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# Eels II: Survival and Health of European Eels, *Anguilla anguilla*, Entrained in Water Pumps of Varying Size, Design and Specification AND Wider Considerations

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Bolland, J. D.; Stanford, R.; Lewin, N. C.; Williams, C. F.; Angelopoulos, N. V.; Baker, N. J.; Murphy, L.; Cowx, I. G.; Reeds, J.; Jerrom, K.; Hooker, J.; and Wright, R. M., "Eels II: Survival and Health of European Eels, *Anguilla anguilla*, Entrained in Water Pumps of Varying Size, Design and Specification AND Wider Considerations" (2016). *International Conference on Engineering and Ecohydrology for Fish Passage*. 8.

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**Presenter Information**

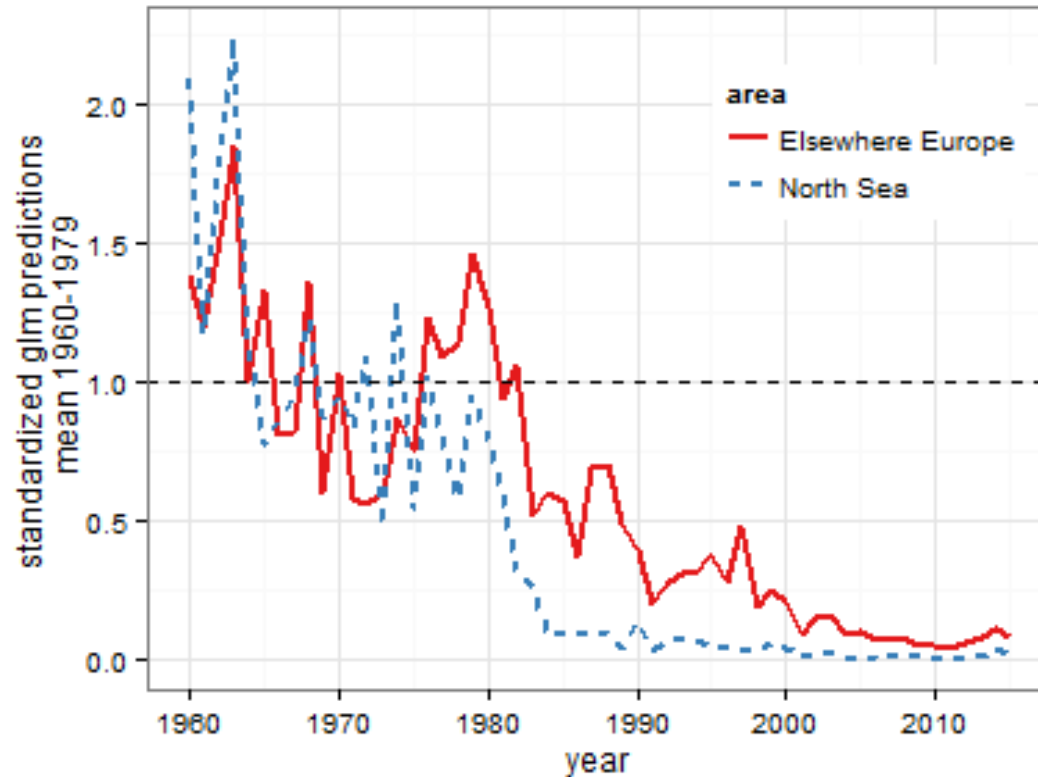
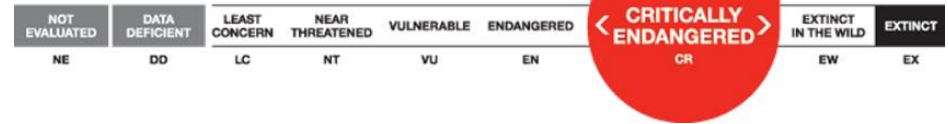
J. D. Bolland, R. Stanford, N. C. Lewin, C. F. Williams, N. V. Angelopoulos, N. J. Baker, L. Murphy, I. G. Cowx, J. Reeds, K. Jerrom, J. Hooker, and R. M. Wright

Survival and health of European eels, *Anguilla anguilla*, entrained in water pumps of varying size, design and specification  
AND wider considerations



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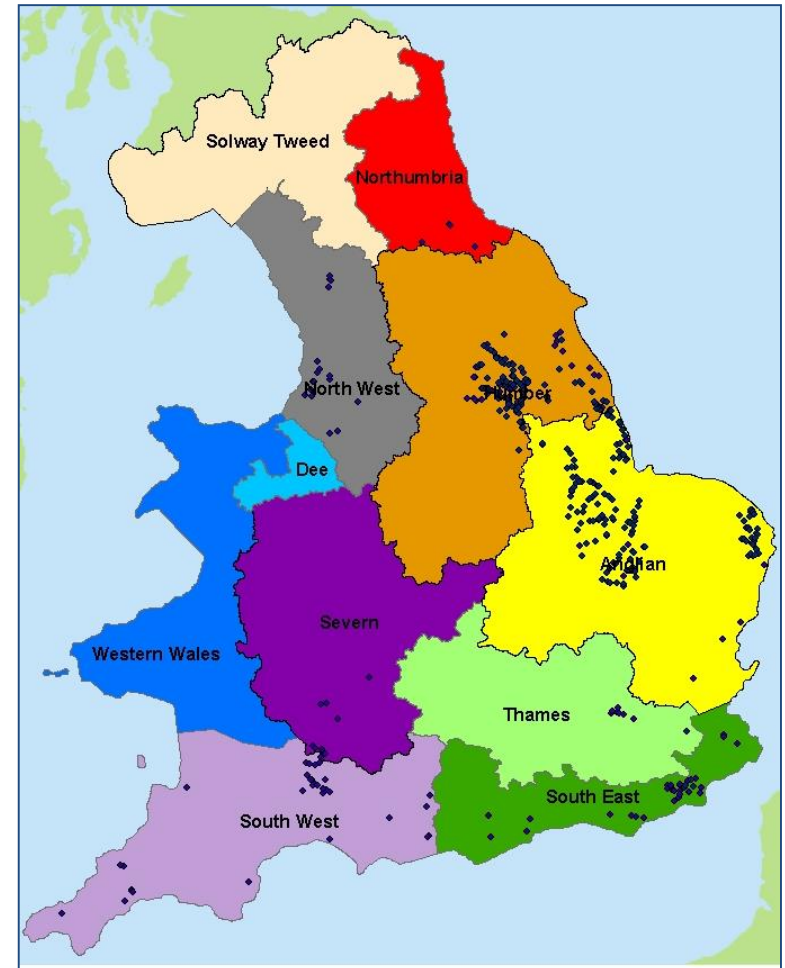
# European eel decline



- The EC Eel Regulation (1100/2007) to protect them from human mediated activities.

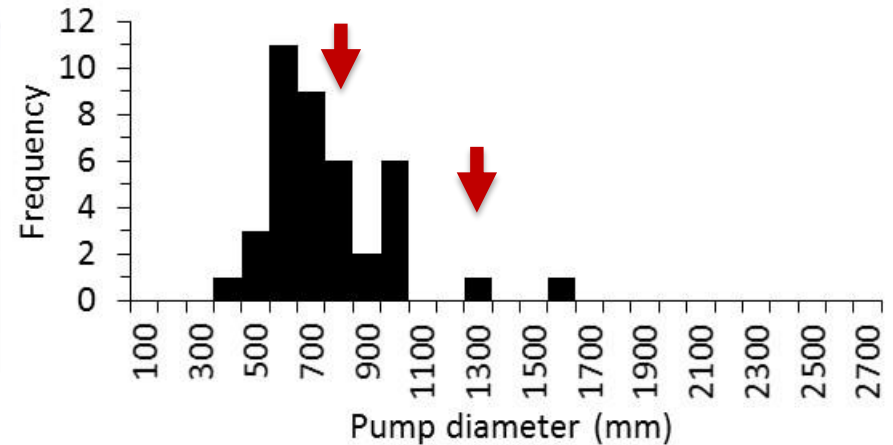
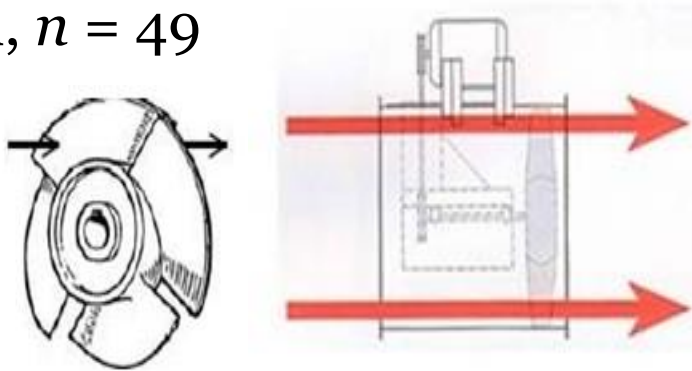
# Pumping stations in England

- In England, the European regulation is enacted through the Eels Regulations 2009 Statutory Instrument (the Eel SI), which includes powers to screen water intakes (including pumping stations) abstracting greater than 20 m<sup>3</sup> a day.
- Evidence of eel injury and mortality during pumping station operation is limited to anecdotal reports.
- Robust site specific assessments are required to confirm whether pumping stations are compliant under the Eels Regulations 2009 or require eel protection measures.

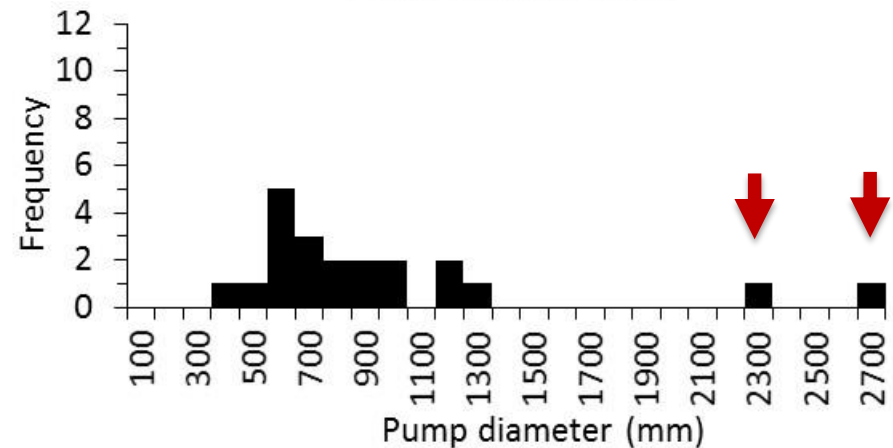
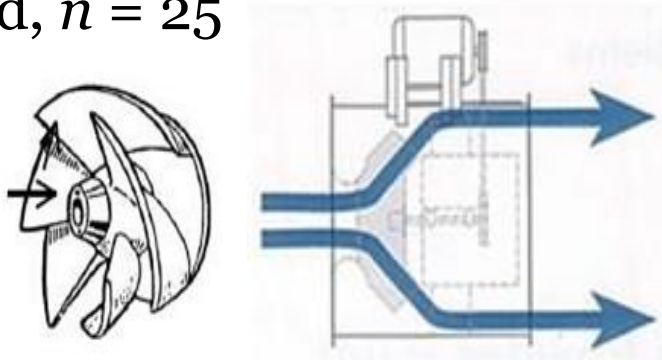


# Review of high priority pumping stations, e.g. type of pump, size, rpm and number of blades

Axial,  $n = 49$



Mixed,  $n = 25$



No information,  $n = 65$

## Pumps studied in 2015

The entire site, not just the pump, was assessed!

Pumping station	Type	Power supply	Diameter (metres)	Number of blades	Speed (rpm)	Capacity (cumecs)
MF-2.23	Mixed flow	Electric	2.23	3	120	28.0
MF-2.23	Mixed flow	Diesel	2.23	3	100	9.4
AF-1.3	Axial flow	Diesel	1.3	4	200	3.8
AF-0.8	Axial flow	Electric	0.8	4	400	1.9
FF-0.6	'Fish-friendly'	Electric	0.6	2	872	1.2

- Eels captured, condition assessed, PIT tagged (under Home Office licence) and released upstream
- Recaptured downstream, scanned for PIT tag, external condition visually assessed and internal condition assessed at EA National Fish Lab
- Catchment and net controls



# Field methodology





# Mortality / survival

Pumping station	Mortality (%)	48-hr mortality (%)
MF-2.65	0/31 (0%)	0/31 (0%)
MF-2.23	0/57 (0%)	0/27 (0%)
AF-1.3	6/58 (10%)	1/39 (3%)
AF-0.8	10/17 (58%)	-
FF-0.6	1/60 (2%)	3/30 (10%)



- The greatest level of mortality was found for the smallest axial flow pump with the most blades on the impeller and the highest rotation speed.
- Larger mixed flow pumps with fewer blades and slower rotation speed did not kill eels.
- Three eels entrained in a pump marketed as ‘fish friendly’ (the first of its kind in the UK but with original pipework) died after 48-hours.

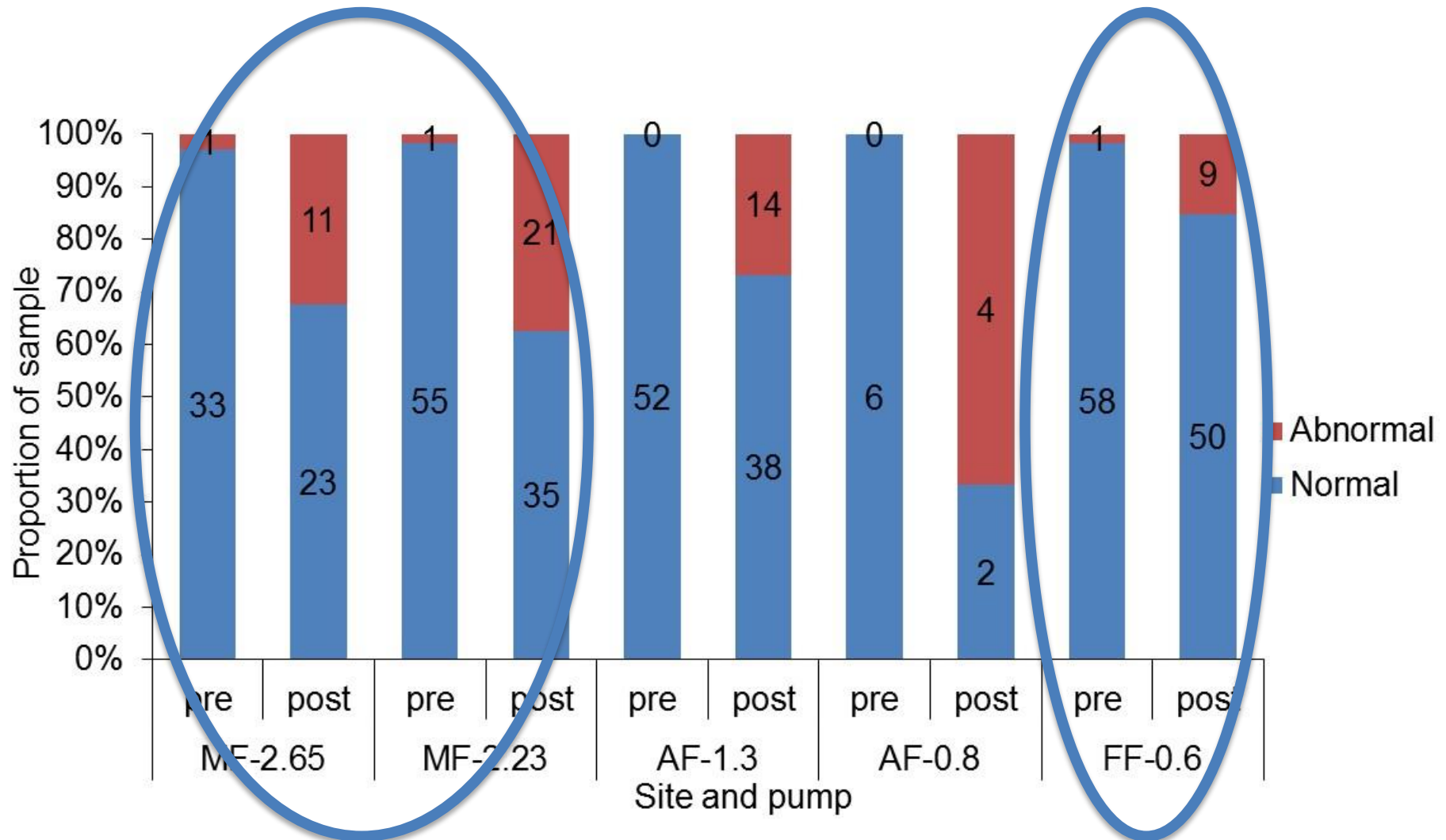
# Behavioural assessment

- **Motor capacity** – Is the eel moving and lively?
- **Response** – Does the eel respond to stimuli?
- **Bodyform** – Does the eel conform to a anguilliform shape?
- **Buoyancy** – Is the eel neutrally buoyant position?

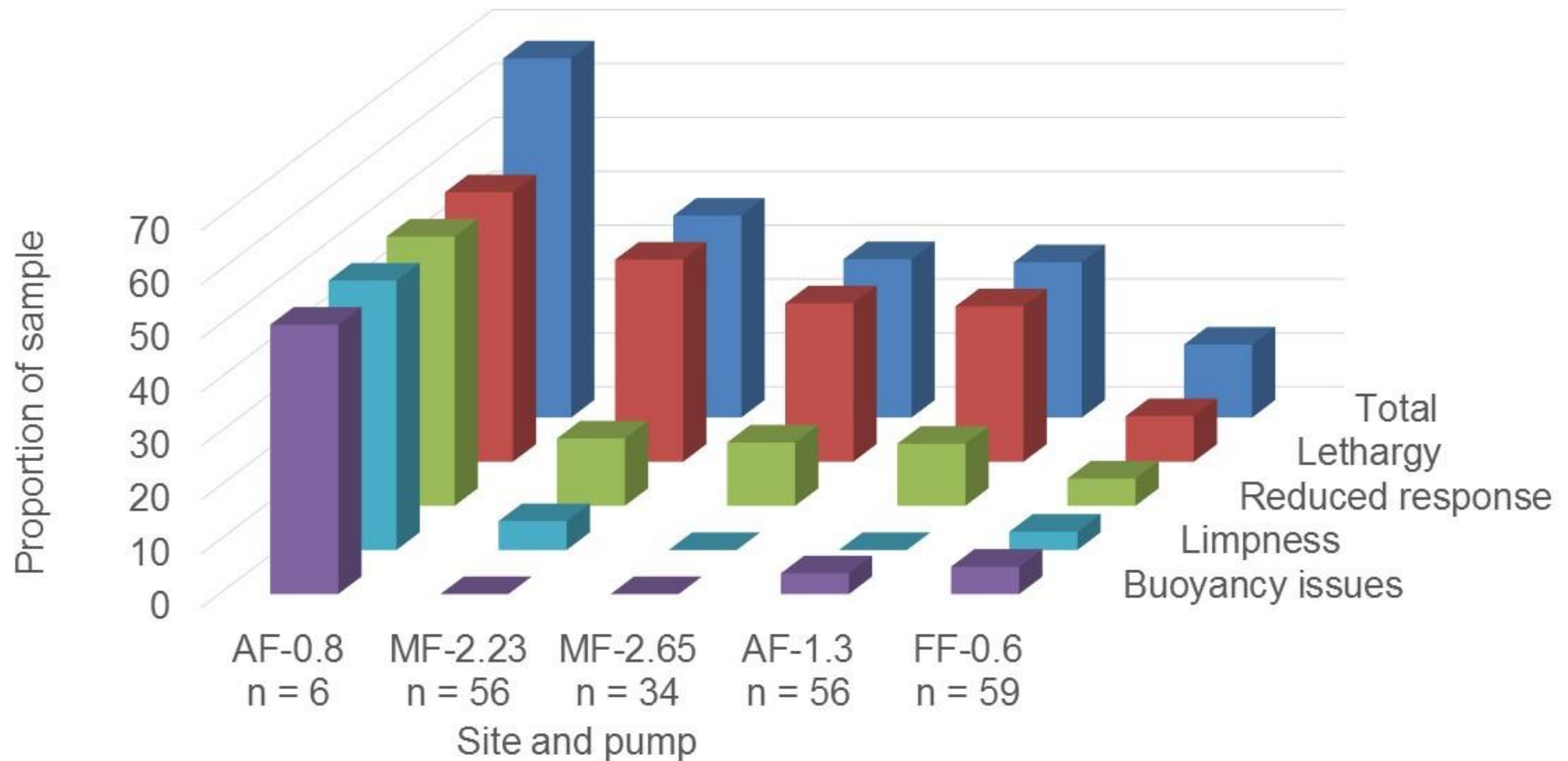
If the answer to **all** questions was **yes** the eel was assigned a behaviour category of “**Normal**”

If the answer to **any** question was **no** the eel was assigned a behaviour category of “**Abnormal**”

# Change in behaviour

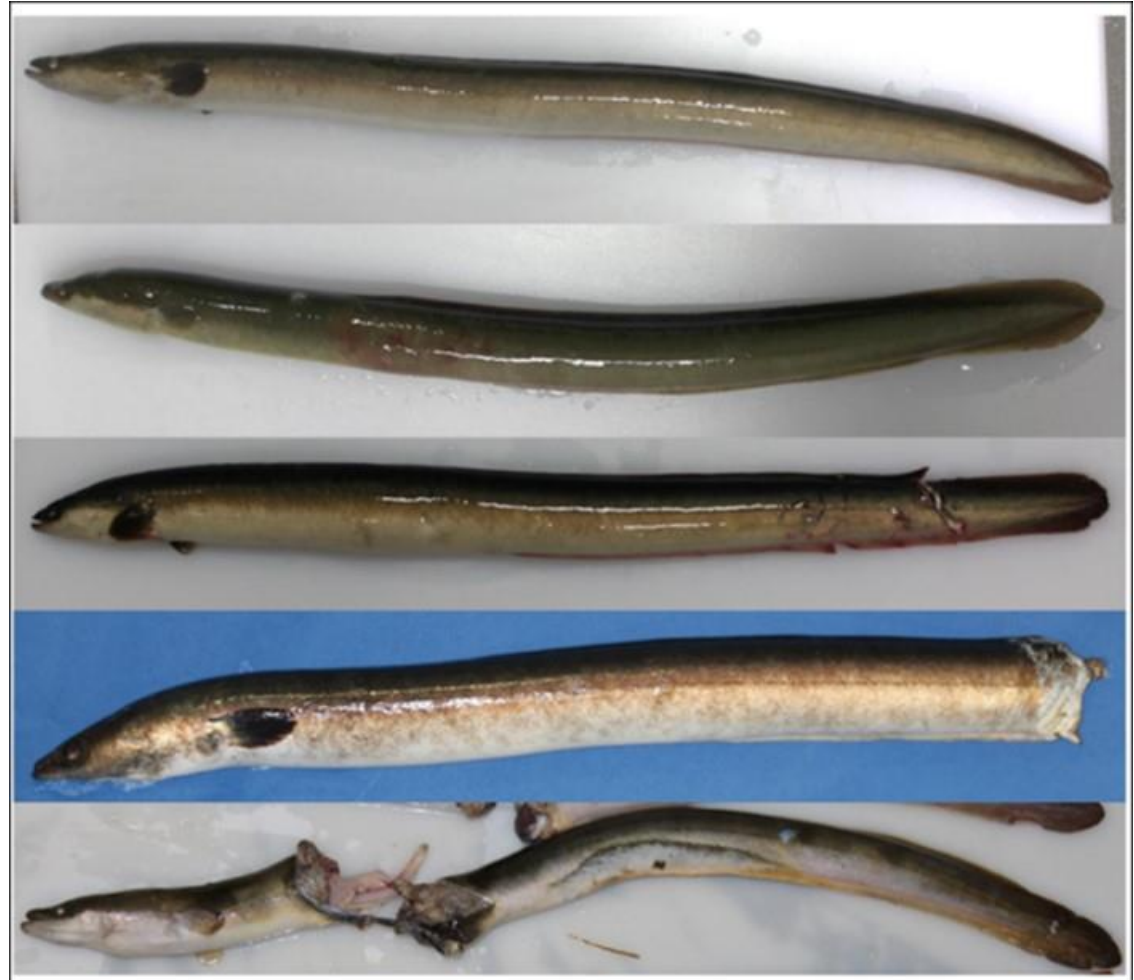


# How behaviour changed



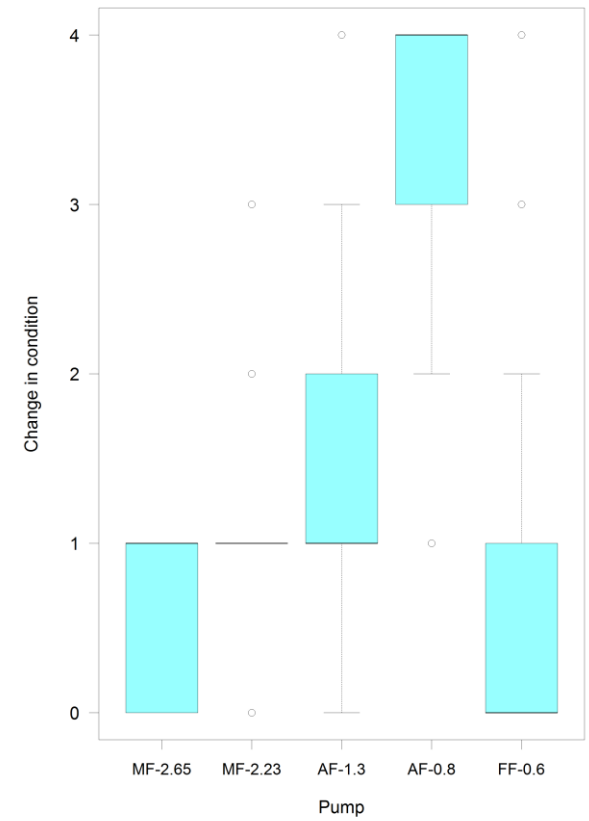
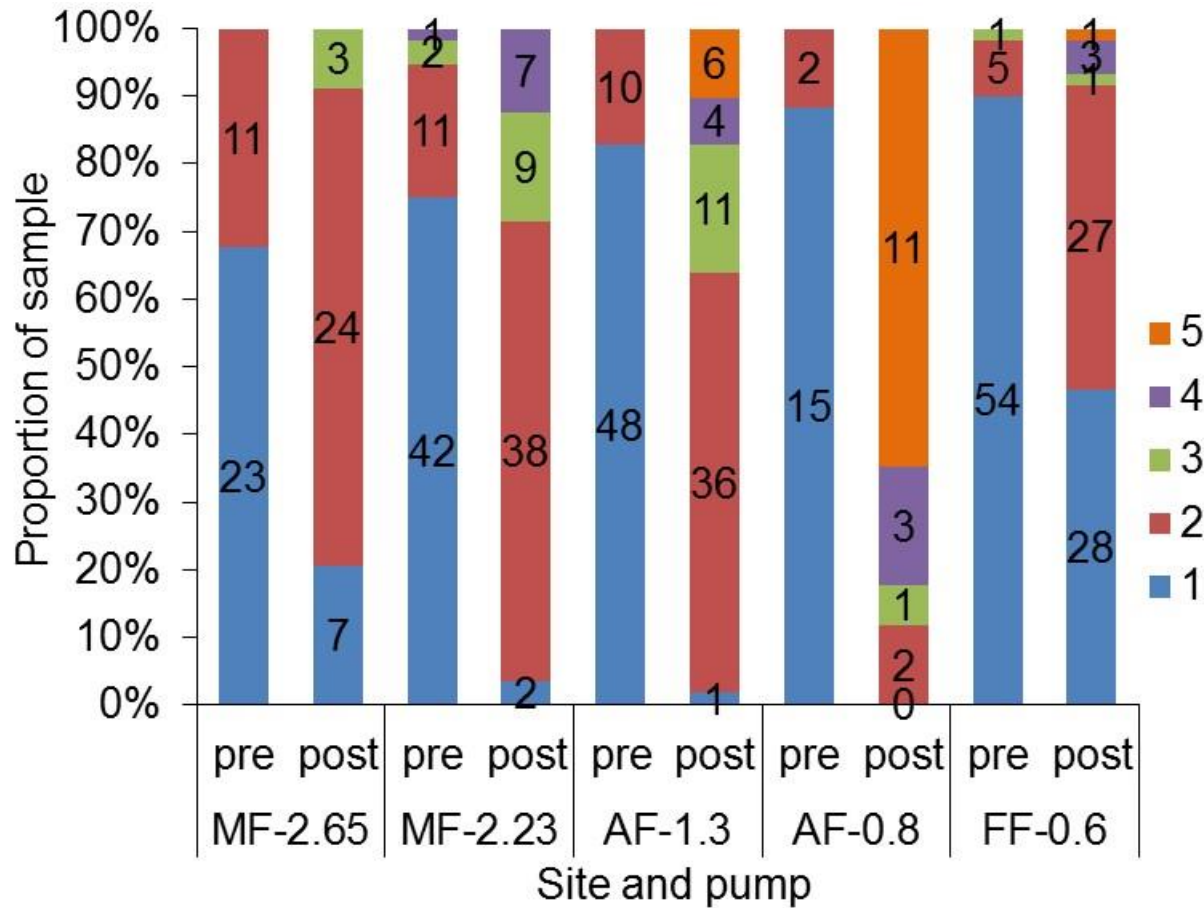
# Eel condition assessment

1. No visible damage to the fish exterior, the fish should be alive and appear healthy.
2. Minor injury; mainly superficial – unlikely to affect function or survival.
3. Moderate injury; more substantial injury – likely to affect function.
4. Major injury; severe injury – likely to affect both function and survival.
5. Mortality, the fish is no longer alive

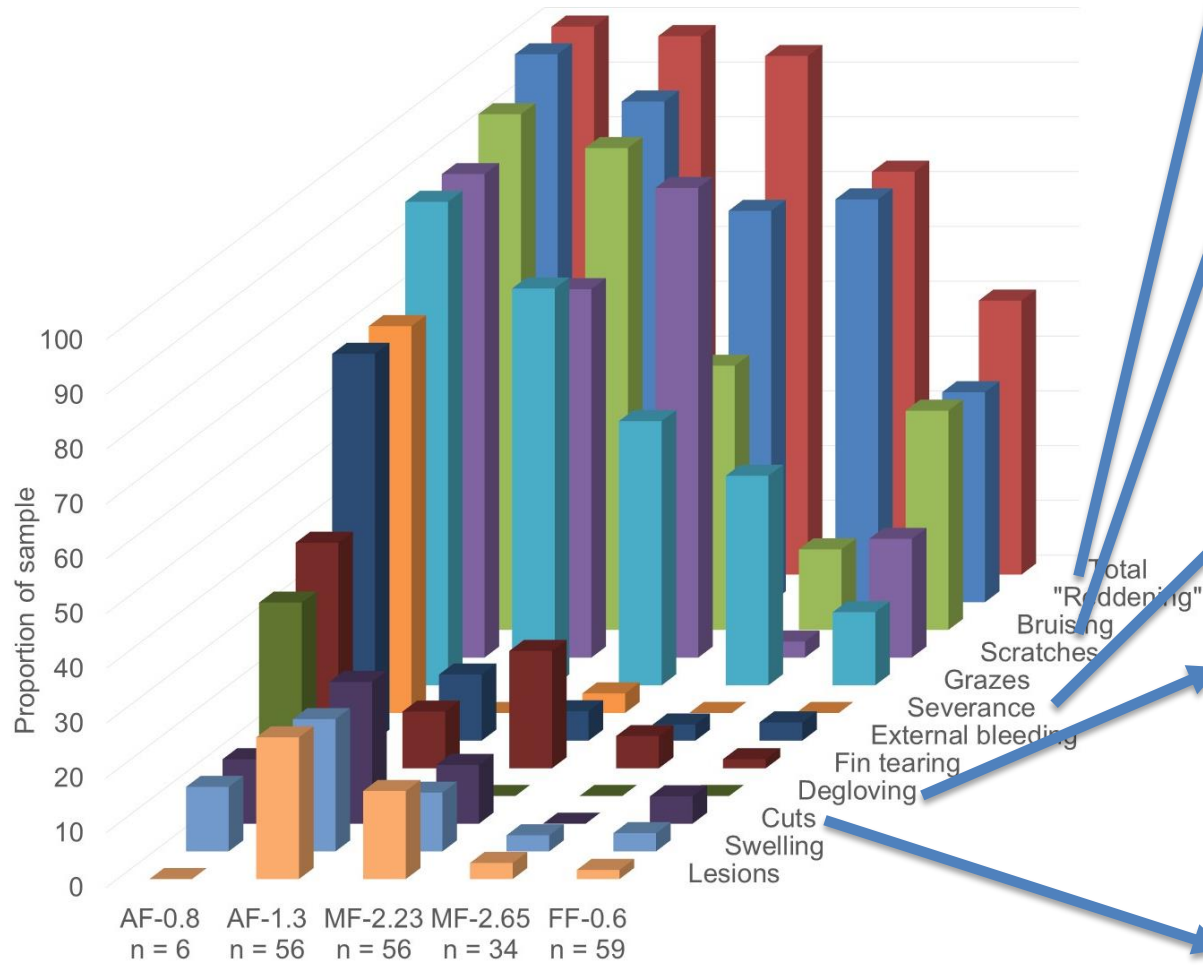




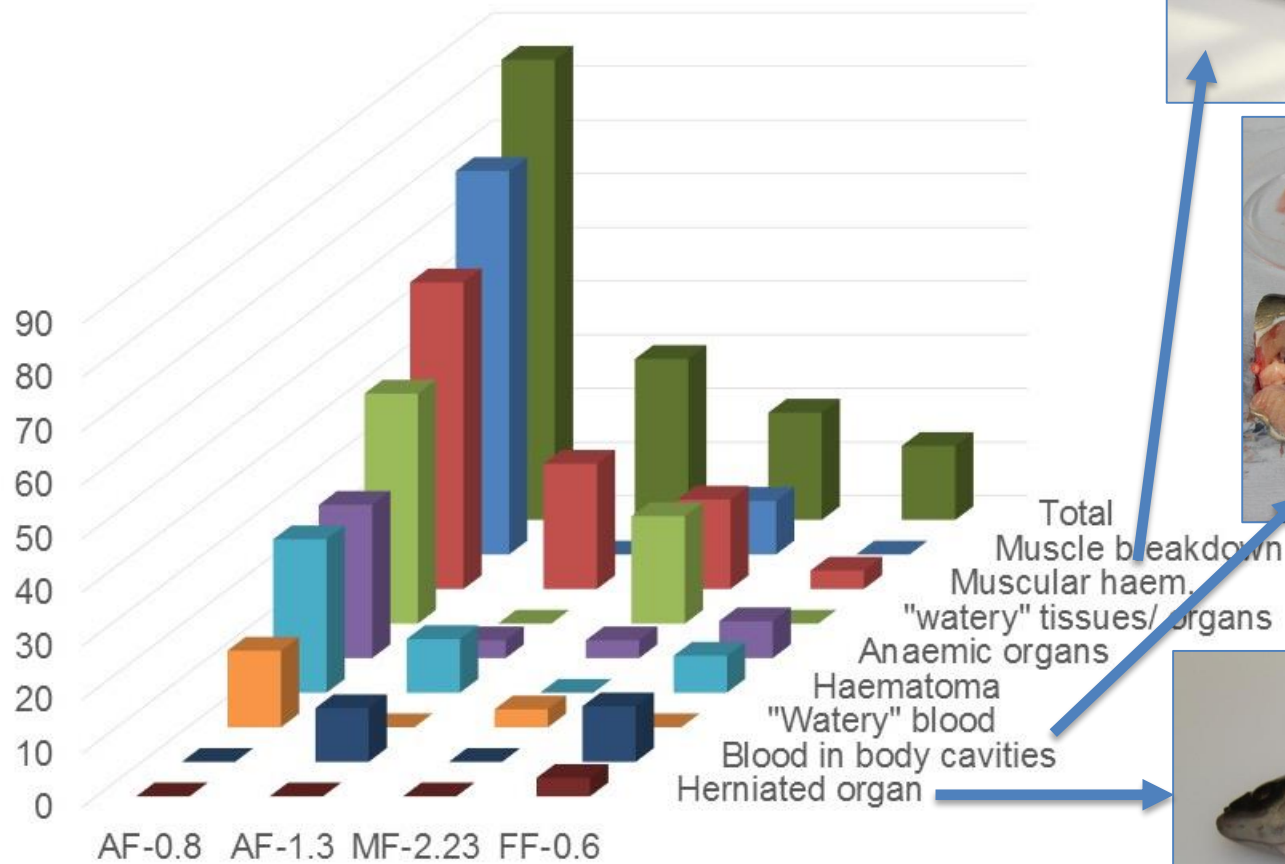
# Change in condition



# External injuries



# Internal injuries

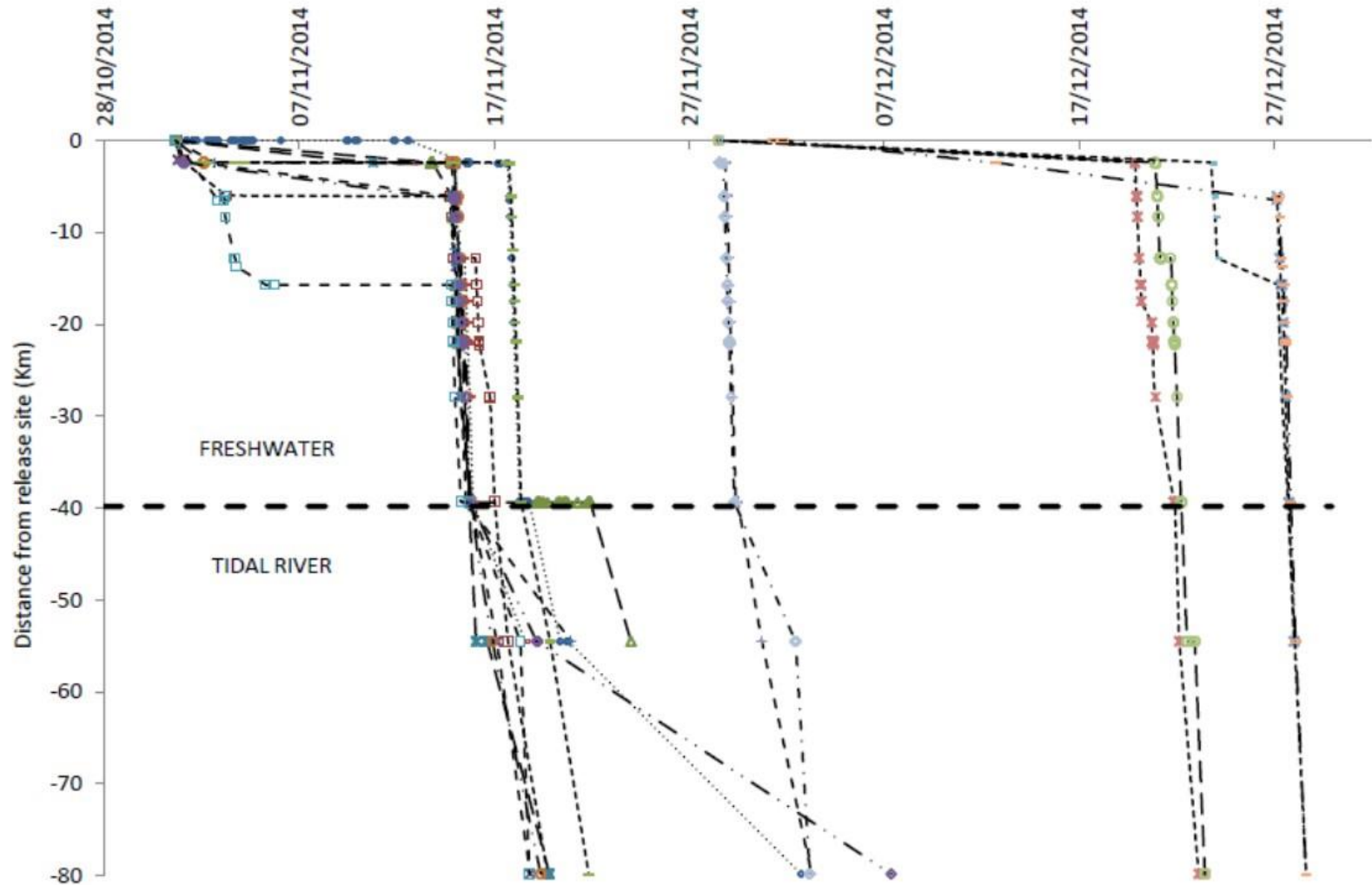


# Direct impact of entrainment summary

Site	Mortality	48-hr mortality	Abnormal behaviour	External condition
MF-2.65	0%	0%	32%	0.56
MF-2.23	0%	0%	38%	1.05
AF-1.3	10%	3%	27%	1.45
AF-0.8	58%	-	67%	3.24
FF-0.6	2%	10%	15%	0.58

- BUT... what about the indirect impacts:
  - Migration through catchment (acoustic telemetry)
  - Behaviour immediately upstream (ARIS)

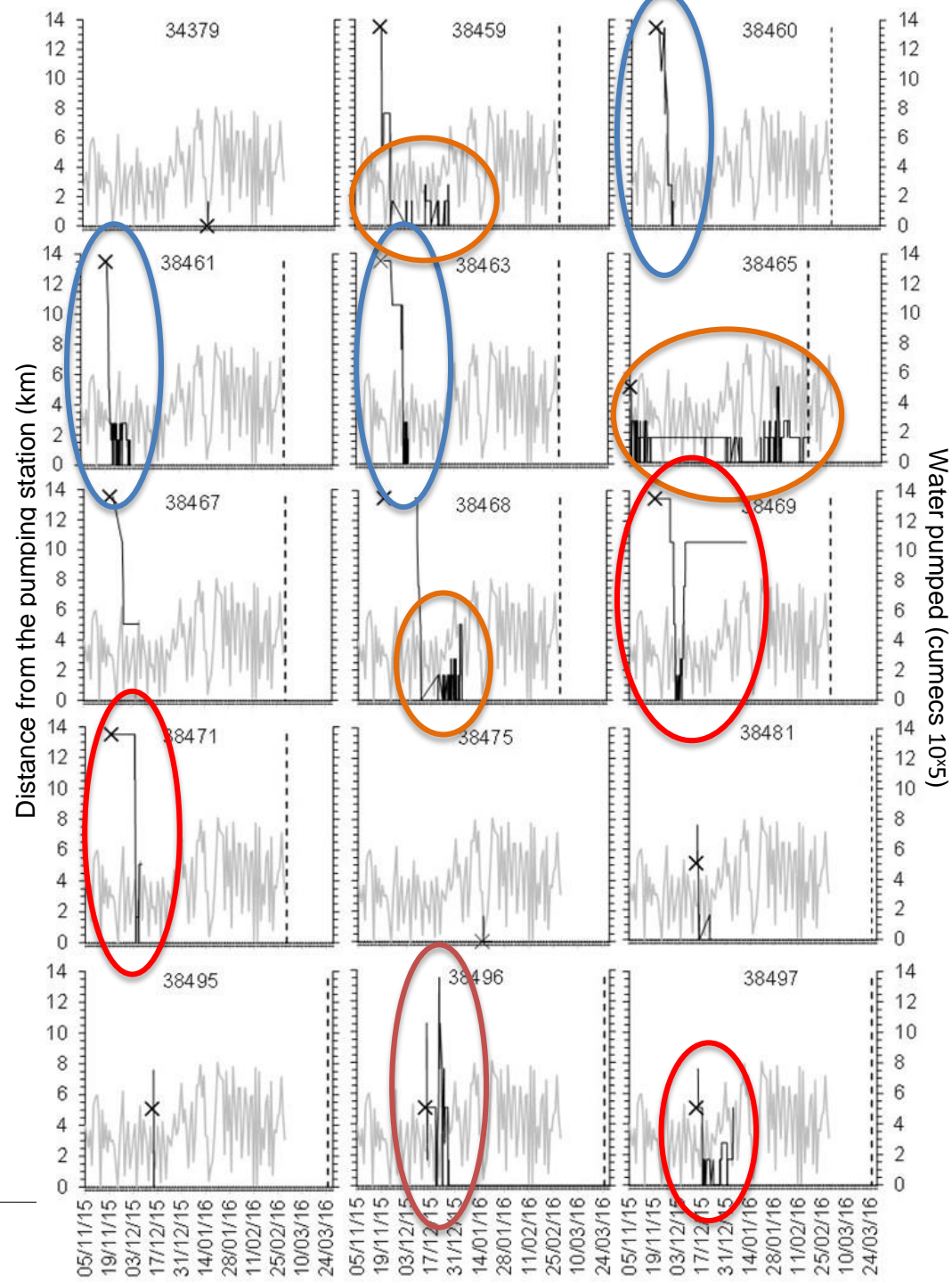
# 1. Catchment-wide migration; unregulated river



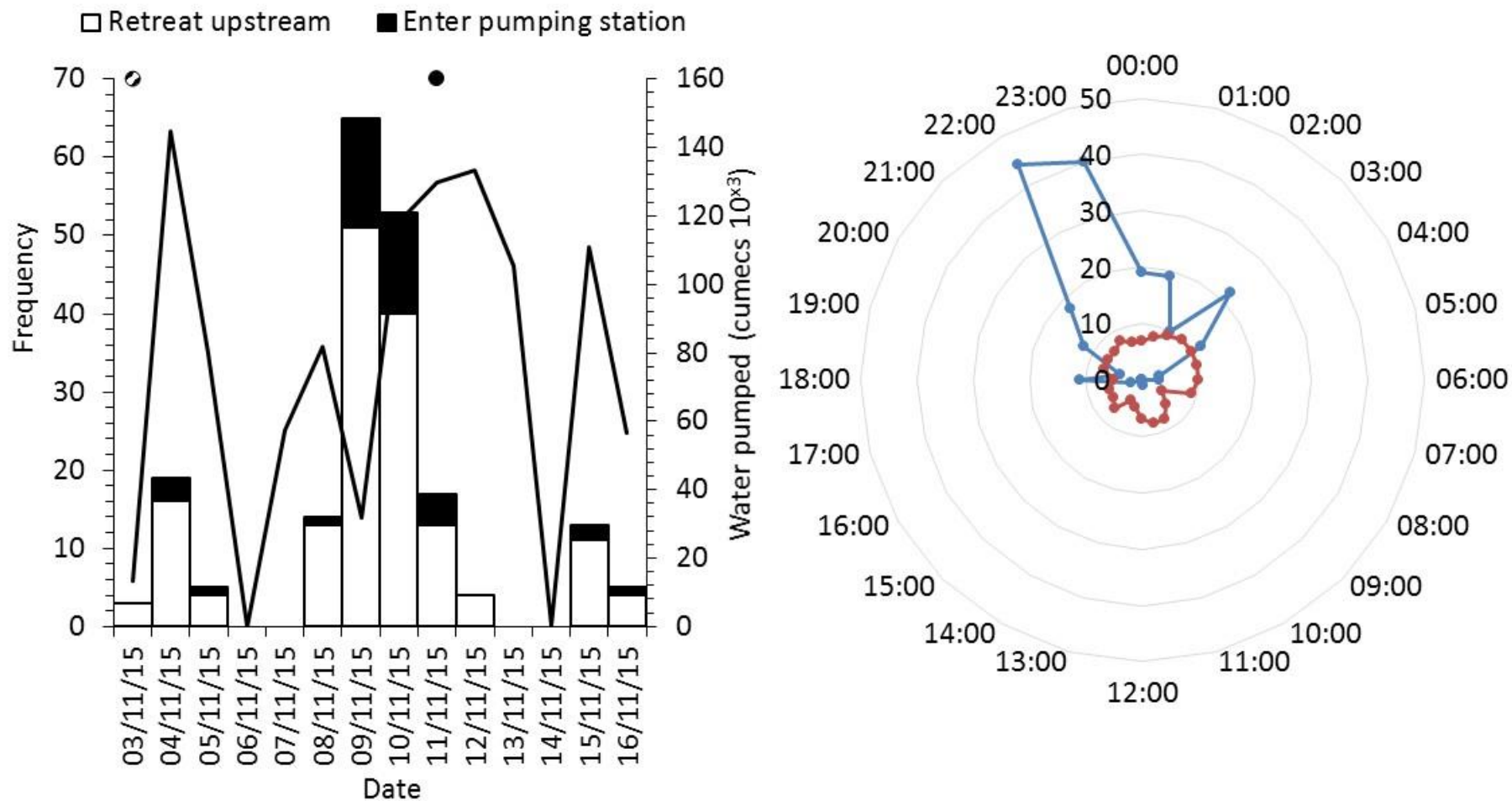


# 1. Catchment-wide migration; regulated by a pumping station

- Moved quickly through the catchment
- Delay:
  - Average = 10 days
  - Max = 33 days
- 14/15 (93%) retreated upstream:
  - Average distance = 4.2 km
  - Max distance = 13.5 km
- 6 eels last detected in middle of the catchment



## 2. Behaviour immediately upstream (ARIS footage)



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## Conclusions

- Mortality increased as pump size decreased and operational speed increased.
- The pumping station with a fish-friendly pump but original pipework killed four eels but there was the lowest overall impact on behaviour and external condition.
- Types of injuries observed being used to identify likely cause.
- Impact on downstream migration may be more detrimental than entrainment?
- Eels are reluctant to pass through weed screen, possibly leading to trails of alternative passage routes.
- Eels almost exclusively approach pumping stations at night, possibly leading to operational changes.

# Thanks for listening

Thank you to the Environment Agency, especially the team at the National Fish Lab, Internal Drainage Boards, Reuben Page and the commercial eel fishermen!



- Please see posters by Leona Murphy (#24) and Nicola Baker (#1) for more information about catchment-wide migration and behaviour immediately upstream of pumping stations