Severn Unlocked? The response of two anadromous fishes to catchment-scale barrier mitigation in the River Severn revealed using acoustic telemetry

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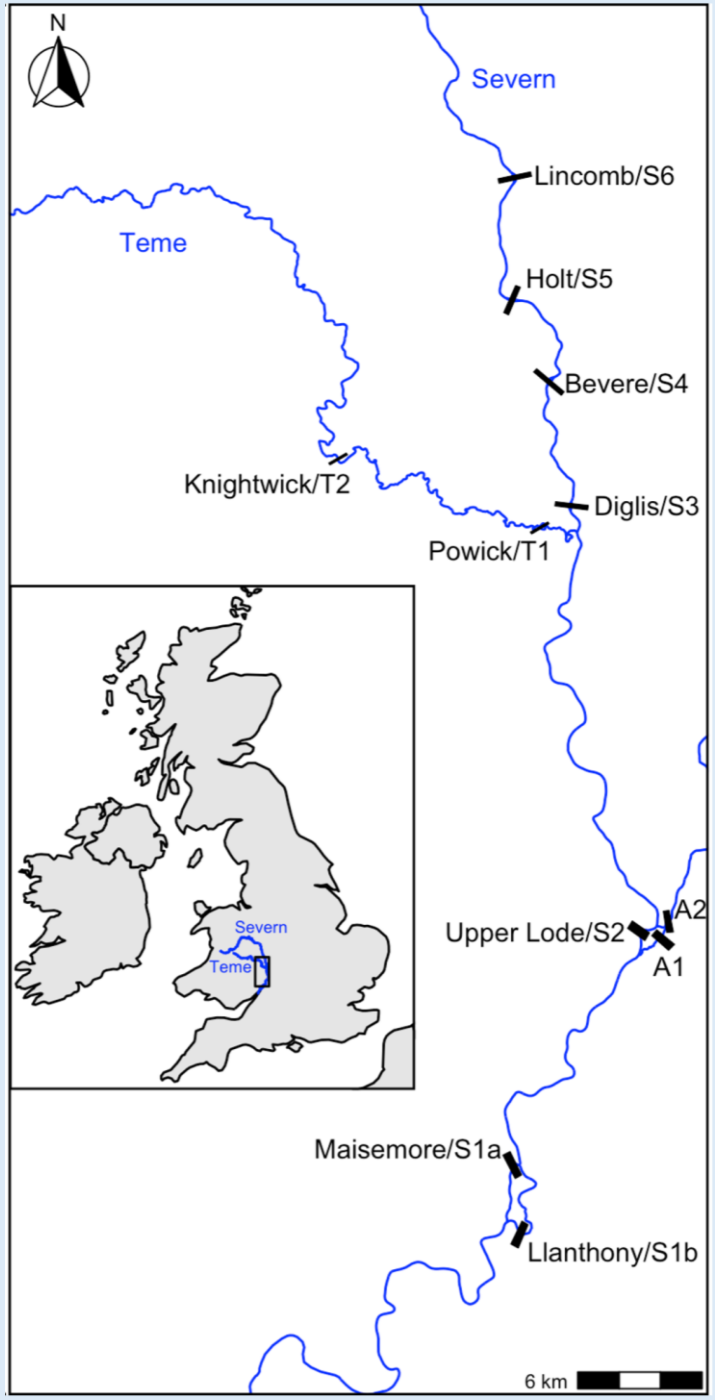
The River Severn

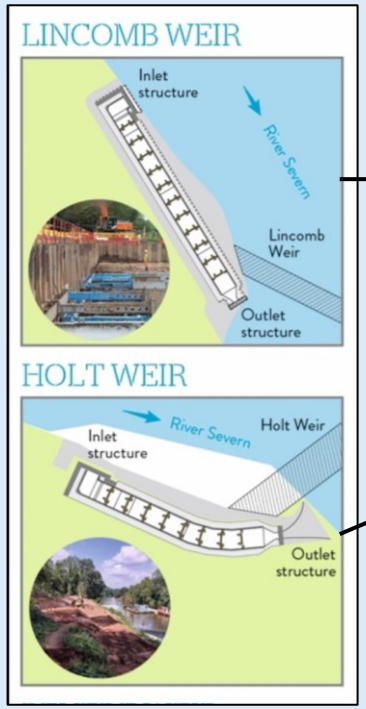
- Britain’s longest river.
- Historically important river for anadromous fishes.
  - Atlantic salmon *Salmo salar*.
  - Sea lamprey *Petromyzon marinus*.
  - Twaite shad *Alosa fallax*.
  - Allis shad *Alosa alosa*.
- Important for drinking water, transport, irrigation, etc.
  - Highly fragmented due to weir construction.

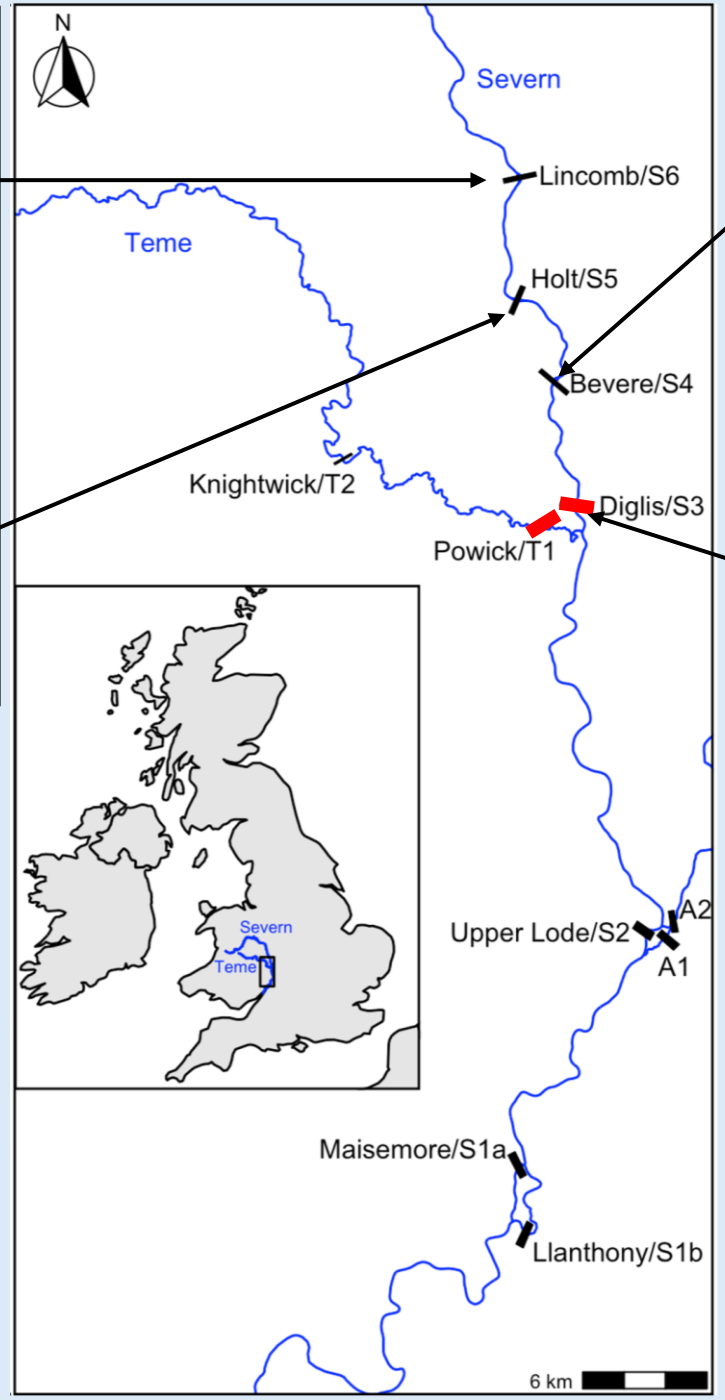


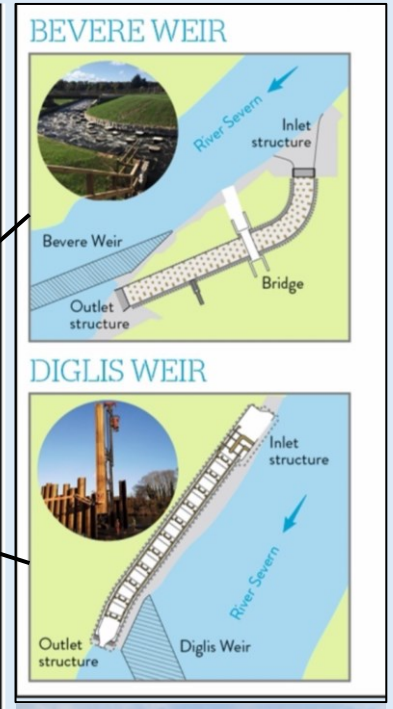
Unlocking the Severn

UNLOCKING THE SEVERN

- Allis shad extirpated from river.
- Twaite shad limited to habitat downstream of Diglis/Powick weirs.
- Sea lamprey pass weirs during high flows/tides (Davies et al. 2022).
  - Diglis: Q_{45}
  - Powick: Q_{17}
- Unlocking the Severn – EU Life and National Lottery Heritage funded project.
  - 4 fish passes on Severn mainstem (mitigation; 2021-2022).
  - 2 weir modifications on Teme tributary (remediation; 2019).







Study Species

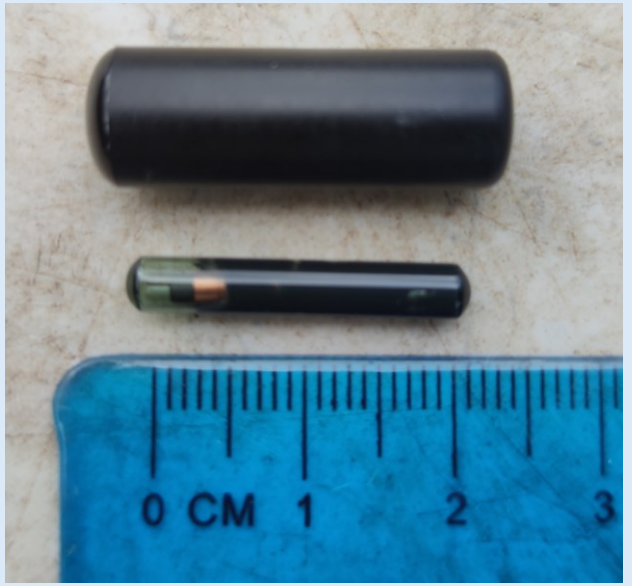
- Twaite shad *Alosa fallax*
  - Iteroparous.
  - Natal homing.
  - Vulnerable in Britain (Nunn et al. 2023).
  - Pelagic – must swim over/round barriers.
- Sea lamprey *Petromyzon marinus*
  - Semelparous
  - Attracted into rivers by juvenile pheromones.
  - Varying conservation status across range (Hume et al. 2021).
  - Demersal – uses sucker-like mouth to latch on to surfaces.

Aim: Assess response of shad and sea lamprey to river reconnection.

- Identify approach rates at ‘Unlocking the Severn’ weirs.
- Compare weir passage rates and passage times pre- versus post-reconnection.
- Compare distribution within reconnected reaches pre- versus post-reconnection.
- Identify factors influencing weir passage:
  - Mitigation/remediation.
  - Environmental variables.
  - Individual factors (i.e. sex, body length, spawning history).

Methods – Acoustic Telemetry

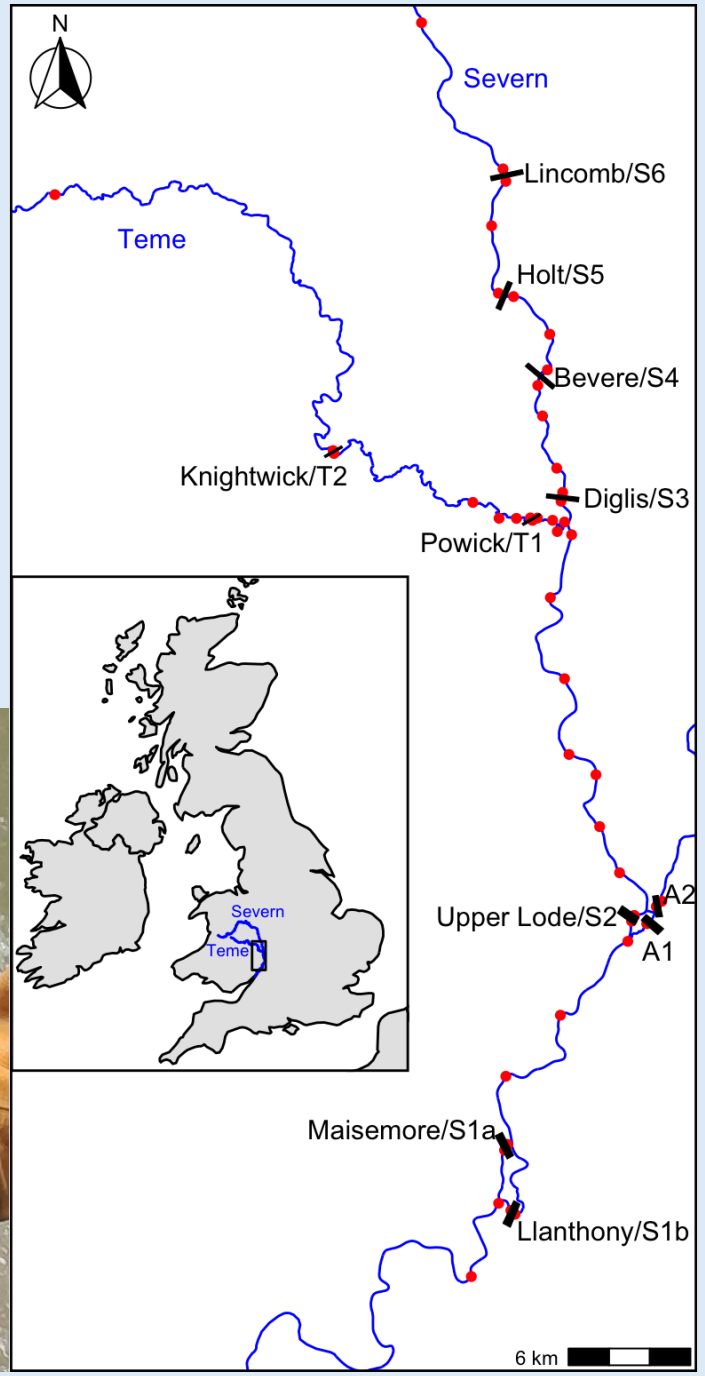
- Internal implantation of (Vemco V9) acoustic transmitters.
- Batteries last for up to three spawning seasons.



	Twaite shad	Sea lamprey
2018	84	60
2019	100	-
2020	-	-
2021	47	-
2022	100	58
2023	50	21
Total	**381**	**139**

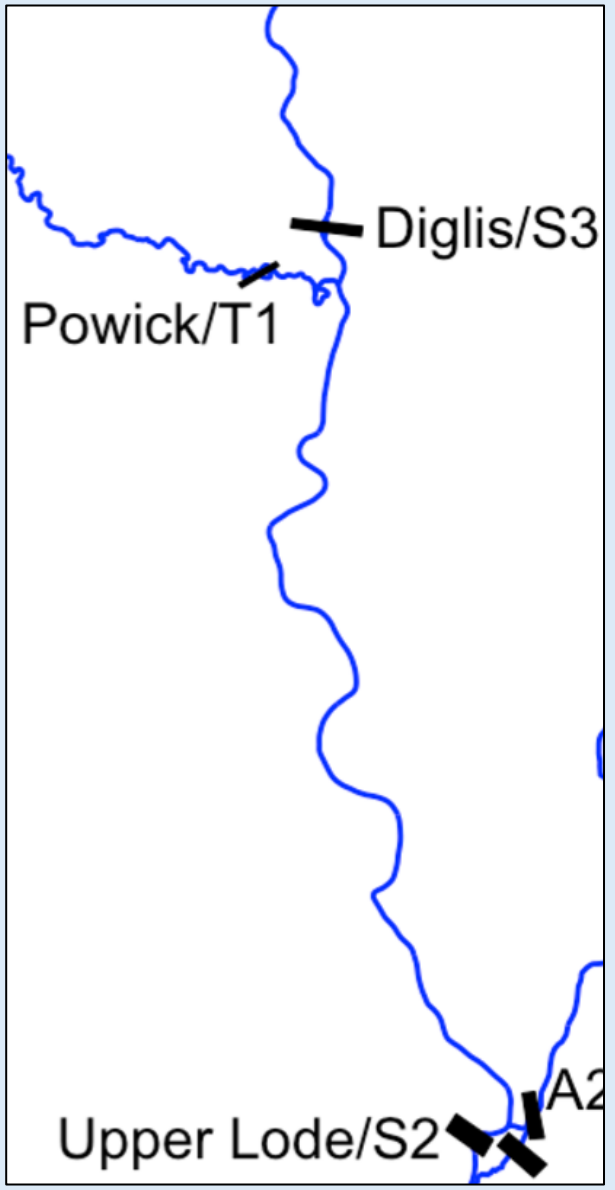
Methods – Acoustic Telemetry

- Acoustic receivers positioned in ~ 50 locations.
- Study area upstream of the Weir S2.
  - Accessible to 2/3 of shad (Davies et al. 2023).
  - Accessible to lamprey depending on tides and river levels (Davies et al. 2022).
- Sample size:
  - Shad: 315 (387 separate migrations).
  - Sea lamprey: 86.



Approach Rates

- High approach rates at most downstream project weirs:
  - Shad: 71%
  - Sea lamprey: 87%
- Majority of fish approached weir on Severn mainstem (Diglis/S3) rather than Teme tributary (Powick/T1) during first upstream movement.
  - Shad: 95%
  - Sea lamprey: 89%
- Some individuals approached both weirs.
  - Shad: 25%
  - Sea lamprey: 16%



Passage Rates – Severn Mainstem

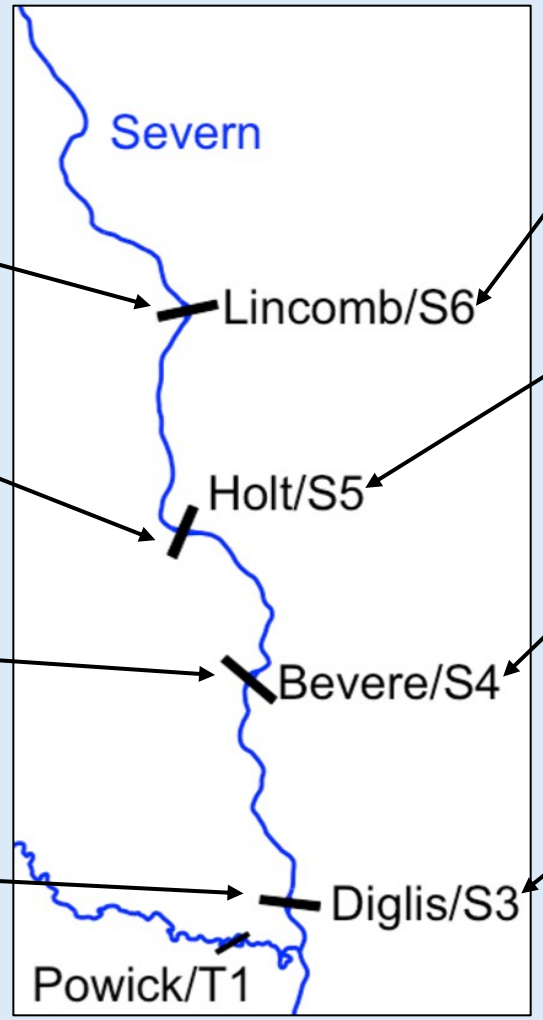
Pre-mitigation

S6: Shad: NA
Sea lamprey: NA

S5: Shad: NA
Sea lamprey: **12%** (2/17)

S4: Shad: NA
Sea lamprey: **100%** (17/17)

S3: Shad: **3%** (3/93)
Sea lamprey: **41%** (17/41)



Post-mitigation

S6: Shad: **0%** (0/2)
Sea lamprey: **50%** (1/2)

S5: Shad: **43%** (3/7)
Sea lamprey: **25%** (2/8)

S4: Shad: **64%** (7/11)
Sea lamprey: **90%** (9/10)

S3: Shad: **7%** (13/174)
- High variability: 0-13%

Sea lamprey: **48%** (13/27)

Passage Rates – Teme Tributary

Pre-mitigation

T2: Shad: NA

Sea lamprey: **100%** (4/4)

T1: Shad: **0%** (0/18)

Sea lamprey: **40%** (4/10)

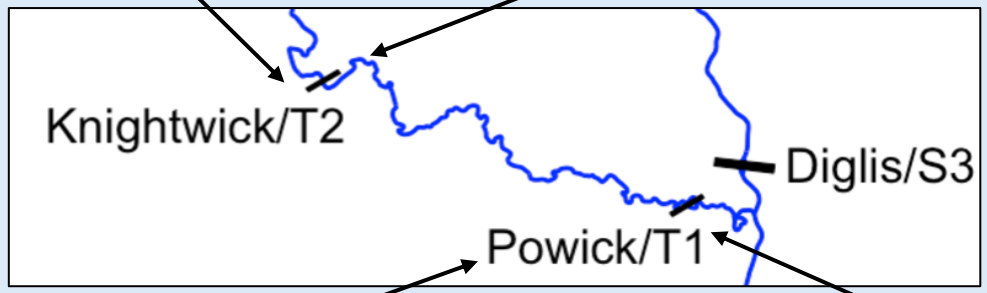
Post-mitigation

T2: Shad: **80%** (4/5)

Sea lamprey: **100%** (1/1)

T1: Shad: **58%** (33/57)

Sea lamprey: **78%** (7/9)

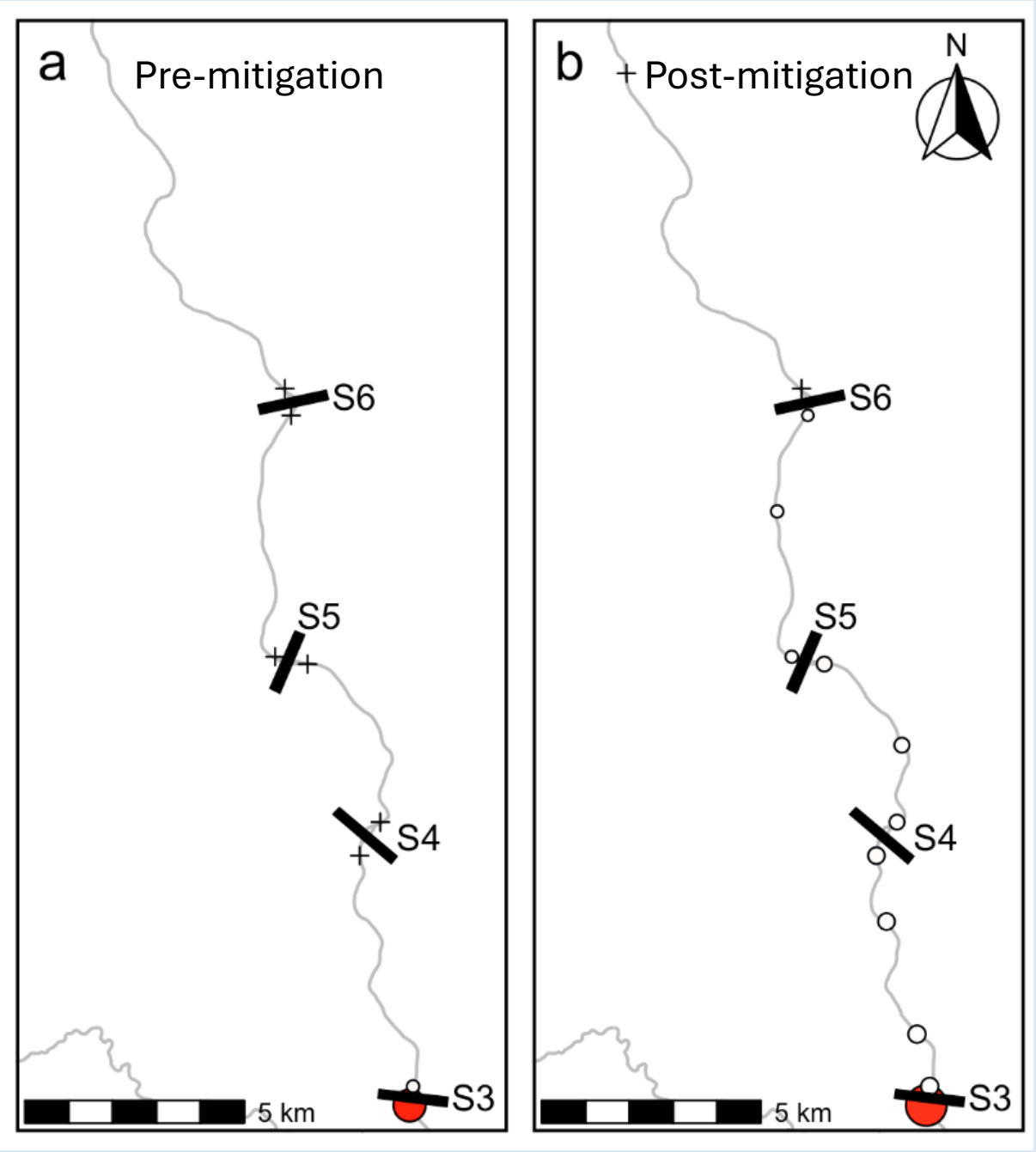


Passage Times

		Pre-reconnection		Post-reconnection	
Spp.	**Weir**	**n passed**	**Median passage time (days)**	**n passed**	**Median passage time (days)**
Shad	S3	3	**23.3 (22.1-25.8)**	13	**3.3 (2.2-8.2)**
	S4	0	-	7	2.2 (1.6-2.6)
	S5	0	-	3	1.9 (1.1-3.0)
	T1	0	-	33	0.08 (0.02-1.05)
	T2	0	-	4	0.21 (0.06-0.73)
Lamprey	S3	17	5.3 (4.1-13.0)	13	2.2 (0.1-12.0)
	S4	17	0.2 (0.1-0.3)	9	3.0 (0.1-7.1)
	S5	2	6.1 (4.9-7.3)	2	11.5 (7.7-15.2)
	S6	0	-	1	16.9
	T1	4	0.04 (0.03-0.07)	7	0.01 (0.01-0.03)
	T2	4	0.6 (0.5-0.7)	1	0.004

Distribution

- **Severn mainstem:** Maximum distance reached increased for both species, but overall distribution did not differ significantly.
- **Teme tributary:** Maximum distance reached and overall distribution significantly further upstream for shad, but not sea lamprey.



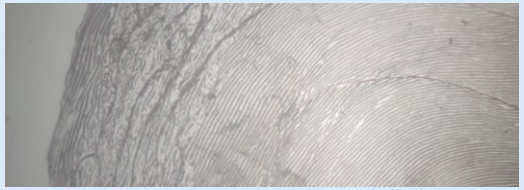
Passage Conditions

- Pre-mitigation, shad passage at Diglis/S3 only occurred during high flows (Q_3).
- Only spawning history significantly influenced shad passage at Diglis/S3 post-mitigation.
- River level and temperature positively influenced shad passage at Powick/T1 post-remediation.
- Flow/river level influenced lamprey passage at Diglis/S3 and Powick/T1 pre-, but not post-reconnection.
- Remediation positively influenced lamprey passage at Powick/T1.

Mixed Effects Cox model for shad passage at Diglis/S3 post-mitigation

Predictor	Coefficient	P
Flow	-0.03	0.75
Temperature	0.85	0.08
Diel period: night	-1.58	0.14
Spawning history: virgin	3.83	**0.0013**
Fork length	0.02	0.18

Virgin spawner



Previous spawner

Conclusions

- Weir **remediation** (removal/modification) more successful than **mitigation** (fish pass provision) in initial reconnection period.
  - Higher passage rates and lower passage times.
- Fish passes provide passage opportunities when weirs were previously impassable (i.e. during low flows).
- Fish pass use by shad may increase as shad that pass in their virgin season return in future years.
  - Twaite shad have high fidelity to previous spawning reach (Davies et al. 2024).
  - May explain slower response by *Alosa* spp. to river reconnection than other species (e.g. Whittum et al, 2023).

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