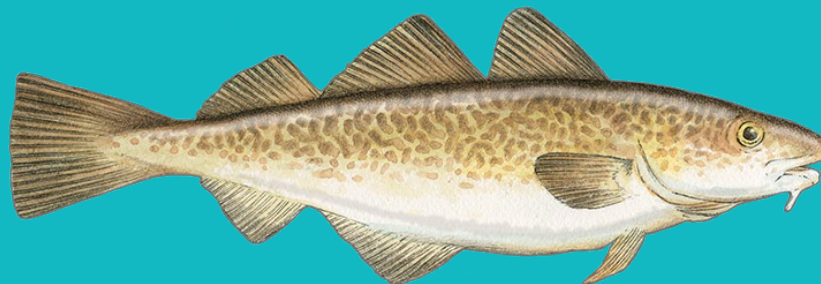




**NOAA**  
**FISHERIES**

# Aleutian Islands Pacific cod Research Updates

Ingrid Spies, Steve Barbeaux, Pete Hulson, Laura  
Spencer, Laura Timm



# Assessment



**NOAA**  
**FISHERIES**

# Assessment

Government shutdown in 2025 – no new assessment.

A new age-structured model was accepted in 2024 for Aleutian Islands Pacific cod.

2026 assessment – similar to 2024.

- Looking for better ways to link natural mortality to temperature.
- Exploring ways to estimate heatwave mortality without increasing recruitment in the model.



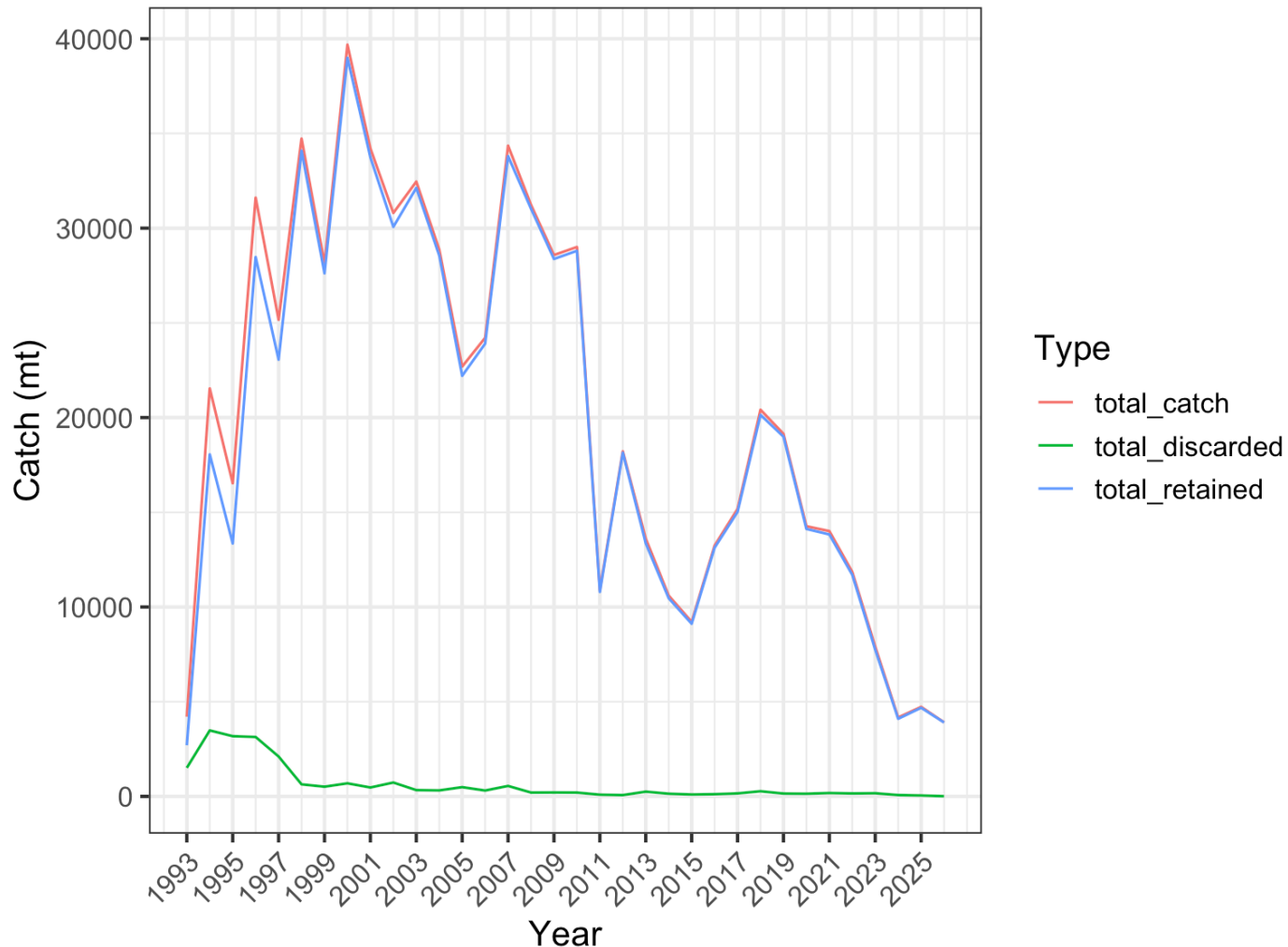
**NOAA**  
FISHERIES

# Catch

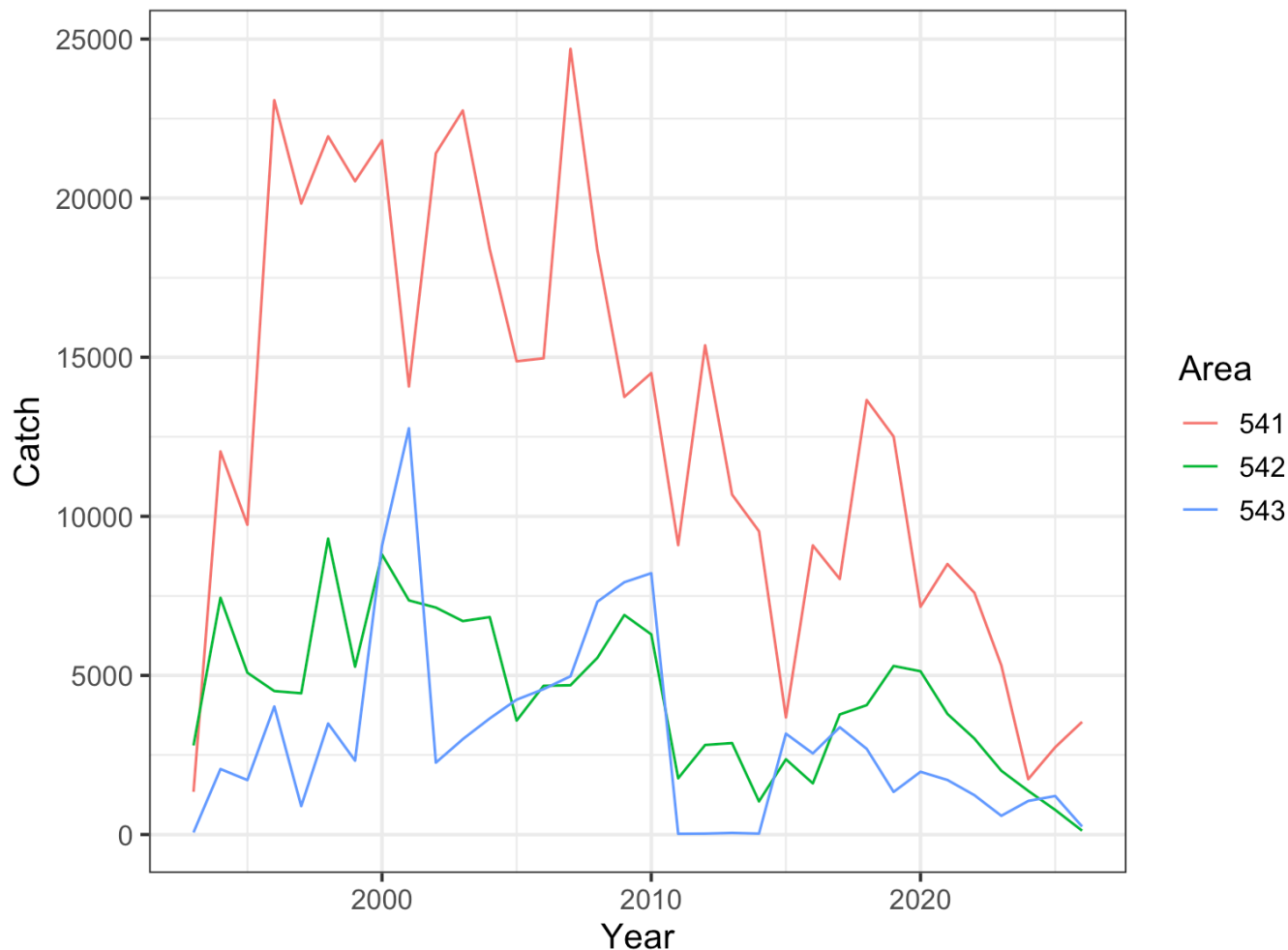


**NOAA**  
**FISHERIES**

# Aleutian Islands catch has declined, most catch is retained.



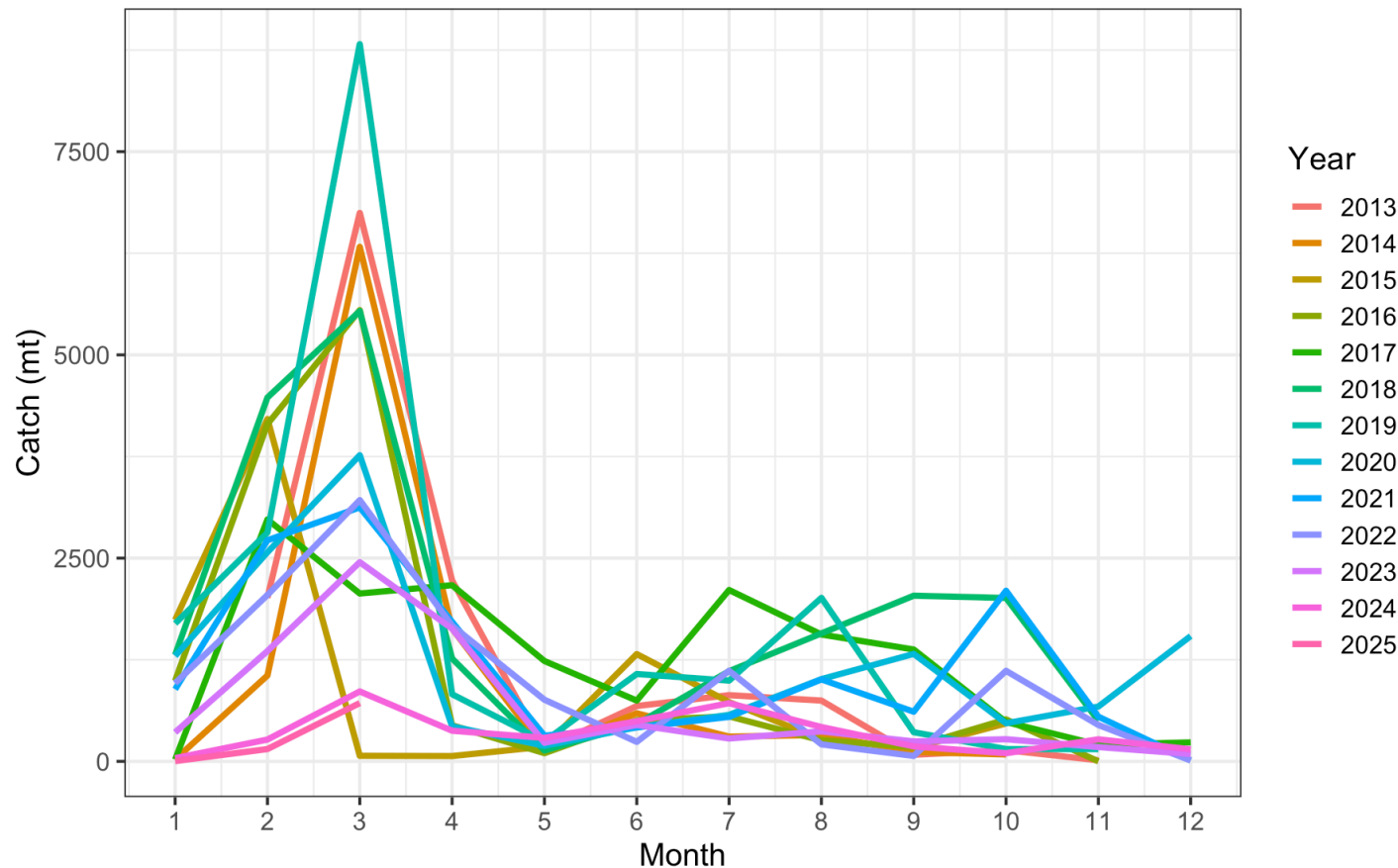
# Most catch takes place in the eastern Aleutians, area 541.



**NOAA**  
FISHERIES

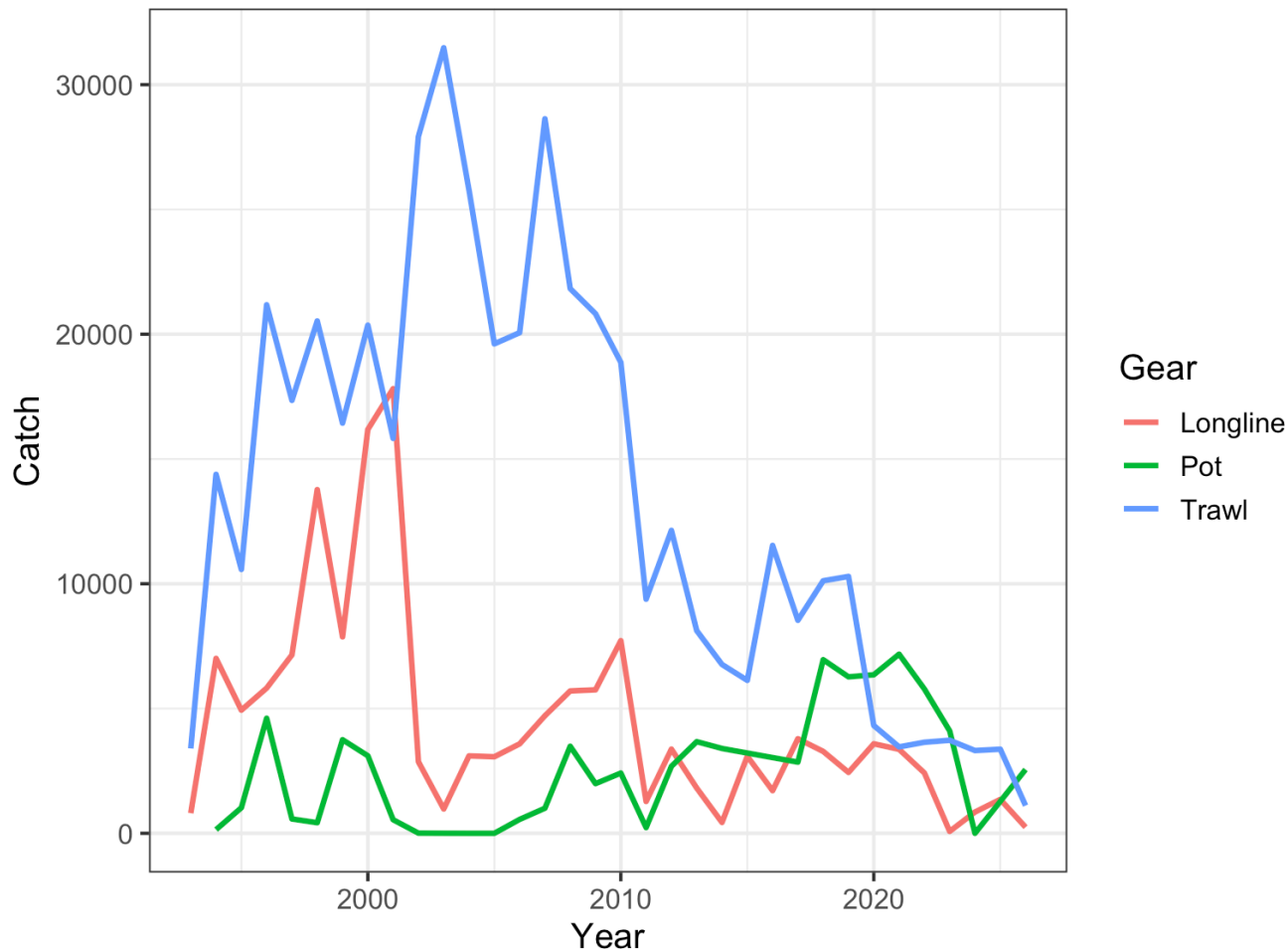
# Catch primarily occurs during winter when cod are aggregating to spawn.

Aleutian Islands catch by month since 2013



**NOAA**  
FISHERIES

# Gear is predominantly trawl, although pot has become more predominant.



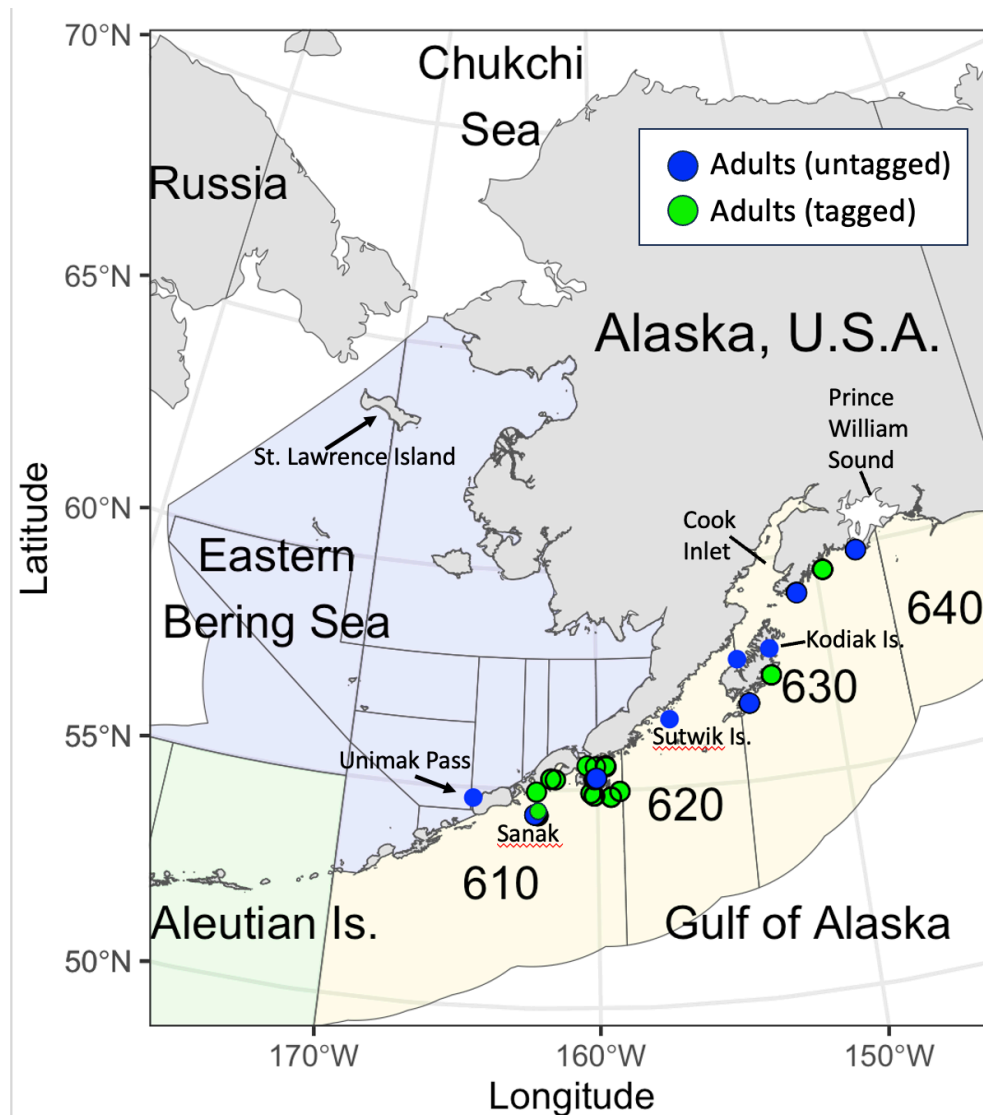
# Genetics update

## Recent genetics+tagging study

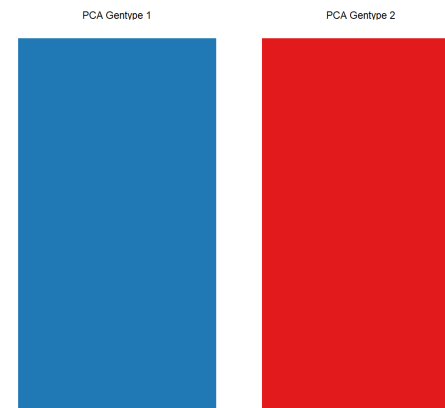
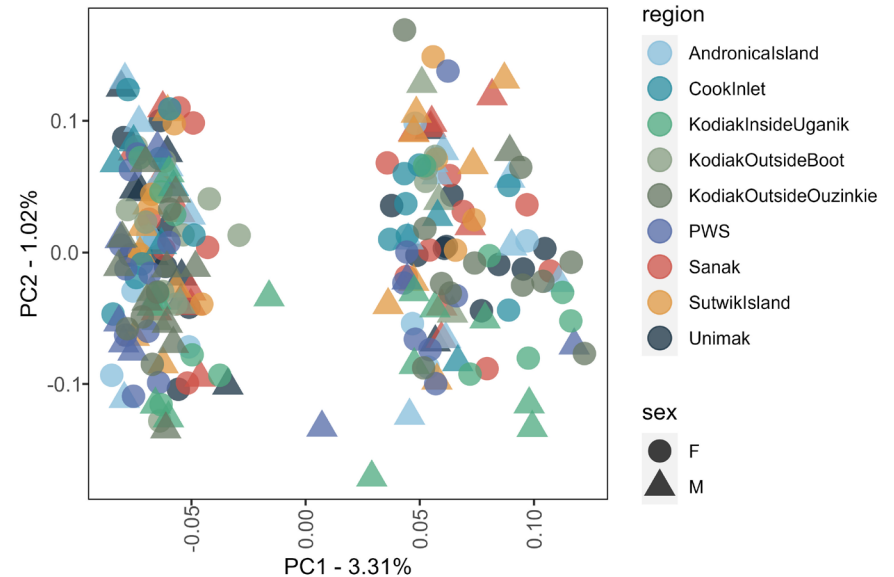
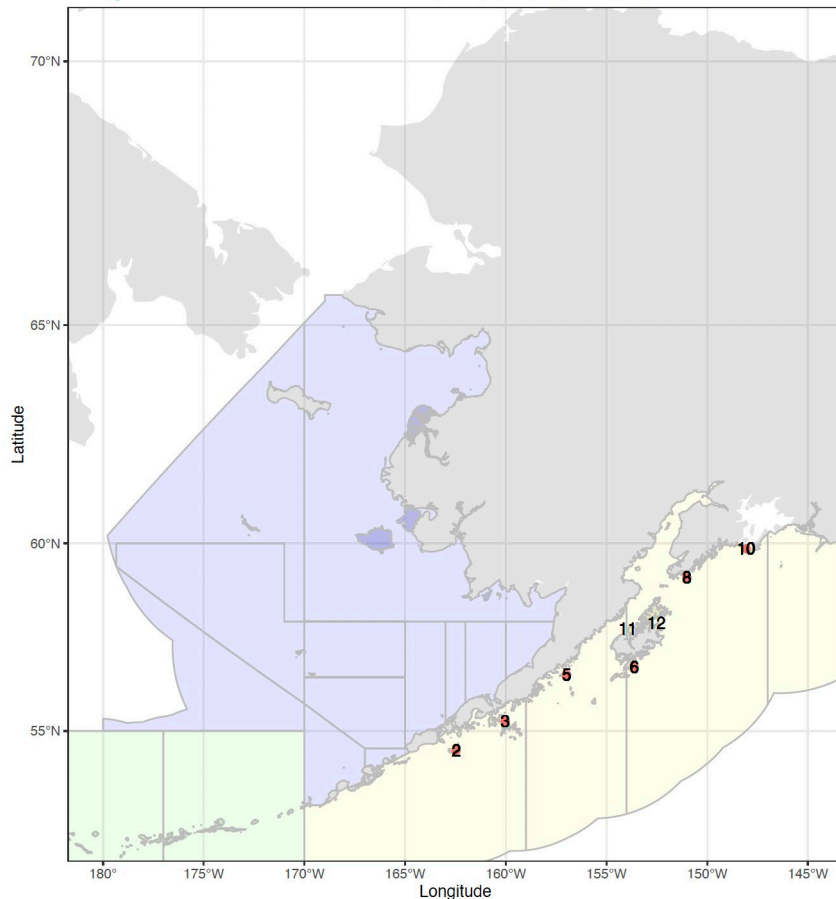


**NOAA**  
FISHERIES

# Samples from the western GOA + Unimak



Sequencing to examine whether subtle differences exist between EBS and western GOA cod resulted in evidence for ecotypes.



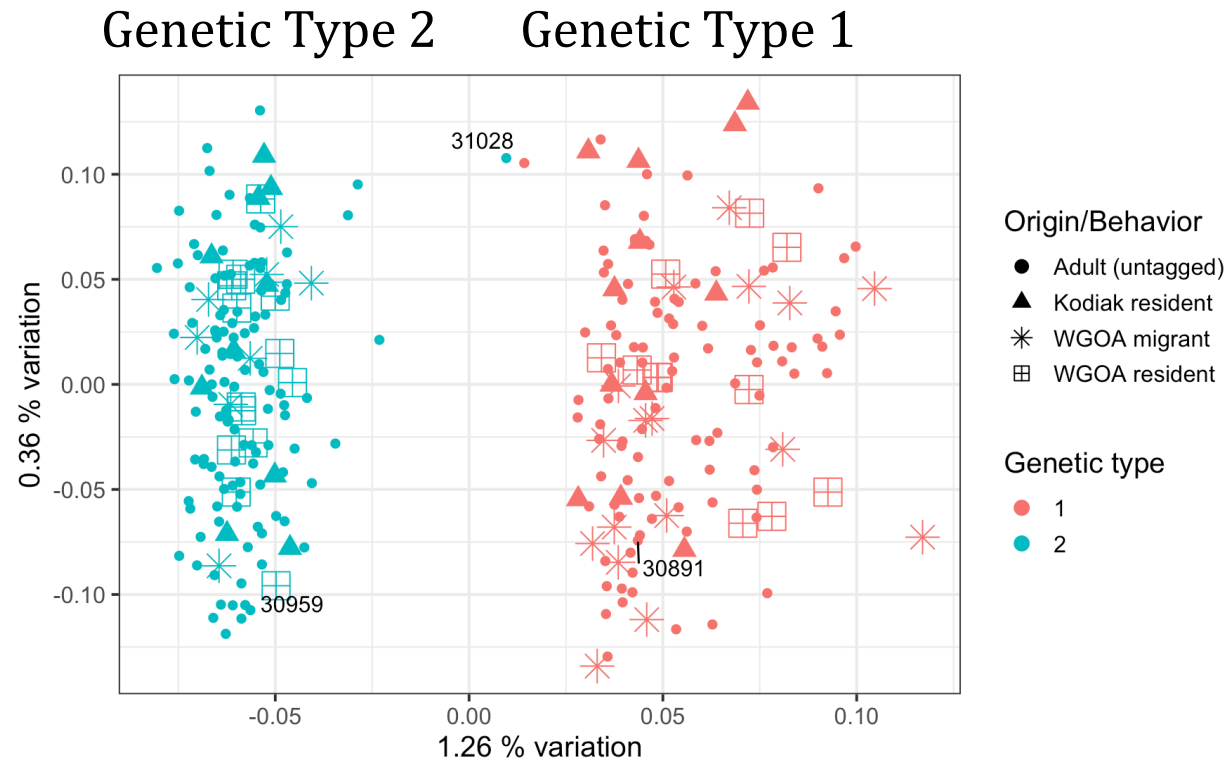
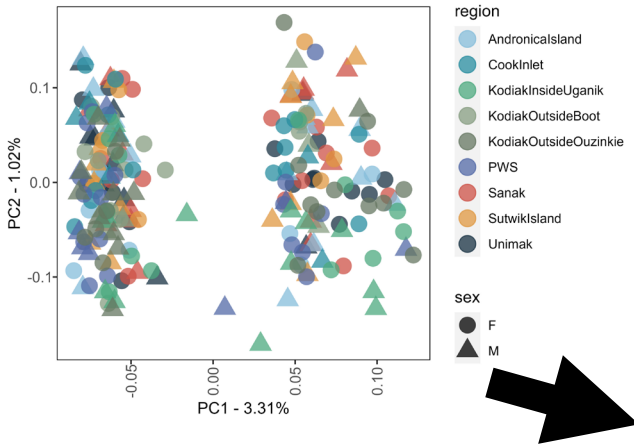
100% assignment success.

Assigned Genotype  
Genotype1  
Genotype2



**NOAA**  
FISHERIES

# PCA of combined adult (tagged) and untagged adults; pattern is not due to migratory behavior.

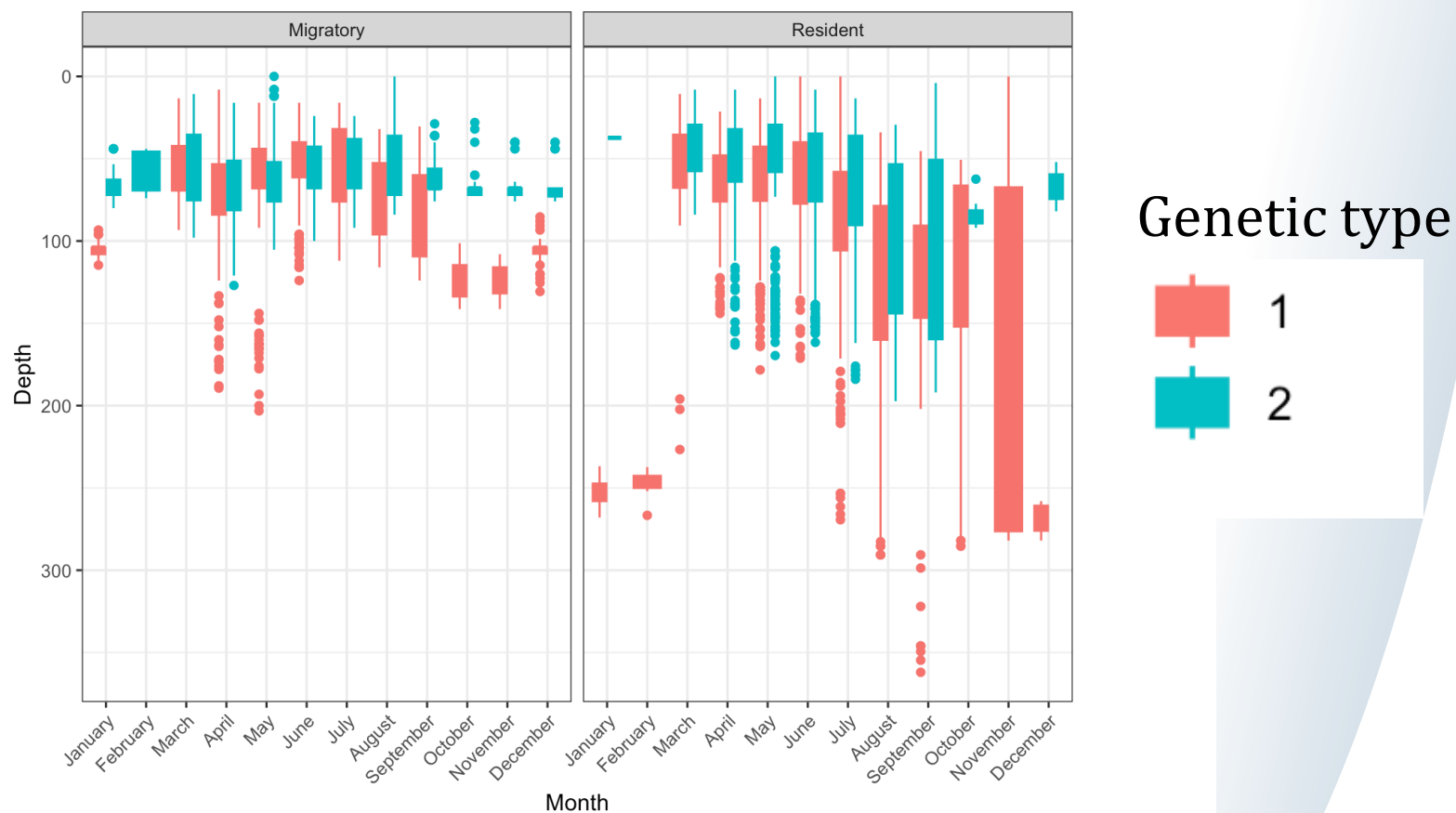


# Differences related to behavior and physiology.



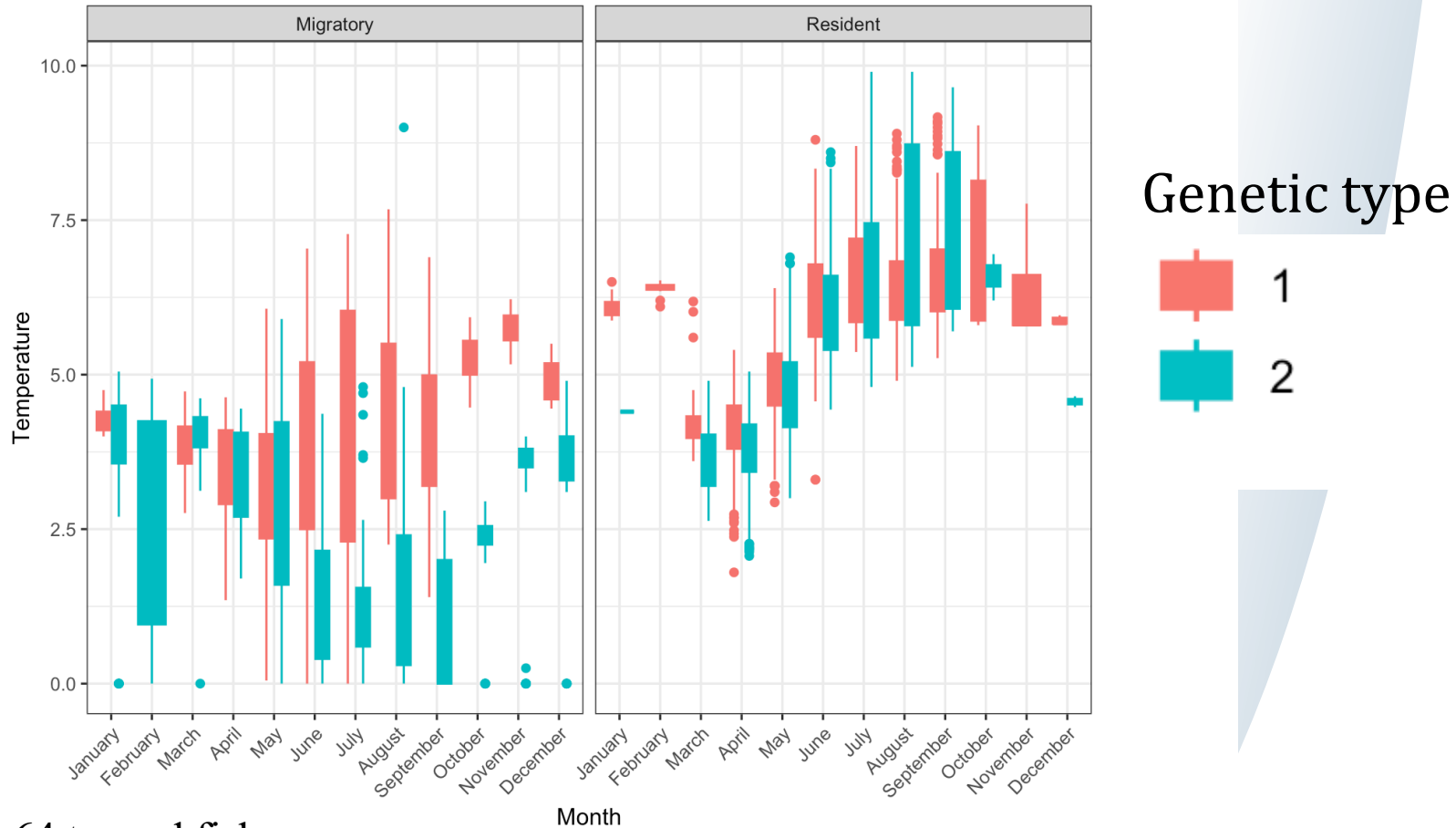
**NOAA**  
**FISHERIES**

# Boxplot by month of tagged cod mean depth for migratory vs. resident



Data includes 64 tagged fish.

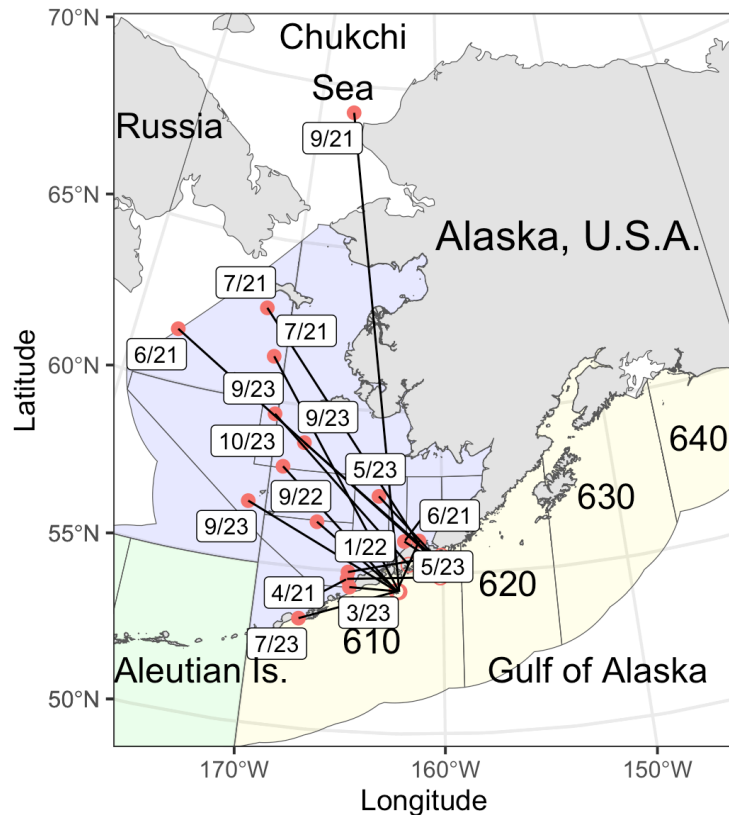
# Boxplot by month of tagged cod showing daily mean temperature for migratory vs. resident



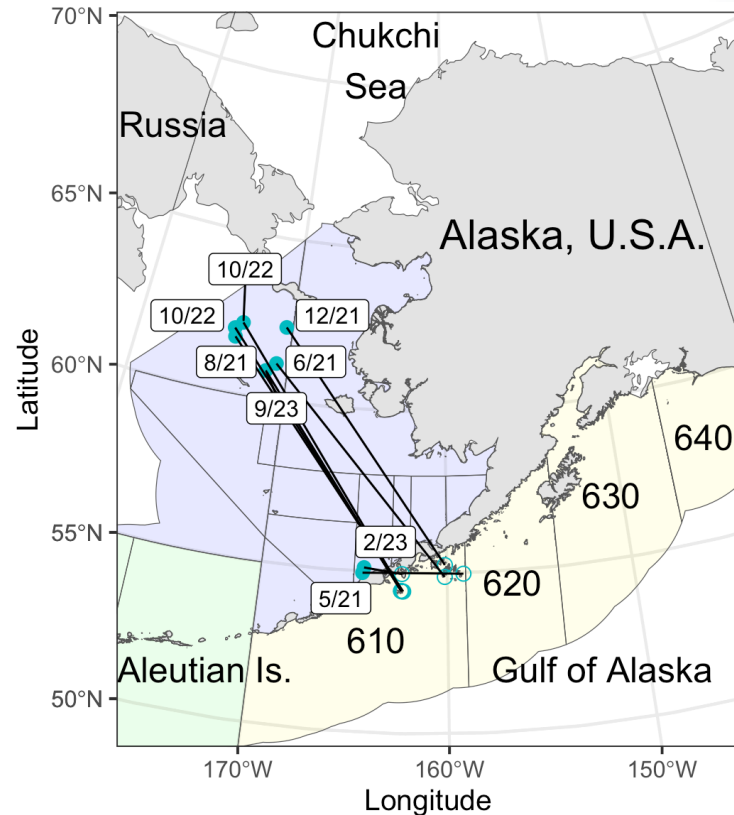
Data includes 64 tagged fish.

Tag pop-up locations for migratory genetic type 1 fish (left, pink) and type 2 (right, teal) with month/year of the tag recovery. Note the eastern Bering Sea management area is shaded in blue.

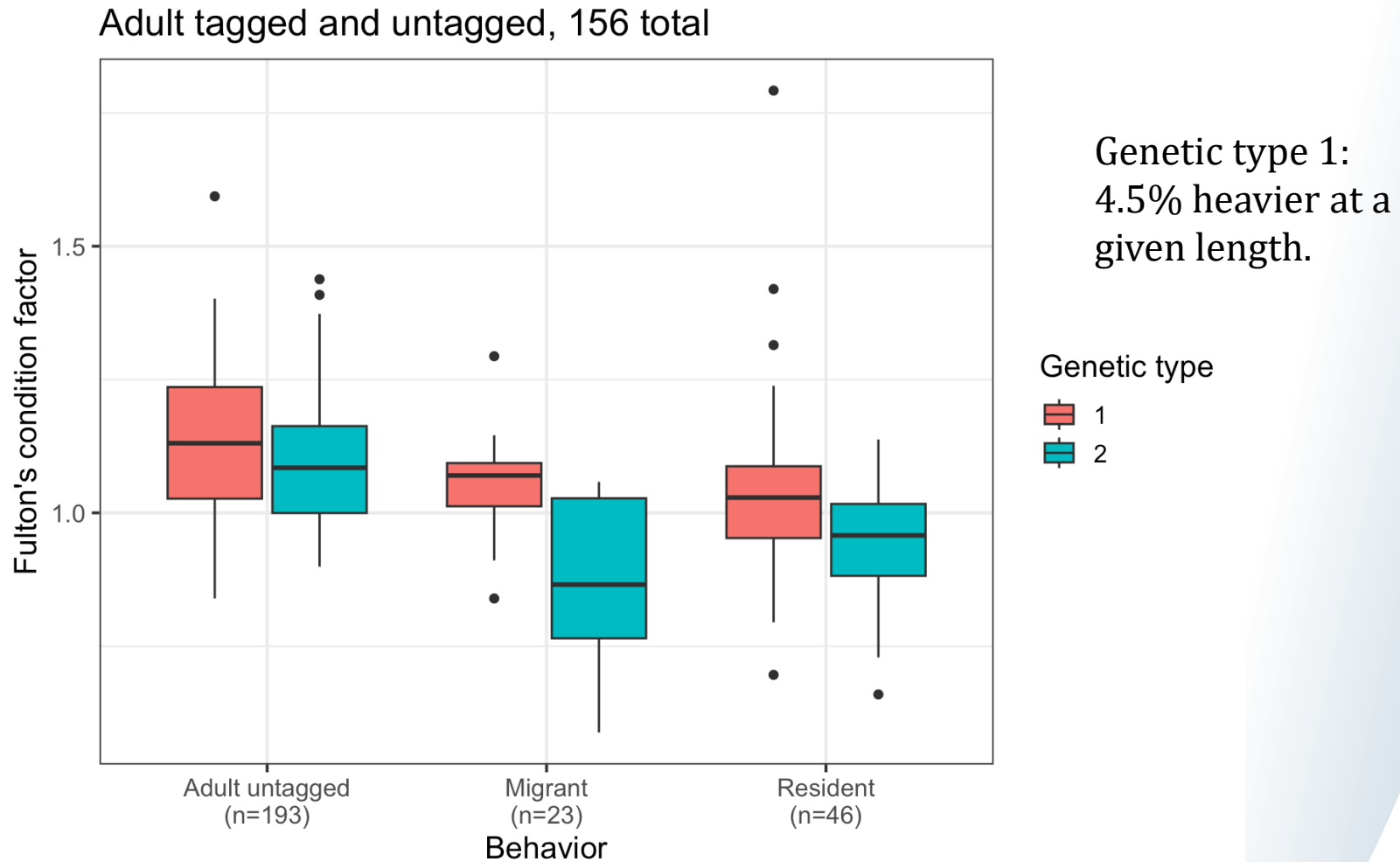
Genetic Type 1 “Generalist”



Genetic Type 2 “Specialist”

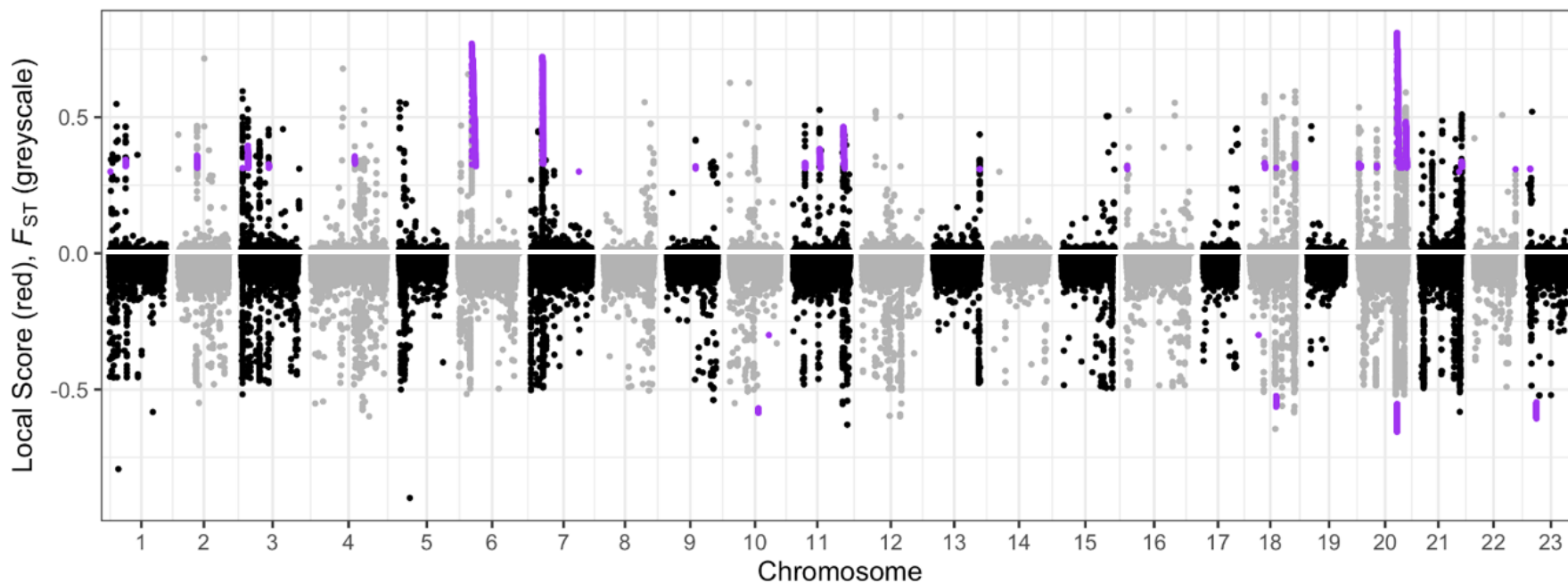


Fulton's condition factor ( $100 \times \text{Weight} / \text{Length}^3$ ) was significantly bigger for genetic type 1 ( $p\text{-value} = 0.001$ ).

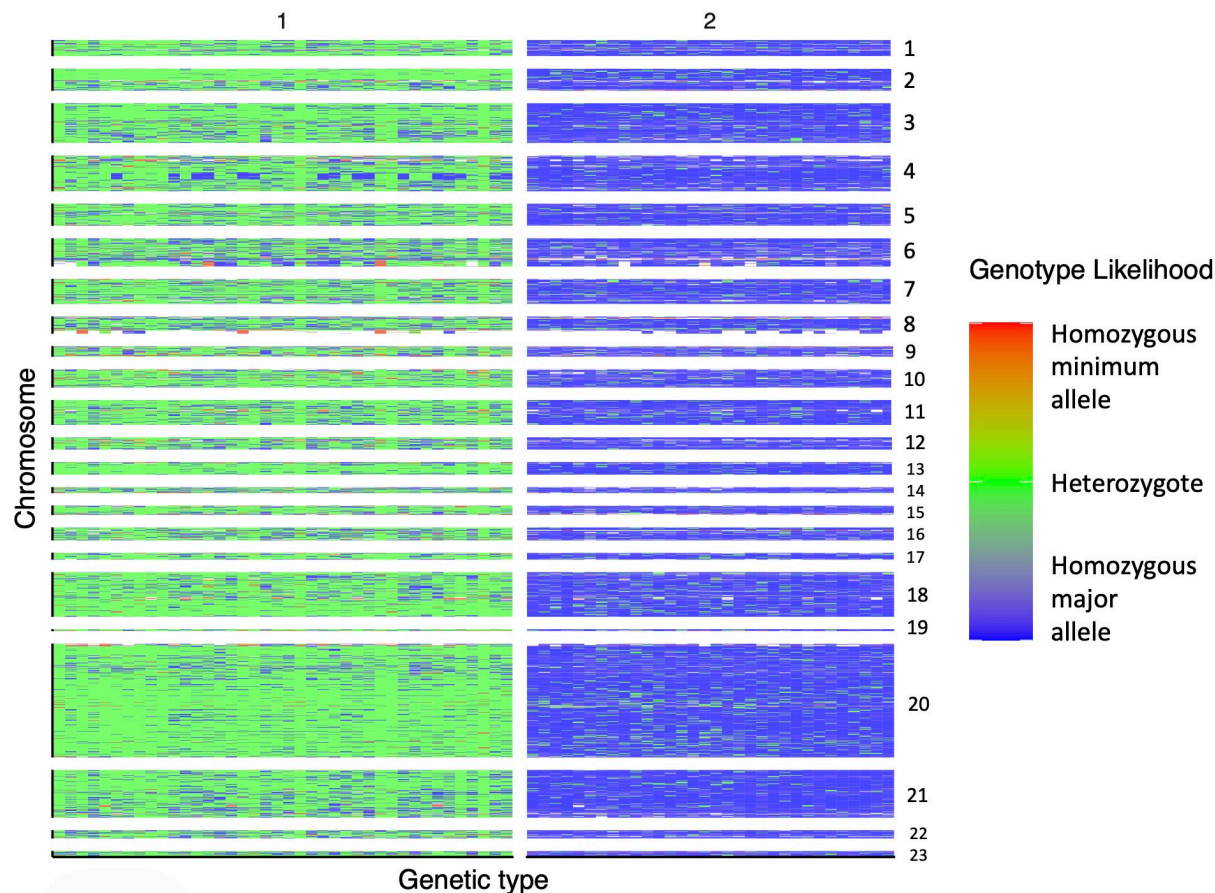


Manhattan plot  $F_{ST}$  and local score across genetic type 1 and 2 for untagged adult data above zero, and tagged adult data below zero.

Untagged data, 334,165 SNPs (above), Tagged data, 2,819,440 SNPs (below)

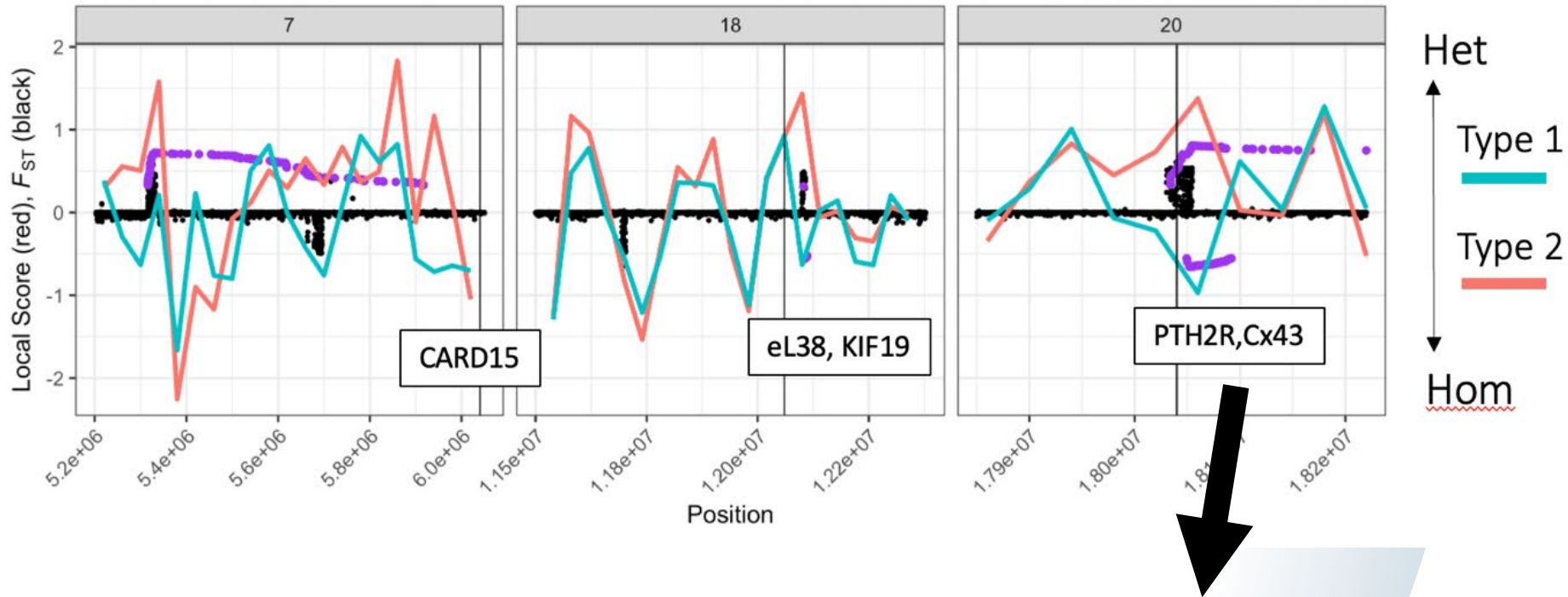


# Genetic heatmap of heterozygosity of the tagged adult dataset at all SNP sites with $F_{ST} > 0.250$ .



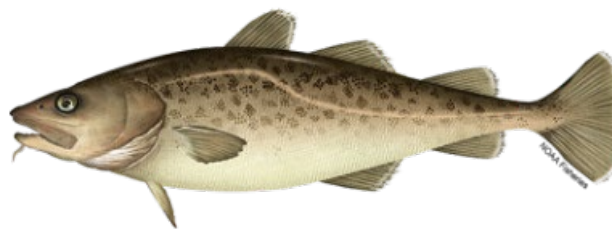
Regions on three chromosomes (7, 18, and 20) seem to be driven by genes under selection.

## Chromosome number



PTH2 maintains body temperature via cold-induced thermogenesis in mammals (Dobolyi et al. 2012). Functions synergistically with Cx43.

# Conclusions



| Trait                          | Type 1 ('generalist')           | Type 2 ('specialist')           |
|--------------------------------|---------------------------------|---------------------------------|
| Migratory range                | Broad (EBS + Chukchi)           | Narrow (S. of St. Lawrence Is.) |
| Body condition                 | Heavier at given length         | Lighter at given length         |
| Ploidy at differentiated sites | heterozygotic                   | homozygotic                     |
| Depth preference               | Mean 64 m (95% CI: 55 m – 72 m) | Mean 48 m (95% CI: 42 m – 55 m) |
| Proportion observed            | 47.6%                           | 52.4%                           |

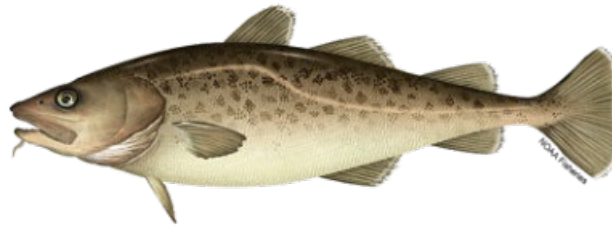
- Genetic type 2 represents a new ecotype.
- Evolved based on standing genetic variation.
- Soft genetic sweep.
- Most common form of rapid evolution.

# Conclusions

Could we tell these two types apart visually?

Does this explain at all the WGOA natural mortality following the 2014-2016 heatwave?

Would two growth platoons help fit models better?



Extra slides below.



**NOAA**  
**FISHERIES**

# Age-structured model:

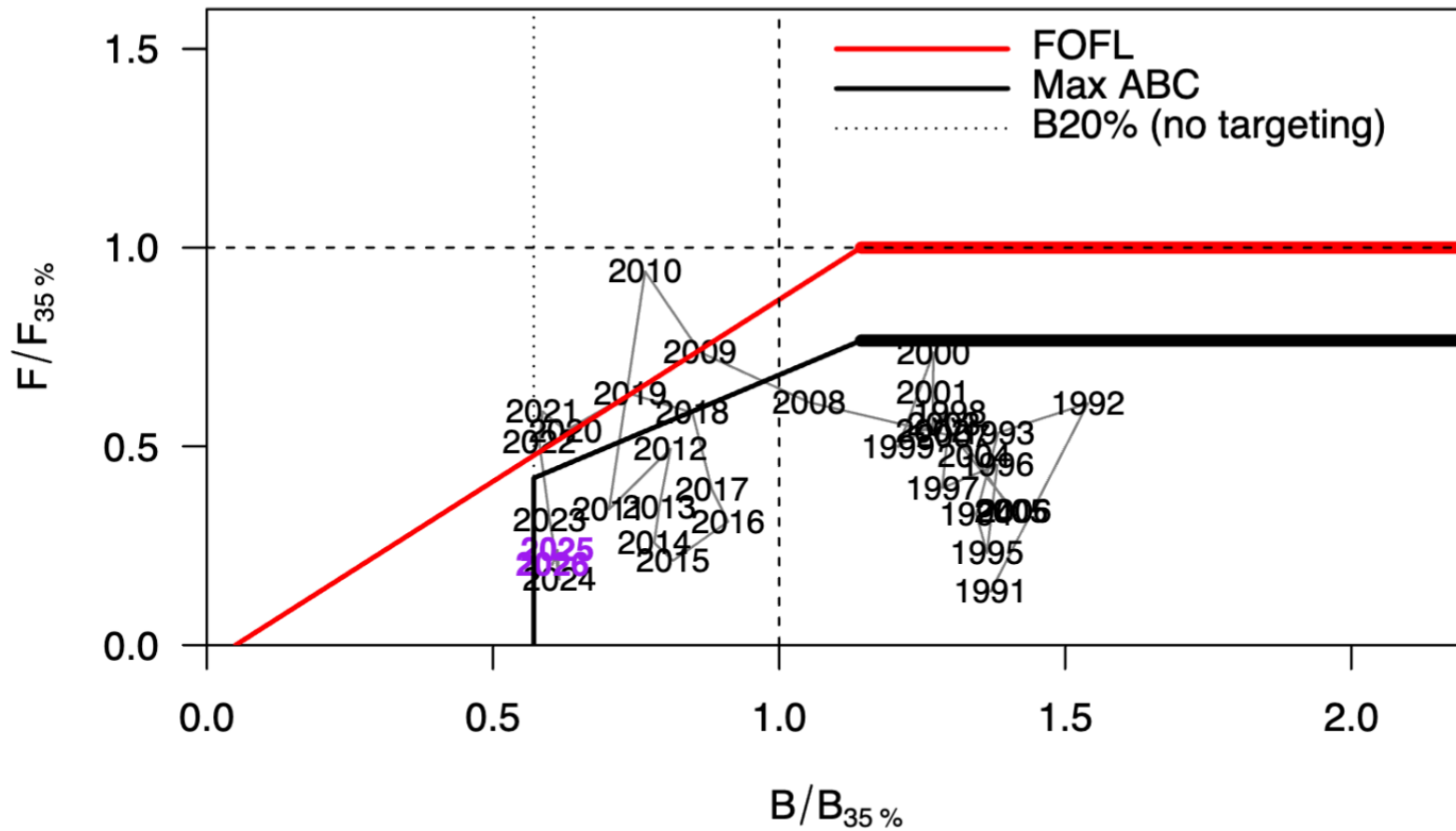
- Single sex model, 1:1 male female ratio.
- Survey age and length data were input as conditional age-at-length.
- Recruitment estimated as a mean with lognormally distributed deviations (1991 – 2021).
- Maturity-at-age was estimated externally using observer data, then input into the model.
- Single-fleet fishery that combines trawl, longline, and pot fishery data, weighted by quarter, gear, and NMFS area, from 1991 - current year (through September 22).
- Survey and fishery selectivity were modeled as logistic and constant over time.



**NOAA**  
**FISHERIES**

# Phase plane diagram for Model 24.1

Model 24.1

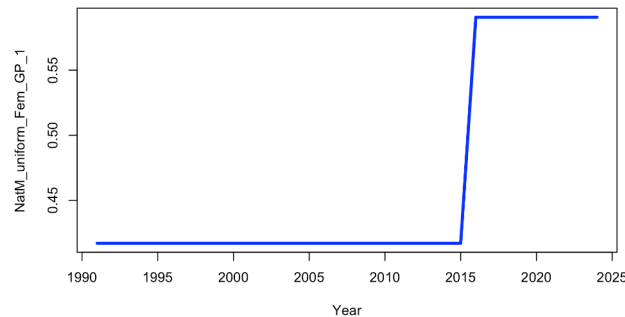


NOAA  
FISHERIES

# Incorporating an increase in natural mortality in response to heatwave can improve the fit to the data.

Time block on natural mortality was incorporated to explain the shift in the 2010s.

Pacific cod are sensitive temperature, which can result in increased mortality.



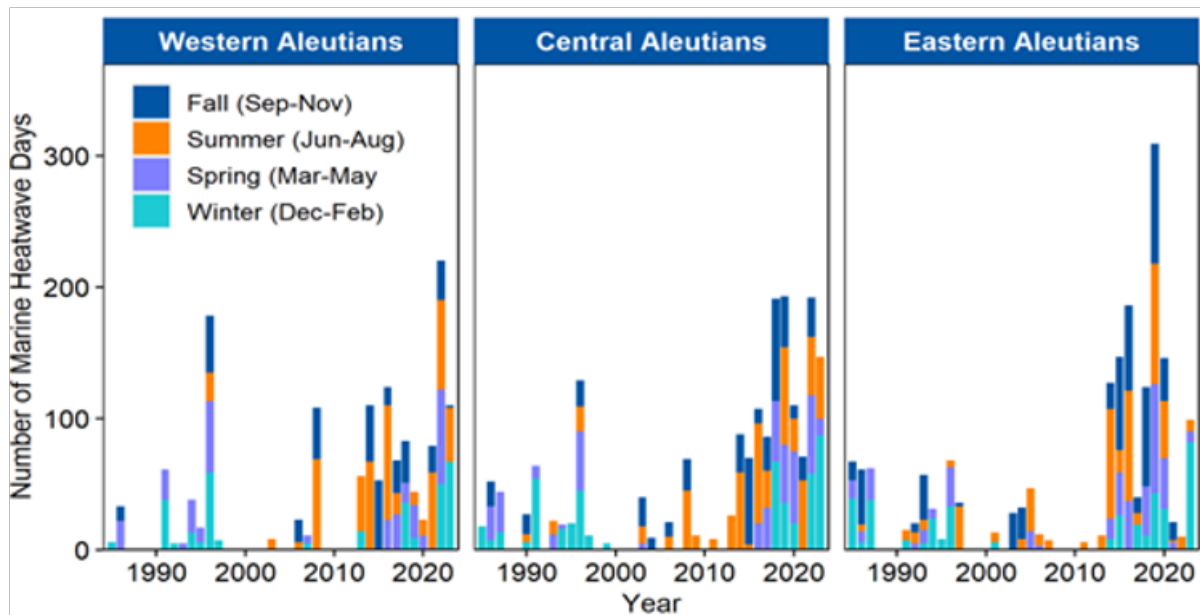
Time varying M has been implemented for GOA Pacific cod as a result of heatwave conditions.

# Assessment (more details)



**NOAA**  
**FISHERIES**

Age structured model incorporates an increase in natural mortality due to recent high temperatures in the Aleutian Islands.



## Data in the model – 2024 assessment:

| Source                   | Type                                  | Years                                                                        |
|--------------------------|---------------------------------------|------------------------------------------------------------------------------|
| Fishery (Trawl, Pot, LL) | Catch biomass                         | 1991-2024*                                                                   |
| Fishery (Trawl, Pot, LL) | Length composition                    | 1991-2024                                                                    |
| AI bottom trawl survey   | Biomass estimate + Length composition | 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022 |
| AI bottom trawl survey   | Age composition                       | 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022 |

\*10,134 records of aged and lengthed Pacific cod taken from NMFS research surveys between 1991 and 2022.

Data to be added:

Catch - 2025, 2026,

Fishery lengths - 2025, 2026,

Survey biomass estimates - 2026,

Age composition - 2024.

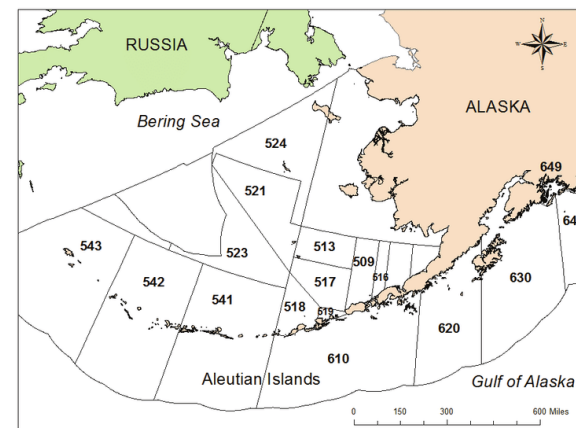
Summary table for Model 24.1. The Tier 5 Model 13.4 was the accepted model in 2023. \*Natural mortality estimated within 2016-2024 timeblock.

| Quantity                              | As estimated or <i>specified</i><br><i>last year for:</i> |        | As estimated or <i>recommended</i><br><i>this year for:</i> |             |
|---------------------------------------|-----------------------------------------------------------|--------|-------------------------------------------------------------|-------------|
|                                       | 2024                                                      | 2025   | 2025                                                        | 2026        |
| $M$ (natural mortality rate)          | 0.34                                                      | 0.34   | 0.42, 0.57*                                                 | 0.42, 0.57* |
| Tier                                  | 5                                                         | 5      | 3b                                                          | 3b          |
| Projected total (age 1+) biomass (t)  | 54,165                                                    | 54,165 | 73,679                                                      | 77,731      |
| Projected female spawning biomass (t) | -                                                         | -      | 25,078                                                      | 24,729      |
| $B_{100\%}$                           | -                                                         | -      | 102,361                                                     | 102,361     |
| $B_{40\%}$                            | -                                                         | -      | 40,944                                                      | 40,944      |
| $B_{35\%}$                            | -                                                         | -      | 35,826                                                      | 35,826      |
| $F_{OFL}$                             | 0.34                                                      | 0.34   | 0.655                                                       | 0.645       |
| $max F_{ABC}$                         | 0.255                                                     | 0.255  | 0.502                                                       | 0.494       |
| $F_{ABC}$                             | 0.255                                                     | 0.255  | 0.502                                                       | 0.494       |
| $OFL$                                 | 18,416                                                    | 18,416 | 16,782                                                      | 16,273      |
| $max ABC$                             | 12,431                                                    | 12,431 | 13,376                                                      | 12,973      |
| $ABC$                                 | 12,431                                                    | 12,431 | 13,376                                                      | 12,973      |
| Status                                | 2022                                                      | 2023   | 2023                                                        | 2024        |
| Overfishing                           | No                                                        | n/a    | No                                                          | n/a         |
| Overfished                            | n/a                                                       | No     | n/a                                                         | No          |
| Approaching overfished                | n/a                                                       | No     | n/a                                                         | No          |



# Aleutian Islands Pacific cod trawl survey estimates by NMFS area

| Biomass (t) |         |         |         |         |
|-------------|---------|---------|---------|---------|
| Year        | Western | Central | Eastern | Total   |
| 1991        | 39,729  | 64,926  | 75,515  | 180,169 |
| 1994        | 51,538  | 78,081  | 23,797  | 153,416 |
| 1997        | 30,252  | 28,239  | 14,357  | 72,848  |
| 2000        | 36,456  | 47,117  | 43,298  | 126,870 |
| 2002        | 24,687  | 25,241  | 23,623  | 73,551  |
| 2004        | 20,731  | 51,852  | 9,637   | 82,219  |
| 2006        | 22,033  | 43,349  | 19,480  | 84,861  |
| 2010        | 11,207  | 23,277  | 21,341  | 55,826  |
| 2012        | 14,804  | 30,592  | 13,514  | 58,911  |
| 2014        | 8,488   | 47,032  | 18,088  | 73,608  |
| 2016        | 19,496  | 45,138  | 19,775  | 84,409  |
| 2018        | 20,596  | 49,251  | 11,425  | 81,272  |
| 2022        | 14,045  | 23,837  | 13,661  | 51,543  |
| 2024        | 18,379  | 22,188  | 9,817   | 50,383  |



The 2024 survey showed a small decrease from 2022.

# With the exception of 2024, water temperatures in the Aleutian Islands have been above the long term mean since 2014.

