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Modeling Decisions in Hawaii's Deep-set Longline Fishery: simulations under climate-driven biomass change

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Outline

- Brief overview of utility-theoretic choice models
- The deep-set longline fishery in Hawaii
- Longline site choice model development
- Results and applications
- Feedback and questions welcome!



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Overview of Fisheries Site-Choice Model

- Grounded in economic theory - choices we make about goods/services are a function of attributes & how we make trade-offs among them
- Fishing site is the good - fisher's choose to fish a particular site based the attributes of the site such as expected revenue, expected catch, environmental features of site, cost or distance to get to site – making trade-offs to maximize utility
- Repeated or cross section of observations about site choice – fit a model that tells us something about how fishers make trade-offs e.g. cost and expected catch
- Fitted model - predict effort redistribution, welfare changes, marginal substitution rates, under different policy or attribute-related scenarios
- Lots of applications in commercial and recreational fisheries, fewer for Hawaii-based commercial fisheries



Fitted Model: RUM

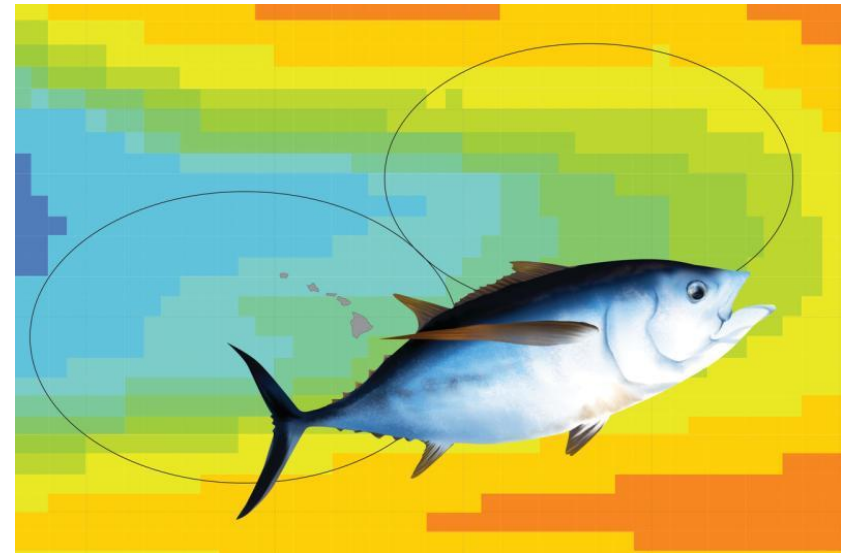
Probability of choosing 'j' from choice set:	$\Pr(j C) = \Pr(U_{ij} \geq U_{ik}) \quad \forall k \in C$
Utility of 'j' a function of deterministic component (indirect utility) and random error:	$U_{ij} = V_{ij} + \varepsilon_j$
Indirect utility a function of attributes of 'j':	$V_{ij} = \beta X_{ij}$
Model estimated through maximum likelihood:	$\Pr(j C) = \frac{\exp(\beta X_{ij})}{\sum_{k=1}^K \exp(\beta X_{ik})}$

Many extensions to conditional logit to address and relax assumptions: nested logit, random parameters (mixed) logit, latent class logit, latent class with random parameters, error components logit



Hawaii's Longline Fishery

- Hawaii deep-set longline target adult Bigeye tuna (*Thunnus obesus*)
- Limited entry fishery, 164 permits, renewable and transferrable (147 active vessels, 2022)
- Area fished spans 13 million km²
- Fishery effort and area fished has increased over last 20 years
 - Annual hooks set increased 8m to 47m, landings and revenue increased
 - Mid 90s, most effort operated in southern waters around Hawaii
 - 2015, 40% of effort operated in waters northeast of Hawaii



Map & Info credits: NOAA Fisheries PIFSC, 2018
Woodworth-Jefcoats et al.

Hawaii's Longline Fishery

- One of state's largest food producer, 80% of landings stay in state
- High value fishery, represents 85% of commercial fisheries landings and revenue
- Managed by Western Pacific Fishery Management Council (U.S. and Territories) and Western Central Pacific Fisheries Commission (RFMO, 25 members)
- Hawaii deep-set ll just quota 6,554 (~10% of total catch)
- Reporting regulations, gear regulations, area closures



Model Development

- Build a model that predicts the choice of fishing site as a function of other measurable site-specific variables.
- Data-rich fishery:
 - longline logbook data for 2021-2023 (post-Covid)
 - CPUE, number of fish kept, lbs. of fish kept, lat./long. of each set in trip, many other variables
 - Ocean Watch Central Pacific Node
 - Environmental variables, SST, ONI
 - PIFSC Trip Cost Model
 - Predictive model developed by Hing Ling Chan and Minling Pan – can predict cost per km travelled (by vessel & trip)
 - Hawaii dealer data, Fisheries Statistics of the US



Modeling Decisions



“All my decisions are objective and well thought out.”

- **How to define the fishing site?**
 - Latitude/longitude of set
 - Aggregation of sets (e.g. 5 x 5 degree grid)
 - Other delineations
- What are fishing site attributes?
 - Expected CPUE, number or pounds of fish, revenue,
 - Distance to site, cost to get to site

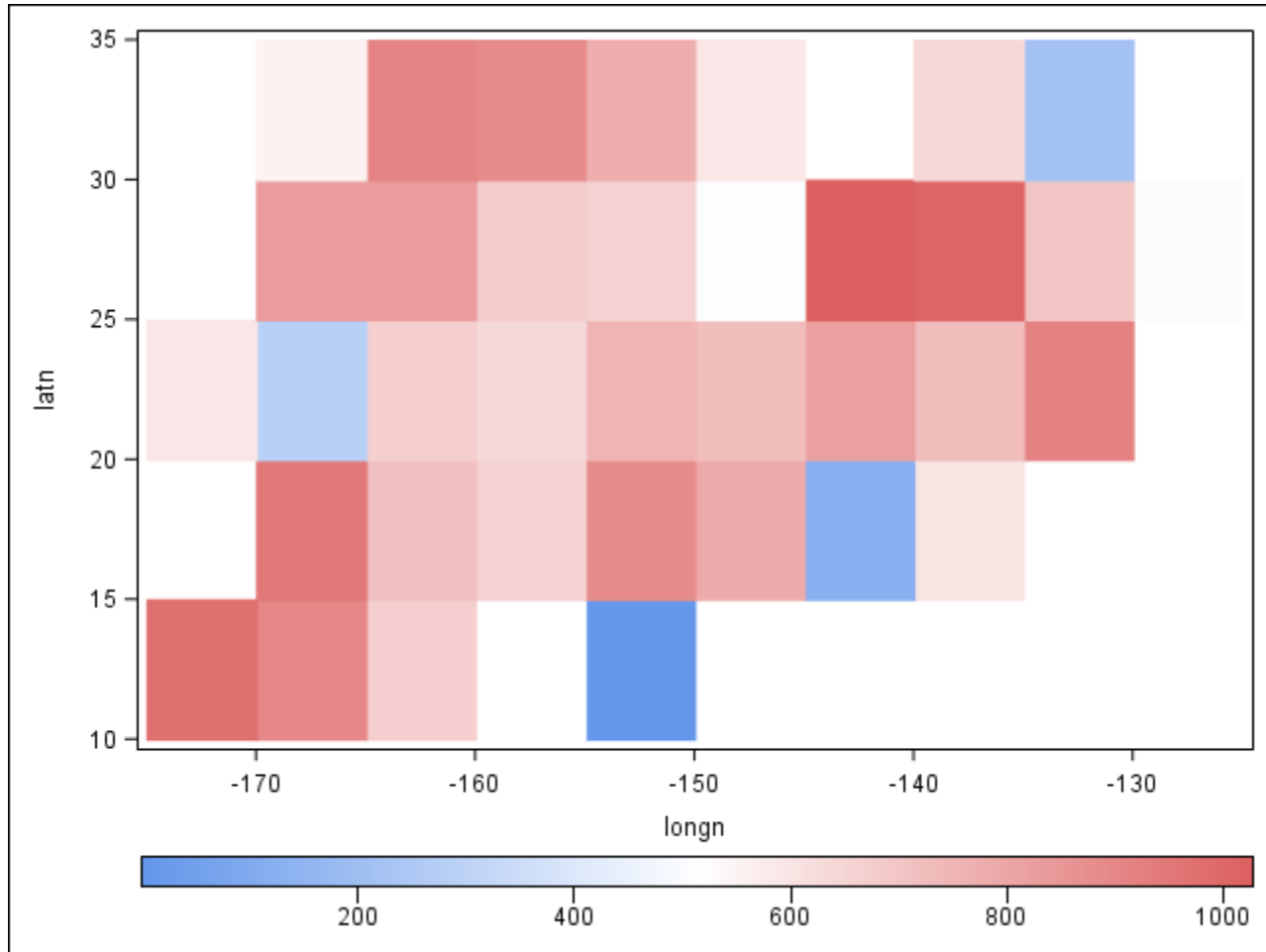
- **What is/how many sites are in the fisher's choice set?**
 - All potential lat/long coordinates of sites fished
 - All aggregated sites fished
 - Nearest neighbors to observed choice
 - Random sample of sites
 - Other ?
- Inclusion of other variables
 - Environmental, choice-invariant, other
- Model specification
 - Conditional logit, extensions to relax assumptions (*error components, nested logit, random parameters, latent class*)

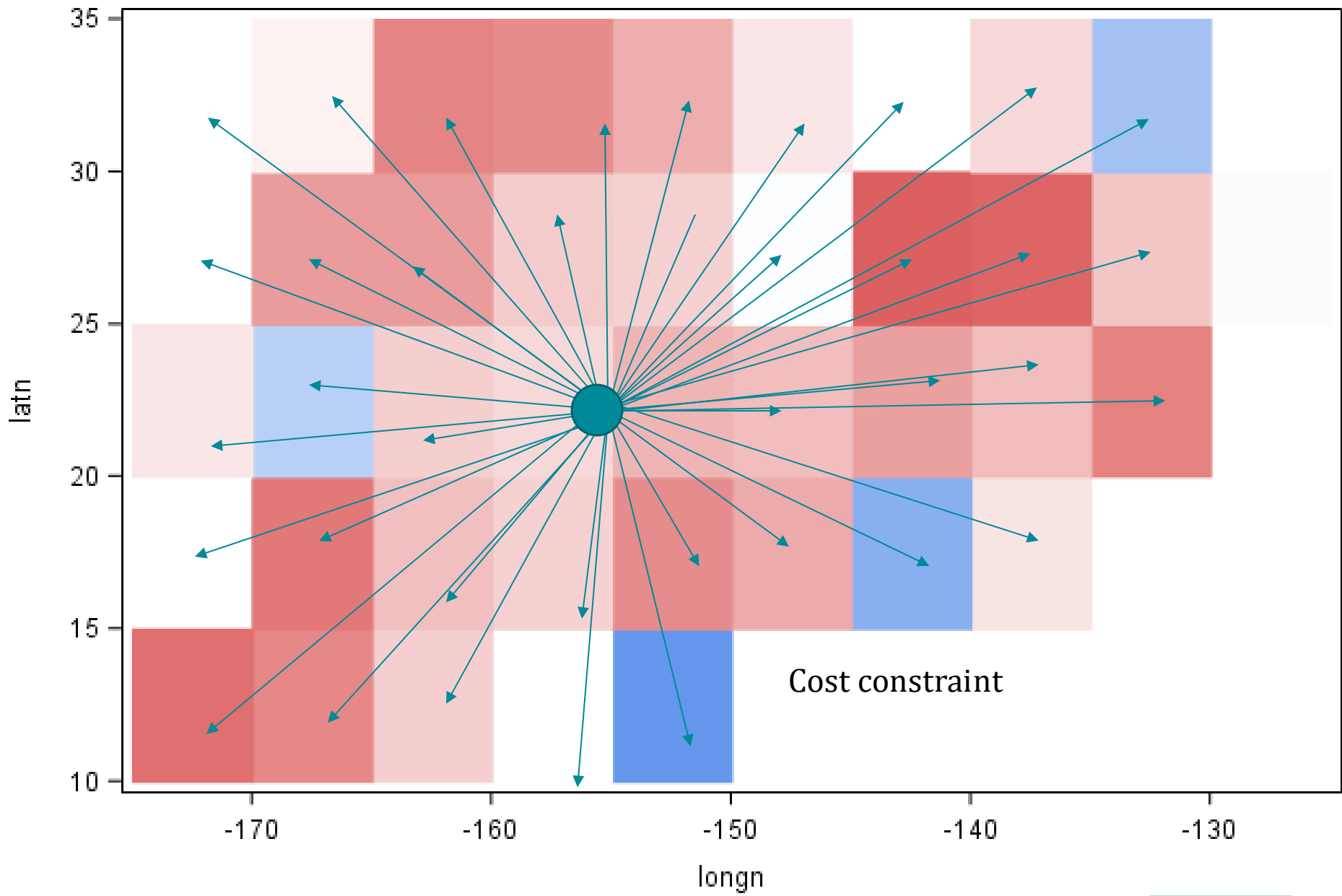
Final Model Specs

- Fishing site choice as a function of expected lbs of bigeye caught, expected sea surface temp., expected ONI, and expected cost to reach site
 - Expected lbs., sst, and ONI – average by month/quarter from previous three years
 - Expected cost – predicted cost per mile using model developed by Hing Ling Chan and Minling Pan at PIFSC
- Fishing site is defined a lat/long cell 5 x 5
- Post-covid 2021 – 2023
- Models for each quarter (q1=Jan, Feb, March)...
- Conditional logit



Expected Site Attributes: Q1: Lbs. of Bigeye





QTR 1 37 Site Alternatives

CHOSEN	Coefficient	Standard Error	z	Prob. z >Z*	95% Confidence Interval	
EXPLBSBE	.00209***	.00012	18.15	.0000	.00186	.00231
EXP_SST	.38109***	.01566	24.33	.0000	.35039	.41178
EXP_ONI	-.31151**	.13845	-2.25	.0245	-.58286	-.04015
COST	-.00040***	.2604D-05	-154.93	.0000	-.00041	-.00040

QTR 2 38 Site Alternatives

CHOSEN	Coefficient	Standard Error	z	Prob. z >Z*	95% Confidence Interval	
EXPLBSBE	.00324***	.7699D-04	42.04	.0000	.00309	.00339
EXP_SST	.10976***	.01951	5.63	.0000	.07152	.14800
EXP_ONI	-.71641***	.06756	-10.60	.0000	-.84882	-.58401
COST	-.00043***	.2738D-05	-155.58	.0000	-.00043	-.00042



QTR 3 47 Site Alternatives

CHOSEN	Coefficient	Standard Error	z	Prob. z >Z*	95% Confidence Interval	
EXPLBSBE	.00258***	.7675D-04	33.68	.0000	.00243	.00274
EXP_SST	.14109***	.02100	6.72	.0000	.09992	.18225
EXP_ONI	-.00798	.03772	-.21	.8325	-.08191	.06595
COST	-.00044***	.2648D-05	-165.64	.0000	-.00044	-.00043

QTR 4 41 Site Alternatives

CHOSEN	Coefficient	Standard Error	z	Prob. z >Z*	95% Confidence Interval	
EXPLBSBE	.00120***	.9686D-04	12.41	.0000	.00101	.00139
EXP_SST	.26424***	.02452	10.77	.0000	.21618	.31231
EXP_ONI	-.15759***	.03003	-5.25	.0000	-.21645	-.09873
COST	-.00039***	.2301D-05	-168.34	.0000	-.00039	-.00038



Simple Utility-theoretic Model Outputs

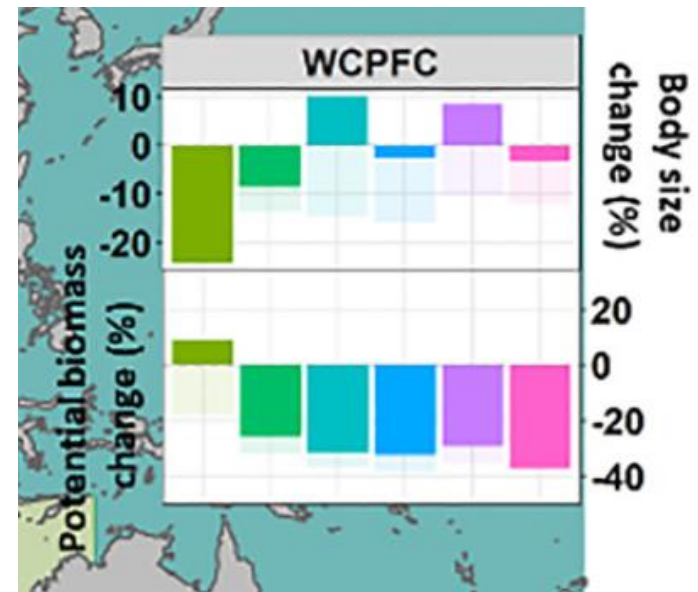
Marginal Rate of Substitution	Output expression	QTR 1	QTR 2	QTR 3	QTR 4
What fisher would trade-off (i.e. spend) for additional 1 lb of tuna	B_{lbs} / B_{cost}	\$5.25	\$7.53	\$5.86	\$3.07
What fisher would trade-off for 0.1 unit decrease in ONI	B_{ONI} / B_{cost}	\$77.80	\$166.60	ns	\$40.40
What fisher would trade-off for 0.1 degree increase in sst	B_{sst} / B_{cost}	\$95.20	\$25.5	\$32.06	\$67.70



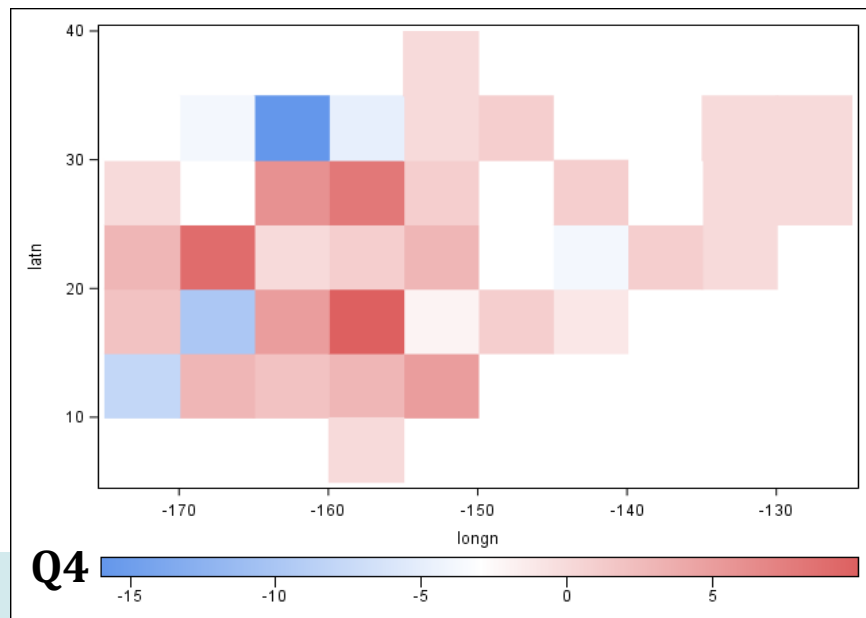
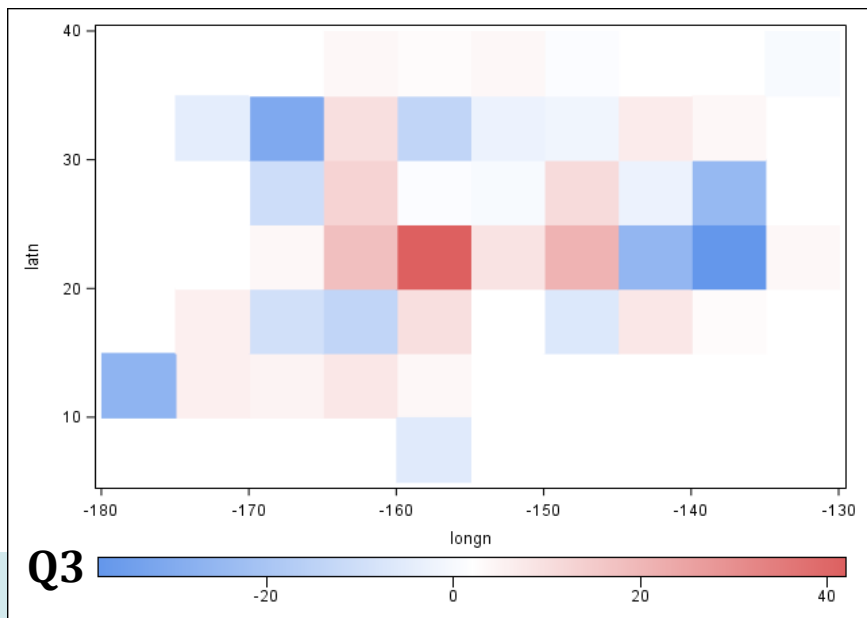
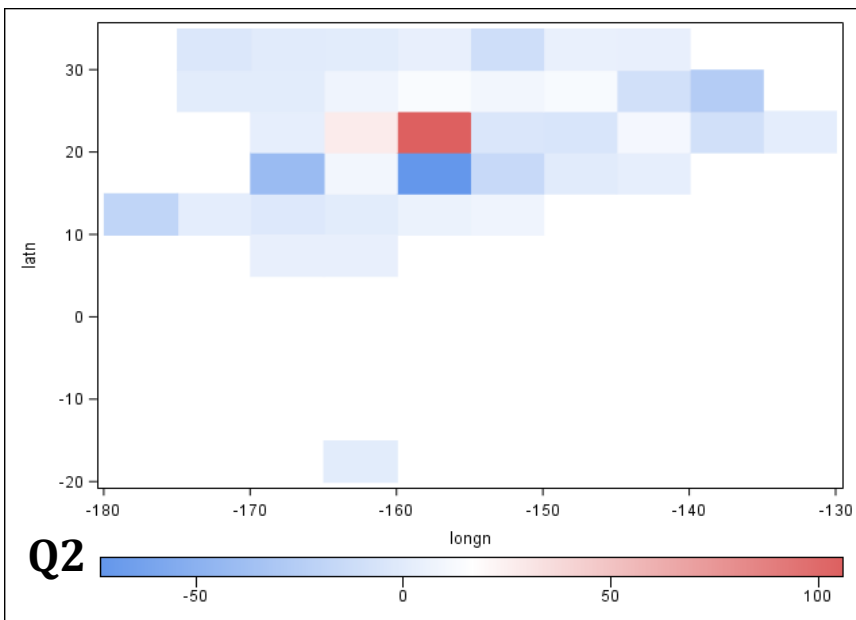
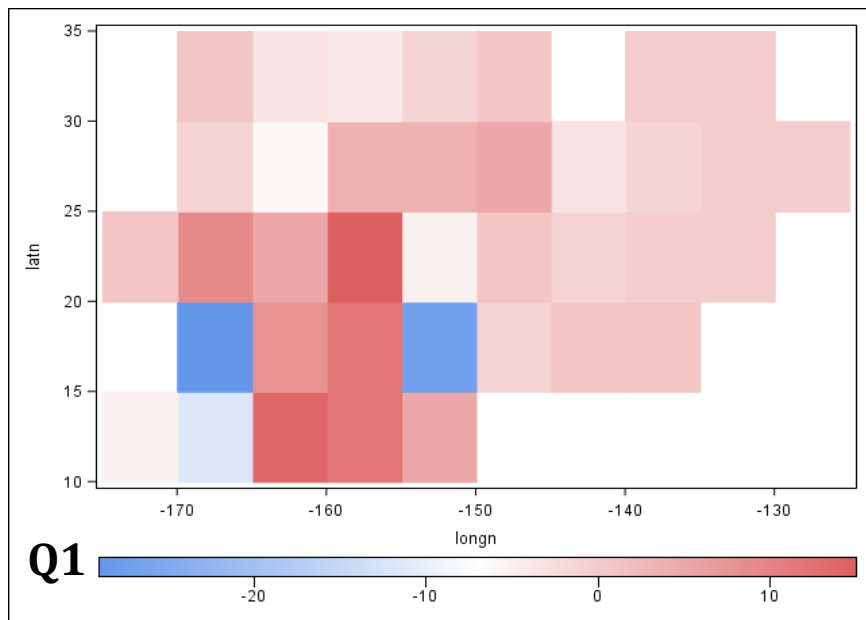
Effort and Revenue Under Climate-driven Biomass Changes

Scenario 1

- Erauskin-Extramiana et al. (2023) suggest overall 20% decreases to BE biomass by 2050 (but potential increases by 2100)
- emissions based on RCP 8.5 (business-as-usual scenario) and fishing at MSY



Predicted Change in Number of Sets at Site: Climate Scenario 1



Predicted Average Changes: Scenario 1

Q1

- ~.75 million lbs bigeye decrease
- Using market prices from dealer data ~ \$3.8 million

Q2

- ~.8 million lbs bigeye decrease
- Using market prices from dealer data ~ \$4.3 million

Q3

- ~.58 million lbs bigeye decrease
- Using market prices from dealer data ~ \$3.4 million

Q4

- ~.65 million lbs bigeye decrease
- Using market prices from dealer data ~ \$3.3 million

Conversion factor*

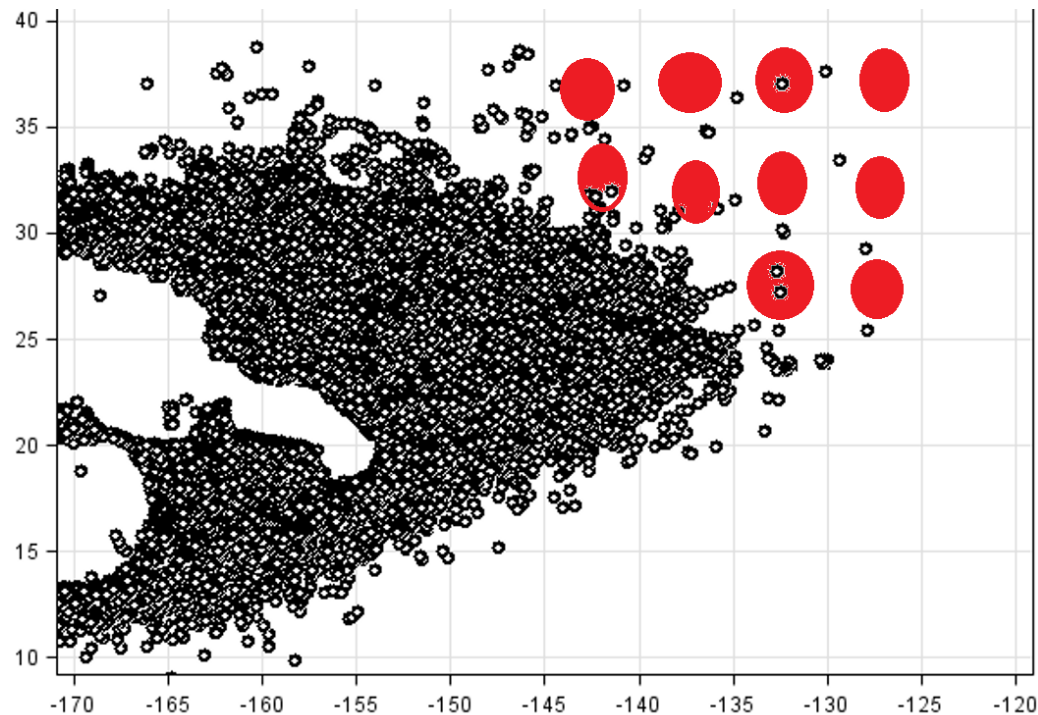


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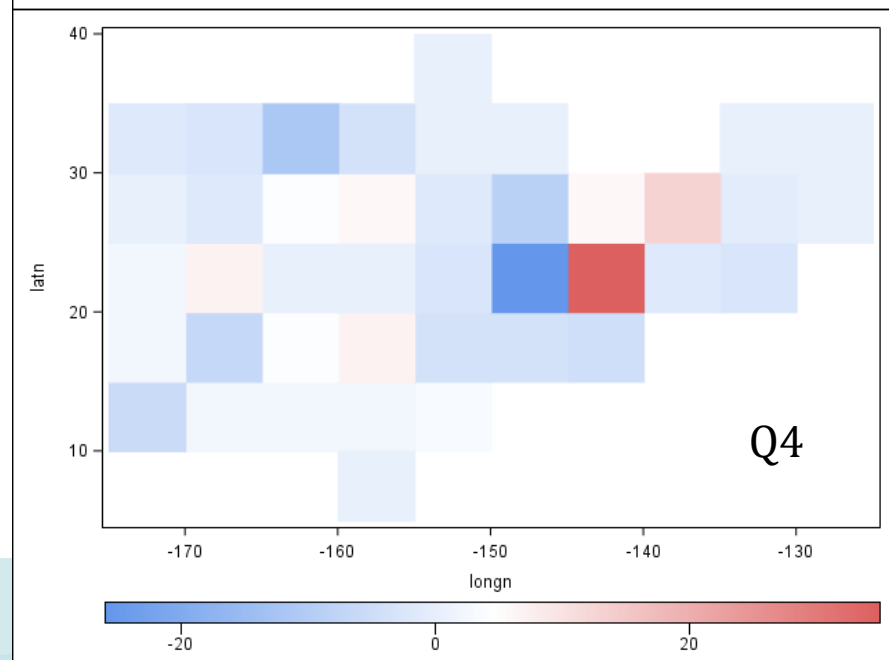
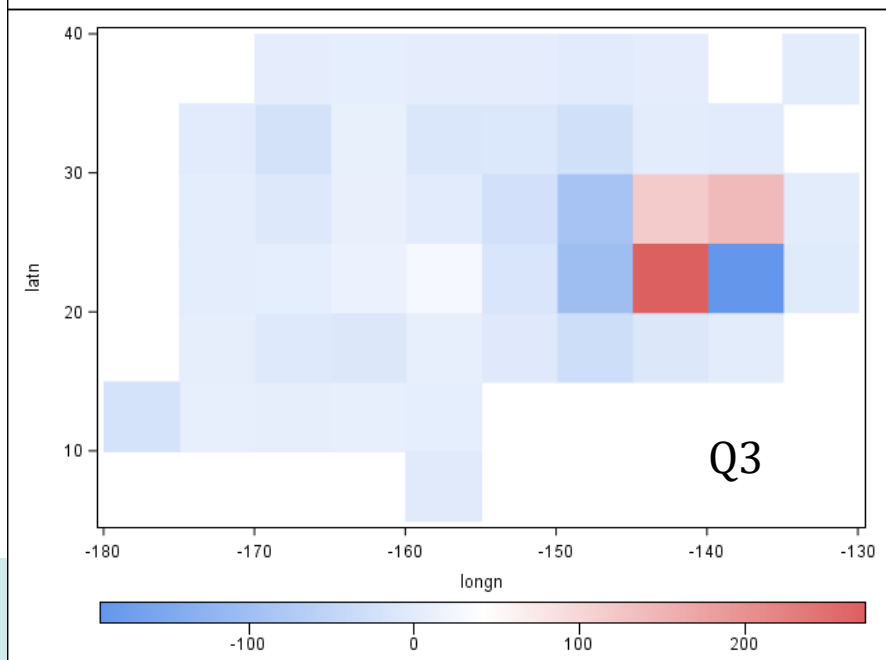
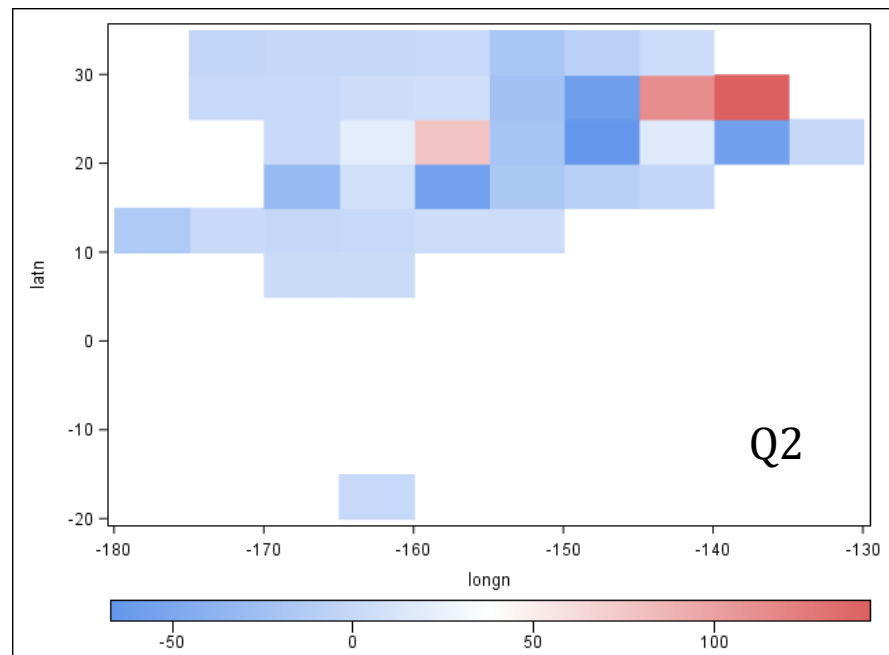
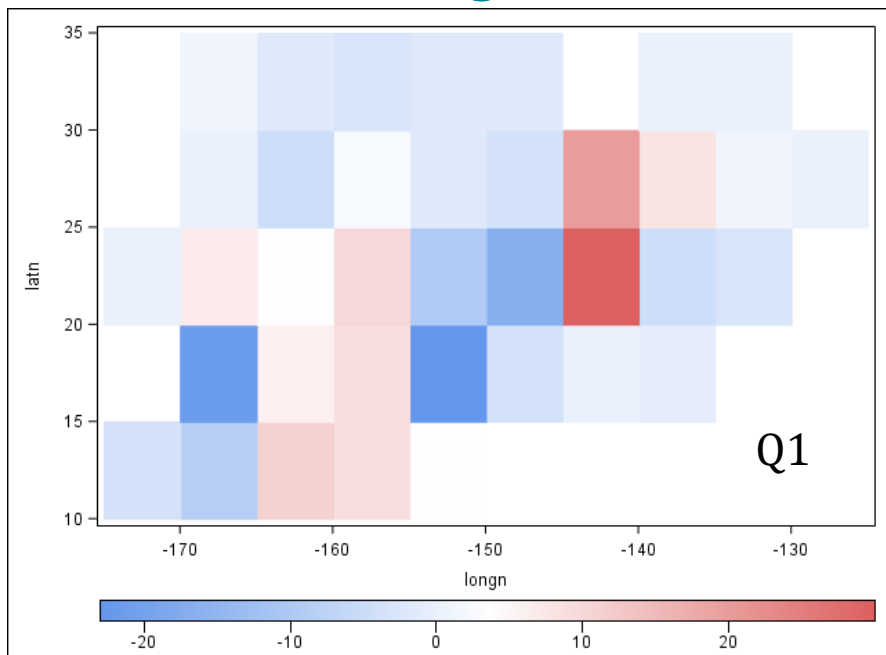
Effort and Revenue Under Climate-driven Biomass Changes

Scenario 2

- Furthest northeast sites experience biomass increase of 30%
- All other sites experience biomass decrease of 15%



Predicted Change in Number of Sets at Site: Climate Scenario 2



Predicted Average Changes: Scenario 2

Q1

- ~.54 million lbs bigeye decrease
- Using market prices from dealer data ~ \$2.72 million

Q2

- ~.44 million lbs bigeye decrease
- Using market prices from dealer data ~ \$2.35 million

Q3

- ~115.3 K lbs bigeye decrease
- Using market prices from dealer data ~ \$674.8K

Q4

- ~.45 million lbs bigeye decrease
- Using market prices from dealer data ~ \$2.30 million

Conversion factor*



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Challenges/Next Steps (there are many)

- Definition of a fishing site?
- What are the right climate-driven biomass scenarios to examine?
- Currently fishing grounds based on observed set data – how to expand to allow currently unfished sites enter the choice set
- Integrate with FishSET

FishSET
Spatial Economics
Toolbox for Fisheries

Many modeling challenges exist. While predictive models are valuable tools for sustainable fisheries management and conservation, challenges to their development include: identifying a relevant many data sources, choosing appropriate models, and interpreting results.

FishSET's goal is to address these challenges to enable NOAA Fisheries economists and policy scientists to better inform policy decisions by providing a wide variety of factors that influence fish behavior.

FishSET is a comprehensive toolbox for assessing the spatial and predictive challenges of modeling fish behavior.

FishSET Supports Better Management
Fisheries management involves complex trade-offs in a changing environment. FishSET enables decision makers to better analyze policies so that they will be cost-effective and achieve the greatest protection for the lowest cost.

FishSET provides:

1. Superior data organization, analysis, and integration for spatial models.
2. Best management practices for data, modeling, and model conversion.
3. Many models in a single location to ease or ease comparison and use. Customizes several fisheries economics modeling approaches in one toolbox.

What tools are in the FishSET toolbox?

- Model Tools**
 - Model Design and Refinement Tool**
Enables modeling of different combinations of species and models.
 - Modeling Tool**
Enables model integration, and model development.
 - Model Comparison and Reporting Tool**
Provides an overview comparison of model performance and summarizes their results and results.
- Data Tools**
 - Data Management and Integration Tool**
Facilitates acquisition and integration of data for spatial modeling.
 - Monte Carlo Tool**
Enables the fisheries data sets with creating uncertainty, assessing better model testing and performance.
 - Data Analysis and Mapping Tool**
Enables produce and geographic data viewing and prepare data for spatial modeling.
- Policy Tool**
 - Policy Simulation Tool**
Provides custom checks and simulations within results.

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Fisheries Research and Assessment
The impacts of global trends, catch trends, climate change, and habitat avoidance on fisheries.

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Thanks!

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Phoebe Woodworth-
Jefcoats**

I would welcome feedback, comments, or questions.



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