
- Small proportion of 60-80 mm eels (9.2%) did not approach the screen = migratory separation (i.e., positive rheotaxis)

Aperture	Velocity	60–80 mm				100–160 mm			
(mm)	(m s^{-1})	MS	BA	I	P	MS	BA	I	P
1	0.2	0	1 (1)	9 (9)	0				
1	0.15	2 (2)	2 (2)	6 (6)	0				
1	0.1	2 (2)	3 (3)	5 (5)	0				
1	0	2 (2)	8 (8)	-	0				
2	0.2	1	2 (1)	5	2	0	0	10 (10)	0
2	0.15	1	0	4	5	0	1 (1)	9 (9)	0
2	0.1	1 (1)	1	7 (1)	1	0	1 (1)	9 (9)	0
2	0	0	6 (1)	-	4	0	10 (10)	-	0
3	0.2	0	1	3	6	0	1	7 (6)	2
3	0.15	1	1	5	3	0	3 (2)	6 (4)	1
3	0.1	0	0	8	2	0	3 (2)	4 (4)	3
3	0	0	0	-	10	0	9 (9)	-	1
5	0.2	2	0	1	7	0	0	0	10
5	0.15	1	0	4	5	0	0	0	10
5	0.1	0	1	2	7	0	0	0	10
5	0	0	0	-	10	0	0	-	10

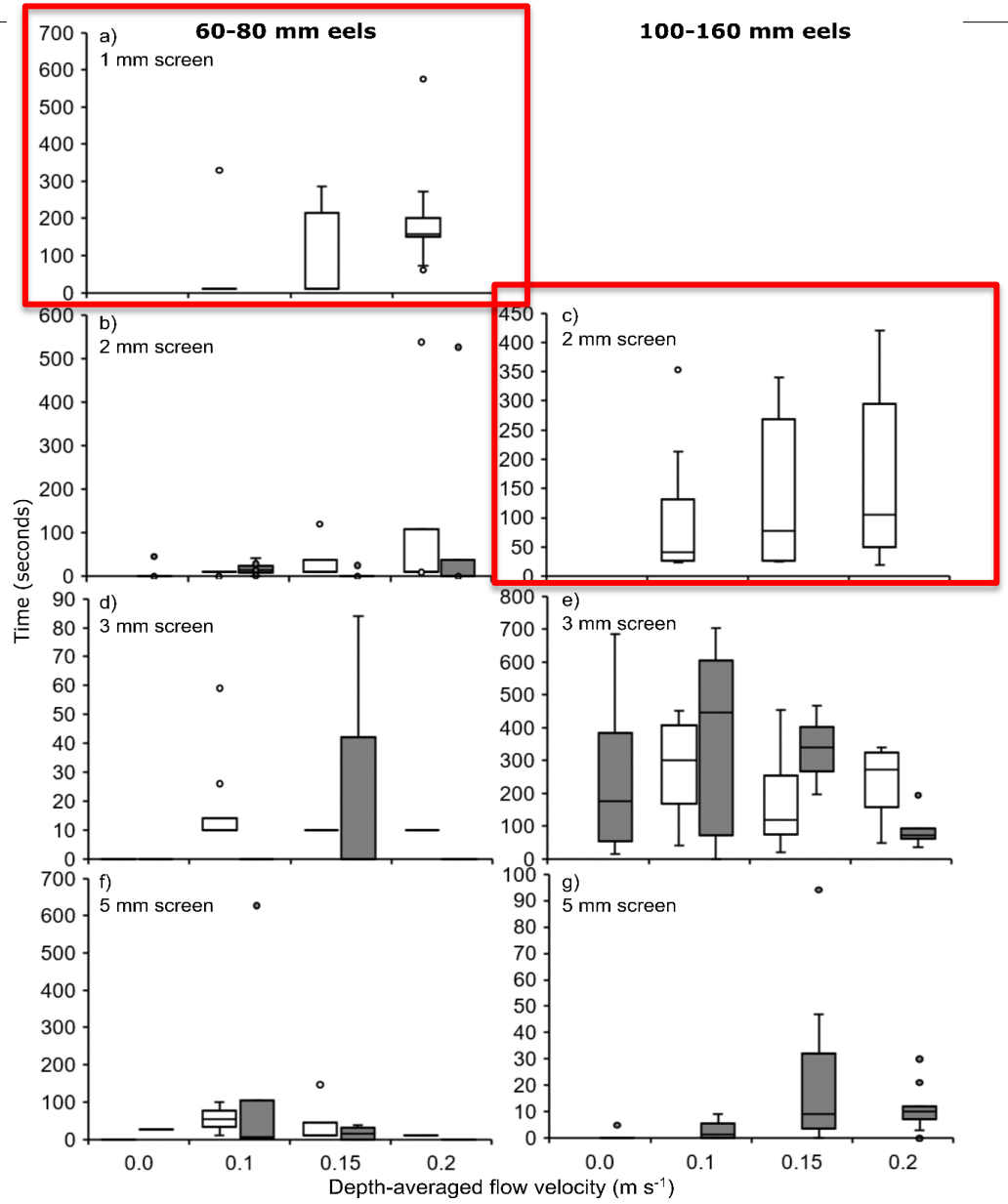
Results – time to contact screen

- Time to contact screen was faster for eels that initially swam downstream compared to upstream following trial commencing (no surprise really!)
- Median time to screen contact for 60-80 mm eels that went upstream dropped with higher flows



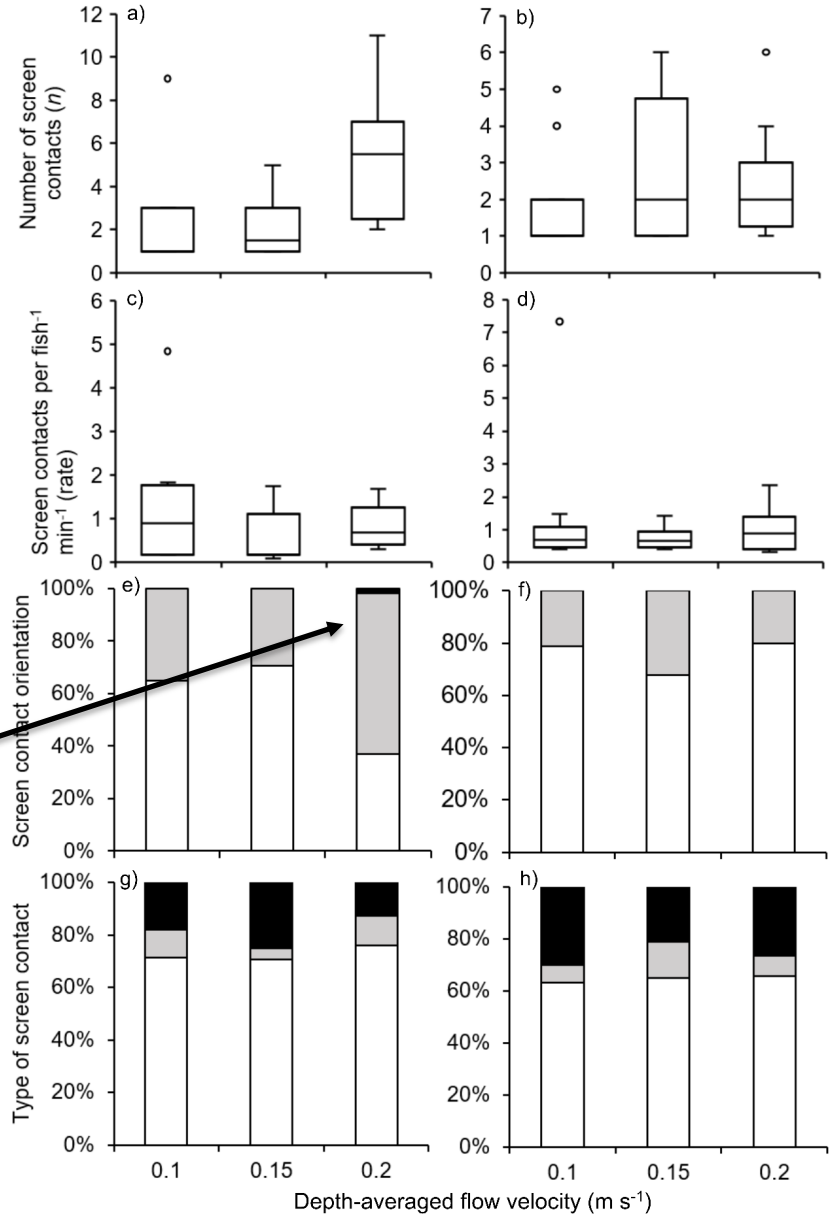
Results – time taken to impinge and pass screen

- Time to impinge (white) increased with increasing flow rates for 1 mm and 2 mm screens for each size class



Results – screen contacts and orientation

- Median screen contacts per eel increased as approach velocity increased
- Rate of screen contacts remained consistent and the time to eel fate (from first contact) increased
- Only one eel made contact with the screen tail first at 0.2 ms



Results – daylight vs nighttime trials

- Dark vs light fate largely comparable for all behavioural metrics
- Expected limited movement during daylight
- Potentially impacted migratory instinct after translocation to flume room

Light	Velocity ($m\ s^{-1}$)	60–80mm				100–160 mm			
		MS	BA	I	P	MS	BA	I	P
Dark	0.2	1	2 (1)	5	2	0	1	7 (6)	2
Dark	0.15	1	0	4	5	0	3 (2)	6 (4)	1
Dark	0.1	1	1	7 (1)	1	0	3 (2)	4	3
Dark	0	0	6 (1)	-	4	0	9	-	1
Light	0.2	3	0	4	3	0	2	5	3
Light	0.15	4	0	5	1	0	4	4	2
Light	0.1	2	0	2	6	0	6	0	4
Light	0	4	0	-	6	0	7 (3)	-	3

Summary

- First evidence of juvenile European eel behaviour at different screens under different flow regimes in an experimental flume.
- All trials conducted at 10 degrees Celsius, consider impingement and entrainment results worst case scenario.
- Difficult to disentangle some of the observed behaviours (i.e. truly impinged or resting on the screen).
- The hope is that findings improve screening guidance for regulators, key stakeholders and water abstraction managers to further improve protective measures.

Next Steps

- Conduct trials at different temperatures. More representative of wider seasonal environmental conditions
- Alternative screening angles. Assessing influence on impingement & entrainment
- Impingement duration impacts on injury, stress and mortality

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Thanks!

Questions?