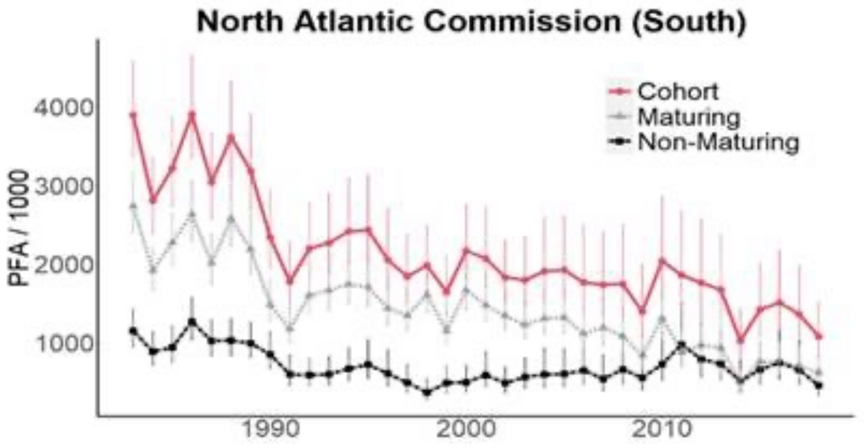
ON THE EDGE OF ABYSS: MODELLING THE MARINE MIGRATION OF ATLANTIC SALMON

Aislinn Borland
aislinn.borland@strath.ac.uk

Supervisors: Dr Neil Banas, Dr Colin Bull
Dr Douglas Speirs, Dr Alejandro Gallego

INVESTIGATING HIGH MORTALITY RATES

- Declines in Atlantic salmon populations may be attributed to decreasing marine survival rates (e.g. Friedland et al (2009), Pardo et al (2021))



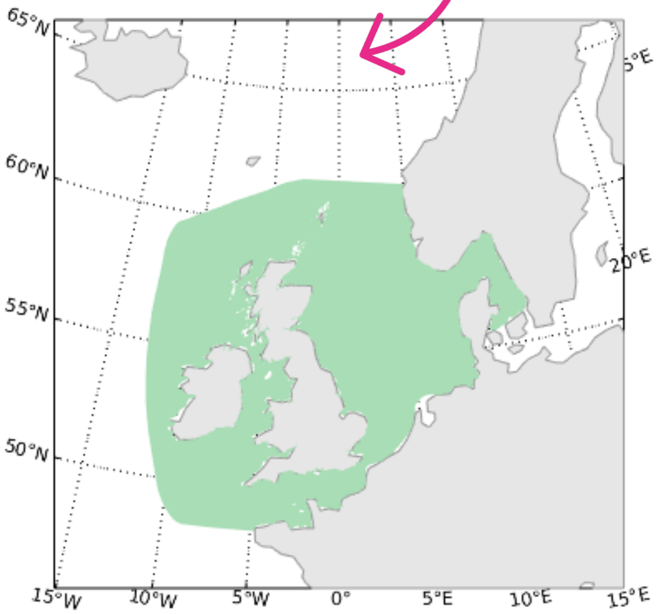
Pre-fishery abundances of Southern European salmon (ICES WGNAS reports)

- Low and variable survival probability following marine entry
- Narrowing the region of focus
- Investigating mechanisms behind high mortality rates

SMALL FISH ON BIG MIGRATIONS

- Migration to summer feeding grounds
- Thousands of kilometres migration for fish initially of length 120-140mm
- UK and Irish rivers, spatial extent of study
- How do migratory paths vary over time and with oceanographic conditions?
- Particle tracking model (ocean currents, diffusion, active movement)

Summer feeding grounds
(Gilbey et al 2021)

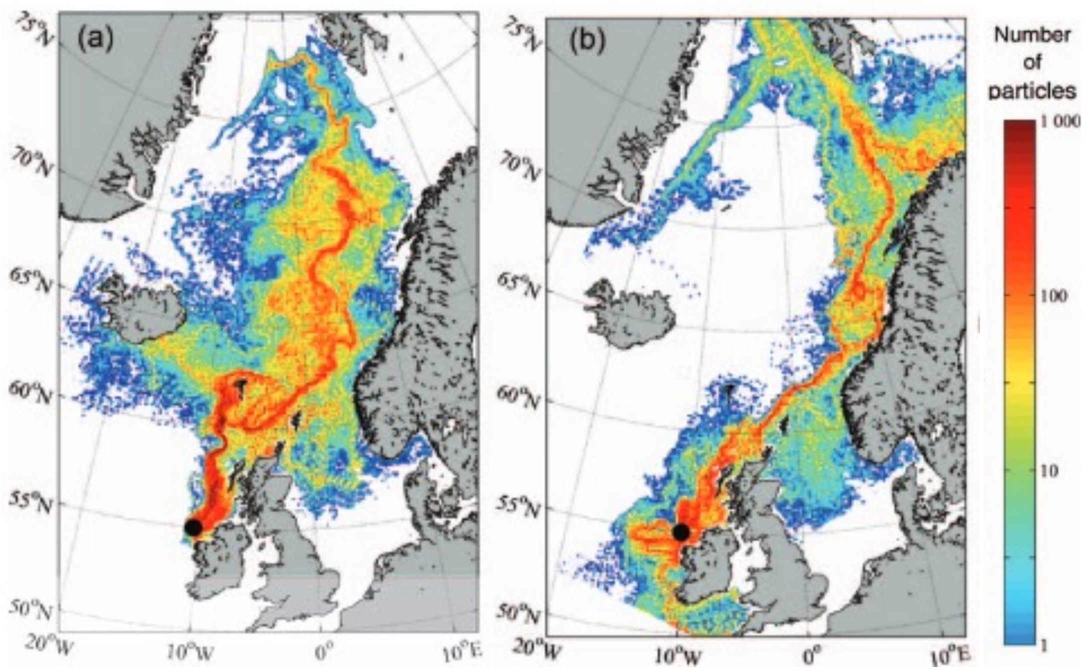


Spatial extent of study

An Atlantic salmon smolt
(https://ness.dsfb.org.uk/salmon-lifecycle/)

PREVIOUS PARTICLE TRACKING STUDIES

Ounsley et al (2019)



Mork et al (2012)

- Passive movement and current following
- Directed swimming
- One-year average climatology

- Current following behaviour
- 2002 and 2008

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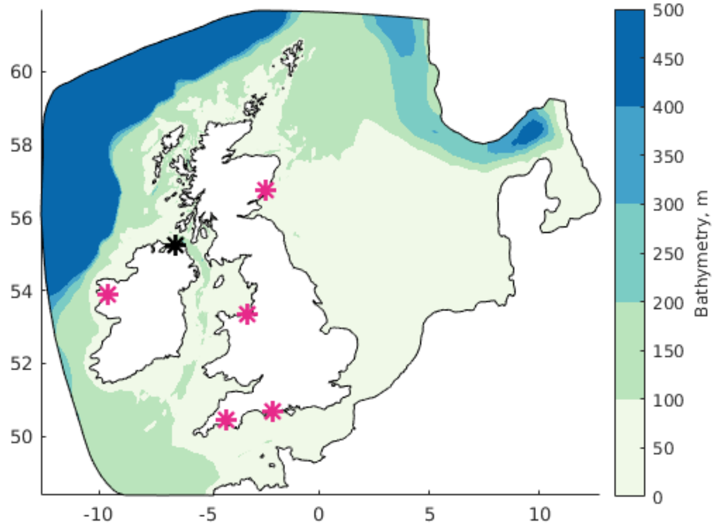
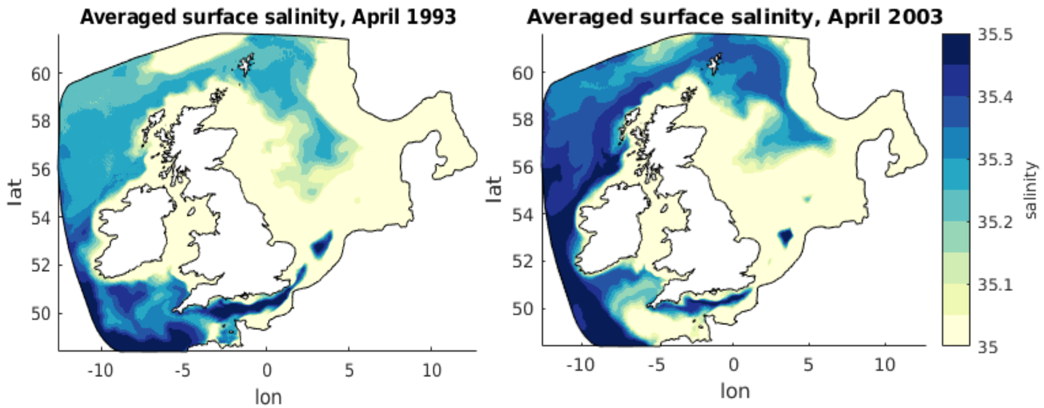
BUILDING ON THESE STUDIES

- Interannual variation in migrations
- Wider range of start points
- 27 year Scottish Shelf Waters Reanalysis Service (SSW-RS)
- Significant physical changes between years



SSW-RS bathymetry with ICES monitored salmon rivers, including the **Bush**

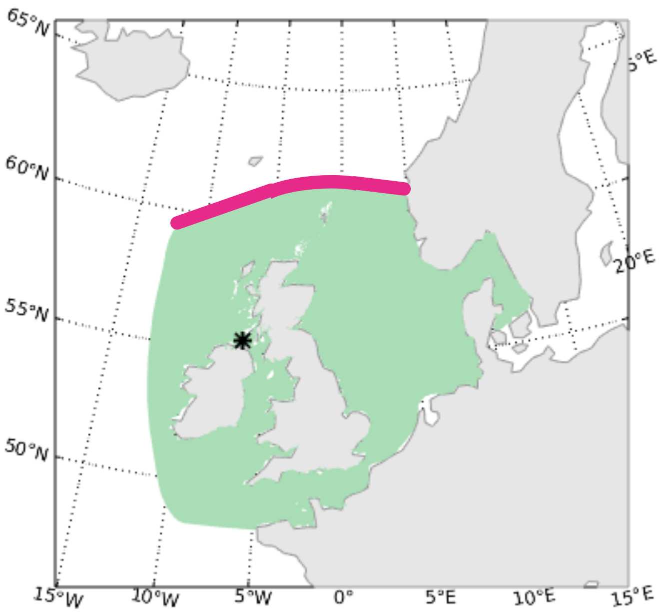


SSW-RS surface salinity in 1993 vs 2003 (averaged over two-week periods)

SSW-RS: https://sites.google.com/view/ssw-rs/home

MANY POSSIBILITIES FOR MODELLING SWIMMING BEHAVIOURS

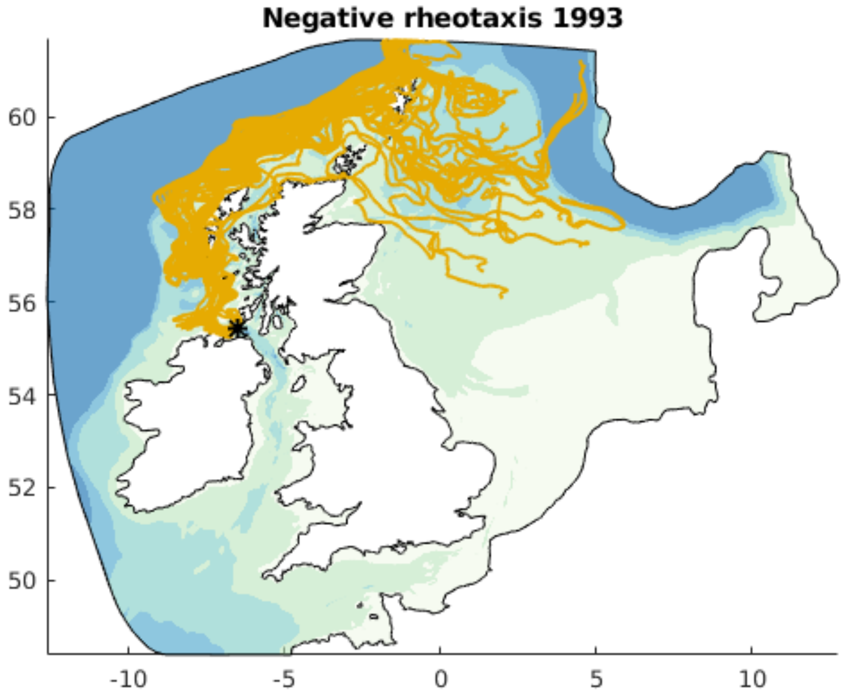
- Basis: passive movement + diffusion
- Negative rheotaxis
- Directed swimming
- Environmental variable gradients
  - Depth, salinity, temperature
- Combinations of these behaviours
- Successful – exiting study region



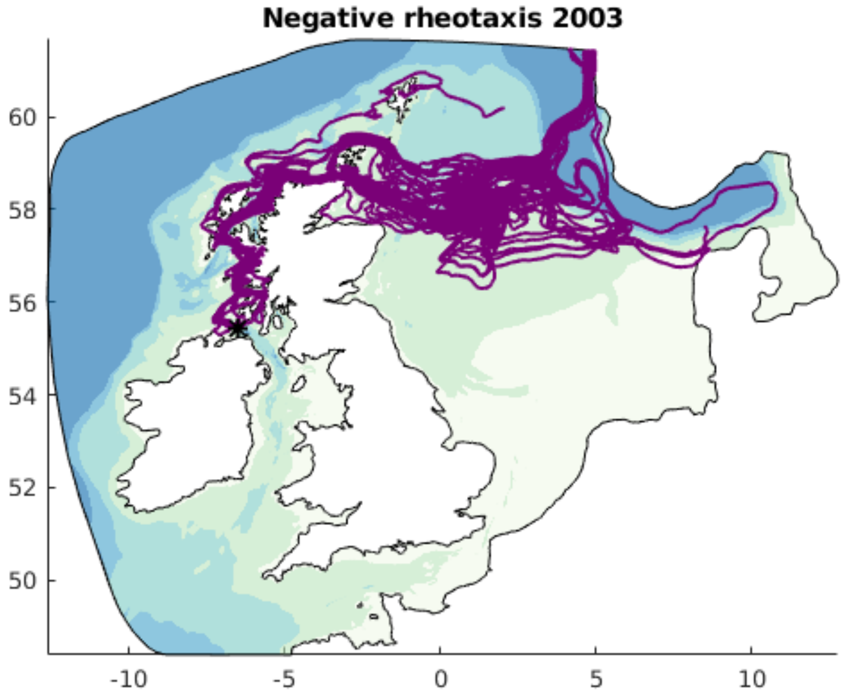
SSW-RS bathymetry with exit region

DIFFUSION + PASSIVE TRANSPORT + NEGATIVE RHEOTAXIS

- Inspired by Mork et al (2012)
- Actively swimming in the direction of local currents

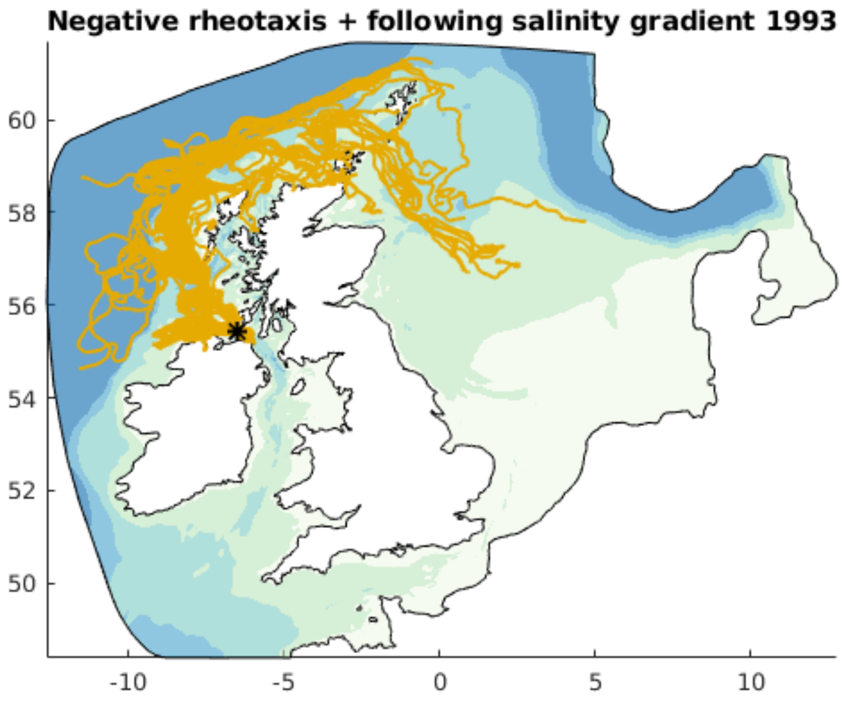


1993



2003

DIFFUSION + PASSIVE TRANSPORT + NEGATIVE RHEOTAXIS + SALINITY GRADIENT FOLLOWING



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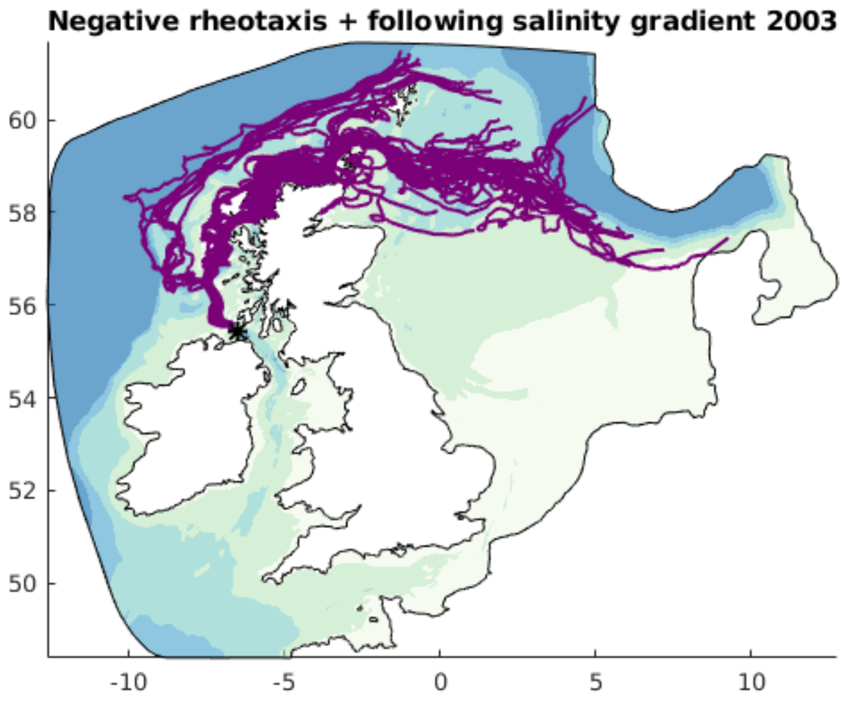
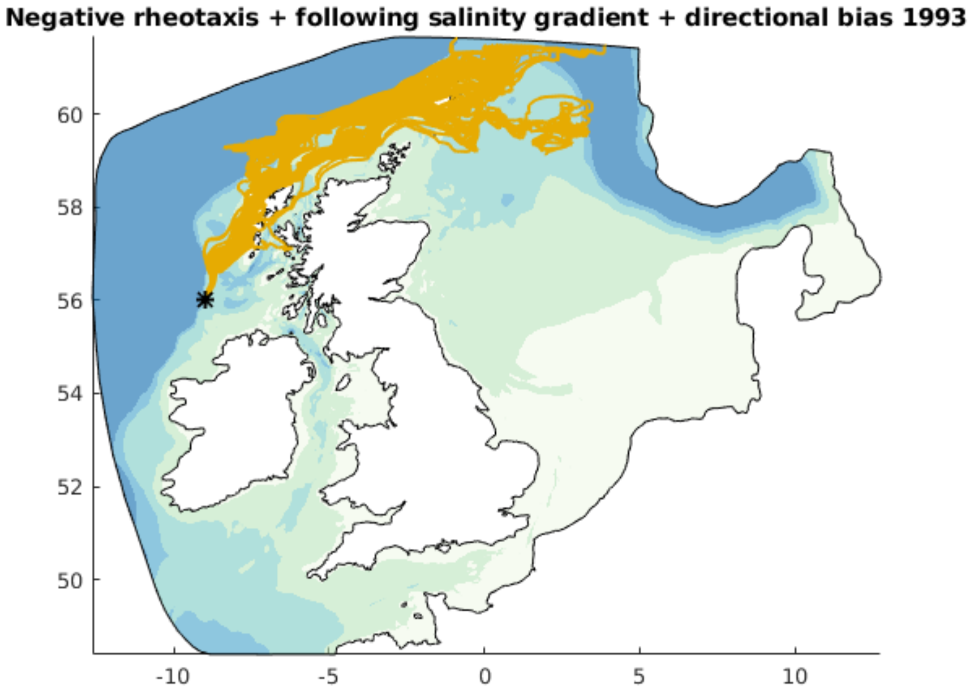


2003

ADDING A DIRECTIONAL BIAS

- Inspired by Ounsley et al (2020)
- Bias movement in preferred direction
- Only following currents which are favourably directed
- Prevent particles from leaving the shelf-edge current
- Implemented through a "restoring force" if movement would otherwise be in the wrong direction
- Magnitude of this force varies
- Added at transition point representing shelf-edge

DIFFUSION + PASSIVE TRANSPORT + NEGATIVE RHEOTAXIS + SALINITY GRADIENT FOLLOWING + DIRECTIONAL BIAS



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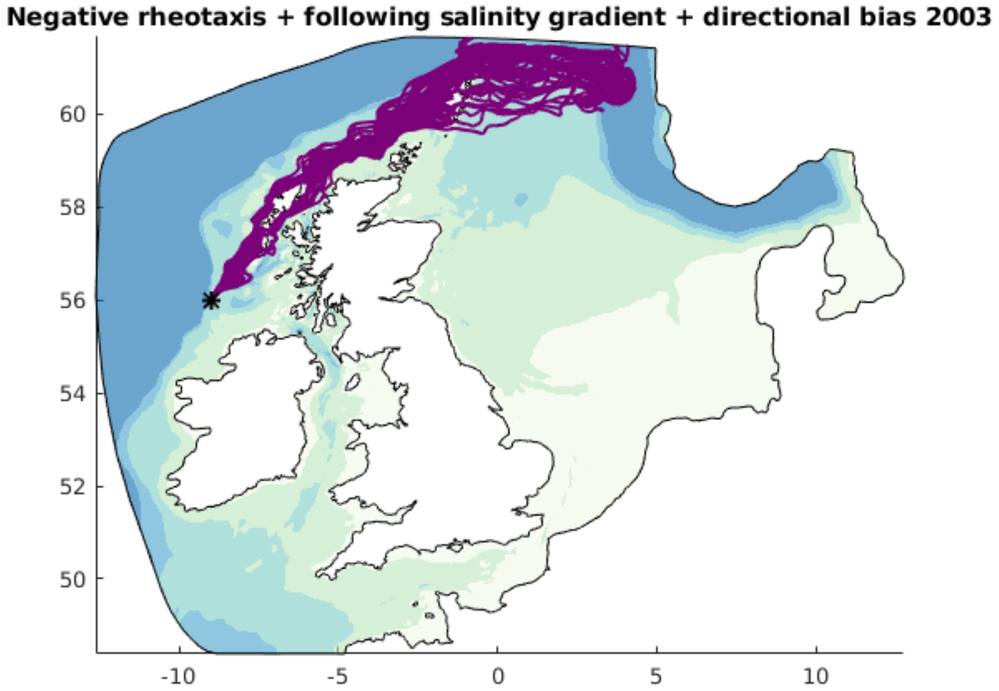

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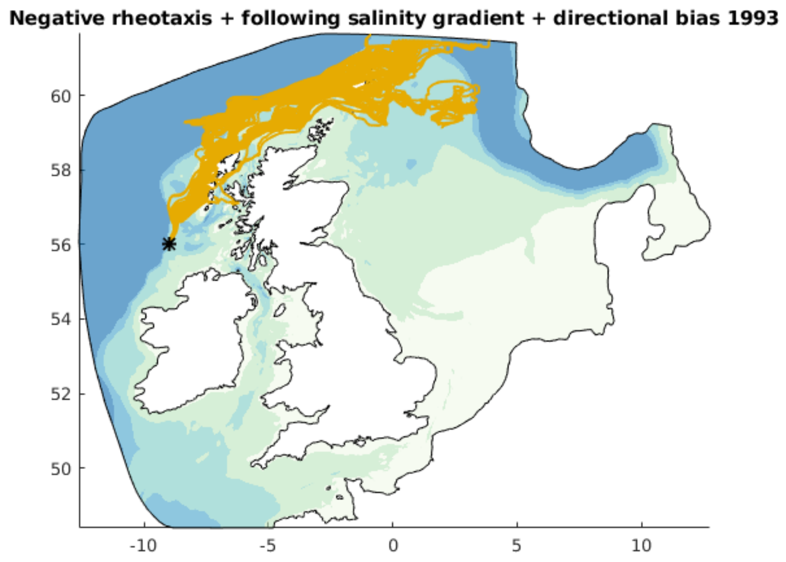
WHAT ARE THE IMPLICATIONS?

- Success rates (exiting study region within 100 days): **87%** vs **89%**
- Mean time taken: **70 days** vs **52 days**
- Mean progression rates: **16.2km/day** vs **19.4km/day**
- Time in shallow (<100m) water: **30.2%** vs **40.2%**
- Prey fields, predators, fishing activity



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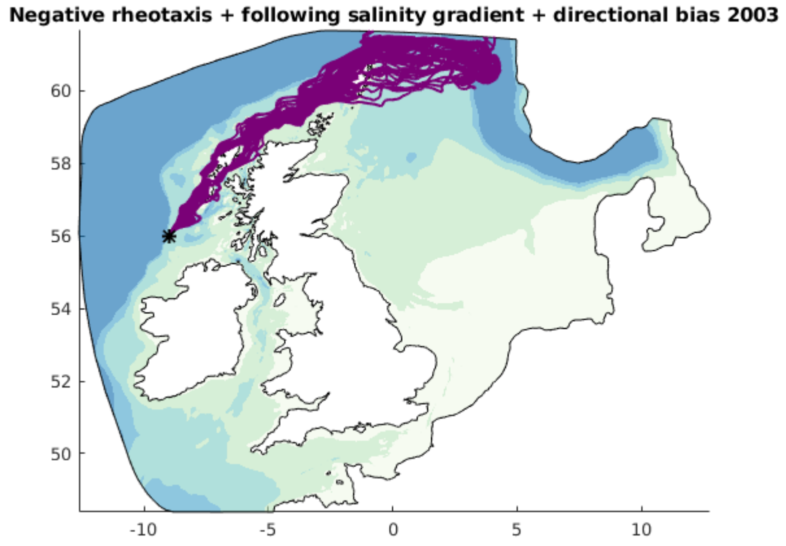

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CONCLUSION & FUTURE WORK

- Negative rheotaxis + following a salinity gradient + addition of a directional component at shelf-edge
- Significant differences in conditions experienced between years
- Extending to other monitored salmon rivers across the UK and Ireland, investigating timing of river emigration
- Investigation of interannual variation (1993-2019) - what conditions are linked to changes in migrations?

Email: aislinn.borland@strath.ac.uk Twitter: @AislinnBorland

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University of Strathclyde Glasgow

Aislinn Borland

aislinn.borland@strath.ac.uk

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