Impacts of climate change on marine animal movement and behavior

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Marine (shark) Animal Movement

- In collaboration with the Shark Lab @ California State University, Long Beach, run by Dr. Chris Lowe... https://www.csulb.edu/shark-lab

- Undergraduate students at the University of Toronto have worked on leopard shark and juvenile white shark projects (Vinky Wang, Yi Liu, ecological statistics summer club group)

- Beyond how they move, much of the aim is to understand how the environment shapes their decisions and behavior

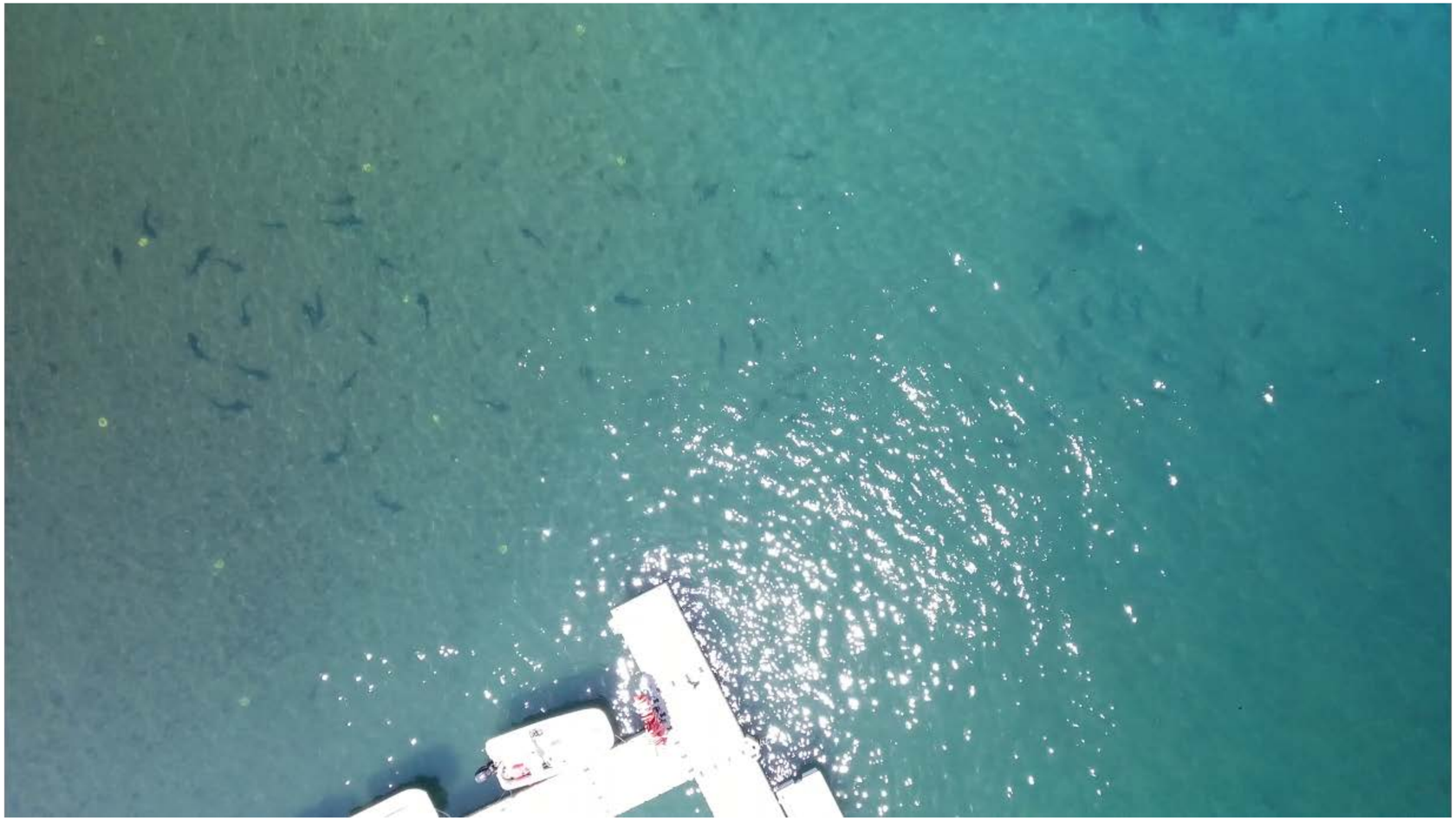
Data Structure

- Types of data being collected is rapidly changing

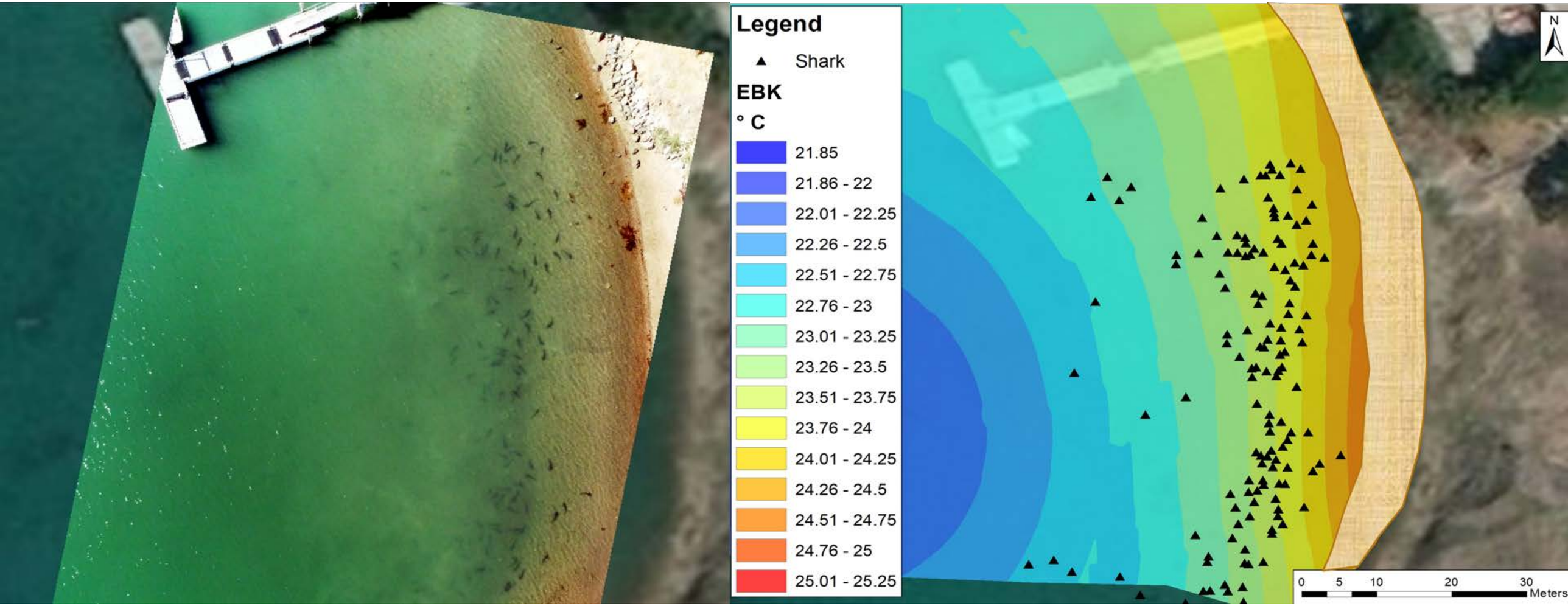
- In addition to telemetry data, drones and robots are in use

Leopard Shark Aggregations

- A total of 48 independent flights were done, each capturing different leopard shark aggregations off the coast of California at Catalina Island by Jack May + team



Leopard Shark Data Prep



Applying a Spatial Point Process Model

- We first grid the area and count the number of sharks per grid cell. Then we model the counts, y_{ti}, for

- $y_{ti} \,|\, \eta_t(s_i) \approx Pois\left(|s_i| exp(\eta_t(s_i)) \right)$

  $\eta_t(s_i) = \beta_0 + \beta_1 \times rel\_temp + f_t(s_i) + f_u(s_i) + f_v(s_i)$

  where we have random effects for across different flights, a spatially structured random effect we take to be a Gaussian random field, and an unstructured random effect taken to be *iid* normally distributed

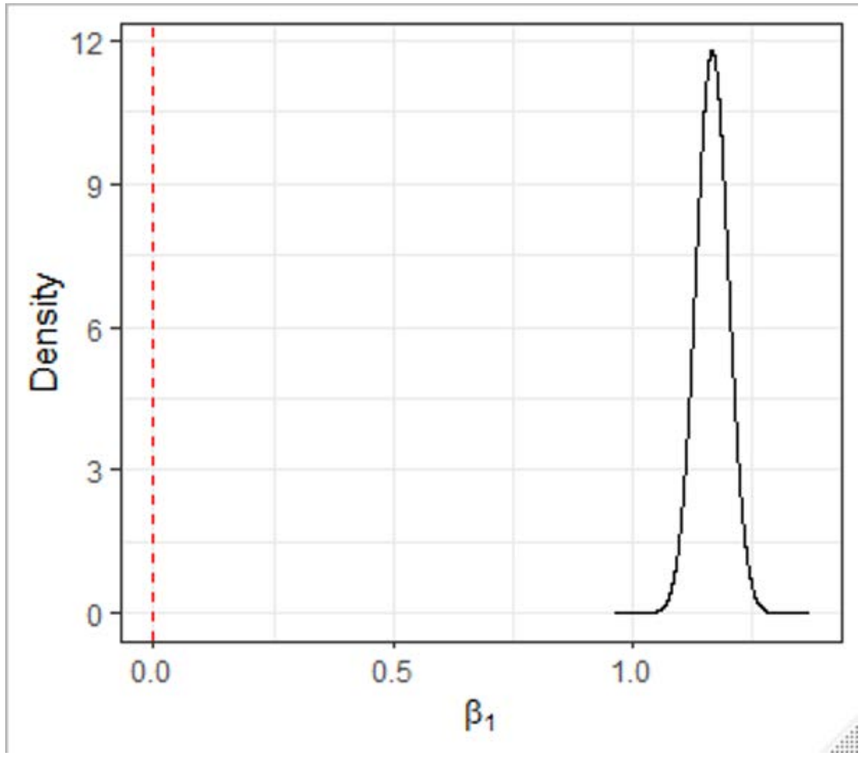
Results

Fixed effects

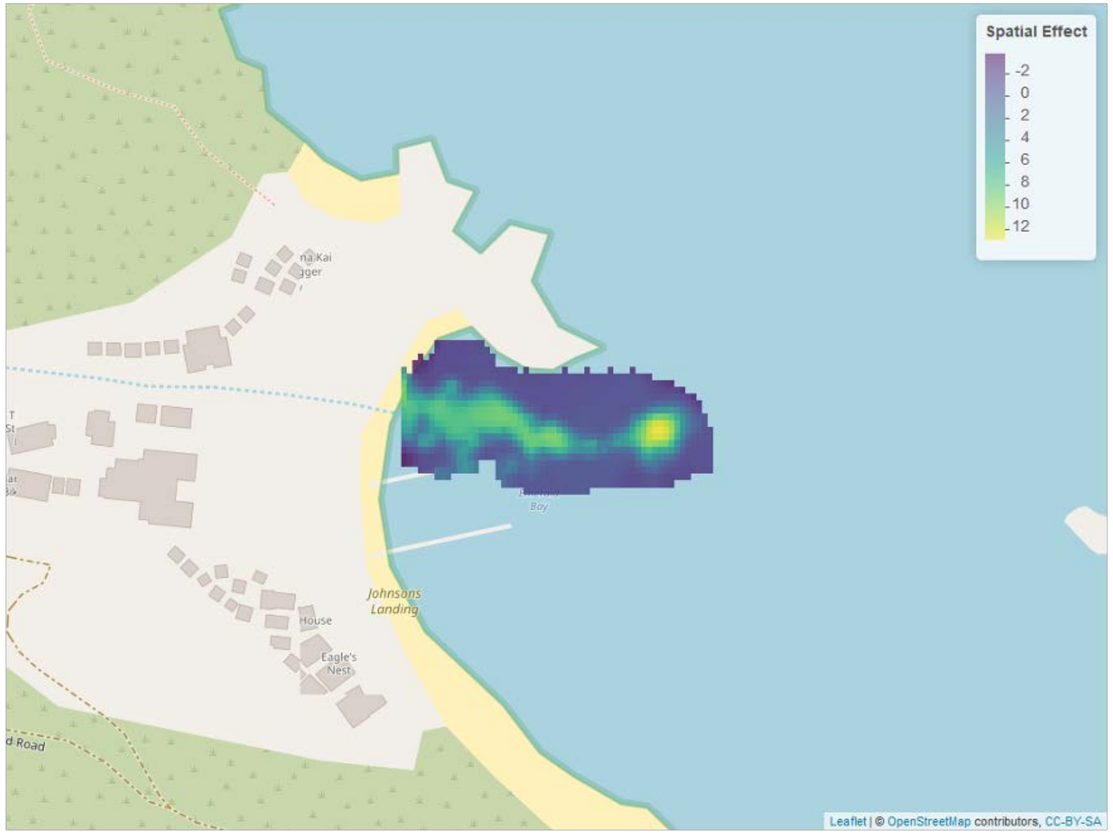
Estimates	Mean	95% CI
Intercept β_0	1.640	[1.564, 1.715]
Relative Temperature β_1	1.165	[1.098, 1.231]

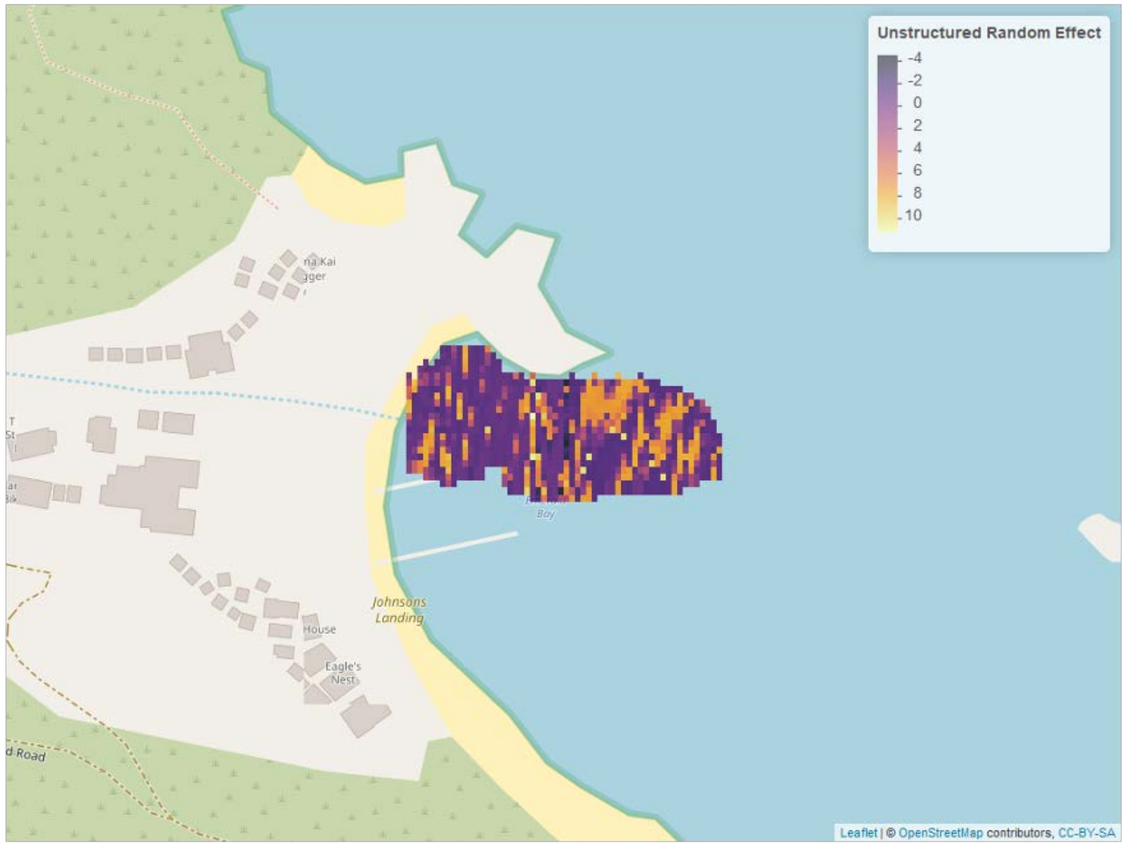
Random effects

Estimates	Mean	95% CI
Precision for Flight	0.208	[0.136, 0.301]
Precision for Spatial Random Effect	0.120	[0.099, 0.143]
Precision for Unstructured	0.060	[0.054, 0.066]



Random Effects





Goal + What Remains

- A few goals and modifications to the model remain:

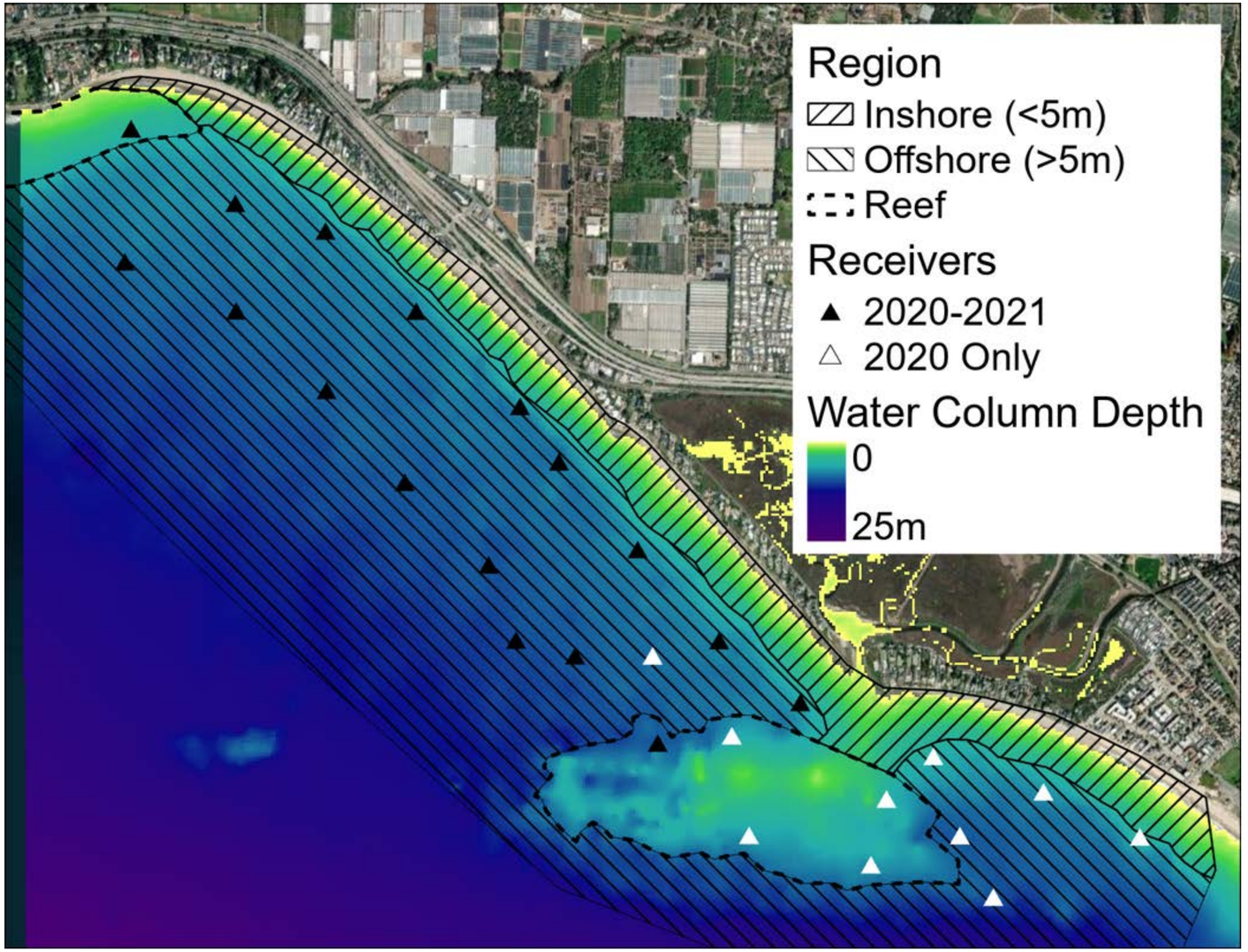
  - our joint model does not capture some of the variability of certain aggregations (include space x time interaction)

  - distribution of available temperatures changes from flight to flight but for now not taking that into account

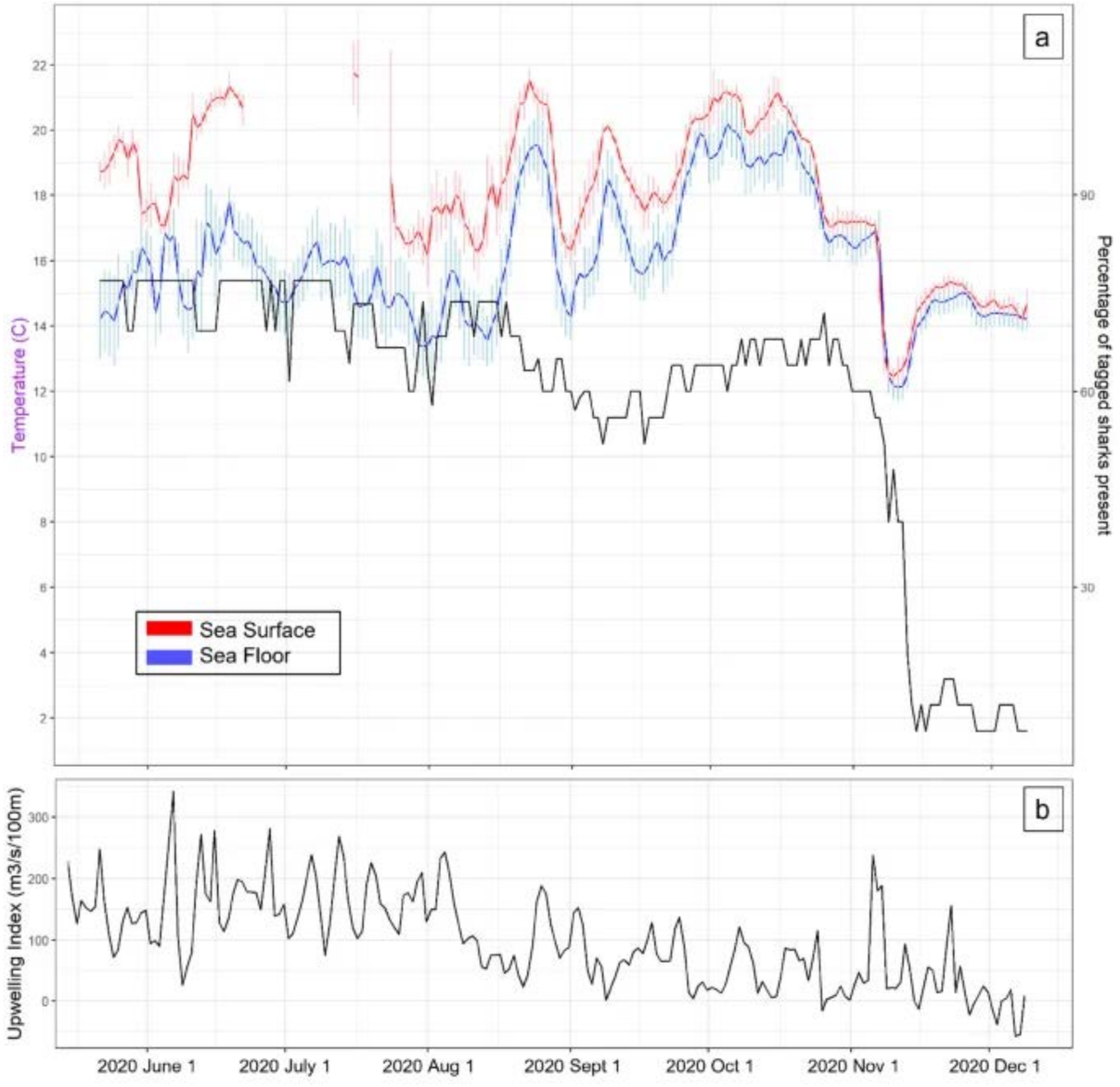
  - model the video of movements rather than a snapshot

Juvenile White Sharks

- Acoustic telemetry is used to track juvenile white sharks off the coast of California
- Temperature loggers are used at the site of the acoustic receivers
- To get a temperature profile, the AUV is also used to capture temperatures at different depths



Presence vs Temperature

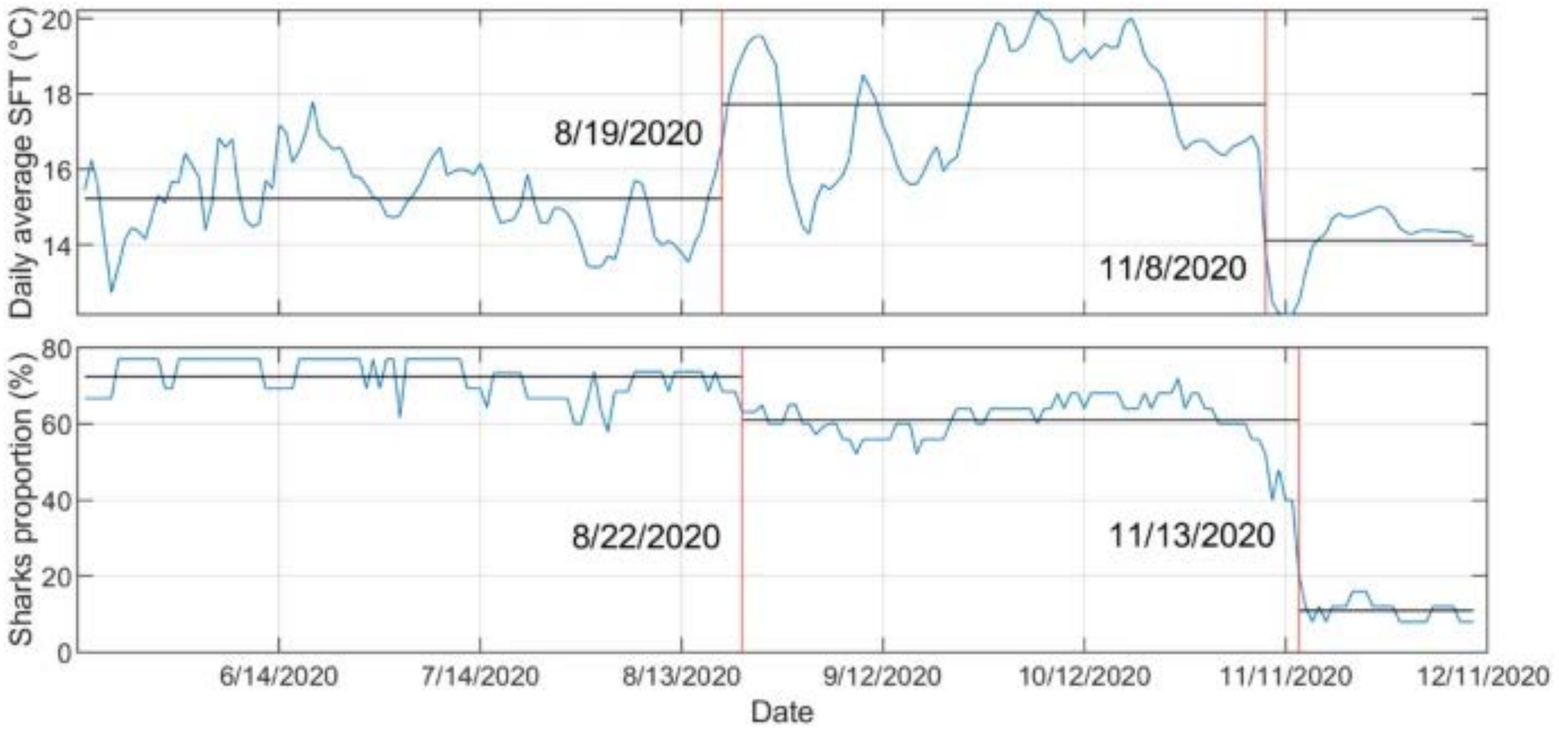


- Yi Liu, a visiting undergraduate student at UofT, worked with Emily Sturgeon from the Shark Lab
- Emily captured average sea surface and sea floor temperature and displayed these against the percentage of sharks that remained in the area
- Led to a paper in Scientific Reports, “Quantifying thermal cues that initiate mass emigrations in juvenile white sharks”

Change-point Analysis for Temperature Cues

- We wanted to understand when there were shifts in presence of sharks in the area and how they might connect with changes in temperature

- Yi conducted change-point analyses for temperatures and percentage of sharks present



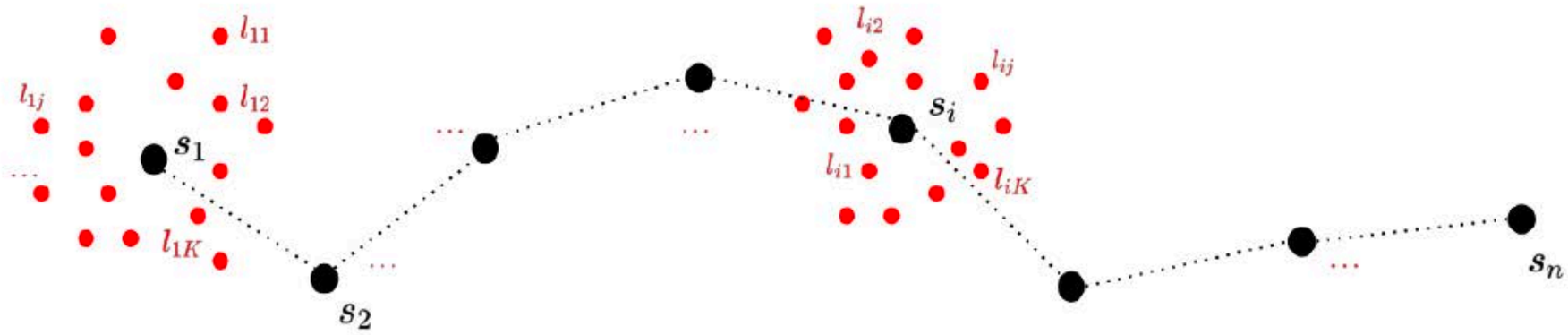
Ecological Statistics Summer Club

- Statistics students, especially undergraduate students, seem to be quite motivated to work on applied projects related to environment + climate change
- We made a club! A group of ~12 students + my postdoc Jessica Lievesley have met all summer to continue analysis on the juvenile white shark data sets

Integrated Step Selection Analysis

- We want to understand how juvenile white sharks move across the habitat and the role that temperature plays at a finer temporal scale

- To do this, we are using an integrated step selection analysis — this is a method that is commonly used in ecology to understand what animals chose instead of what they *could have chosen*

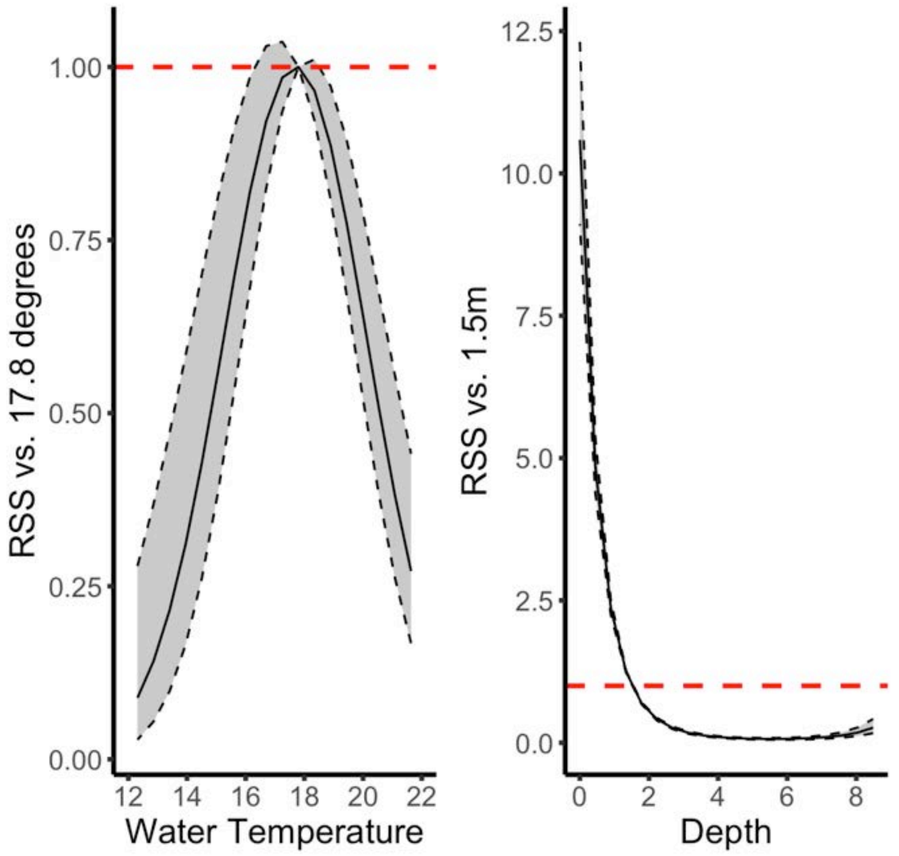


Initial Results

- We are quantifying their horizontal movements and relating that to depth and temperatures — currently working on further including distance to shore, habitat and presence of other sharks

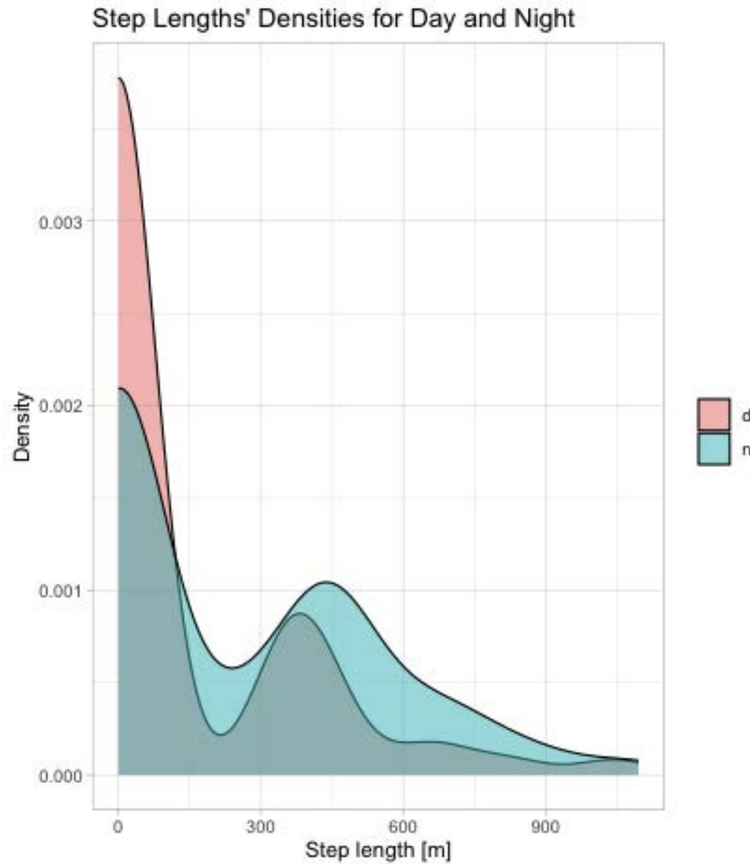
- We've fit models to each shark and are able to understand how the sharks may overall choose to be at certain temperatures and depths

- For this shark, it would much prefer to be around ~17.8 degrees celsius water and at the surface (this shark likes to be warm...enough)



What else is there?

- Tracking prey animals is key to differentiating between the influence of habitat vs prey availability on their movements
- We've got data on giant sea bass, leopard sharks, stingrays (sea pancakes)
- For a further update, account for behavioural affects on how they choose to move, to inhabit different areas (via a Markov-switching iSSA)
- Overall: A core theme is that ocean dynamics (water temperature/prey availability) will affect how the sharks move, behave, aggregate, and so on.



Sea bass movements

Thanks!

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  Vinky Wang, Yi Liu, Hongyu Chen, Alan Yue, Sabrina Sixta, Jessica Leivesley, Ismail Benchekroun, Isaac Hua, Benson Chou, Adele Lauzon, Syed Natiq Ali Abidi, Brian Diep, Zhuoran Li, Huiru Hong, Kaylen Wei