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

Kristy Wallmo, Office of Science and Technology, NOAA Fisheries
Hing Ling Chan, Pacific Islands Fisheries Science Center, NOAA Fisheries

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!

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

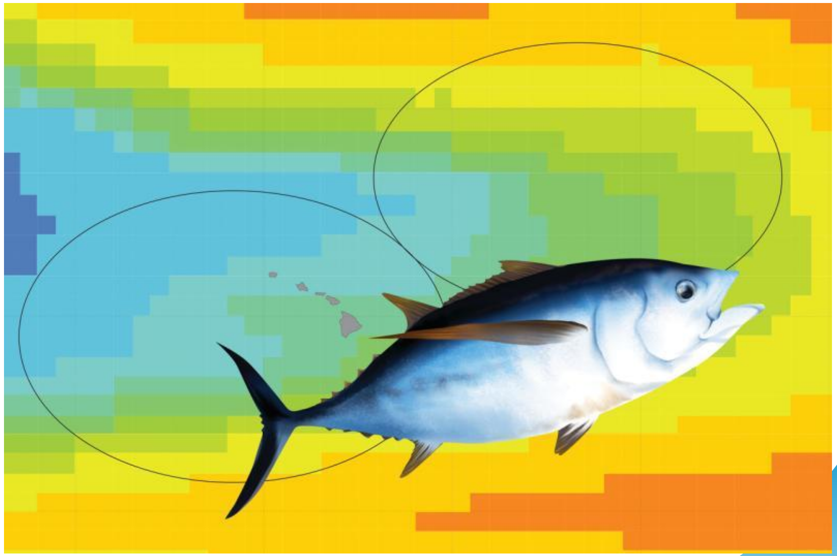
Fitted Model: RUM

Probability of choosing 'j' from choice set:	$\Pr(j\|C) = \Pr(U_{ij} >= U_{ik}) \ \forall k \in C$
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:	$\Pr(j \mid C) = \frac{\exp(\beta X_{ij})}{\sum_{k=1}^{K} \exp(\beta X_{ik})}$

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 km^2
- 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."

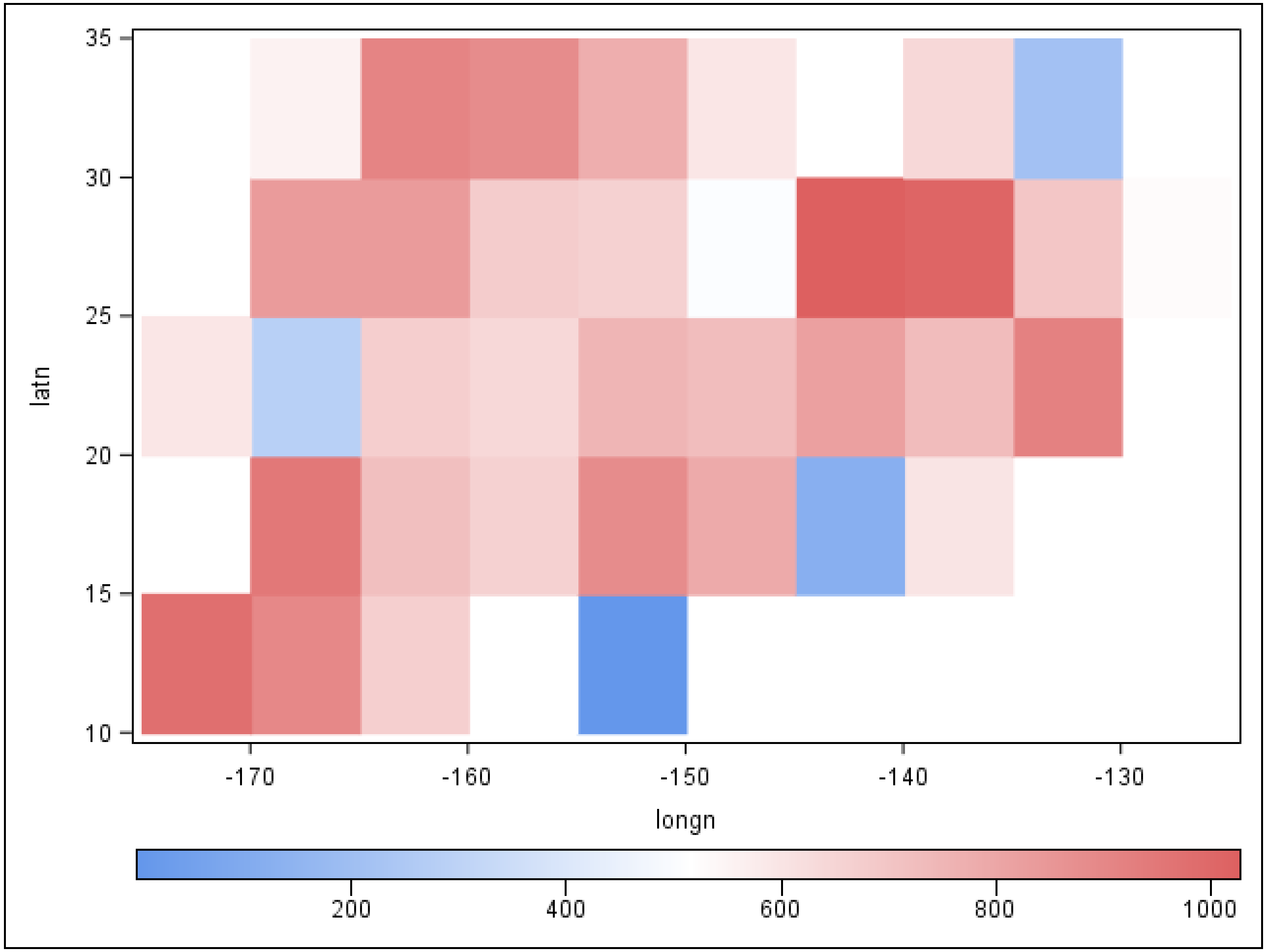
- How to define the fishing site?
  - Latitude/longitude of set
  - Aggregation of sets (e.g. 5 x 5 degree grid)
  - Other delineations
- What are fishing site attributes?
  - Expected CPUE, number or pounds of fish, revenue,
  - Distance to site, cost to get to site
- What is/how many sites are in the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

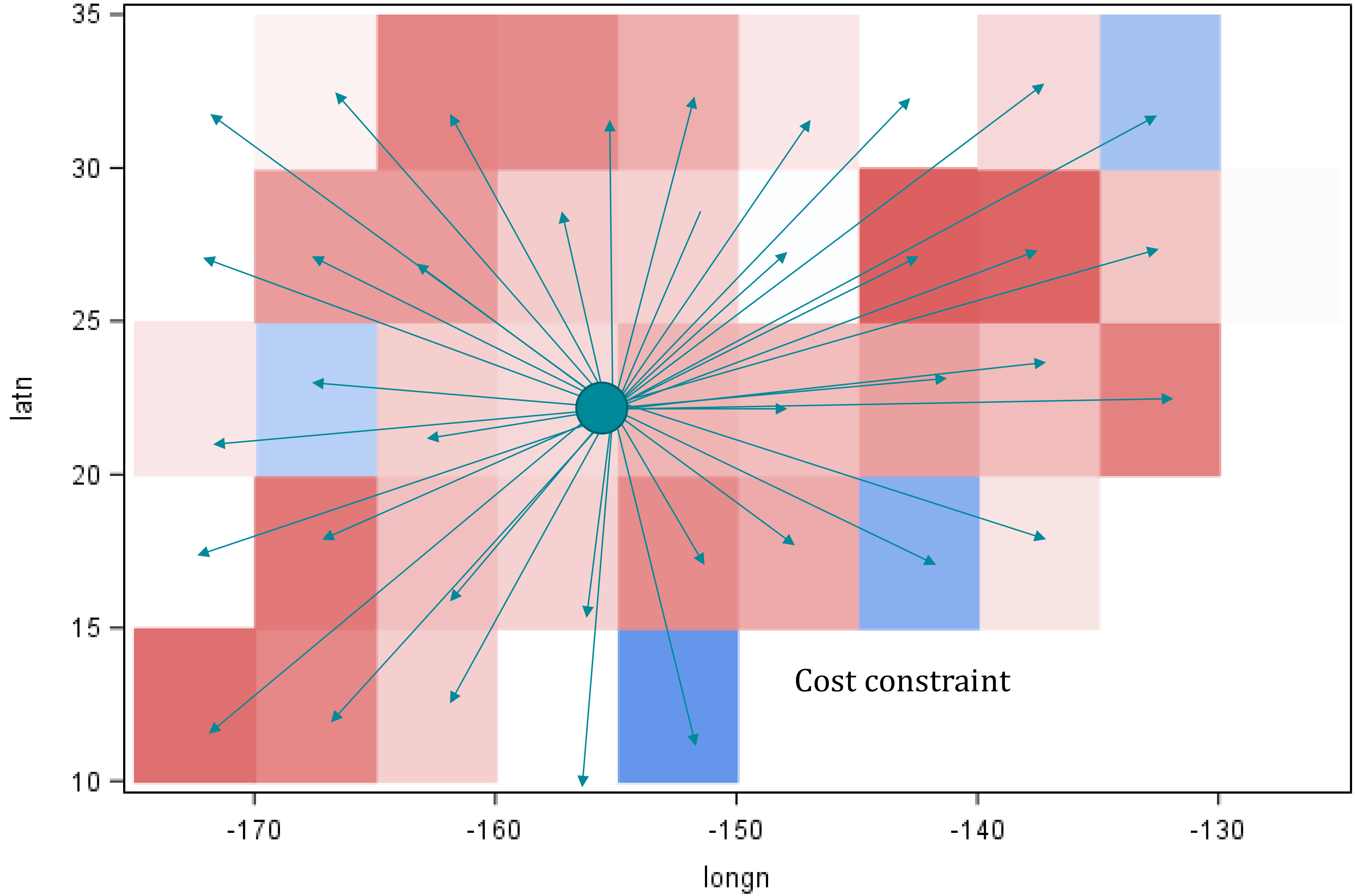
NOAA FISHERIES

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





35
30
25
20
15
10
latn
-170
-160
-150
-140
-130
longn
Cost constraint

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

NOAA FISHERIES

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

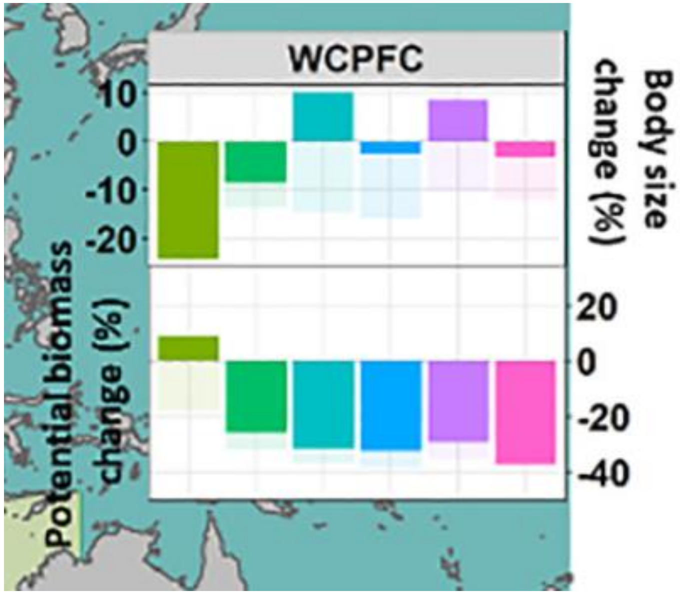
Simple Utility-theoretic Model Outputs

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

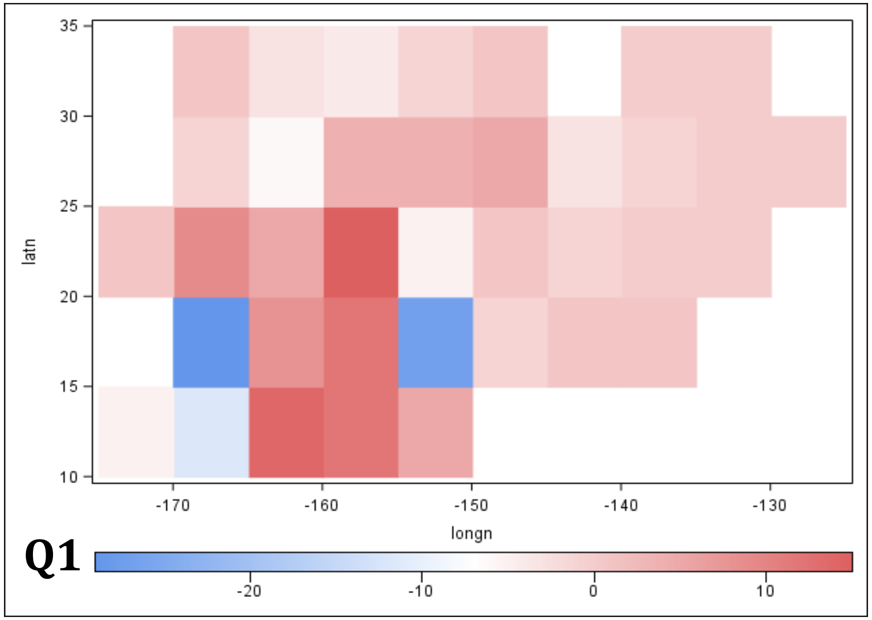
Effort and Revenue Under Climate-driven Biomass Changes

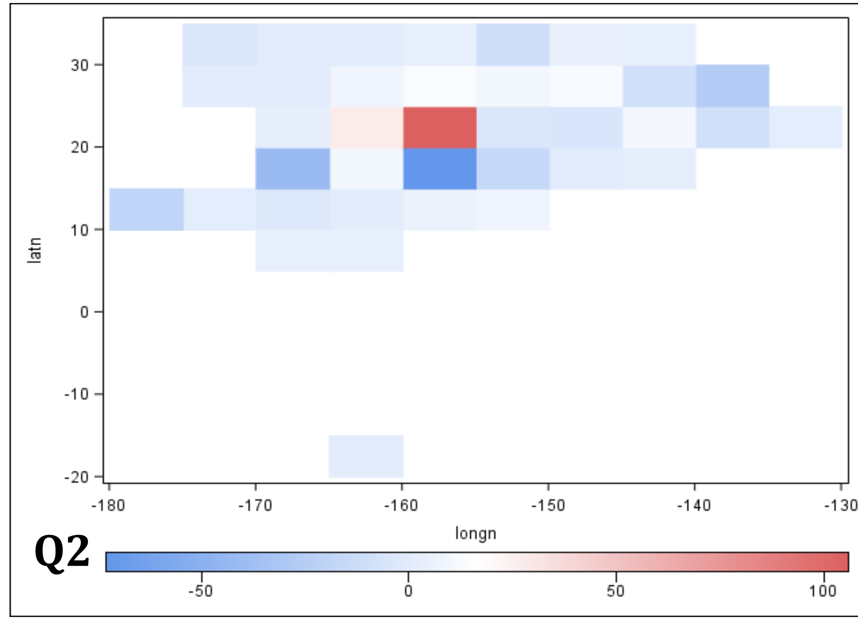
Scenario 1

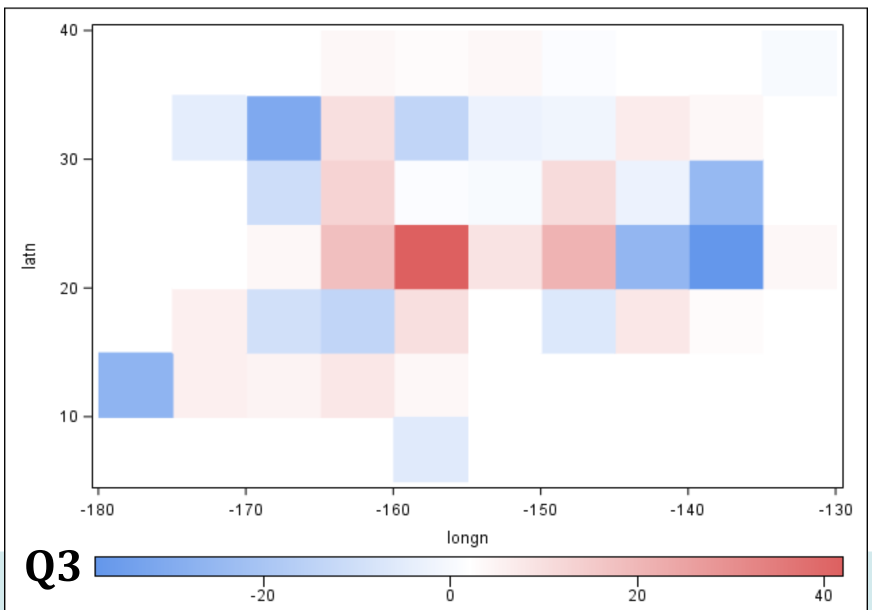
- Erauskin-Extramiana et al. (2023) suggest overall 20% decreases to BE biomass by 2050 (but potential increases by 2100)
- emissions based on RCP 8.5 (business-as-usual scenario) and fishing at MSY

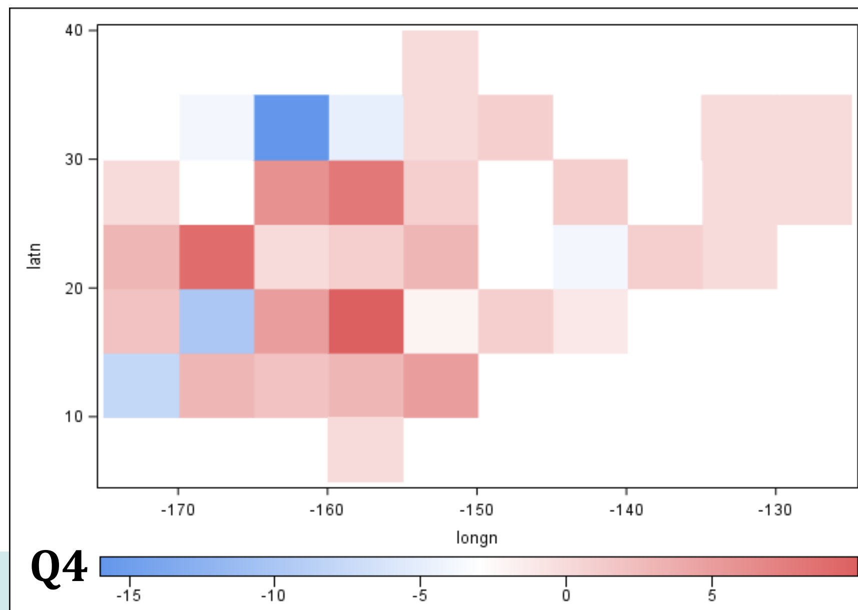


Predicted Change in Number of Sets at Site: Climate Scenario 1









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

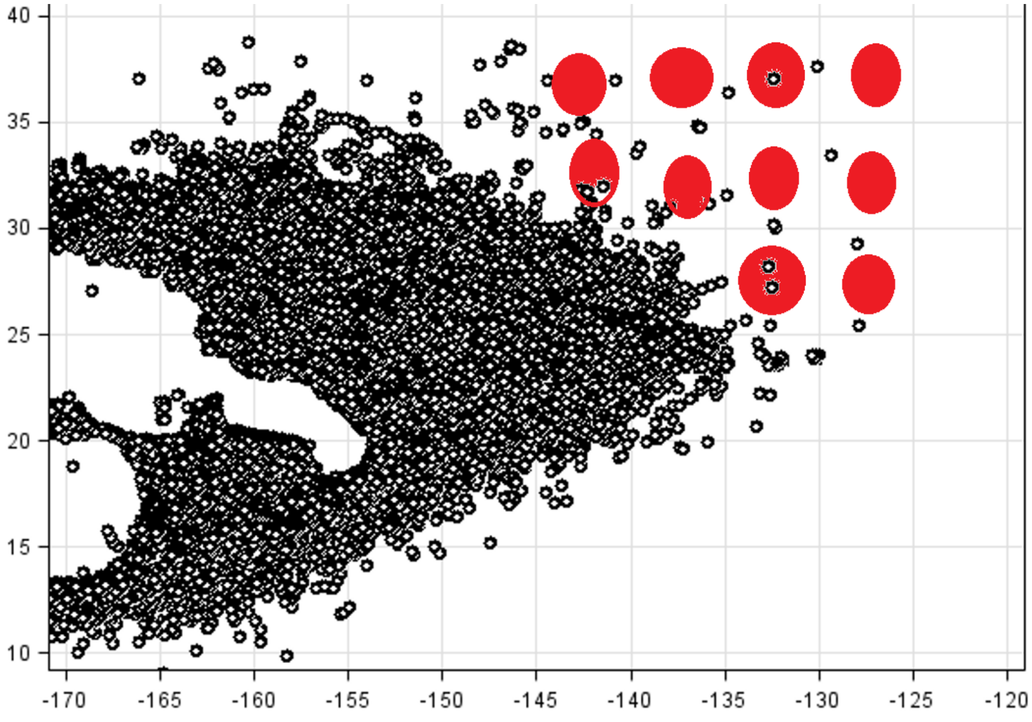
Conversion factor*

NOAA FISHERIES

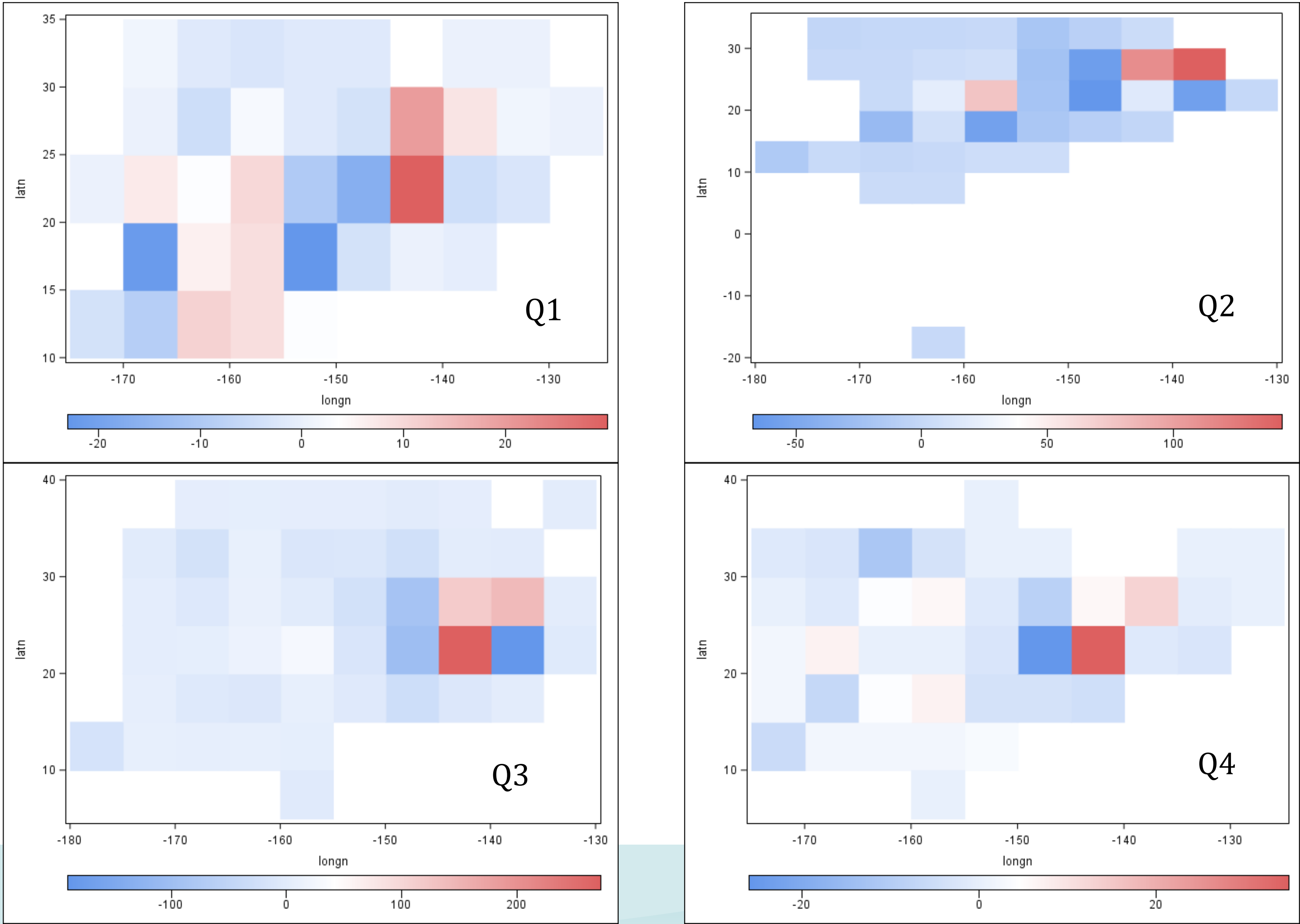
Effort and Revenue Under Climate-driven Biomass Changes

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*

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

Thanks!

-PIFSC & Justin Hospital
Minling Pan, Johanna Wren, Phoebe Woodworth-Jefcoats

I would welcome feedback, comments, or questions.