Evaluating factors affecting the distribution and timing of Pacific Herring spawn in British Columbia

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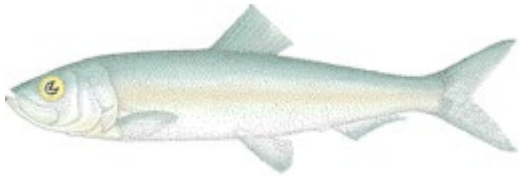


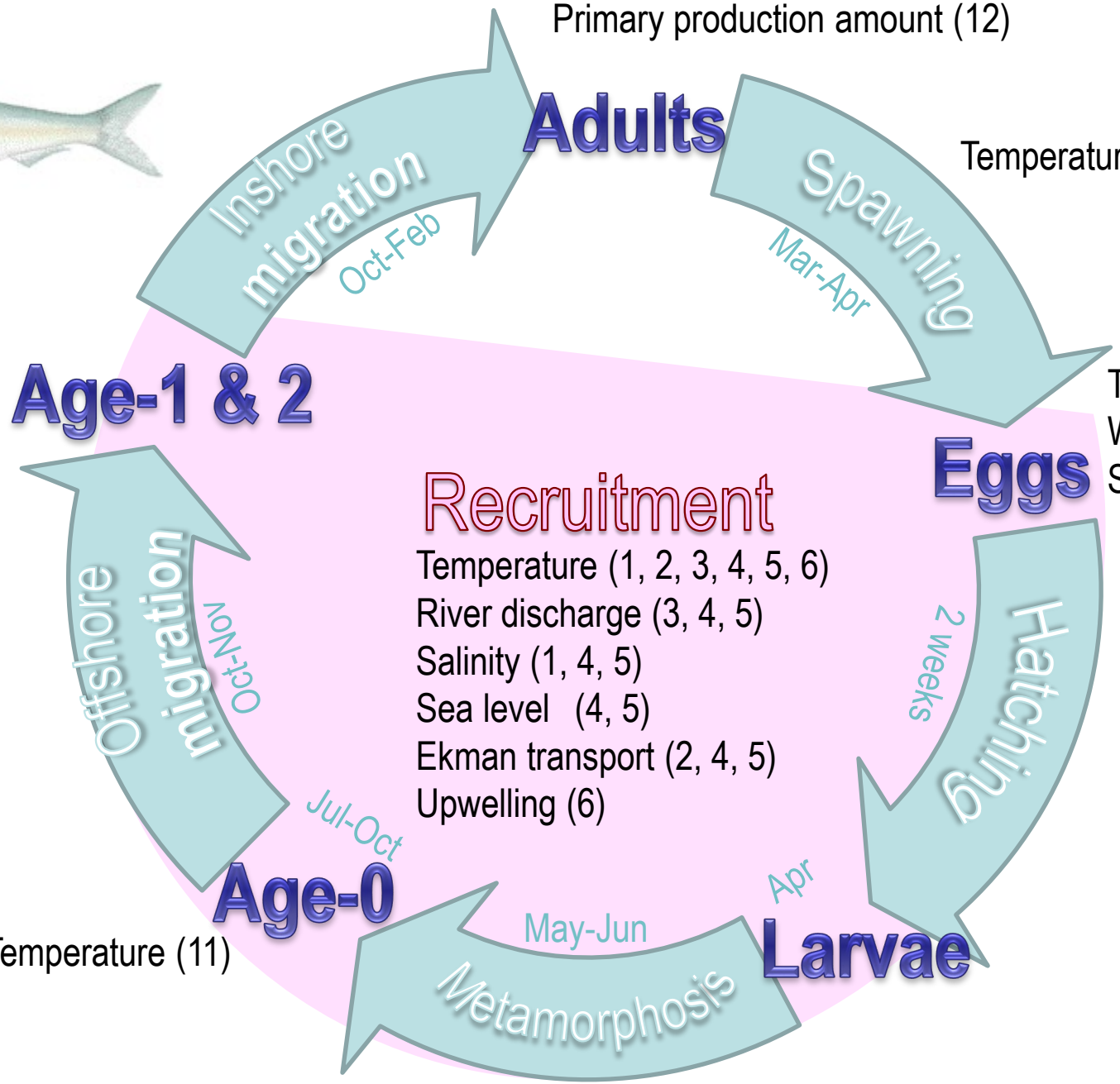
Primary production amount (12)

Temperature (10, 13)

Temperature (10)
Water movement (9)
Salinity (9)

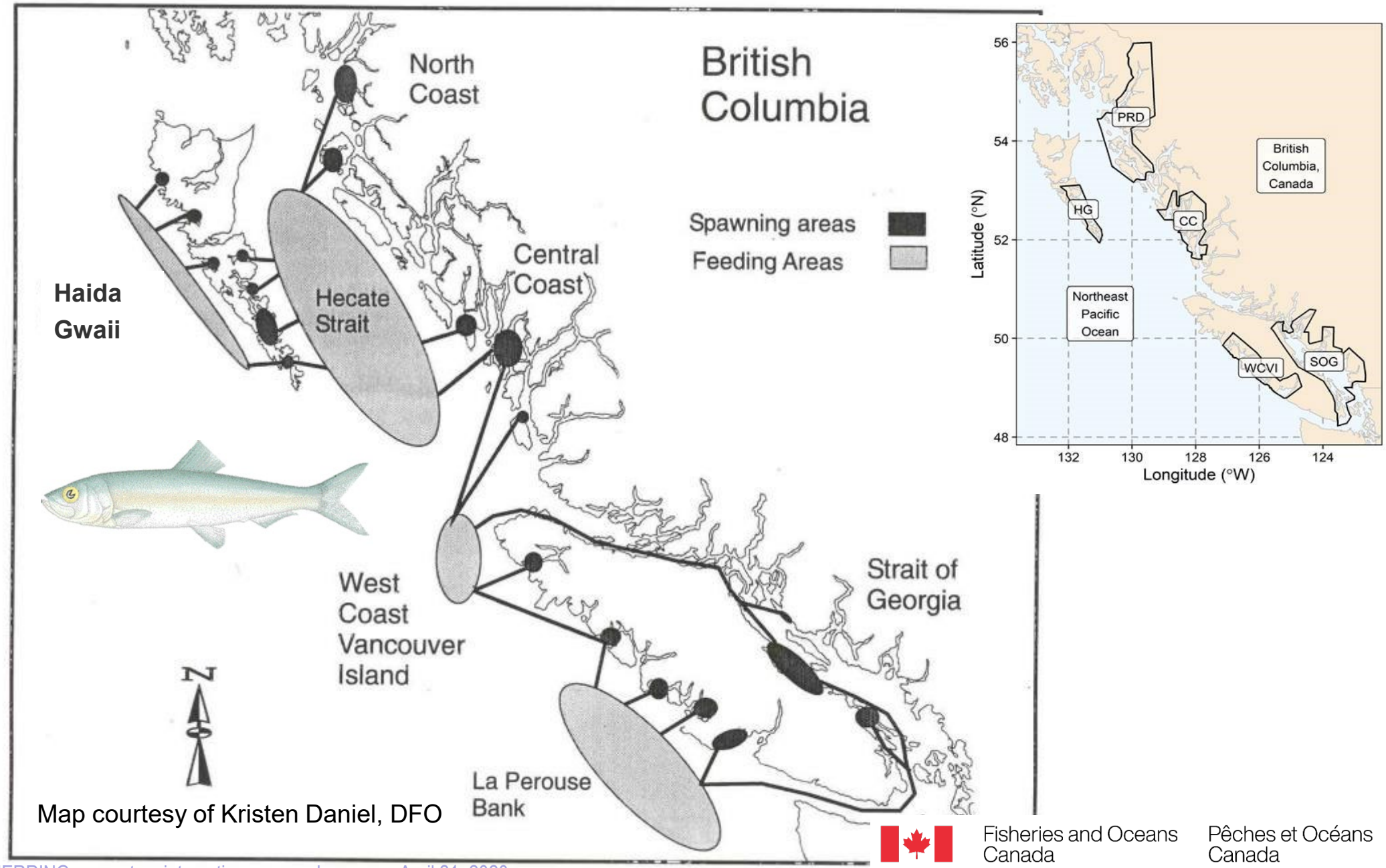
Primary production timing (7)

Temperature (11)



	Publication
1	Dreyfus-Leon and Schweigert 2008
2	Zebdi and Collie 1995
3	Stocker et al. 1985
4	Stocker and Noakes 1988
5	Schweigert and Noakes 1990
6	Williams and Quinn 2000
7	Schweigert et al. 2013
8	Ramey and Wickett 1973
9	Alderdice and Hourston 1985
10	Tanasichuk and Ware 1987
11	Tanasichuk 1997
12	Perry and Schweigert 2008
13	Hay and Kronlund 1987
14	Ware and Thomas 2005

Pacific Herring summer feeding & winter spawning



Map courtesy of Kristen Daniel, DFO

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Does the environment determine when and where spawning occurs in each year?

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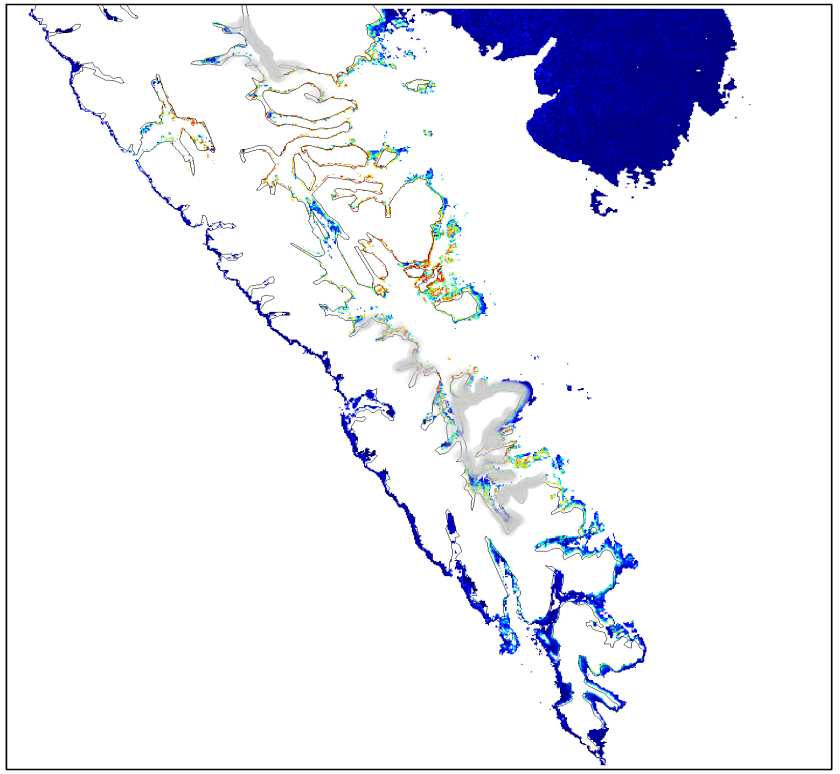

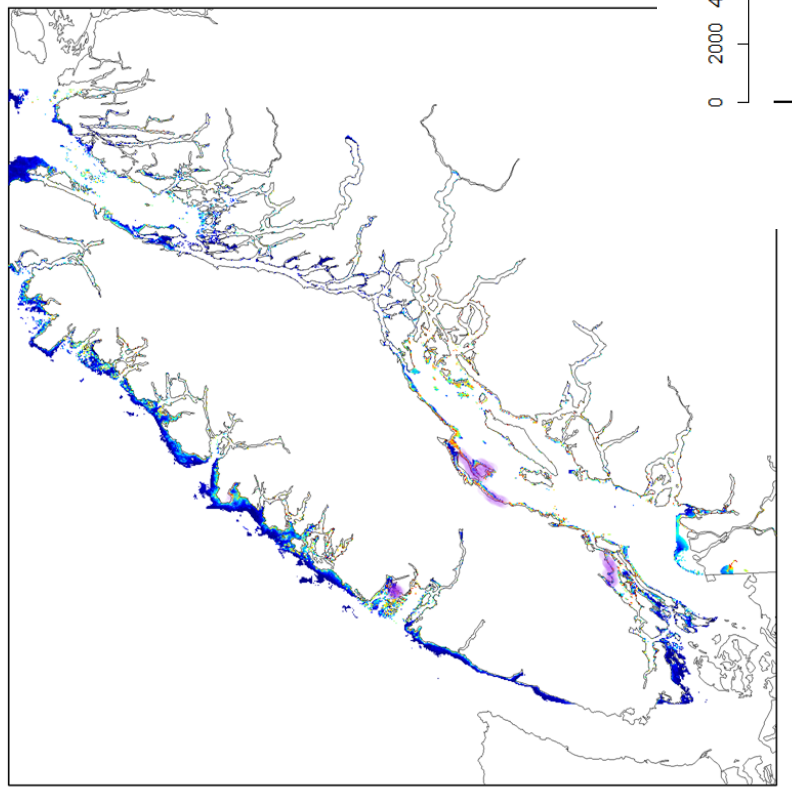

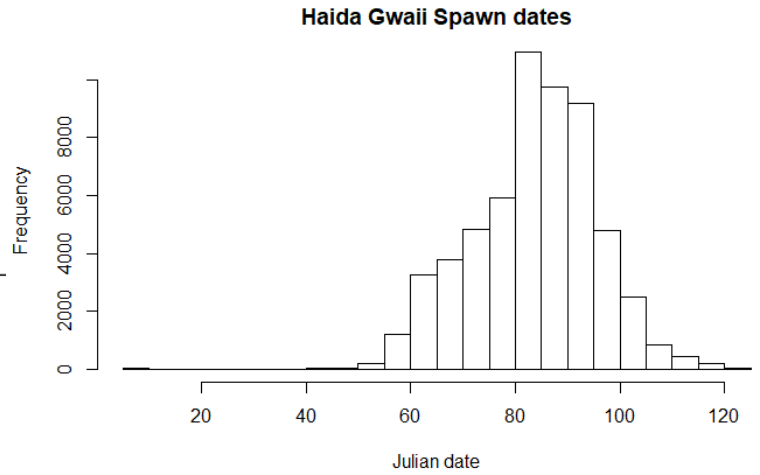

Objectives

1) Model the relationships between oceanographic variables and the timing of spawn deposition (1988-2018)

2) Model the relationship between the realized distribution of spawn deposition and the physical and biological characters of the habitat

3) Given these results, anticipate potential changes in realized spawn timing and distribution relative to ocean warming in future years .

Spawn Survey Data

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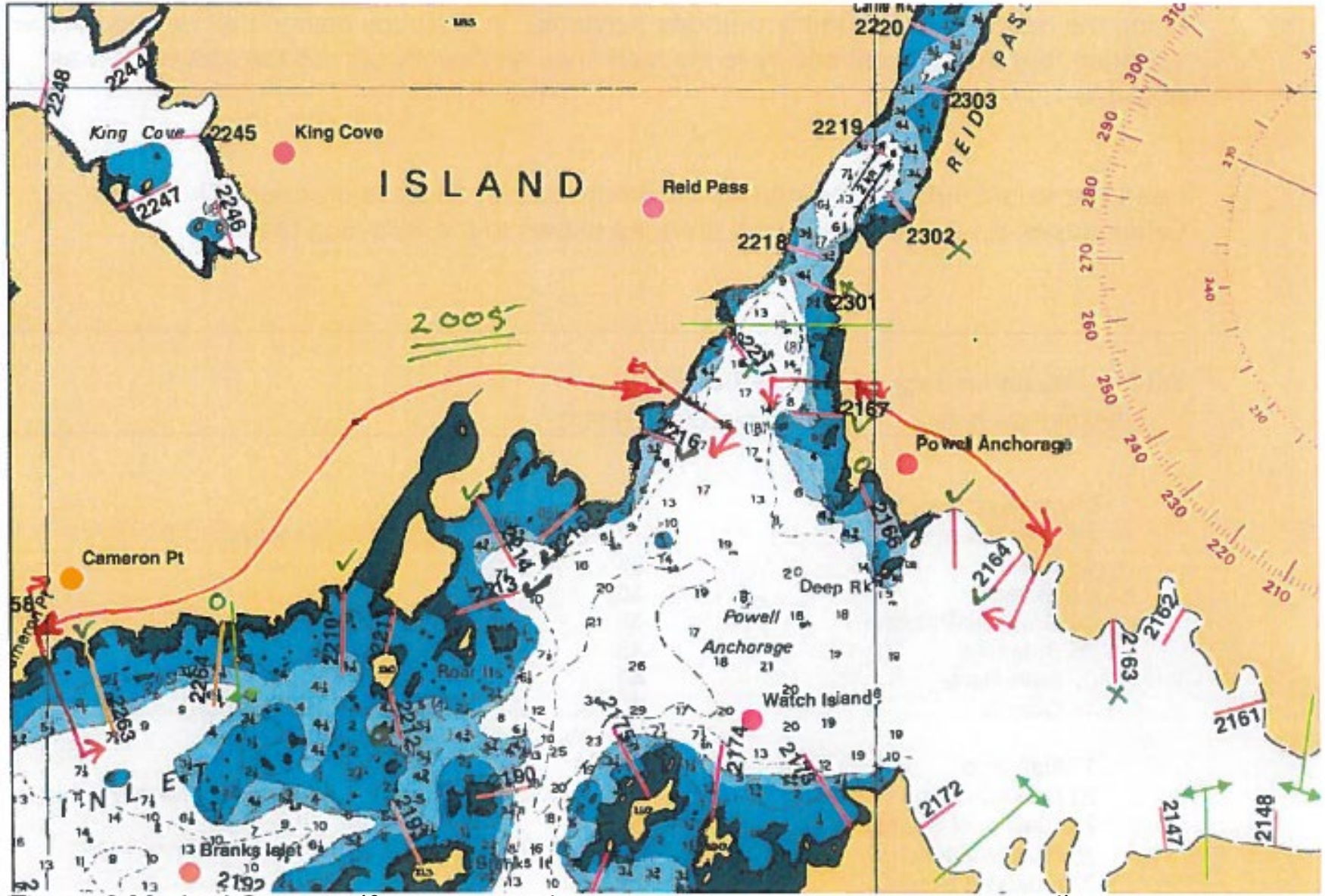


Figure 2 Marked Spawns (from Fort et al. 2013 – Herring Spawn Survey Manual)

Details/Methods

Mapped spawn events (aerial, vessel based)

Locations, transects, quadrats

350 m spacing

Transects represent historical presence

Scaled up to biomass estimate

Spawn timing – Environmental variables

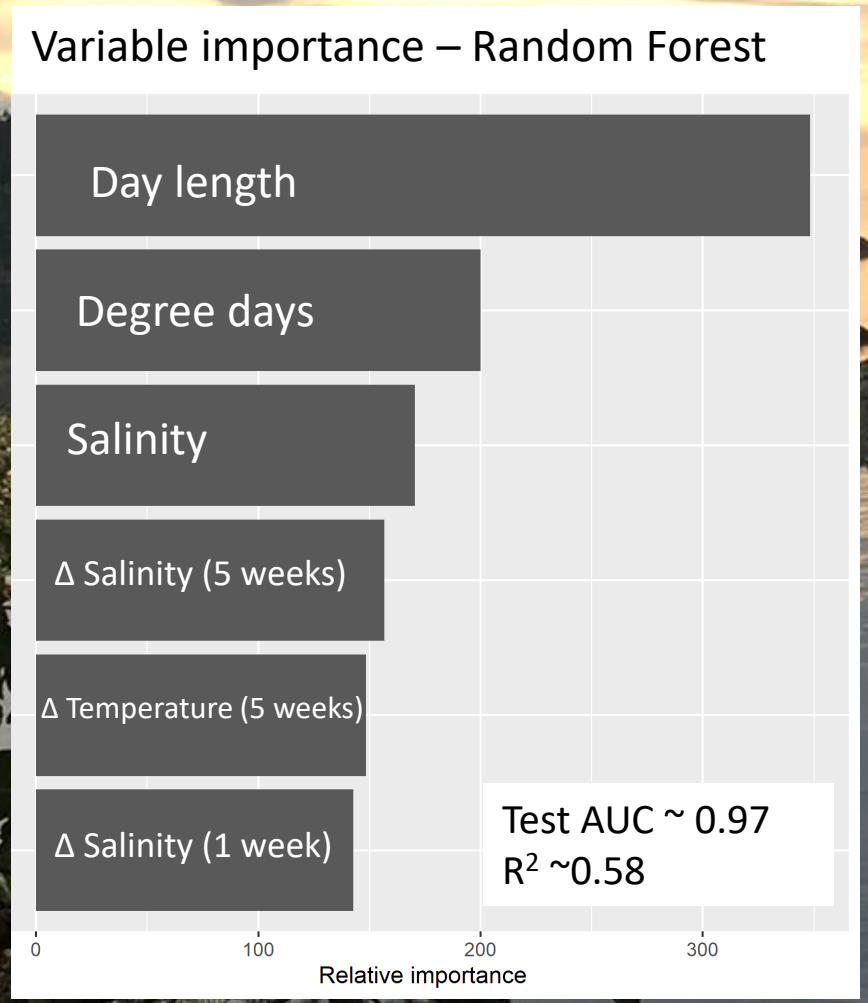
- Length of day (genetic evidence – Petrou et al. 2021)
- Degree days over 5° C (egg development – Alderdice & Velsen 1971, Hay 1985)
- Rate of warming (slope of temperature change in last week and five weeks – Allen et al. 2013)
- Rate of freshwater input (slope of salinity change in last week and five weeks – Allen et al. 2013)
- Temperature on date of spawn
- Salinity on date of spawn
- Current speed at time of spawning

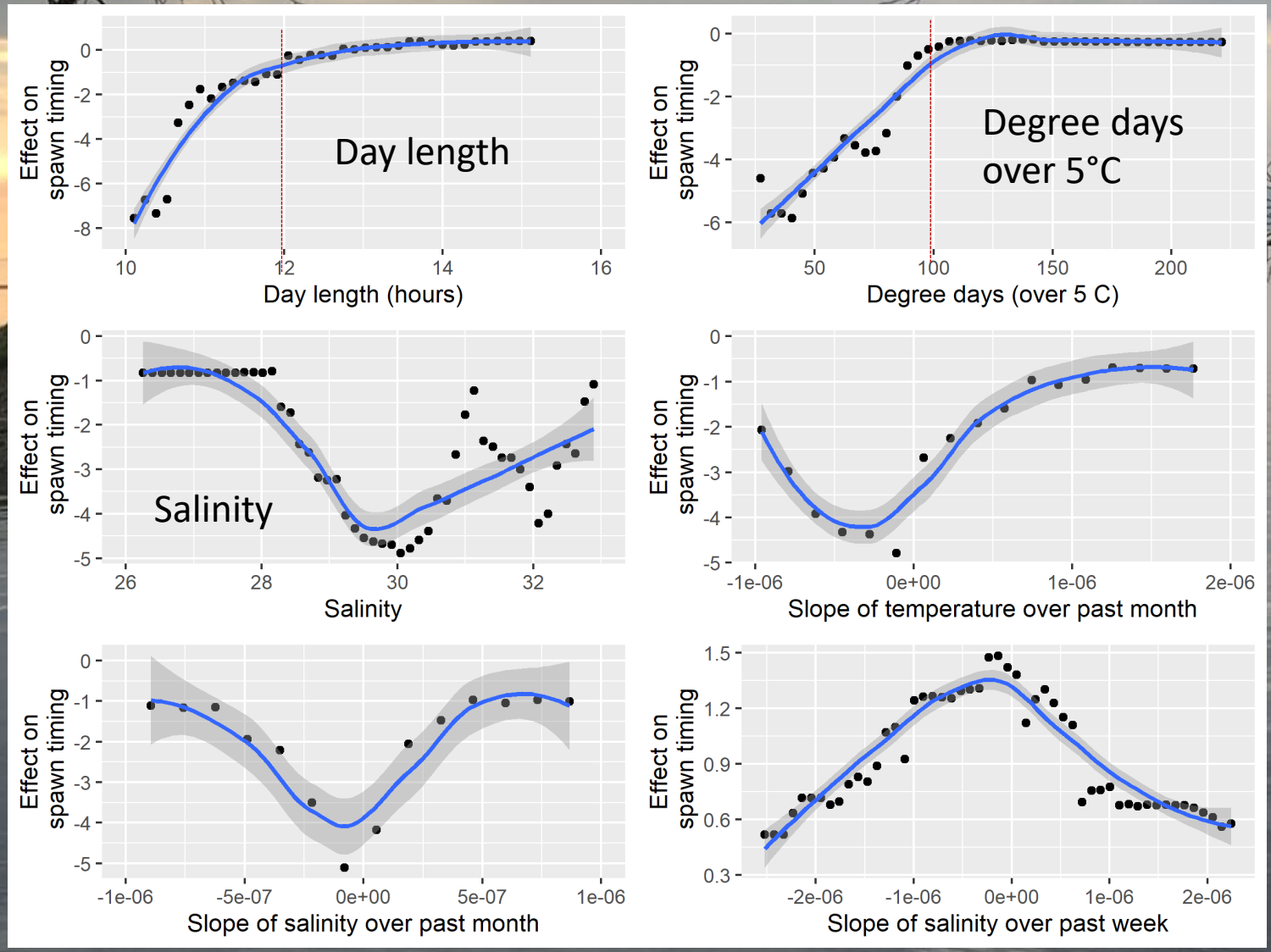
Predicting spawn timing - Data

- n = 4,987 locations with spawn (spawning events by date)
- Generated absences on weekly basis for previous 5 weeks (n = 226K)
- ROMS model outputs for temperature, salinity and currents (3 day intervals, 3 km resolution)
- Random forest model

  Time ~ degree days + slope of temperature and salinity (1 week and 5 weeks prior) + day length + temperature + salinity + current speed
- Variable importance testing using permutation
- Cross validation (by stock and leave out 5 year blocks)

Spawn timing - Environmental relationships





Spawn distribution – Environmental variables

- Physical features of the transect
  - Slope of bathymetry
  - Ruggedness (VRM)
  - Topographic position index
  - Fetch (distance over which wind/waves can build)
- Oceanographic conditions at time of spawning
  - Current speed
  - Alignment relative to current direction
  - Temperature
  - Salinity
- Distance to geographic center of historical spawning
- Biomass of adult herring (standardized across stocks)

Predicting spawn distribution – Data

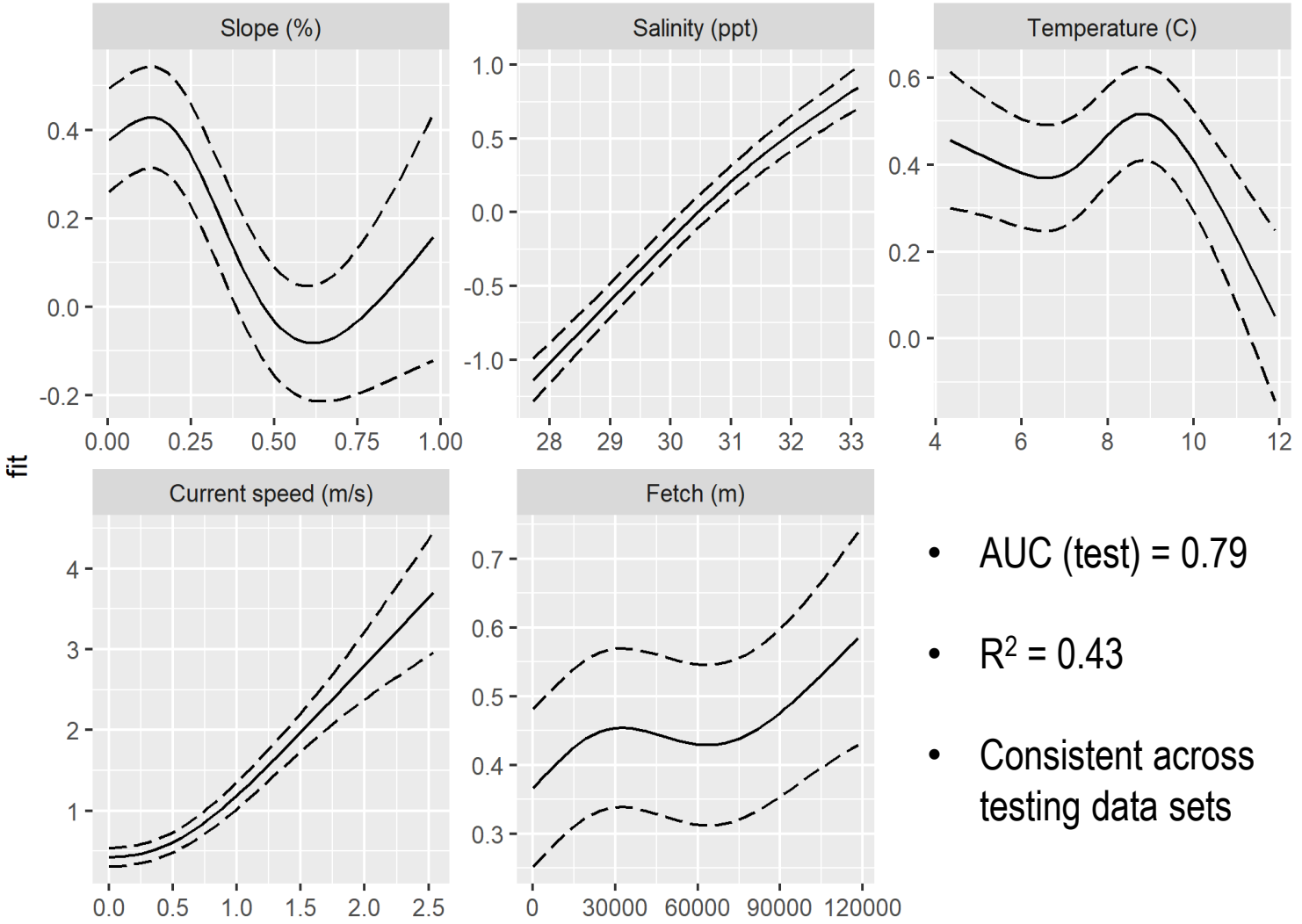
- n = 3,851 transects by 31 years (presence or absence)
- ROMS model outputs for temperature, salinity and currents (3 day intervals, 3 km resolution)
- General additive model (GAM)

$$\text{Presence} \sim \text{temperature} + \text{salinity} + \text{slope} + \text{VRM} + \text{TPI} + \text{fetch} + \text{alignment} + \text{current speed} + \text{biomass anomaly} + \text{distance from center of spawning} + \text{biomass anomaly} * \text{distance from center of spawning} + \varepsilon$$

- Backwards stepwise elimination
- Cross validation (by stock and 5-fold)

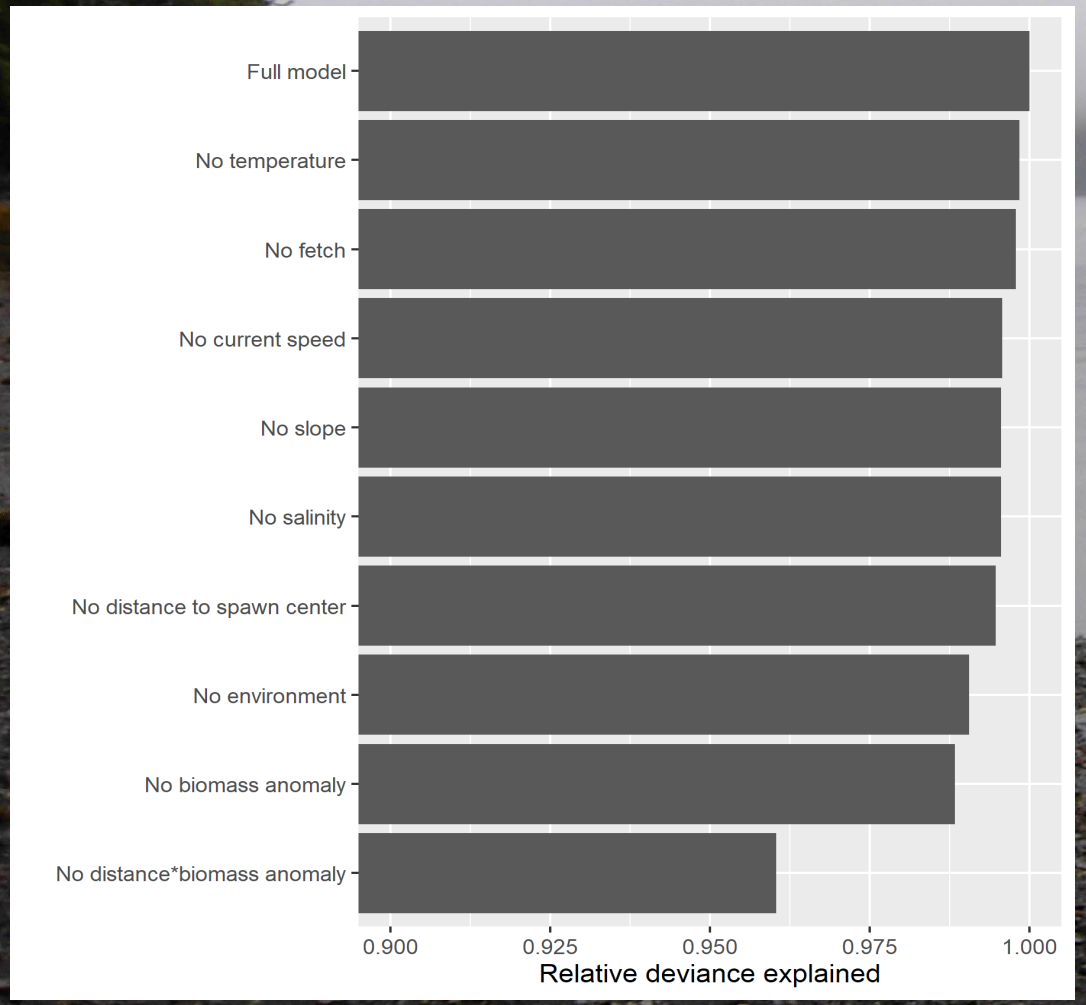
Spawn distribution – Environmental relationships

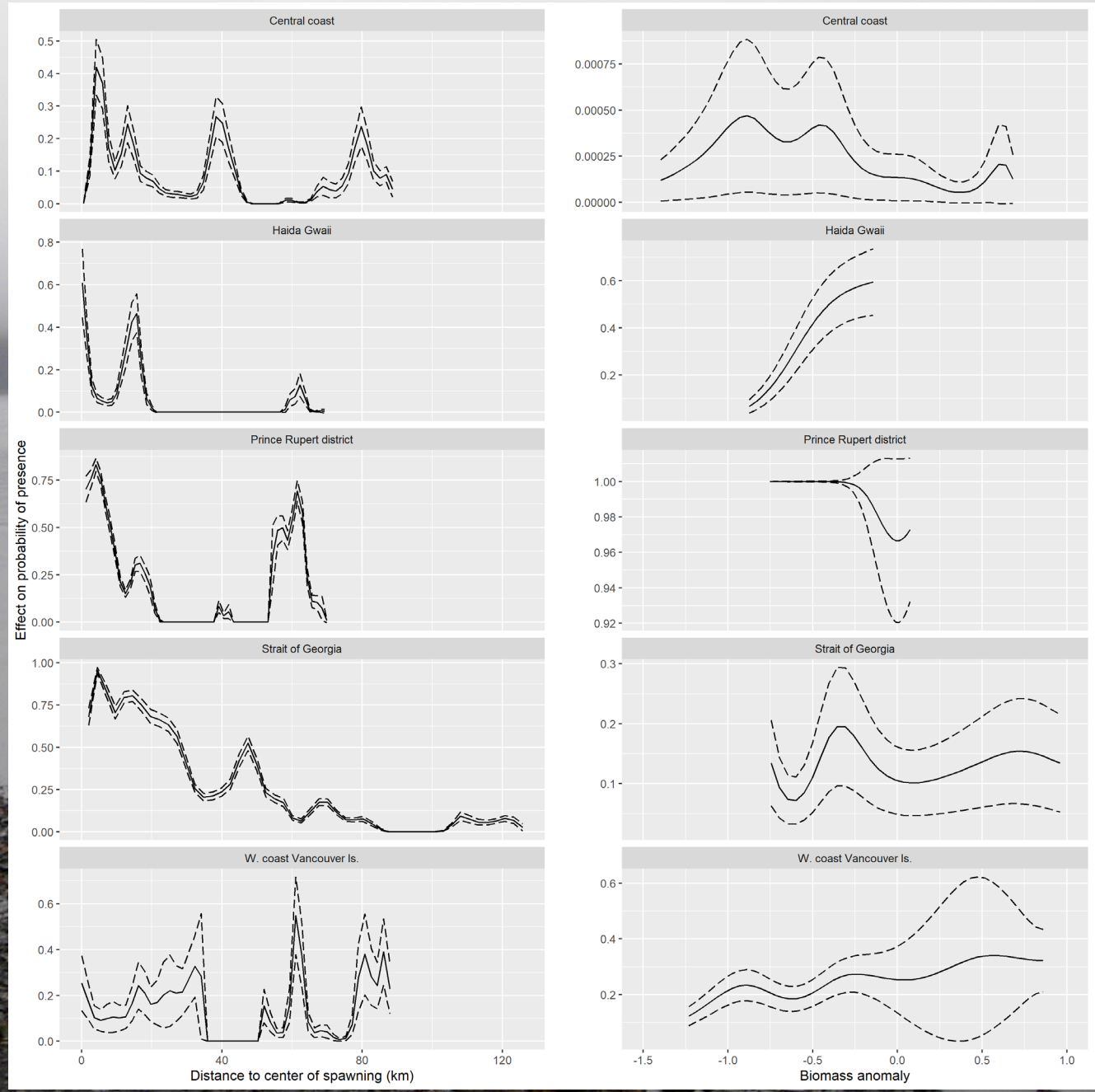
- Model terms explain about 20% of the deviance in realized spawn distribution
- Very different results among stocks



- AUC (test) = 0.79
- R^2 = 0.43
- Consistent across testing data sets

Spawn distribution – Environmental relationships



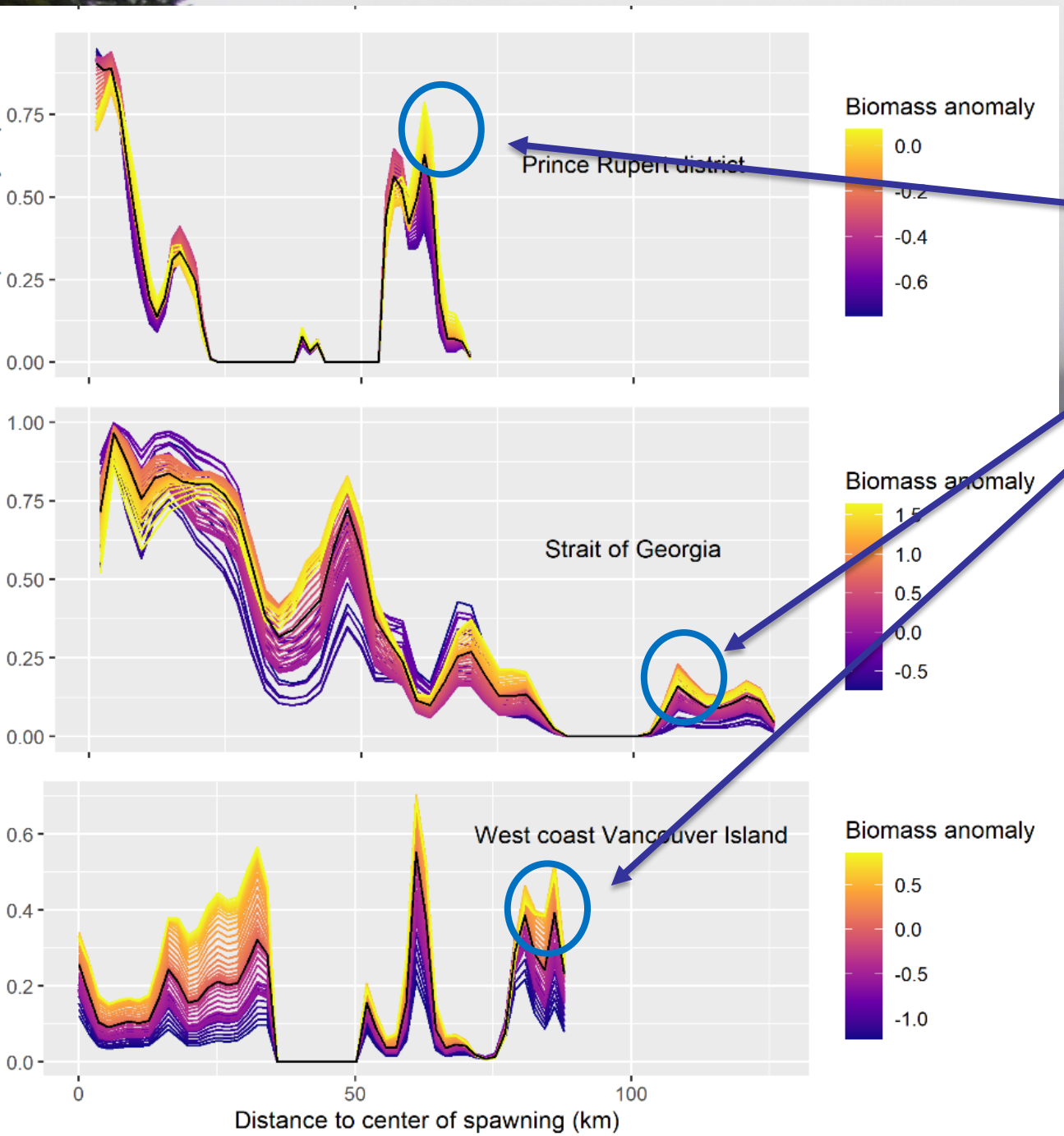


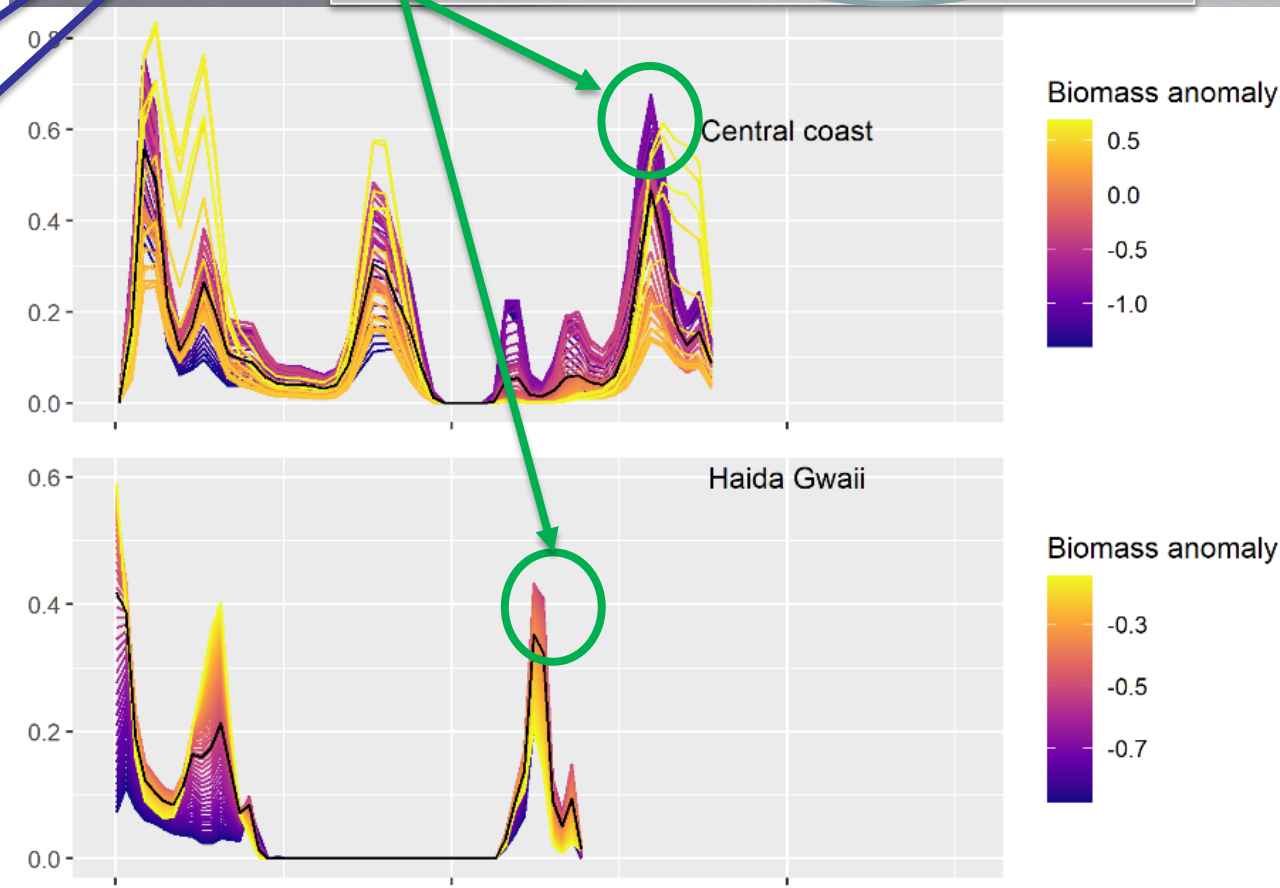
Spawn distribution – Evidence for basin effect?

Yes

Maybe? ☹

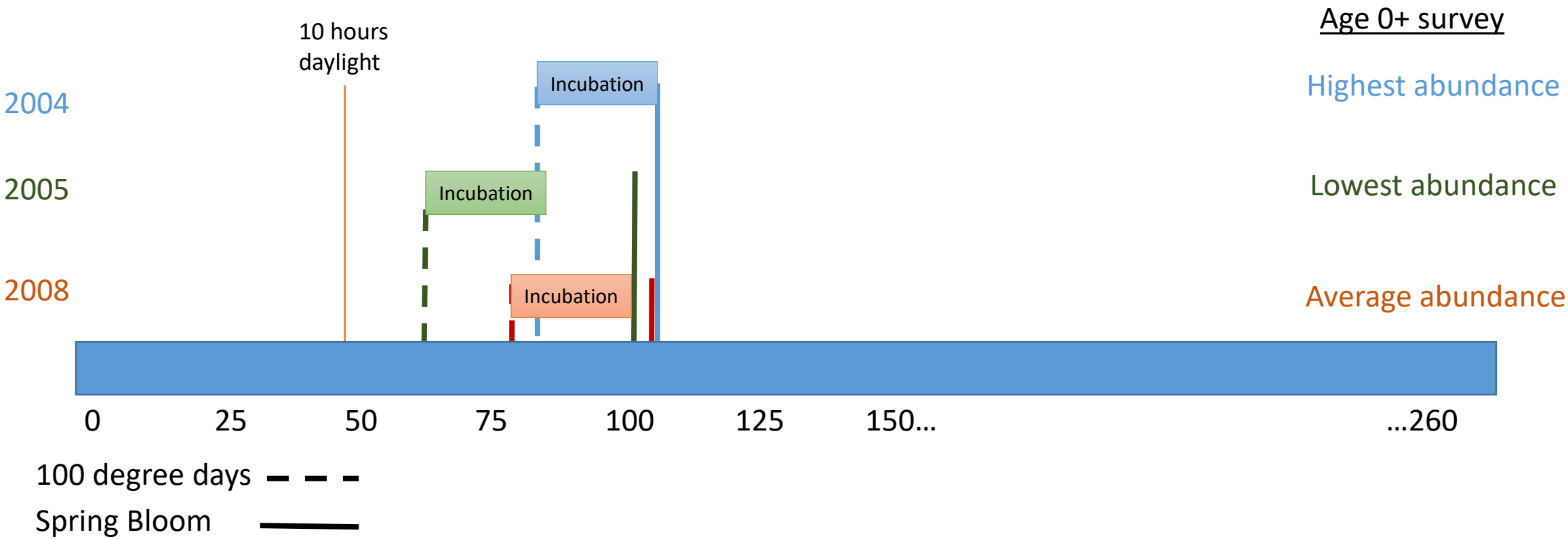
No





Implications for Pacific herring spawning in BC

Optimum time between spawning and spring bloom = 20 days (Boldt et al. 2018)



Future Work

- Climate forecasts to try to make some forecasts?
- More spatial model exploration
- More model validation work to be completed
- Need to address the minor stocks as well

Summary

- Spawn time very linked to processes around match-mismatch with spring bloom
  - Genetic and developmental basis
- Location of spawning, consistent across years
  - Perhaps less driven by environmental variables at the site
  - Spawning habitat (at least the physical features) is unlimited
- The seasonal progression of temperature and salinity patterns need to continue to temporally align to promote a match between herring spawning and prey

Acknowledgements

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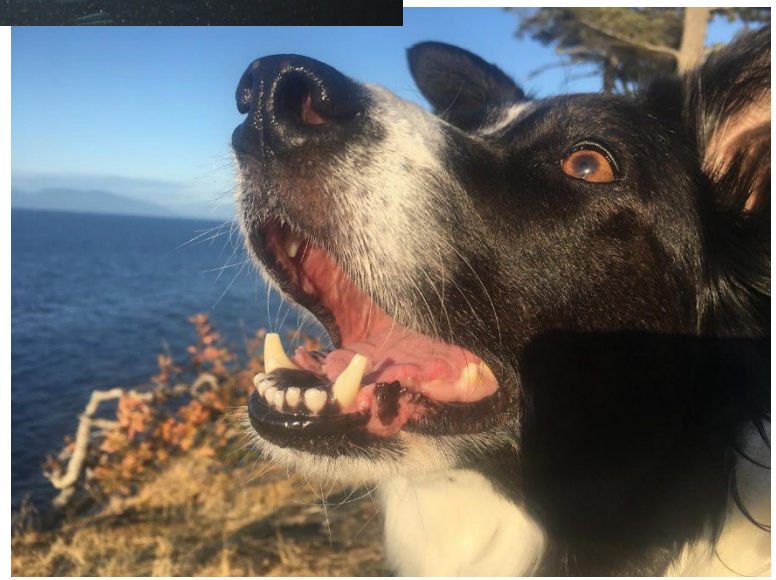
- 3 anonymous reviewers



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