Spatial and temporal variation in Pacific halibut size-at-age and the harvest policy implications.

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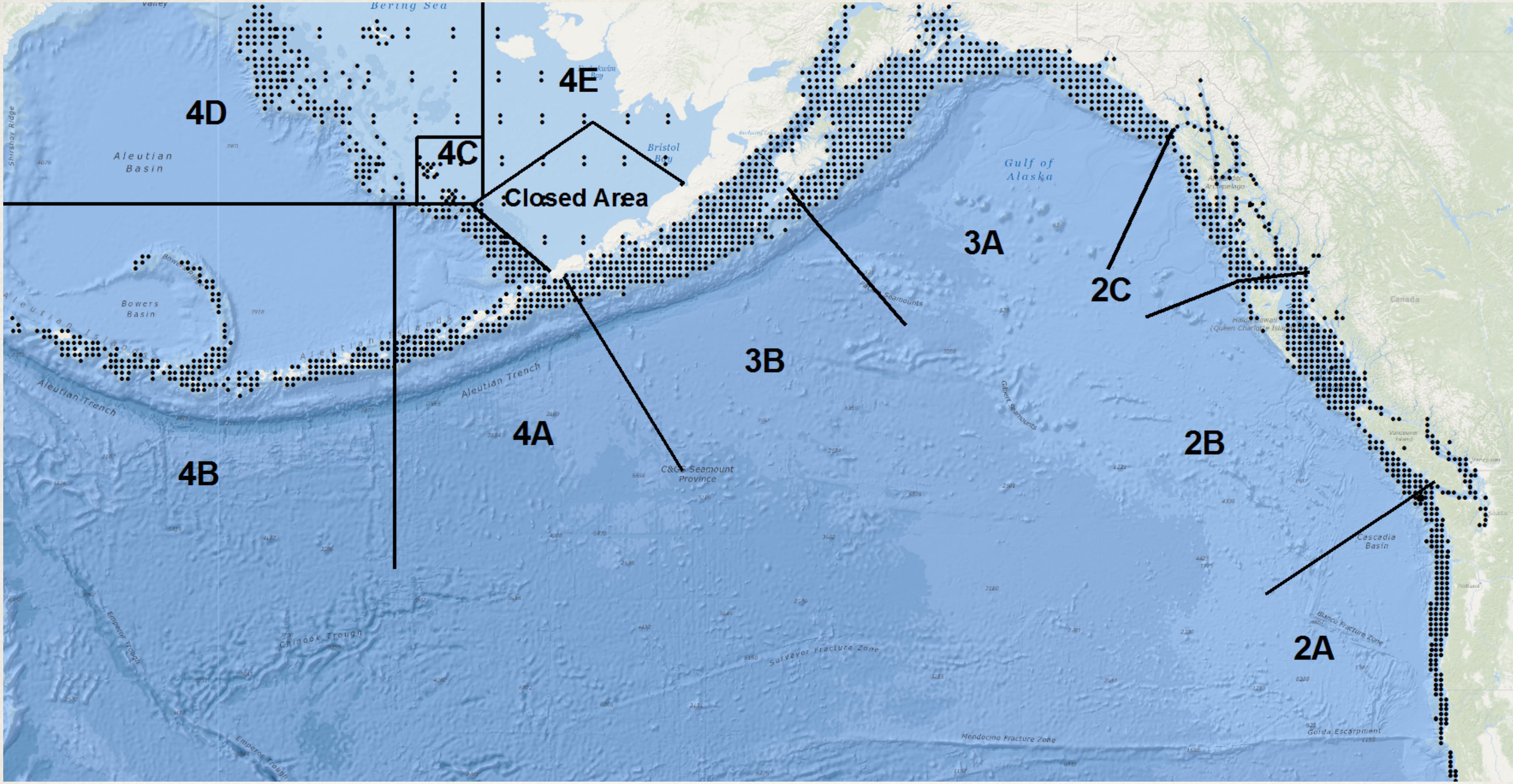
Overarching Themes

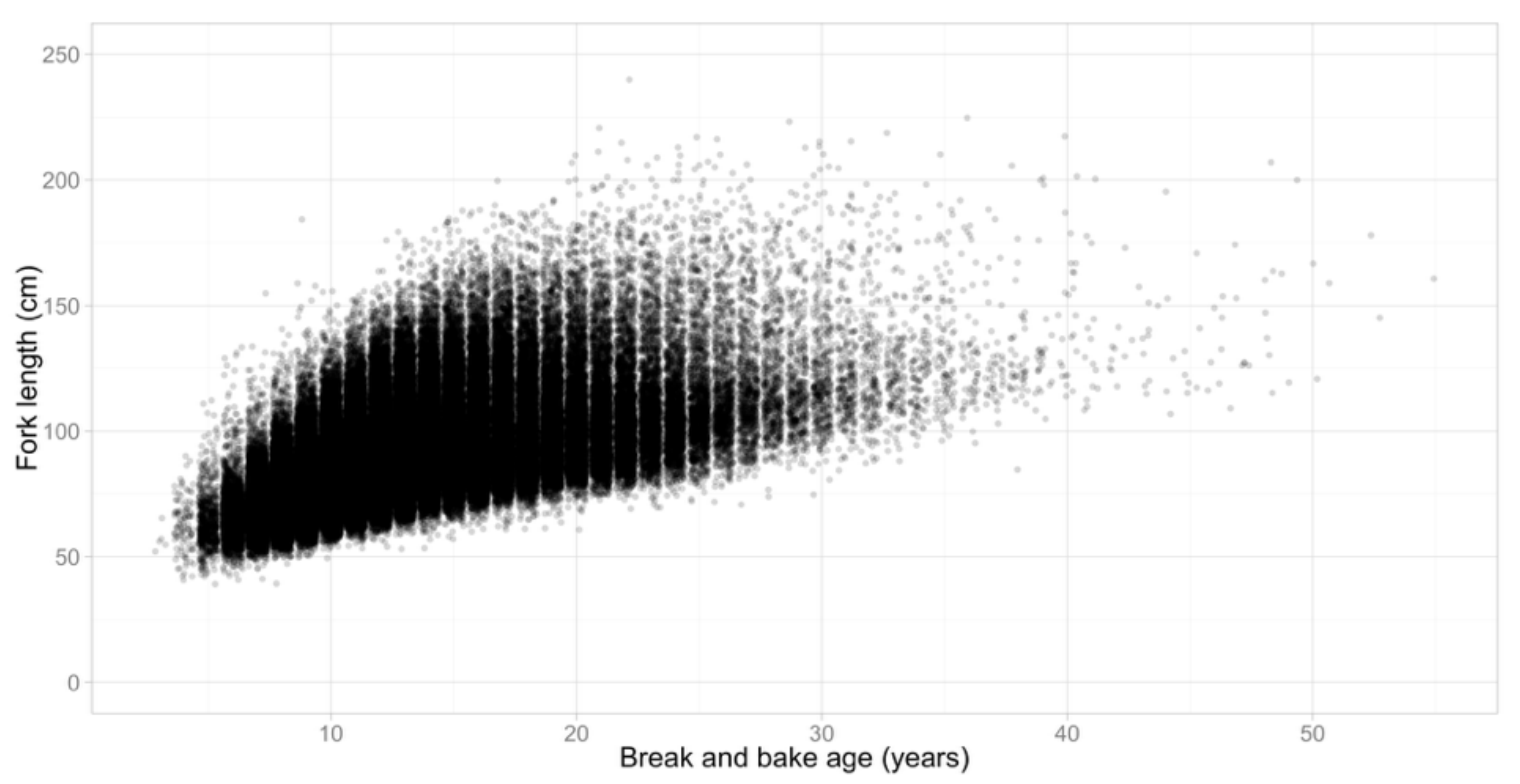
- Spatiotemporal variation in size-at-age.
- Alternative hypotheses for changes in size-at-age.
- Stock assessment & harvest policy.



IPHC Regulatory Areas

Set-line survey stations (2014-2019), 10 nautical mile grid.

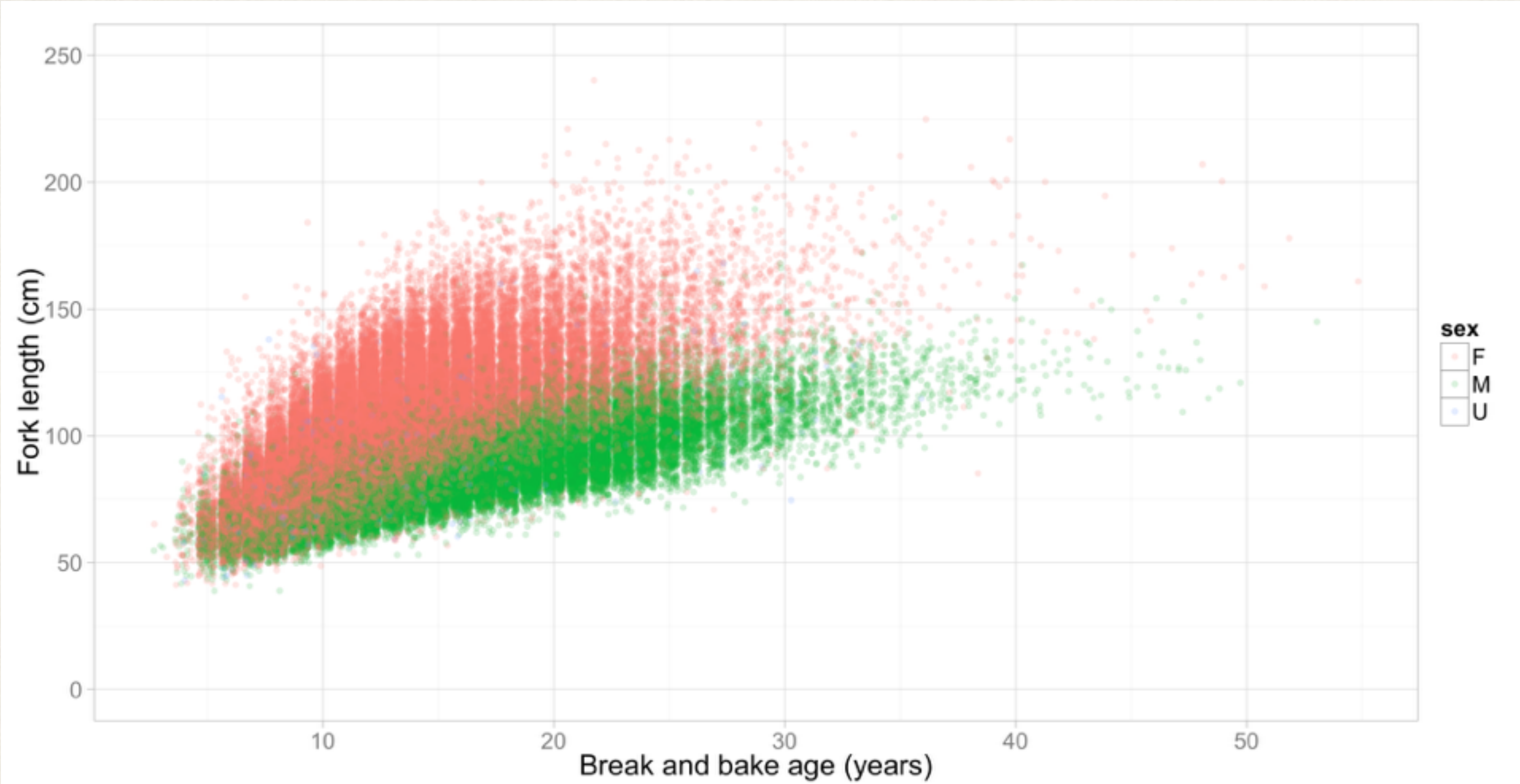
2013: > 1000 stations (600 hooks per station). Over 600,000 hooks deployed annually.



Size-at-age data (1998 – 2014)

All halibut from all regulatory areas.

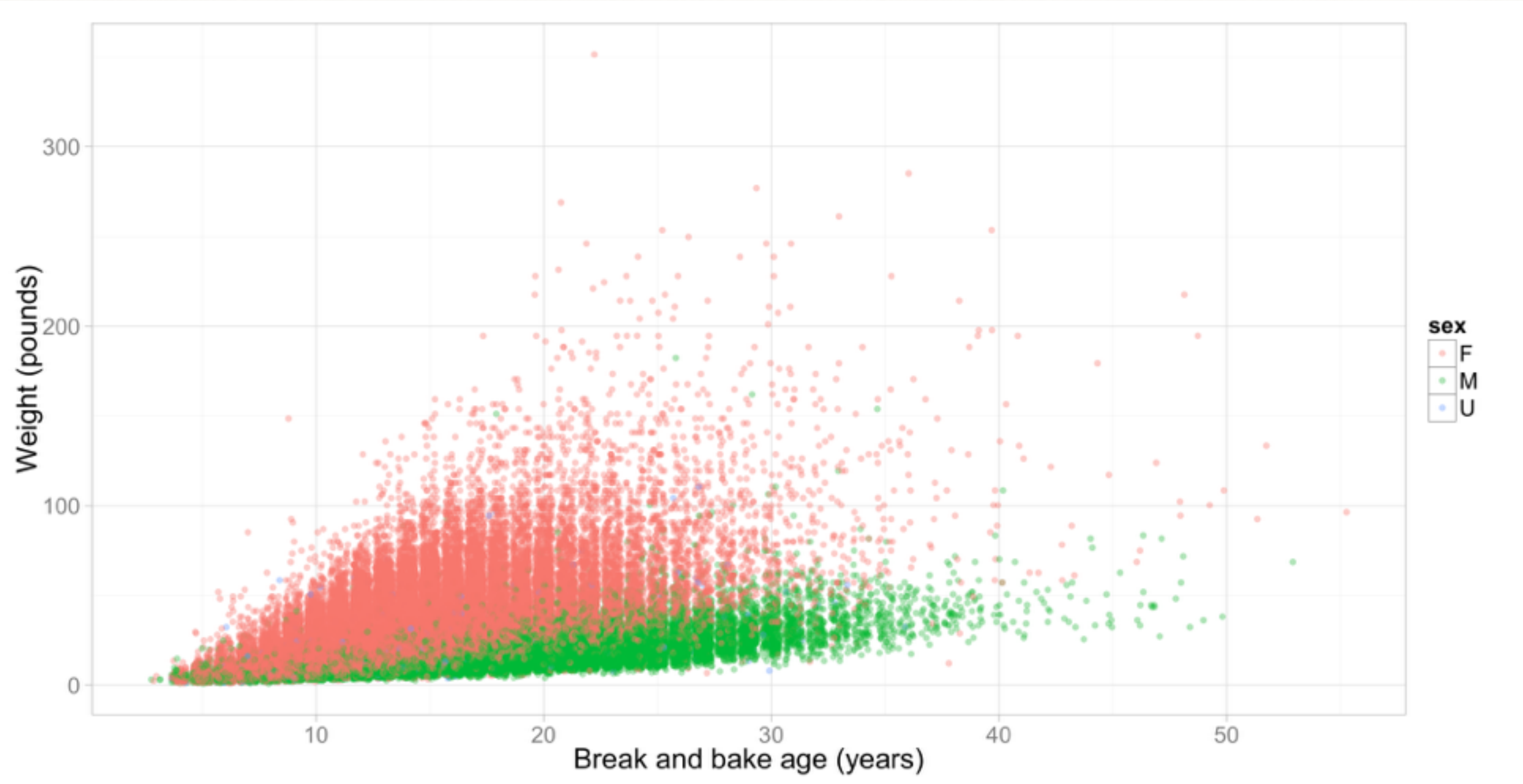
N = 203,091 fish aged using the break and bake method.



Size-at-age data (1998 – 2014)

Female and male halibut from all regulatory areas.

Girls grow faster than boys.

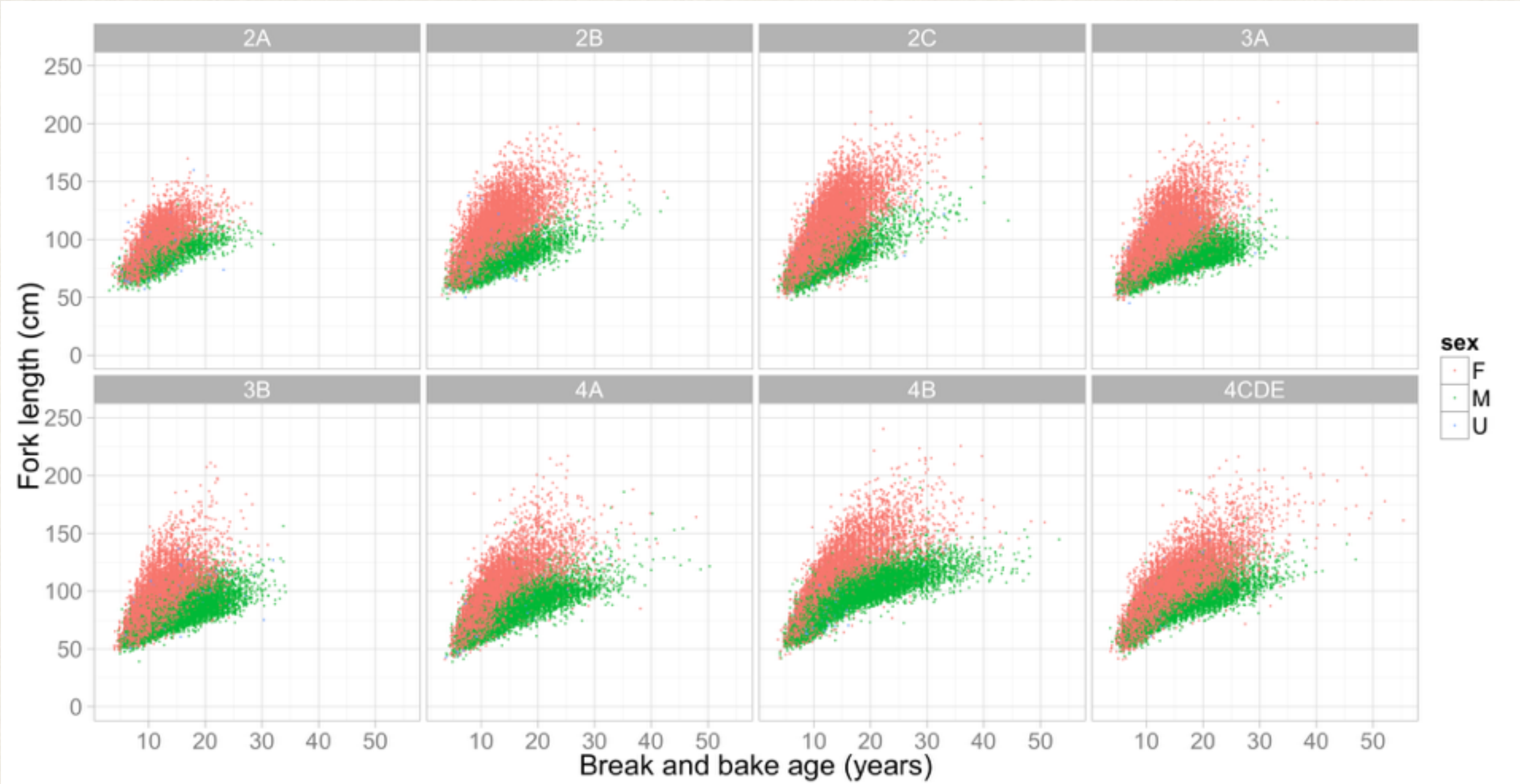


Weight-at-age data (1998-2014)

American halibut in pounds.

Weight-at-age data (1998-2014)

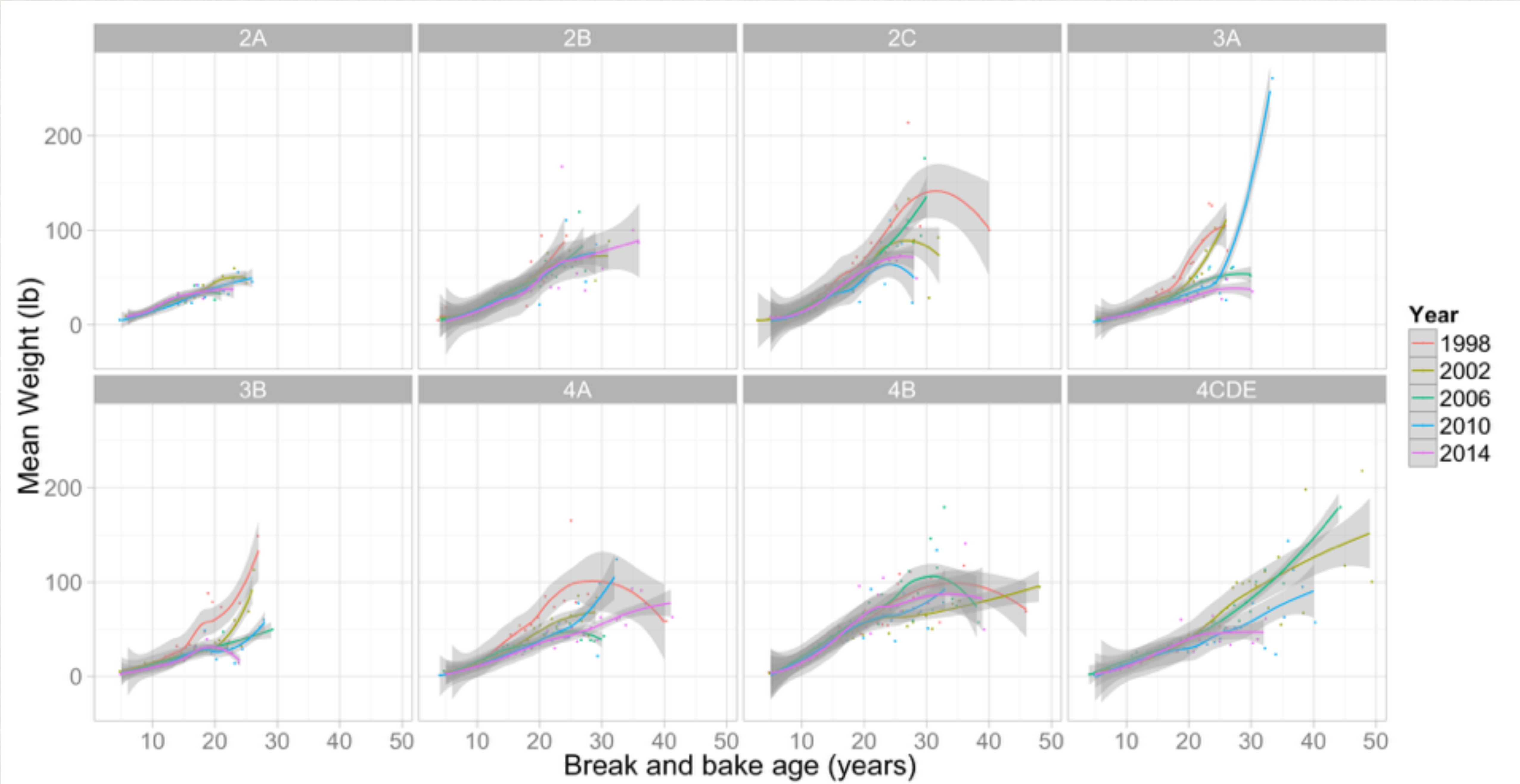
Canadian halibut in kilograms



Size-at-age data by regulatory area

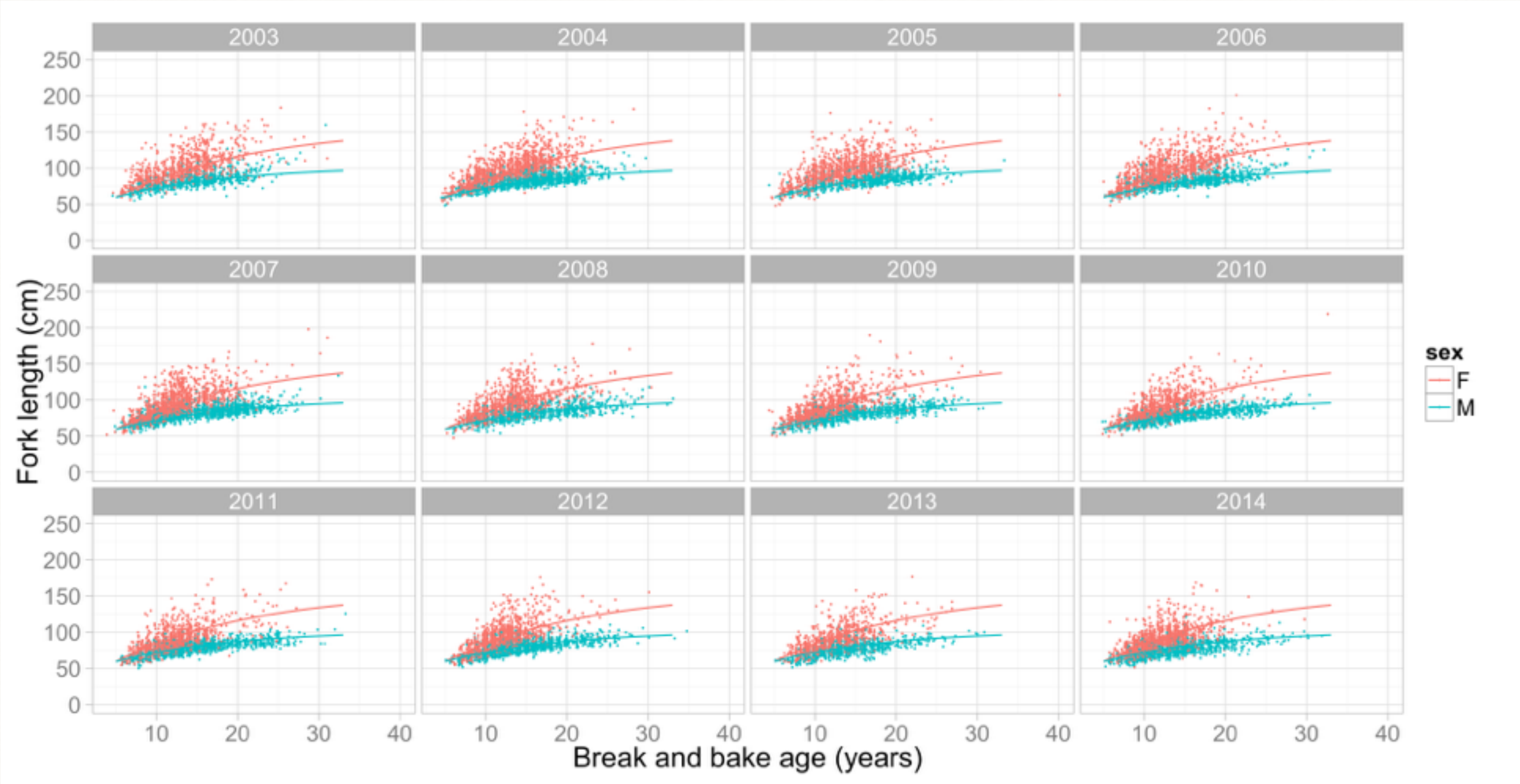
Spatial variation in size-at-age data.

Variation in size-at-age is much greater for females than males.



Mean weight-at-age

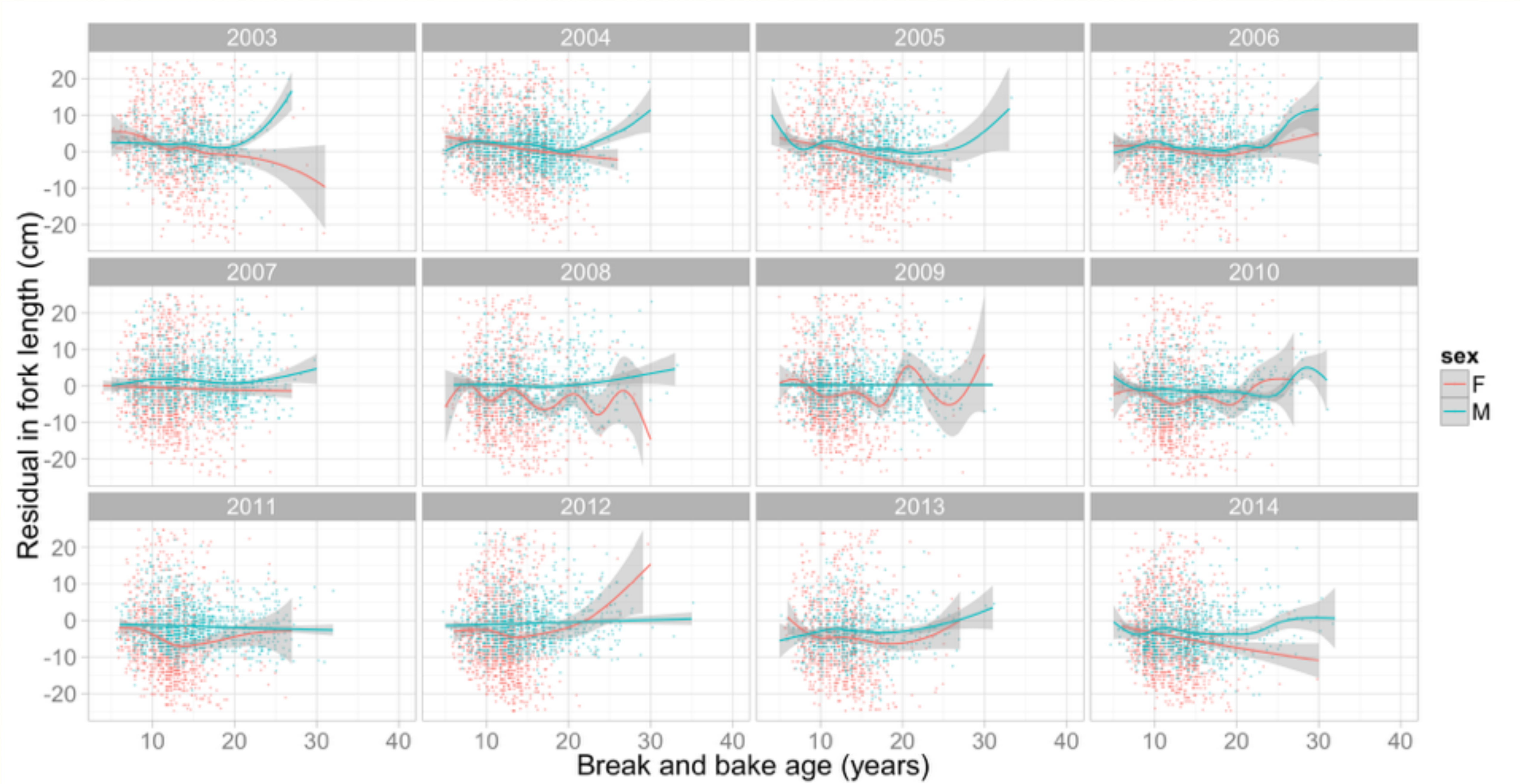
Central tendency



Size-at-age in GOA by year

von Bertalanffy growth curves fit to all years.

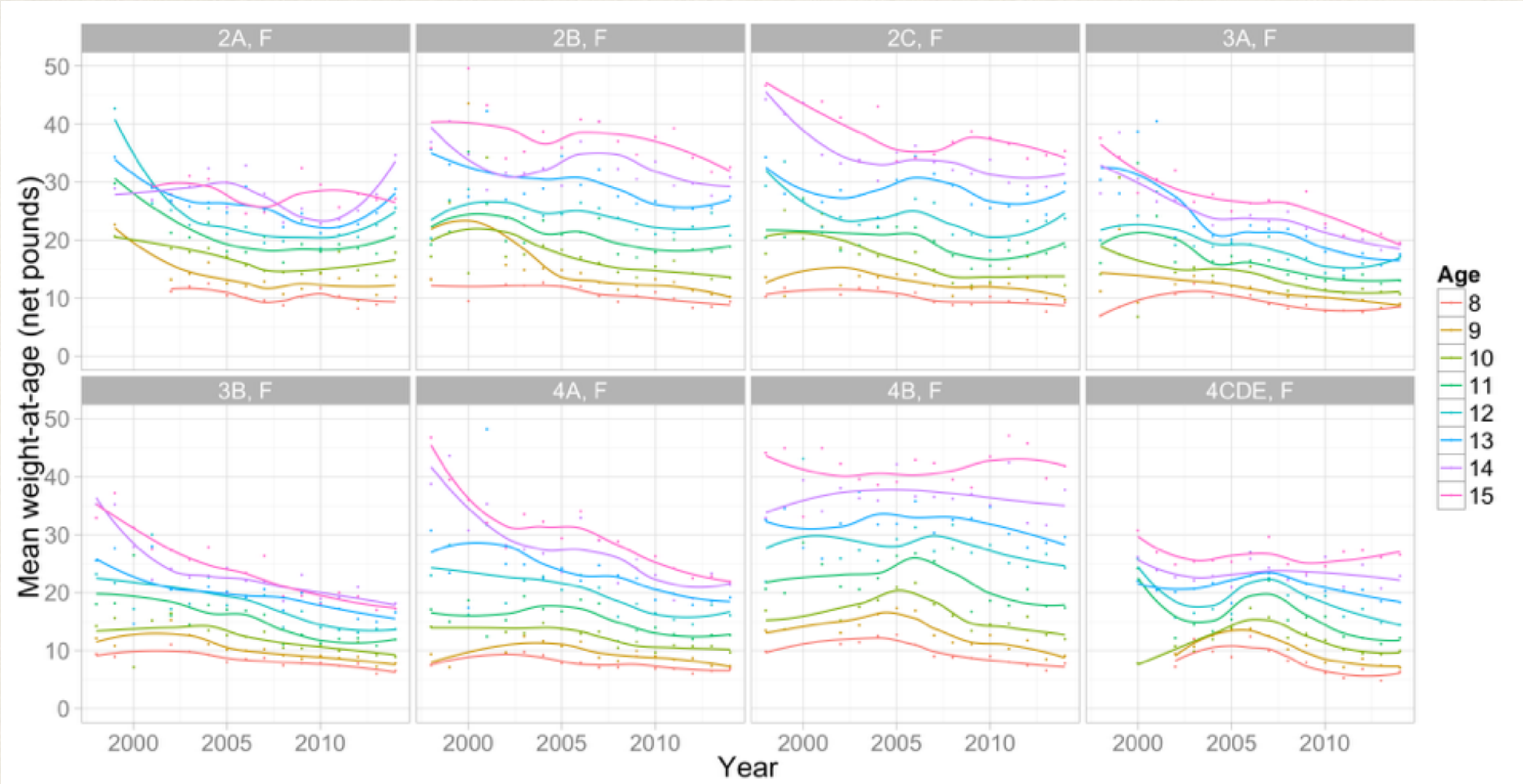
Estimates of growth are biased due to non random sampling (gear selectivity effects).



Temporal residual patterns in GOA

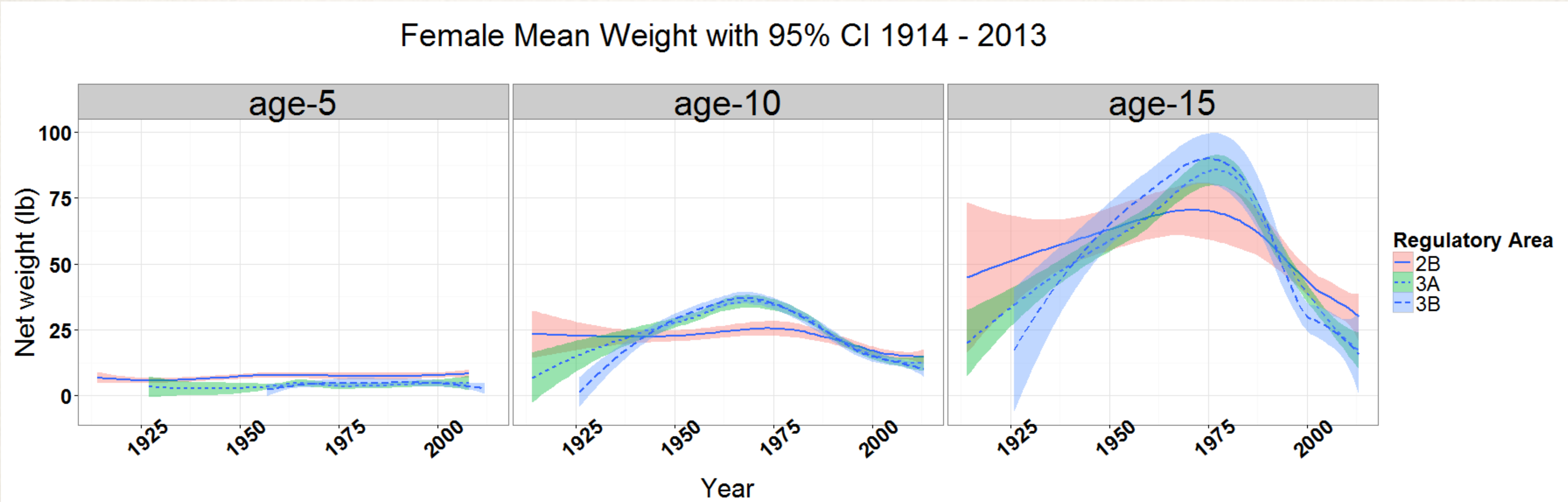
Residual patterns indicate trends in size-at-age.

Residuals relative to a growth curve fitted to all data in GOA (Regulatory area 3A).



Average female weight-at-age

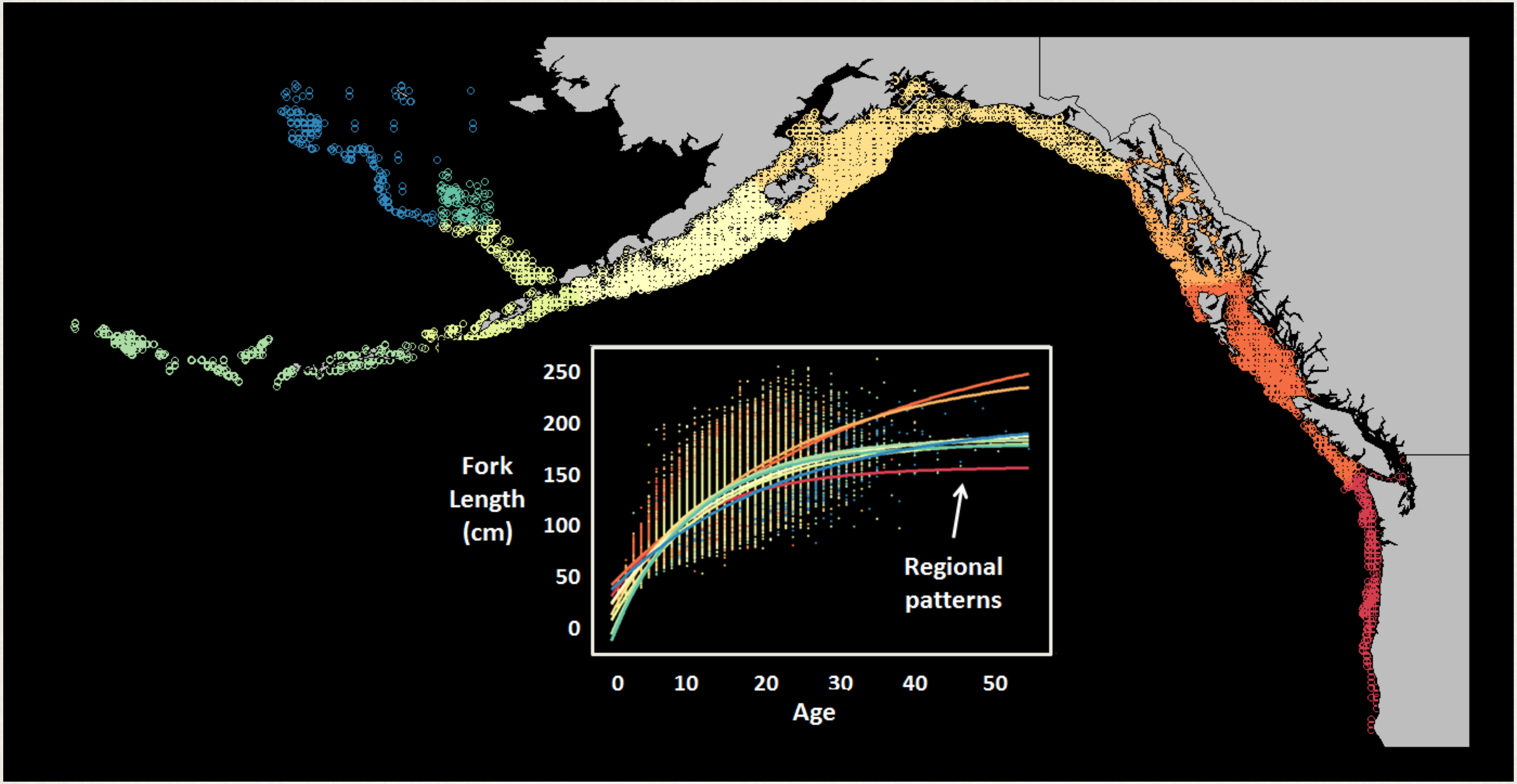
Continued declines in size-at-age in areas 3 and 4A.



Trends in female weight-at-age

1914-2013

Date



Growth curves by regulatory area.

Date

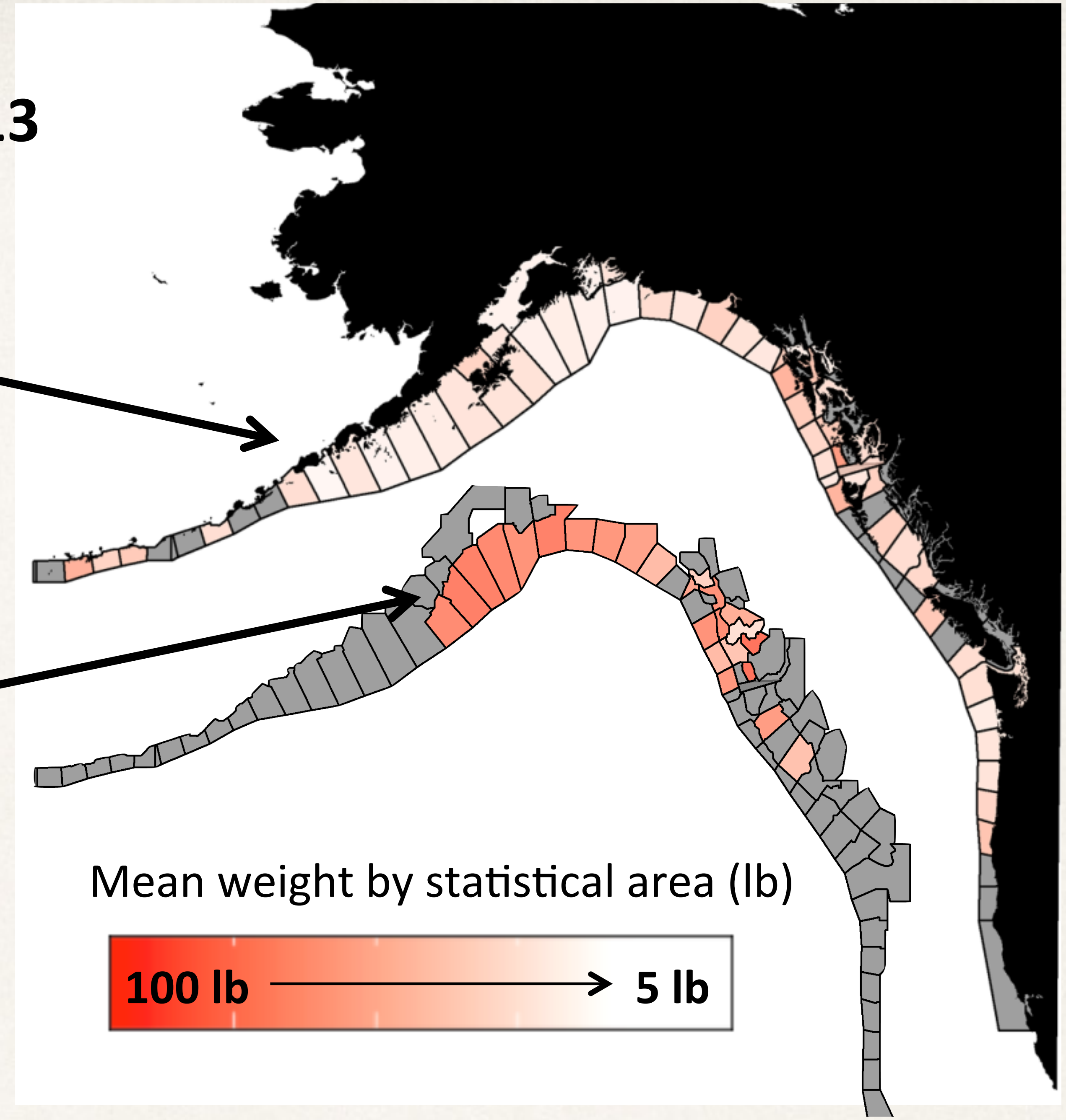
Age-15 Females
Declines from 1983 to 2013

2013

Coastwide weight (lb)	
Min	5
Mean	27
Max	78

1983

Coastwide weight (lb)	
Min	25
Mean	62
Max	95



Changes in size-at-age

Mean weight-at-age in 1983, and 2013 based on set-line survey data.

1983 & 2013

Summary: spatiotemporal variation

- Extreme variation in female size-at-age for Pacific halibut.
    - Females in SE Alaska and BC are among the largest.
- Recent trends in weight-at-age continue to decline in the GOA, Bering sea self, and Dutch Harbor regions.
- Small size-at-age was also observed in the 1920-30s.
- Western Aleutian Islands, predominantly large males with little trend in size-at-age.

Hypotheses: changes in size-at-age

(A) Density-dependent growth.

(B) Interspecific competition.

(C) Bias in aging methods.

(D) Cumulative effects of size-selective fishing.

(E) Environmental covariates.

(F) Growth retarded by prior hook injuries.

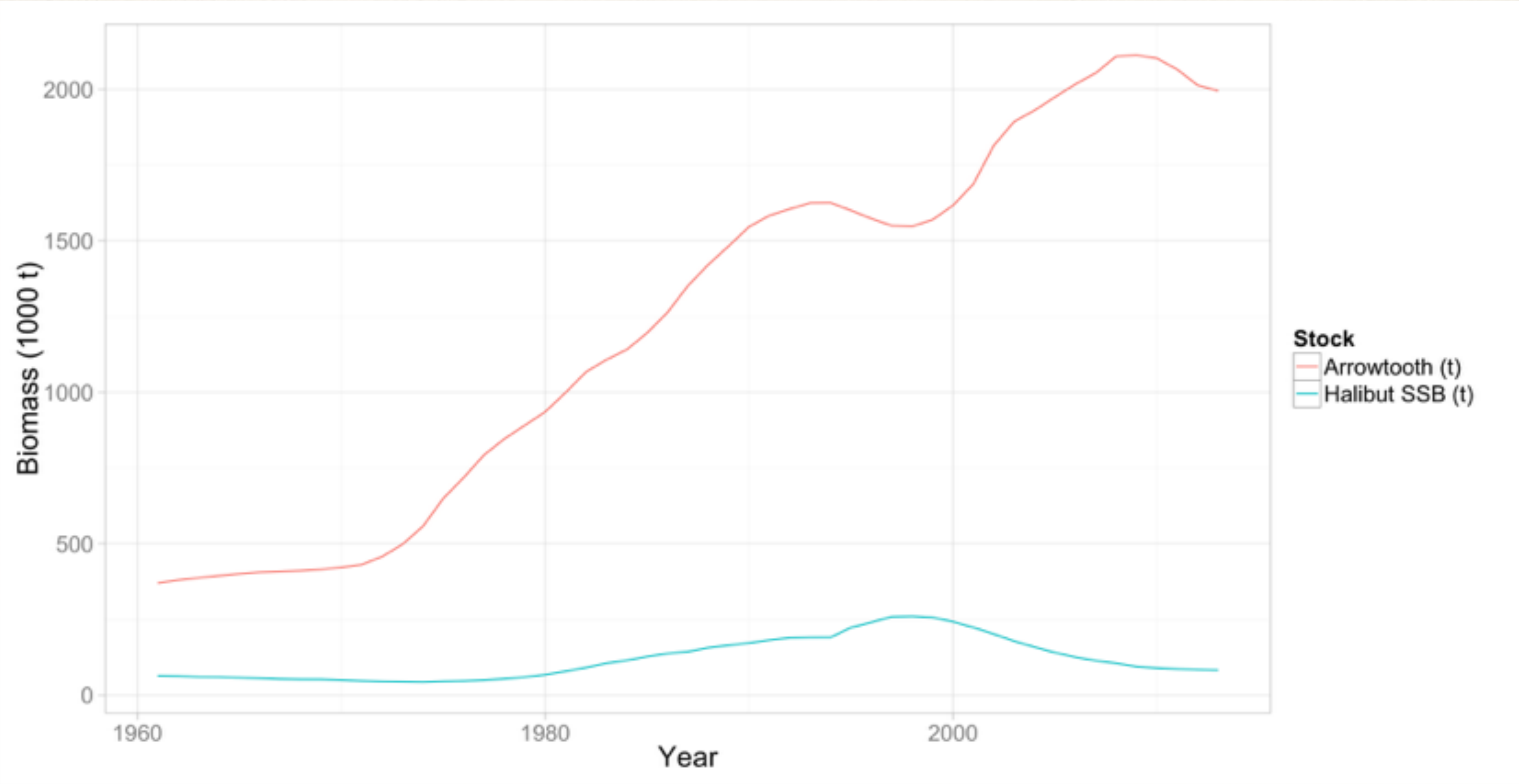
(G) All of the above.

(A) Density-dependent growth

- Existing harvest policy was developed assuming density-dependent growth.
  - Density = abundance of age 10+ halibut (numbers).
  - 1970s halibut abundance low, 1980-90s saw some of the largest halibut size-at age.

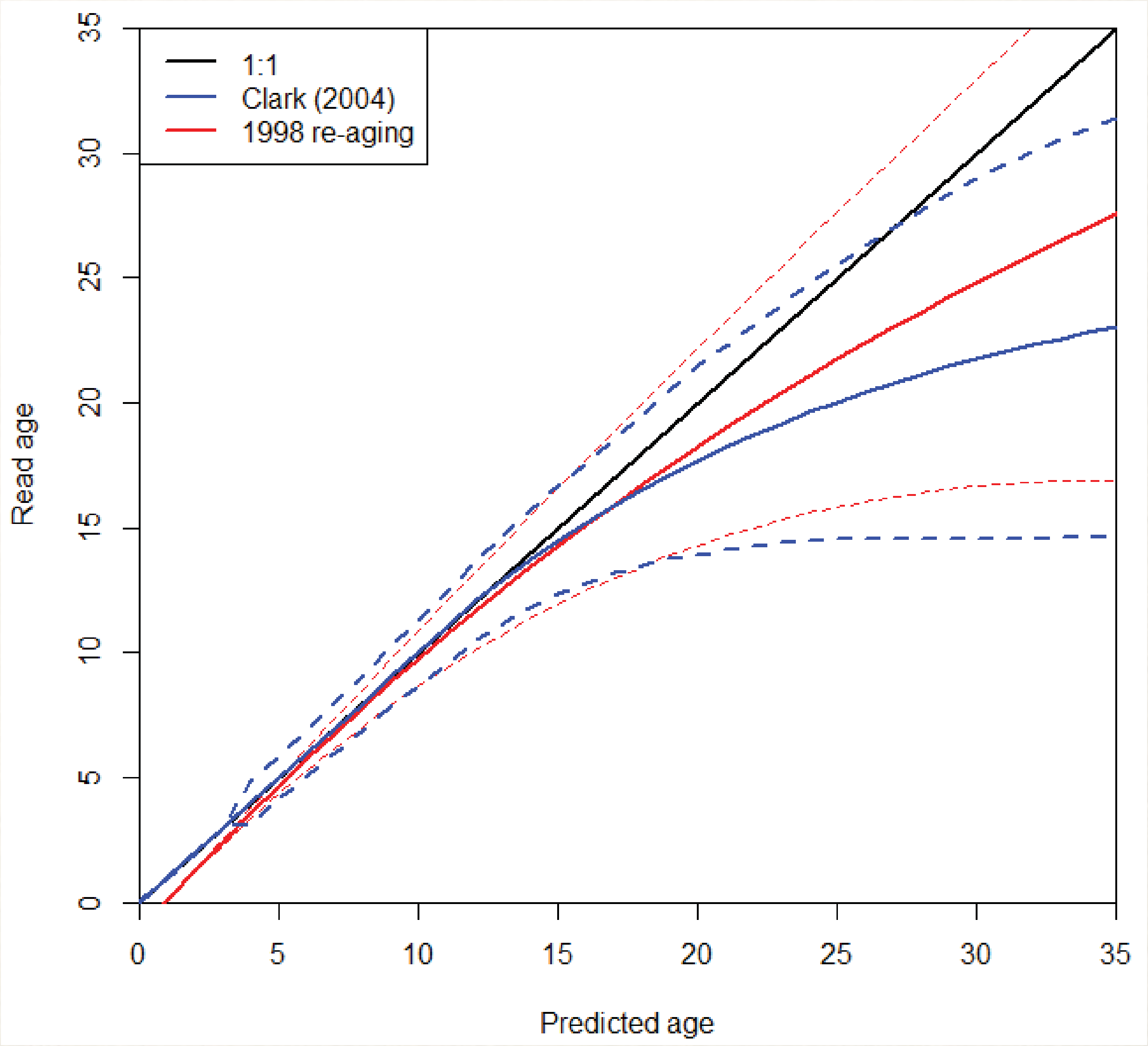
(B) Interspecific competition

- Exponential increase in Arrowtooth flounder.



Bias in ageing methods

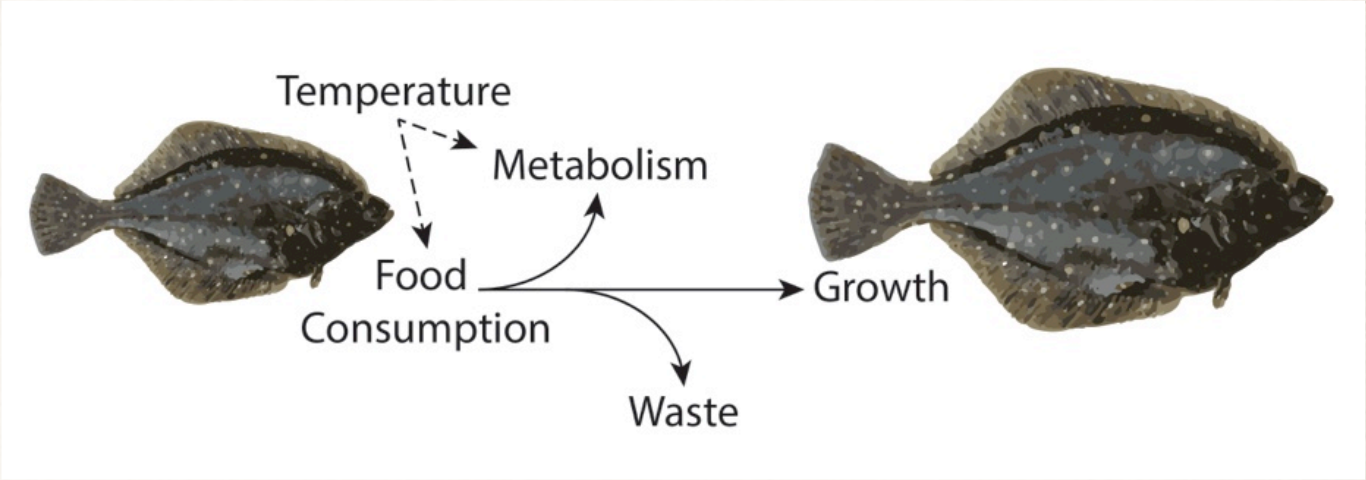
- Surface reads & break and bake reads.
    - Unbiased upto 12-15 years.
- Surface age > 15 years are likely much older.

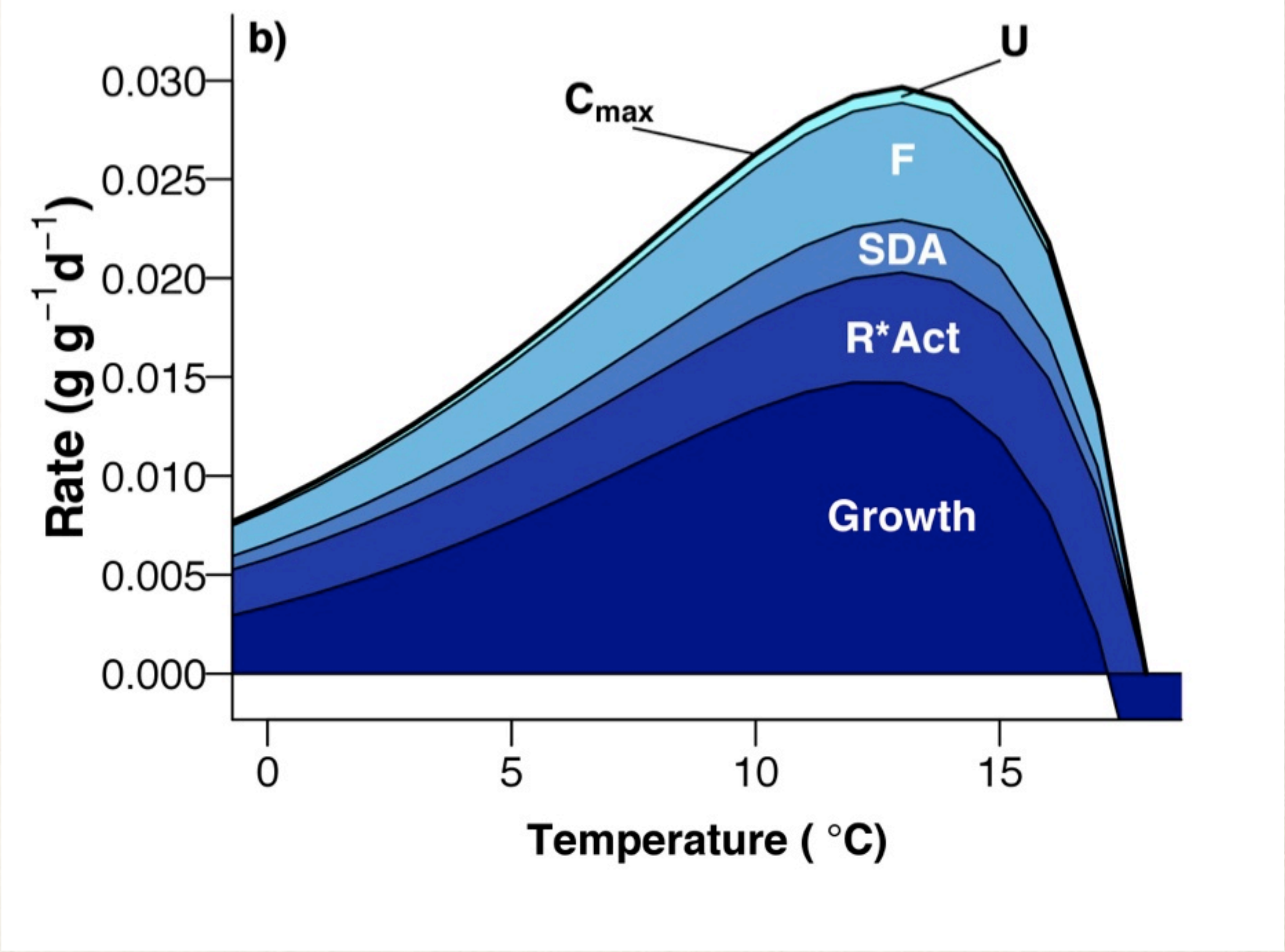


Cumulative size-selective fishing

- Faster growing fish recruit to minimum size limit earlier in life and are therefore subject to higher total mortality than slow growing fish.
- Slow growing fish are subject to a lower total mortality rate.
  - Extremely slow growing fish may never recruit to the minimum size limit.

Environmental covariates



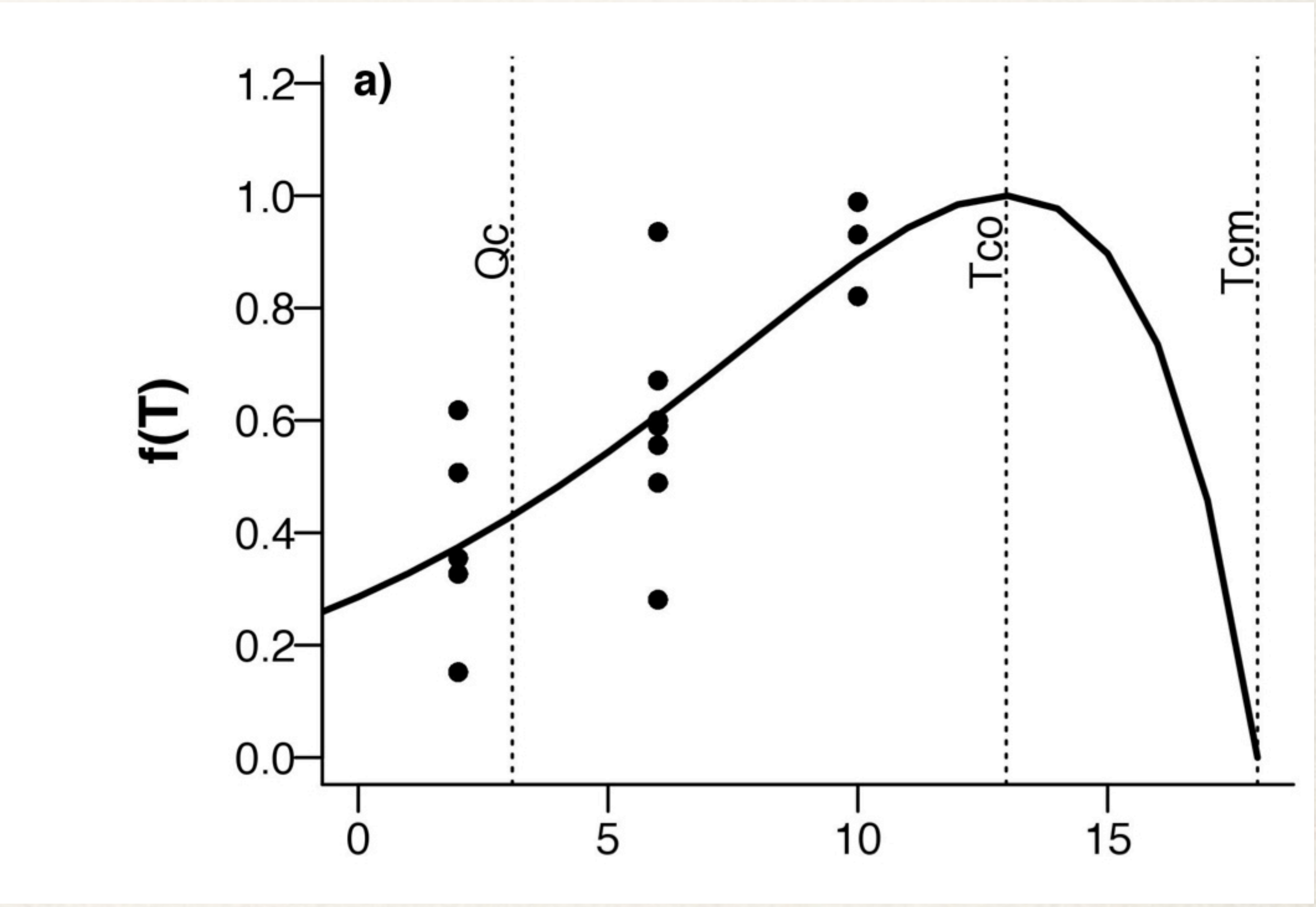


- Bio-energetic Temperature effects.
- Changes in diet composition.

Environmental covariates

$$C_d = C_d^{max} \cdot f(T) \cdot P_y$$

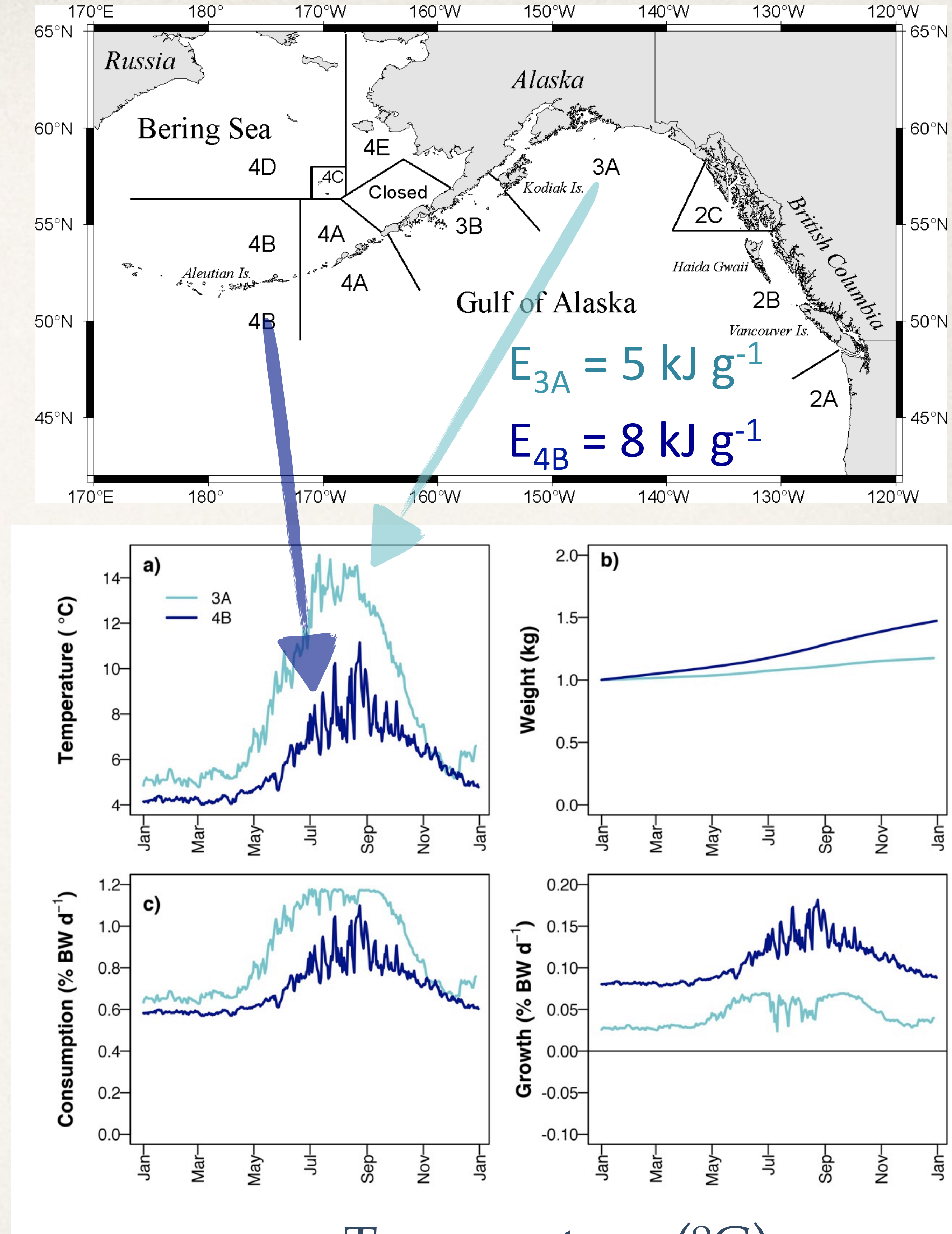
- Bio-energetic Temperature effects.
- Changes in diet composition.



Temperature (ºC)

Environmental covariates

- Bio-energetic Temperature effects.
- Changes in diet composition.



Temperature (°C)

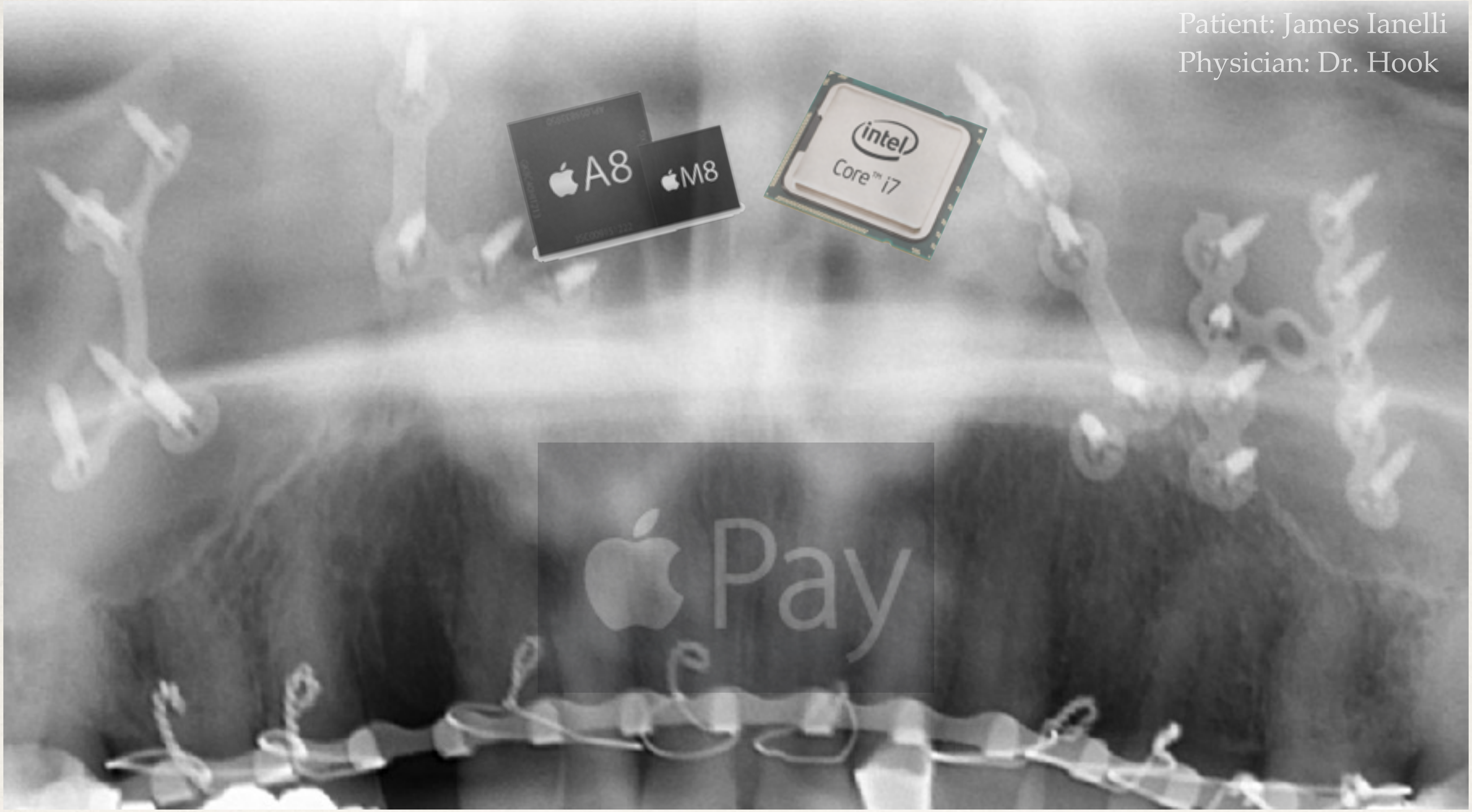
Prior hook injuries

NO PRIOR

MINOR

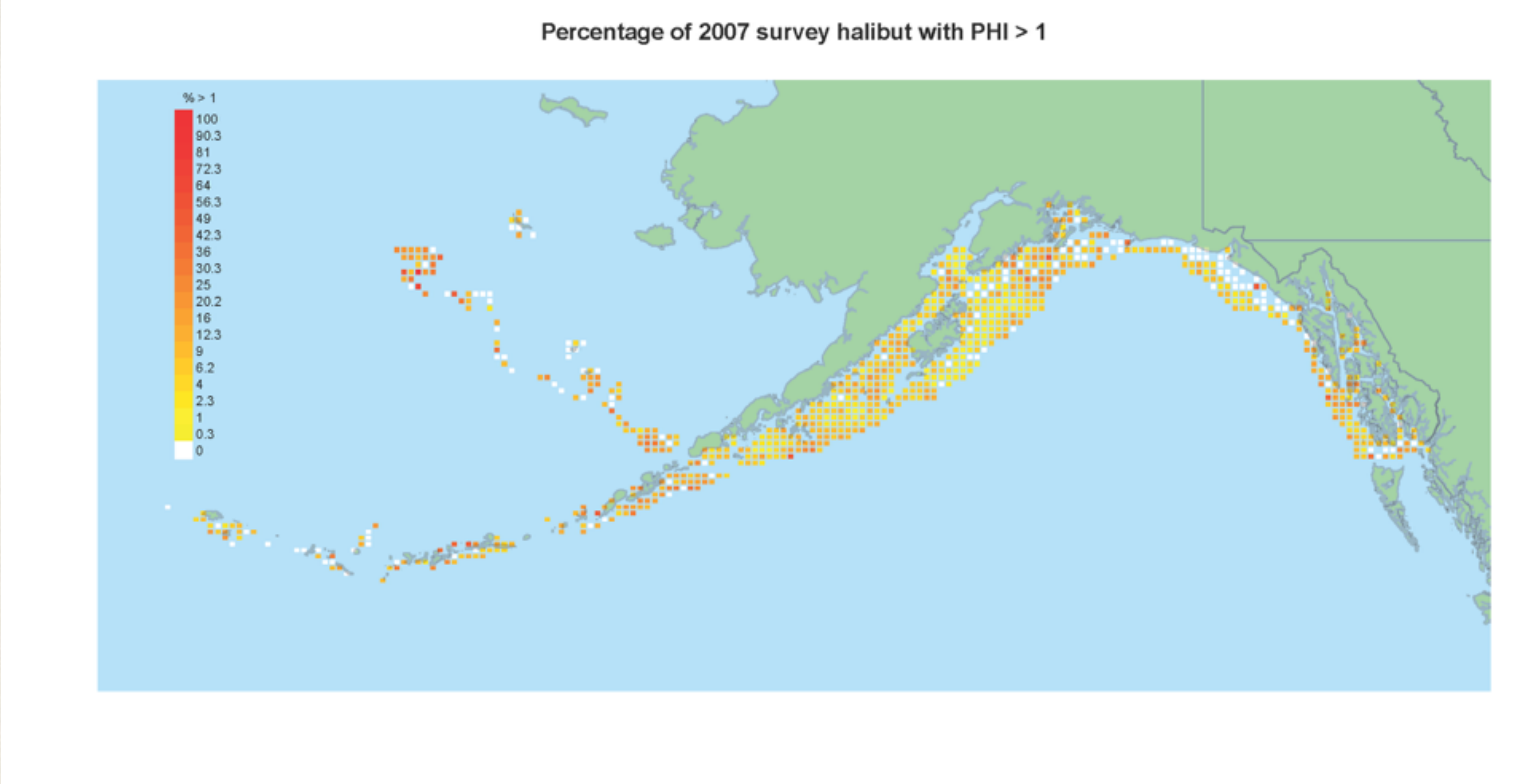
MODERATE

SEVERE



Ask Jim

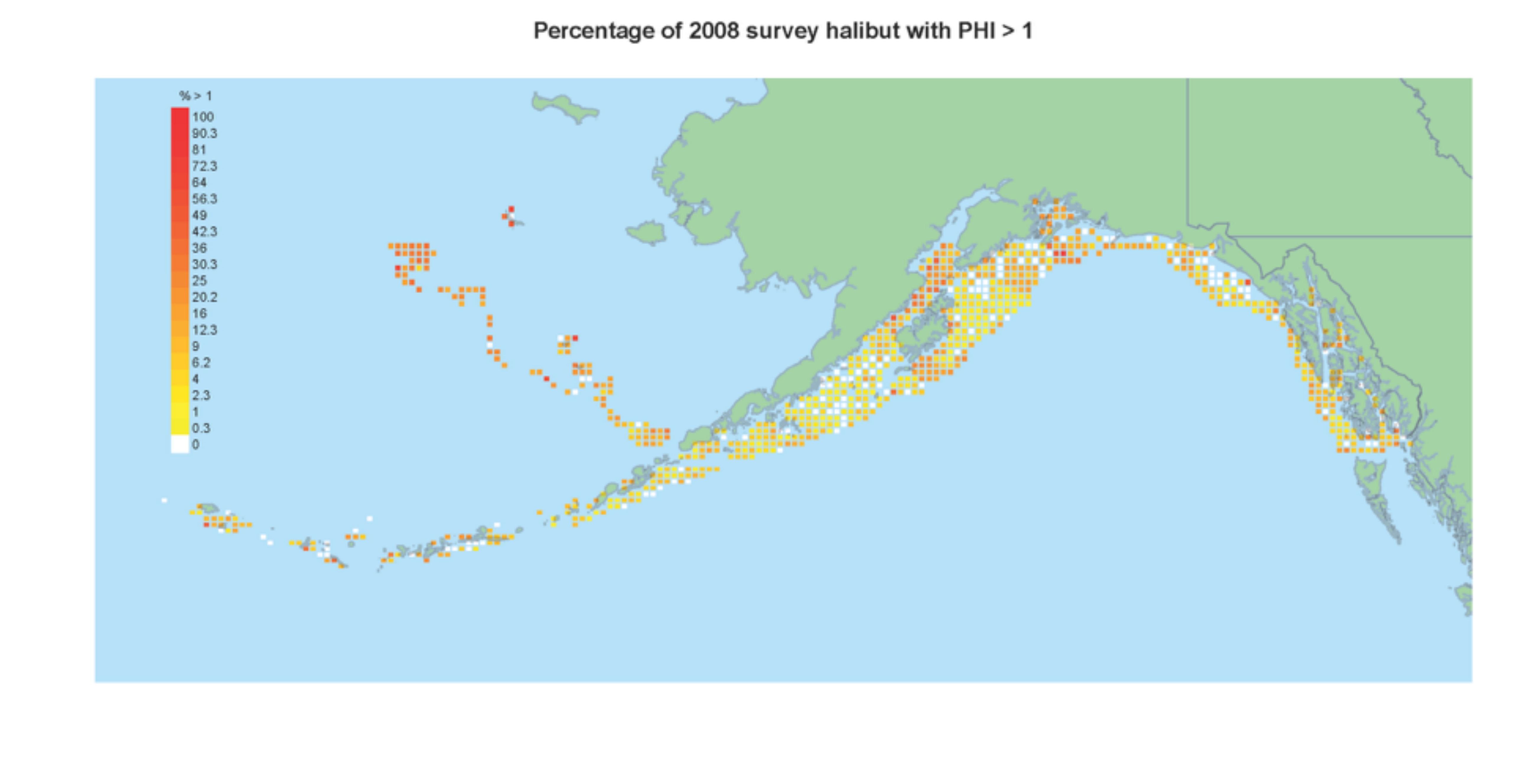
Hard to eat when you have a prior hook injury



2007

Percent of fish with prior hook injuries in the IPHC set line survey.

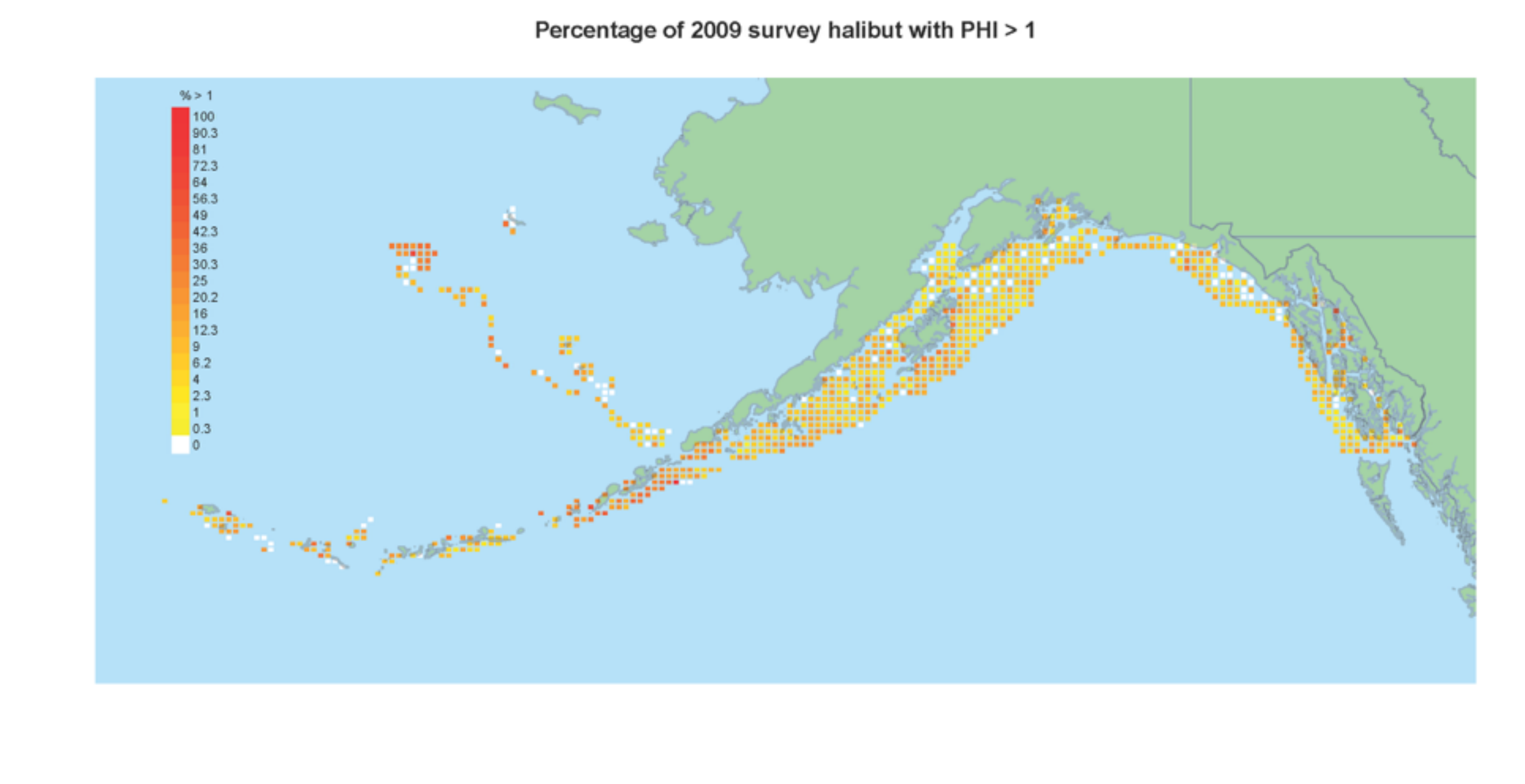
Date



2008

Percent of fish with prior hook injuries in the IPHC set line survey.

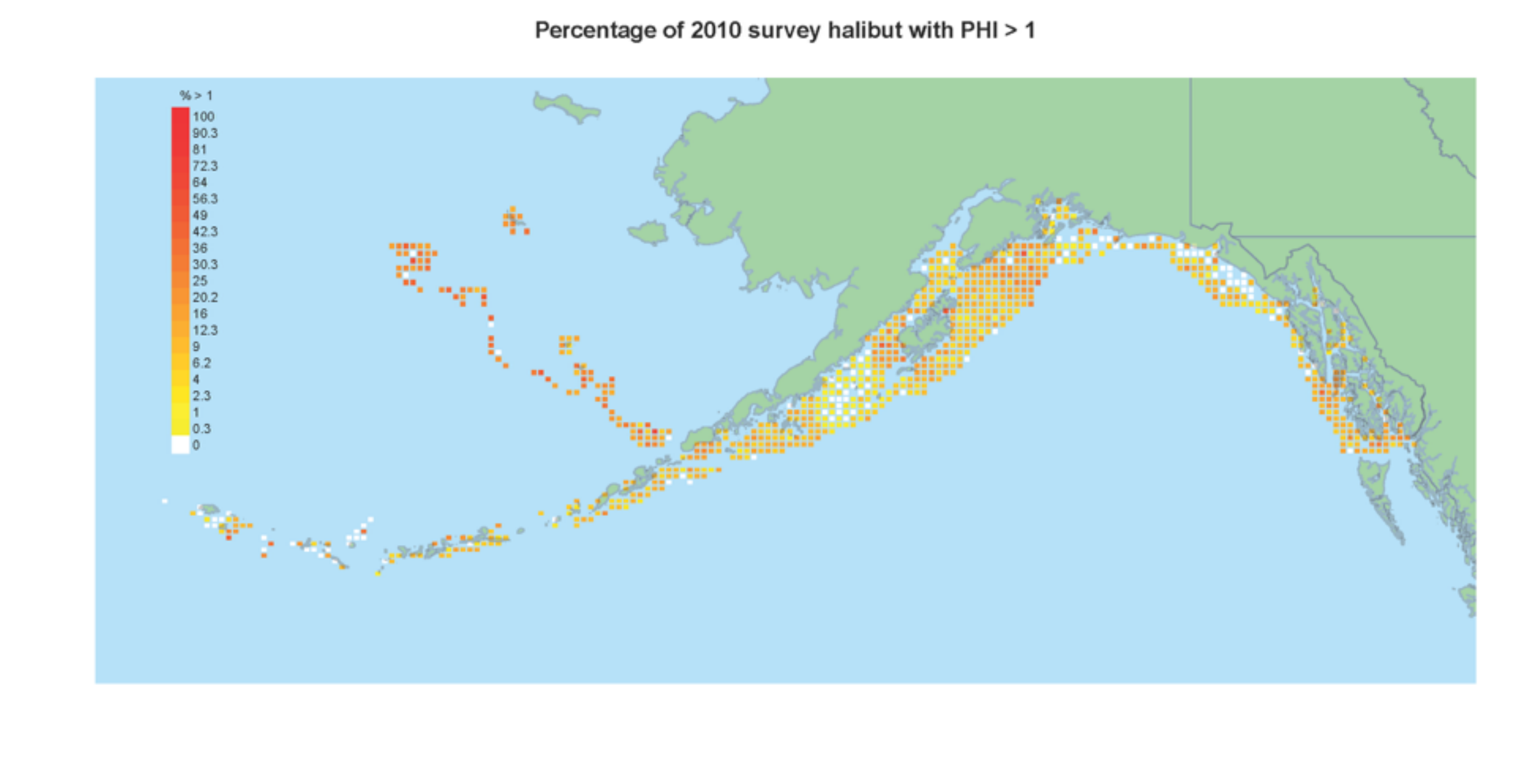
Date



2009

Percent of fish with prior hook injuries in the IPHC set line survey.

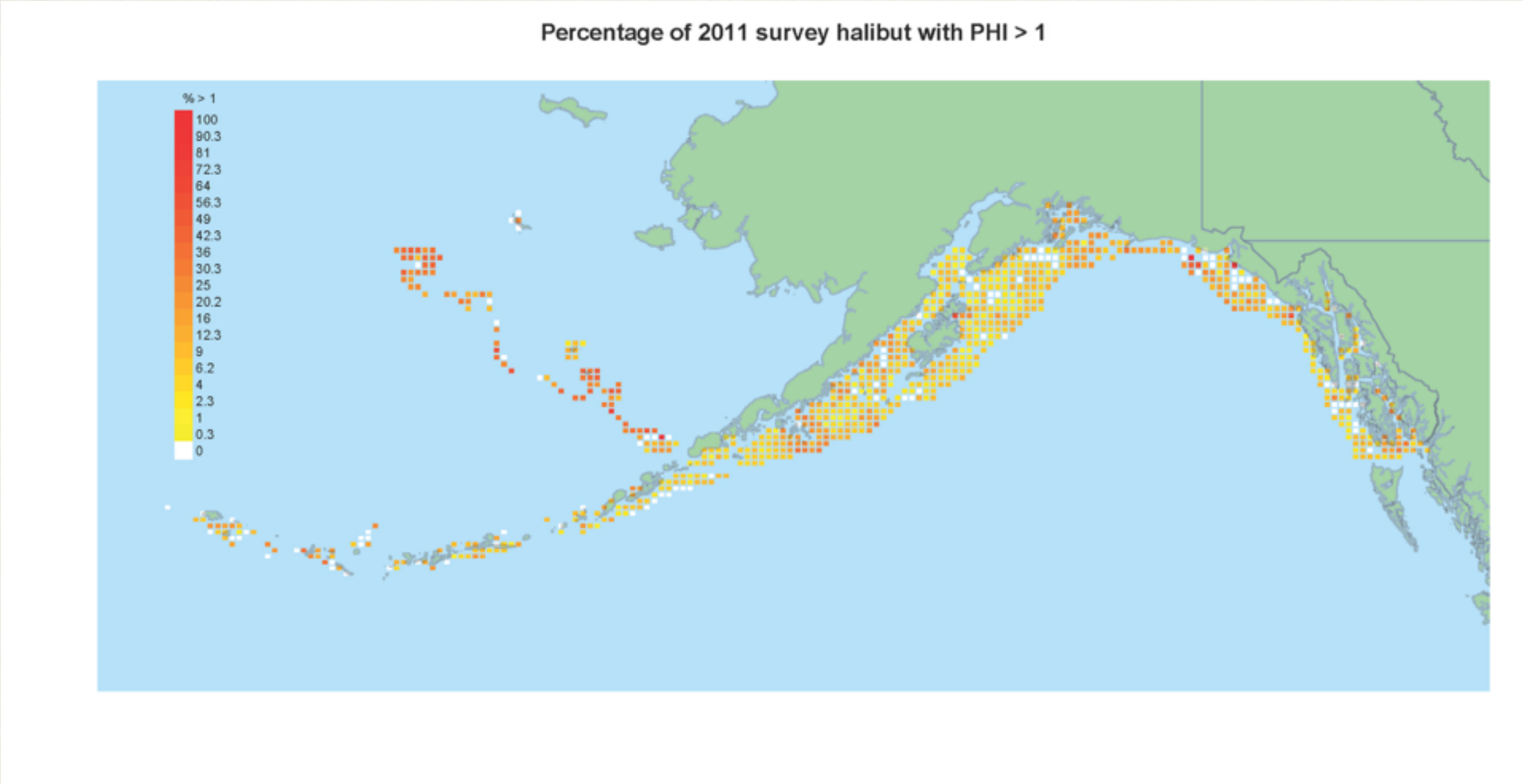
Date



2010

Percent of fish with prior hook injuries in the IPHC set line survey.

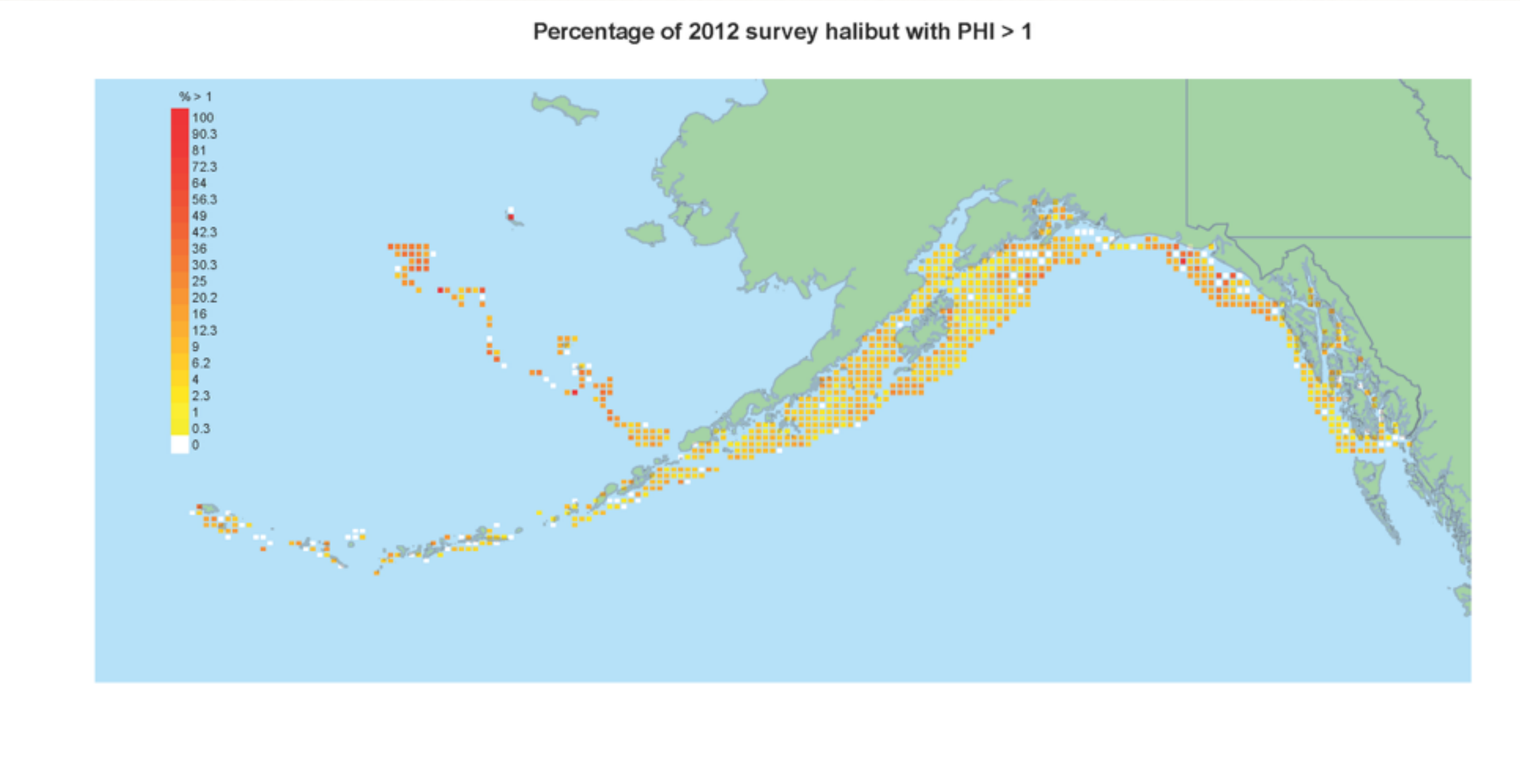
Date



2011

Percent of fish with prior hook injuries in the IPHC set line survey.

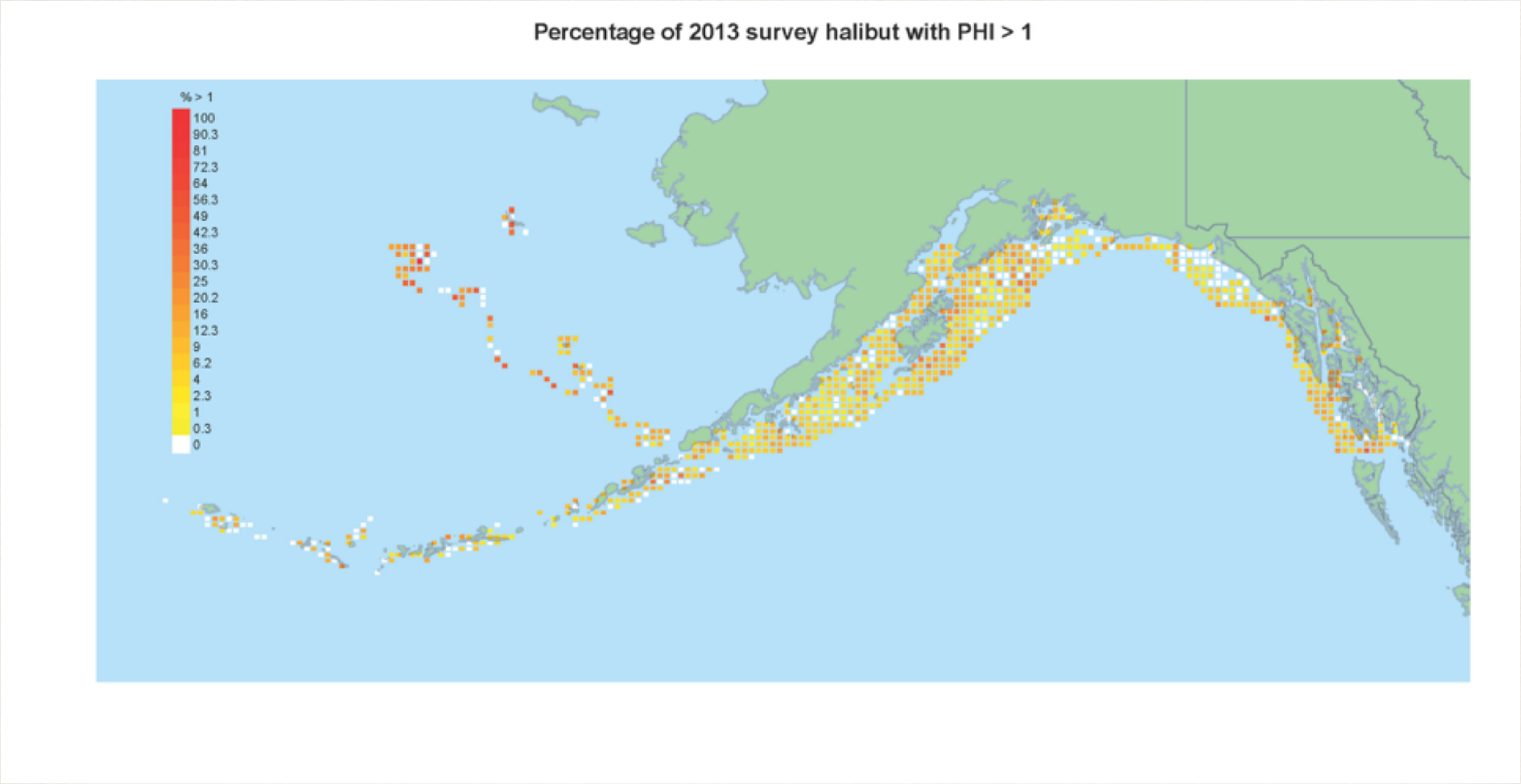
Date



2012

Percent of fish with prior hook injuries in the IPHC set line survey.

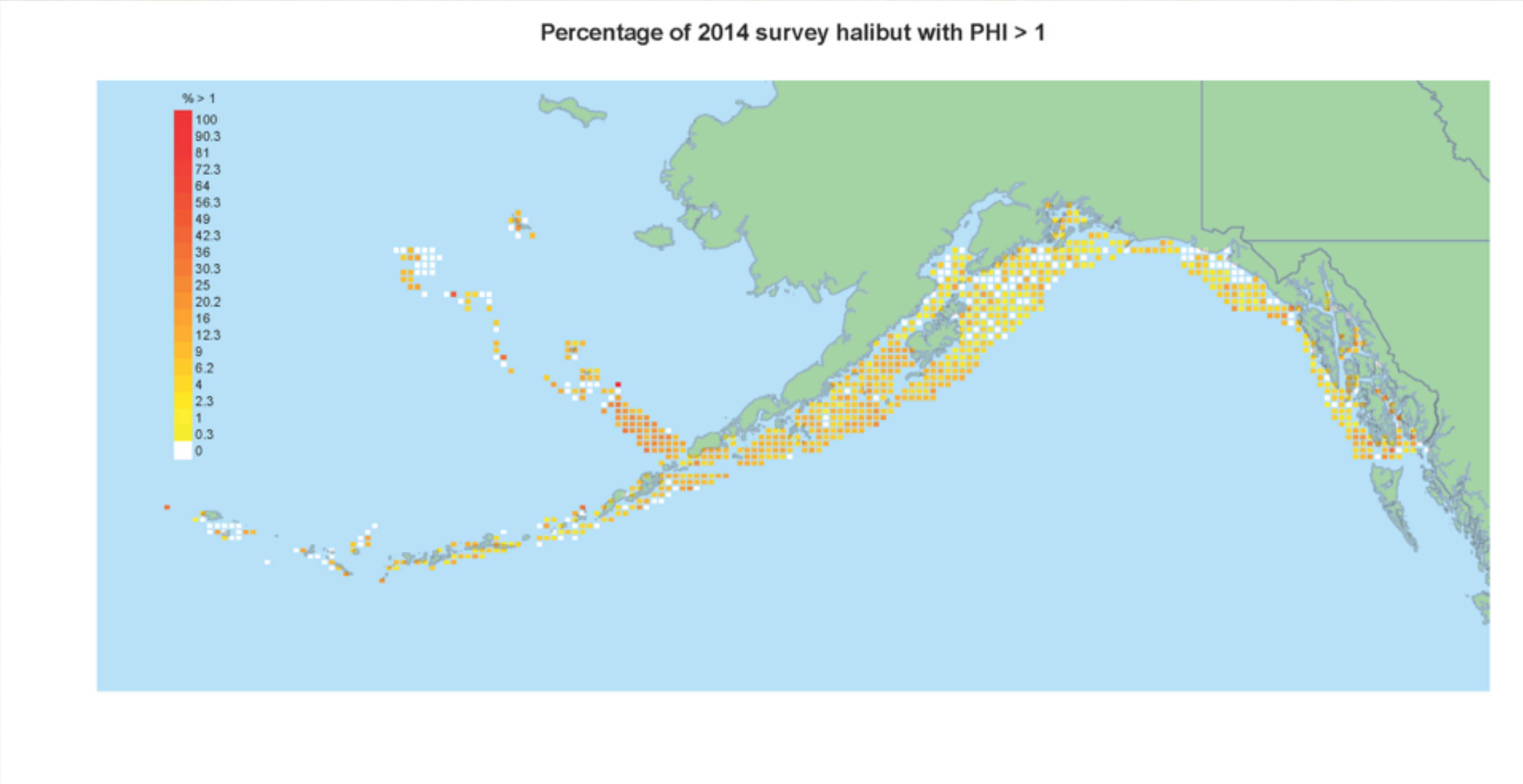
Date



2013

Percent of fish with prior hook injuries in the IPHC set line survey.

Date



2014

Percent of fish with prior hook injuries in the IPHC set line survey.

Date

Summary of alternative hypotheses

- Little doubt that all of these hypotheses have contributed to the observed changes in size-at-age.
- Important question is what can we “manage” to slow or reverse in declining trends in size-at-age?
  - Fishing related effects (size-limits & cumulative mortality).
  - Hooking mortality on sub-legal fish.
  - Bycatch in non-target fisheries.

Stock assessment and harvest policy

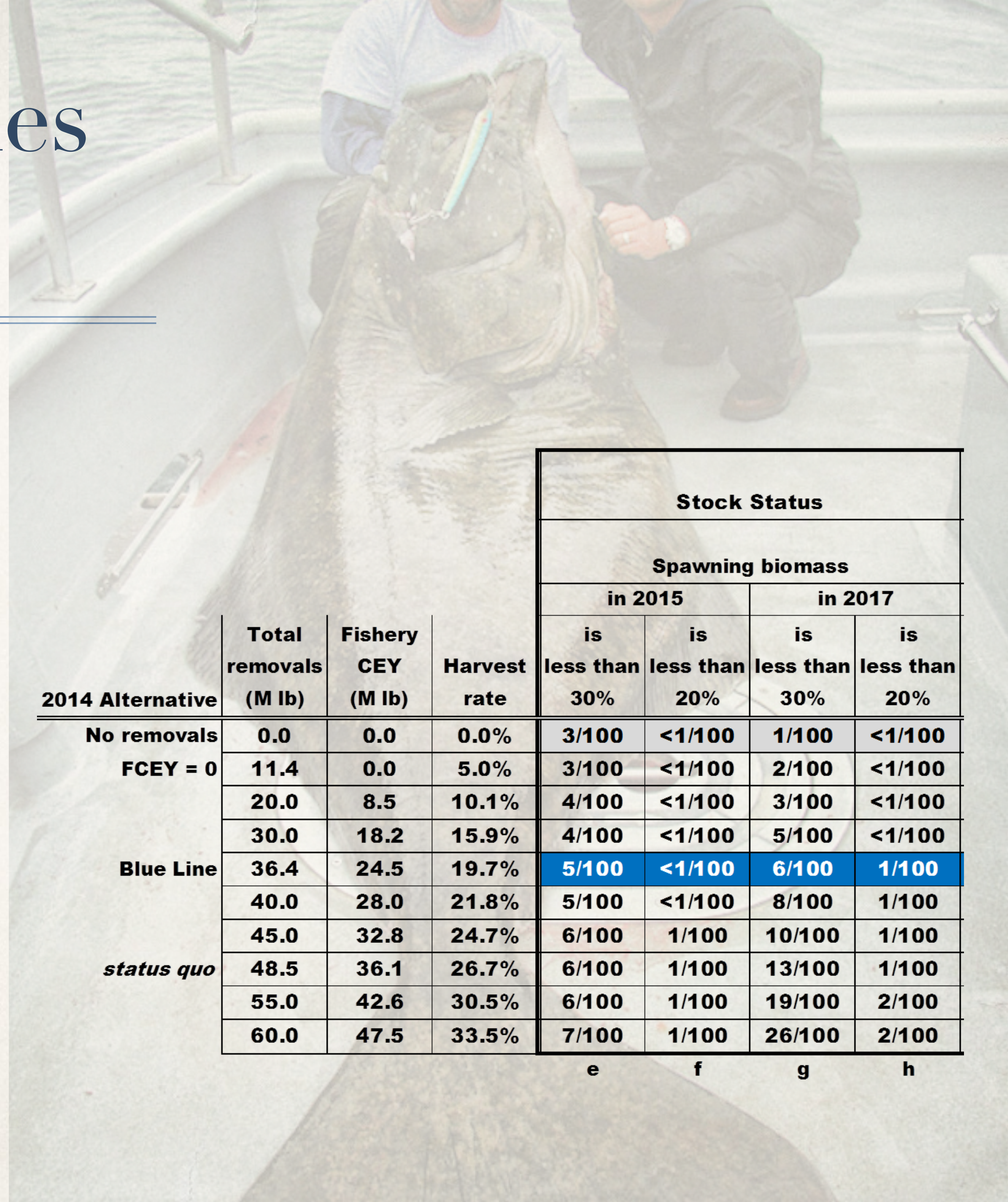
- Growth in the context of Pacific halibut assessments
- Harvest policy implications

Stock assessment overview

- Coast wide assessment– data: weighted average by area.
- Assessment is based on empirical weight-at-age data.
- Time-varying age-based selectivity.
- Recent empirical weight-at-age used for short-term (1-3 year) projections.
- No parametric growth model used in the assessment at this time.

Decision tables & growth.

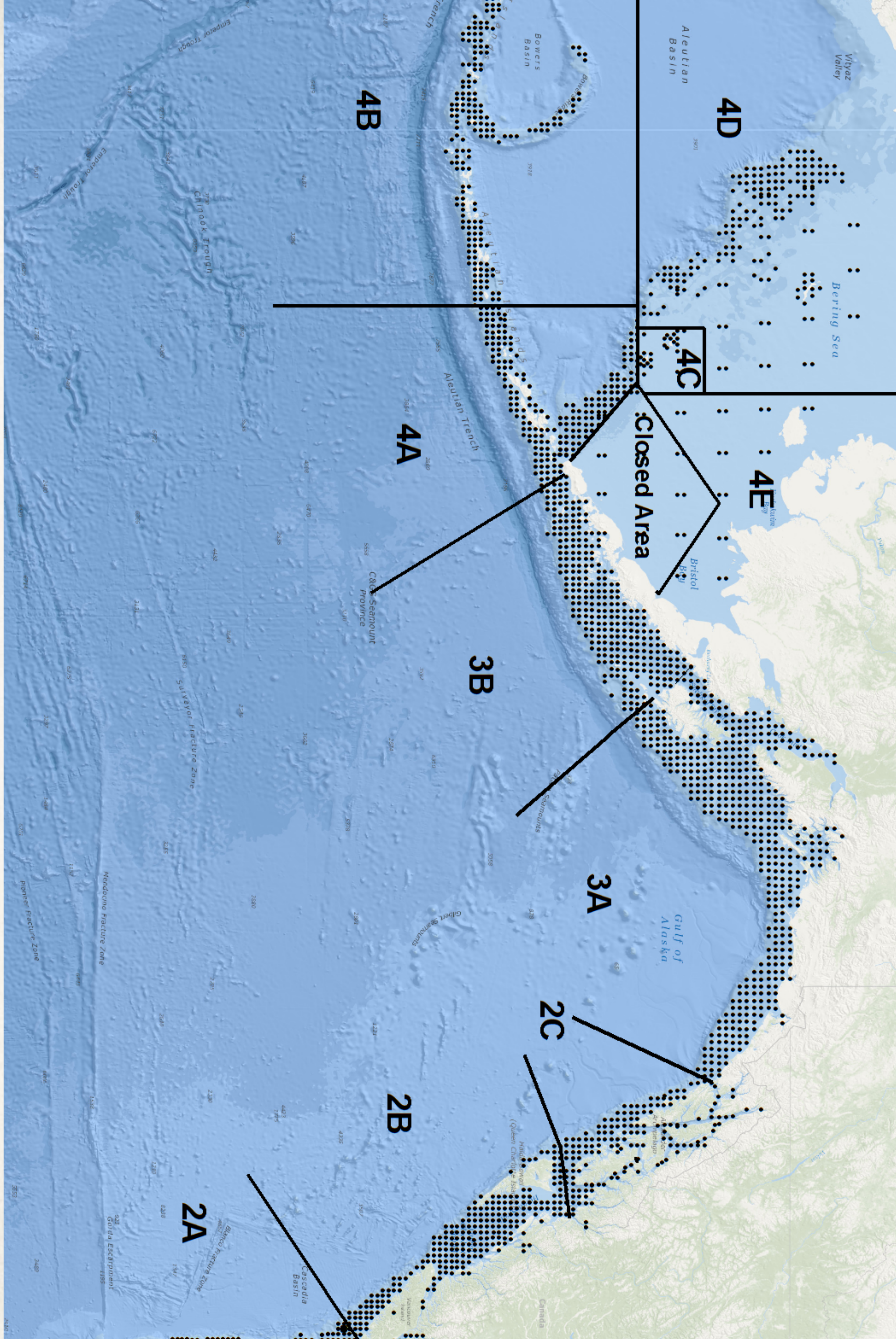
- Spawning biomass depletion is sensitive to changes in halibut growth.
- Subjective decision on how to project recent trends in growth rates.

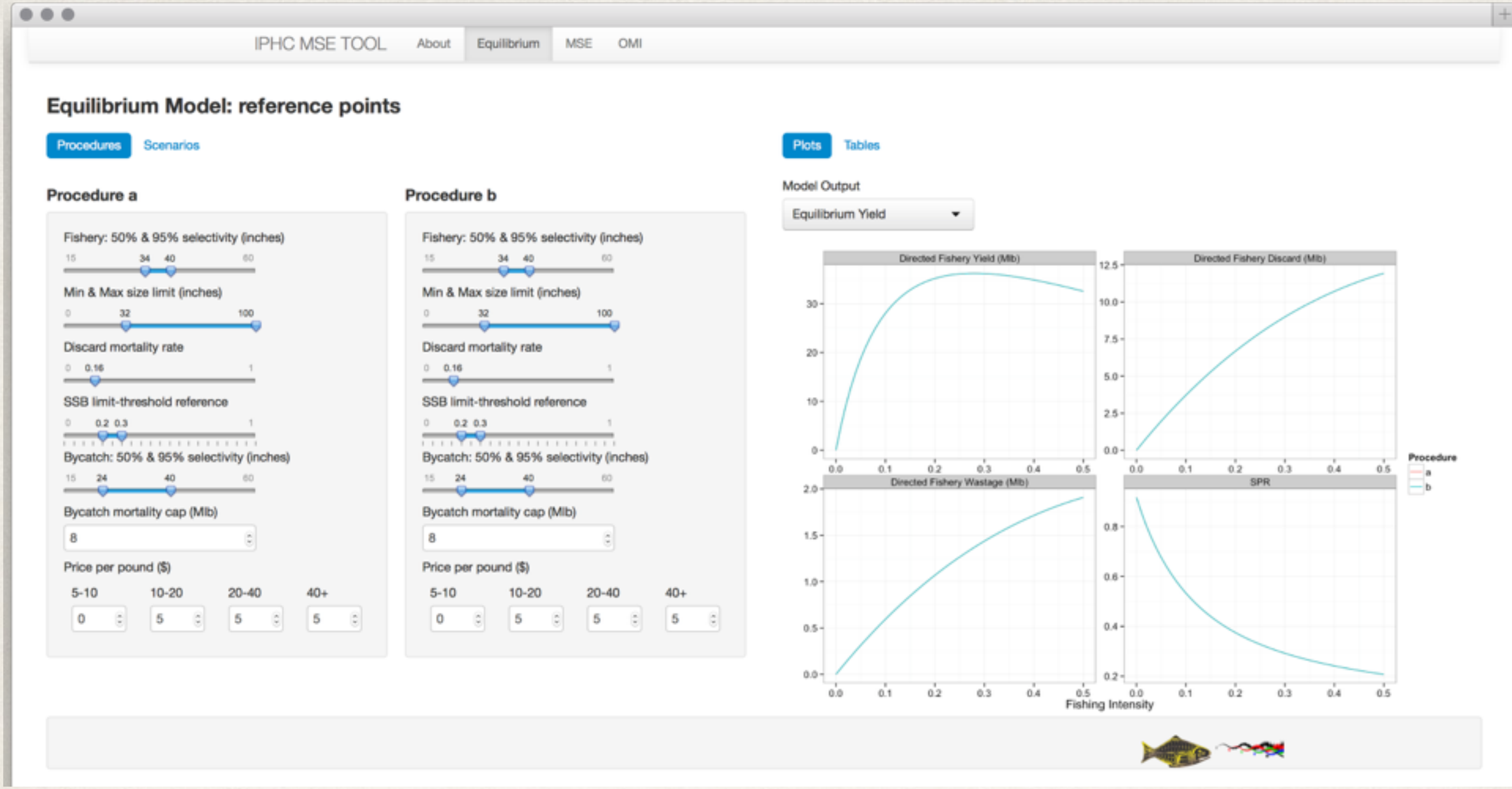


2014 Alternative	Total removals (M lb)	Fishery CEY (M lb)	Harvest rate	Stock Status: Spawning biomass in 2015 is less than 30%	Spawning biomass in 2015 is less than 20%	Spawning biomass in 2017 is less than 30%	Spawning biomass in 2017 is less than 20%
No removals	0.0	0.0	0.0%	3/100	<1/100	1/100	<1/100
FCEY = 0	11.4	0.0	5.0%	3/100	<1/100	2/100	<1/100
	20.0	8.5	10.1%	4/100	<1/100	3/100	<1/100
	30.0	18.2	15.9%	4/100	<1/100	5/100	<1/100
Blue Line	36.4	24.5	19.7%	5/100	<1/100	6/100	1/100
	40.0	28.0	21.8%	5/100	<1/100	8/100	1/100
	45.0	32.8	24.7%	6/100	1/100	10/100	1/100
status quo	48.5	36.1	26.7%	6/100	1/100	13/100	1/100
	55.0	42.6	30.5%	6/100	1/100	19/100	2/100
	60.0	47.5	33.5%	7/100	1/100	26/100	2/100
				e	f	g	h

Harvest policy

- Determine total coast-wide removals based on decision table.
- Use survey (3-yr wt.average) to apportion biomass to 8 areas.
- Apply area-specific harvest rates to biomass in each area, and scale up/down to be consistent with coast-wide removals.





Harvest policy implications

Understanding how changes in growth affects harvest policy.

https://iphc.shinyapps.io/shiny/

Many moving parts in determining optimal harvest policies.

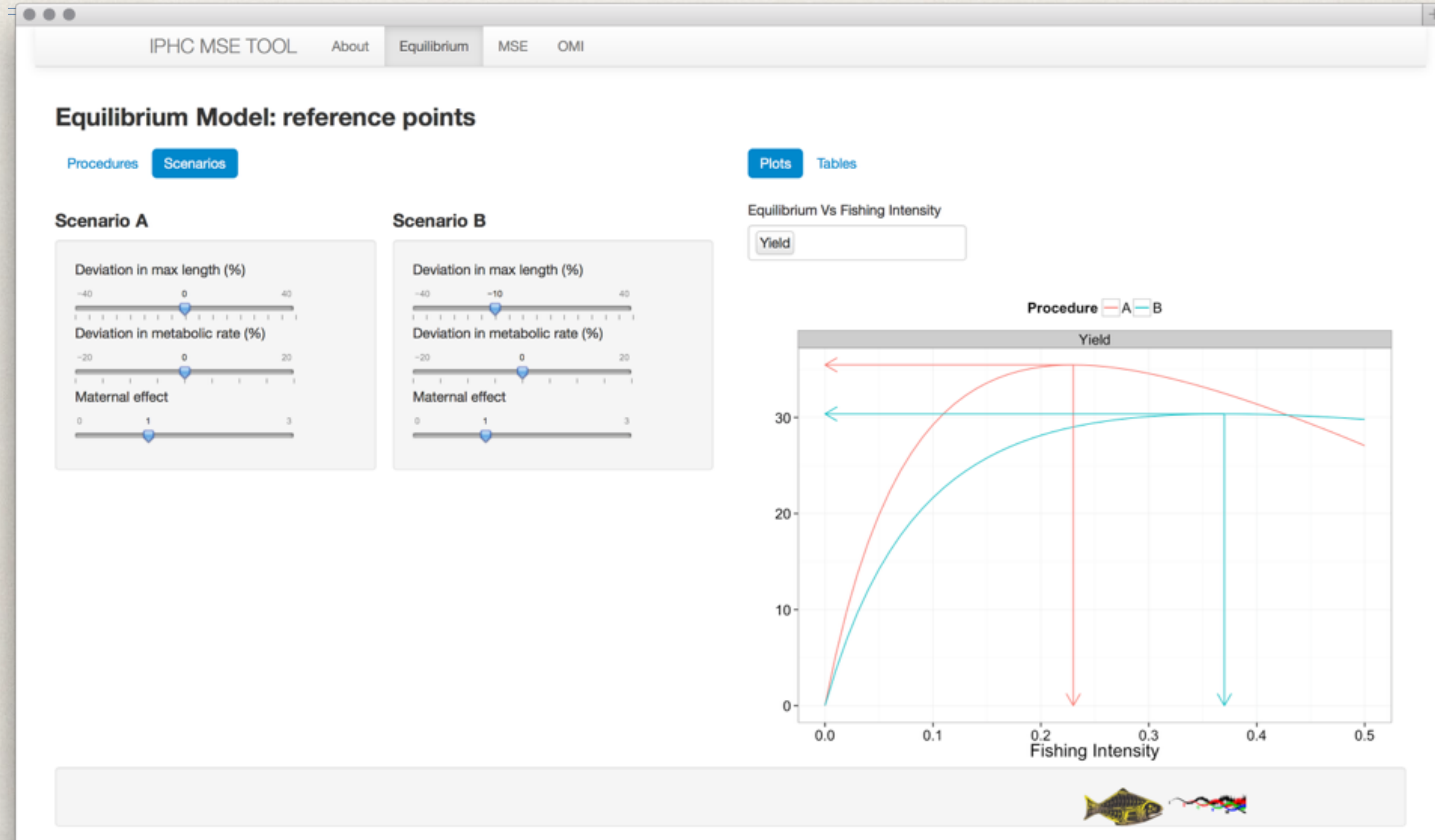
- Growth & size-at-age
- Selectivity
- Bycatch & allocation among fisheries
- Size-limits & discard mortality rates.

How do we begin to understand how each of these moving parts alone affect harvest policy?

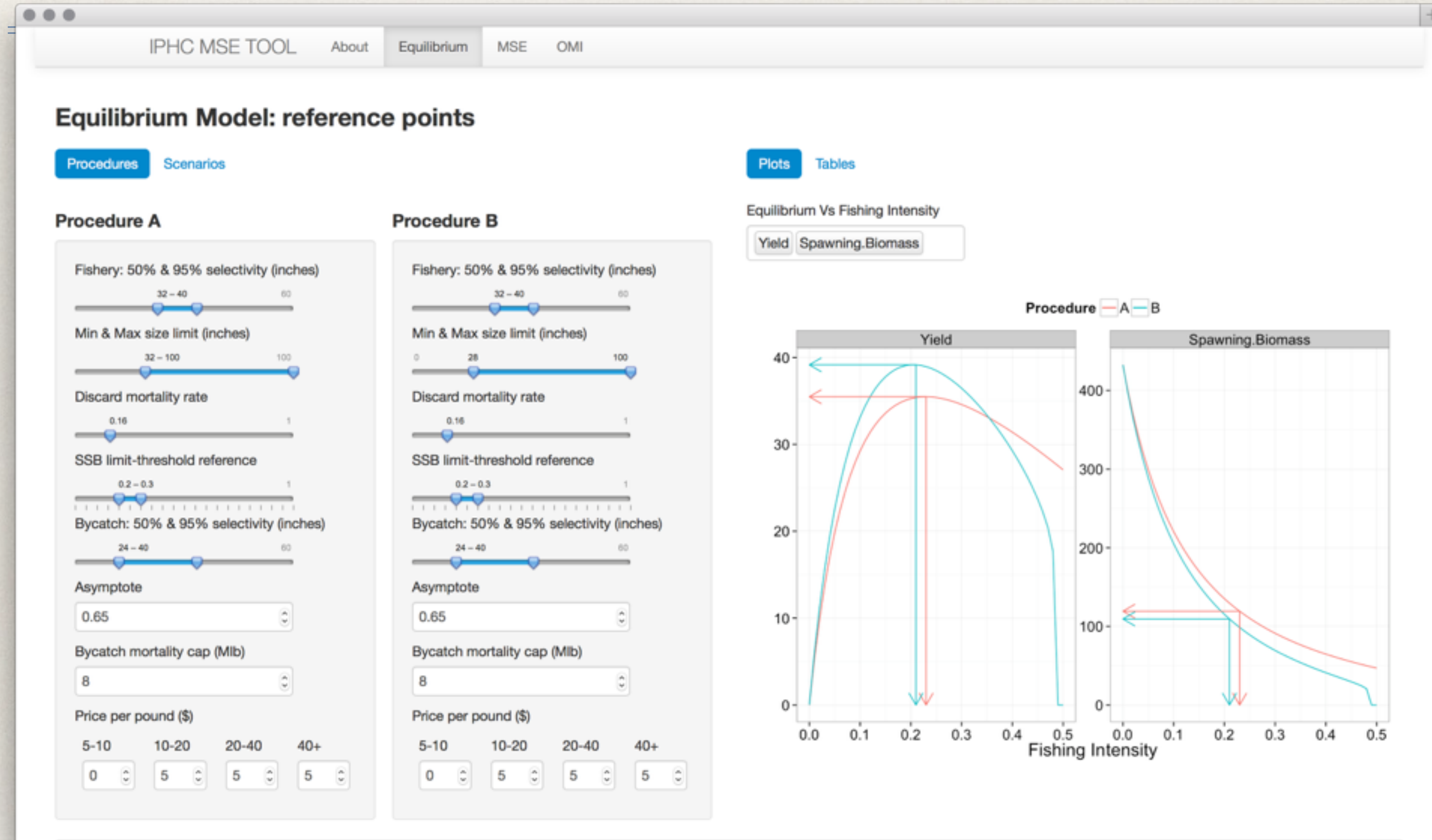
How sensitive are reference points to each of these moving parts?

–IPHC Management Strategy Evaluation Board

10% decrease in Linf



Reduce size-limit: 32 cm to 28 cm.



Summary

- IPHC relies heavily on empirical size-at-age data to overcome the challenges with spatiotemporal variation in halibut growth.
- Harvest policy is sensitive to changes in size-at-age (growth).

Key Challenges

- How should fishing mortality be distributed in space when there is spatial variation in size-at-age and migration?

- Temporal variation in growth is just one form or non-stationarity in the underlying production function; is it possible to develop procedures that are robust to this variation?

Acknowledgements

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- Lucie, Sunday, & Tabitha
- & My WIFE!