Relationships between length and habitat characteristics of select Bering Sea flatfish.

Summary: This investigation uses the NOAA RACE Eastern Bering Sea Continental Shelf Survey dataset from years 2000-2018. The species of interest are Alaska plaice, flathead sole, northern rock sole, and yellowfin sole. The habitat characteristics of interest are depth, temperature, and sediment size. Primary findings surrounding depth and temperature were consistent with the literature, though more investigation into the contour plots may be useful. For sediment size the smallest of northern rock sole and of yellowfin sole may behave differently in extreme marine heat wave years, but the difference is slight.

Methods

I. Data Manipulation

Expand Lengths: Lengths are collected from subsets of a haul, but for this analysis a length for every fish caught in every haul was desired. These values were determined by first taking a given species and calculating the proportions of each fish of each length in a specific haul subset sample. These proportions were then applied to the total number of fish of that species in that same haul such that the various proportions of each length value matched the same proportions of that length value in the subset sample. This method was used for every haul in the dataset.

Length Binning: For a given species, after expanding the lengths such that each fish in each haul has an individual length, lengths were split up into quantiles. Each quantile contains 12.5% (1/8) of the data. This was done for the boxplots but not for contour plots or hexagonal heat maps.

Sediment Size (Phi): This information is not in the original data retrieval for this project, so instead a dataset for Arrowtooth Flounder was used. In this dataset the variable Phi is used as a proxy for sediment size. ($\varphi = -ln(Sediment\ Size)$). Since the Phi data ended in 2010, it was filtered to include only the years of overlap with our original data (2000-2010). Station numbers are inconsistent, so the only way to match the same station over time is by the latitude and longitude values for each haul. Though these are close year to year, they are not the same and are therefore difficult to match together. To accomplish this matching the leaderCluster package in R was used. The leaderCluster function calculates clusters based on a user provided radius using Hartigan's Leader Algorithm. The value for radius was determined through trial and error to be 0.175. Using these clusters as a grouping factor allowed for determination of an average Phi value for each latitude and longtitude centroid ("station"). For further explanation and validation of this application please see Dec032020_phi_data.html in the work sessions folder of the GitHub Repository. Finally, the phi data was matched to each haul in our expanded length dataset by use of leaderCluster again and joins.

Marine Heat Wave Years: This categorization was determined by subject matter knowledge. The Extreme Marine Heat Wave years are 2015 and 2016.

Warm vs. Cold Years: Data were pared down to include only bottom depths between 50 and 100 meters within the time period of interest (2000-2018). From these data gear temperature was averaged to determine an overall mean temperature for the period. This overall mean was compared with the yearly gear temperature means (again, only years 2000-2018 and depths 50-100m) to categorize each year as “warm” or “cold” depending on if the average temperature was more or less than the overall average. Note that 2017 was determined to be cold by this method.

Year	**Average Temperature (°C)**	**Category**
2000	1.477	cold
2001	2.031	warm
2002	2.561	warm
2003	3.203	warm
2004	2.502	warm
2005	2.275	warm
2006	0.975	cold
2007	0.713	cold
2008	0.679	cold
2009	0.536	cold
2010	0.383	cold
2011	2.000	warm
2012	0.208	cold
2013	0.561	cold
2014	2.384	warm
2015	2.481	warm
2016	3.716	warm
2017	1.434	cold
2018	3.798	warm
Overall Average Temperature (°C):		1.743

II. Visualization

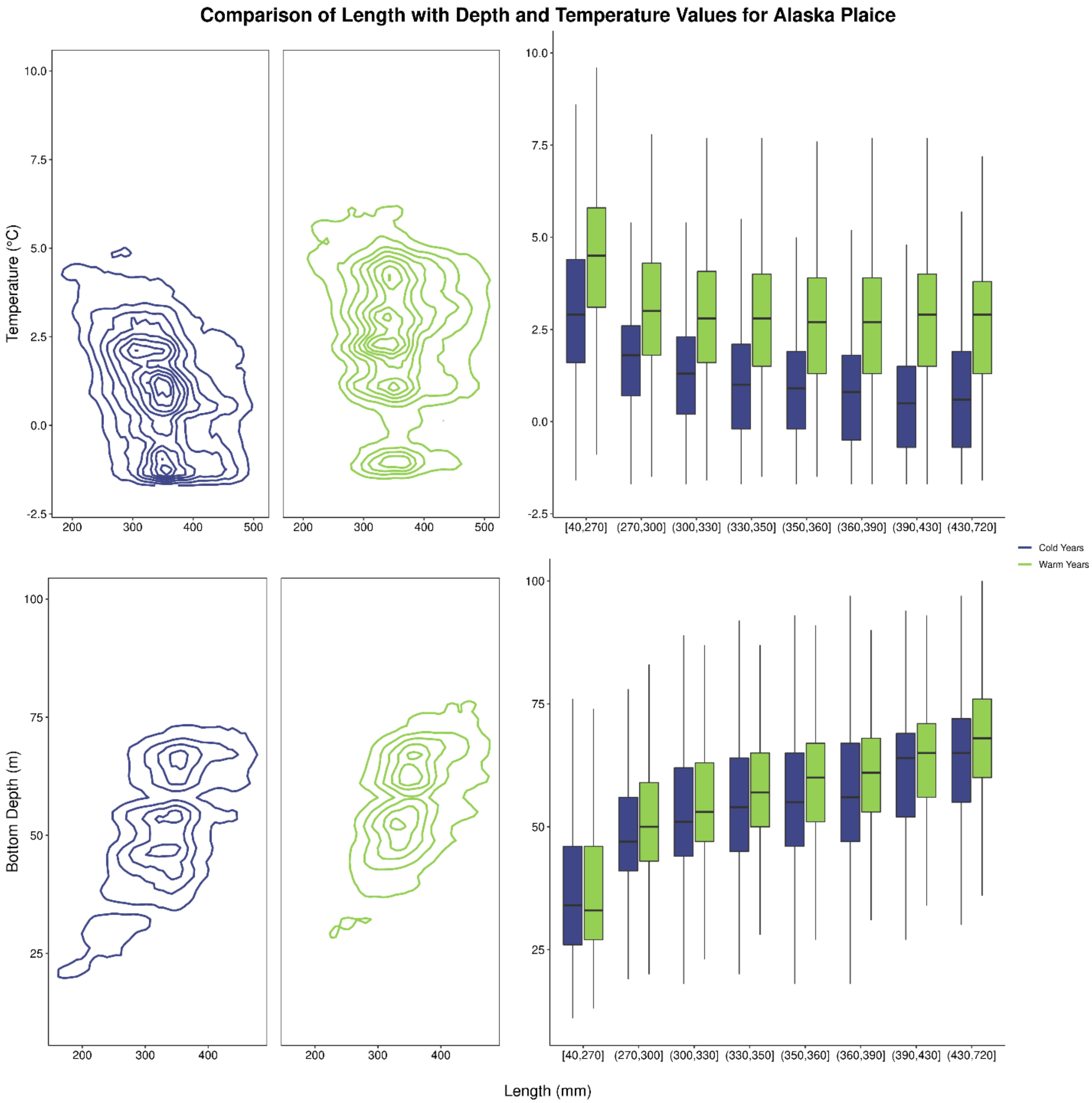
Boxplots: gear depth, bottom temperature, and phi were each individually compared with the binned length values for each species. This was done once with everything grouped into “warm” and “cold” years, and then repeated with everything grouped into “Extreme Marine Heat Wave Years” and “Non-Extreme Marine Heat Wave Years”.

Contour Plots: gear depth, bottom temperature, and phi were each individually compared with the un-binned length values for each species. This was done only once with everything grouped into “warm” and “cold” years.

Hexagonal Heat Maps: gear depth, bottom temperature, and phi were each individually compared with the un-binned length values for each species. This was done only once with everything grouped into “Extreme Marine Heat Wave Years” and “Non-Extreme Marine Heat Wave Years”. Originally contour plots were tried for these comparisons, but they were too computationally intensive in this grouping.

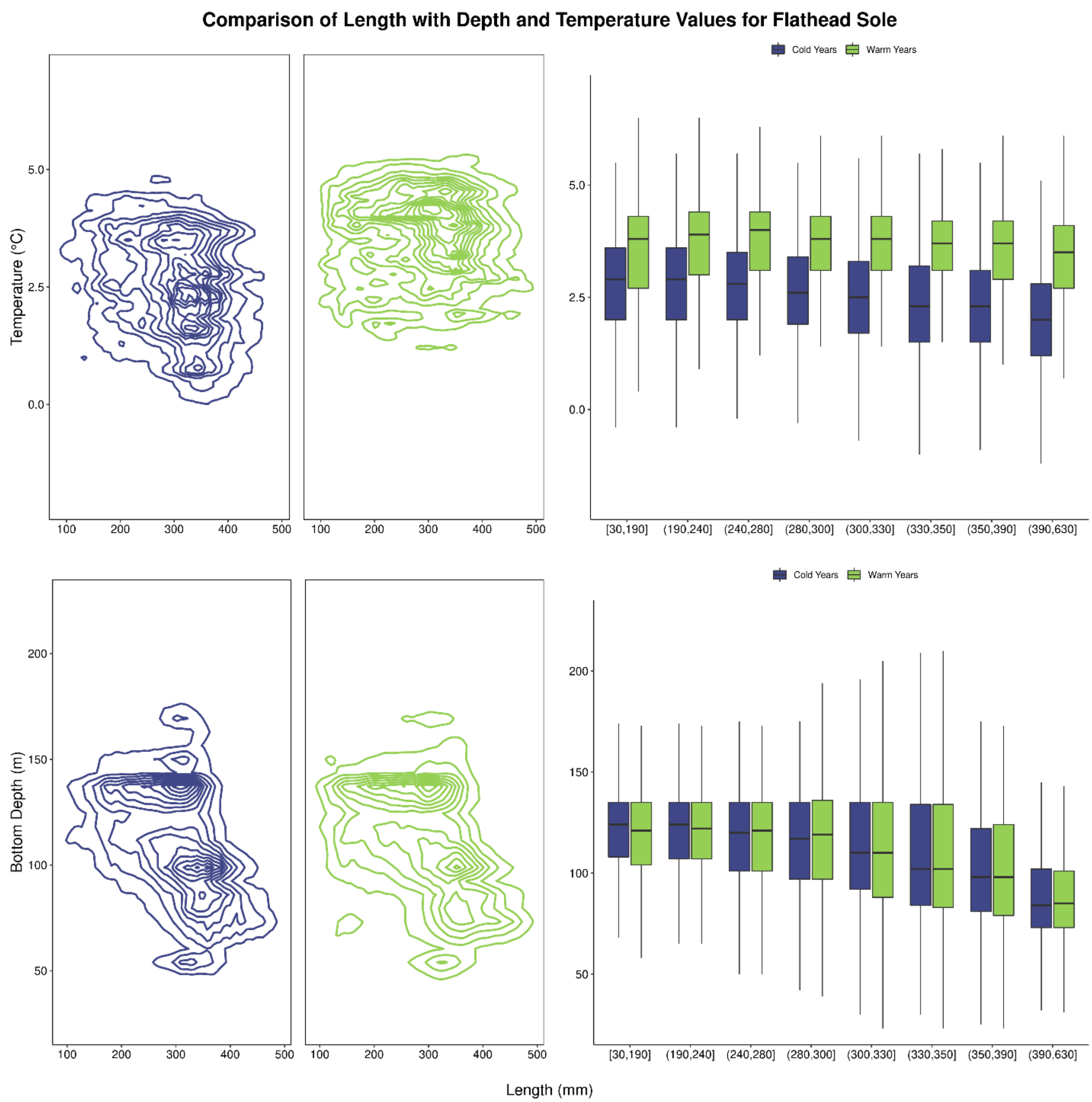
Results

I. Warm vs. Cold years:



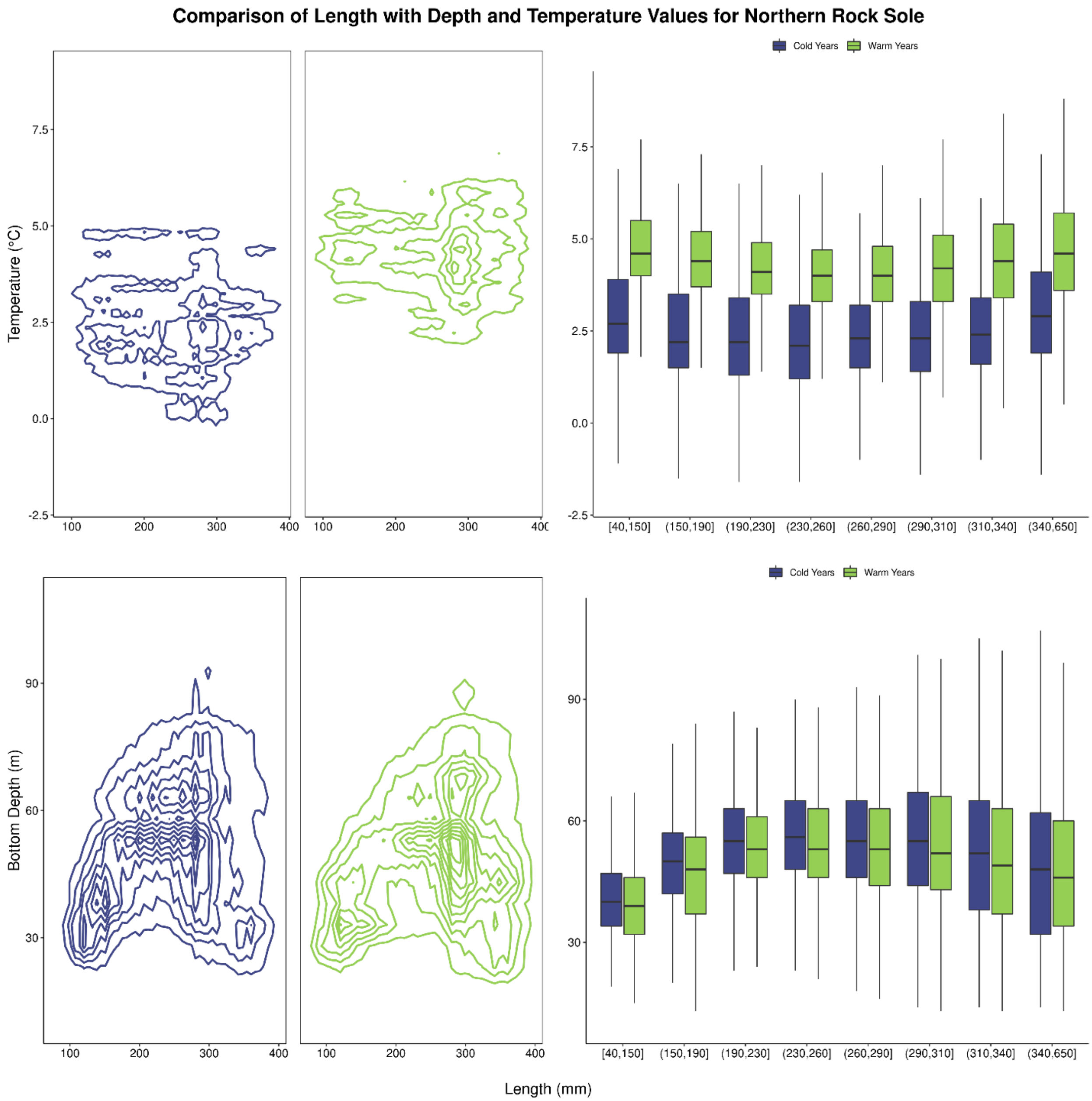
In warm vs. cold years Alaska plaice appear to accommodate changes in their surrounding temperature rather than changing depth.

The smallest of the species seem to inhabit shallower depths.



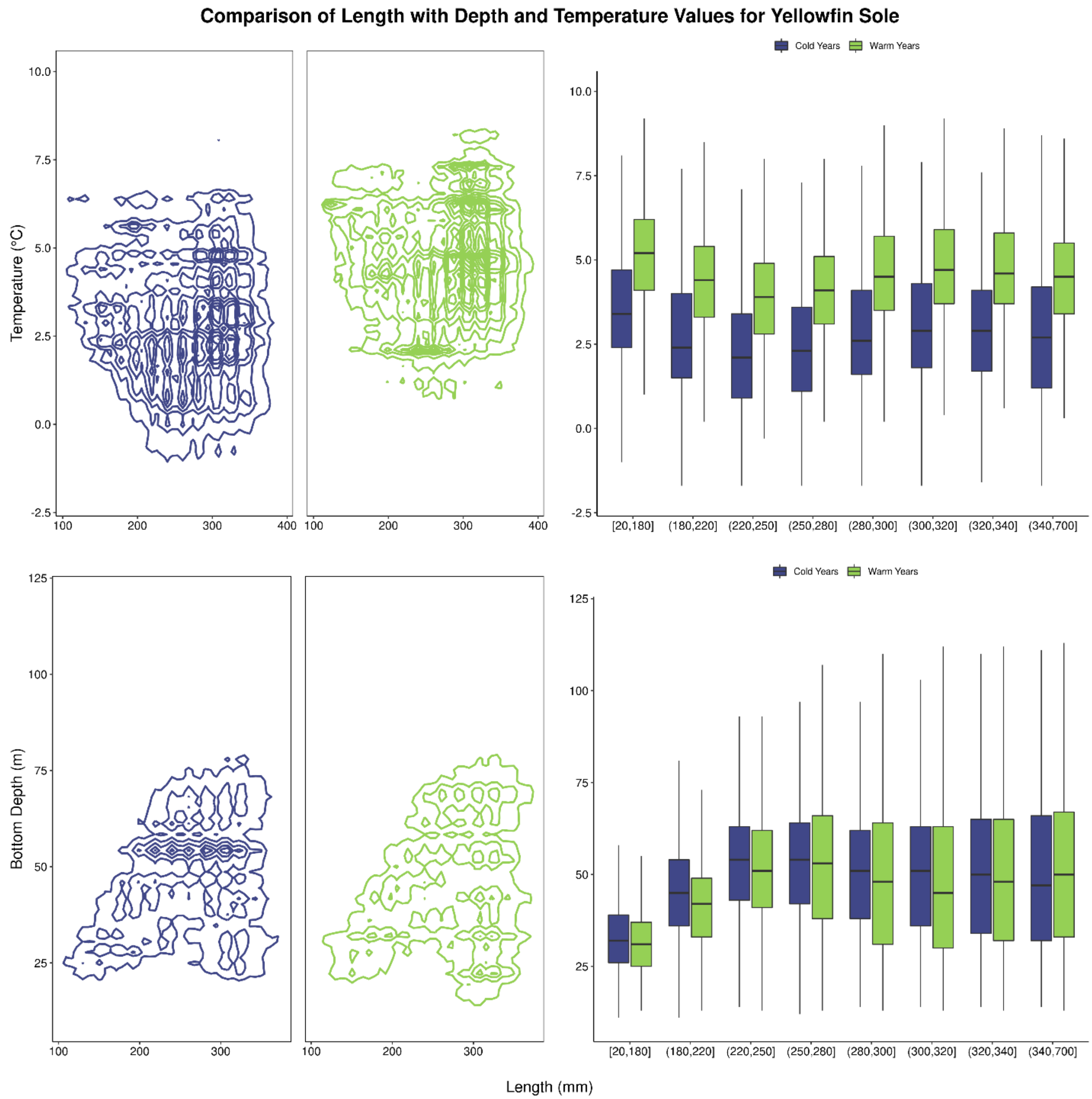
In warm vs. cold years flathead sole appear to accommodate changes in their surrounding temperature rather than changing depth.

Similar depths are inhabited throughout lifespan, though it is possible that the largest of the fish prefer shallower depths.



In warm vs. cold years northern rock sole appear to accommodate changes in their surrounding temperature rather than changing depth.

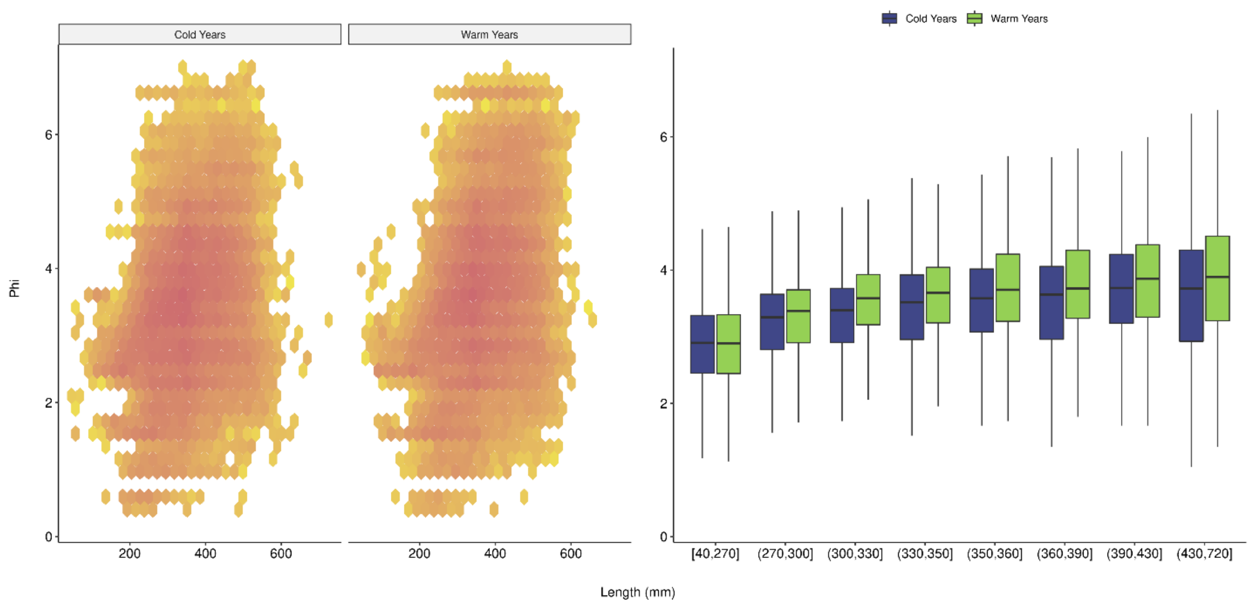
There seems to be a curve to the depths inhabited throughout the size range, with the smallest and the largest fish appearing at slightly shallower depths. There also may be an increase in variance of depth inhabited for the largest fish.



In warm vs. cold years yellowfin sole appear to accommodate changes in their surrounding temperature rather than changing depth.

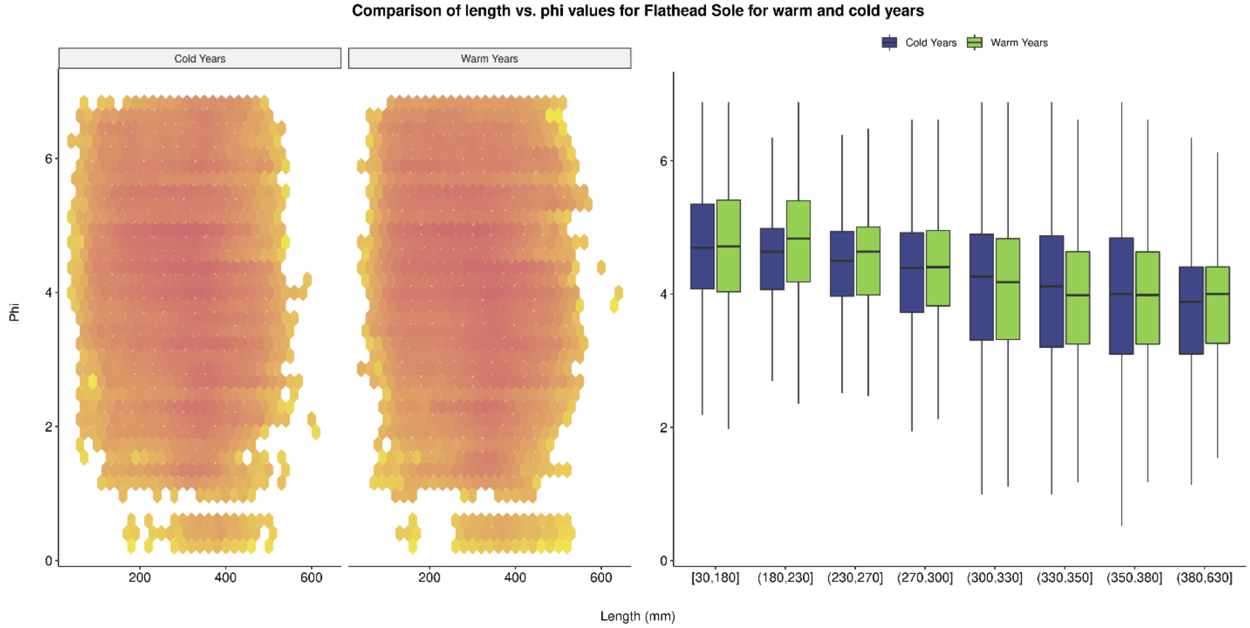
The smallest fish seem to have much less variance in their inhabited depth.

Comparison of length vs. phi values for Alaska Plaice for warm and cold years

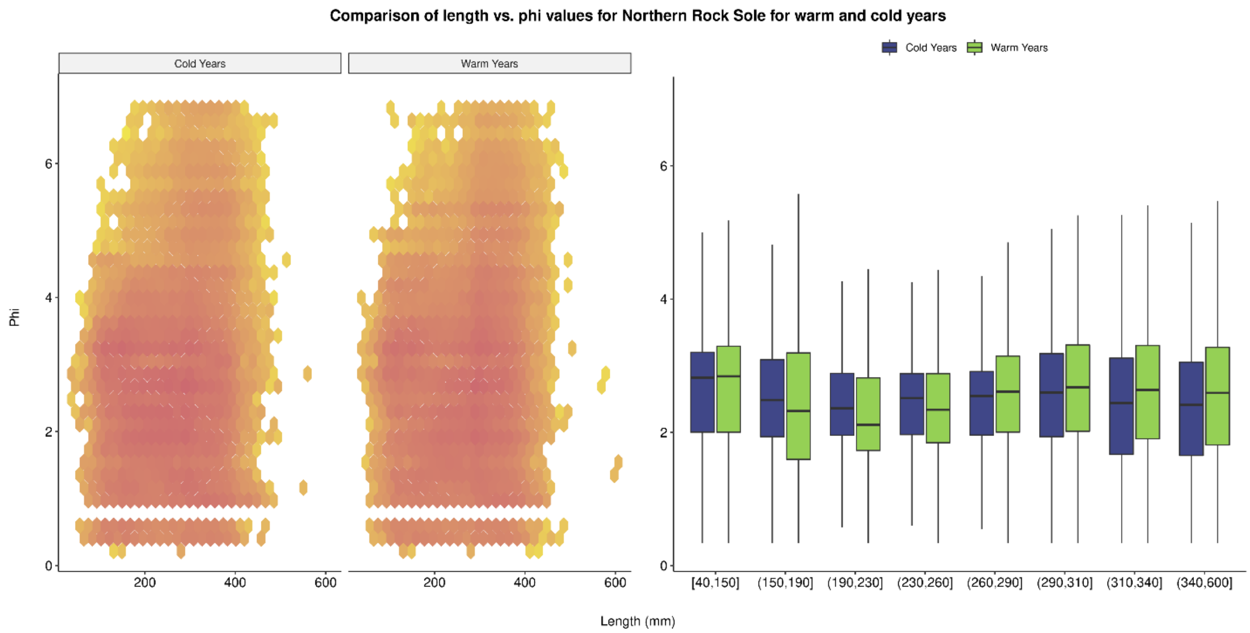


Sediment size of inhabited area seems to be constant for Alaska plaice of a given length in warm vs. cold years. Variance and sediment size may increase for larger fish, but the change is small if there at all.

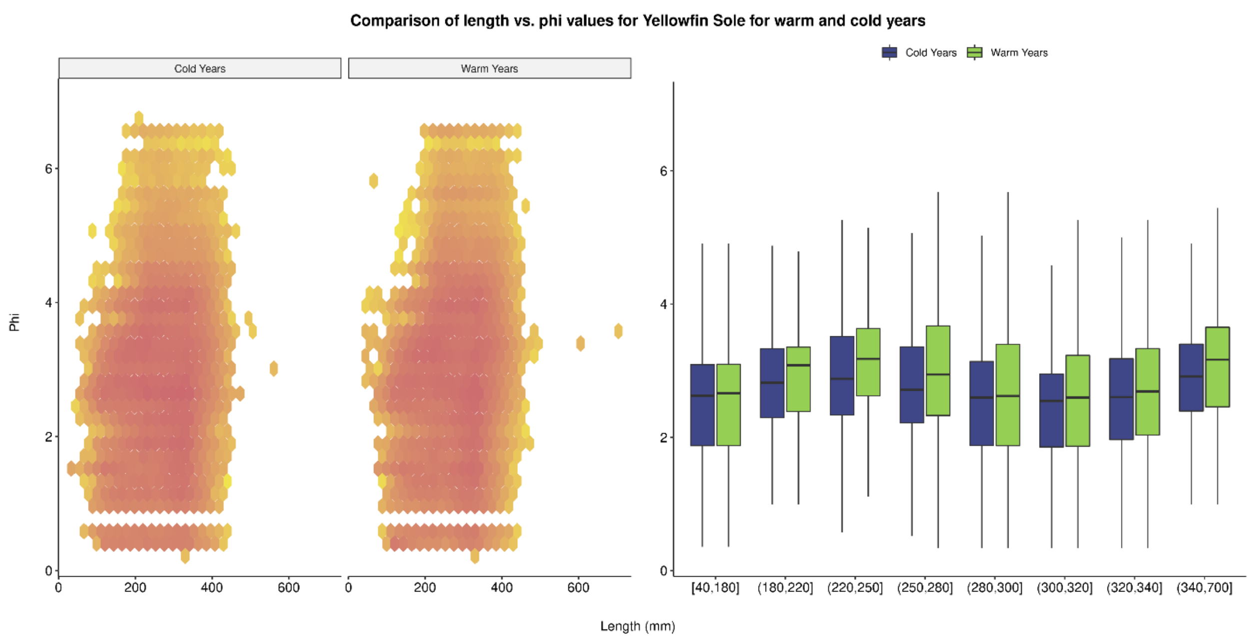
Comparison of length vs. phi values for Flathead Sole for warm and cold years



Sediment size of inhabited area seems to be constant for flathead sole in warm vs. cold years.

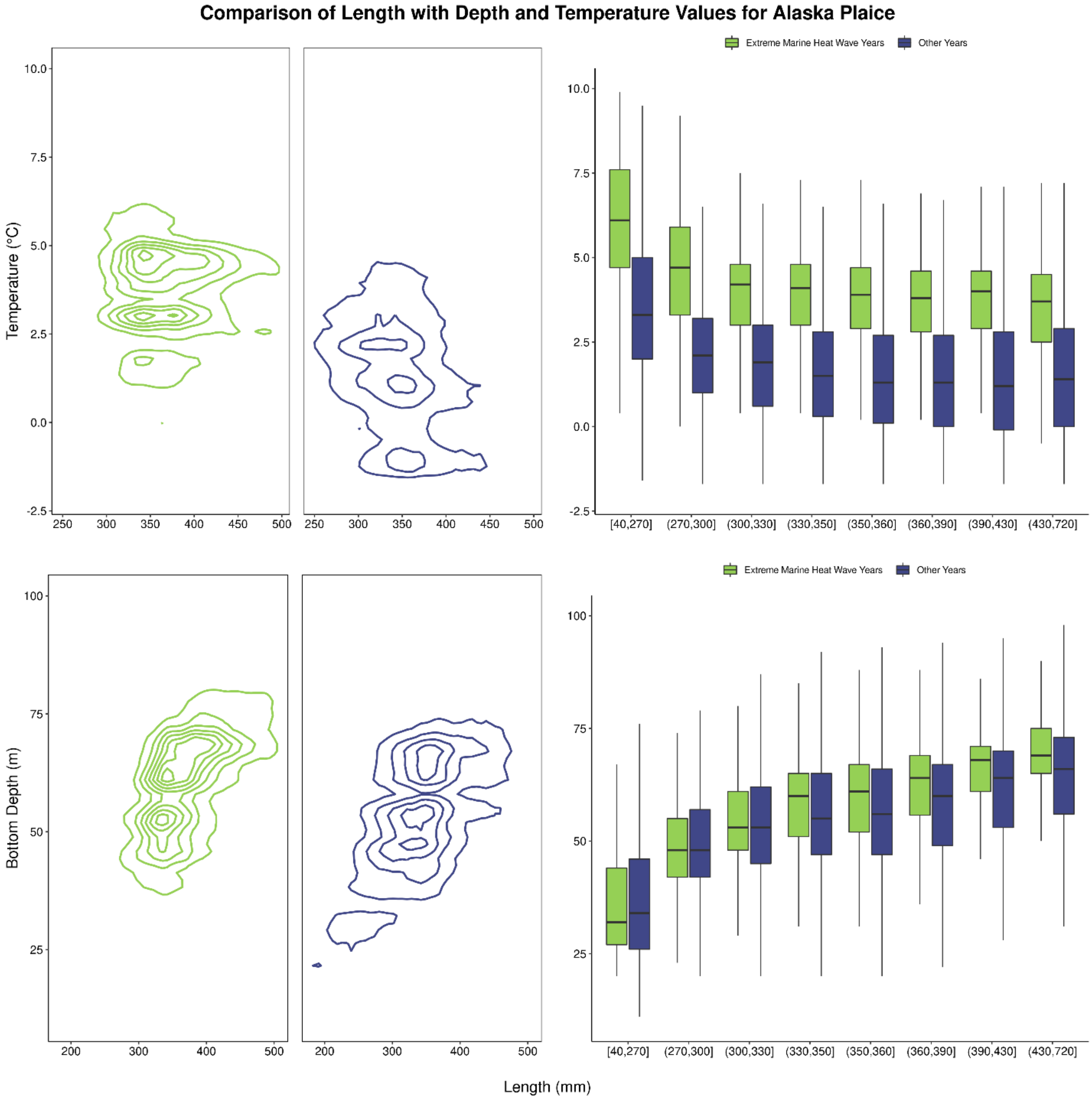


Sediment size of inhabited area seems to be constant for northern rock sole in warm vs. cold years.

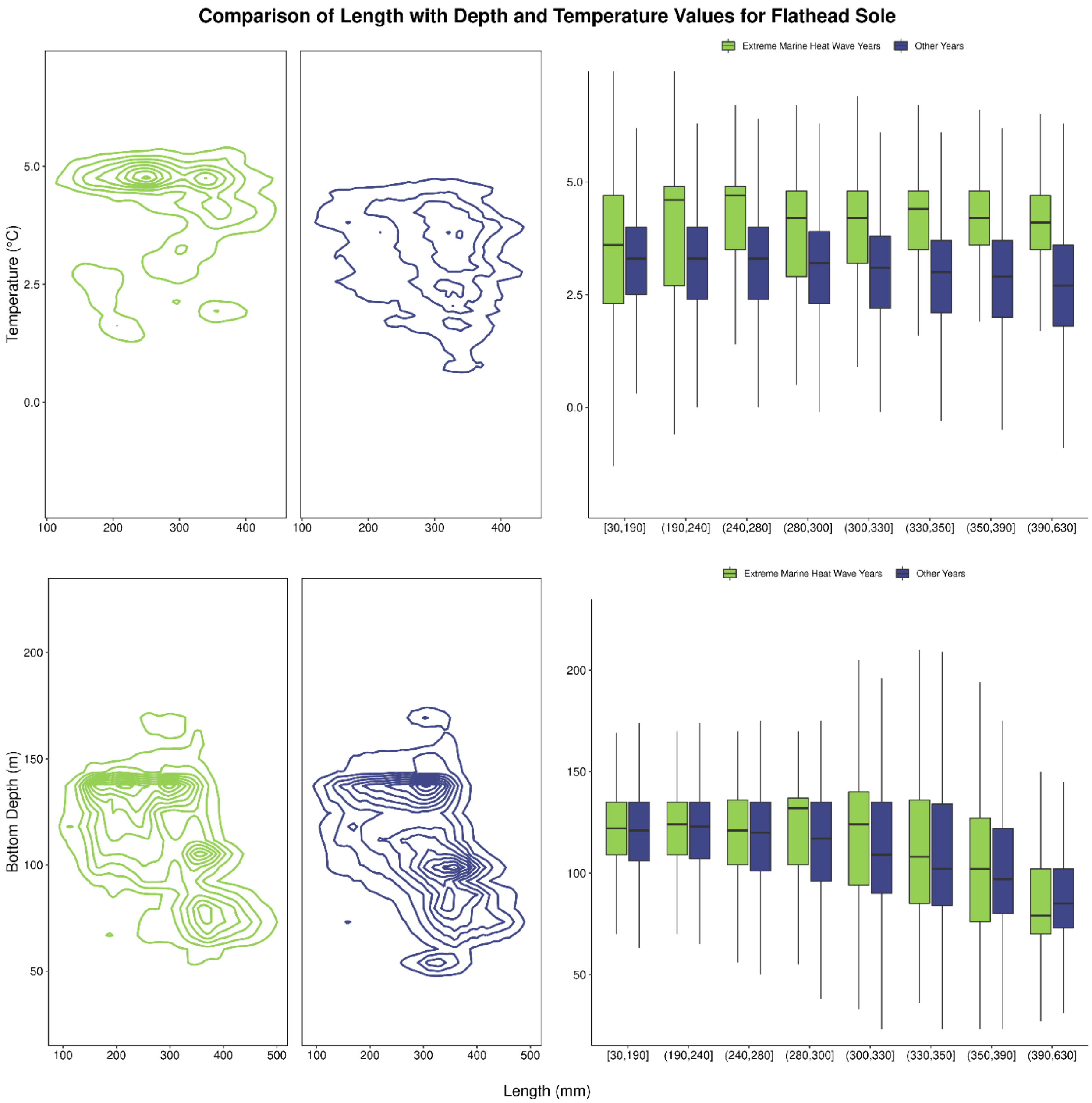


Sediment size of inhabited area seems to be constant for yellowfin sole in warm vs. cold years.

I. Extreme Marine Heat Wave vs. Other Years:

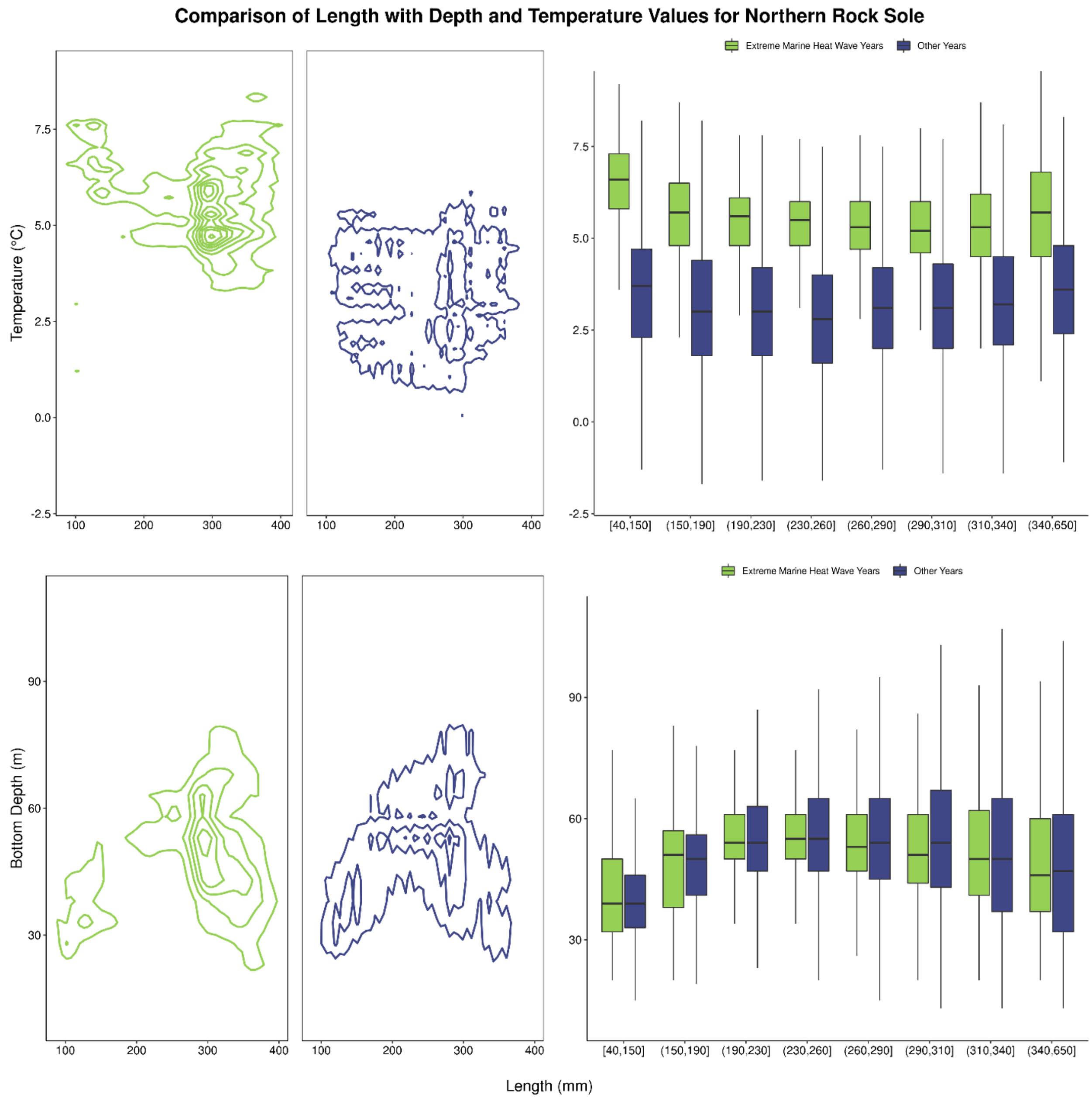


There may be indication that during extreme marine heat wave years larger Alaska plaice don't inhabit the shallower depths that are within their typical range in other years.



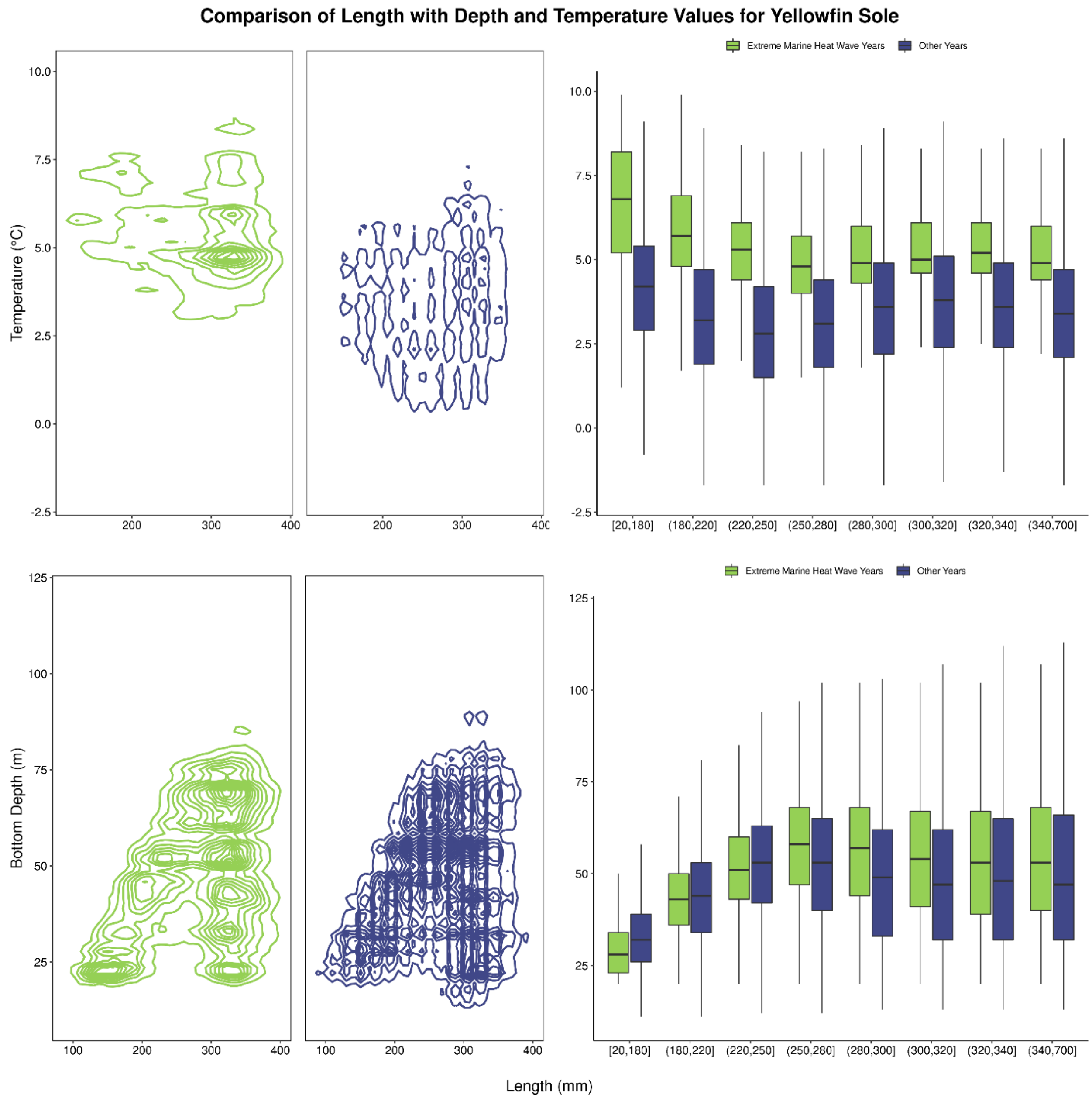
In extreme marine heat wave years flathead sole appear to accommodate changes in their surrounding temperature rather than changing depth.

Again, we see that similar depths are inhabited throughout lifespan, with the possibility that the largest of the fish prefer shallower depths. It also appears that the smallest and largest of the species have less variation in their inhabited depths.



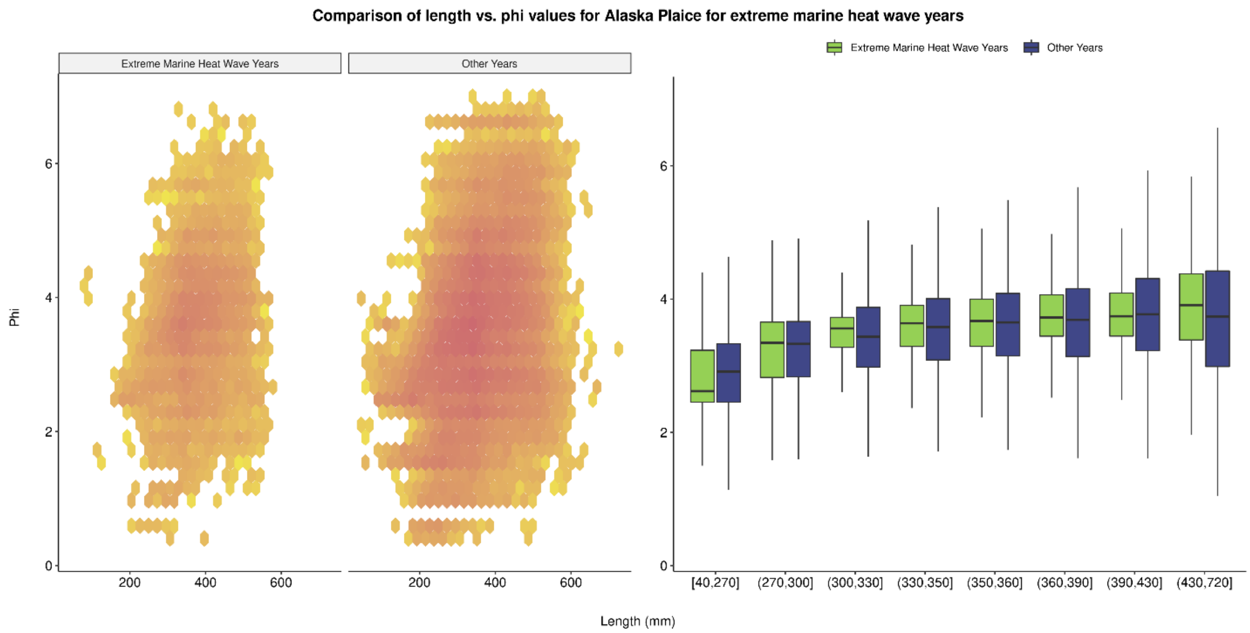
In extreme marine heat wave years northern rock sole appear to accommodate changes in their surrounding temperature rather than changing depth.

Again, we see that there seems to be a curve to the depths inhabited throughout the size range, with the smallest and the largest fish appearing at slightly shallower depths. There also may be an increase in variance of depth inhabited for the largest fish

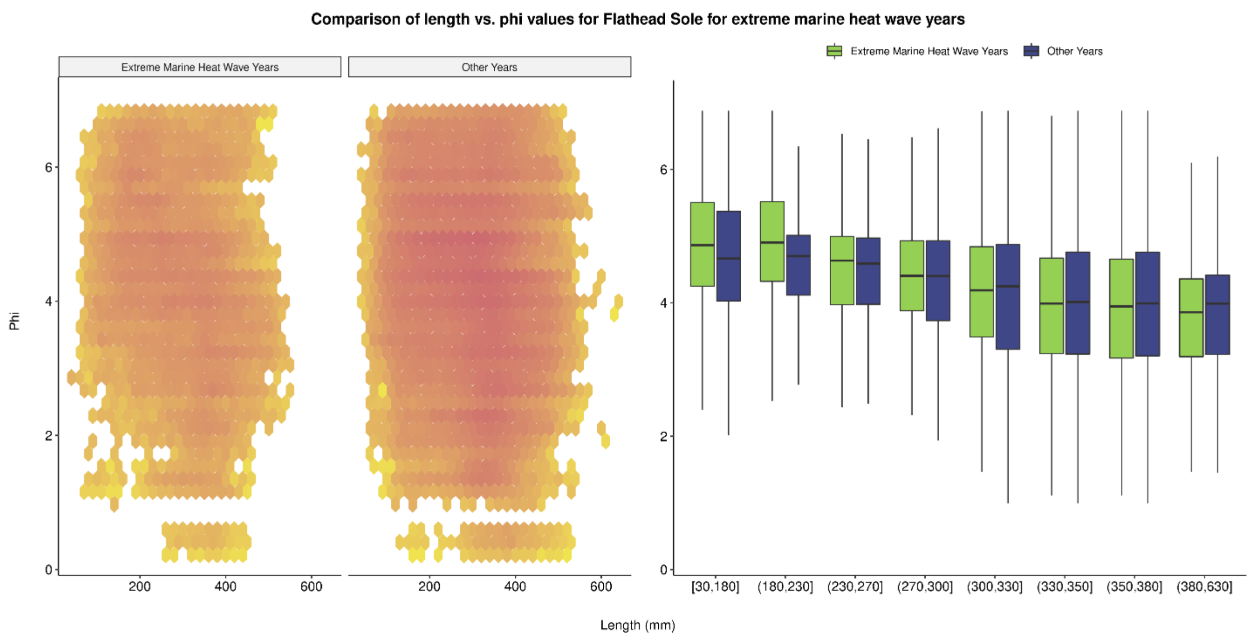


In warm vs. cold years yellowfin sole appear to accommodate changes in their surrounding temperature rather than changing depth.

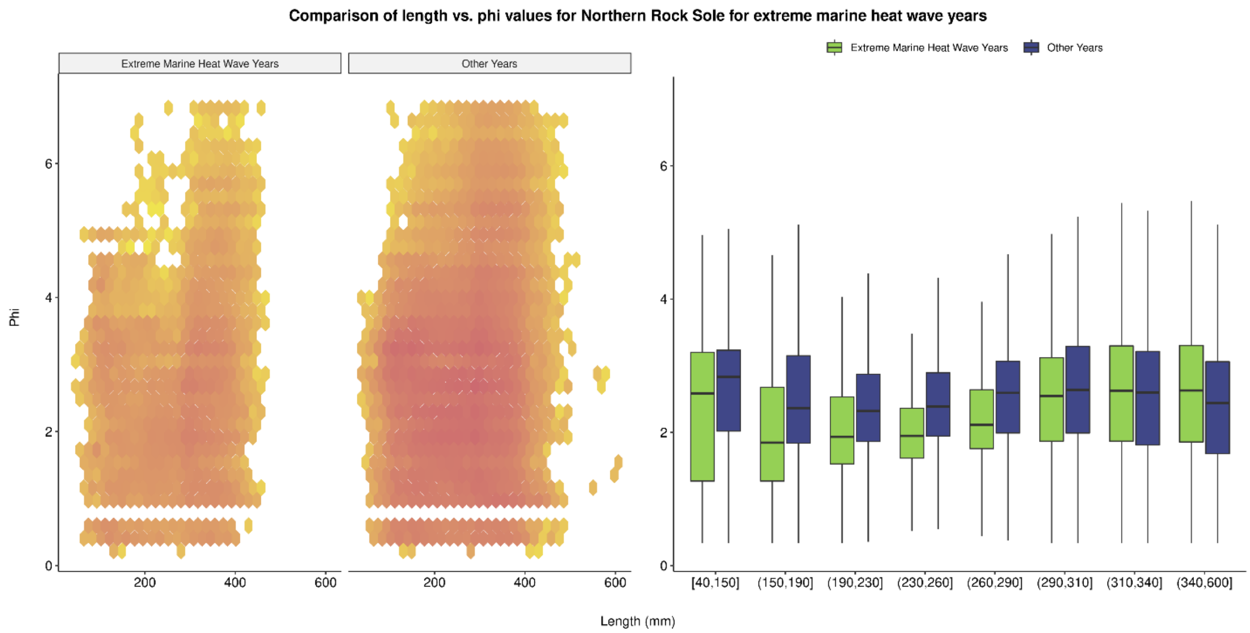
The smallest fish seem to have much less variance in their inhabited depth as compared to the larger fish.



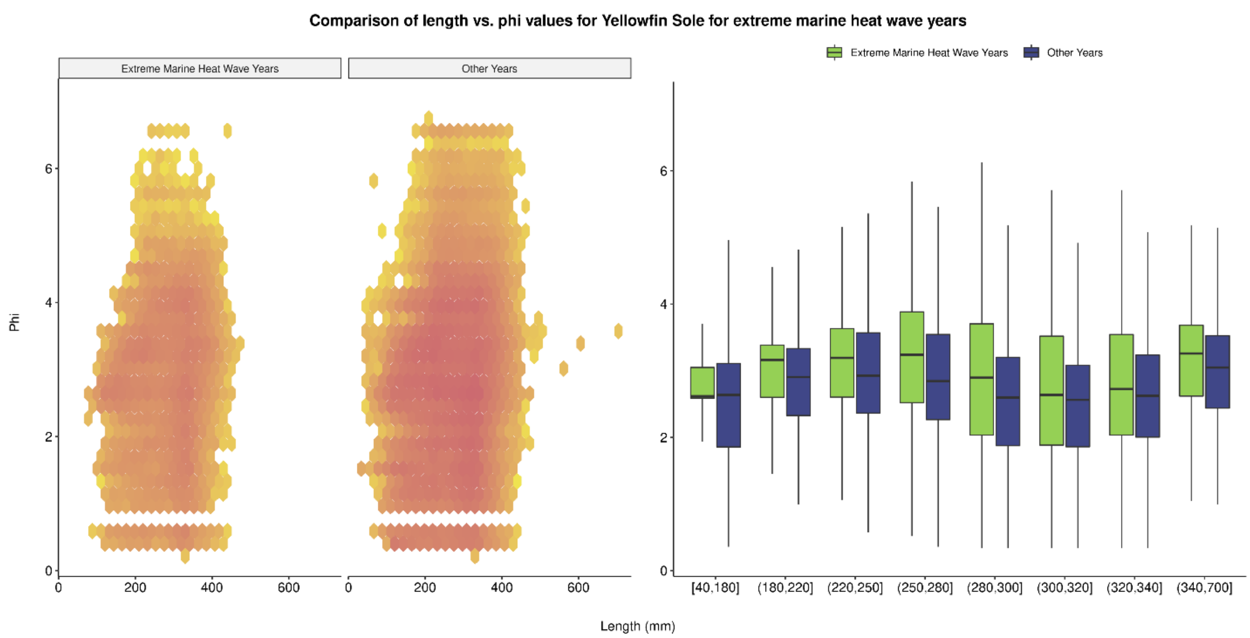
Sediment size of inhabited area seems to be constant for Alaska plaice of a given length in extreme marine heat wave years as compared to other years. Variance may be greater for years that are not extreme marine heat wave years, but this is likely just due to the increased number of data points in a grouping of 16 years vs. 2 years.



Sediment size of inhabited area seems to be constant for flathead sole in extreme marine heat wave years as compared to other years.



Sediment size of inhabited area seems to be similar for northern rock sole in extreme marine heat wave years as compared to other years, though the smaller fish may be more likely to inhabit areas with smaller sediment size in extreme marine heat wave years.



Sediment size of inhabited area seems to be constant for yellowfin sole in extreme marine heat wave years as compared to other years, though the smaller fish may be more likely to inhabit areas with larger sediment size in extreme marine heat wave years.

Conclusions

Findings for depth and temperature variation between warm and cold years aligned well with those by Barbeaux and Hollowed (2017, https://doi.org/10.1111/fog.12229). For sediment size, there is some discrepancy for the smallest of the northern rock sole and yellowfin sole in extreme marine heat wave years. For the small northern rock sole, we see more variation and an increased presence in smaller sediment in extreme marine heat wave years. For small yellowfin sole we see less variation and a decreased presence in smaller sediment in extreme marine heat wave years. However, these differences are small.

Feel free to send any questions to smith.ericka.b@gmail.com or @erickabsmith on GitHub.