Apr 5th, 2:30 PM - 2:45 PM

Big Sharks in the Salish Sea: combining passive acoustics with the Salish Sea model to predict Sixgill Shark (Hexanchus griseus) presence

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Deep Data

Modeling Sixgill Shark (*Hexanchus griseus*) Movements

Alli N. Cramer
Dr. Steve Katz, Kelly Andrews, Dr. Daniel H. Thornton

@AlliNCramer #SalishSeaSharks

Photo credit: NOAA 2016 http://fishesofaustralia.net.au/Images/Image/HexanchGriseusNOAA.jpg, Modified through cropping and flipping by Alli Cramer

For ecology, movement is important

- Animal movements impact connectivity
  - Within populations
  - Between communities
- Predator movements alter ecosystem structure
- Knowing where animals are likely to be helps develop effective management

Photo credit: NOAA Ocean Explorer 2016 https://www.flickr.com/photos/27077560@N05/26688971116/. Modified through cropping by Alli Cramer.

The Technical Problem…

- What we want: estimates of probabilities for animal locations in time and space
- What we get: each technology has unique impact on the data used for those estimates.

How do we get from here to there?

How do we get from here to there?

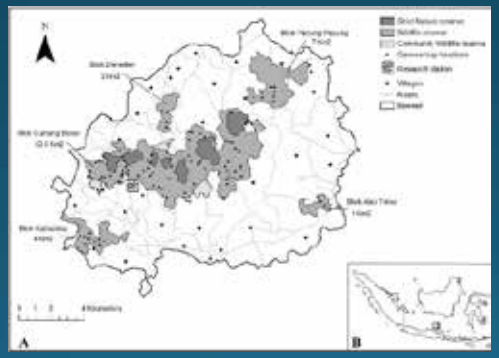
			Data Properties
GPS TRACKING			Individual determinant Continuous in time and space
WILDLIFE CAMERAS			Individual indeterminate Discontinuous in time and space

Photo credits (left to right): Dr. Zoe Hanley, National Parks Service https://www.nps.gov/yose/blogs/so-where-are-you-taking-that-bear.htm, Kyle Ebenhoch,
Rademaker M, Meijaard E, Semiadi G, Blokland S, Neilson EW, Rode-Margono EJ (2016) First Ecological Study of the Bawean Warty Pig (*Sus blouchi*), One of the Rarest Pigs on Earth. PLoS ONE 11(4): e0151732. https://doi.org/10.1371/journal.pone.0151732

How do we get from here to there?

Data Properties

GPS TRACKING

WILDLIFE CAMERAS

ace

space

S_ID	LONG	LAT	YEAR	MONTH	DAY	HOURS	MINUTES	SECONDS	OBS_NAME
13	-119.39610000	34.02270000	2011	5	21	21	20	51	Unid. Small Cetacean
94	-119.85000000	34.08940000	2011	6	17	21	18	58	Blue Whale
137	-119.84660000	34.13430000	2011	6	17	22	59	17	Humpback Whale
138	-119.82590000	34.11920000	2011	6	17	23	3	11	Blue Whale
139	-119.82590000	34.11920000	2011	6	17	23	3	11	Humpback Whale
140	-119.85130000	34.12760000	2011	6	17	23	4	13	Humpback Whale
141	-119.80230000	34.11380000	2011	6	17	23	5	59	Humpback Whale
142	-119.88070000	34.09870000	2011	6	17	23	10	6	Blue Whale
143	-119.88690000	34.11340000	2011	6	17	23	10	58	Blue Whale
144	-120.05200000	34.11770000	2011	6	17	23	20	1	Humpback Whale
145	-120.04050000	34.12080000	2011	6	17	23	21	18	Unid. Large Whale
146	-120.04720000	34.12090000	2011	6	17	23	21	34	Humpback Whale
147	-120.03420000	34.10980000	2011	6	17	23	22	30	Unid. Large Whale
148	-120.05320000	34.12040000	2011	6	17	23	23	53	Unid. Large Whale
149	-120.06300000	34.11620000	2011	6	17	23	24	20	Blue Whale
150	-120.06300000	34.11620000	2011	6	17	23	24	20	Humpback Whale
151	-120.04450000	34.10880000	2011	6	17	23	25	1	Unid. Large Whale
152	-120.02920000	34.12080000	2011	6	17	23	26	56	Humpback Whale
153	-120.03810000	34.11700000	2011	6	17	23	27	17	Humpback Whale

BIG Sharks … in Puget Sound

- Sixgill Sharks, *Hexanchus griseus*
- 600 lb sharks in downtown Seattle
- DEEP sharks
  - live in pure darkness where (most) humans never go
- Location Data
  - Northwest Fisheries Science Center, NOAA
- Environmental Data
  - Salish Sea Model
    - Pacific Northwest National Laboratory (PNNL) & Washington State Department of Ecology

Photo credit: NOAA Ocean Explorer 2016 https://www.flickr.com/photos/27077560@N05/26688971116/. Modified through cropping by Alli Cramer.

Why is Puget Sound interesting?

Fish Questions:

- Potential nursery for these fish
- Exploiting food resources (dogfish)
- Highly mobile species?

Puget Sound is a diverse & variable place

Photo credit: NOAA Ocean Explorer 2016 https://www.flickr.com/photos/27077560@N05/26688971116/. Modified through cropping by Alli Cramer.

Questions of interest:

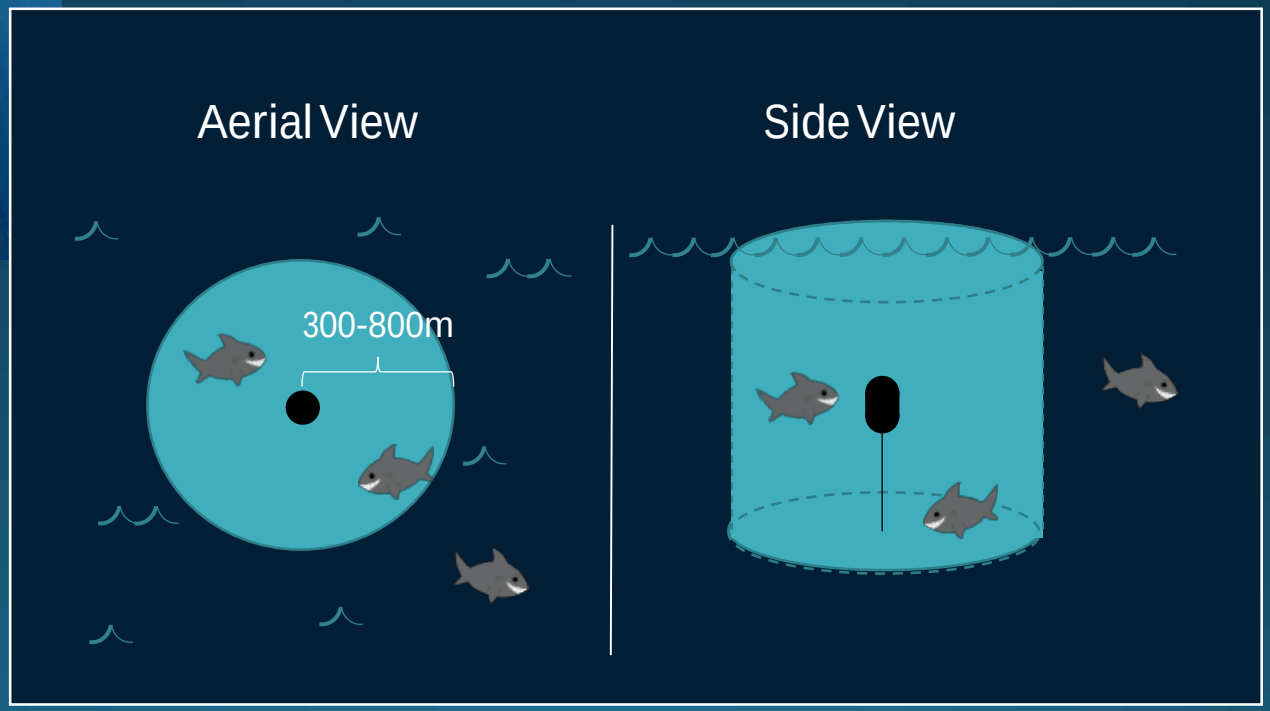
- How does environmental variability correlate with the presence or absence of the shark?

- Can we predict where the shark is likely to be?

Photo credit: NOAA Ocean Explorer 2016 https://www.flickr.com/photos/27077560@N05/26688971116/. Modified through cropping by Alli Cramer.

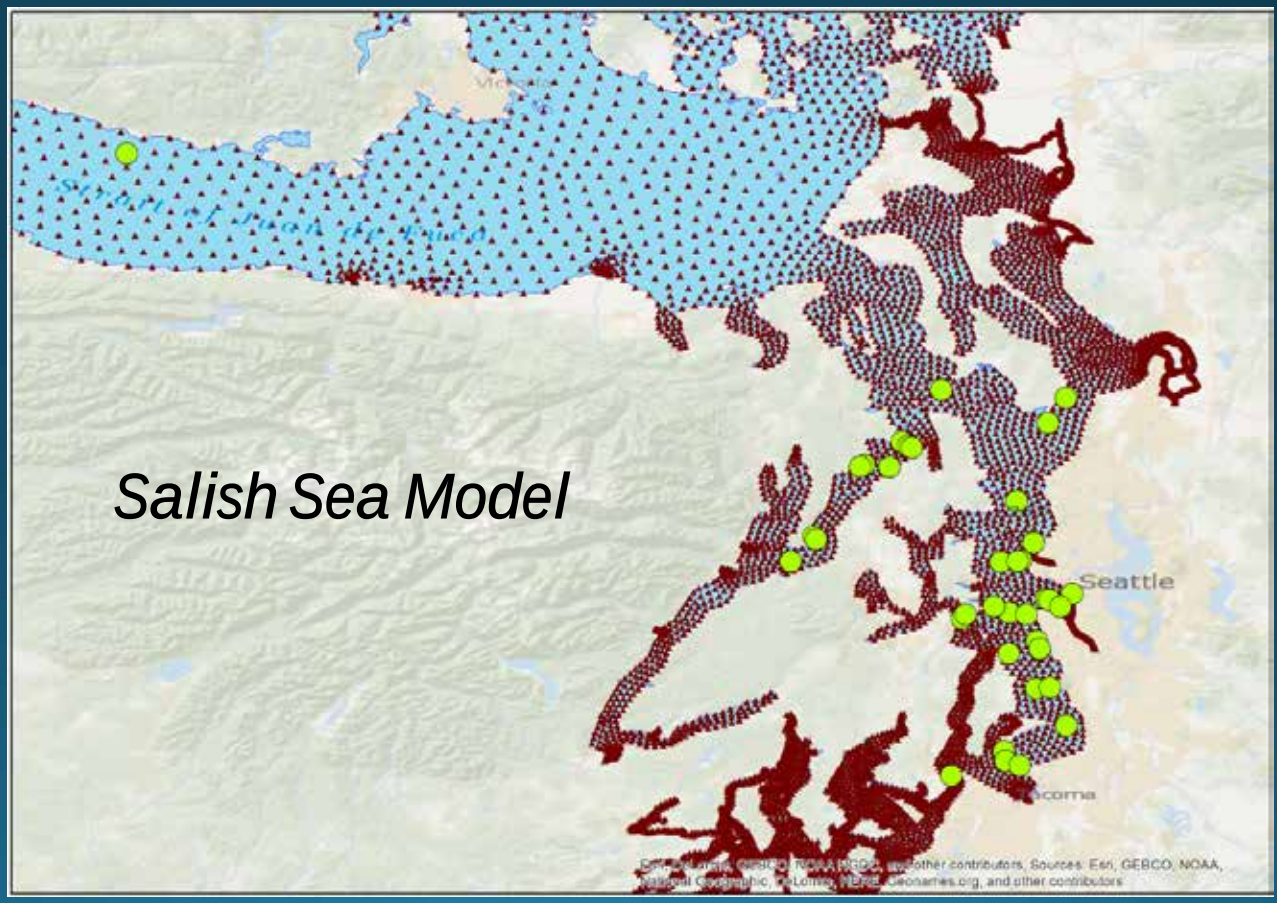
Location Data

Location Data



Environmental Data

- Temperature (°C)
- Salinity (ppt)
- Dissolved O_2 (DO)



FVCOM model

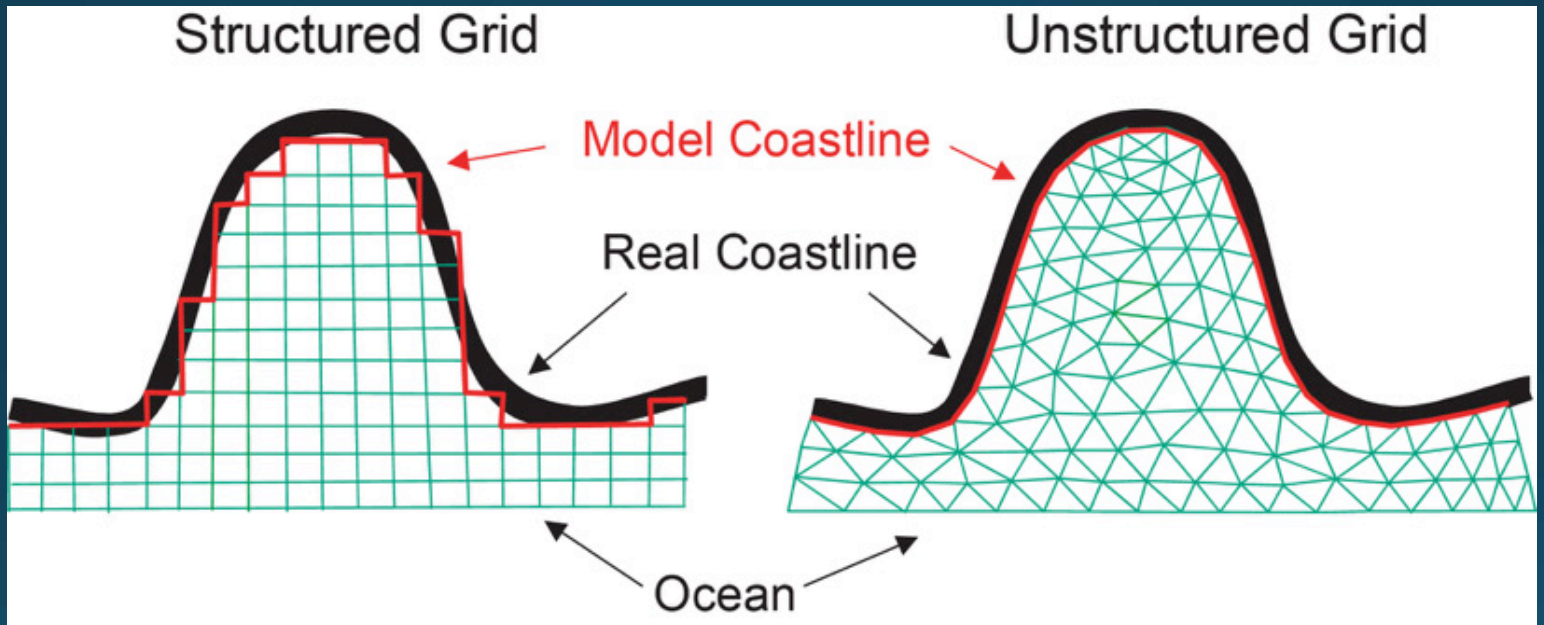
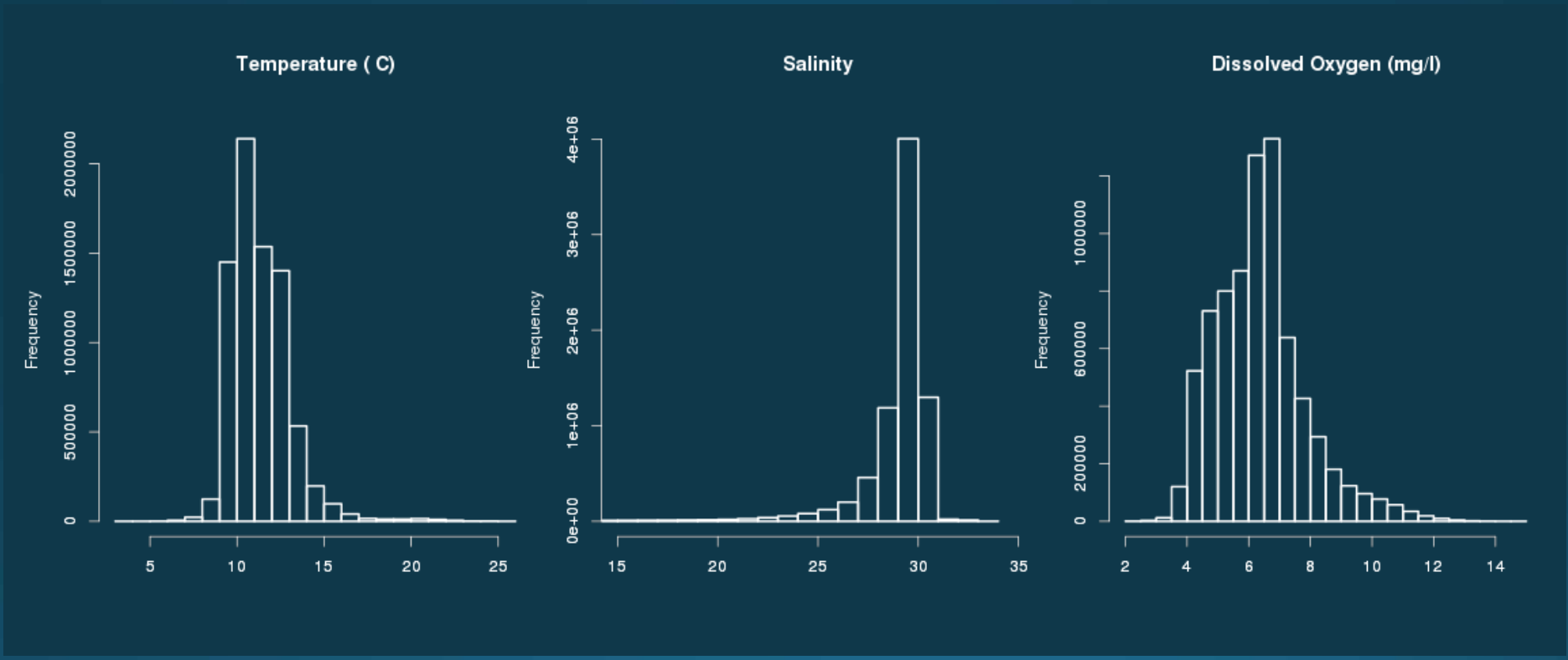


Figure 1. An example of fitting a structured grid (left) and an unstructured grid (right) to a simple coastal embayment. The true coastline is shown in black, the model coastline in red. Note how the unstructured triangular grid can be adjusted so that the model coastline follows the true coastline, while the unstructured grid coastline is jagged -- which can result in unrealistic flow disturbance close to the coast. Credit: Chen, C., R.C. Beardsley, and G. Cowles. An unstructured grid, finite-volume coastal ocean model (FVCOM) System. Oceanography 19(1):78-89 (2006). http://dx.doi.org/10.5670/oceanog.2006.92

Values at sample nodes



At this location, what does the fish chose?

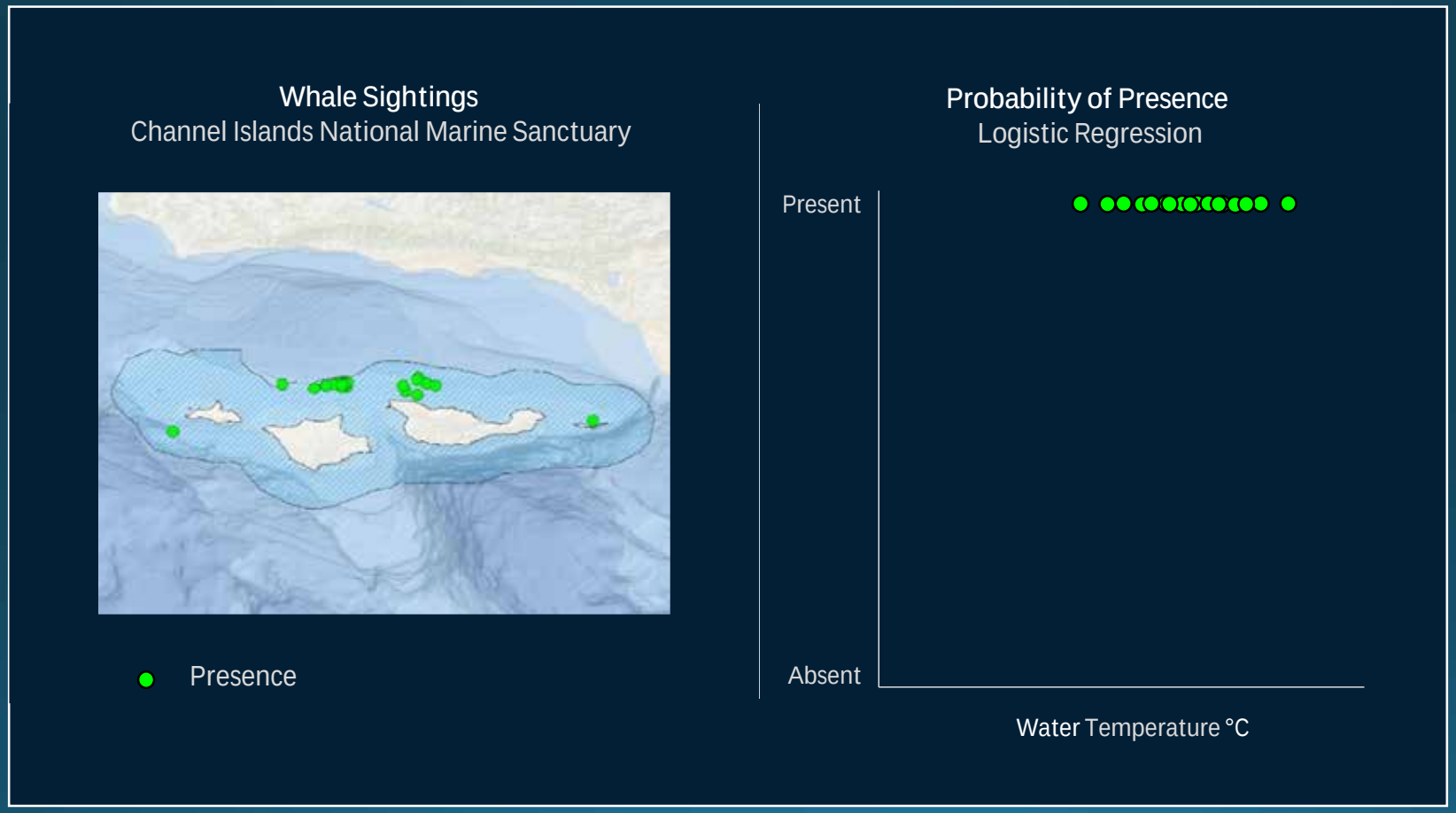
- **Approach: Logistic regression with pseudo-absences data**

- Presence observations
  - 2006
  - 13 sharks
  - 45 receivers – 39 within 800 m of a model node
  - 92,113 observations

- Absence observations
  - "Absences" inferred from background data
  - Absences from observation locations, but at random depths and times

- Environmental data – Salish Sea Model

At this location, what does the fish chose?



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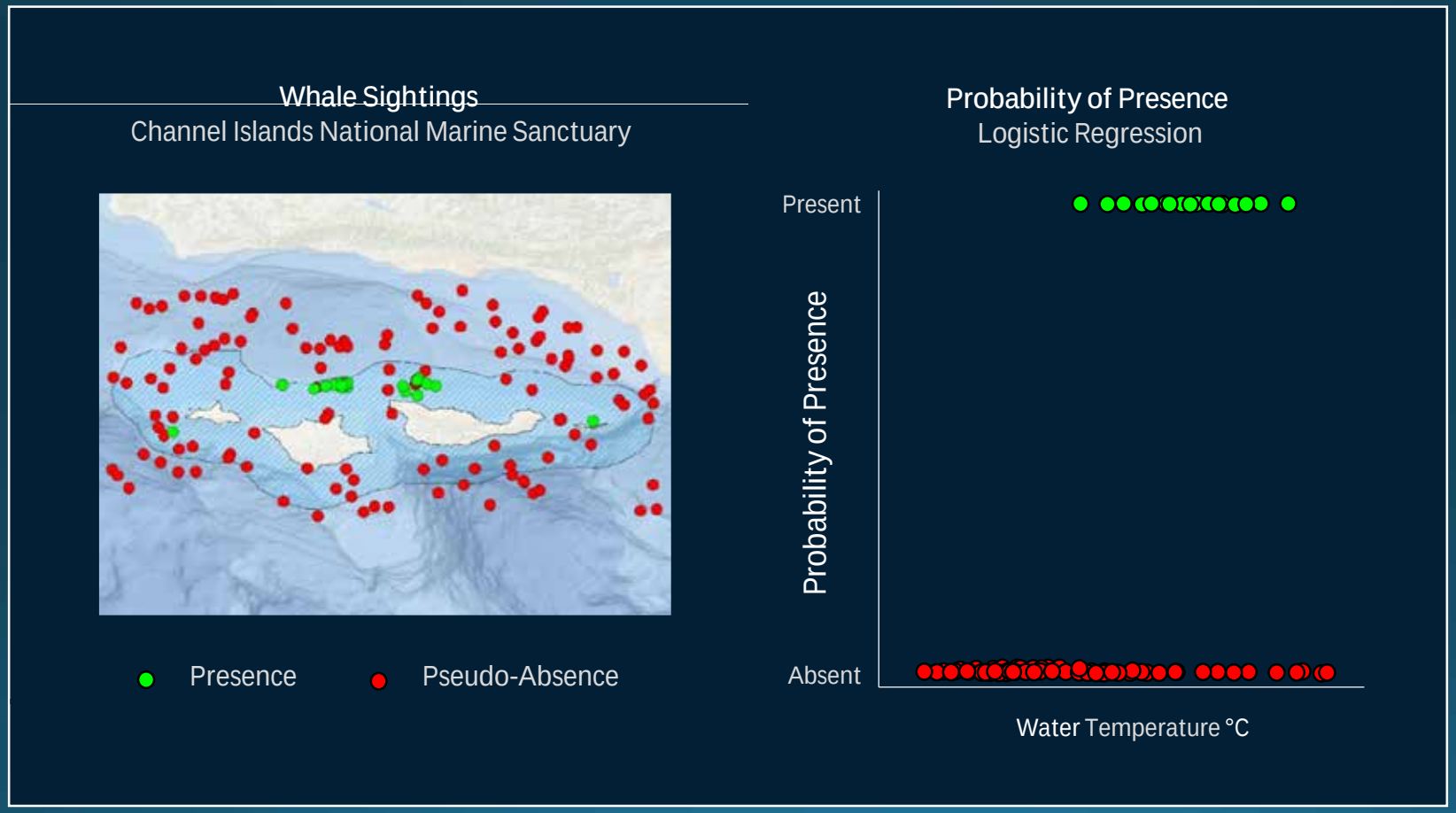

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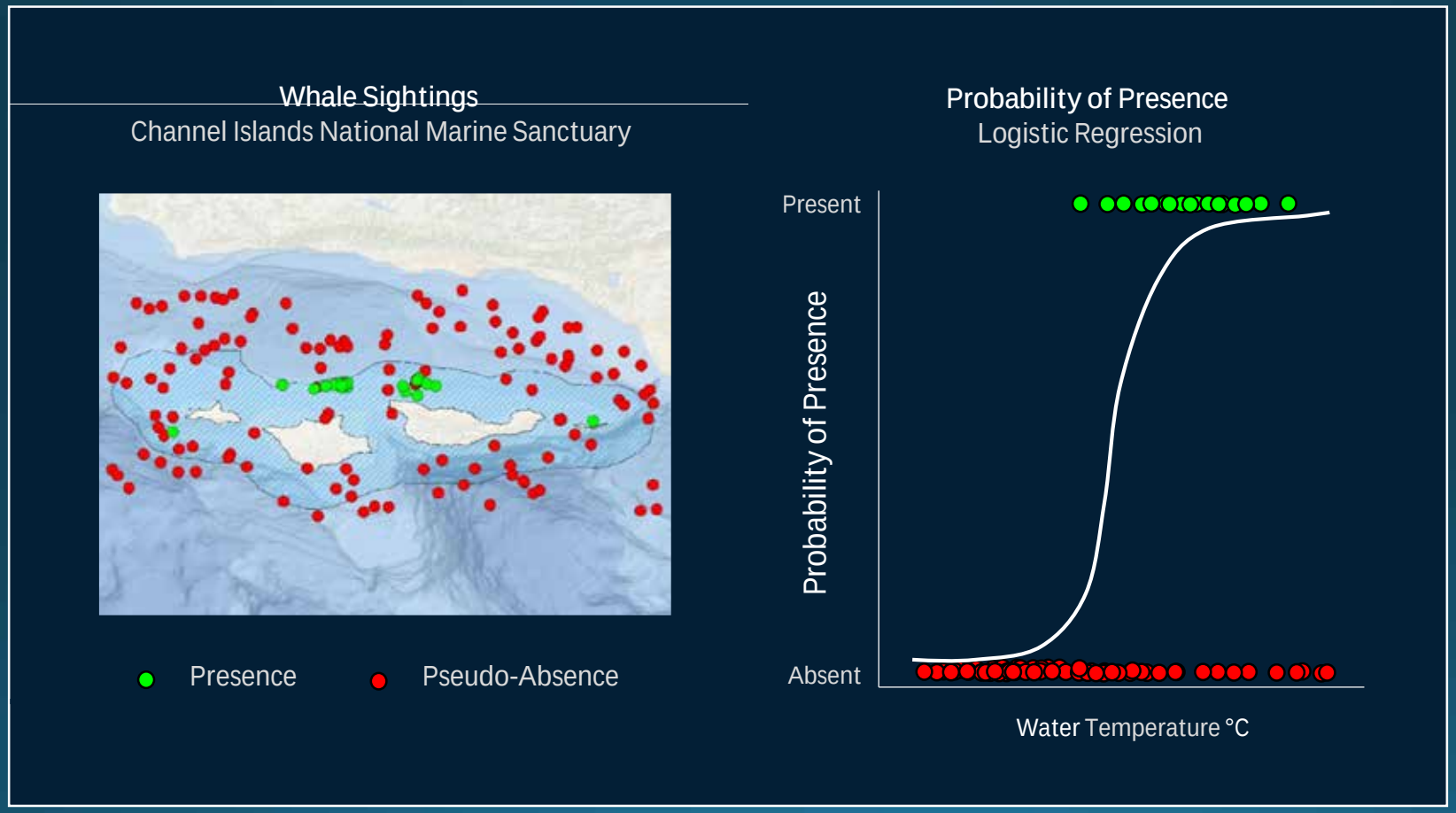
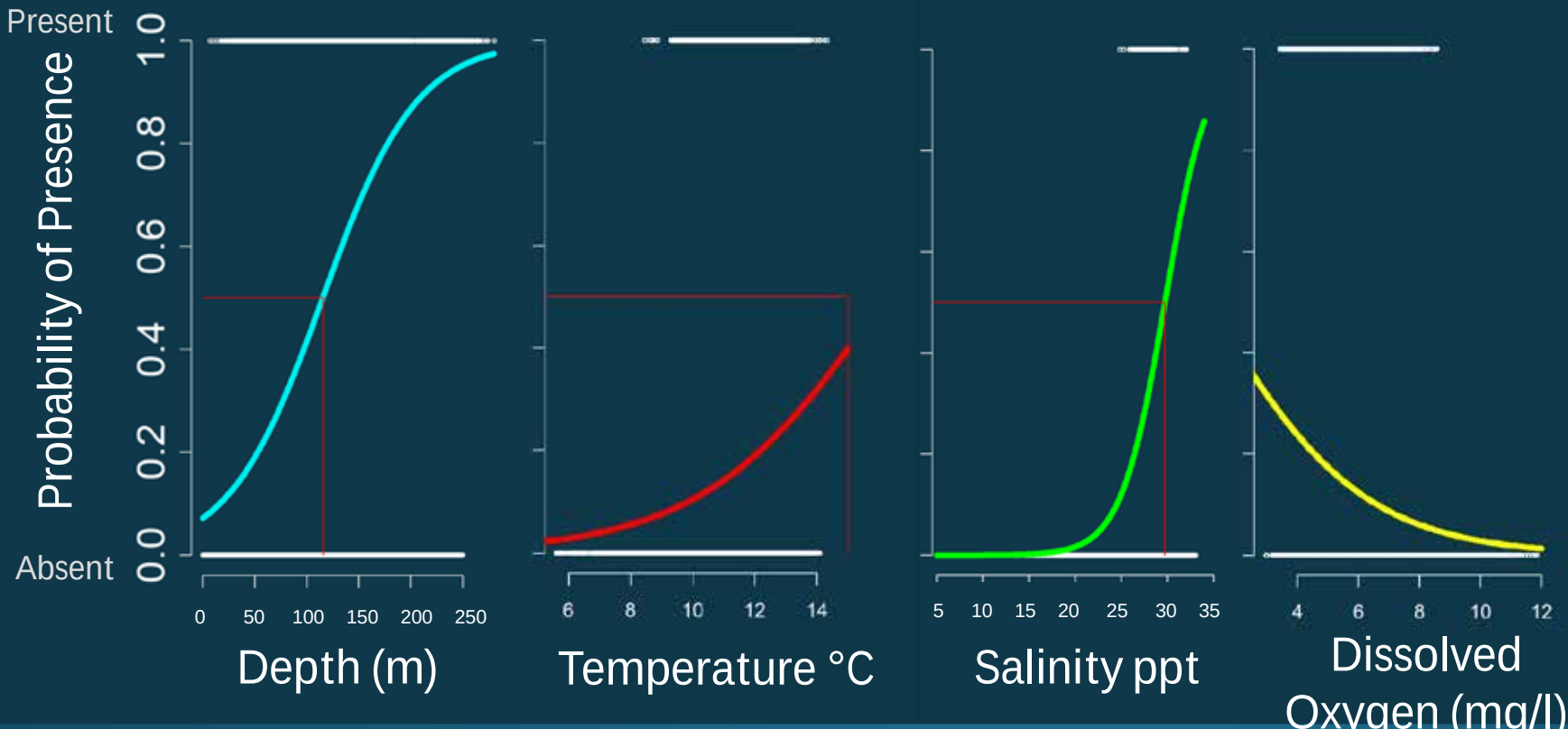


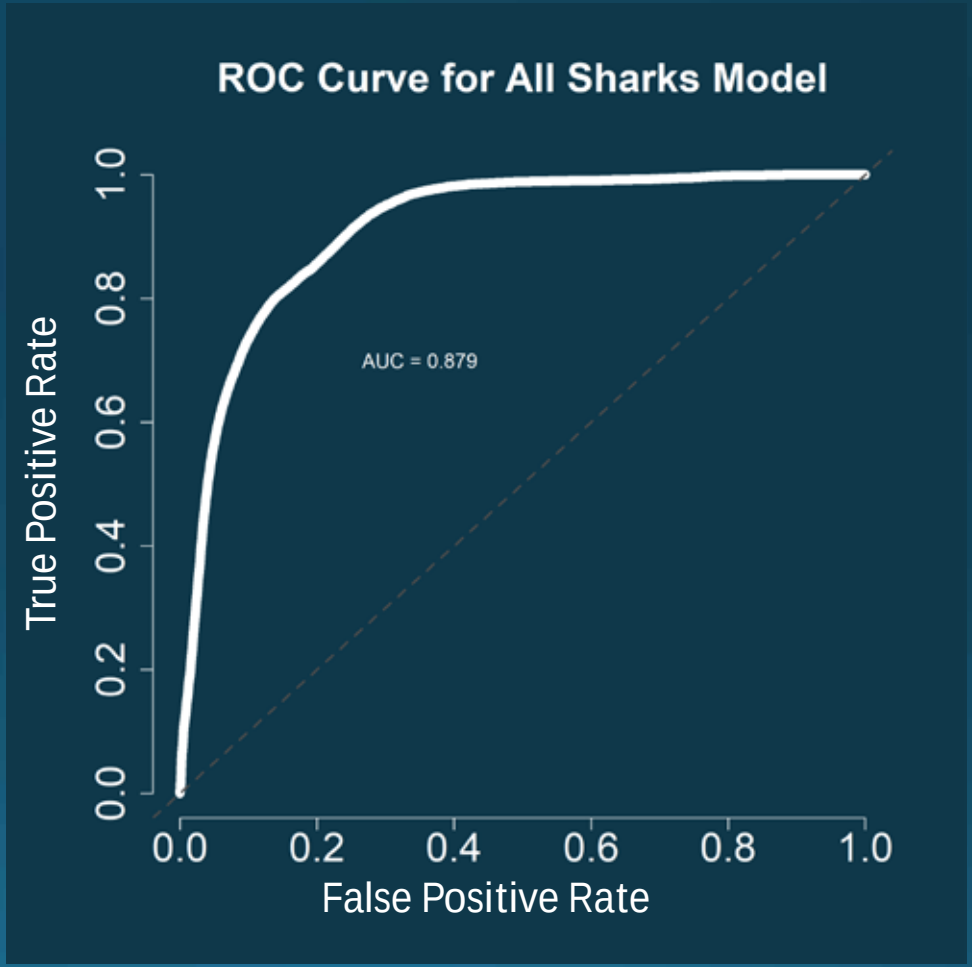
All sharks model

All predictors p < 0.5



Take away from all these figures

- Making maps is possible!
- Sharks respond strongly to salinity
- Puget Sound is an estuary
  - water conditions are complicated



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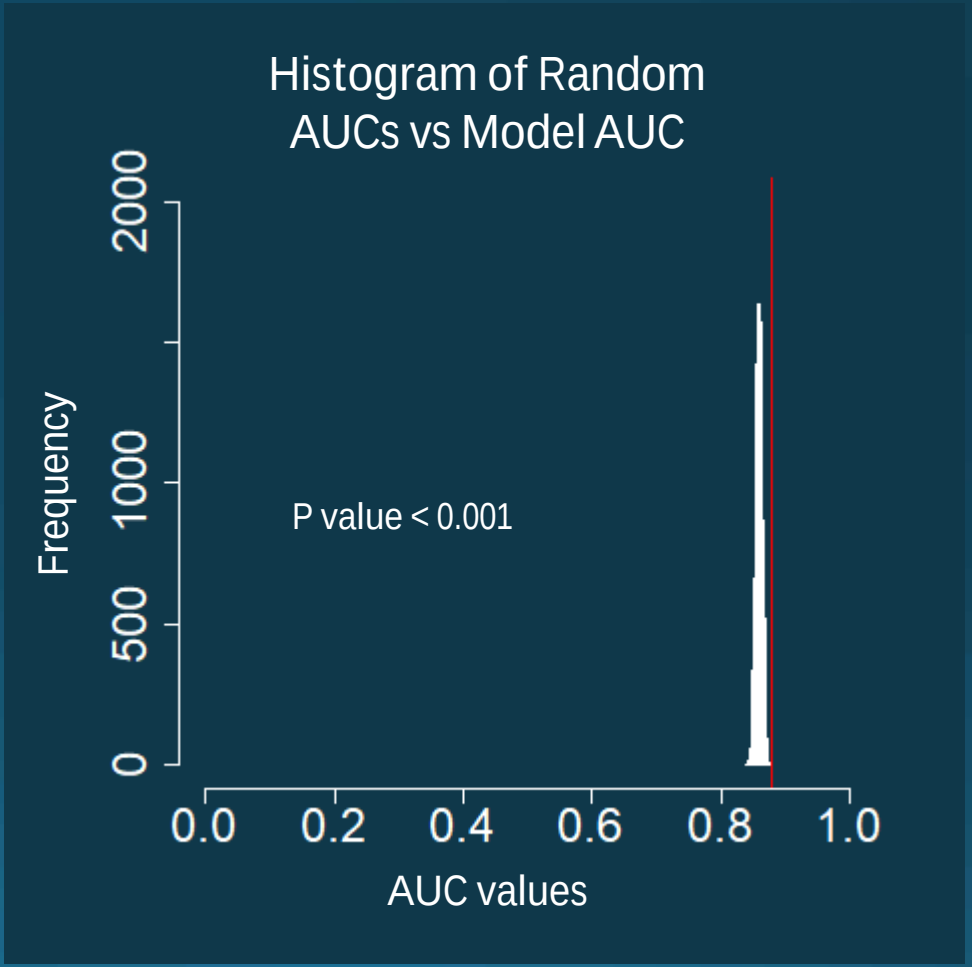

Future steps

- Add more years of environmental data
  - Working with PNNL and the Washington Department of Ecology to evaluate more years
- Look at Sex and Size
- Forecast locations based on environmental conditions
  - Develop suitability space for sharks

Photo credit: NOAA Ocean Explorer 2016 https://www.flickr.com/photos/27077560@N05/26688971116/. Modified through cropping by Alli Cramer.

Acknowledgements

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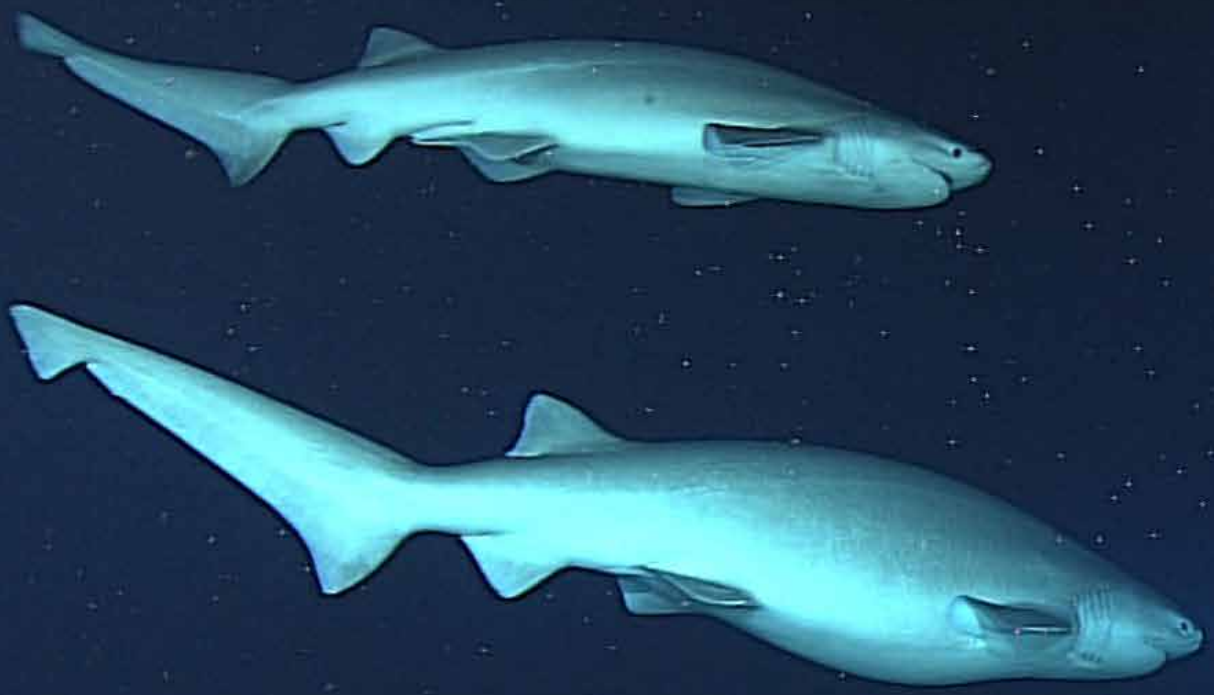
Michael Frederick Meyer, Washignton State University
Dr. Steve Powers, CEREO Washington State University
Dr. Stephanie Hampton, CEREO Washington State University



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Check out the R Working Group!

@CougRstats

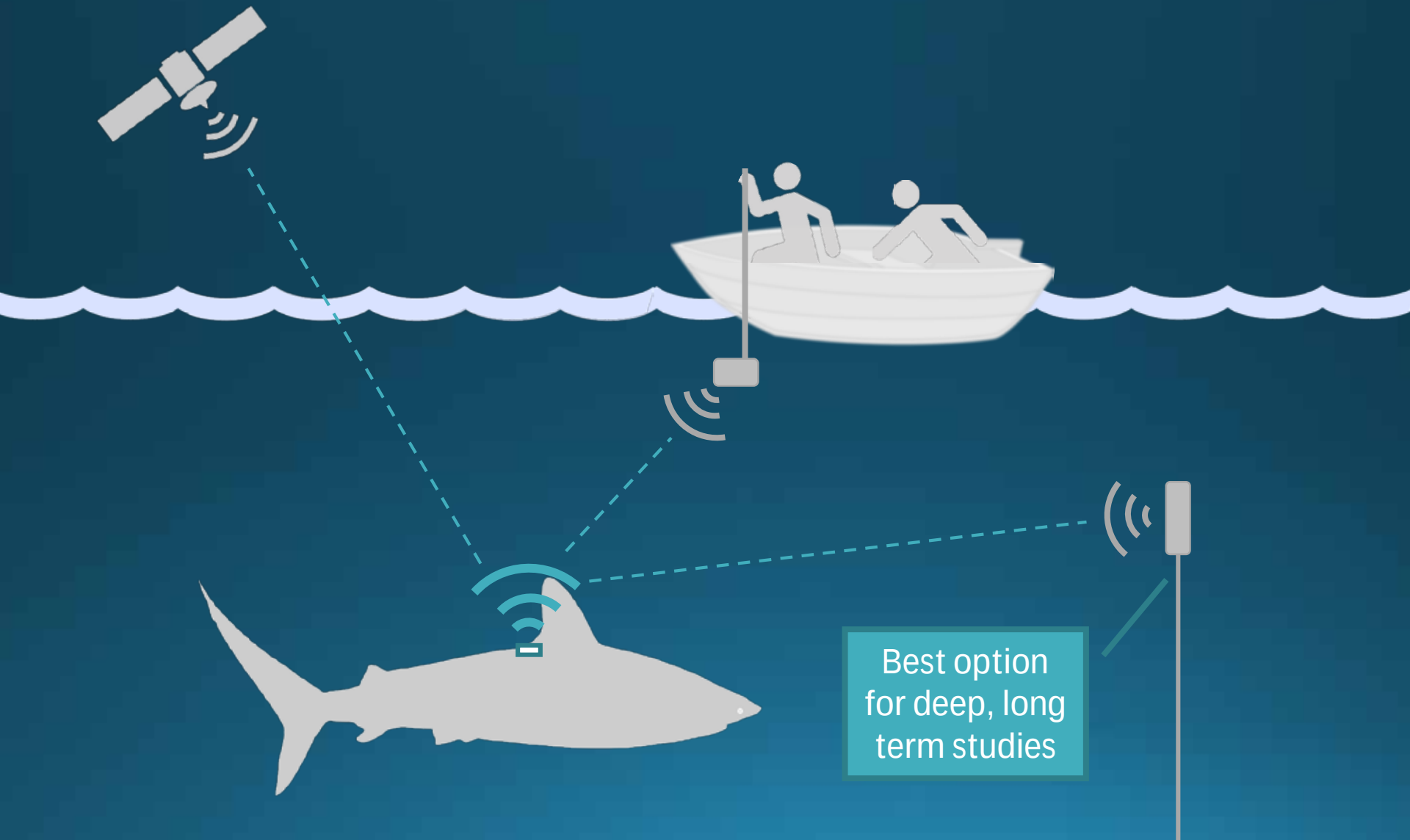
cereo.wsu.edu/r-working-group

Photo credit: NOAA Ocean Explorer 2017 screen grab. https://www.flickr.com/photos/oceanexplorergov/33036849374/in/photostream/.

Key References

- Gotelli NJ, Ellinson AM (2013) A Primer of Ecological Statistics. J Chem Inf Model 53:1689–1699
- Khangaonkar T, Sackmann B, Long W, Mohamedali T, Roberts M (2012) Simulation of annual biogeochemical cycles of nutrient balance , phytoplankton bloom (s), and DO in Puget Sound using an unstructured grid model. Ocean Dyn 62:1353–1379
- Khangaonkar T, Long W, Xu W (2017) Assessment of circulation and inter-basin transport in the Salish Sea including Johnstone Strait and Discovery Islands pathways. Ocean Model 109:11–32
- Andrews KS, Williams GD, Levin PS (2010) Seasonal and Ontogenetic Changes in Movement Patterns of Sixgill Sharks. PLoS One 5
- Ward EJ, Levin PS, Lance MM, Jeffries SJ, Acevedo-Gutierrez A (2012) Integrating diet and movement data to identify hot spots of predation risk and areas of conservation concern for endangered. Conserv Lett 5:37–47
- Khangaonkar T, Yang Z, Kim T, Roberts M (2011) Tidally averaged circulation in Puget Sound sub-basins : Comparison of historical data , analytical model , and numerical model. Estuar Coast Shelf Sci 93:305–319
- Turchin P (1999) Quantitative Analysis of Movement. Meas Model Popul Redistrib Anim Plants

How to study shark movements?



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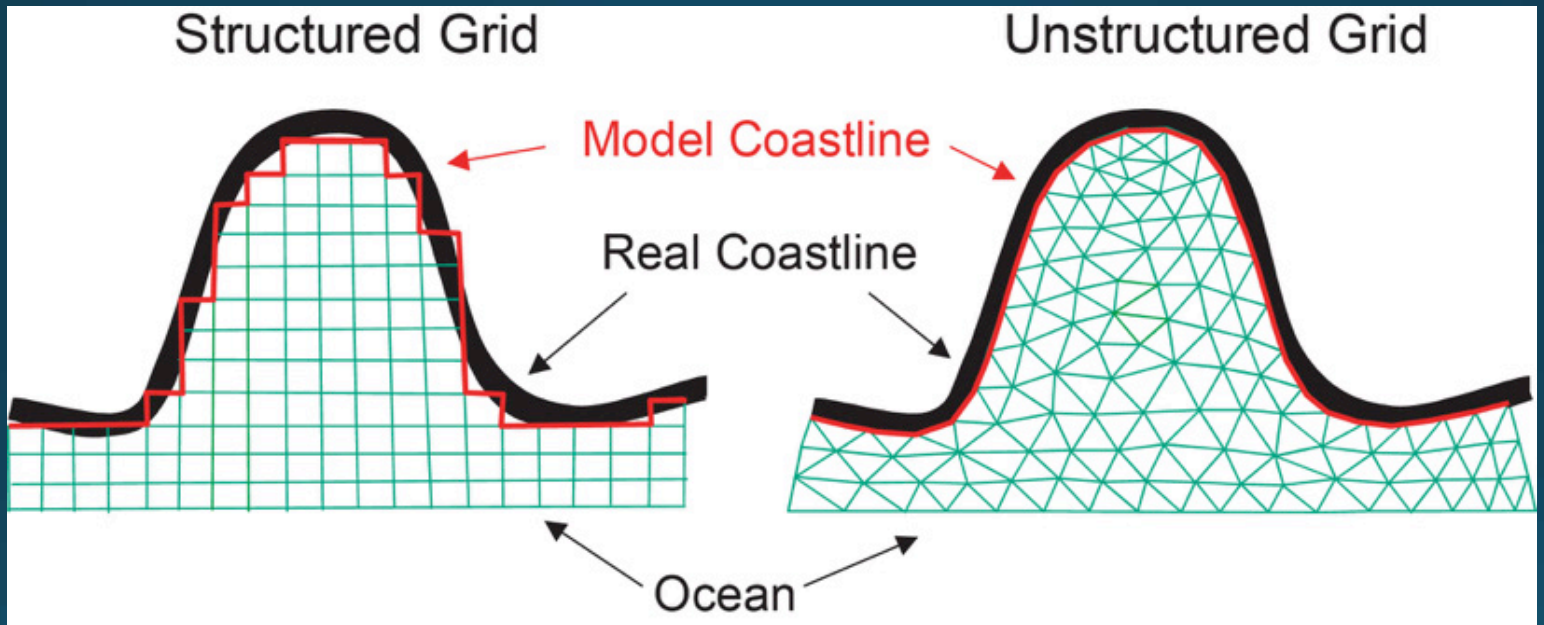

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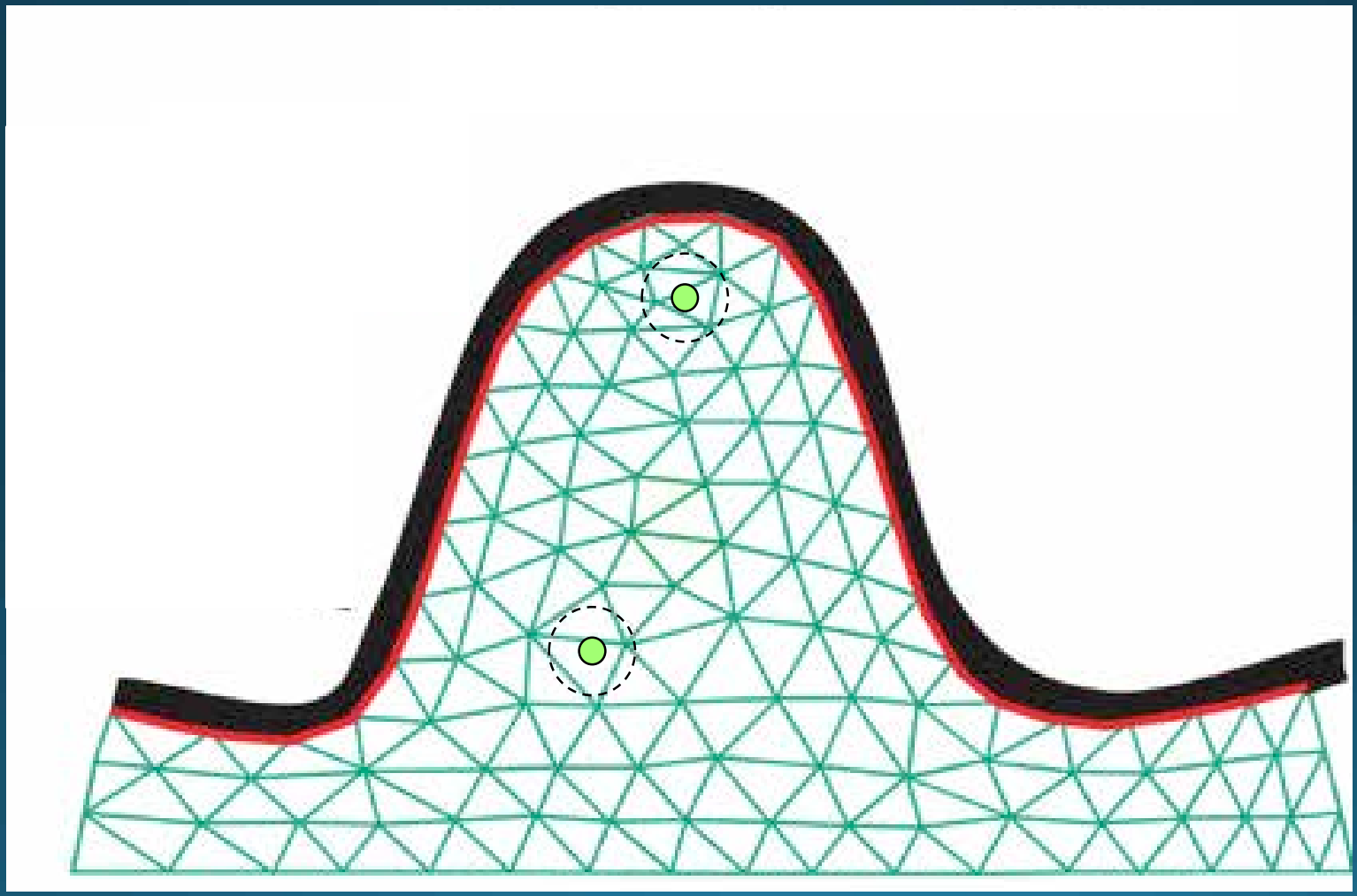
Pairing FVCOM model with Telemetry Data



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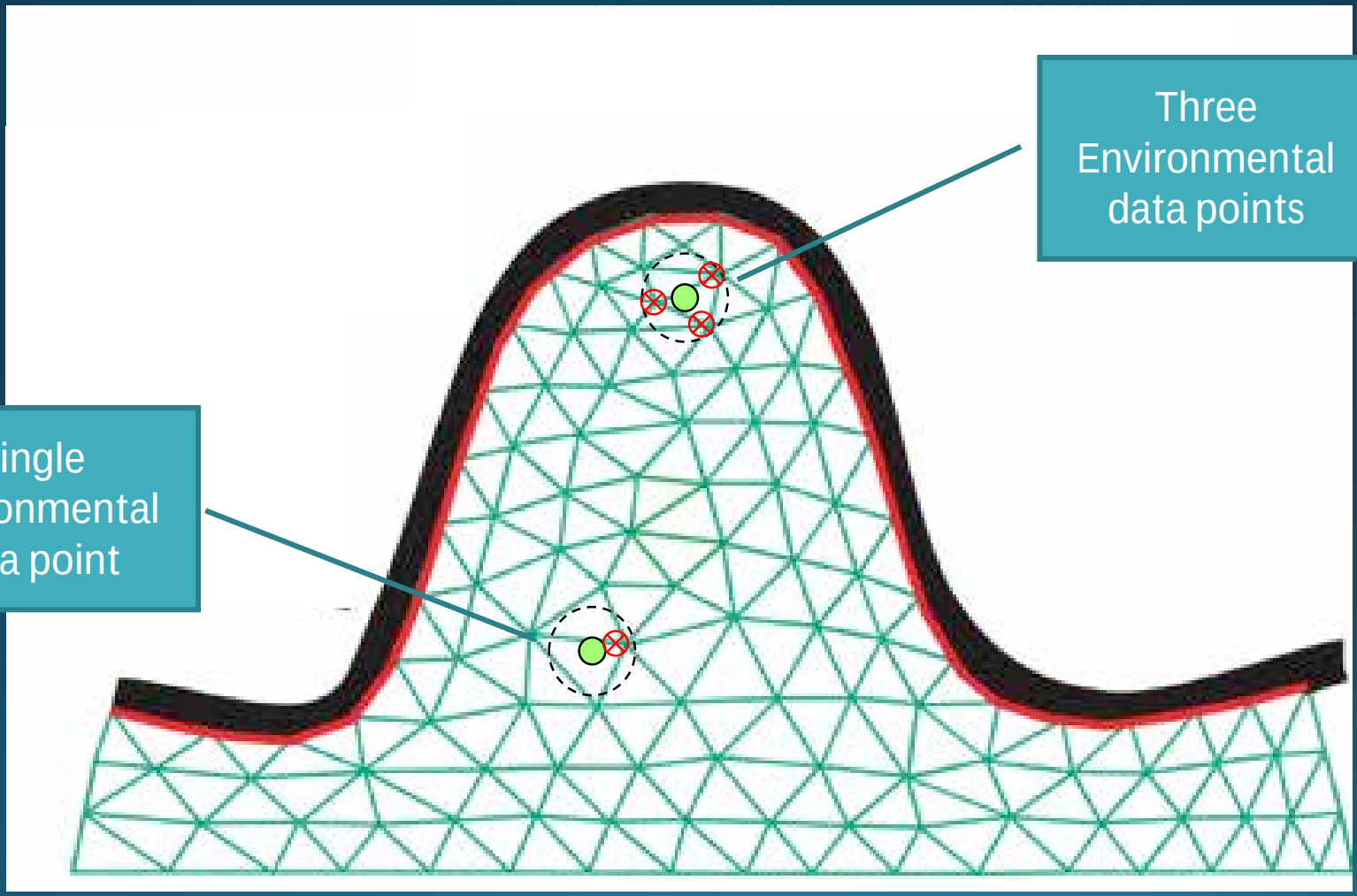
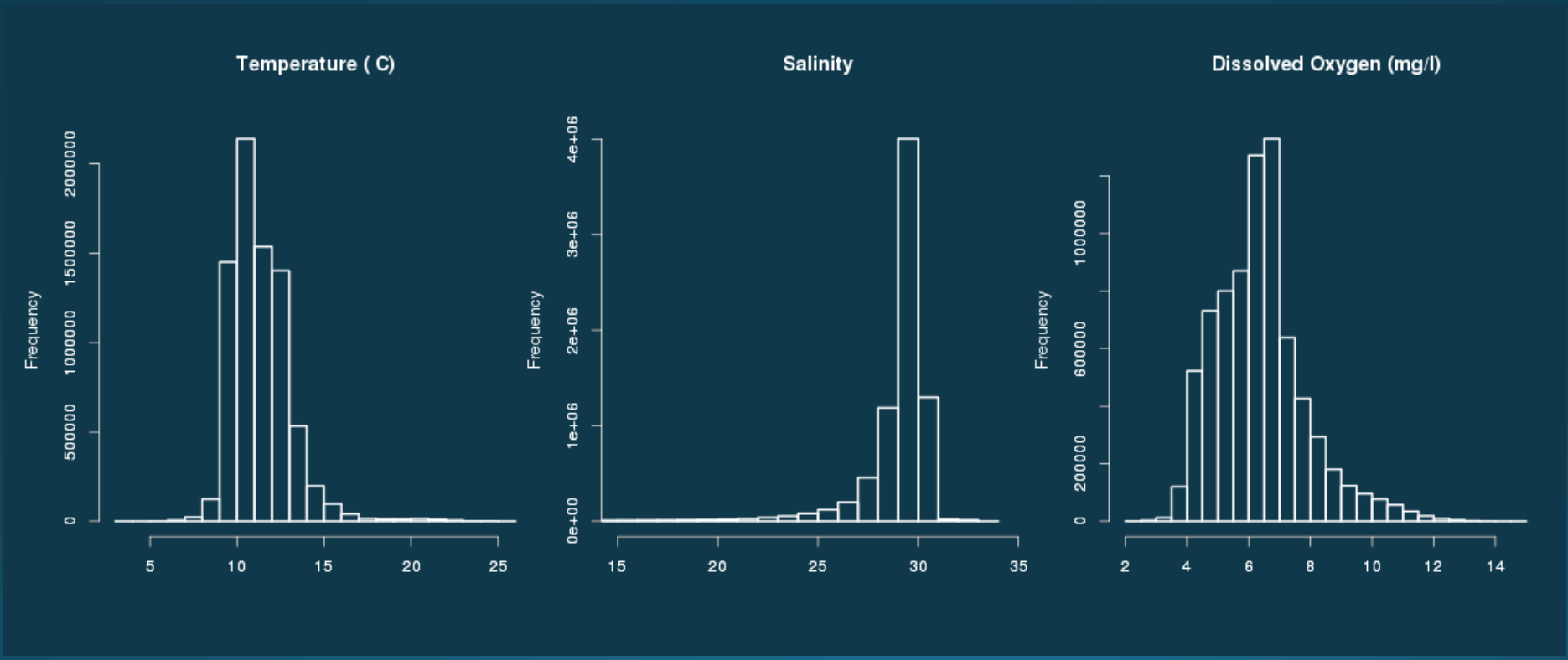
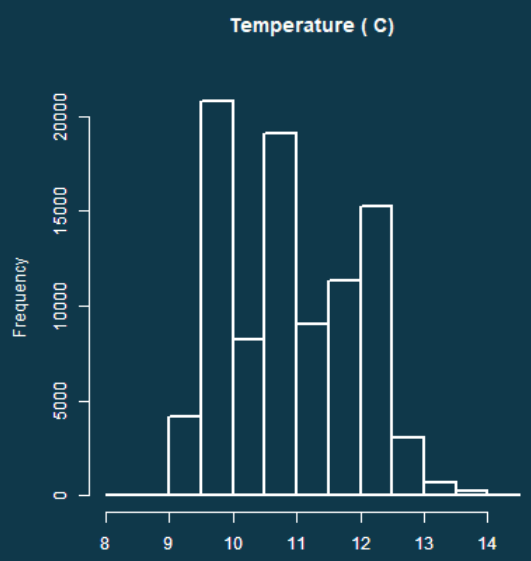
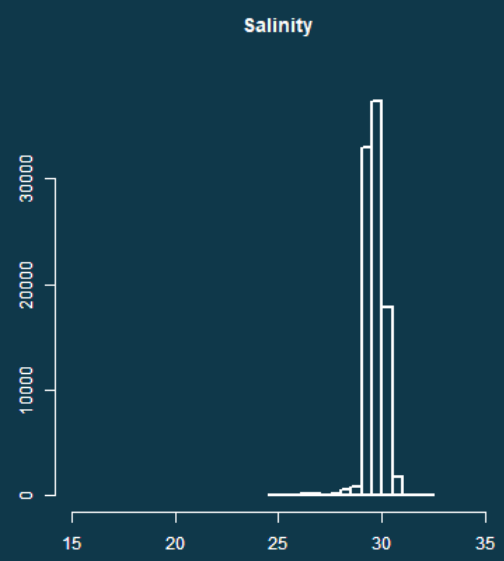


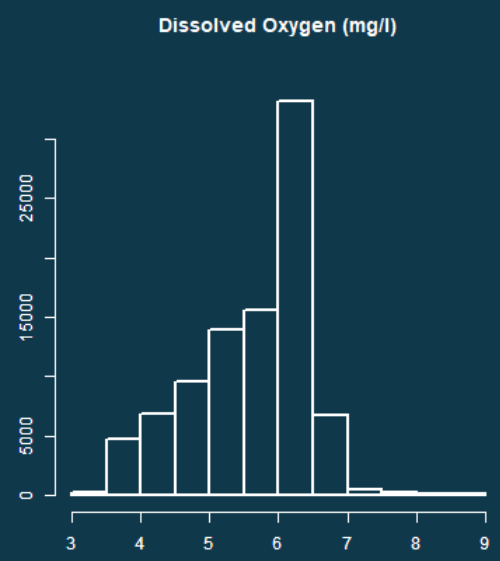
Values at sample nodes

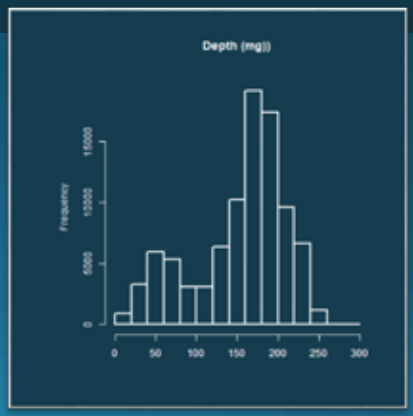


More detailed info about sharks



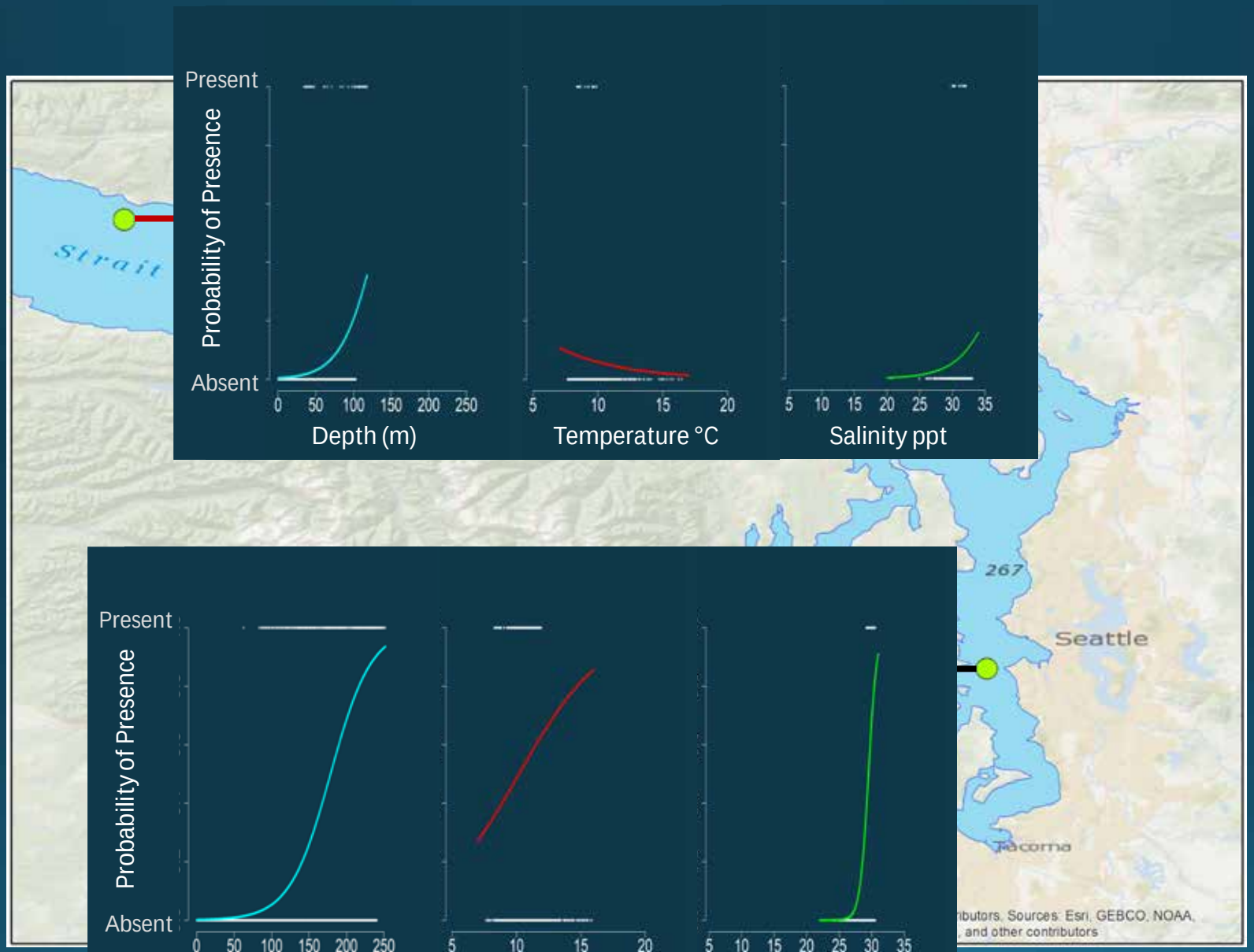




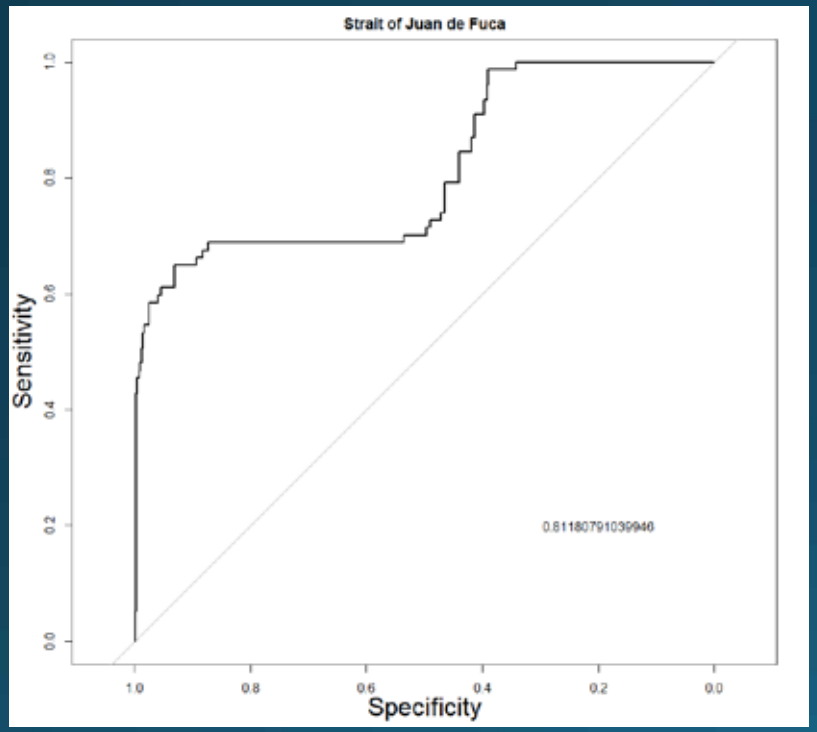


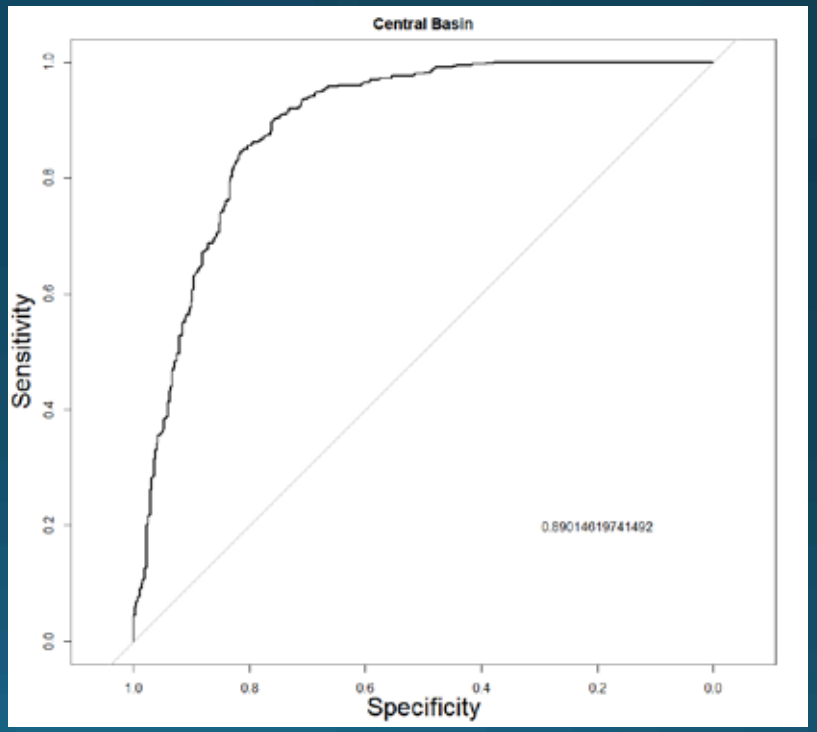
Do decisions change in space?

- Are there different behaviors at different places?
  - Two receivers, each modeled separately
  - Midwater receivers located in basins of the sound
  - Pseudo-absences only from that receiver

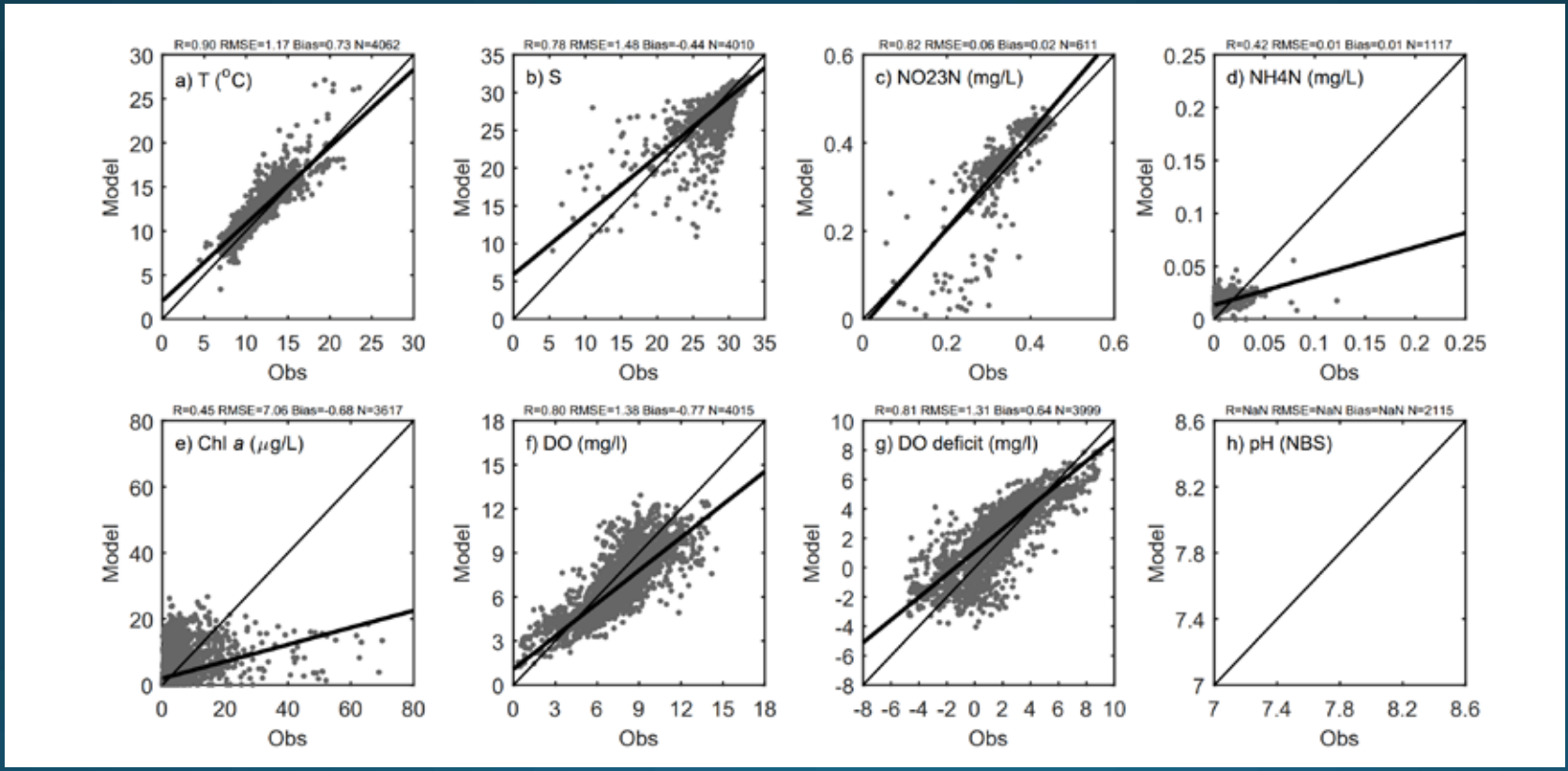

Present
Probability of Presence
Absent
0 50 100 150 200 250
Depth (m)
5 10 15 20
Temperature °C
5 10 15 20 25 30 35
Salinity ppt
Strait
267
Seattle
Tacoma
Present
Probability of Presence
Absent
0 50 100 150 200 250
Depth (m)
5 10 15 20
Temperature °C
5 10 15 20 25 30 35
Salinity ppt
All predictors p< 0.5

AUC for individual Receivers





Salish Sea Model predicted vs observed model concentrations



* and estimates of model bias and RMSE.