Pacific cod explorations

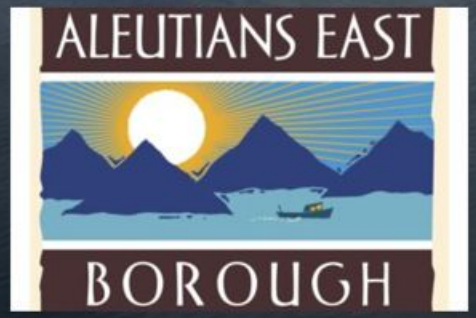
Steve Barbeaux, Pete Hulson,
Julie Nielsen and Ingrid Spies

Joint NPFMC Groundfish Plan Team
September 16, 2025

Pacific cod satellite tagging research in Alaska: An overview

Susanne McDermott[1] , Julie Nielsen[2], Charlotte Levy[3], Kimberly Rand[4], Bianca Prohaska[1], Sean Rohan[1], Alexandra Dowlin[1]

[1]Alaska Fisheries Science Center , [2]Kingfisher Marine Research, [3]Aleutians East Borough, [4]Lynker Technologies



Background

- Warming ocean conditions 2017 - 2019 changed Pacific cod distribution patterns in Alaska waters
  - Bering sea: Northward shift
    - Year-round or seasonal?
  - Gulf of Alaska: Large population decline
    - Migration into Bering sea waters?
- Need information on Pacific cod movement patterns
  - Migration timing, pathways, extent

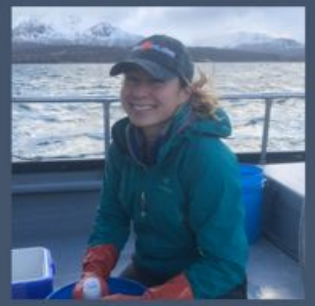
Studying seasonal movement Pacific cod with Pop-up Satellite Archival Transmitting tags (PSATs)

PSATs

- Fishery independent locations
- Detailed information on migrations
- Information on fish behavior

The Pacific Cod Tagging (PACT)Team

Susanne McDermott
NOAA AFSC



Charlotte Levy
Aleutians East Borough

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Kingfisher Marine Research

Kim Rand
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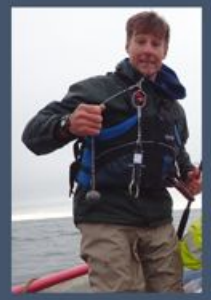


David Bryan
NOAA AFSC

Pete Hulson
NOAA AFSC

Researchers: Biology, ecology, habitat, movement modeling, physiology, genetics, otolith chemistry, stock assessment

PACT Collaborators and Funding Sources

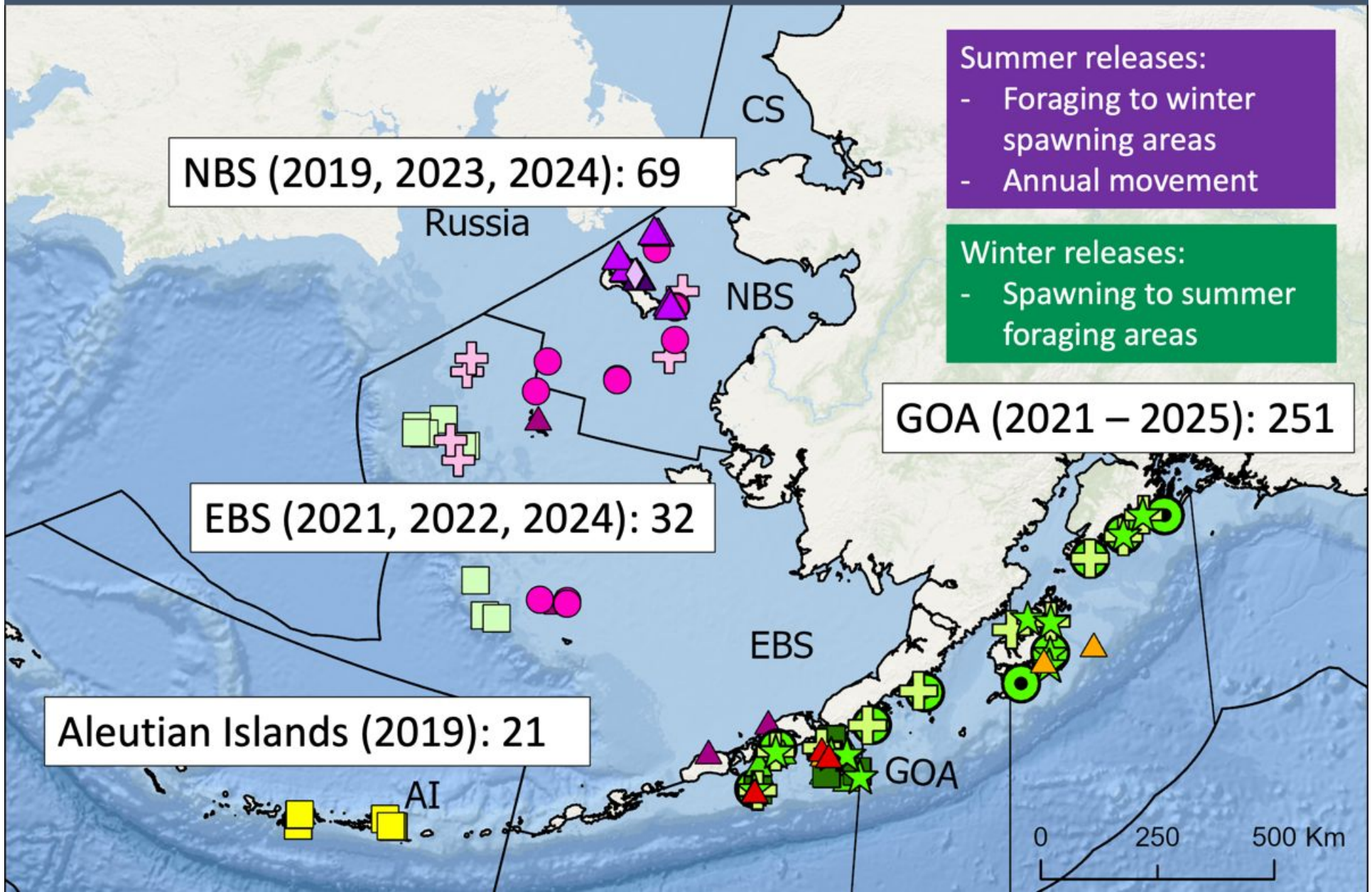
Collaborators:

- Pacific Cod Harvesters
- Aleutians East Borough
- Freezer Longline Coalition
- Norton Sound Economic Development Corporation
- Native Village of Savoonga
- Adak Community Development Corporation

Other Funding Sources:

- Pacific Cod Harvesters
- North Pacific Research Board
- National Cooperative Research Program
- MSA funding
- Gulf of Alaska Pacific cod disaster relief funds

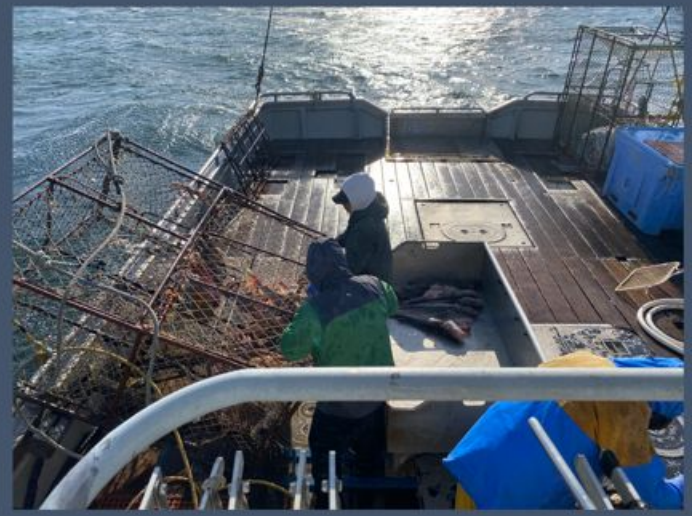
Pacific cod PSAT releases to date: n = 373



PSAT release platforms

Gulf of Alaska (winter)

Chartered survey:
F/V Decision



- Capture in pots and brought to surface in 4 stages
- Depths < 100 m
- Released with descender
- Biological samples collected
- Conventional tags released

PSAT release platforms

Bering Sea (summer)

NOAA summer survey:
- Capture by rod and reel

Native village of Savoonga:
- Capture by hand line

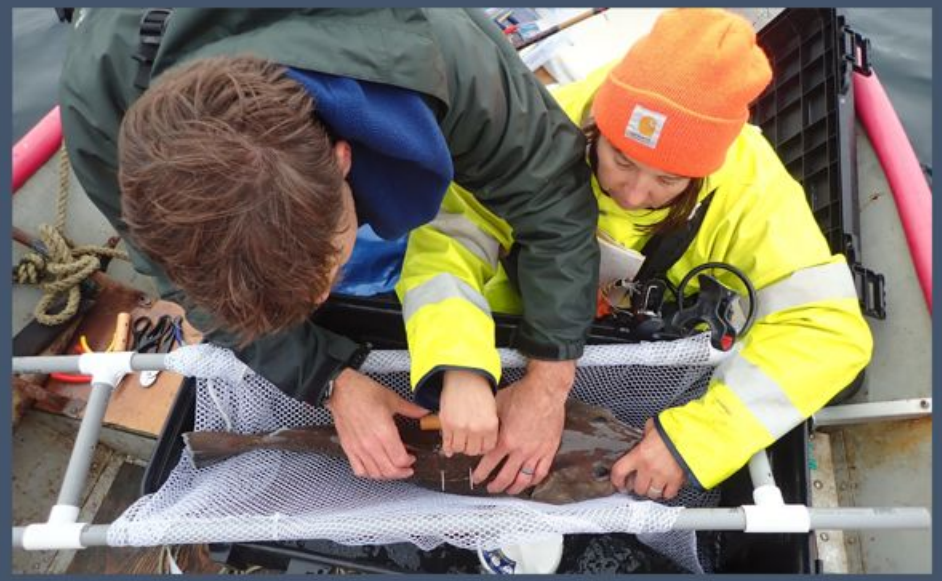
PSAT release platforms

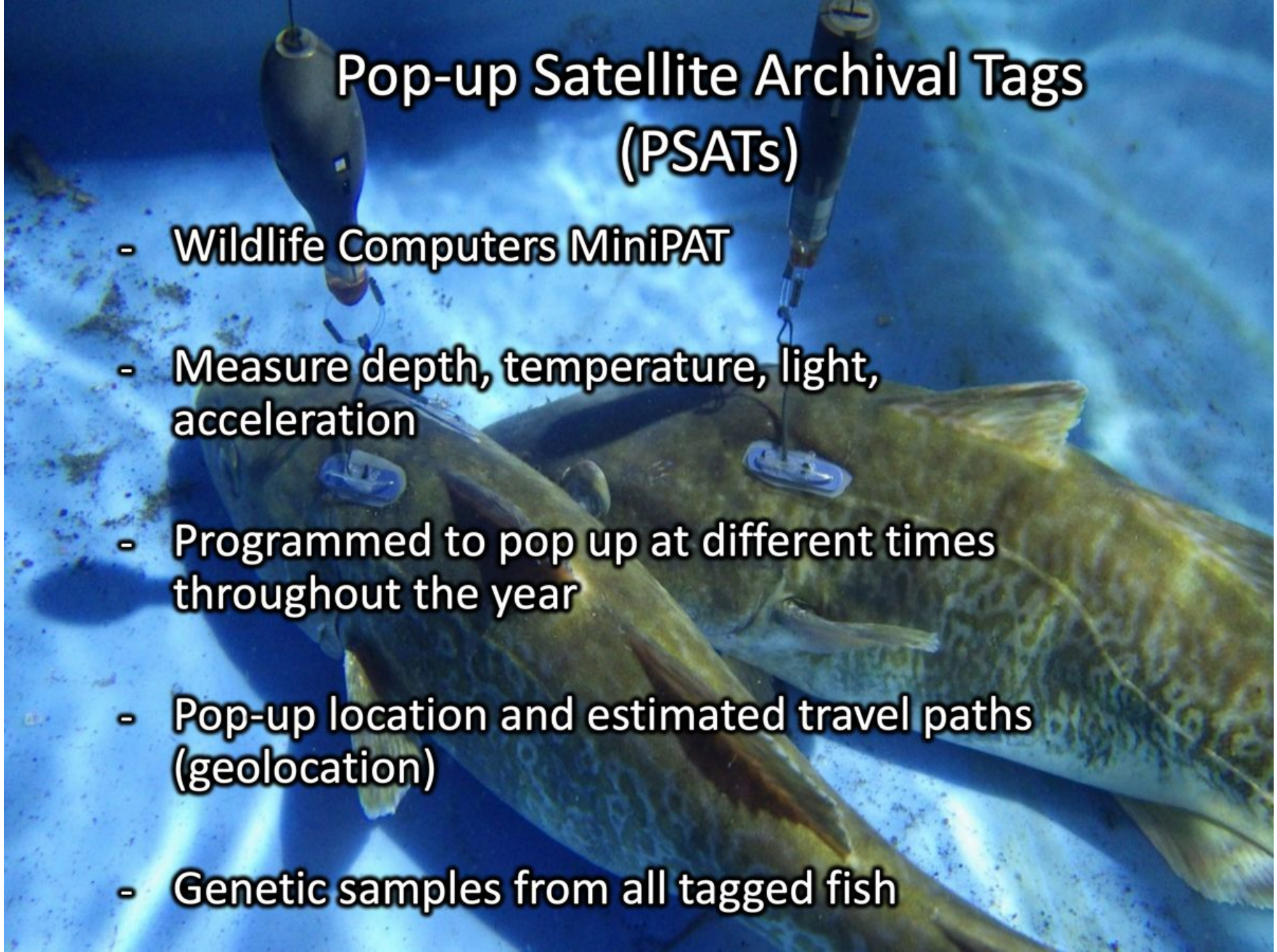
Bering Sea (winter)

F/V Beauty Bay

- Capture on commercial longline vessel
- Depths < 100 m

Attach tag with “backpack” harness




Pop-up Satellite Archival Tags
(PSATs)
- Wildlife Computers MiniPAT
- Measure depth, temperature, light, acceleration
- Programmed to pop up at different times throughout the year
- Pop-up location and estimated travel paths (geolocation)
- Genetic samples from all tagged fish

Geolocation with PSAT data

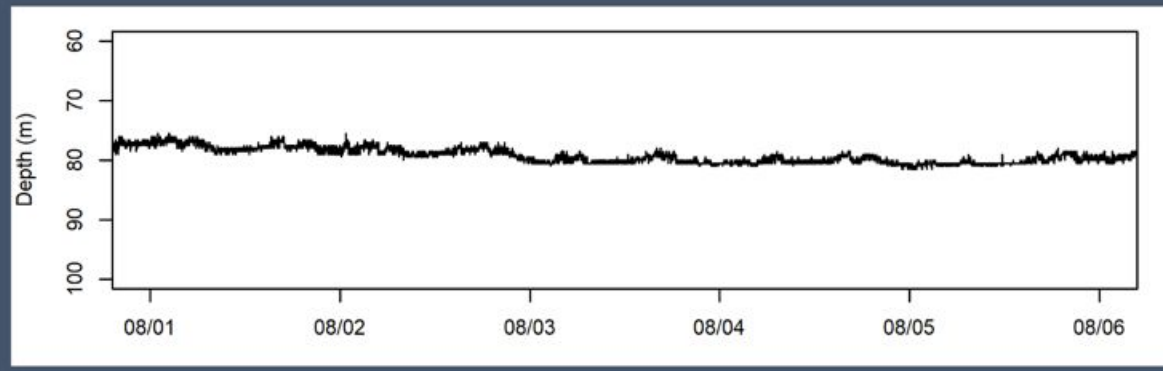
Release

Pop-up

PSAT data “clues”

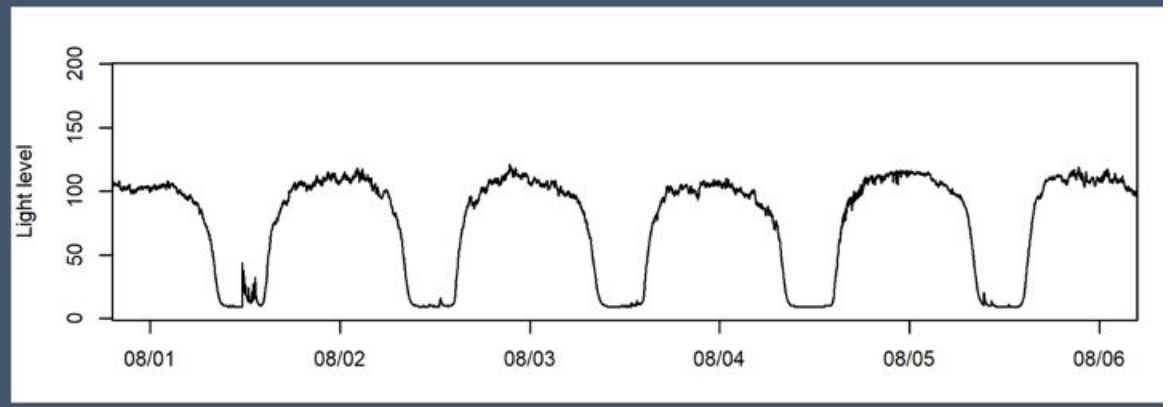
Depth:

- Maximum daily depth = ocean bottom
- Link to bathymetric map



Light:

- Time of local noon = longitude
- Time of dusk and dawn = latitude



Geolocation model

Hidden Markov model (HMM)

- Developed by Martin Pedersen et al. for Atlantic cod
  - **Pedersen et al., 2008.** Geolocation of North Sea cod (*Gadus morhua*) using hidden Markov models and behavioural switching. CJFAS.

- Adapted for use with Pacific cod in North Pacific Ocean using PSAT data
  - **Nielsen et al., 2023.** Geolocation of a demersal fish (Pacific cod) in a high-latitude island chain (Aleutian Islands, Alaska). Animal Biotelemetry.

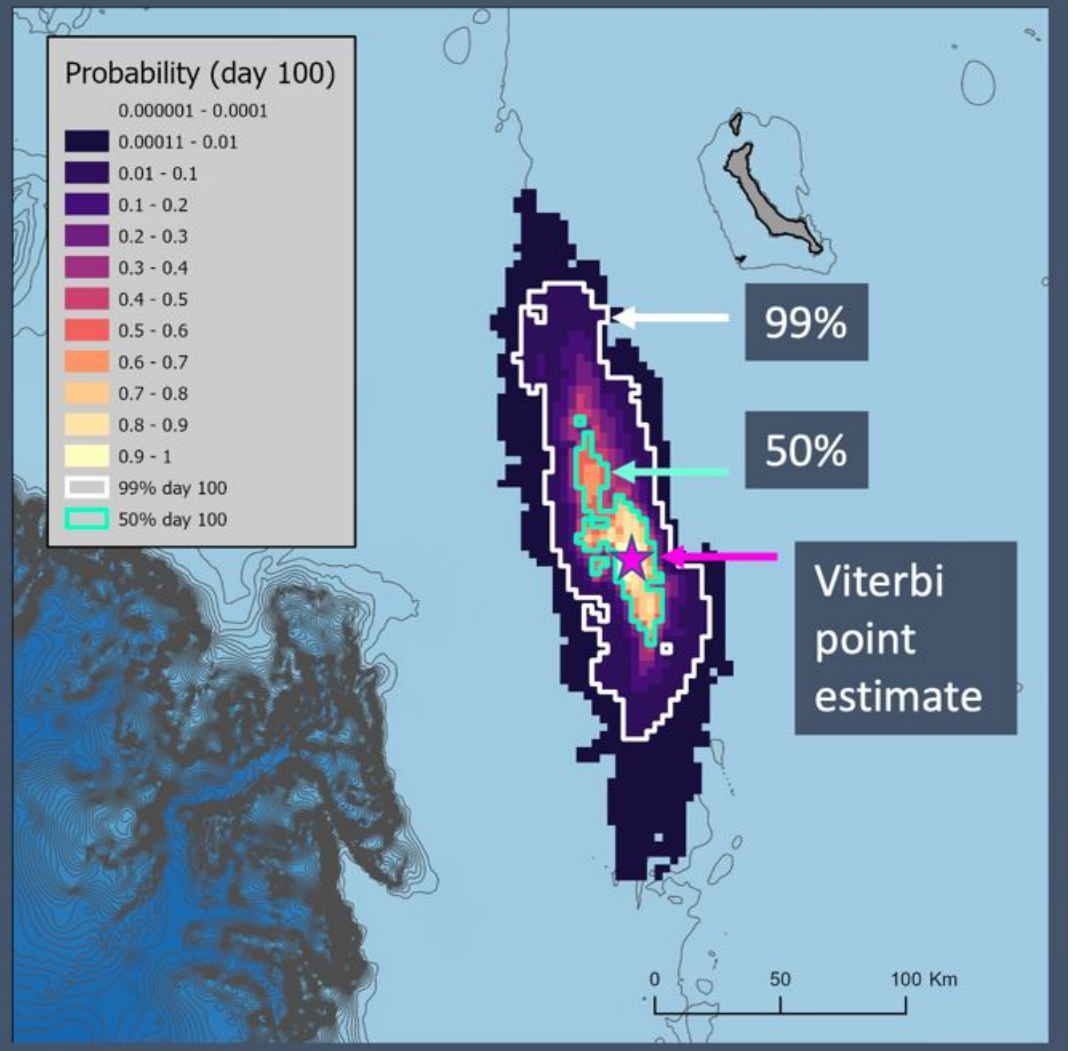
Geolocation model

Model outputs:

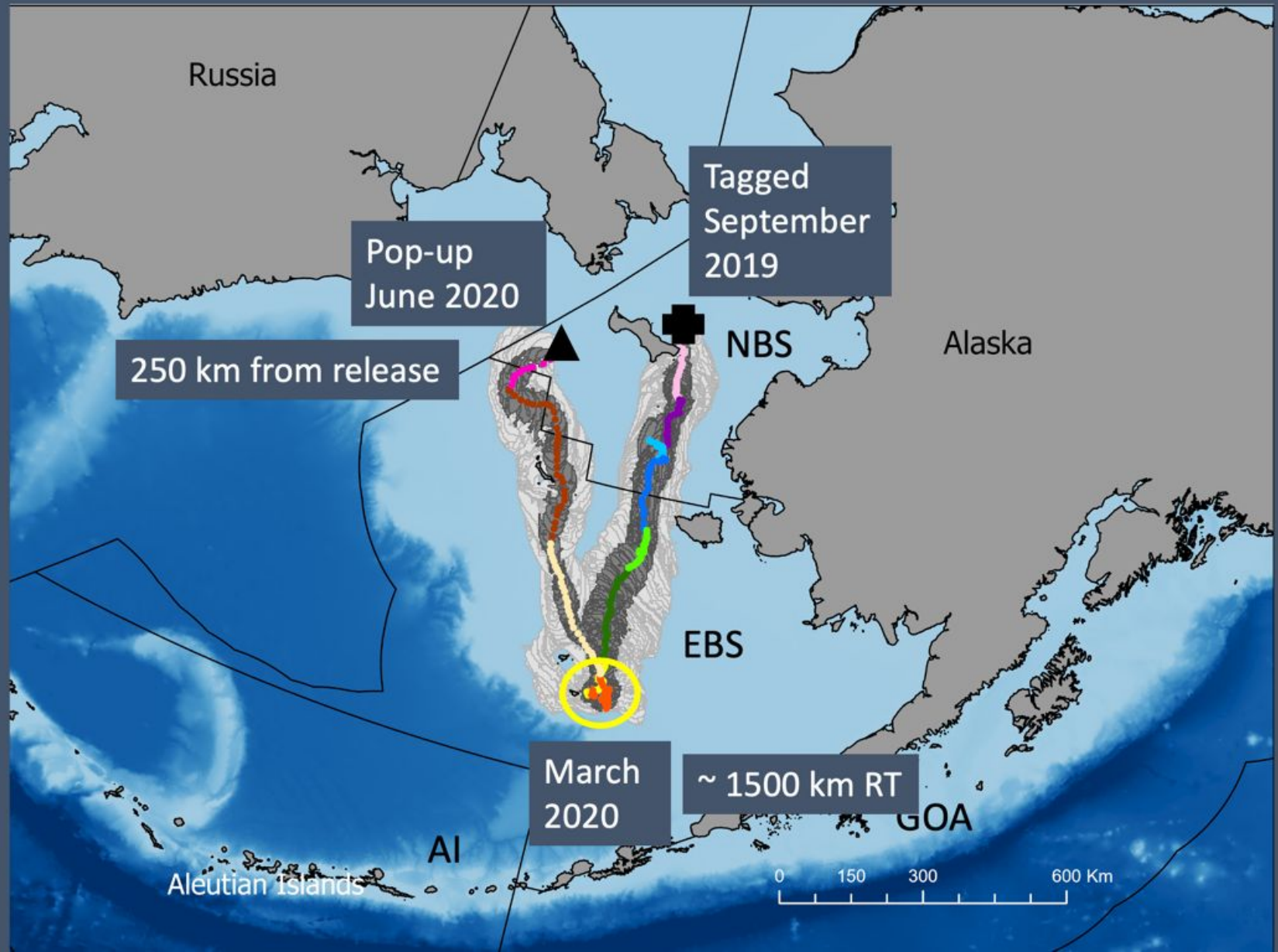
- Probability in each grid cell each day

- Individuals:
  - polygons that encompass highest 50% and 99% of the probability each day
  - Viterbi point locations each day

- All tags: combine probabilities cell-wise by time period
  - Monthly
  - Spawning
  - Summer foraging

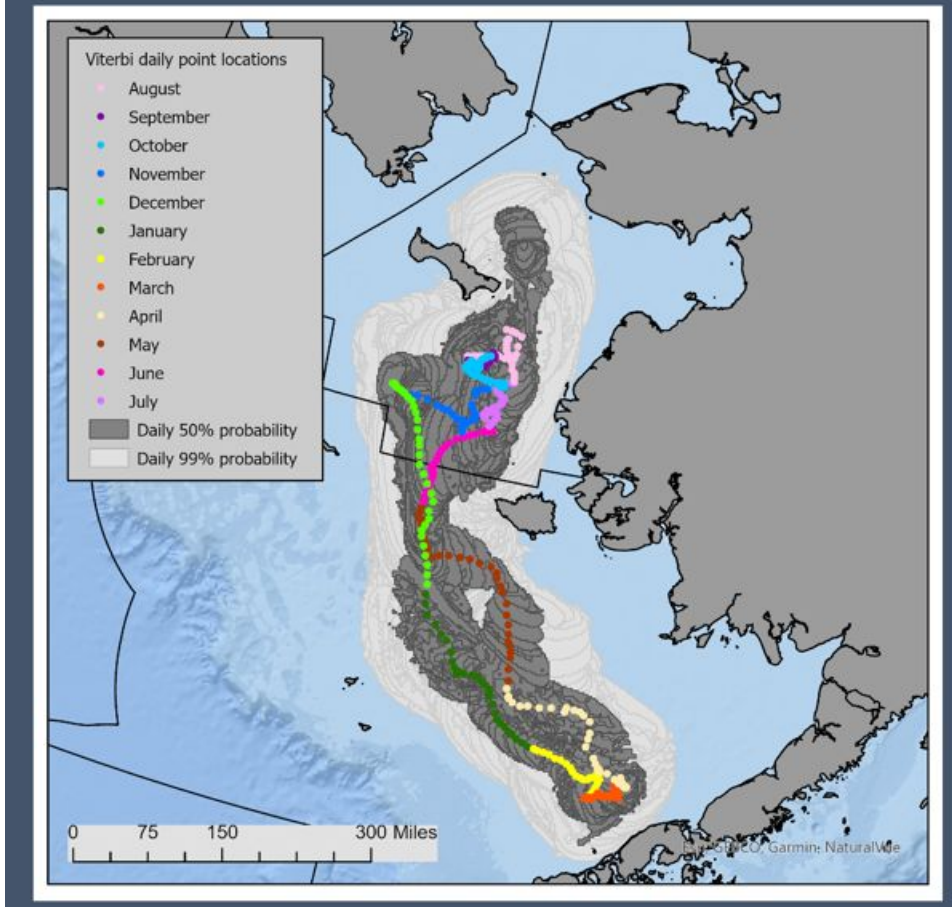


Reconstructed pathways

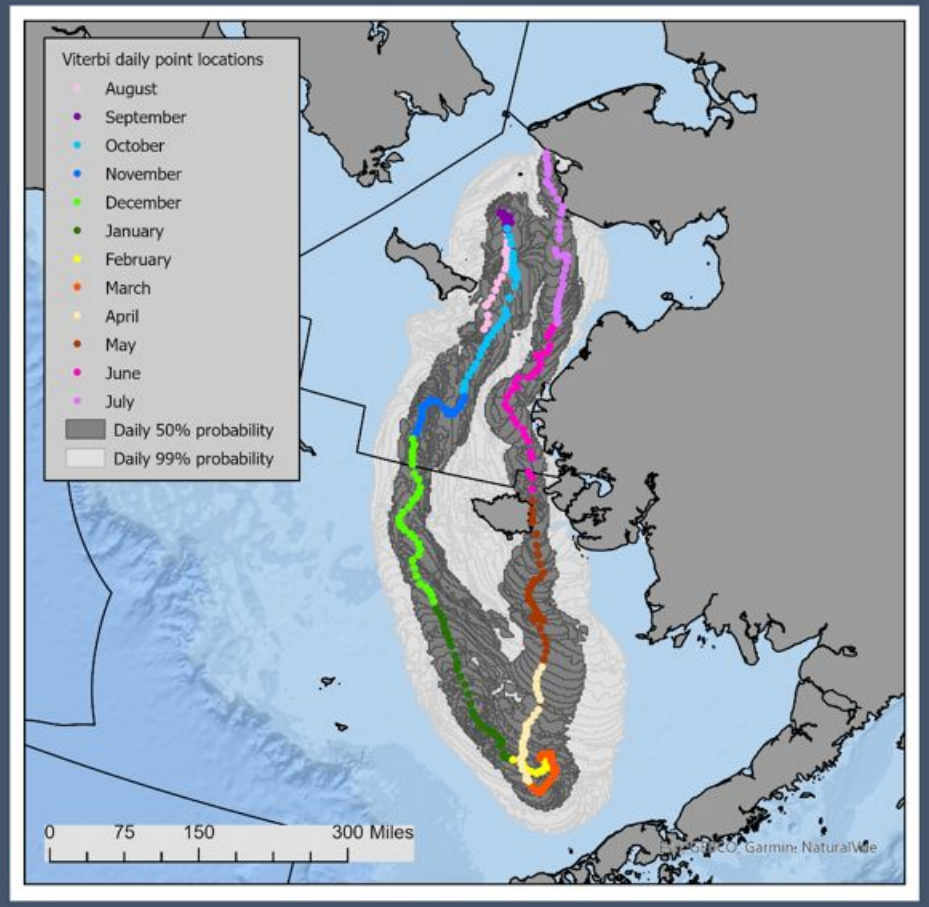


NBS tagging – summer to summer

Leave NBS Nov/Dec

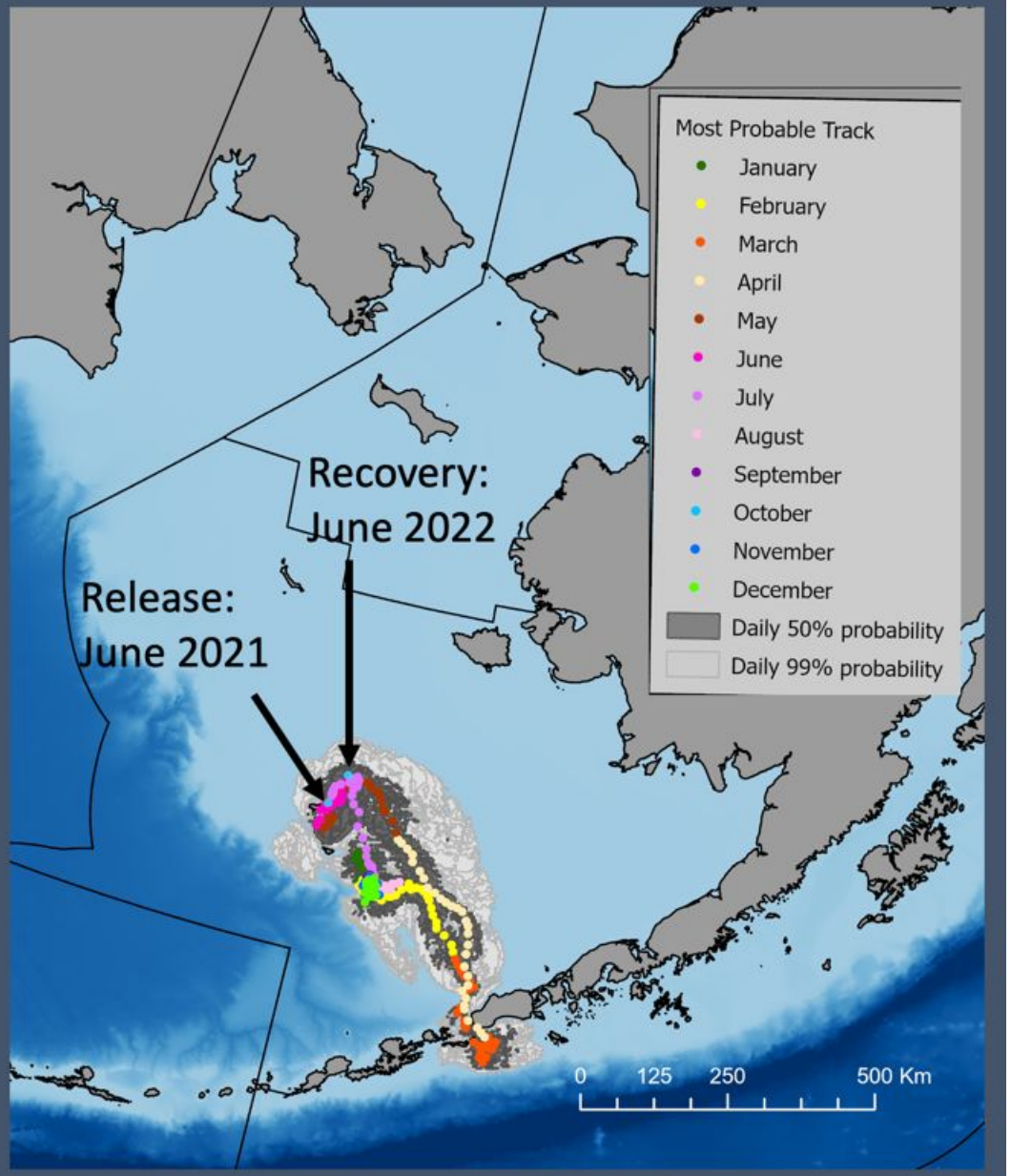


Return in June



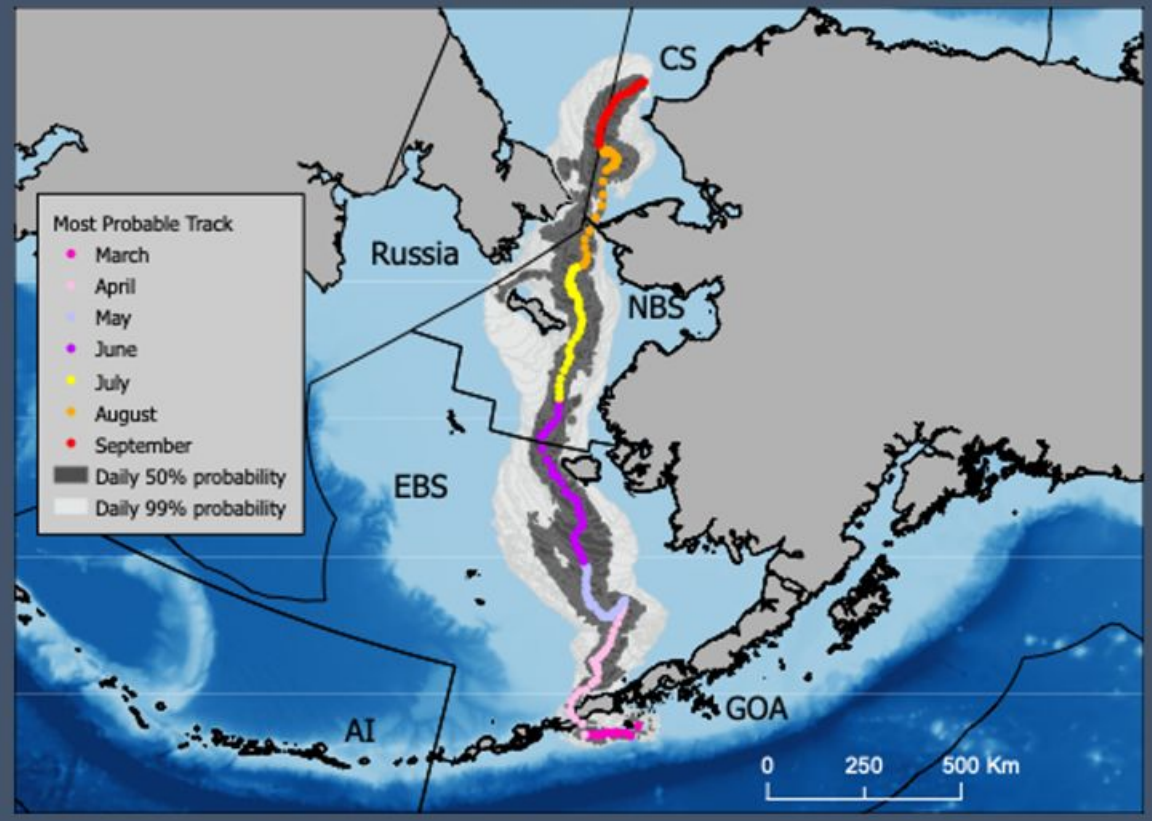
EBS tagging – summer to summer

- Migration to areas within EBS or to WGOA
- Summer site fidelity

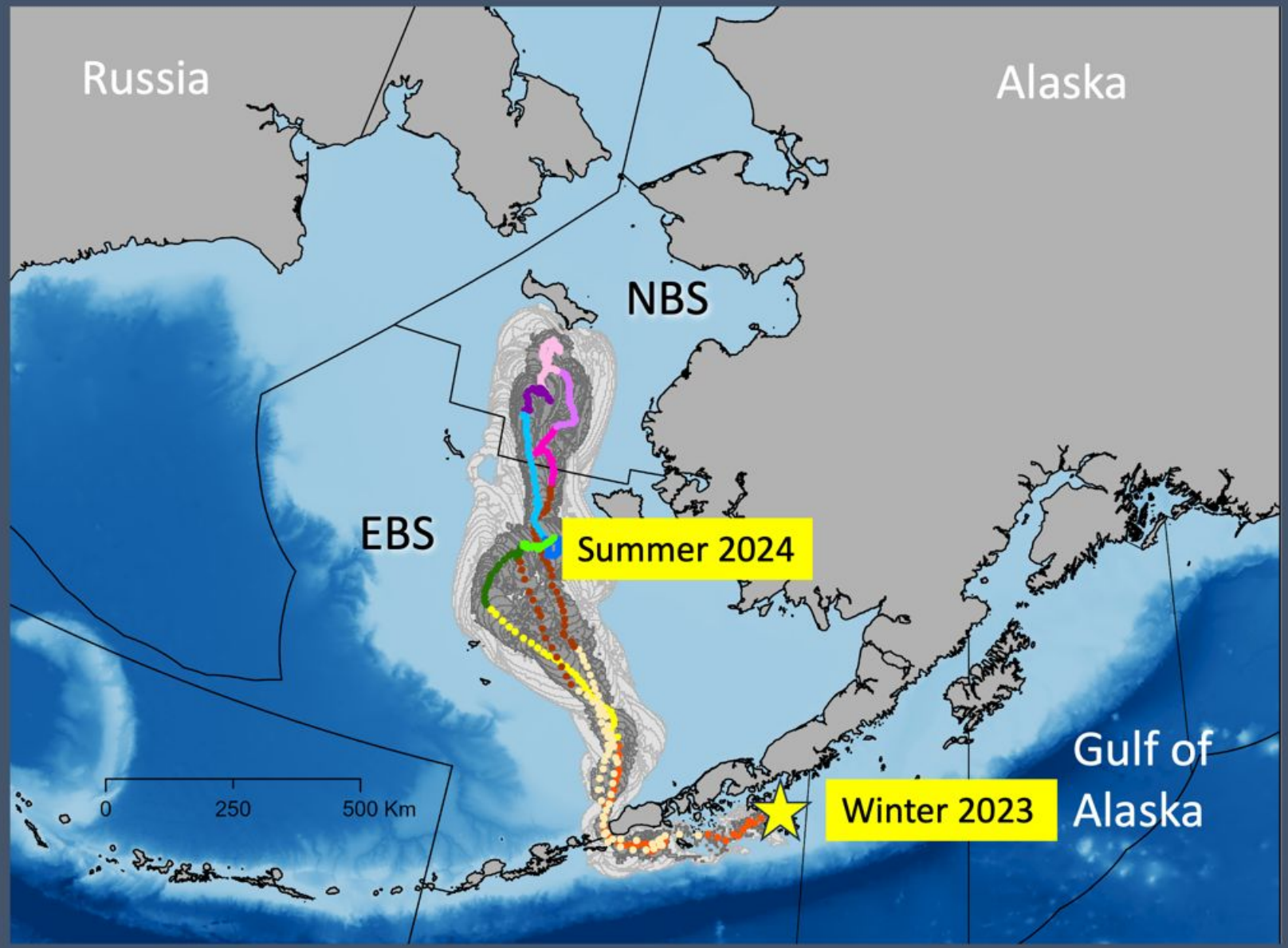


GOA tagging – winter to summer

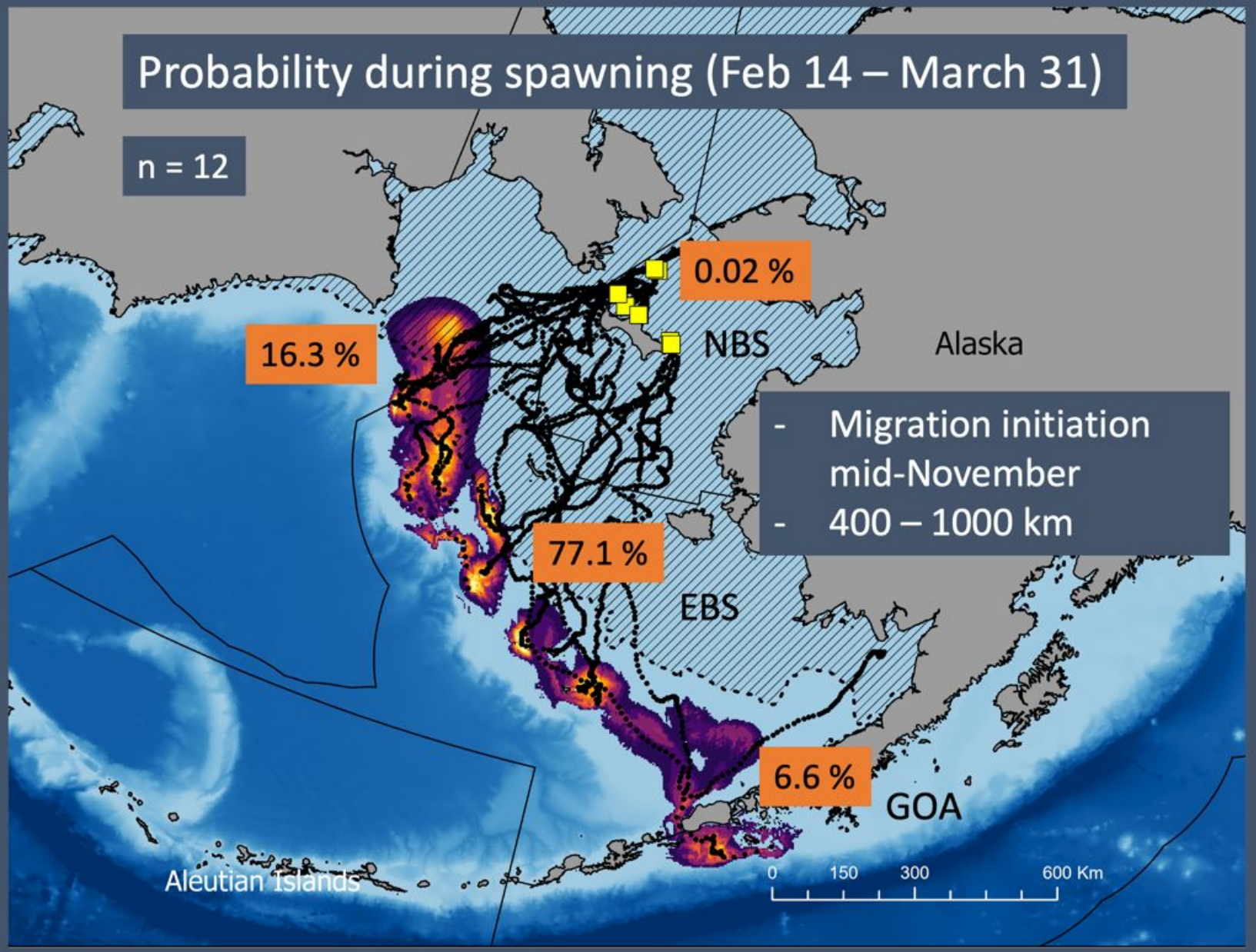
- Migration to Bering Sea
- Year-round residents



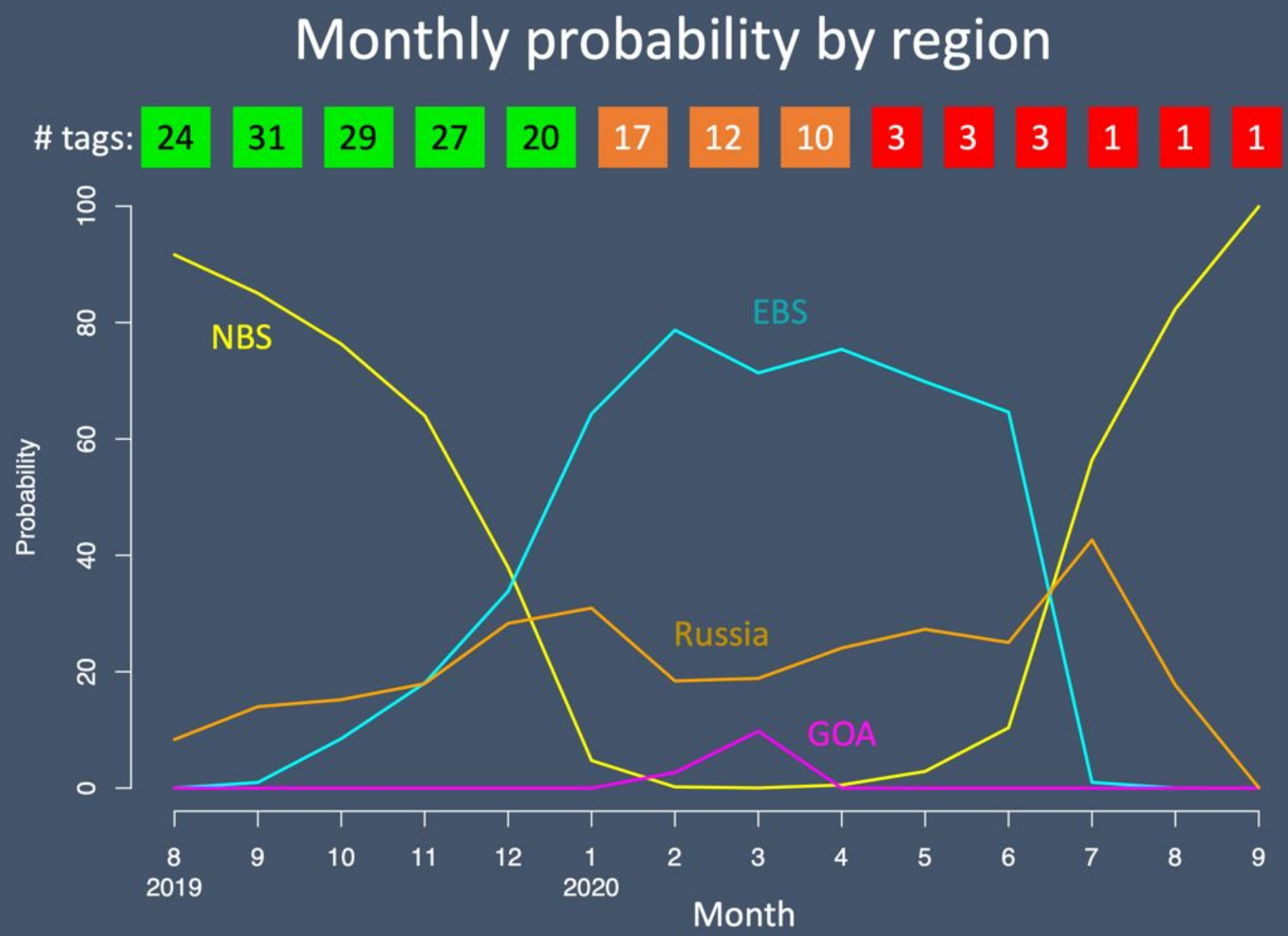
GOA tagging – winter to summer

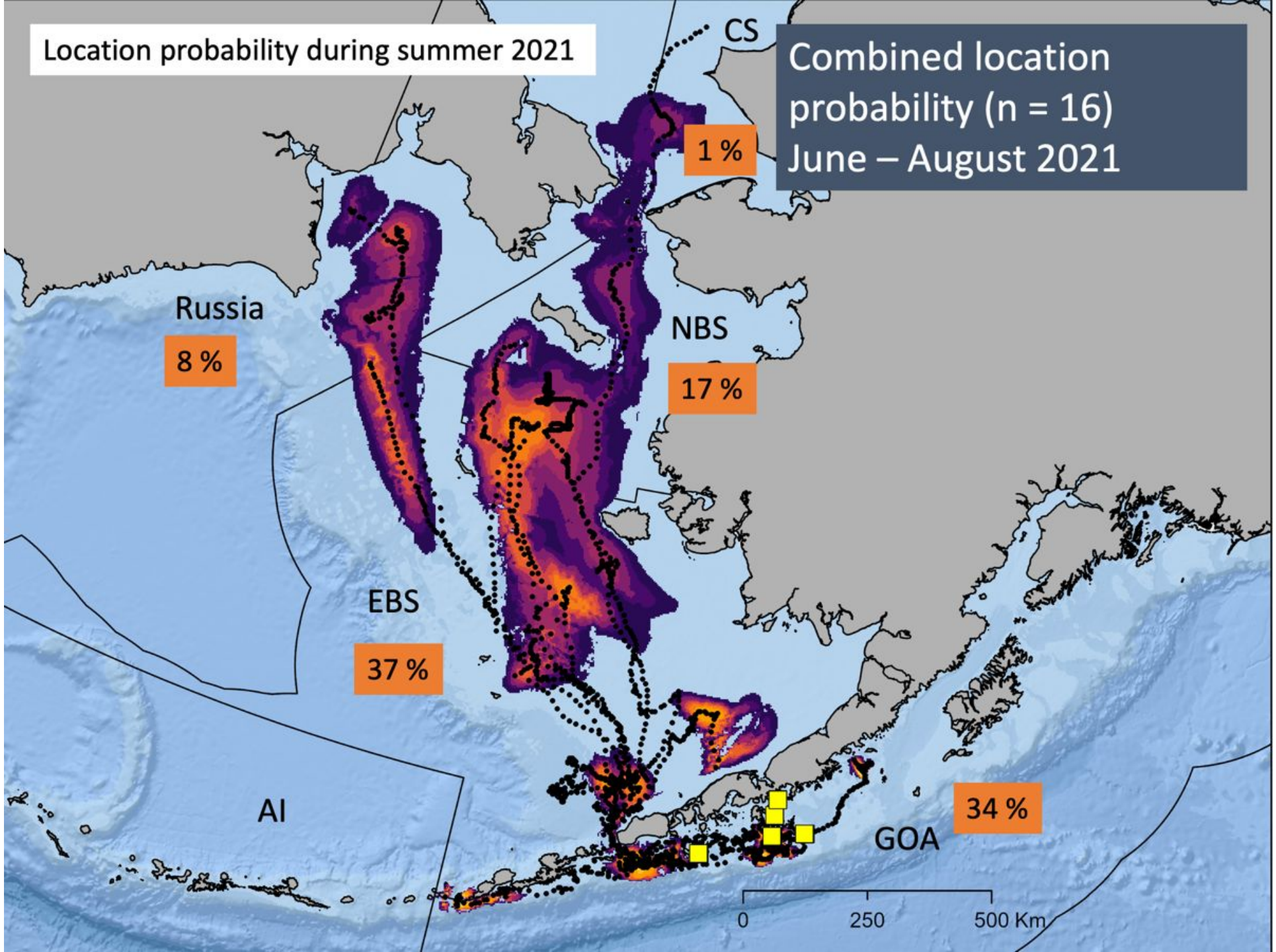


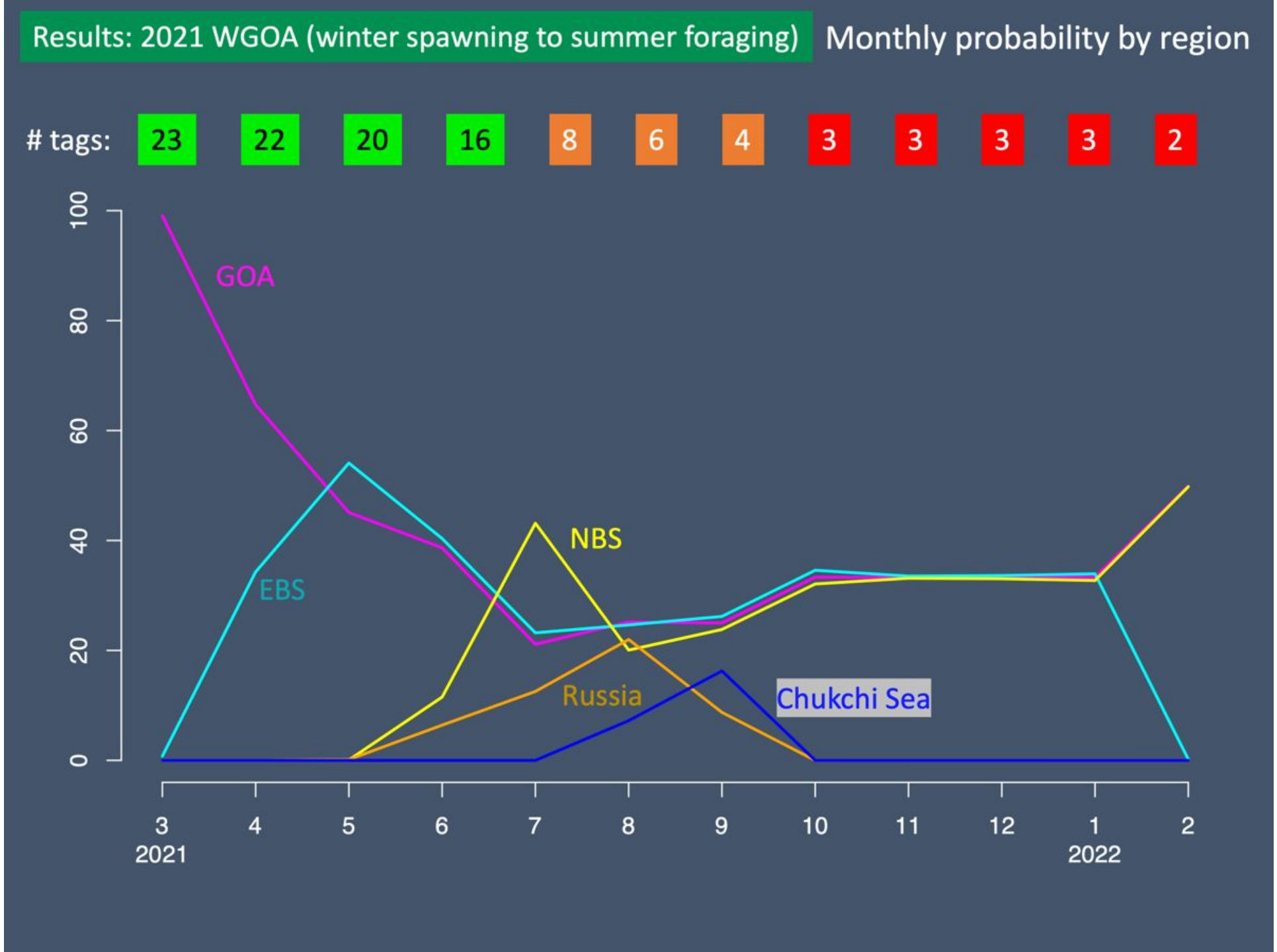
Movement to spawning areas from NBS (2019)



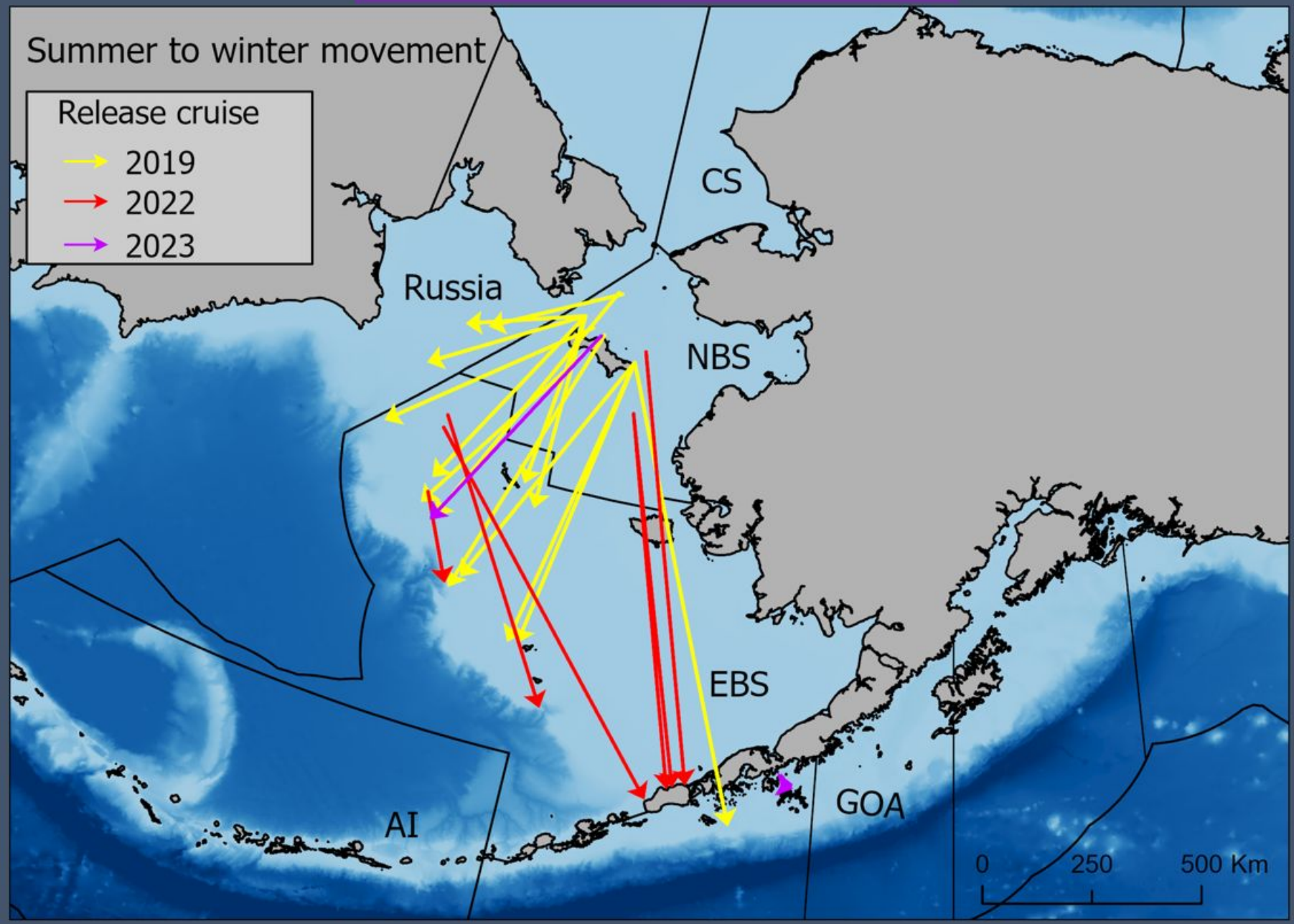
Results: 2019 NBS (summer to winter and annual movement)



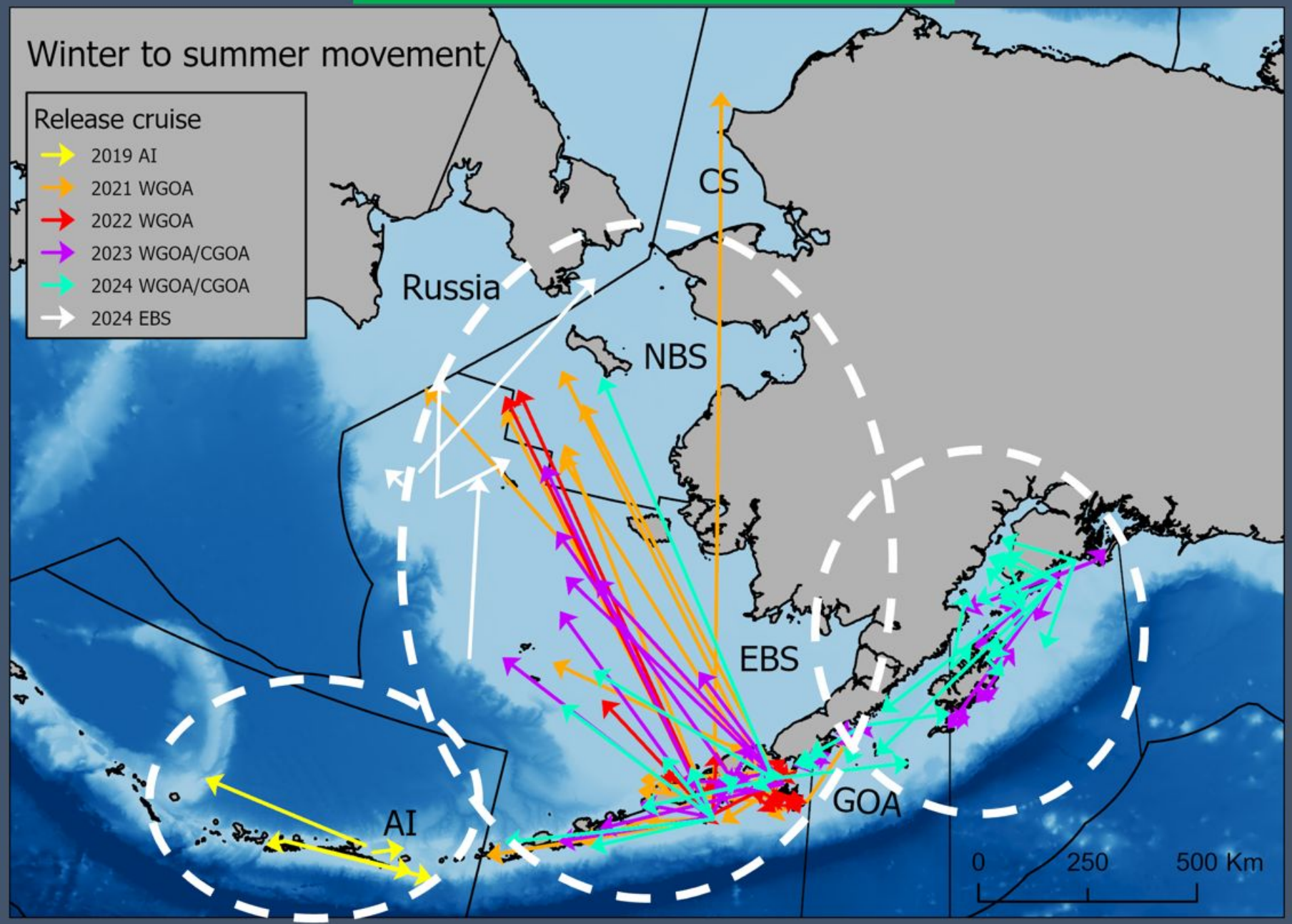

Location probability during summer 2021
Combined location probability (n = 16) June – August 2021
CS
1 %
Russia
8 %
NBS
17 %
EBS
37 %
AI
GOA
34 %
0
250
500 Km


Results: 2021 WGOA (winter spawning to summer foraging)
Monthly probability by region
tags:
23
22
20
16
8
6
4
3
3
3
3
2
100
80
60
40
20
0
GOA
EBS
NBS
Russia
Chukchi Sea
3
2021
4
5
6
7
8
9
10
11
12
1
2022
2

Summer to winter



Winter to summer



PSAT insights

- NBS – currently summertime destination
  - No fish observed to remain there in winter
  - Too cold on shallow shelf under sea ice (-1.8 C)
  - Fish move to EBS, WGOA, Russia during spawning
- Seasonal connectivity
  - Western Gulf and Bering Sea
- Year-round connectivity with Russian waters
  - Greater during summers with warmer temperatures

PSAT advantages

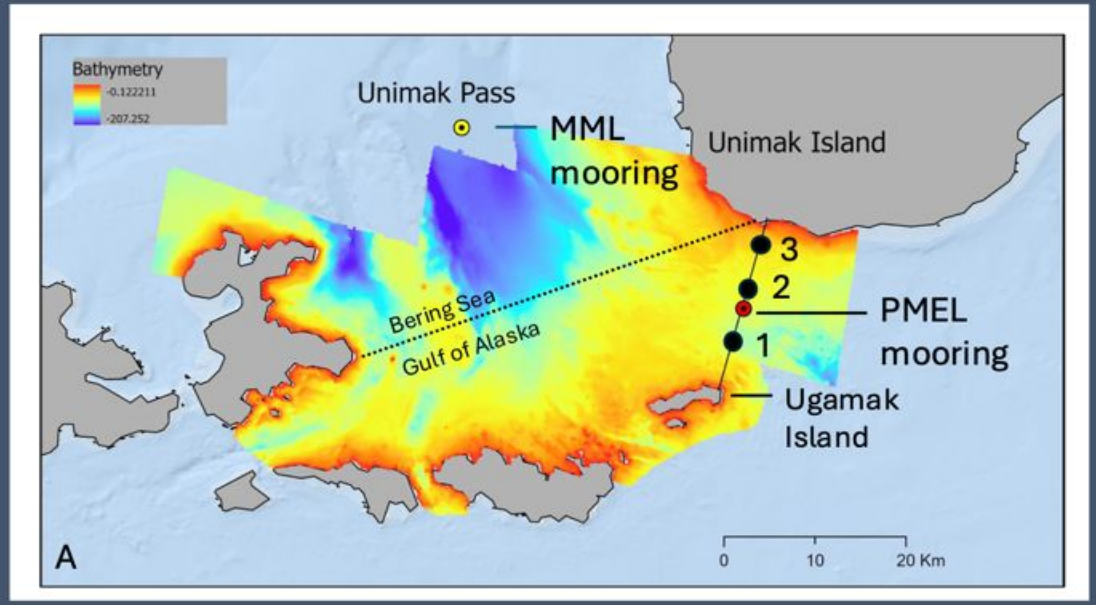
- Migratory vs. residents
- Timing of migration
- Migration pathways
- Time on spawning grounds
- Return to summer foraging areas
- Temperatures and depths occupied
- Behavior
  - Day/night
  - Depth changes
  - Activity patterns

PSAT limitations

- Tag battery/programming issues (2023/2024)
- Poor transmission in winter months
- Latitude needed to determine movement into Gulf from EBS
- Limited to 1 or 1.5 years
- Expensive

NPRB funded proposal:
Acoustic telemetry pilot study in Unimak Pass

- Kingfisher Marine Research
- Aleutians East Borough
- NOAA



Thank you!

AFSC survey charter vessels and crew (F/V Vesteraalen and F/V Alaska Knight)

Native Village of Savoonga
Norton Sound Economic Development Corporation

F/V *Decision* (Capt. Kiley Thompson and crew)

F/V Beauty Bay (Capt. Scott Hansen and crew)

Jim Armstrong, FLC

Comments? Questions?
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Lukas DeFilippo
Chris Long
Emily Ryznar
Emily Markowitz
Rebecca Haehn
Stan Kotwicki
Lyle Britt
Dan Nichol

Genetics

2025 Pacific cod genetics update

Steve Barbeaux

Laura Spencer

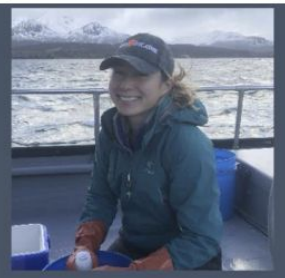
Alisa Abookire

Laura Timm

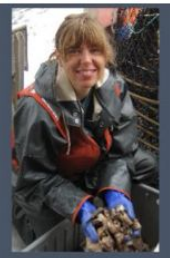
Sara Schaal

Louise Copeman

Susanne McDermott
NOAA AFSC



Charlotte Levy
Aleutians East Borough



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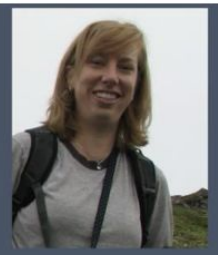

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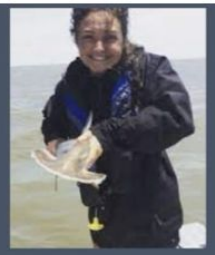

Alexandra Dowlin
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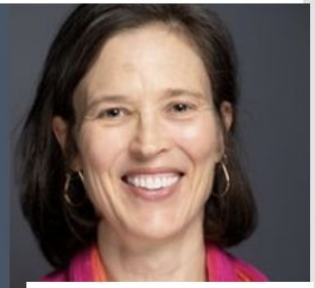

Jessica Miller

Bianca Prohaska
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Steve Barbeaux
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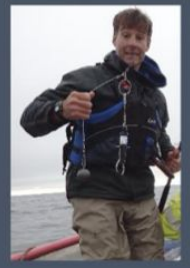
Ingrid Spies
NOAA AFSC



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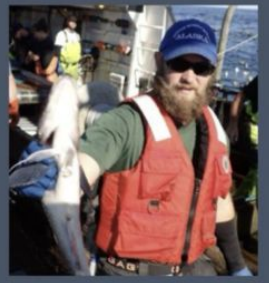
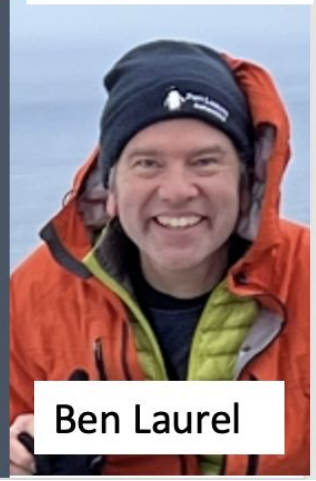


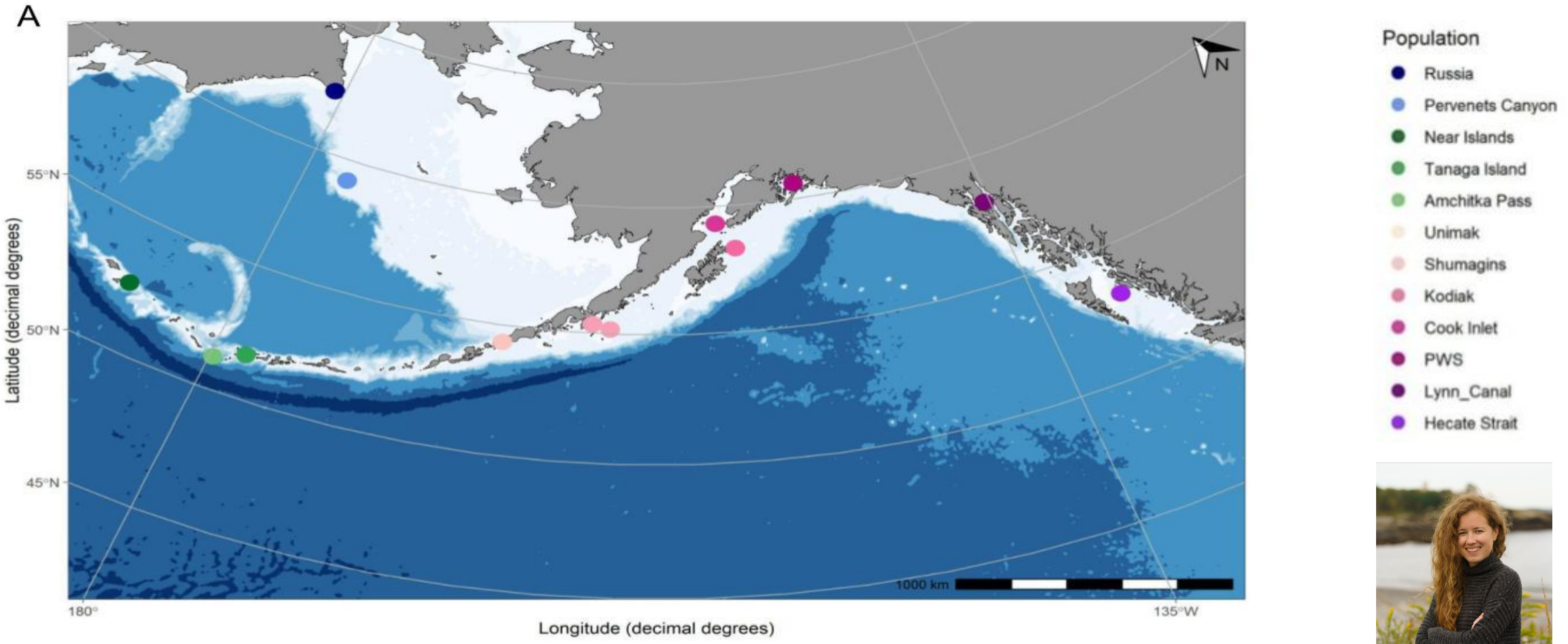
Pete Hulson
NOAA AFSC



Ben Laurel

1. GT-seq panel

Samples from spawning locations were used to develop a Genotyping-in-Thousands by Sequencing (GT-seq) panel, which captures the population genetic structure using a subset of markers

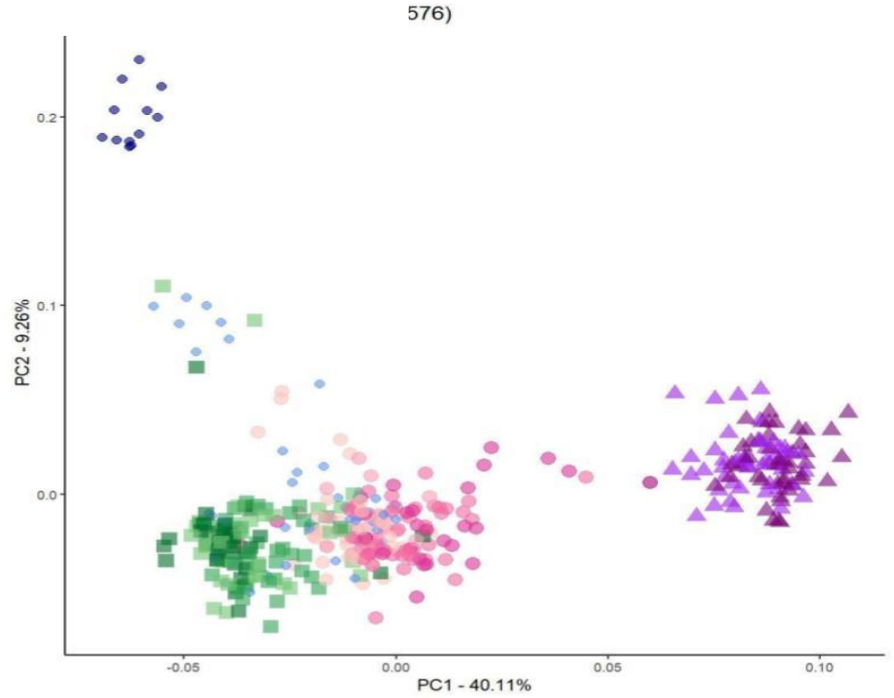


Dr. Sara Schaal

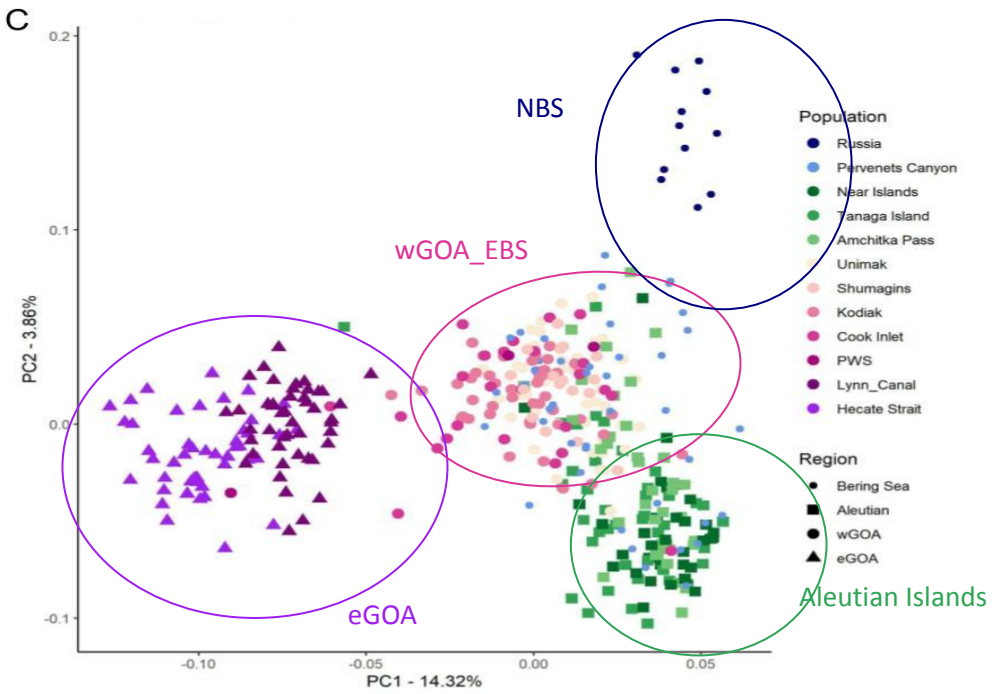
Genotyping-in-Thousands by Sequencing (GT-seq) - captures the population genetic structure using a subset panel of markers

Four genetic reporting groups

High F_{ST} markers: 8576 SNPs



Final Panel: 227 SNPs

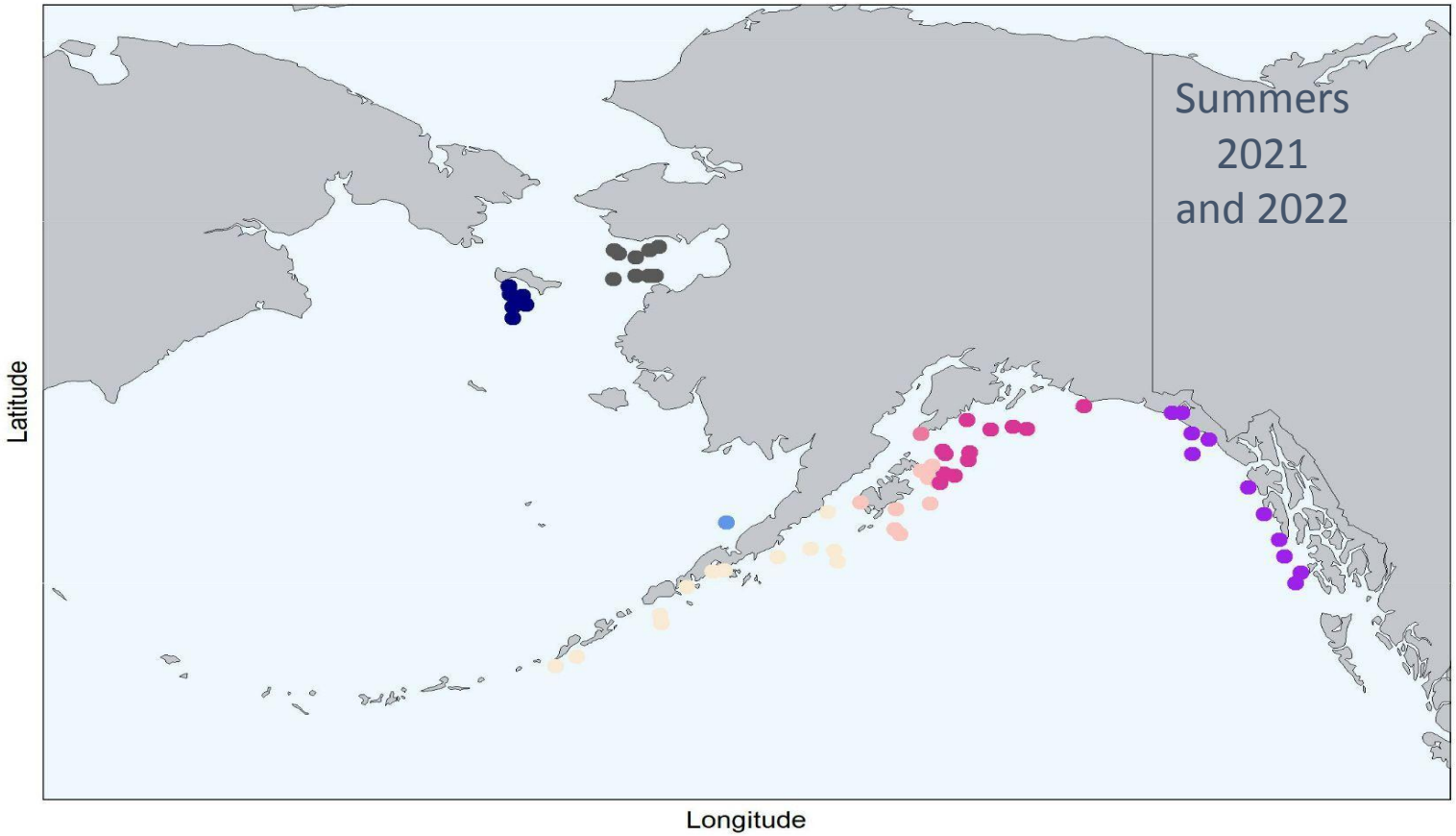


97% assignment accuracy

Dr. Sara Schaal

2. Summer to winter movement

Summer caught Pacific cod adults



Total sample size: 224

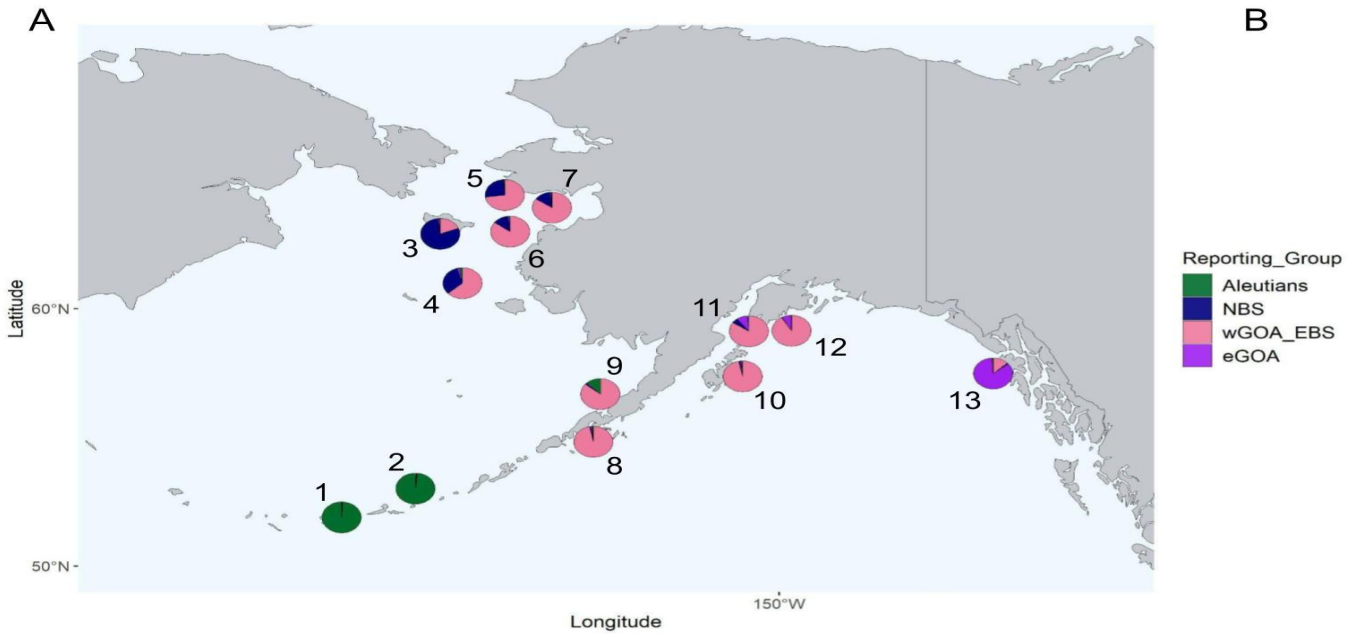
- Norton Sound- 28
- Northern Bering Sea - 24
- Eastern Bering Sea - 25
- Western GOA - 24
- Kodiak - 21
- Outside Cook Inlet - 23
- Central GOA - 54
- Eastern GOA - 25

Dr. Sara Schaal

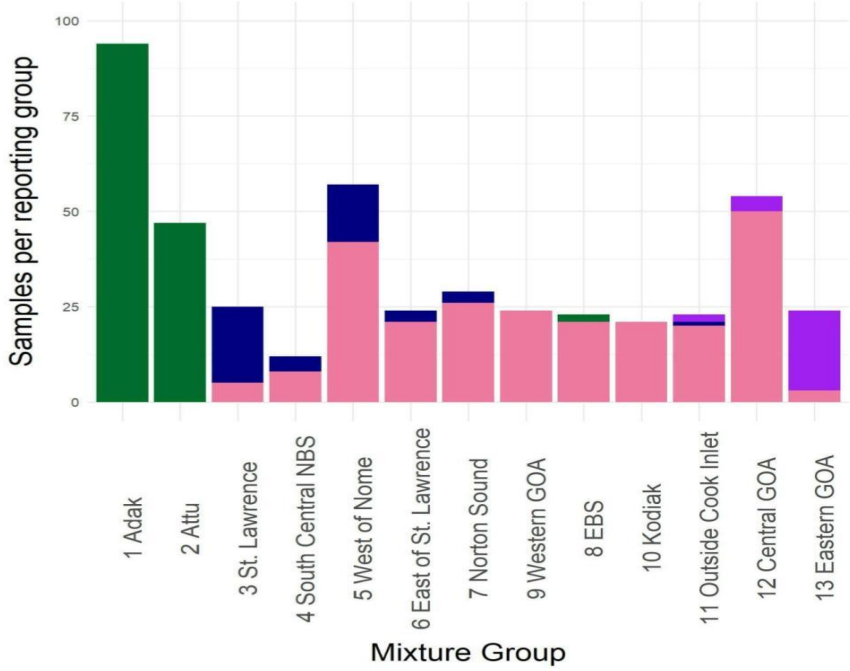
Summer cod – population of origin

Individual assignment based on mixture analysis for samples > 90 probability of assignment

Mixture Proportions Per Collection Site

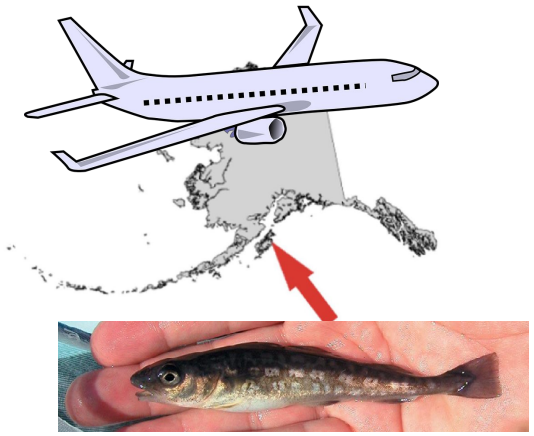


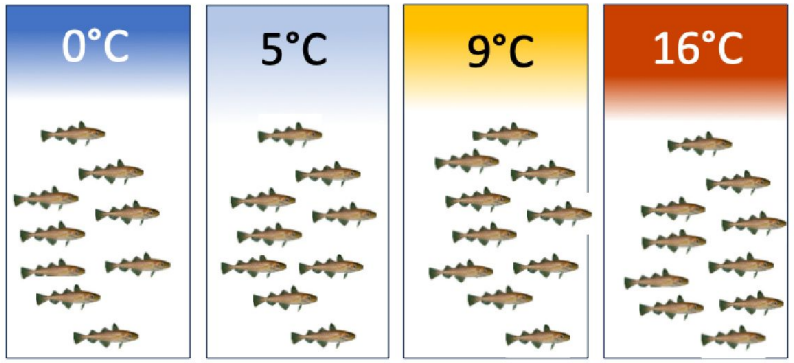
Individual Assignments Per Collection Site

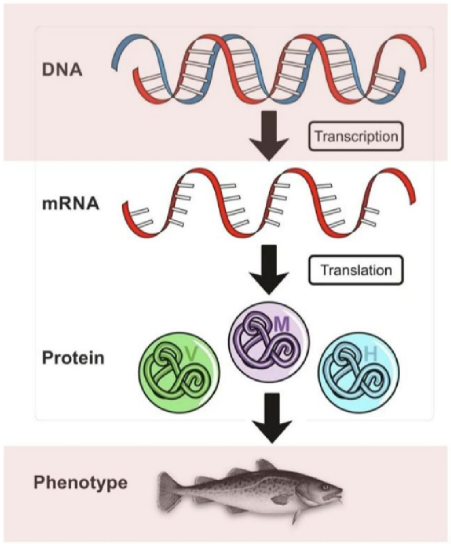


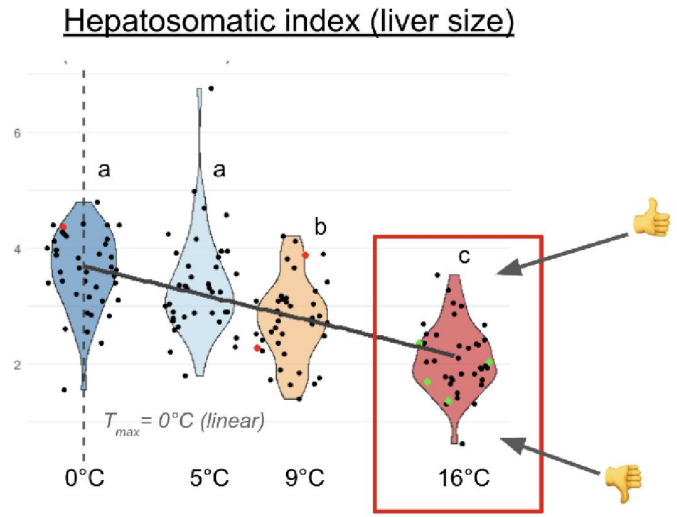
3. Predictive markers

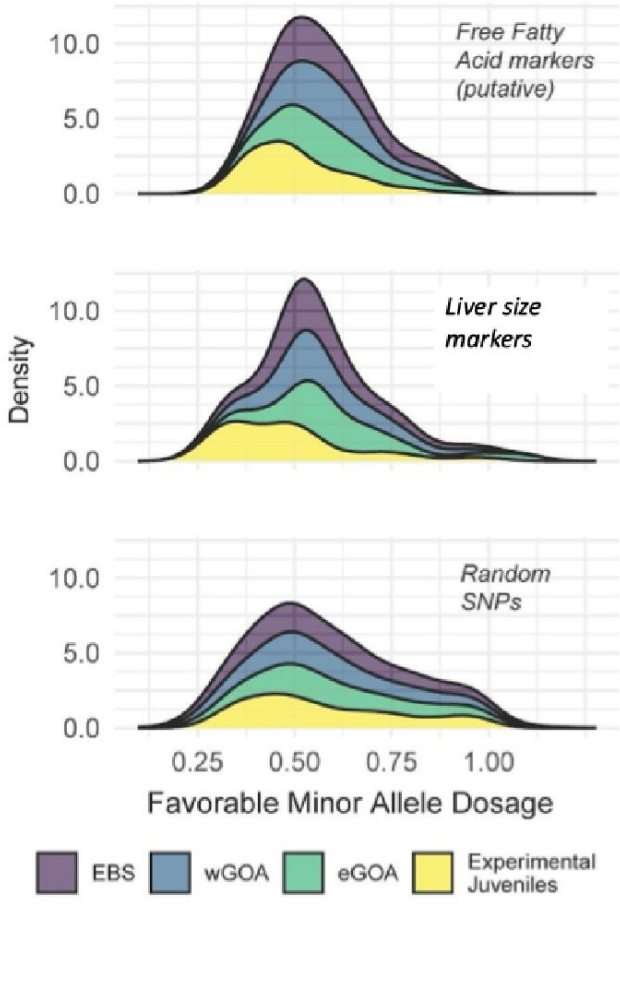
A suite of genetic markers have been identified as potentially predictive for Pacific cod survival







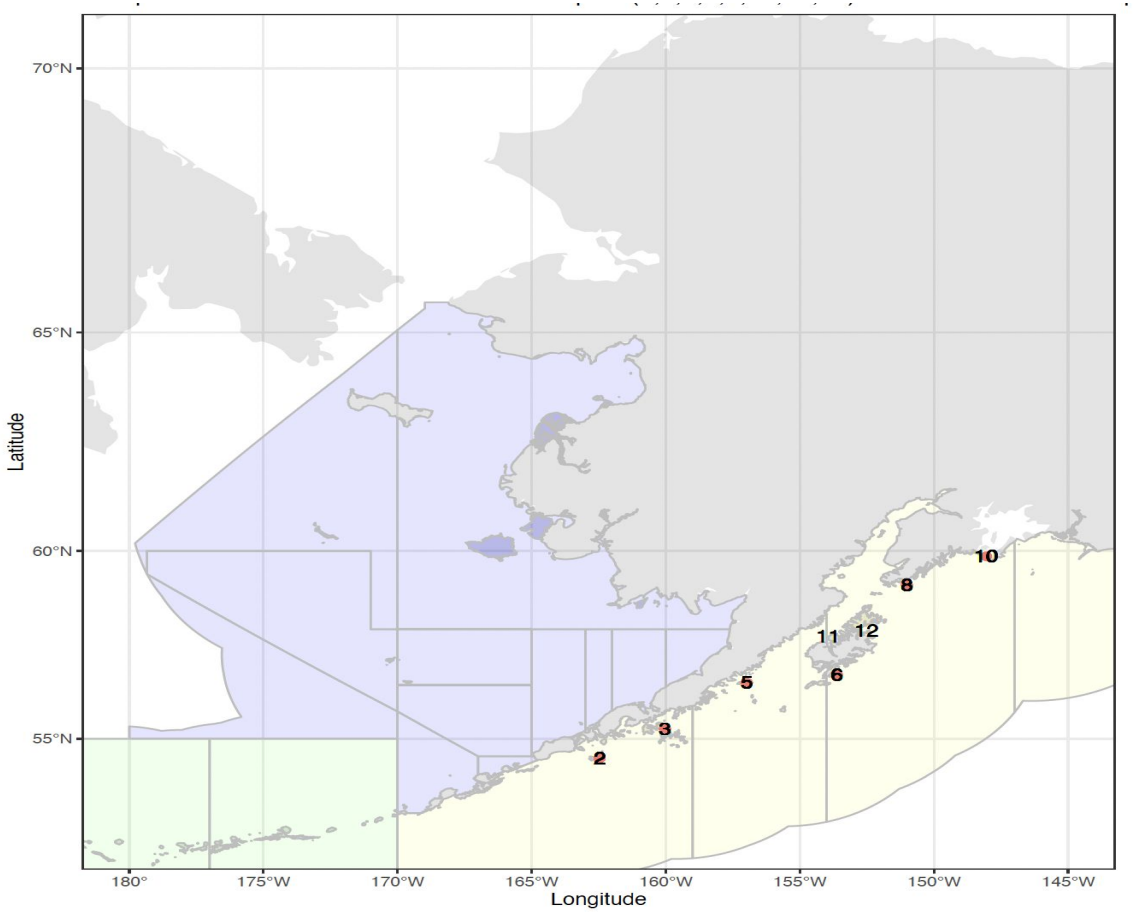


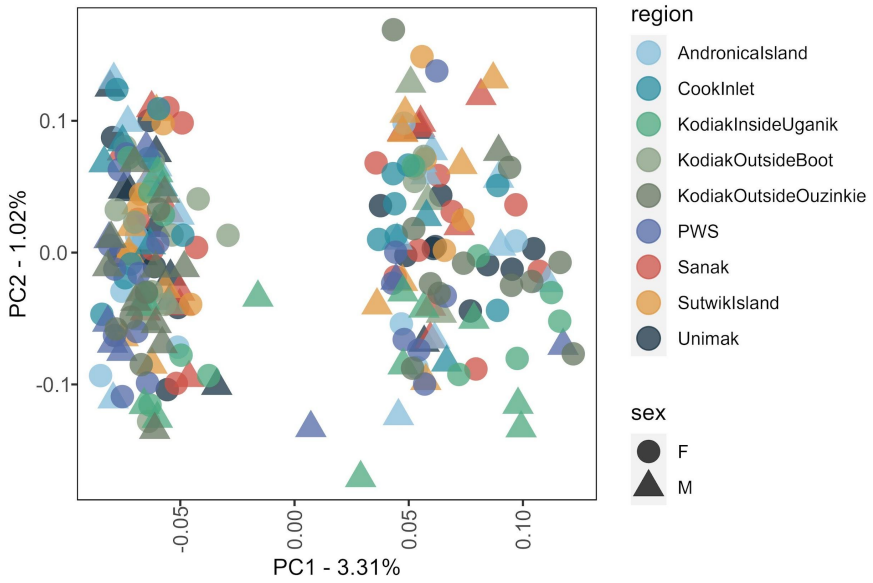


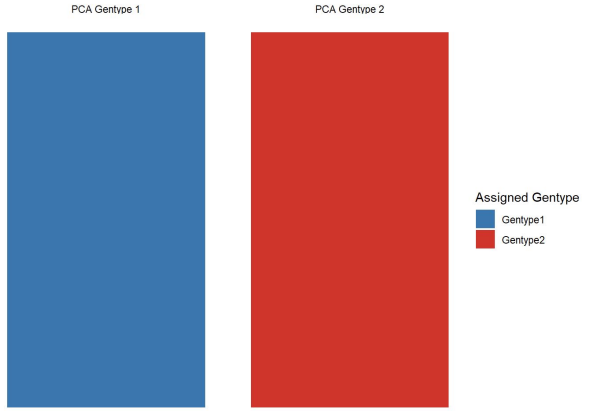
Ben Laurel

Laura Spencer

4. Sequencing EBS and western GOA cod shows evidence for two cryptic genetic types.



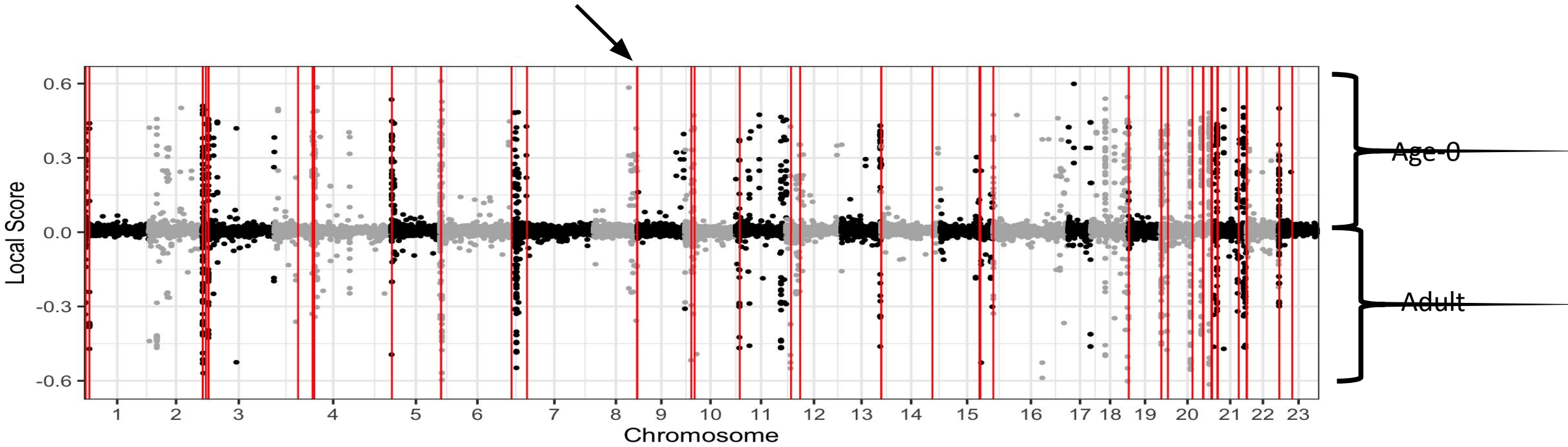




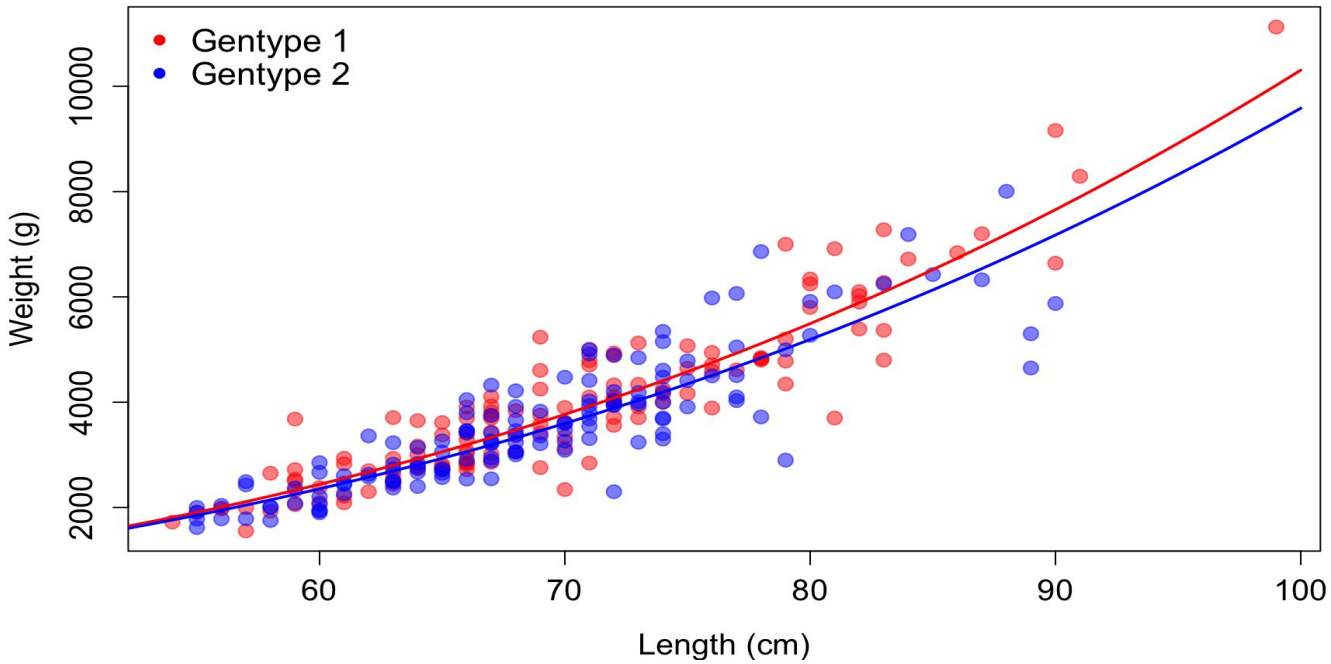
100% assignment success.

There appears to be a large genetic difference between these two types of cod.

Vertical red lines: SNPs identified under selection.

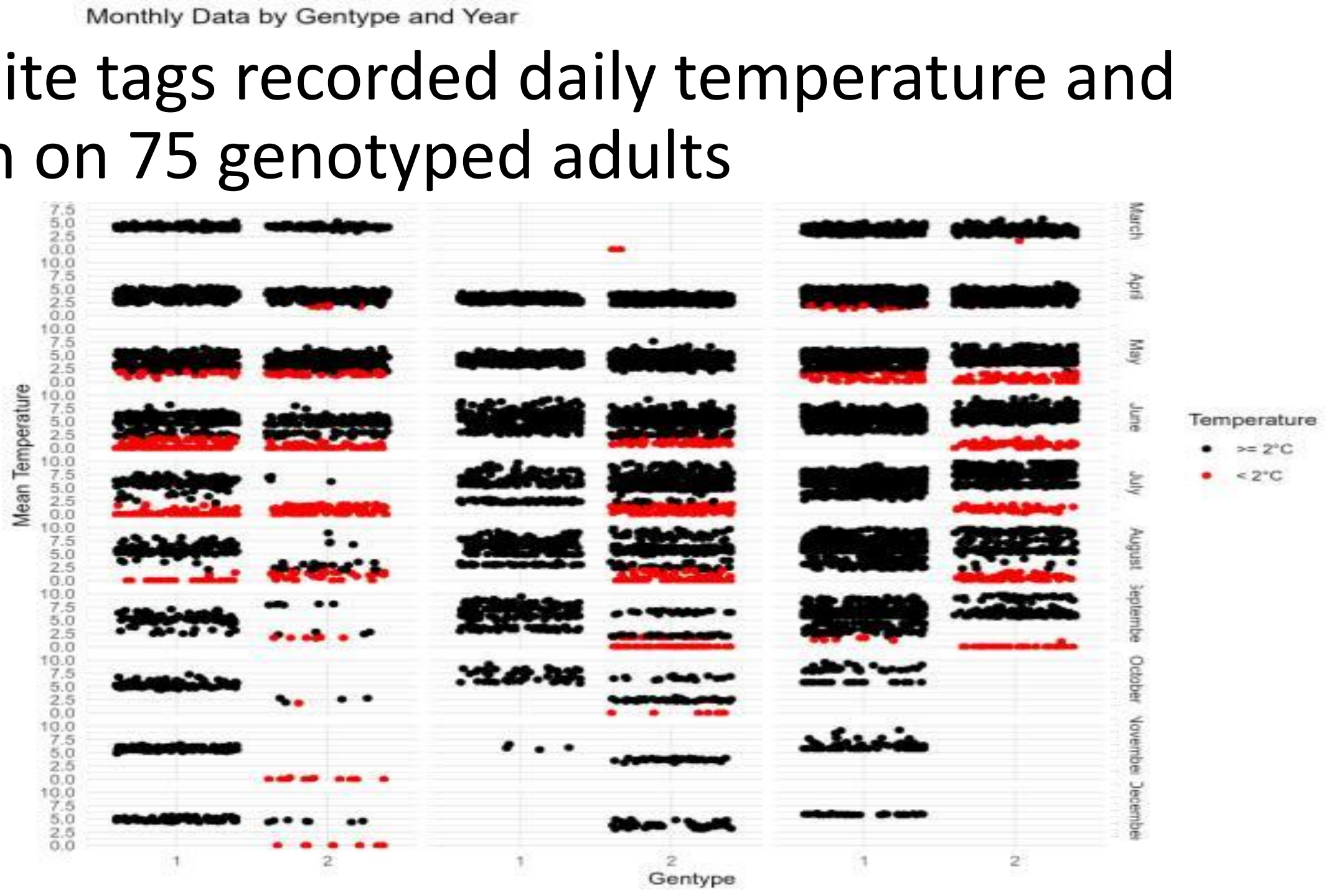


Growth (weight/length) differs significantly by gentype.

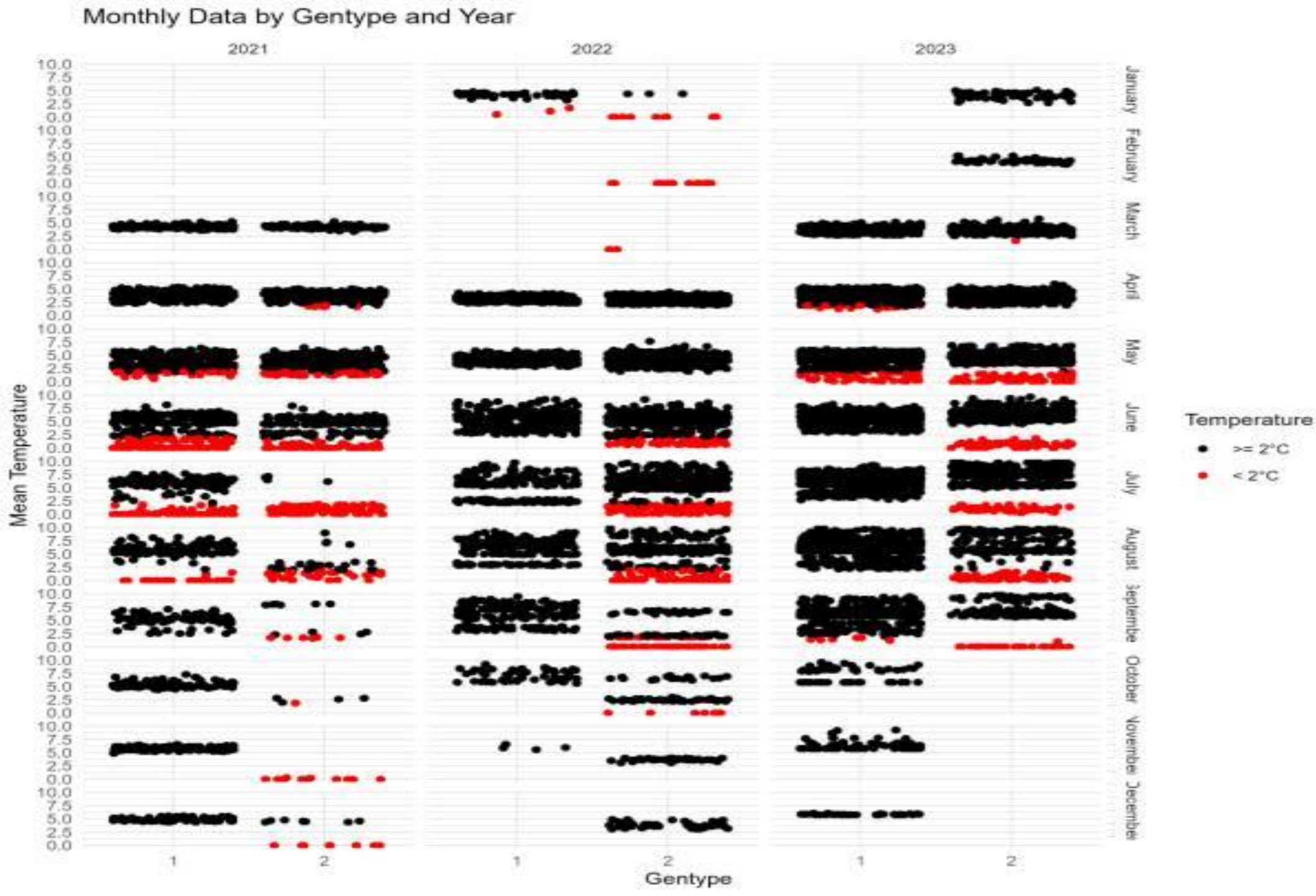


Weight ~ Length + Gentype + Length*Gentype

	df	Sum Sq	Mean Sq	F	pr(>F)
Gentype	1	13015362	13015362	31.963	4.14E-08***
Length	1	418630323	418630323	1028.076	<2.00E-16***
Gentype:Length	1	3286294	3286294	8.071	0.00486**
Residuals	259	105464274	407198		

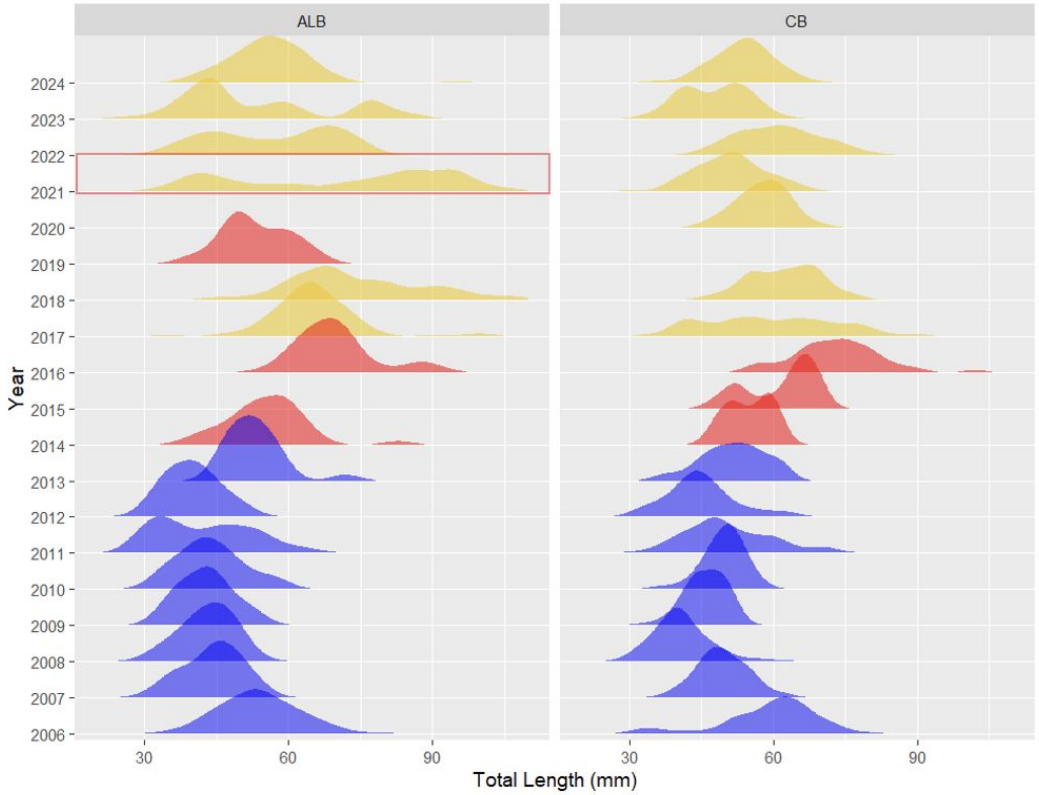


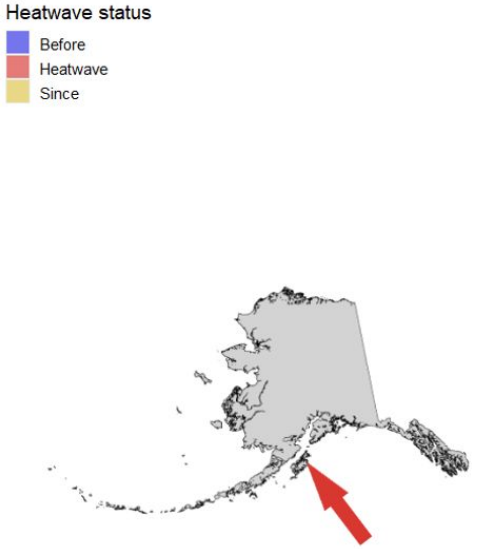
Satellite tags recorded daily temperature and depth on 75 genotyped adults


Monthly Data by Gentype and Year
2021
2022
2023
Mean Temperature
Gentype
January
February
March
April
May
June
July
August
September
October
November
December
Temperature
>= 2°C
< 2°C

5. Evidence of genetically distinct winter- and spring-spawning components of Pacific cod in the Gulf of Alaska

Authors: Benjamin Laurel[1], Jessica Miller[2], Louise Copeman[1], Alisa Abookire[3], Laura Spencer[4], Sara M. Schaal[4], Mary Beth Rew Hicks[1], Nicholas Strait[2], Lauren Rogers[4], Ingrid Spies[4]



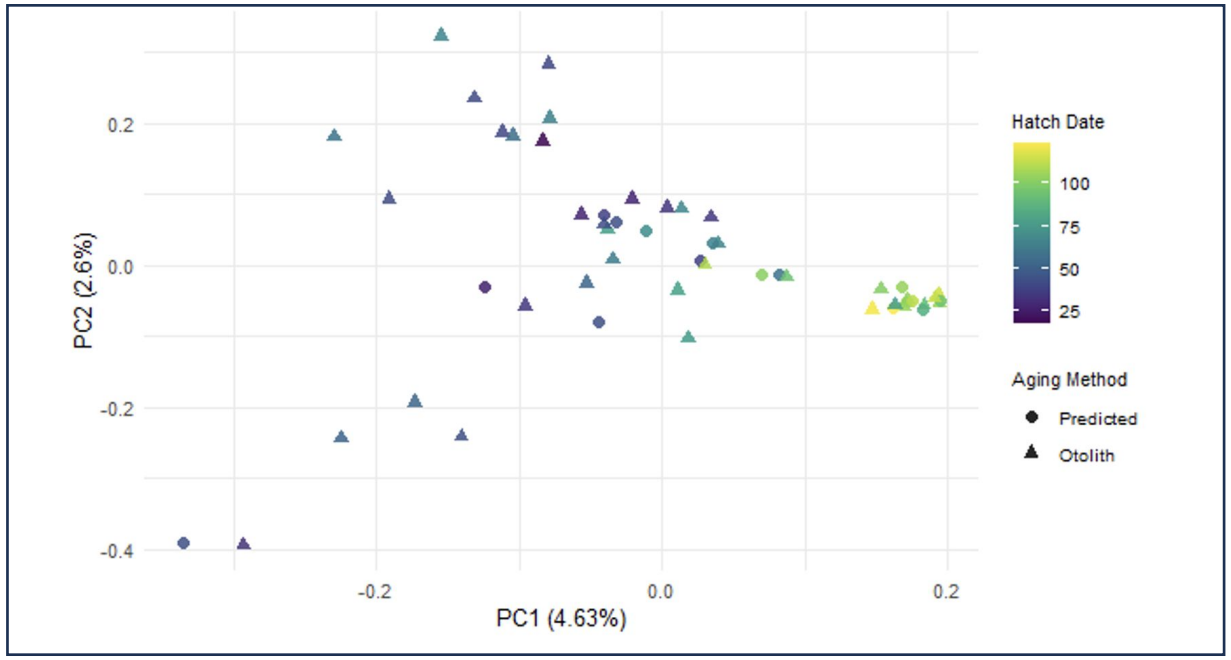


Ben Laurel

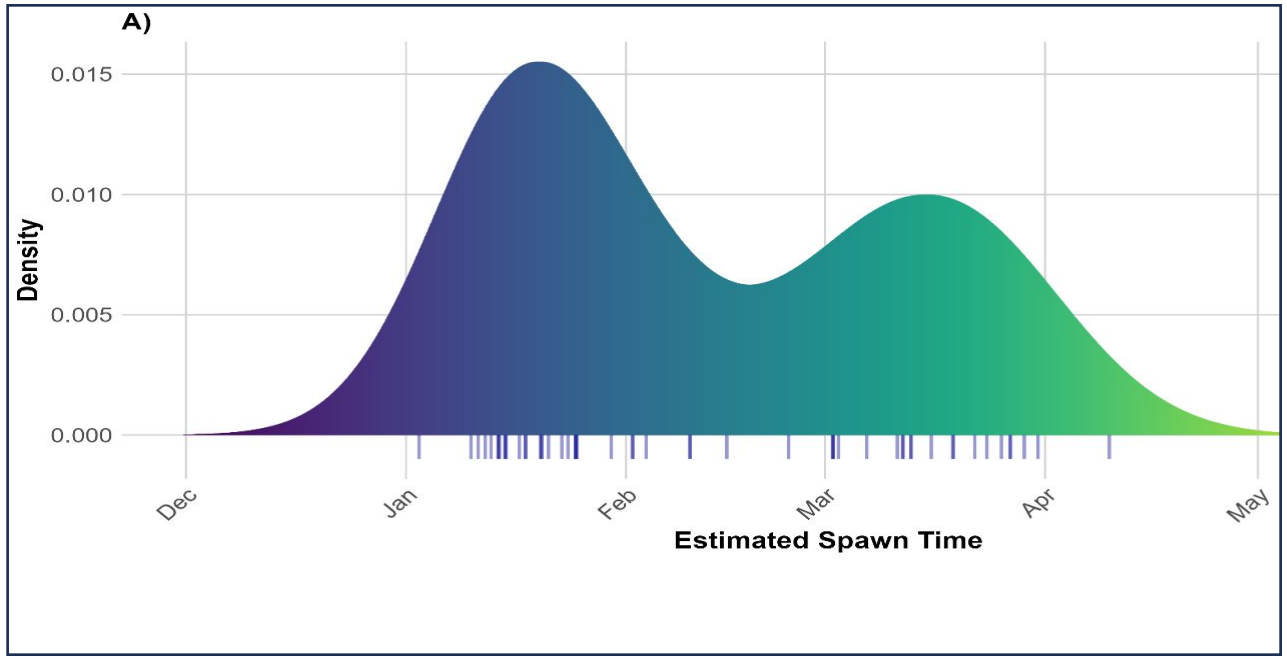
Laura Spencer

Two peaks in spawn timing in Pacific cod inferred in the Gulf of Alaska (based on sampling in 2021)

Genetic difference between large and small individuals



Ages indicated that these individuals were spawned in two distinct peaks.



Conclusions: GT-seq panel has shown little summer to winter movement, except in the northern Bering Sea.

1. GT-seq panel
2. Summer to winter movement
3. Predictive markers.
4. Two cryptic genetic types (growth/temperat
5. Genetically distinct spawn timing.

Conclusions: Predictive markers are a new tool to predict year class strength and heatwave response.

1. GT-seq panel
2. Summer to winter movement
3. Predictive markers.
4. Two cryptic genetic types (growth/temperature).
5. Genetically distinct spawn timing.

Conclusions: New evidence for genetic variation in the western Gulf of Alaska cod stocks

1. GT-seq panel
2. Summer to winter movement
3. Predictive markers.
4. Two cryptic genetic types (growth/temperature).
5. Genetically distinct spawn timing.

Western GOA Pcod assessment research

September 2025 Plan Team

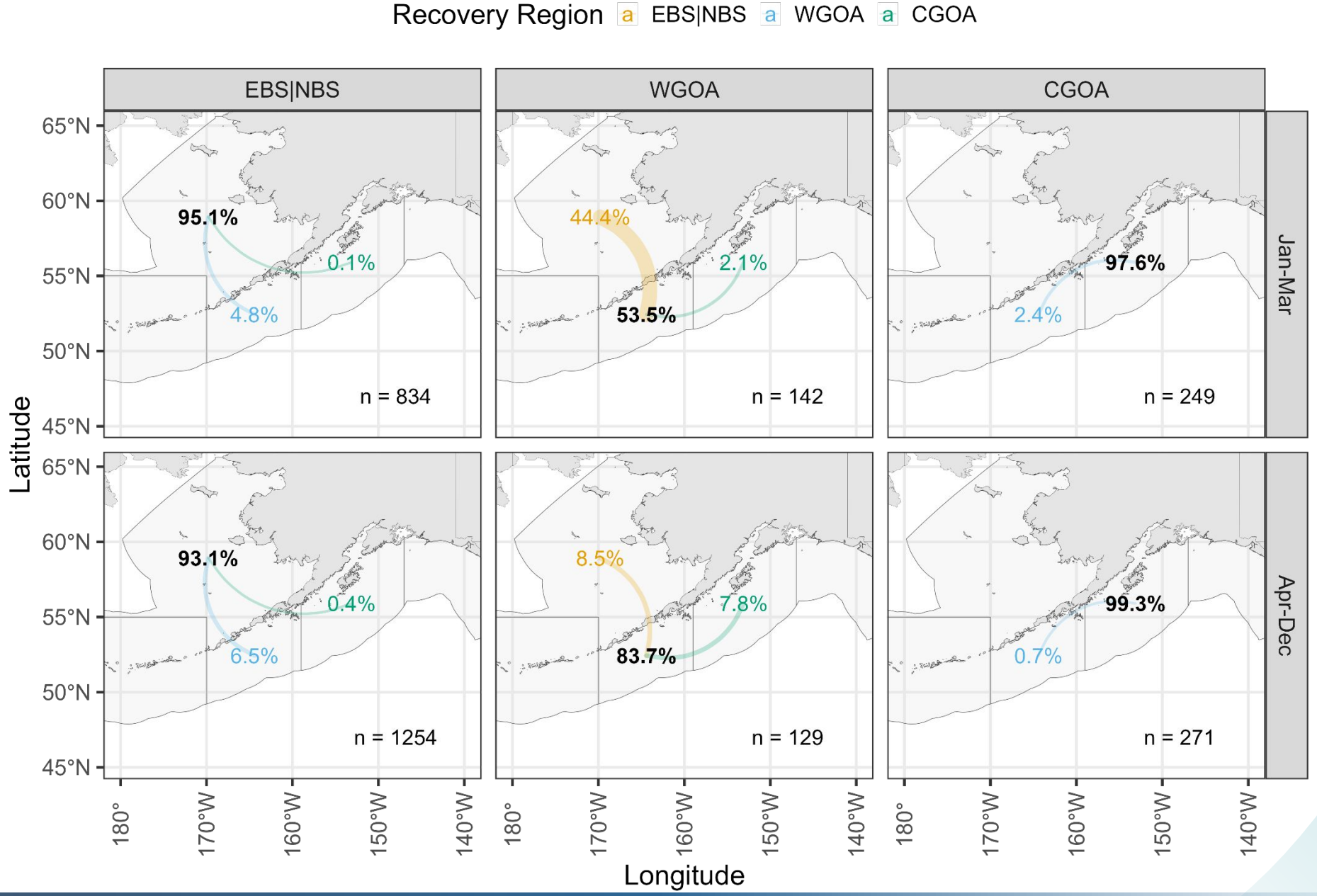
Outline

1. Combined tagging data
2. Fishery characteristics
3. Survey index comparison
4. Brainstorming apportionment options
5. Discussion

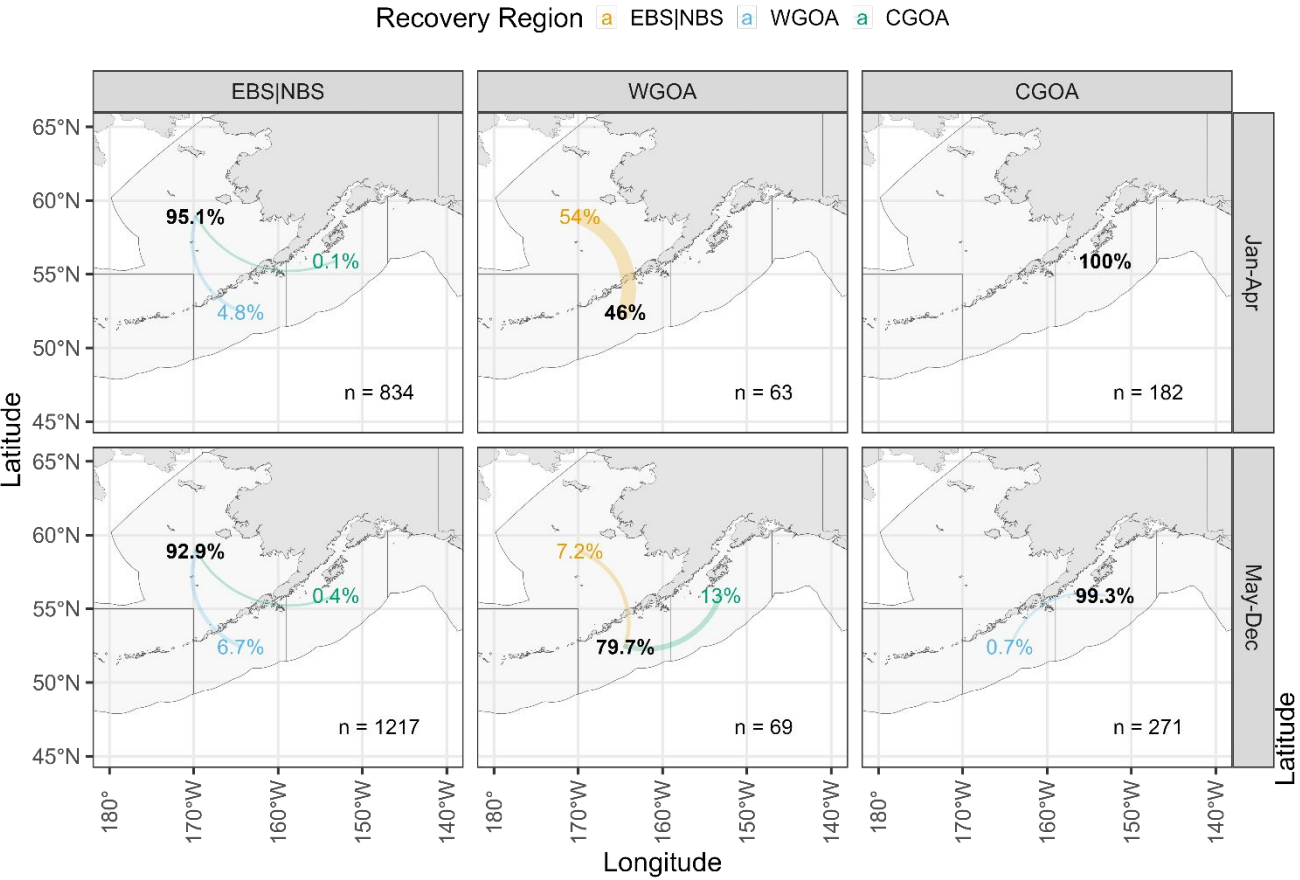
Combined tagging data

- Collated all available tagging data
  - Includes both conventional and satellite tags (using only release/pop-off locations)
  - Starts in 1982, total of 2,879 tags
  - Filter to:
    - At least 30 days at liberty
    - Released-recovered in EBS|NBS, WGOA, and CGOA

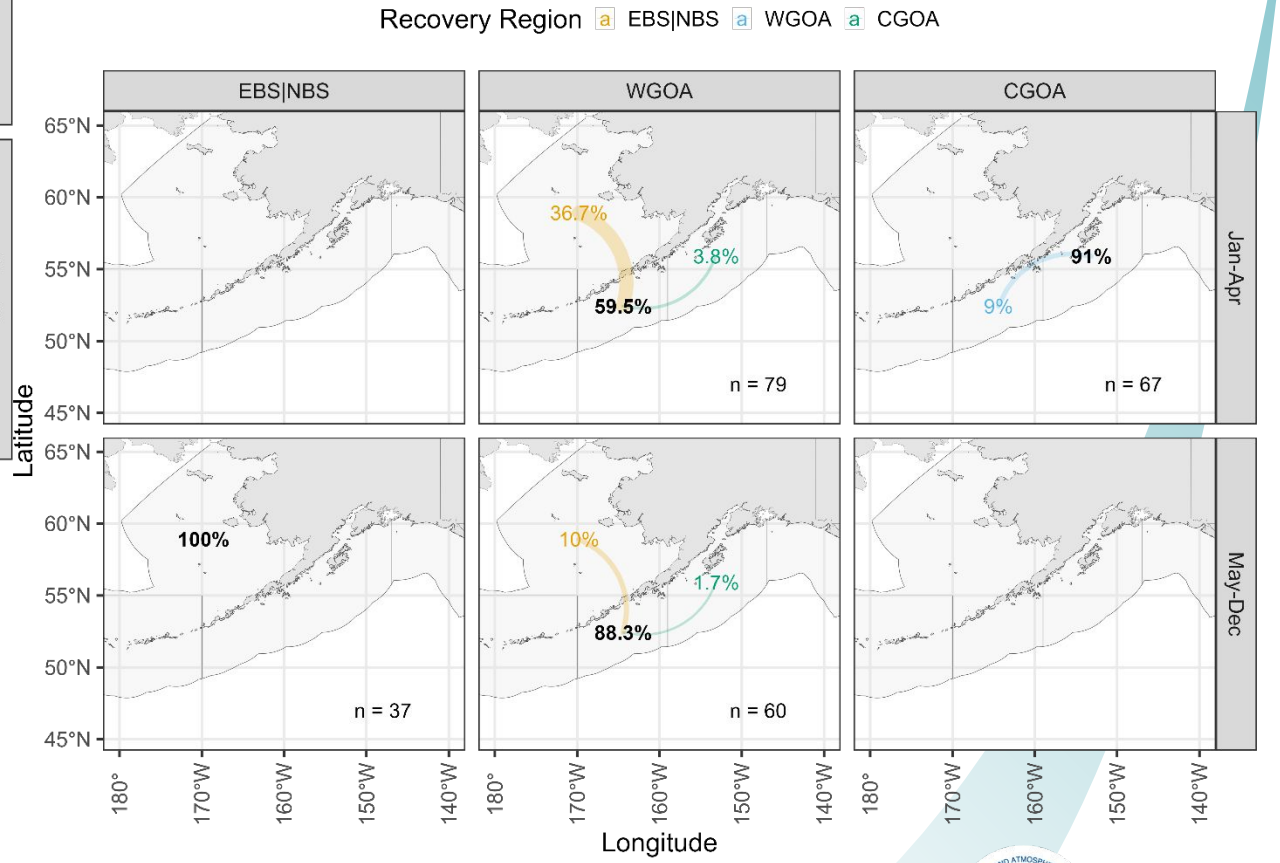
	Release region		
	EBS|NBS	WGOA	CGOA
Pre-2020	2,051	132	453
Post-2020	37	139	67
Total	2,088	271	520


Recovery Region EBS|NBS WGOA CGOA
EBS|NBS
WGOA
CGOA
Jan-Mar
Apr-Dec
Latitude
Longitude
65°N
60°N
55°N
50°N
45°N
180°
170°W
160°W
150°W
140°W
95.1%
0.1%
4.8%
n = 834
44.4%
2.1%
53.5%
n = 142
97.6%
2.4%
n = 249
93.1%
0.4%
6.5%
n = 1254
8.5%
7.8%
83.7%
n = 129
99.3%
0.7%
n = 271

Pre-2020



Post-2020



NOAA FISHERIES

Combined tagging data

- Why Jan-Mar? Seasonality of movement from WGOA:

	From WGOA, to…			
Month	EBS|NBS	WGOA	CGOA	n
1	**33%**	**67%**	**0%**	**42**
3	**49%**	**48%**	**3%**	**100**
4	12%	86%	2%	50
5	*0%*	*100%*	*0%*	*3*
6	*0%*	*100%*	*0%*	*2*
7	4%	96%	0%	23
8	9%	73%	18%	45
9	*0%*	*83%*	*17%*	*6*
All	27%	68%	5%	271

Combined tagging data

- Seasonality of movement from EBS|NBS:

	From EBS|NBS, to…			
Month	EBS|NBS	WGOA	CGOA	n
1	*84%*	*16%*	*0.0%*	*19*
2	95%	5%	0.1%	809
3	*100%*	*0%*	*0.0%*	*6*
4	94%	6%	0.0%	678
6	90%	7%	2.8%	71
7	96%	4%	0.0%	82
8	94%	6%	0.0%	108
9	94%	6%	0.7%	141
10	*84%*	*12%*	*4.0%*	*25*
11	90%	9%	0.7%	149
All	94%	6%	0.3%	2088

Combined tagging data

- Take homes:
  - WGOA has largest amount of movement out of the region as compared to EBS|NBS and CGOA
    - Strong seasonal component, bulk of movement from WGOA to EBS|NBS occurs prior to April
    - Recent tagging has less movement to EBS|NBS (~37%) as compared to historical tagging data (~54%) prior to April
  - EBS|NBS movement to WGOA consistent across month/season, and hovers ~6%
  - CGOA has limited movement to WGOA, none to EBS|BS

Fishery characteristics

- Catch from Cod-targeted trips by season:

		Jan-Mar	Apr-Dec
610	Pre-closure	83%	17%
	Post-closure	82%	18%
620	Pre-closure	76%	24%
	Post-closure	65%	35%
630	Pre-closure	77%	23%
	Post-closure	72%	28%

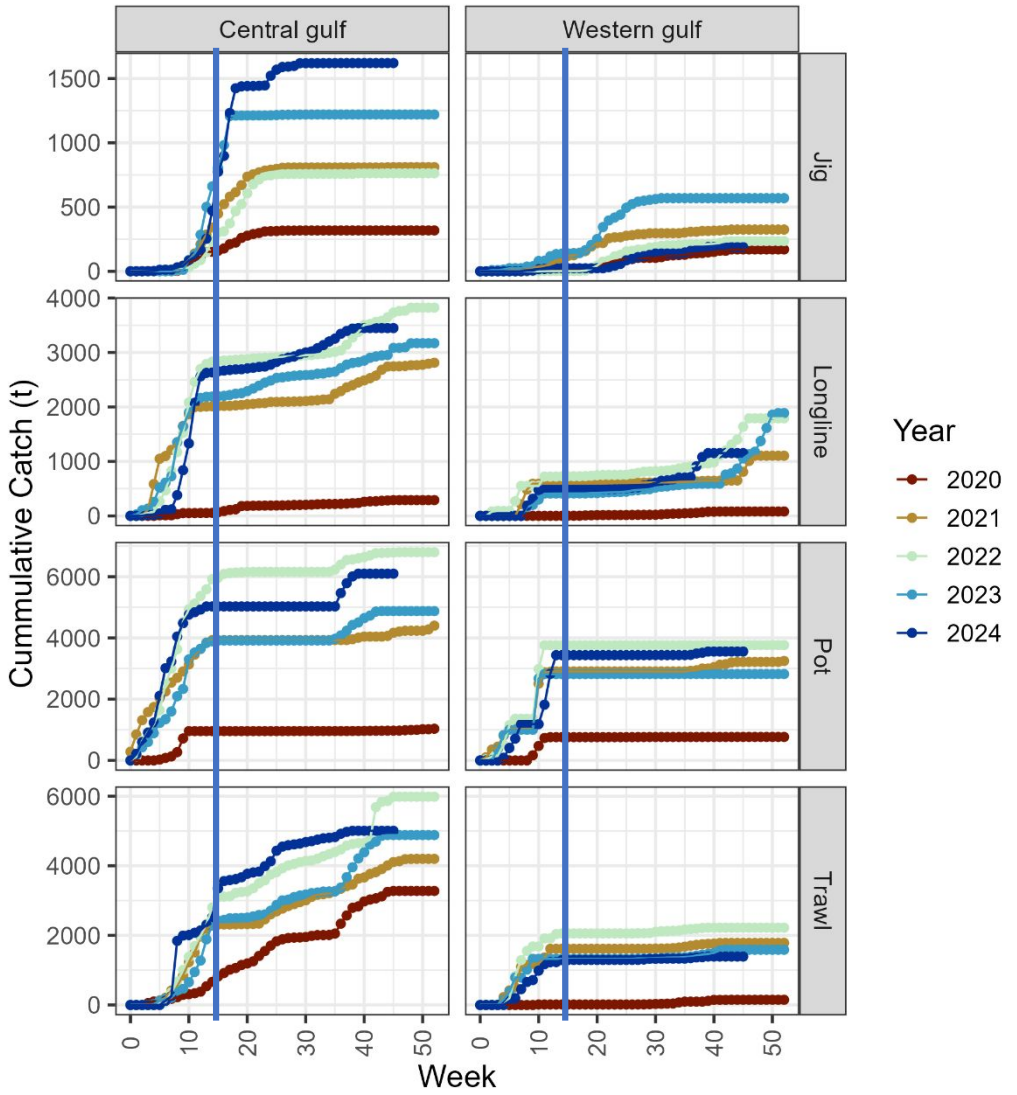
Fishery characteristics

- WGOA catch from Cod-targeted trips by gear and season since 2020:

	Jan-Mar	Apr-Dec	% of total catch
Pot	95%	5%	52%
Trawl	97%	3%	24%
Longline	45%	55%	19%
Jig	19%	81%	5%

Fishery characteristics

- Take home:
  - In general, majority of fishery catch coincides within the time period when EBS|NBS fish are in the WGOA
  - Likely that presence of cod in Jan-Mar not the limiting factor for catch in the WGOA



Survey index comparison

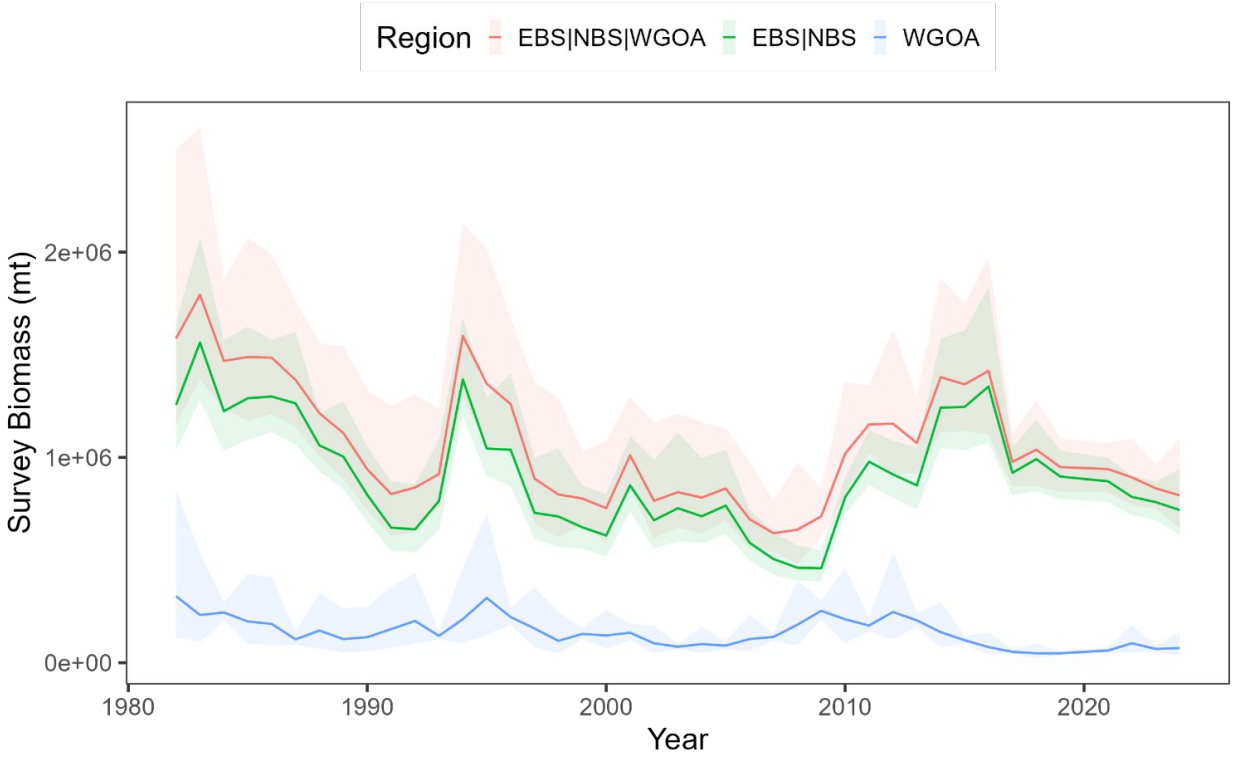
- Purpose is to provide context of how large a proportion of biomass we see in the survey/summer is in the WGOA compared to the EBS|NBS
- sdmTMB used to estimate model-based indices for EBS|NBS and WGOA
  - Provides annual estimates of survey biomass that integrates EBS-NBS surveys for comparison with survey in WGOA

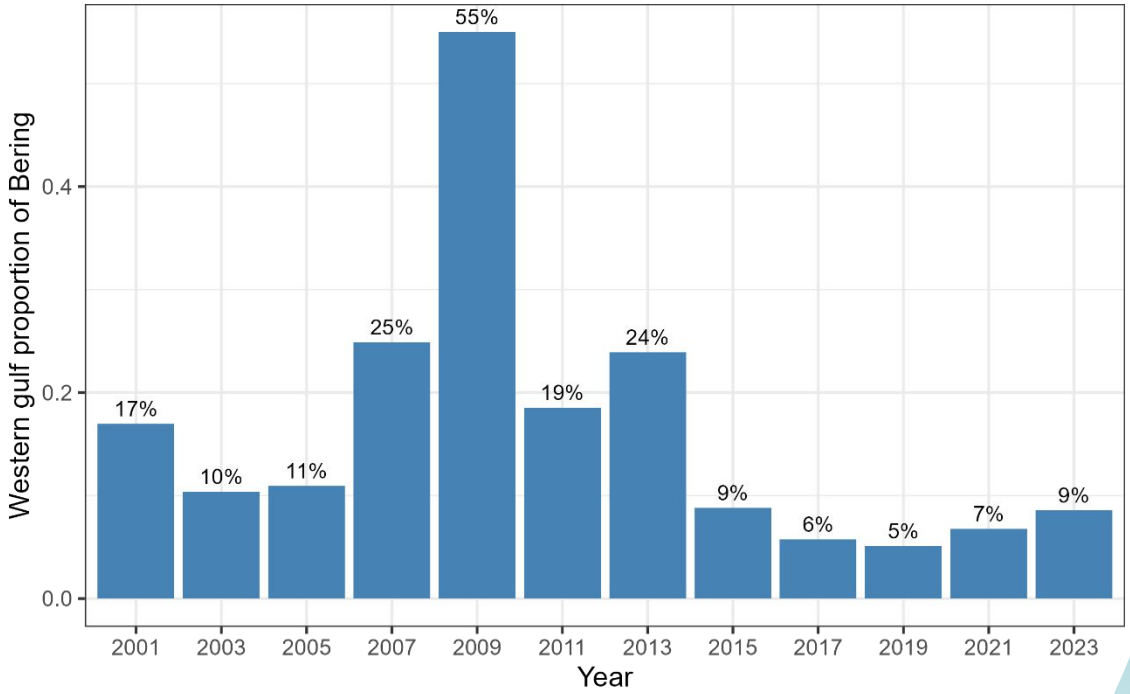
Survey index comparison

- WGOA not quite aligned with current management areas
- Adjusted based on spatial fishery catch, tagging data, and bathymetry
- So, not precisely same as current WGOA biomass used in apportionment, but close enough to provide comparisons

NOAA FISHERIES

Survey index comparison





- Proportion of survey biomass in WGOA as compared to EBS | NBS is variable, and can be large depending on relative regional biomass
- In recent years (post-2015) WGOA biomass is around 5-9% of EBS | NBS biomass, and has increased in the last 3 surveys

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. Spatially and seasonally-explicit model that estimates movement
  2. Single area BS|WGOA integrated model (w or w/o seasonality)
  3. Ad hoc adjustment to current methodology informed by tagging
- Weigh benefits and risks involved with each
- Things to keep in mind from previous presentations/discussion:
  1. There is a seasonal component to movement from the WGOA to the BS
  2. There is evidence of migratory and resident populations in WGOA
  3. Fishery largely operates seasonally as well
  4. Our current system is conservative in the WGOA, a change to adjust BRD will involve increasing risk at some level

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. **Spatially and seasonally-explicit model that estimates movement**
  2. *Single area BS|WGOA integrated model (w or w/o seasonality)*
  3. *Ad hoc adjustment to current methodology informed by tagging*

- Benefits:
  - Would provide regional and seasonal estimates of abundance, from which projections of catch can be determined
  - Provides a framework to estimate and understand movement between the WGOA and BS
  - Would provide an assessment model that aligns with the biological attributes of the WGOA and BS stock

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. **Spatially and seasonally-explicit model that estimates movement**
  2. *Single area BS|WGOA integrated model (w or w/o seasonality)*
  3. *Ad hoc adjustment to current methodology informed by tagging*

- Risks:
  - Extremely data hungry. The biggest hole we have in this type of model is a lack of seasonal index data (i.e., we don't know the abundance in the WGOA during winter/spawning), we also have limited amount of tagging data to inform movement, which is likely driven to a great extent by environmental/ecosystem influences
  - To make this type of model run with our available data, will need to make a large number of assumptions, for example, fixing movement and other key parameters

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. *Spatially and seasonally-explicit model that estimates movement*
  2. **Single area BS|WGOA integrated model (w or w/o seasonality)**
  3. *Ad hoc adjustment to current methodology informed by tagging*

- Benefits:
  - Would provide assessment model that aligns with what we understand to be the biological distribution/connectivity between the BS and WGOA stock
  - Would look very similar to the models we currently use now, would simply be adding survey/fishery data between regions
  - Note: we have this model in development (Steve will talk about soon)

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. *Spatially and seasonally-explicit model that estimates movement*
  2. **Single area BS|WGOA integrated model (w or w/o seasonality)**
  3. *Ad hoc adjustment to current methodology informed by tagging*

- Risks:
  - Would not have regional estimates of abundance
  - The BS data within this model dominates results
  - Would need to develop some sort of apportionment method that (1) provides BRDs, and (2) accounts for seasonality of abundance in WGOA
  - A large risk here is to not overharvest a summer-resident population within the WGOA from a model that essentially swamps out any signal from the WGOA data

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. *Spatially and seasonally-explicit model that estimates movement*
  2. *Single area BS|WGOA integrated model (w or w/o seasonality)*
  3. **Ad hoc adjustment to current methodology informed by tagging**
- Benefits:
  - Would continue to utilize assessment framework that is well understood by managers/stakeholders
  - Could provide a simple approach to adjusting BRD between the BS and WGOA

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. *Spatially and seasonally-explicit model that estimates movement*
  2. *Single area BS|WGOA integrated model (w or w/o seasonality)*
  3. **Ad hoc adjustment to current methodology informed by tagging**
- Risks:
  - Doesn't explicitly address the biology/distribution of the BS and WGOA stock through a model
  - Would need to make an assumption about the movement rate between WGOA and BS

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. *Spatially and seasonally-explicit model that estimates movement*
  2. *Single area BS|WGOA integrated model (w or w/o seasonality)*
  3. **Ad hoc adjustment to current methodology informed by tagging**

- Simple example to get a feel for what magnitude we're talking about:
  - Say X% is the movement rate of WGOA to BS from Jan-Mar, W is biomass in WGOA, and B is the biomass in the BS (use survey biomass in example)
  - The word problem: If X% of cod move from the WGOA, leaving W that is observed behind, what percent of the BS biomass B surveyed in the summer moved from the WGOA?
  - Answer: the proportion of biomass in the BS that moved from the WGOA would be (W/(1-X%)-W) / B

Brainstorming apportionment options

- Range of options, from complex to simple:
  1. *Spatially and seasonally-explicit model that estimates movement*
  2. *Single area BS|WGOA integrated model (w or w/o seasonality)*
  3. **Ad hoc adjustment to current methodology informed by tagging**
- Simple example to get a feel for what magnitude we're talking about:

% of BS biomass	Movement rate from WGOA 30%	40%	50%
2019	2.2%	3.4%	5.1%
2021	2.9%	4.5%	6.7%
2023	3.7%	5.7%	8.6%
Avg	2.9%	4.5%	6.8%

Discussion

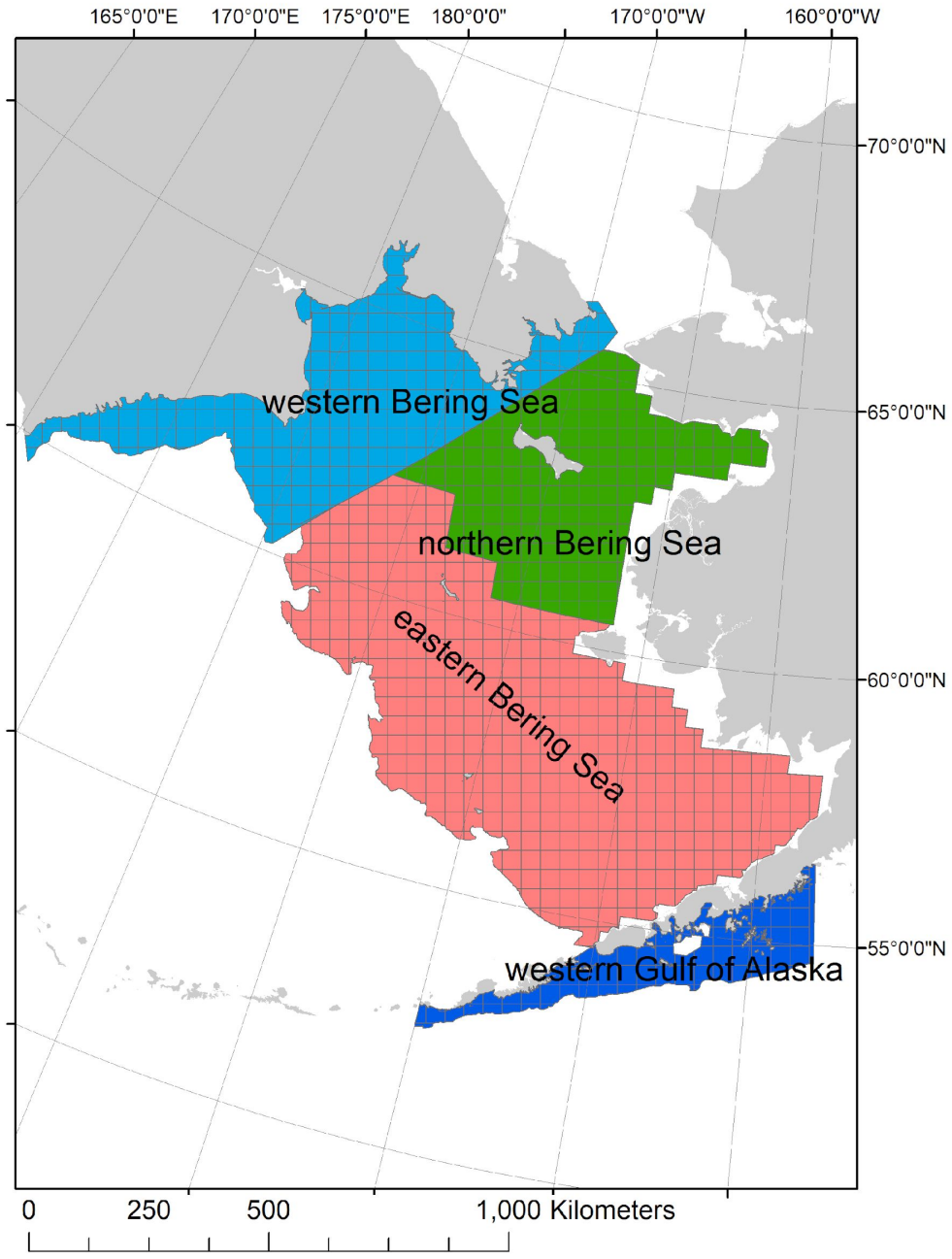
- Strong seasonal component to movement from WGOA to EBS|NBS
  - Any upward adjustment to WGOA BRD involves risk to a resident WGOA stock
  - Indication that abundance is larger in WGOA from Jan-Mar than observed in the survey
- Multiple methods being evaluated to ultimately enable adjustment of WGOA/EBS|NBS BRDs
- Main take homes:
  - Any upward adjustment of WGOA BRD would need to be allocated to a Jan-Mar fishery in the WGOA
  - Whatever model or method we use, we will need to make strong assumptions on movement or other key parameters

Western Bering Sea Pacific Cod

September 2025 Plan Team

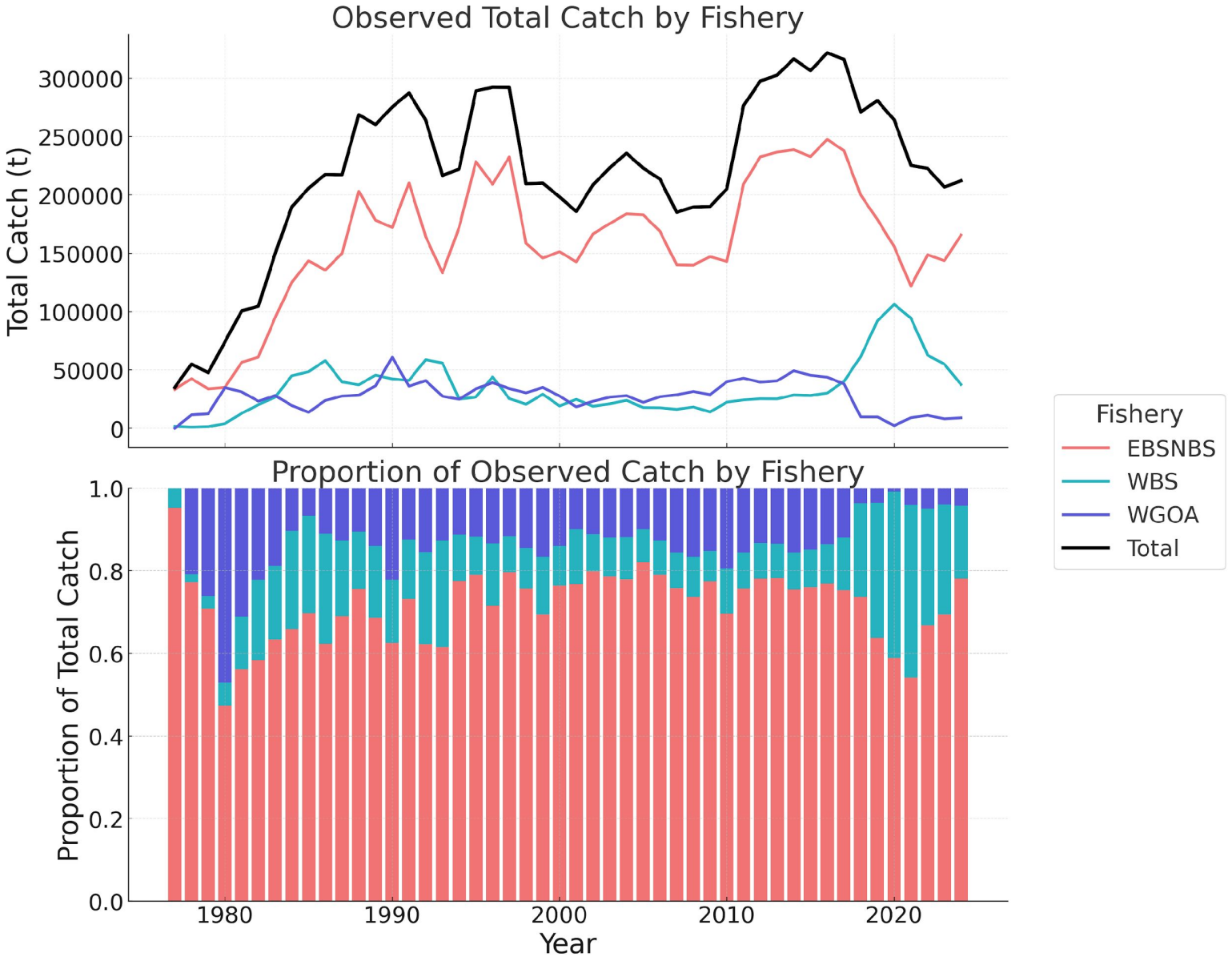
What about the western Bering Sea?

- PSAT data show consistent Pacific cod movement among the eastern, northern, and western Bering Sea.
- Genetic specimen of the western Bering Sea group among the eastern Bering Sea samples.



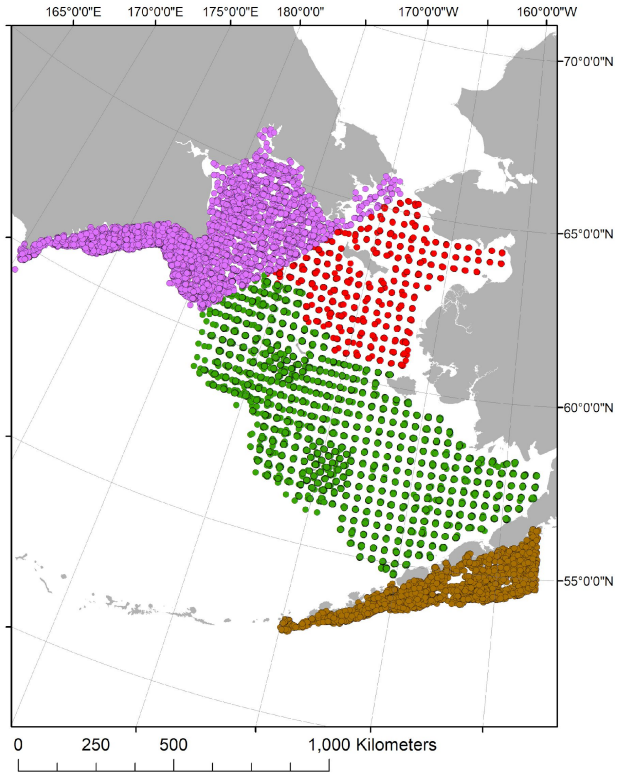
Western Bering Sea catch increase

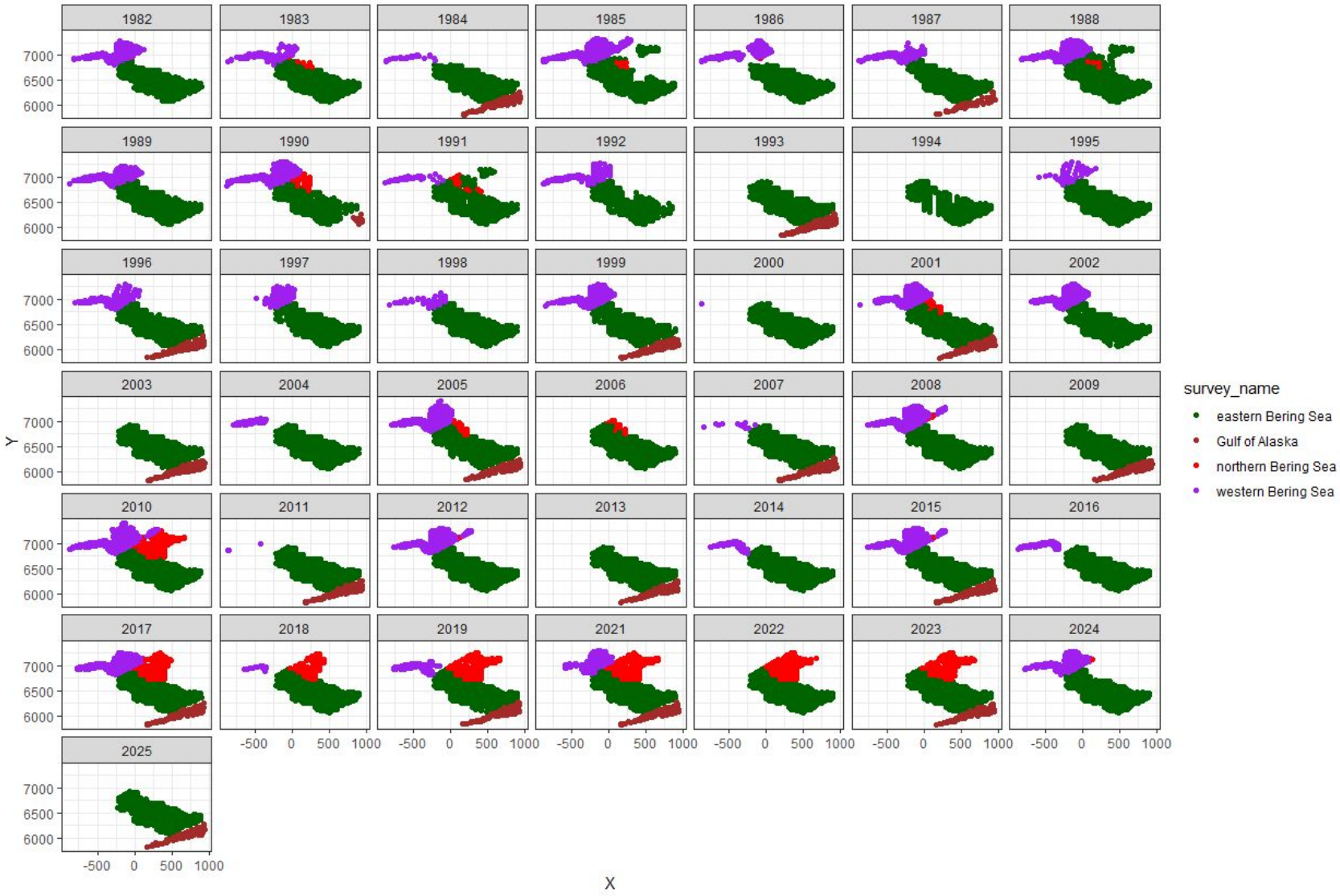
- Western Bering Sea Pacific cod catch has increased substantially in the last 5 years.
- From 1990-2016 WBS catch average ~27,600t (13.1% of the total Bering Sea catch)
- For 2017-2024 WBS catch averaged 68,700 t (28.9% of the total Bering Sea catch) with a peak catch of 106,200 t in 2020



Western Bering Sea Survey Data

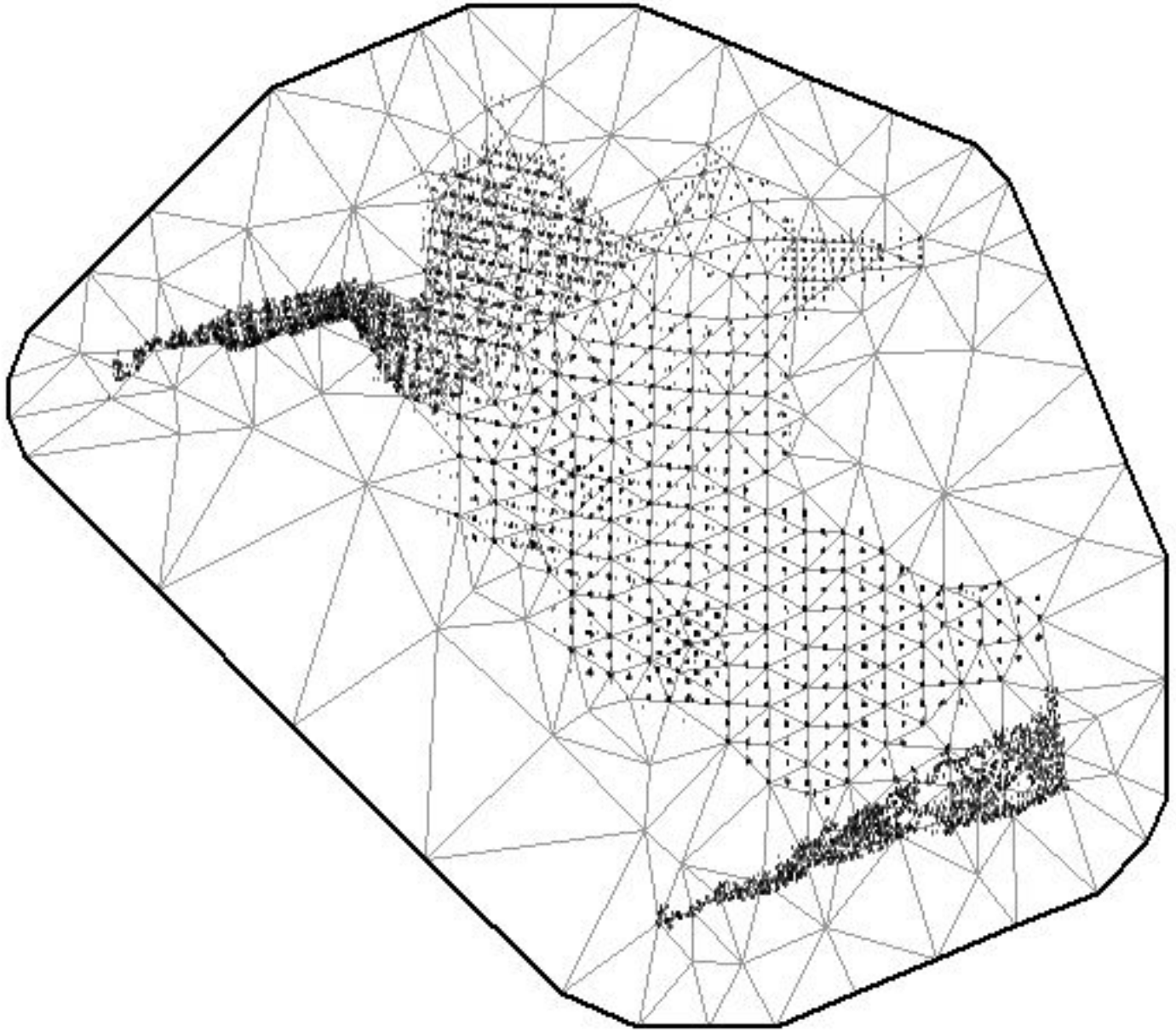
- 1982-2024
- 34 unique vessels





sdmTMB indices

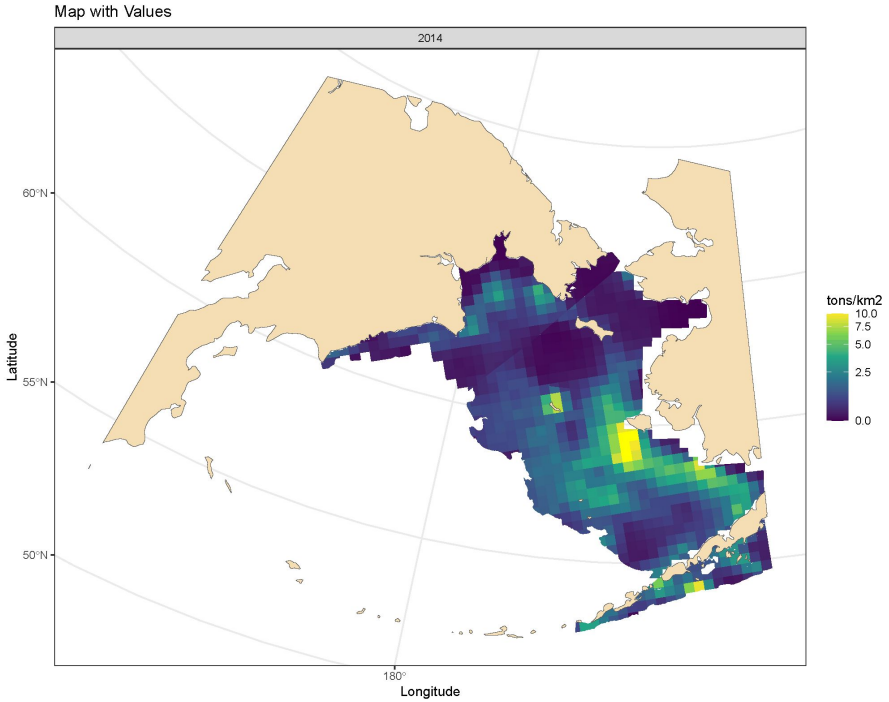
- sdmTMB was used to develop biomass indices using all available survey data
  - Two indices examined
    - W/ WBS survey data
    - Without WBS survey data
  - Tweedie distribution assumed (11% zeros)
  - Barrier mesh with 300 nodes
  - Year, nation, and splined depth by nation as fixed effects
  - Cold pool and survey name as spatial effects
  - Assumed anisotropic

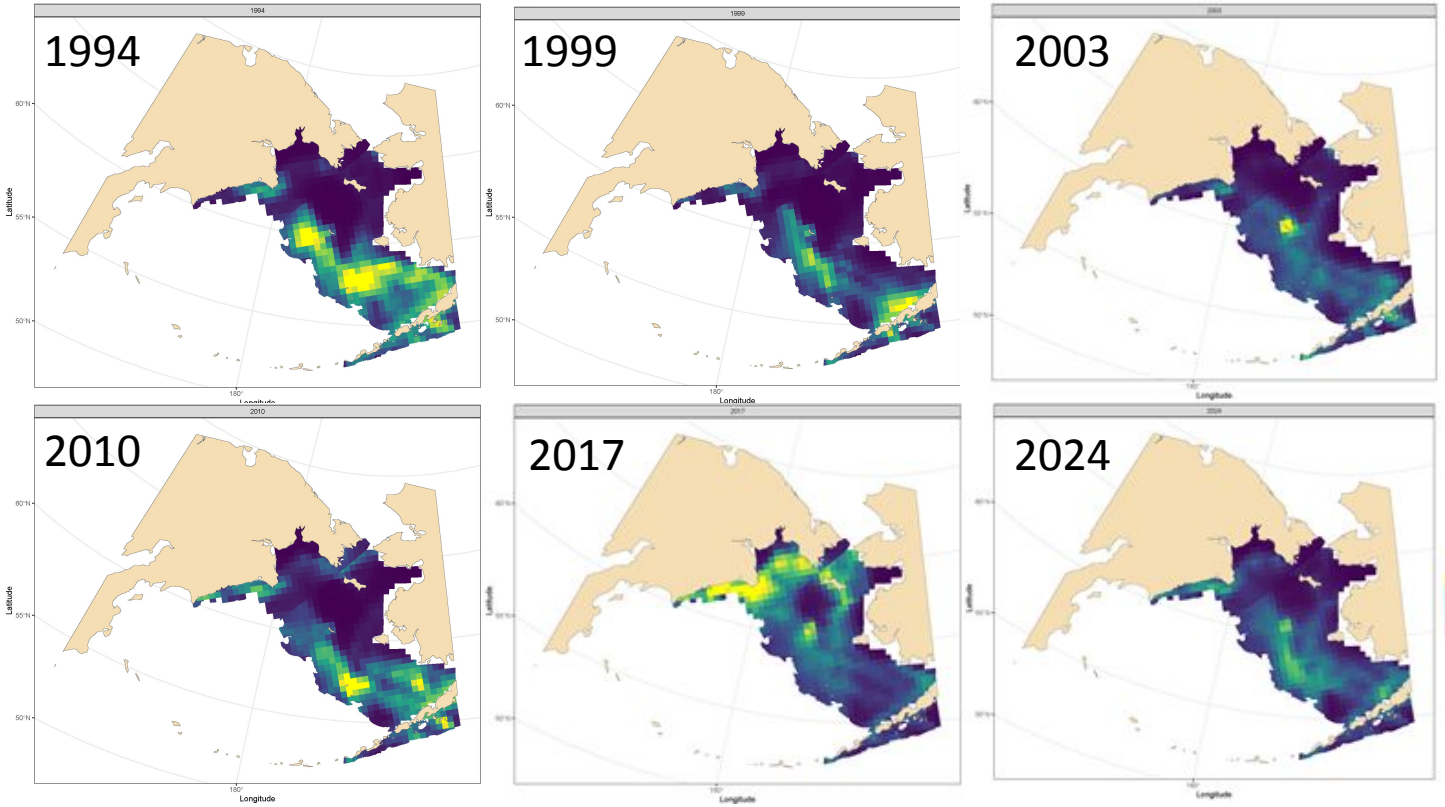


sdmTMB indices

Density plots (t/km2) of Pacific cod distribution for 1994, 1999, 2003, 2010, 2017, and 2024 from the sdmTMB projection with WBS survey data from the western Bering Sea

2014



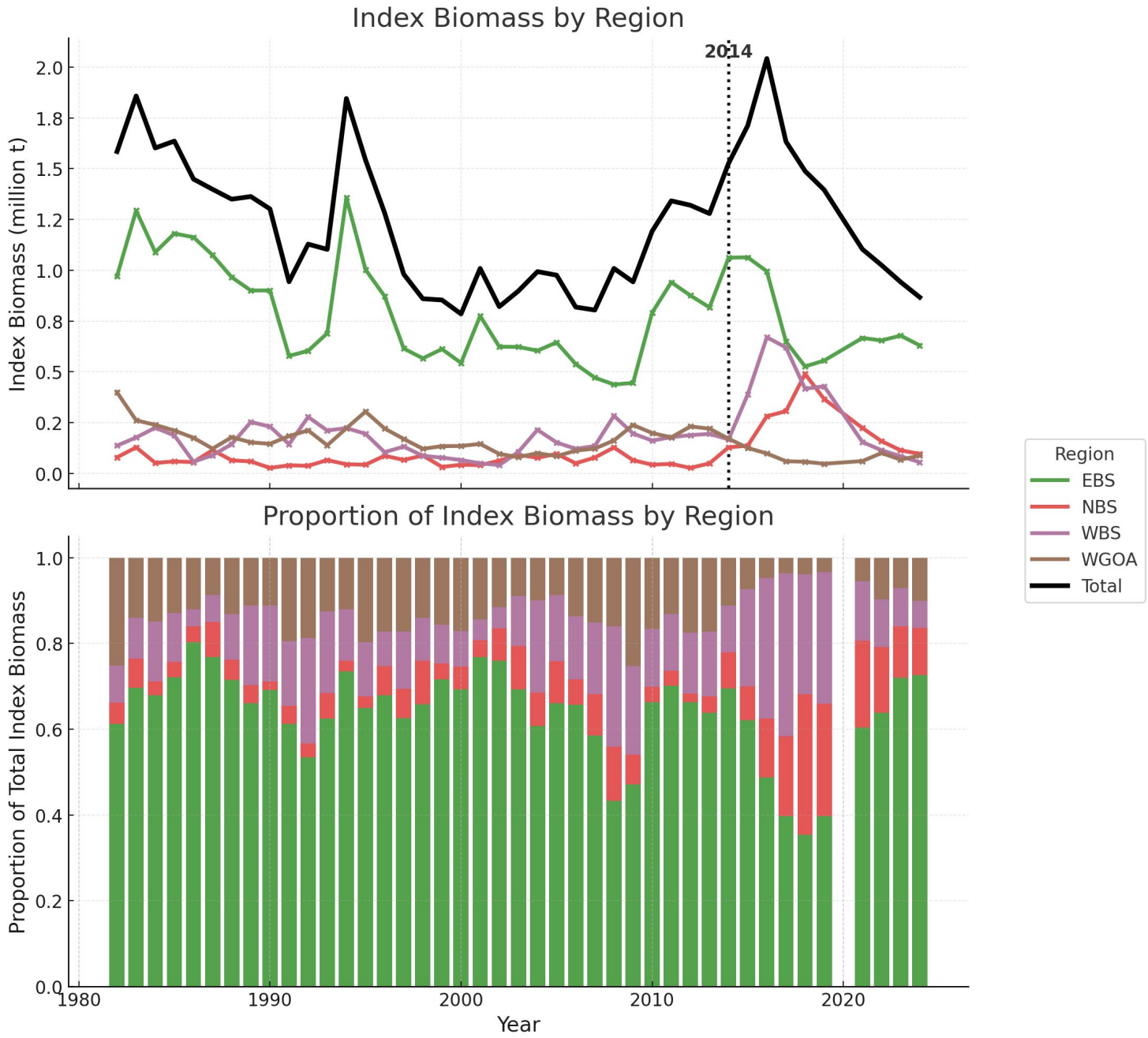


sdmTMB indices

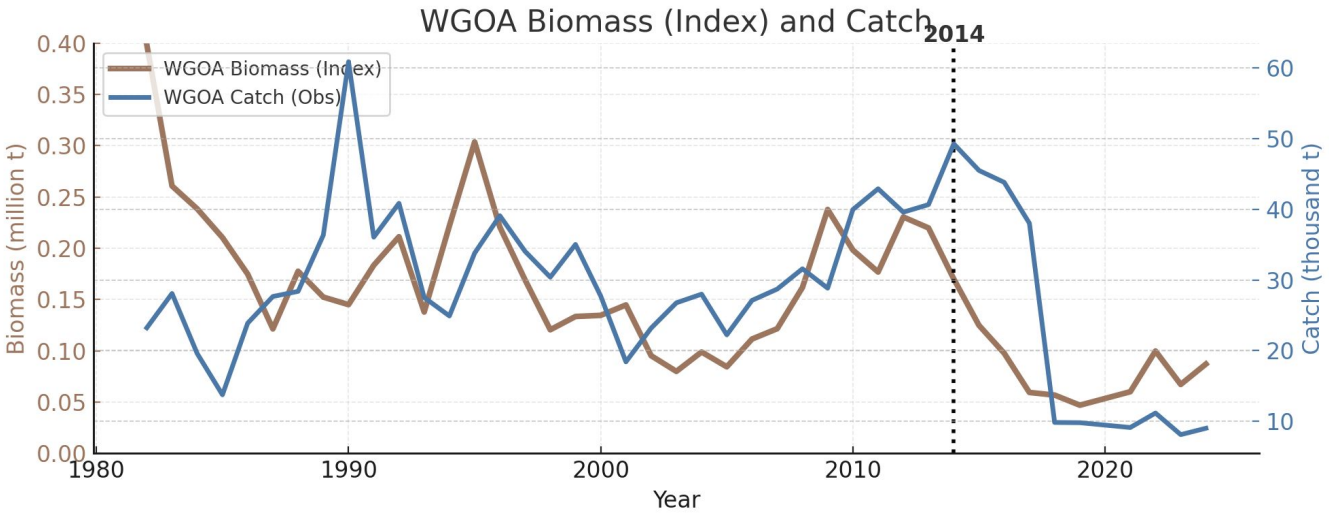
- Comparison of with and without western Bering Sea data
  - Very similar fits for EBS and wGOA with and without WBS data
  - NBS estimates in general slightly lower with WBS survey data included except for 2005-2009
- Overall similar peaks and valleys
  - Sharp increase and fall in NBS and WBS biomass from 2014-2024

sdmTMB indices

- Shift in biomass distribution to WBS and NBS post-2014
- The average proportion of biomass in the WBS compared to the all areas for 1982-2014 was 13.3%
- For 2015-2019 that proportion rose to 30.4%
- For 2024 the WBS share of biomass has dropped to 6.3%
- Although an increase in NBS biomass started prior to the WBS increase, it peaked in 2018, two years after the WBS.

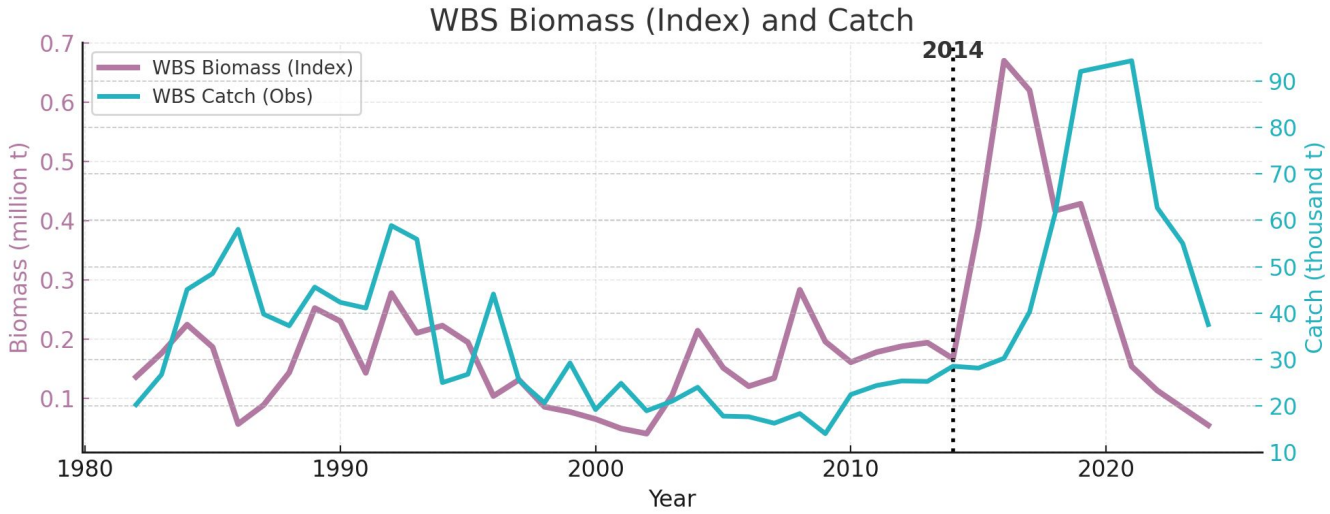


WGOA and WBS Pacific cod Biomass and Catch dynamics



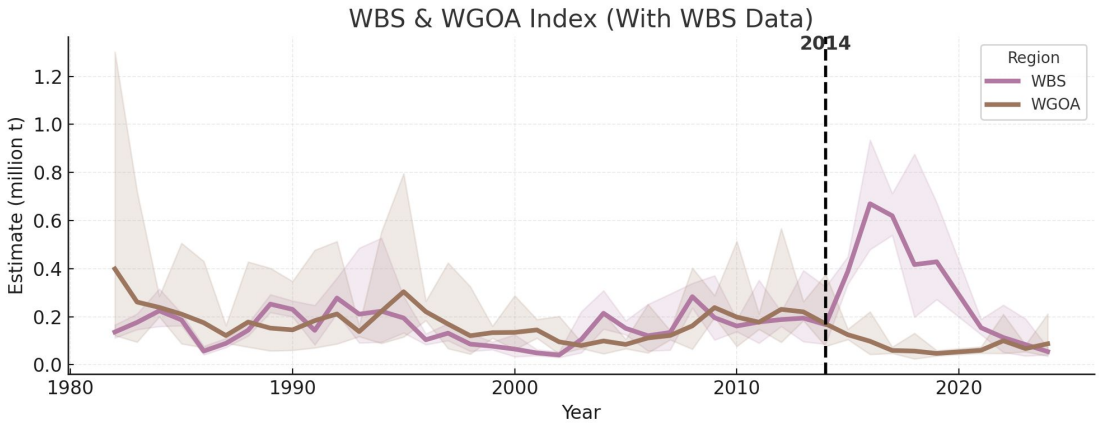
- WGOA catch continued to be high during the collapse, then dropped quickly.

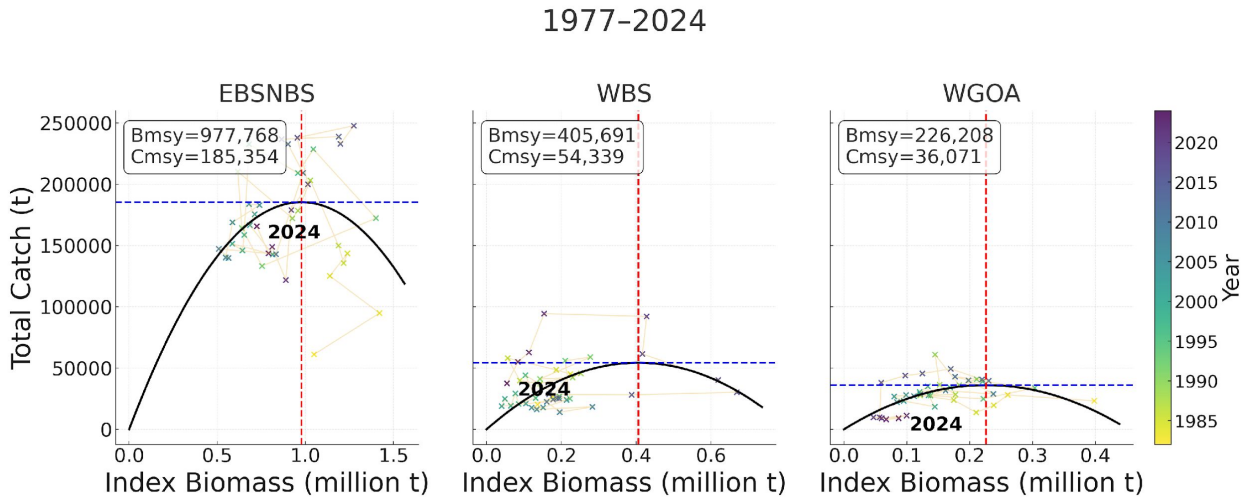
- WBS catch appears to have missed the biomass peak and were high as the stock biomass dropped

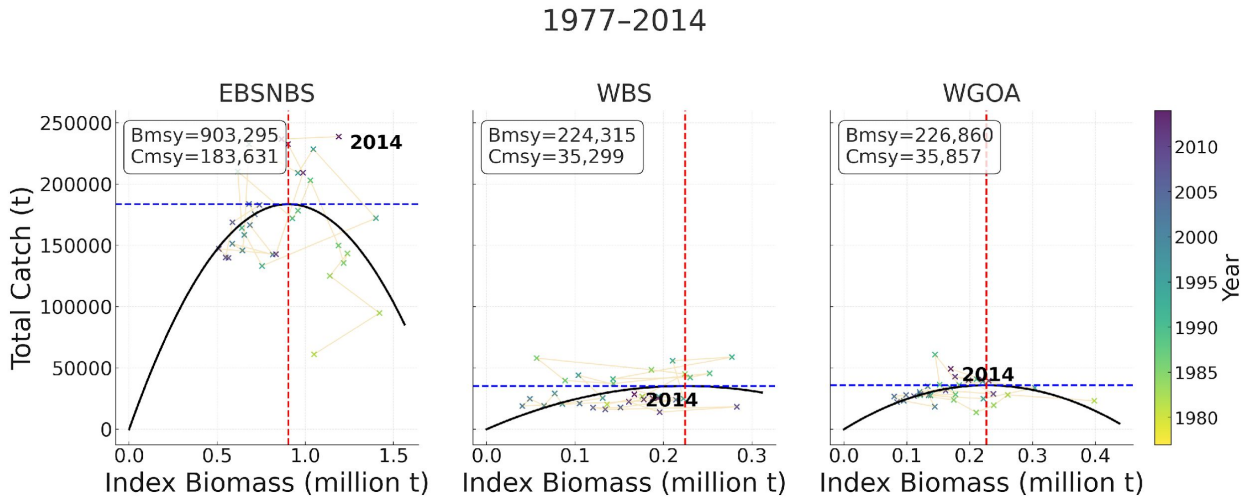


Simple Schaefer Model Fits

- Shows much higher carrying capacity for eastern and northern Bering Sea compared to the other two regions
- Substantial change in estimated MSY for the WBS when including 2015-2024 data.

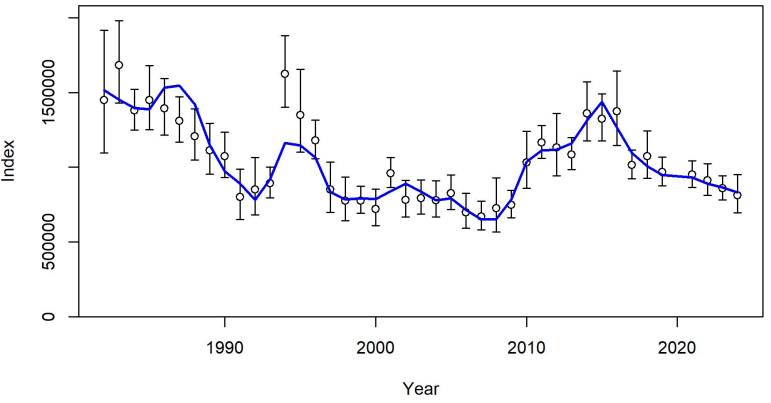


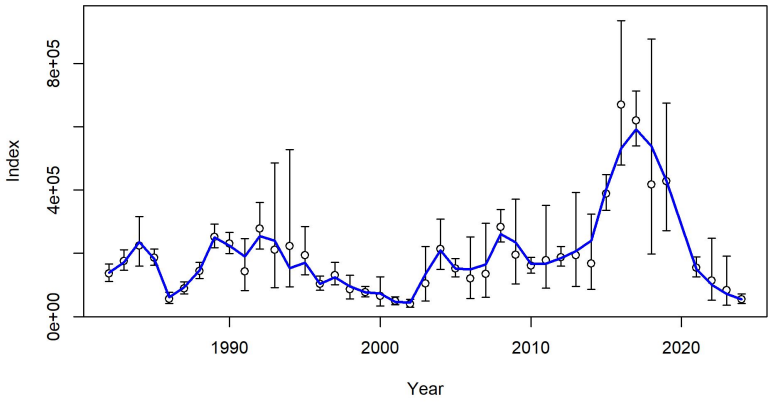


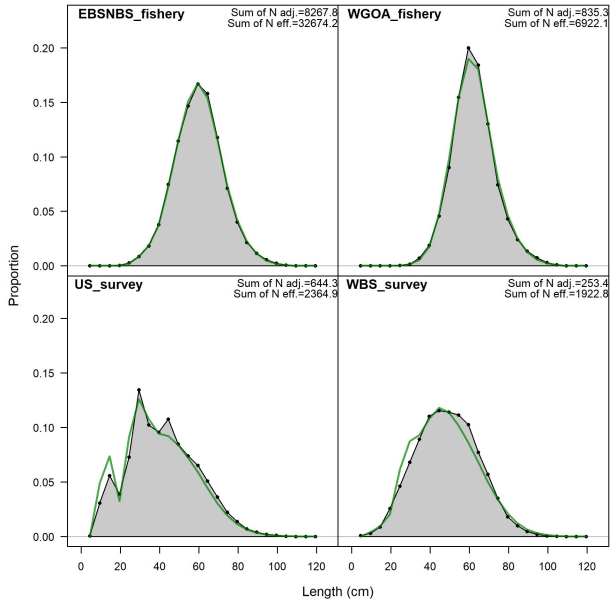


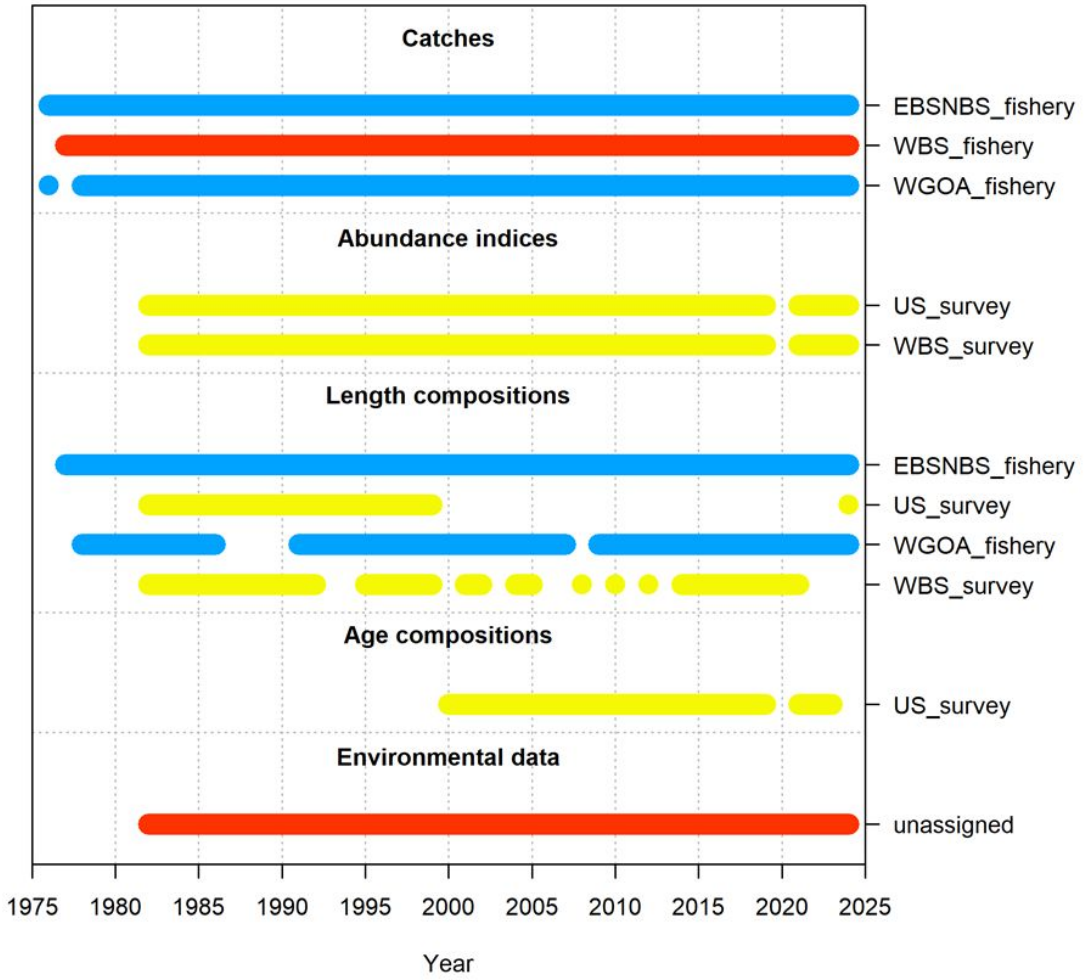
Model

- Exploratory movement model
  - Two areas
    - Area 1 = EBS,NBS, and WGOA
    - Area 2 = WBS
  - Three fisheries
    - EBS+NBS
    - Western Gulf of Alaska
    - Western Bering Sea
  - sdmTMB biomass indices used





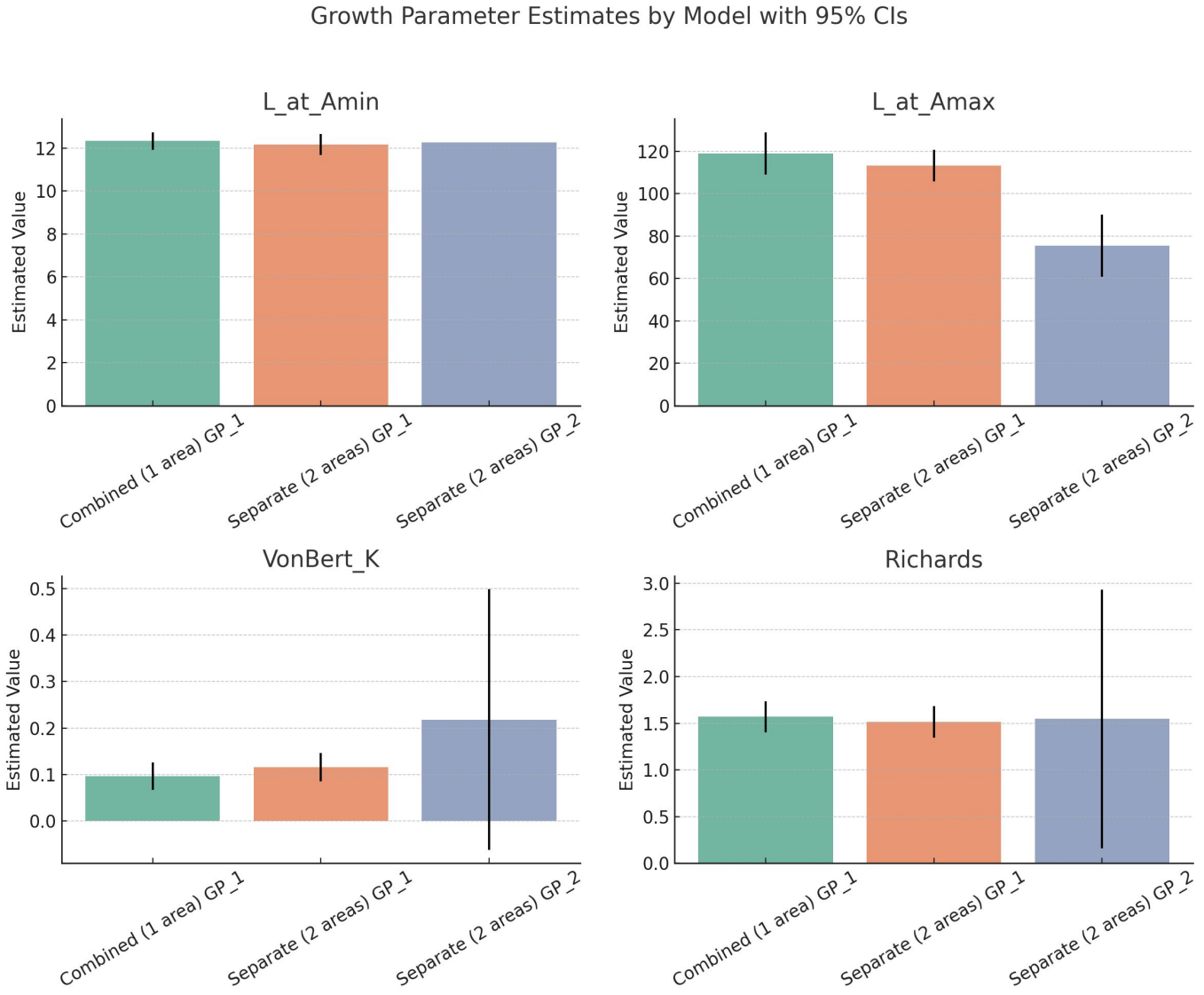




These results are preliminary and should not be considered for management purposes

Stock Synthesis Model: Growth

- No age data available for western Bering Sea
  - Highly uncertain growth for WBS
    - Results in highly uncertain recruitment estimates
    - Results in highly uncertain movement rates

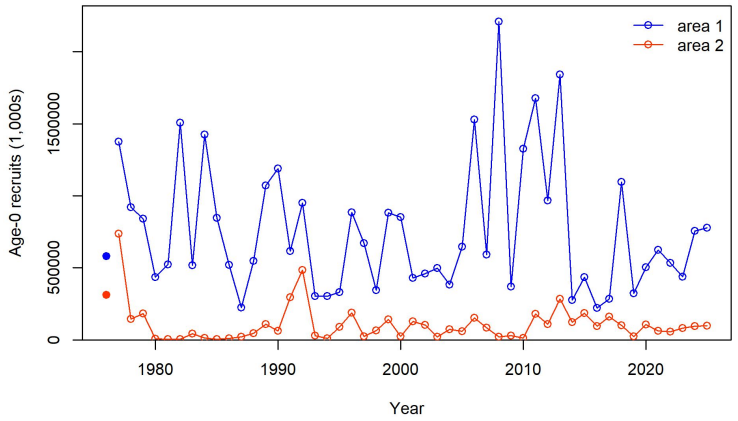


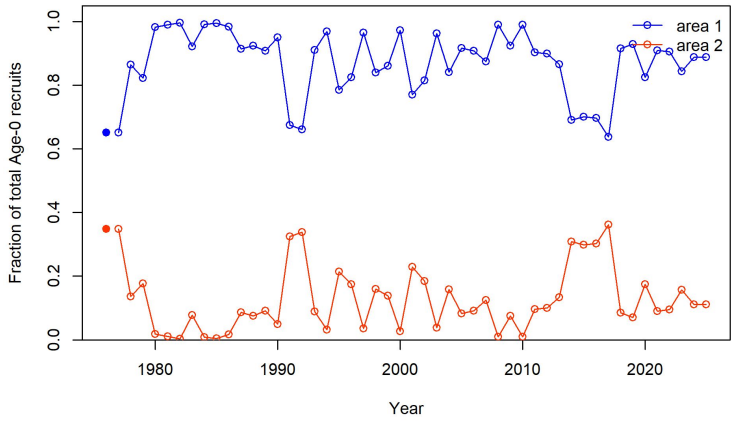
These results are preliminary and should not be considered for management purposes

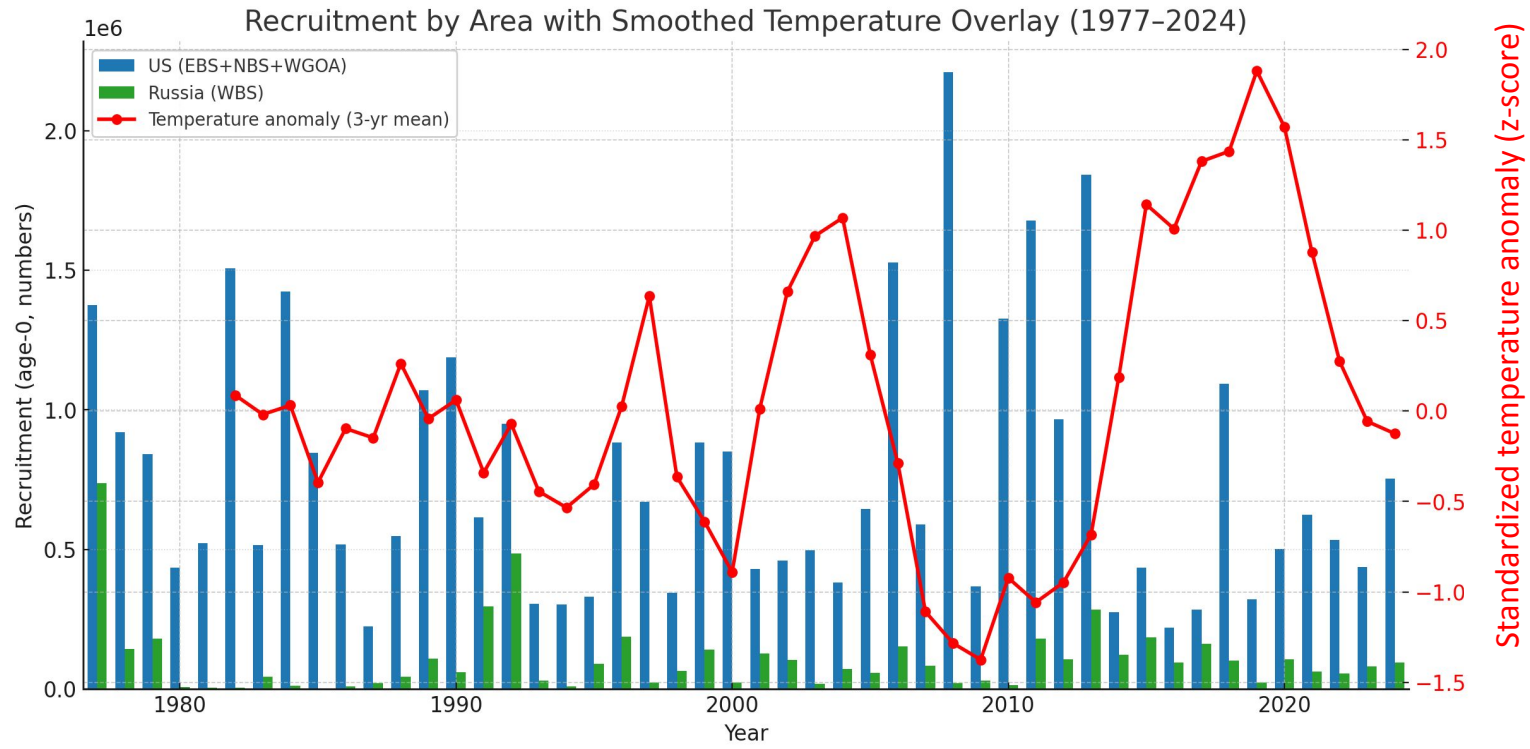
Stock Synthesis Model: Recruitment

- Majority of recruitment estimated originating in U.S. regions
  - caveat – recruitment proportion is highly uncertain due to lack of age data from WBS
- Higher recruitment during cold periods consistent with 2024 stock assessment

These results are preliminary and should not be considered for management purposes



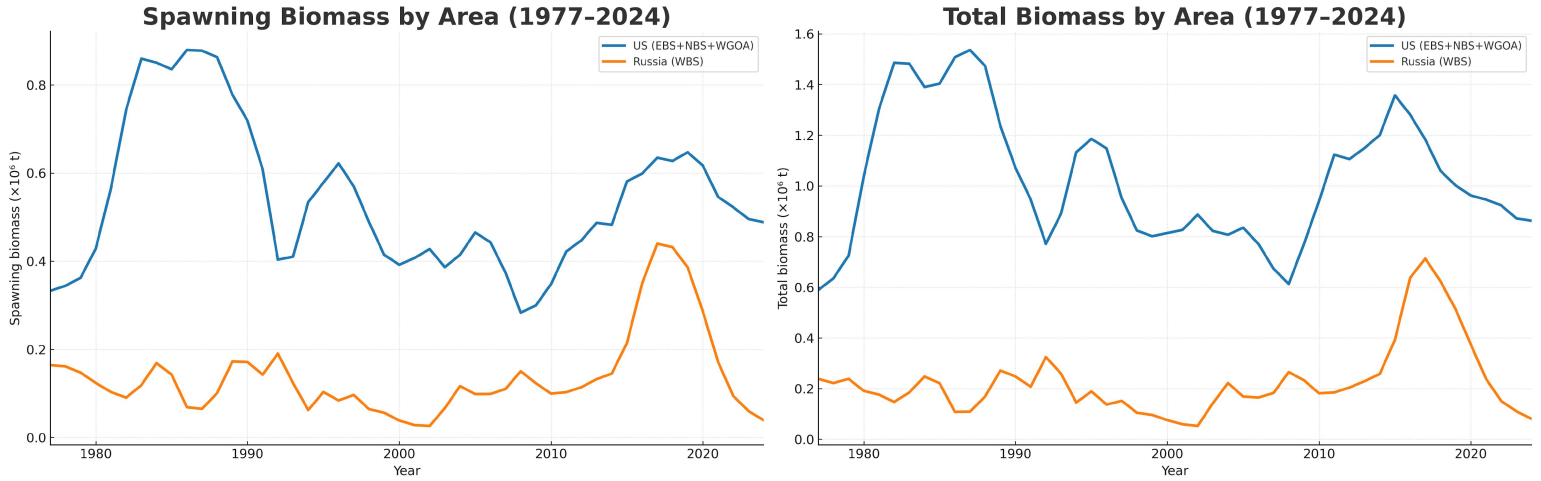


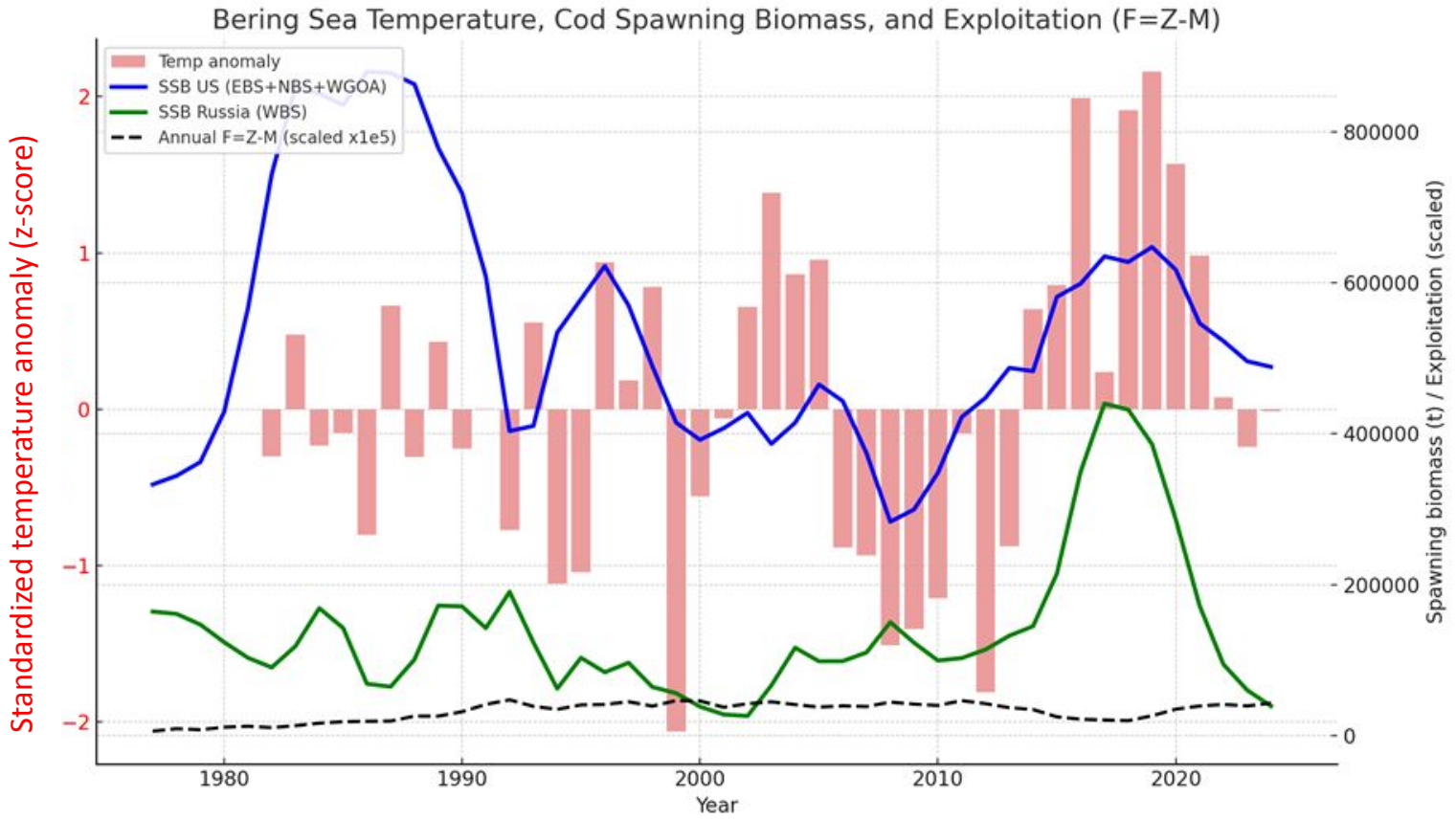


Stock Synthesis Model: Biomass

- Same trend between sdmTMB indices and model estimates for spawning and total biomass
  - Q = 1.0 for both indices
- Higher spawning biomass in warm period followed higher recruitment during cold periods

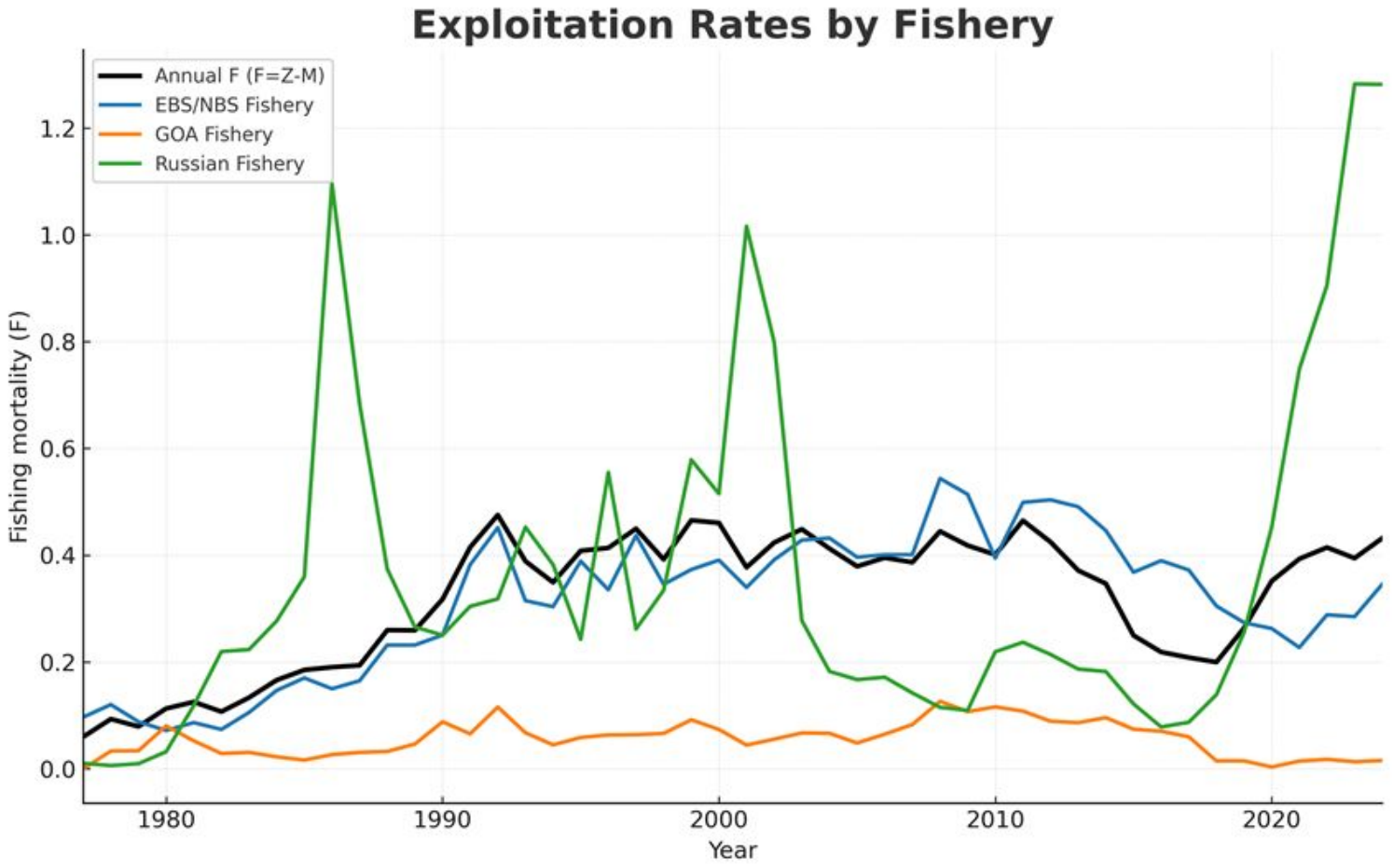
These results are preliminary and should not be considered for management purposes





Stock Synthesis Model: Exploitation

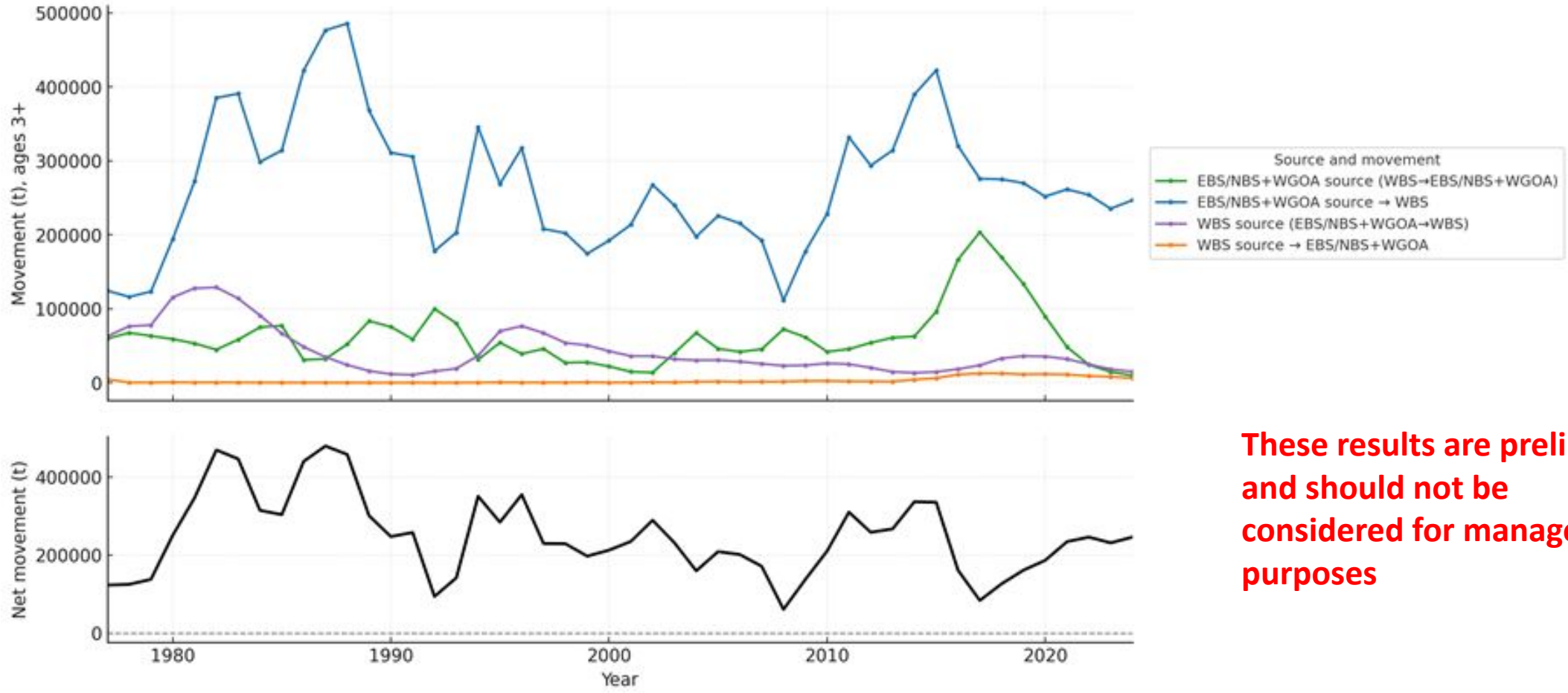
- Exploitation rates were stable in U.S. regions under modern management but more variable in the WBS, where catches appear strongly influenced by immigration from U.S. regions.



These results are preliminary and should not be considered for management purposes

Stock Synthesis Model: Movement

- In this model configuration, with poorly fit growth, U.S. region is a source with the WBS being a sink with the net movement to the WBS from the U.S. zone.



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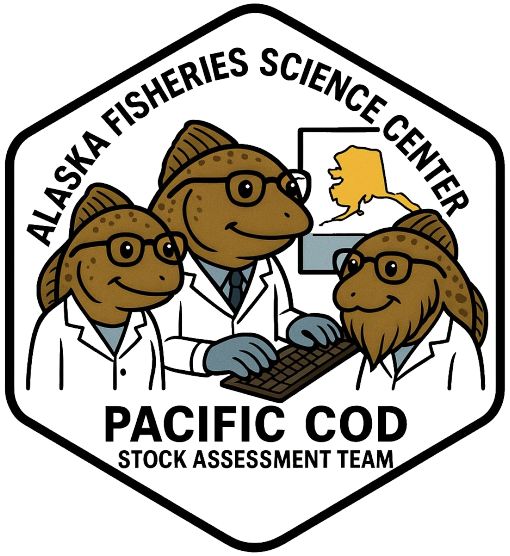
Next Steps



- **General research**
  - Team
    - Attempt to obtain fishery composition and age data for the western Bering Sea
    - evaluate alternative assessment modeling platforms (RCEATTLE, SPoRC, RTMB)
    - Continue to evaluate utility of archived traditional tagging data for spatial modeling and movement
  - Lorenzo Cianelli (OSU) – evaluation of fishery and survey data to ascertain appropriate stock splits for GOA Pacific cod
  - Krista Oke (UAF) – develop a starvation index that will be tested as an environmental-link on time-varying natural mortality in the GOA Pacific cod stock assessment model
- **Tagging**
  - Julie Nielsen et al. (Kingfisher Marine Research) – Unimak Pass Acoustic Array
- **Genetics**
  - Jim Armstrong (FLC) – Linking spawning location of origin to fishery catch using a GT-seq panel
- **Spatial modelling**
  - Stock Synthesis – Team
    - Continue development of alternative spatial models
    - Test sensitivity of two-area model to assumptions on WBS growth
    - Assess risks of not including WBS in our assessments
    - Expand to 3 area model separating wGOA into its own area
  - SPoRC – Matt Cheng (UAF)
    - Stochastic Population model over Regional Components: a generalized, spatial, age/sex-structured stock-assessment framework implemented as an R/RTMB package
    - Create a spatial model for GOA/EBS Pacific cod to explore stock dynamics and environmental forcing of movement and mortality.