Eel tile hydrodynamics: mitigation at entraining flows

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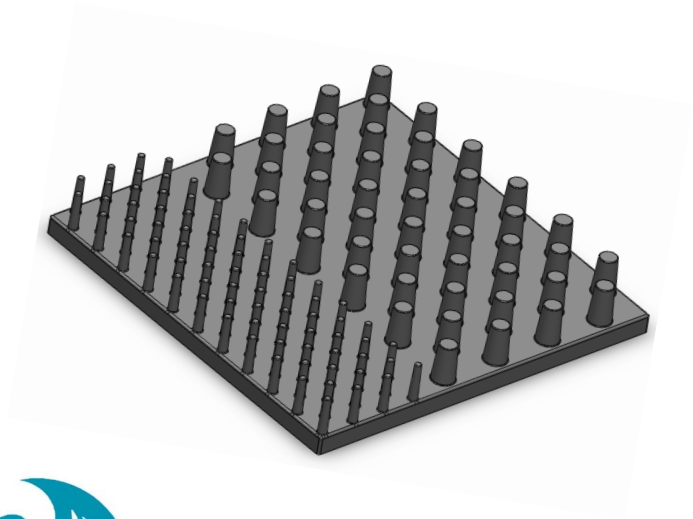

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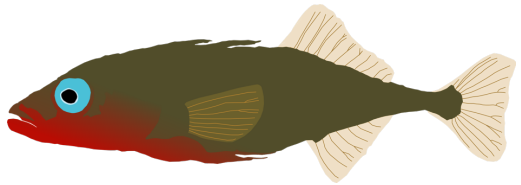

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High Velocity Barriers

- Anthropogenically altered flows too fast and challenging for fish and cause habitat fragmentation
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Eel Tiles as a Solution?

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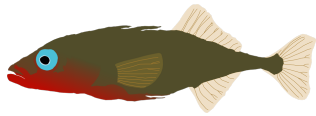
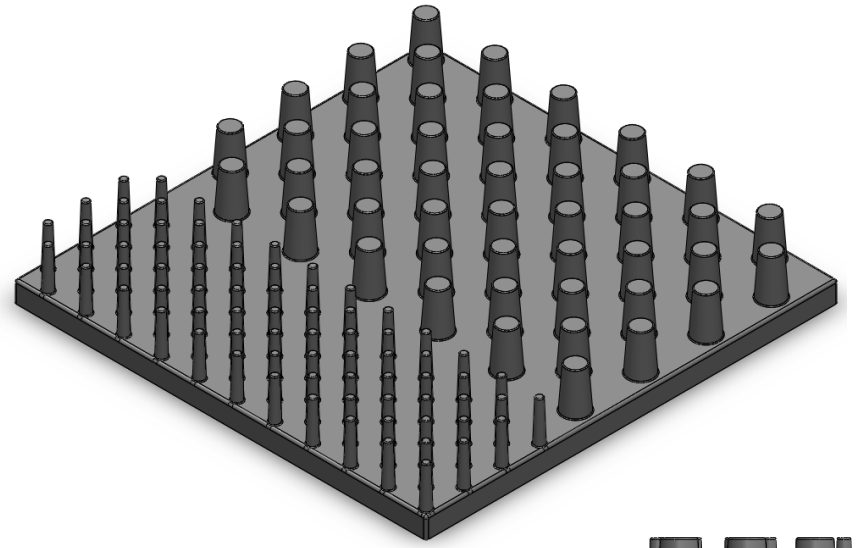
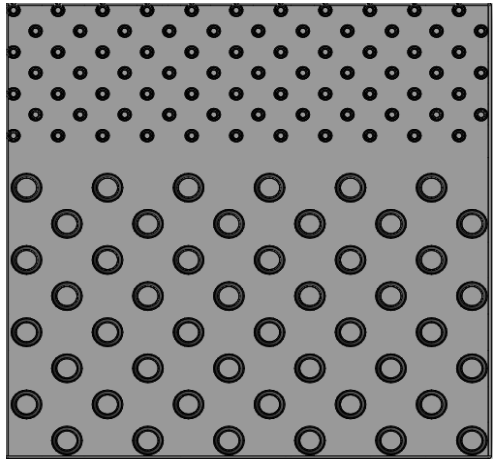
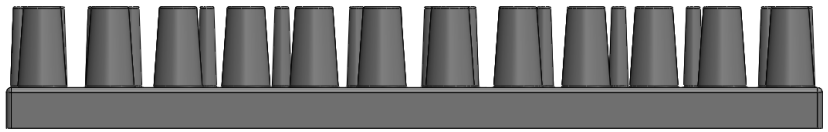
- Critically endangered European Eels (*Anguilla anguilla*) threatened by migratory barriers
- Small, river resident fish like Three-Spined Sticklebacks (*Gasterosteus aculeatus*) face habitat loss
- Eel tiles potentially provide a way for elvers and other fish to traverse these areas



AIM: Effect of tiles on flow, eel and stickleback behaviour and kinematics

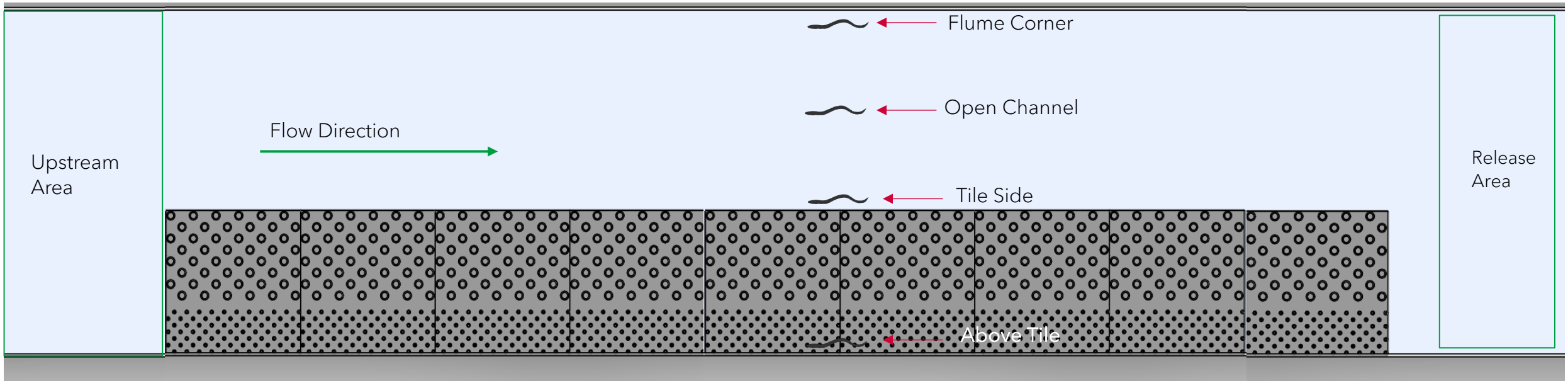






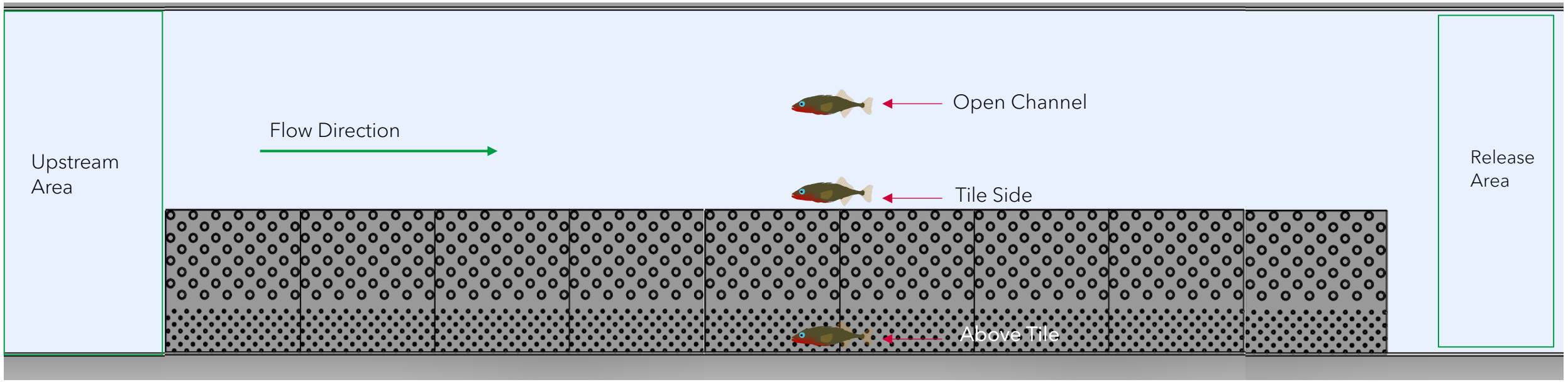
Eel Methods

- Open channel recirculating flume (length 10 m, width 1.2 m, height 0.3 m)
- European eels (n=25) electrofished from River Ely, Wales (UK)
- Flow conditions in four steps of increasing flow depth with U = 0.35 ms^{-1} with and without tiles



Stickleback Methods

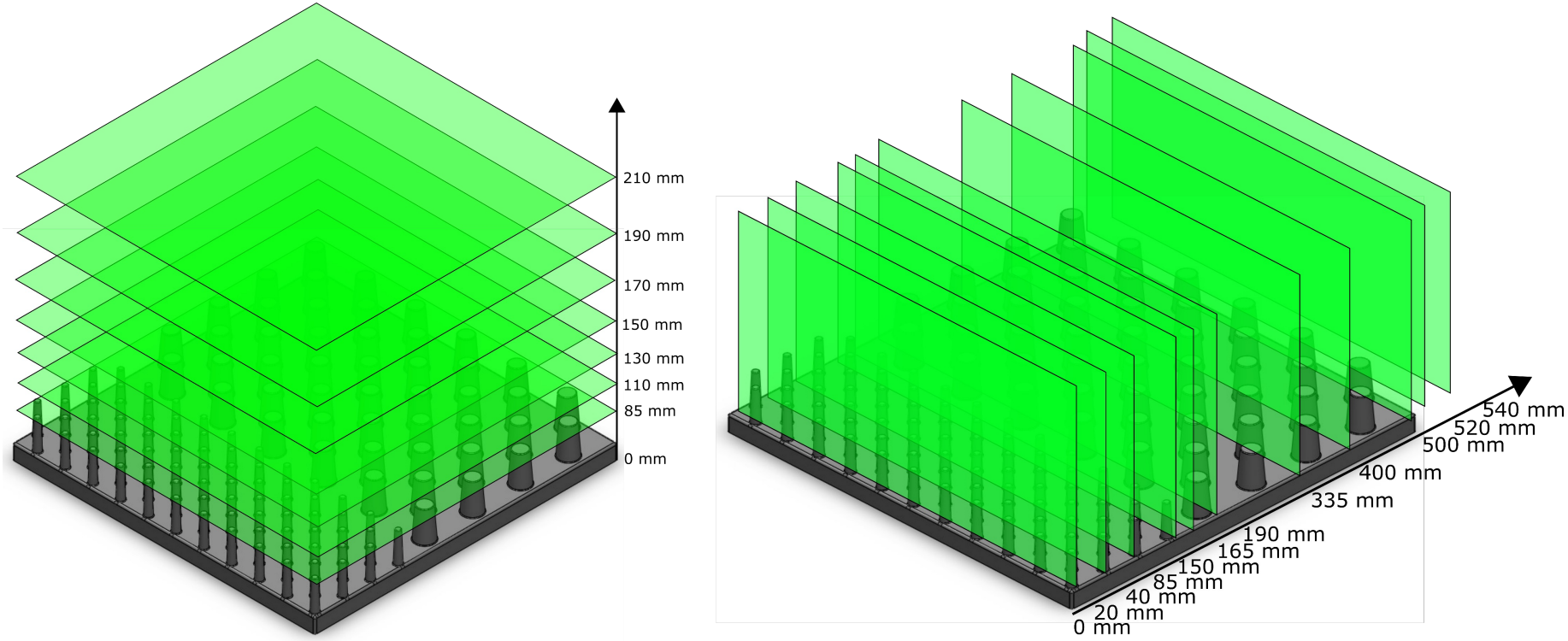
- Open channel recirculating flume (length 10 m, width 1.2 m, height 0.3 m)
- Three-Spined Sticklebacks (n=240) from St Fagans Ponds (UK)
- Flow conditions fixed with U = 0.35 ms^{-1} for sticklebacks and tested alone or in a shoal of 3



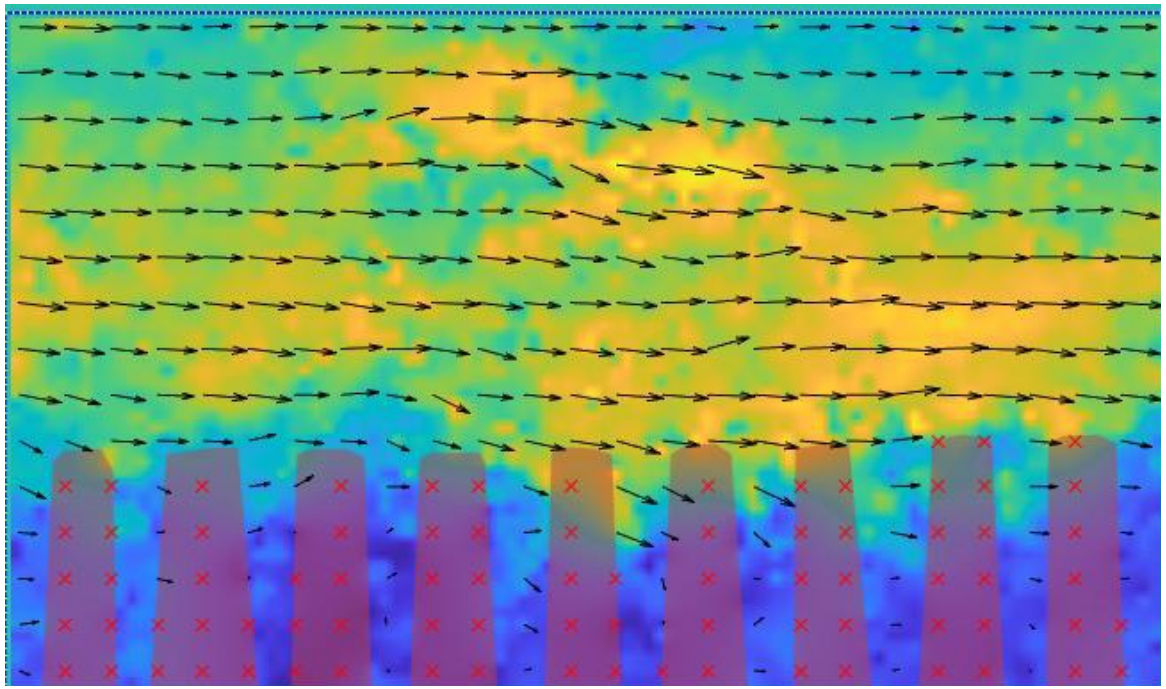
Particle Image Velocimetry Methods

- Open channel recirculating flume (length 10 m, width 1.2 m, height 0.3 m)

- PIV recorded with a high-speed camera at 120 frames per second at different sections horizontally and vertically

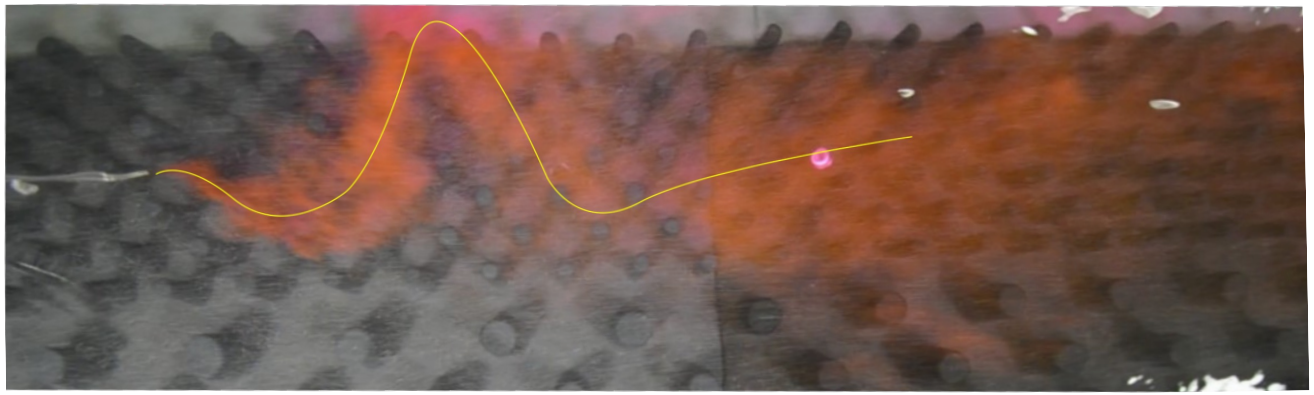


Flow Field: Large Scale Structures



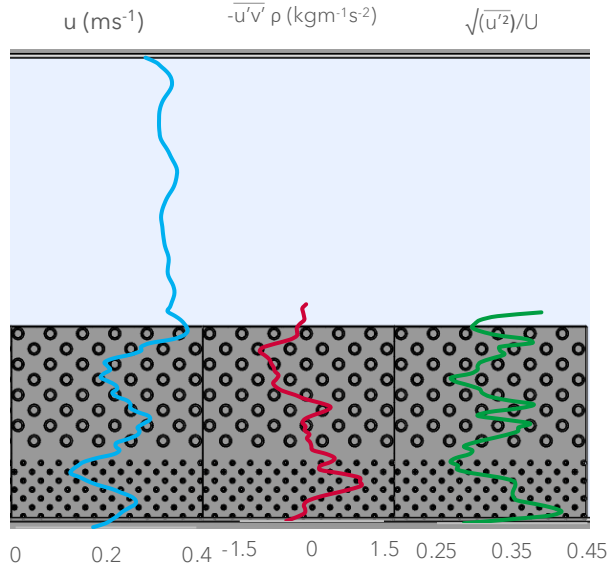
- Periodical vertical shedding above tiles
- Shear layer is not strong enough to produce fully formed Kelvin-Helmholtz vortices

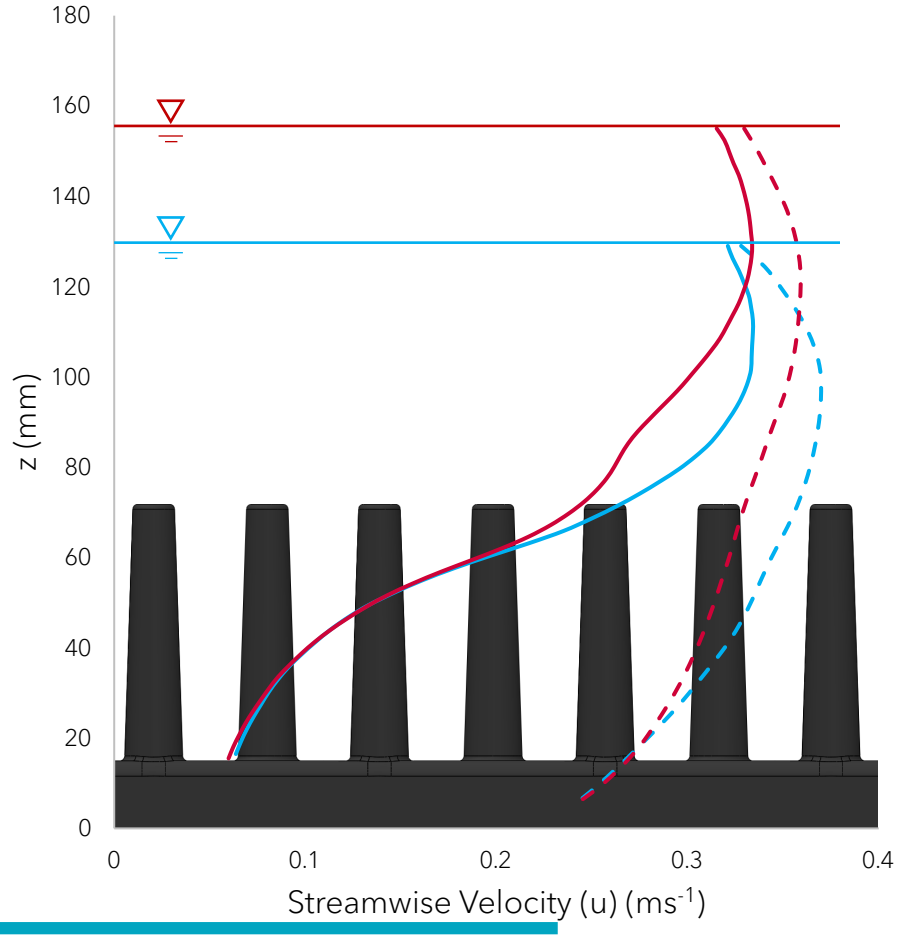
- Periodical horizontal shedding at interface between tile and open channel flow
- These large scale structures have potential to destabilise swimming eels

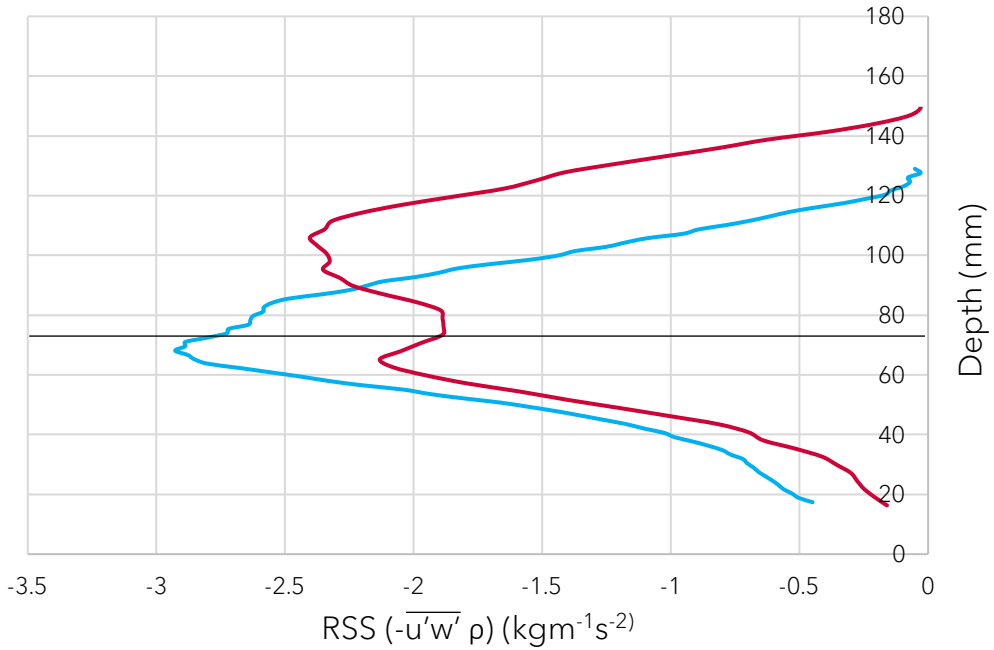


Tiles Slow the Flow

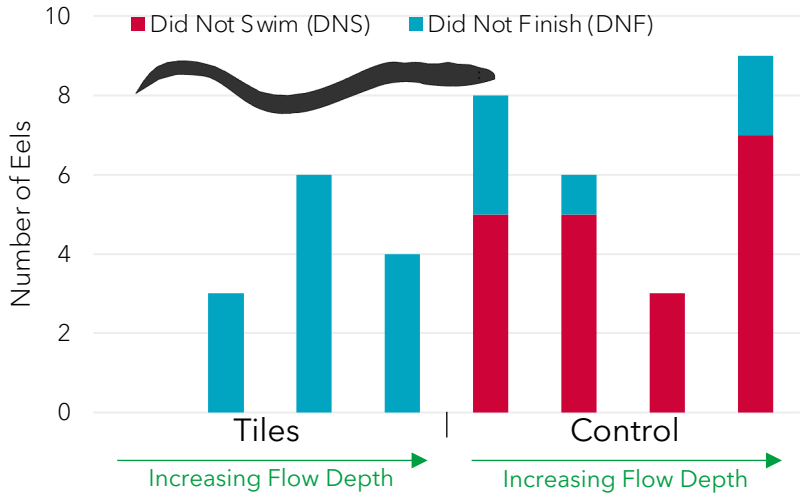
- Tiles reduced the streamwise flow velocity within and adjacent to them
- Reynolds Shear Stress (RSS) peaks due to velocity gradient in the canopy and surface flow regions





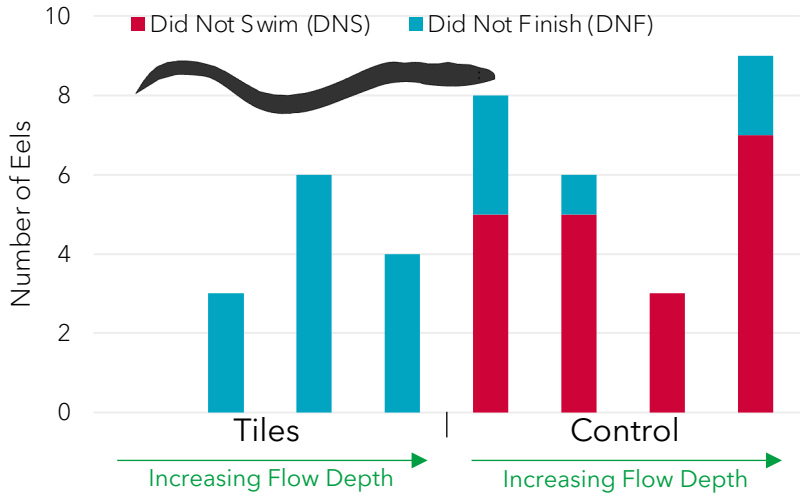


Tiles Improve Fish Passage



- Overall, eel passage was increased by the tiles
- With tiles all eels swam
- More passage attempts made with tiles

Tiles Improve Fish Passage



Overall, eel passage was increased by the tiles

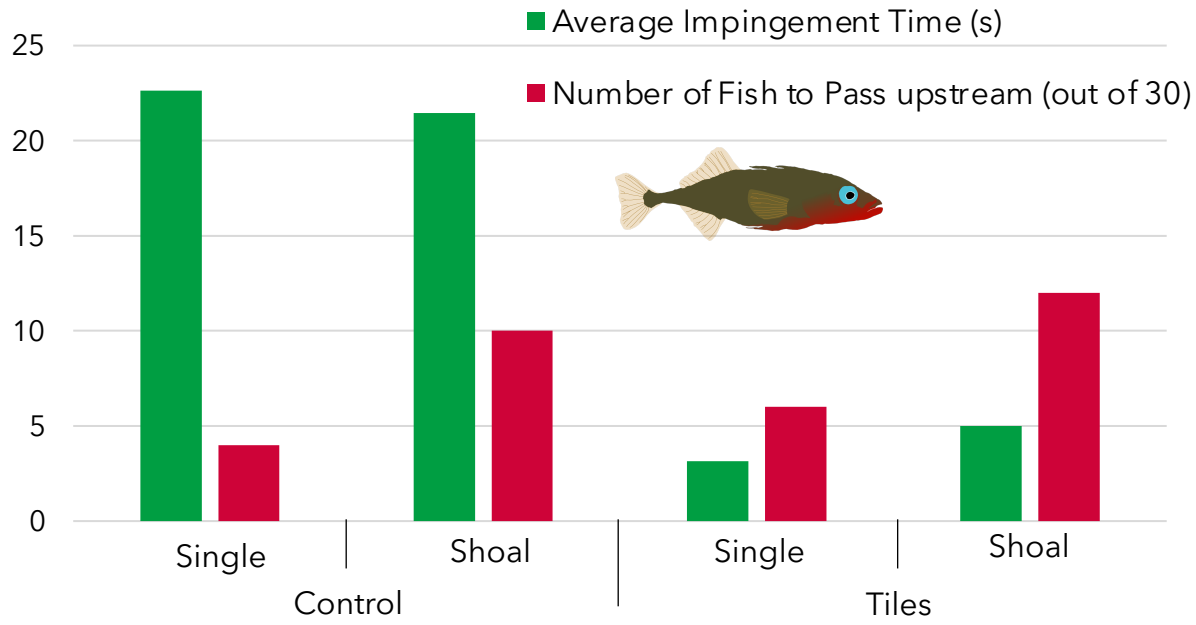
With tiles all eels swam

More passage attempts made with tiles

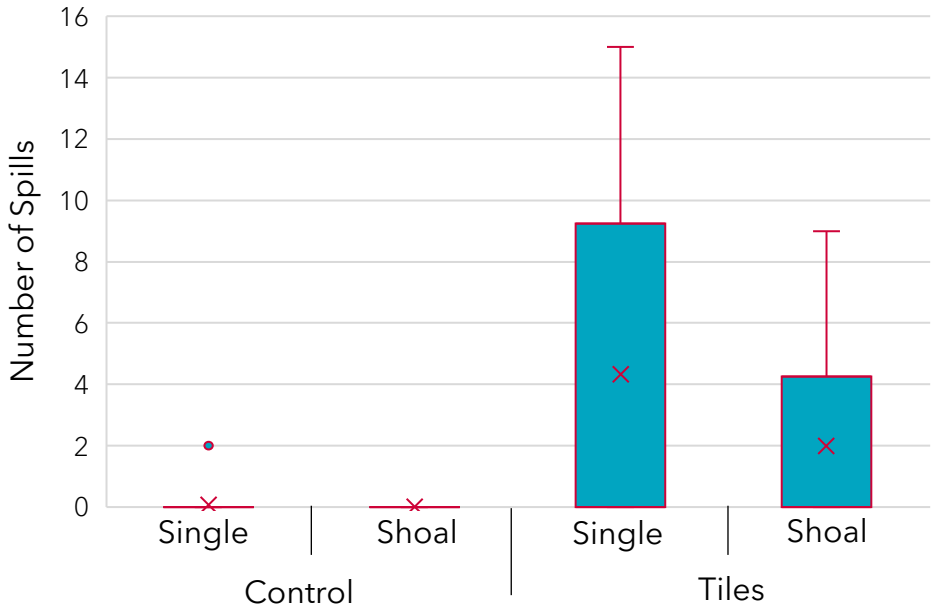
Stickleback passage increased with shoaling more than with the tiles

The tiles reduced impingement

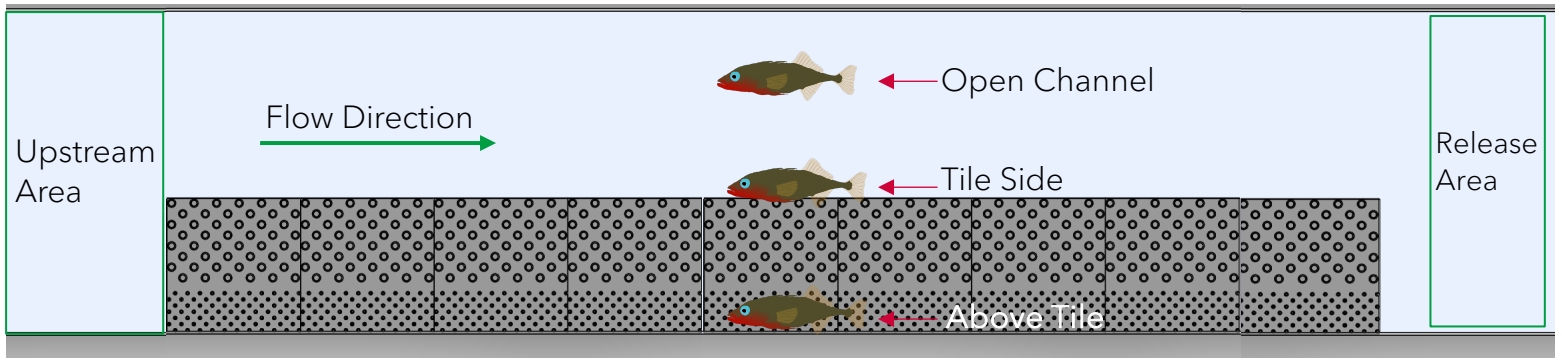
Stickleback performance linked to fish length

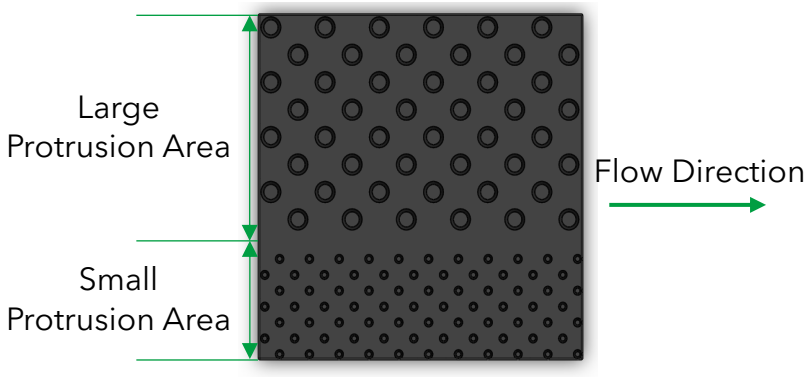


Sticklebacks are Destabilised by Turbulence



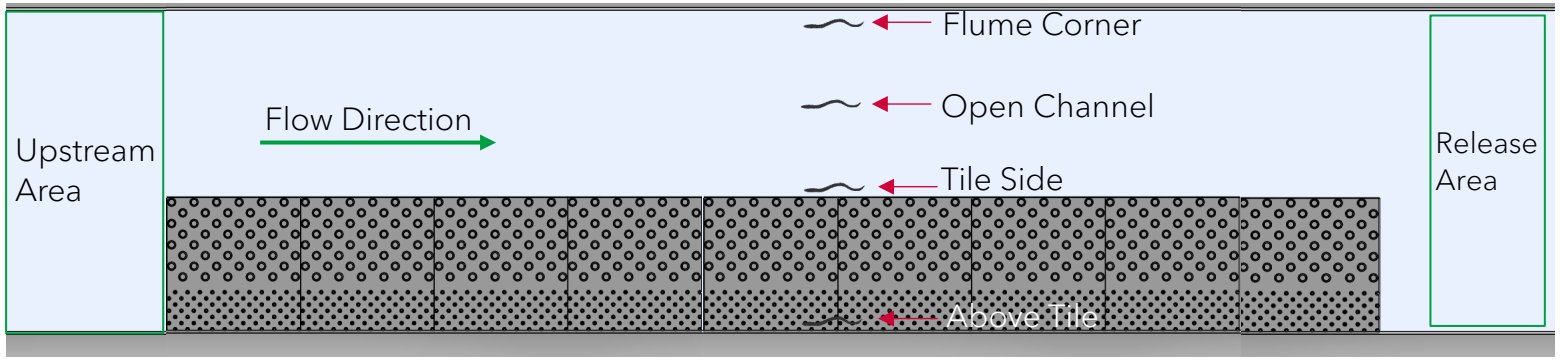
- Burst swimming in open channel for sticklebacks
- Large protrusions of tiles caused destabilisation in stickleback swimming
- Harsh flow conditions make shoaling difficult

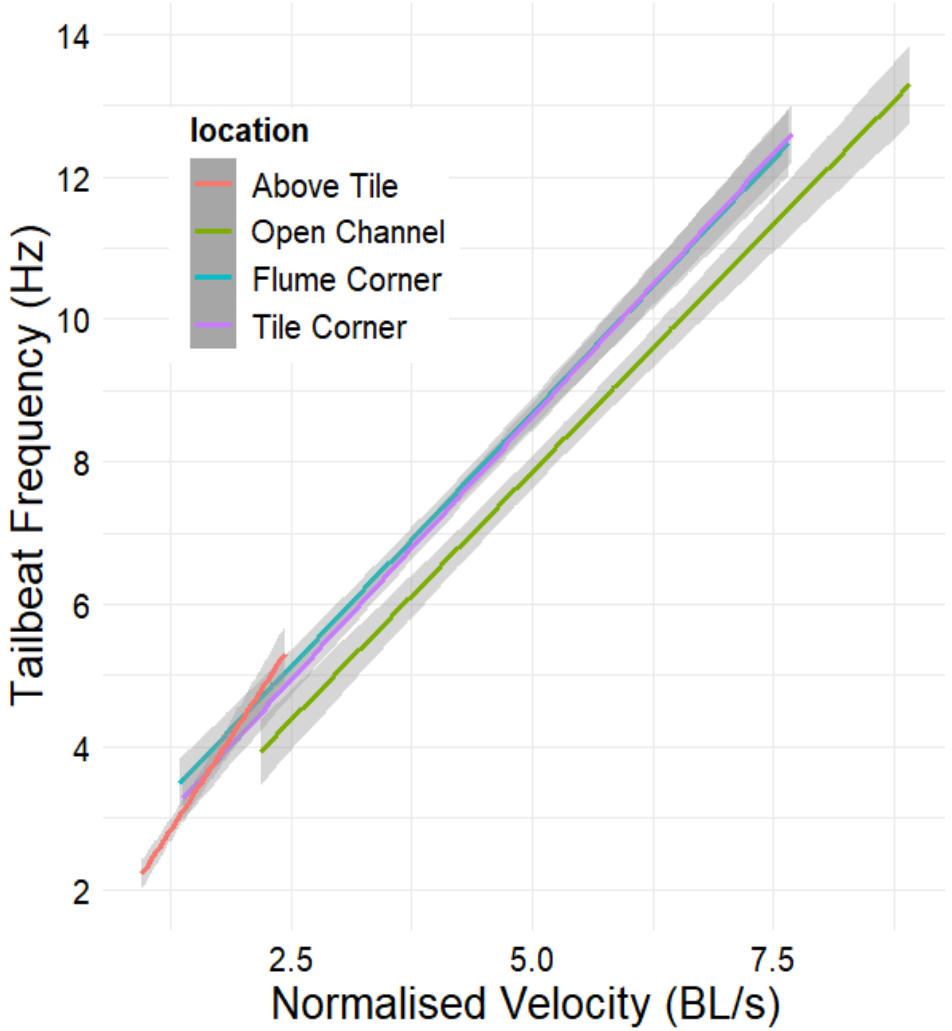




Eel Efficiency Changes with Flow

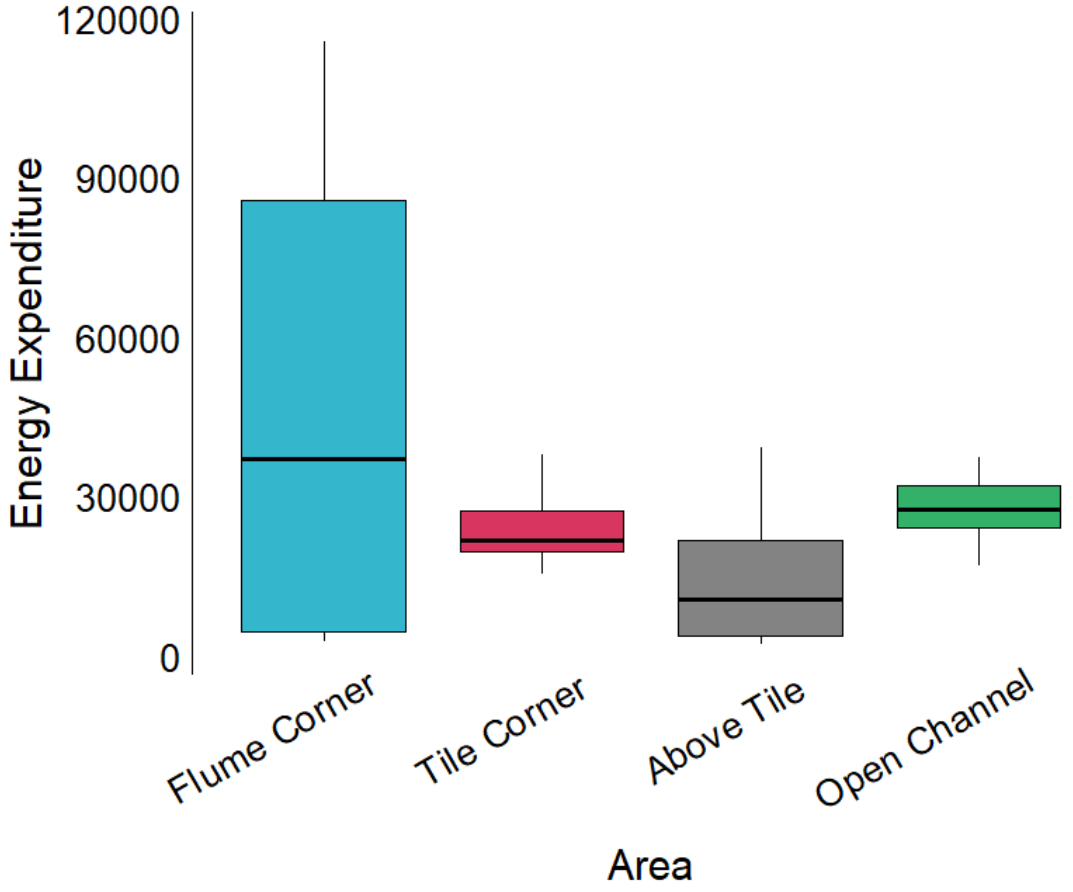
- Increasing TailBeat Frequency (TBF) with increasing speed
- More efficient swimming in regions with no large-scale turbulence?
- Decreasing TBF and amplitude with increasing Reynolds Shear Stress



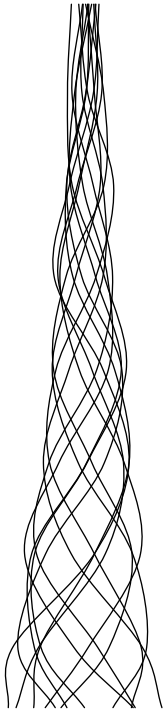


Energy Expenditure is Affected by the Tiles

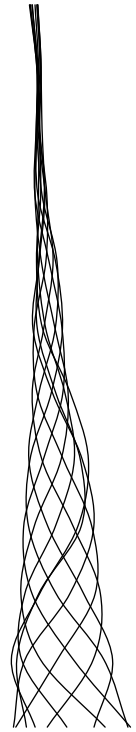
- Burst swimming in most areas
- Burst swimming cannot be sustained for long periods of time and is energetically expensive
- The eels used the least energy in the above tile area when normalised by fish length and speed



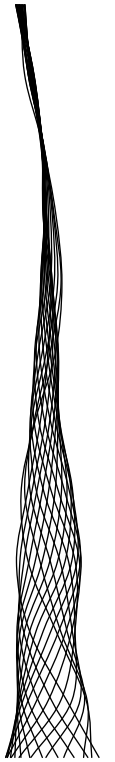
Eels Adapt their Gait to Reduce Drag



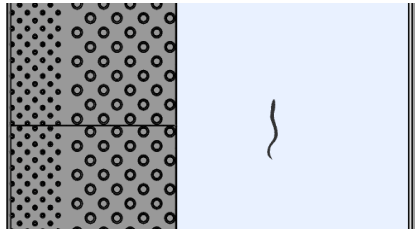
Open Channel

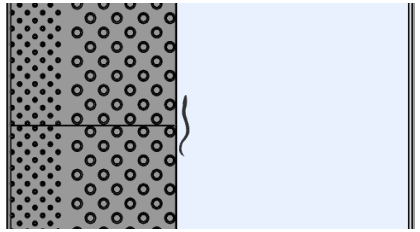


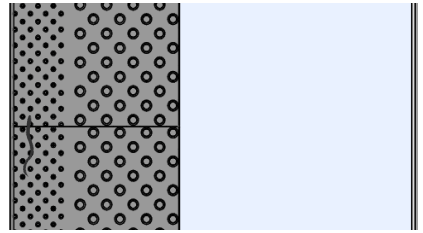
Tile Side



Above tile

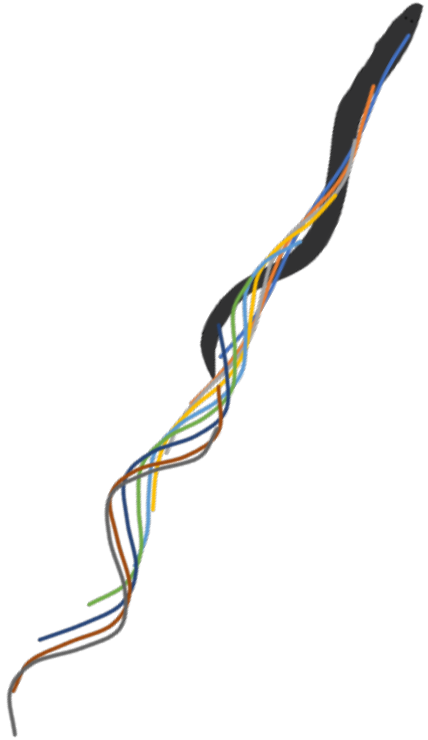


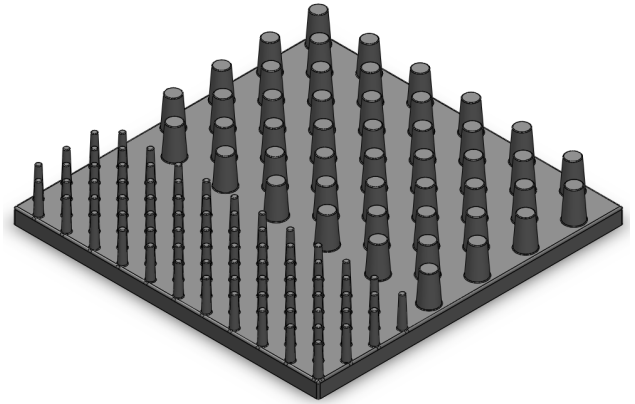


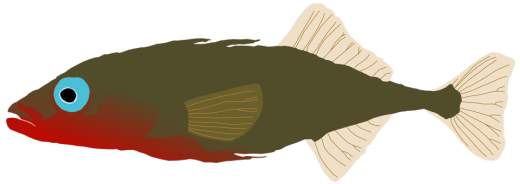


Conclusions

- Tiles are a possible way to reconnect habitats and migration routes
- Tiles increased passage and decreased energy expenditure and predation







- Potential to help eels pass high velocity barriers or guide eels to passes
- Eels adapt their kinematics in areas of turbulence and to reduce drag

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