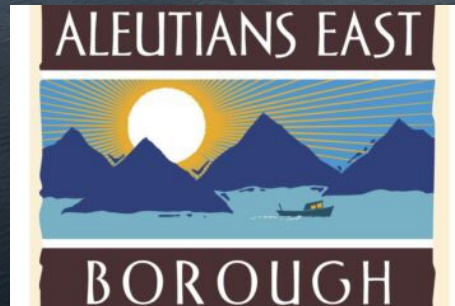


Pacific cod satellite tagging research in Alaska

Susanne McDermott¹, Julie Nielsen², Charlotte Levy³,
Kimberly Rand⁴, Liz Dawson¹

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





Background

- Seasonal movement of Pacific cod in Alaskan waters is not well understood in many areas
 - Migration timing, extent, pathways
 - Proportion of population that migrates
- Warming Ocean conditions are changing 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?



Why do we care?

- Seasonal movement across management boundaries
 - Fish are assessed during summer AFSC survey
 - Winter fishery might harvest fish attributed to different management areas
- Northward movement
 - Fish can move outside of NMFS management area
 - Shifting resources necessitate fleet shifting into areas of historically low fishing effort in NBS
 - Northward shift of Pacific cod resource in the summer makes fishing in SEBS more challenging in historic fishing grounds

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

PSATs

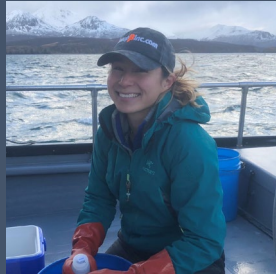
- Fishery independent locations
- Detailed information on migrations
- Information on fish behavior



The Pacific Cod Tagging (PACT) Team



Susanne McDermott
NOAA AFSC



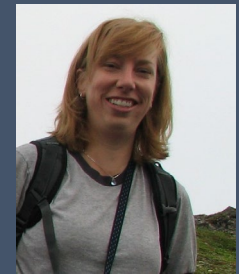
Charlotte Levy
Aleutians East Borough



Julie Nielsen
Kingfisher Marine
Research



Liz Dawson
NOAA AFSC



Kim Rand
Lynker
Technologies



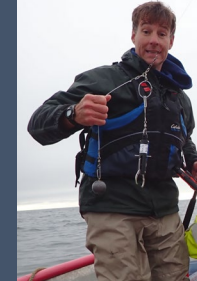
Bianca Prohaska
NOAA AFSC



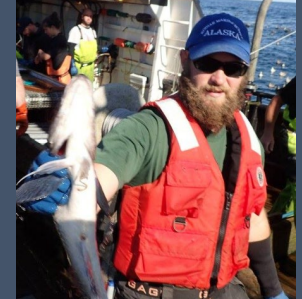
Steve Barbeaux
NOAA AFSC



Ingrid Spies
NOAA AFSC



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



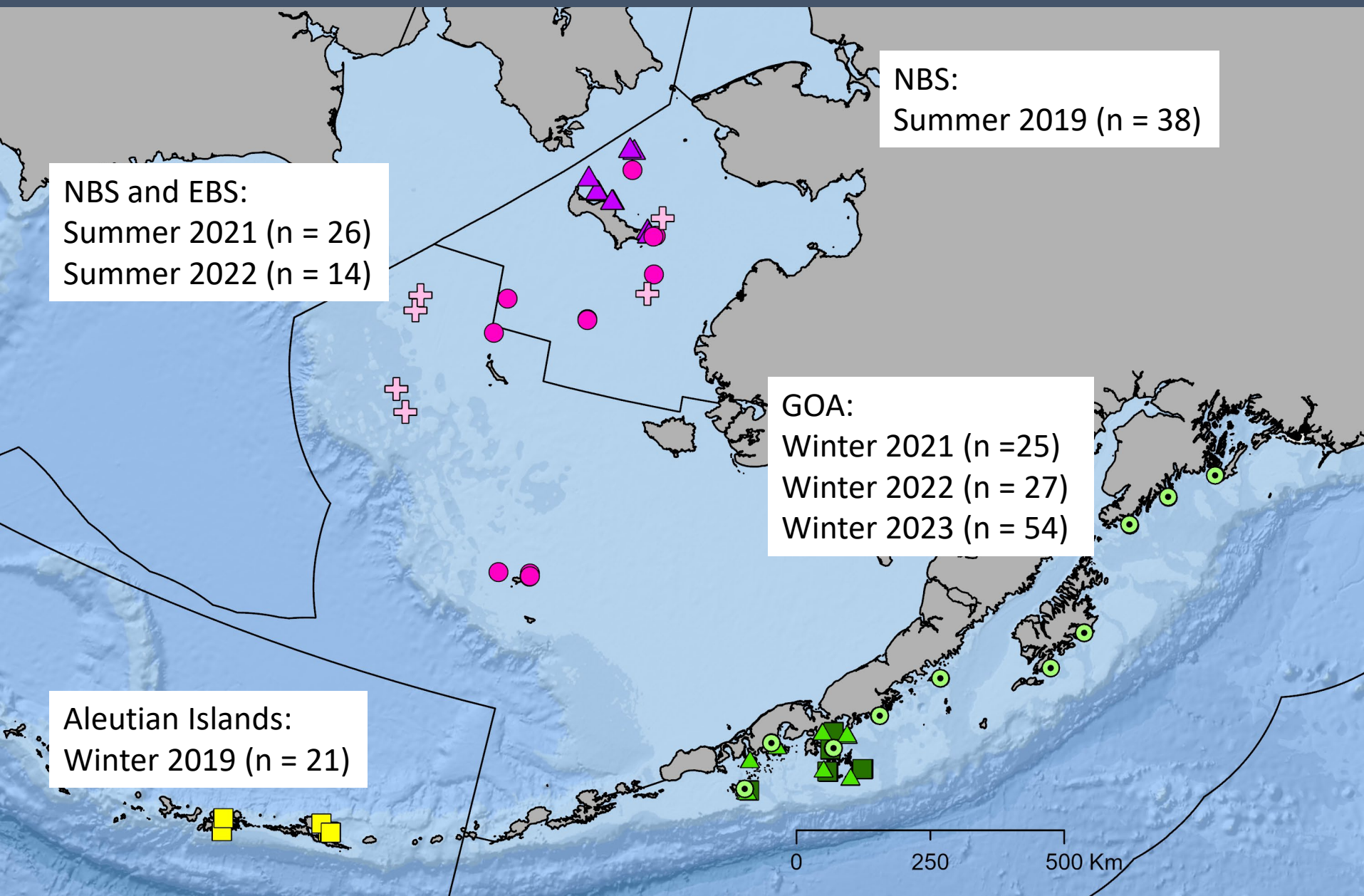
PACT Highest Research Priorities

- Seasonal connectivity between management areas
 - NBS/EBS
 - EBS/GOA
 - Western/Central GOA
- Movement out of managed areas
 - Russia/Arctic
- Investigate nature of northward shift to NBS
 - Effects of warming waters on seasonal shifts in distribution
- Fish activity patterns
 - Diel, seasonal, geographic
 - Relate to diet

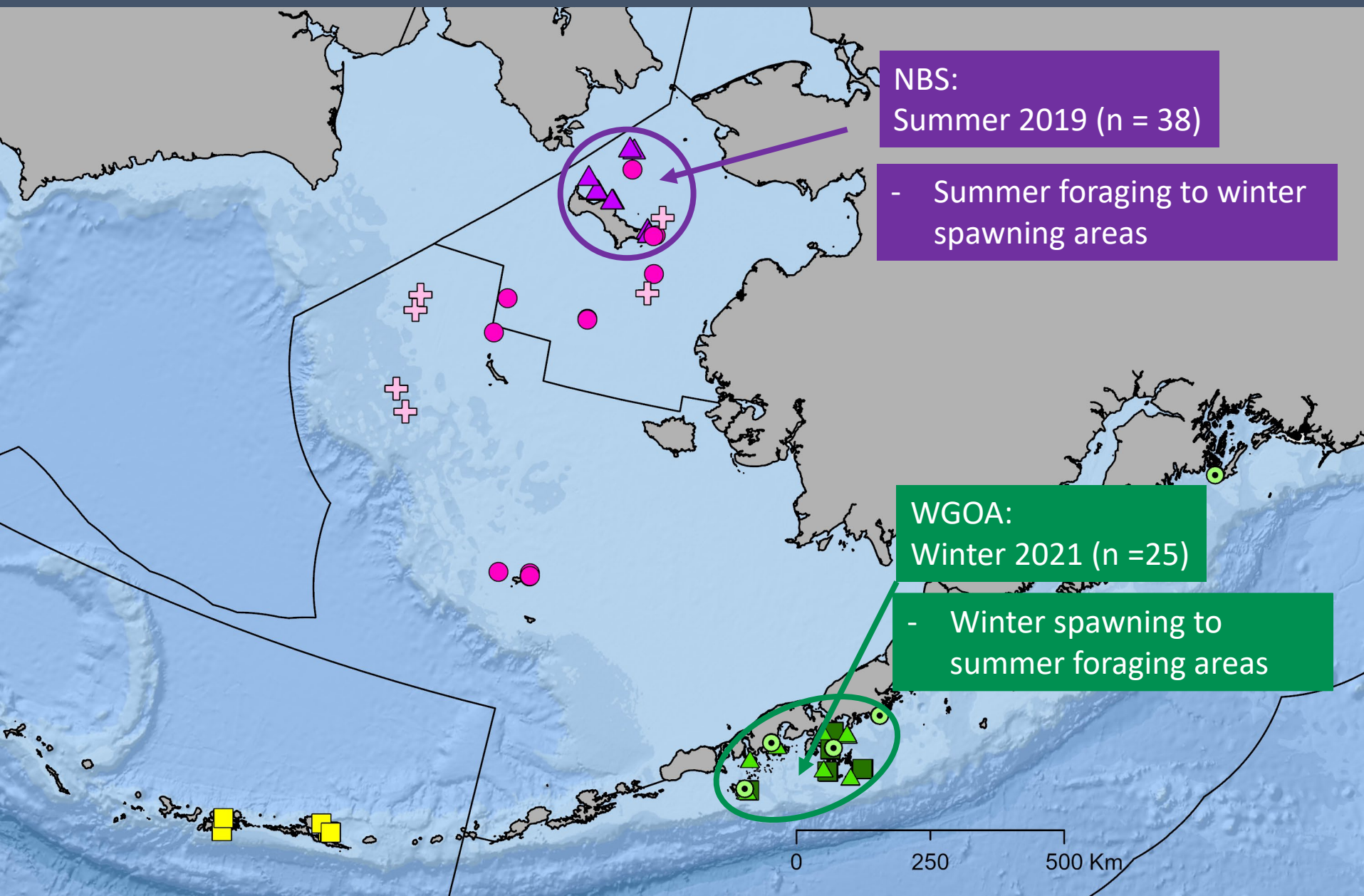
Genetics

Pacific cod PSAT releases to date:

n = 201



Pacific cod seasonal movement examples



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

Hidden Markov model (HMM)

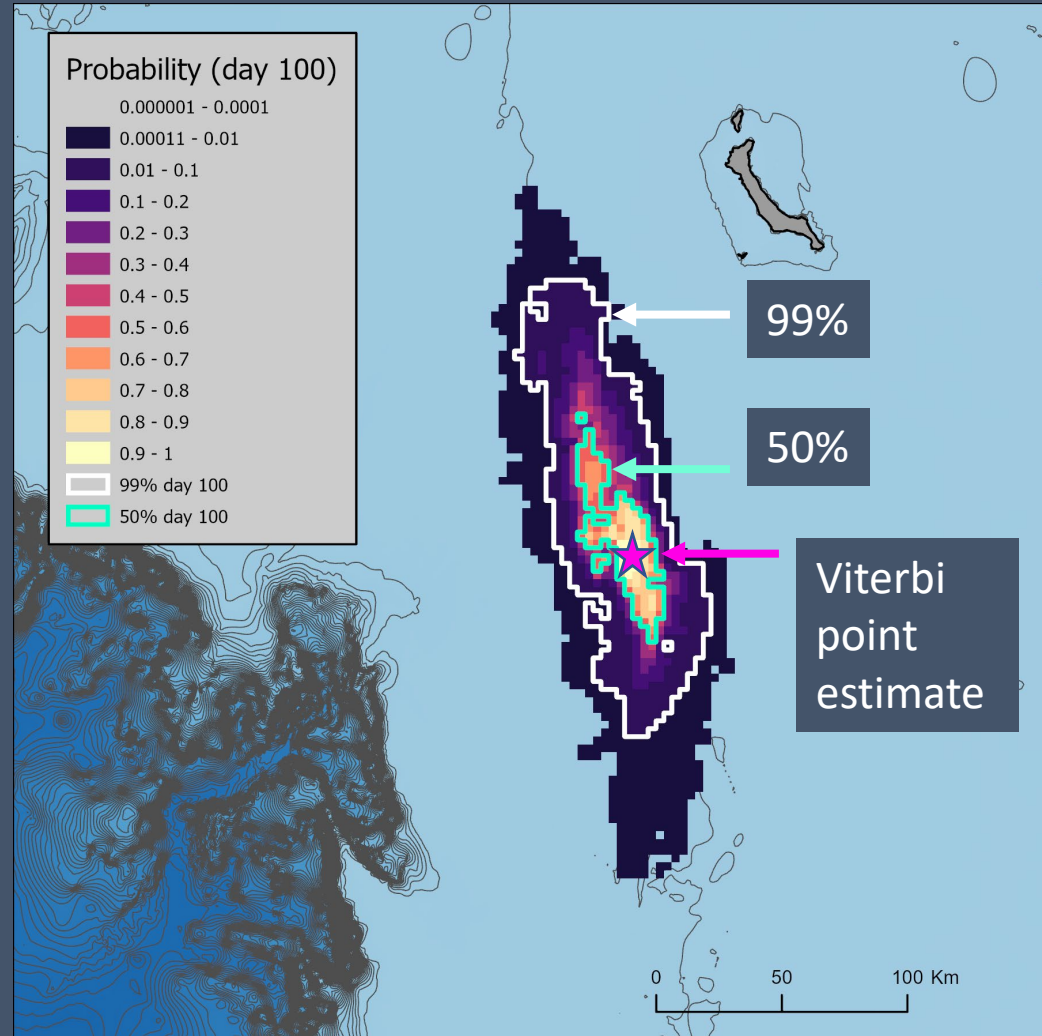
- Developed by Martin Pedersen et al. for Atlantic cod
 - **Pedersen et al., 2008.** Geolocation of North Sea cod (*Gadus morhua*) using hidden Markov models and behavioural switching. Canadian Journal of Fisheries and Aquatic Sciences **65**:2367-2377.
- Adapted for use with Pacific cod in North Pacific Ocean using PSAT data
 - Nielsen et al., in revision. Animal Biotelemetry.
- Probability of location in discrete study grid cells for each day
- Geolocation based on maximum daily depth and light-based longitude collected by PSATs



Geolocation

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



2019 Northern Bering Sea (NBS) capture and tagging

(Summer foraging to winter spawning)

August/September release



NOAA summer survey:

F/V Alaska Knight

F/V Vesteraalen

- Capture by rod and reel
- $n = 30$



Native village of Savoonga:

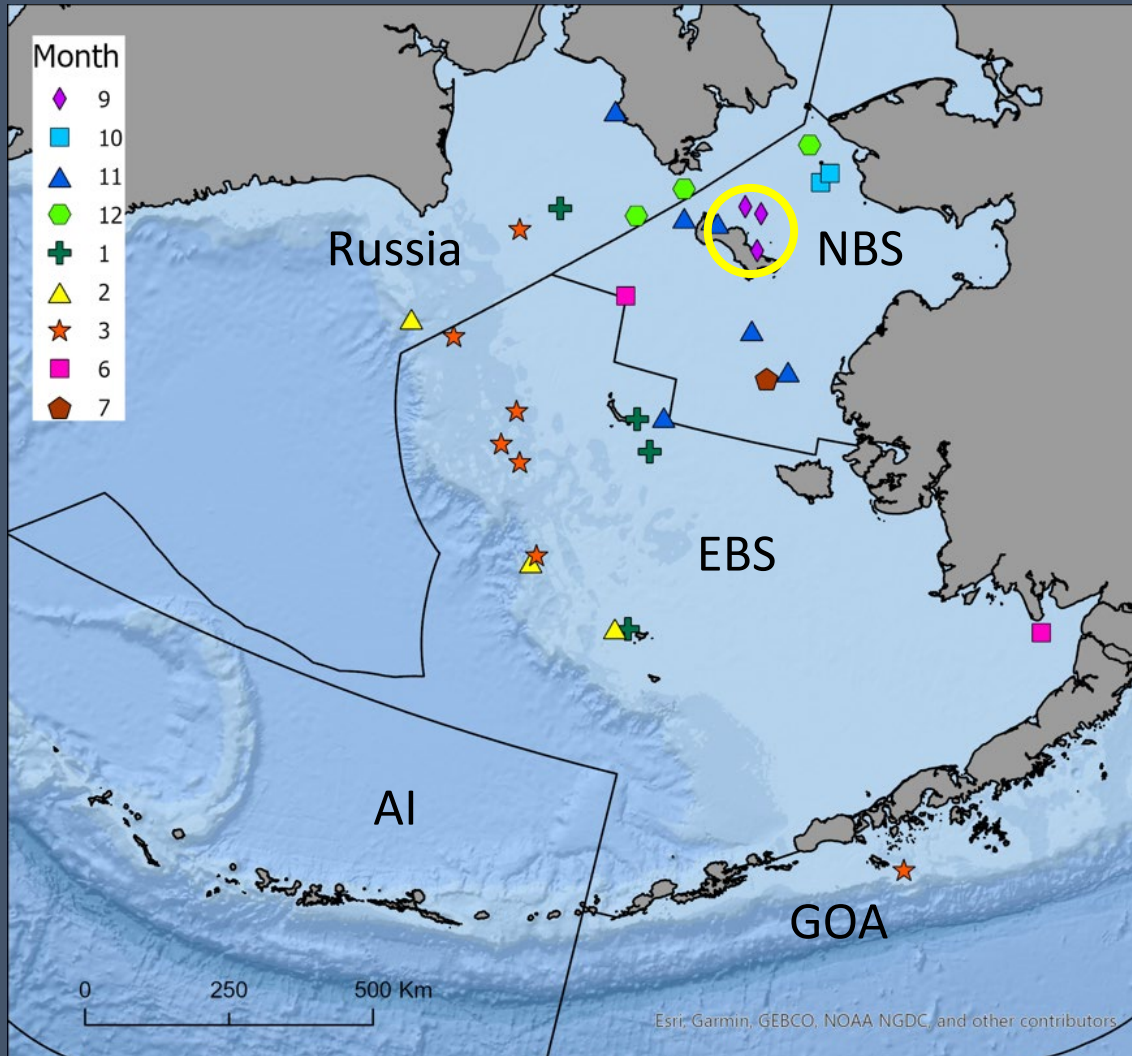
Skiffs launched from shore

- Capture by hand line
- $n = 8$

Average depth = 30 m

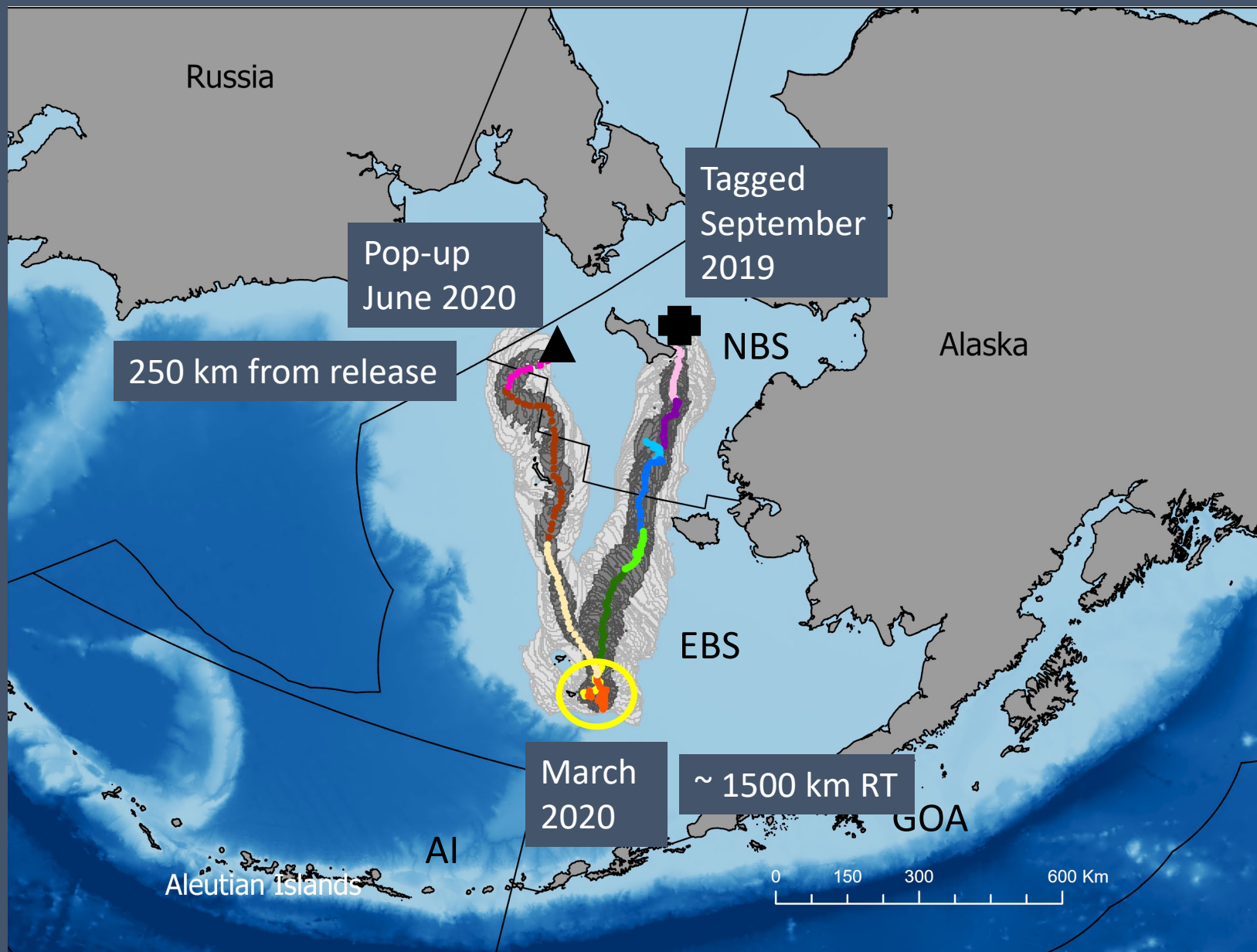
Results: 2019 NBS (summer to winter and annual movement)

Pop-up locations

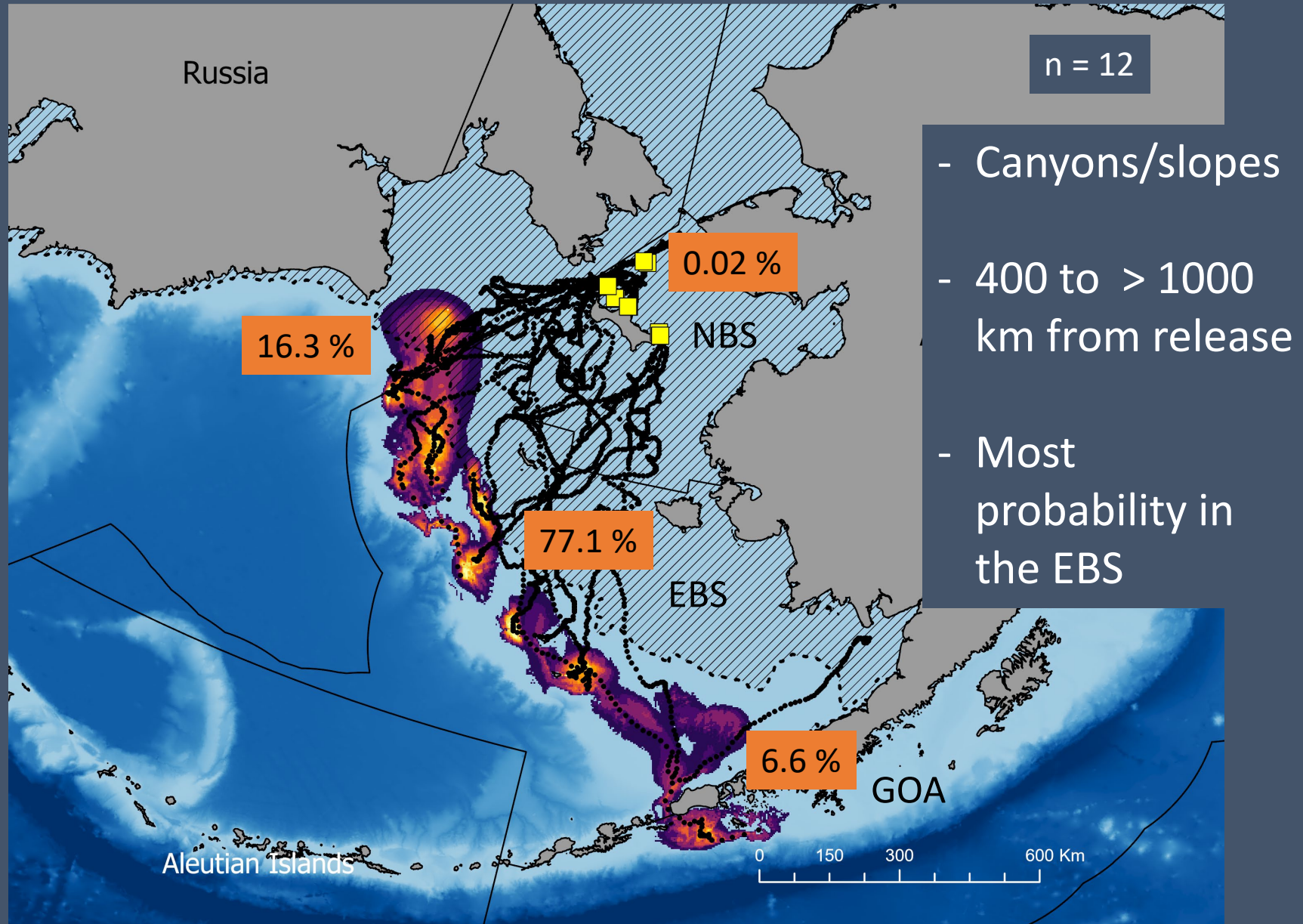


- 33 of 38 tags
- 6 recovered in fishery
- No tagging mortality
- Geolocation for 31 fish

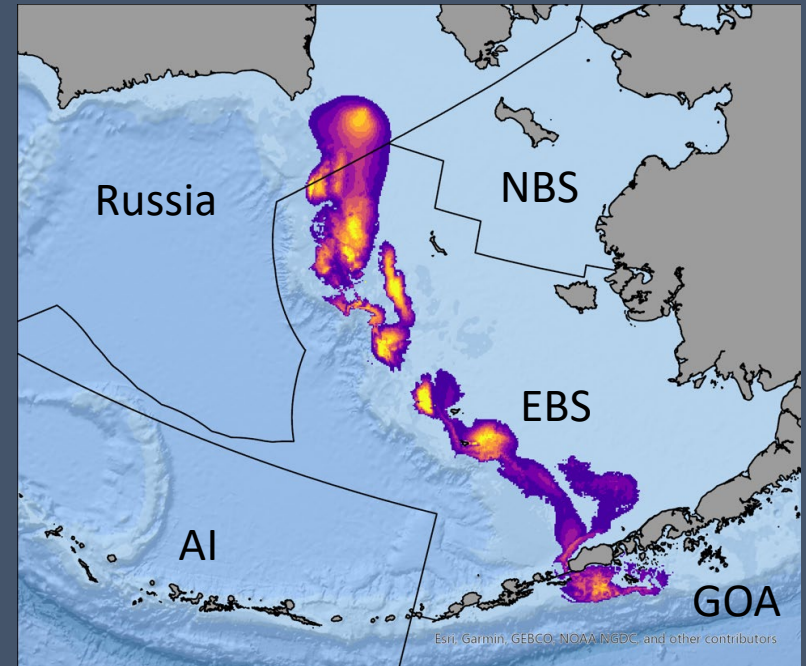
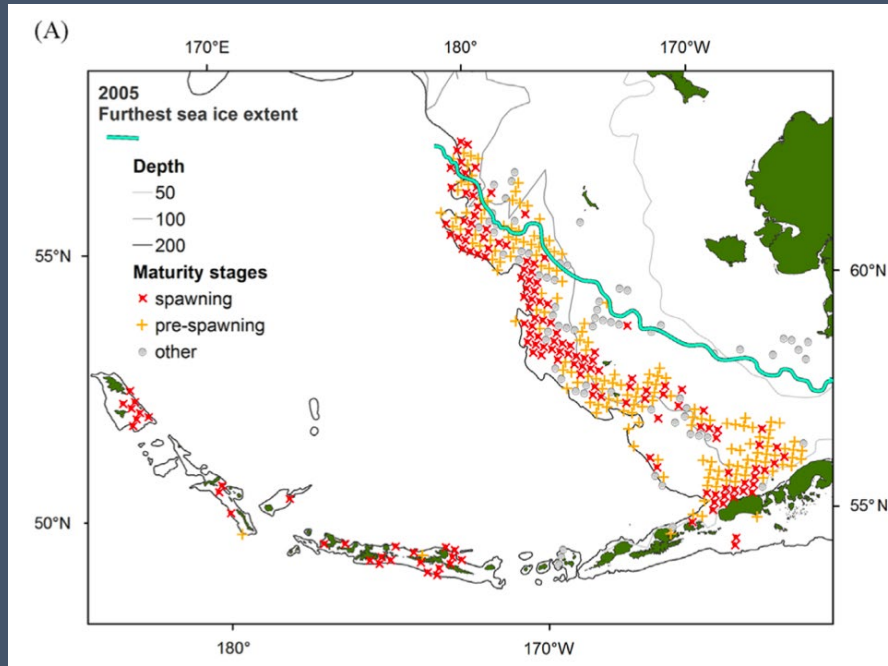
Estimated pathways



Probability during spawning (Feb 14 – March 31)



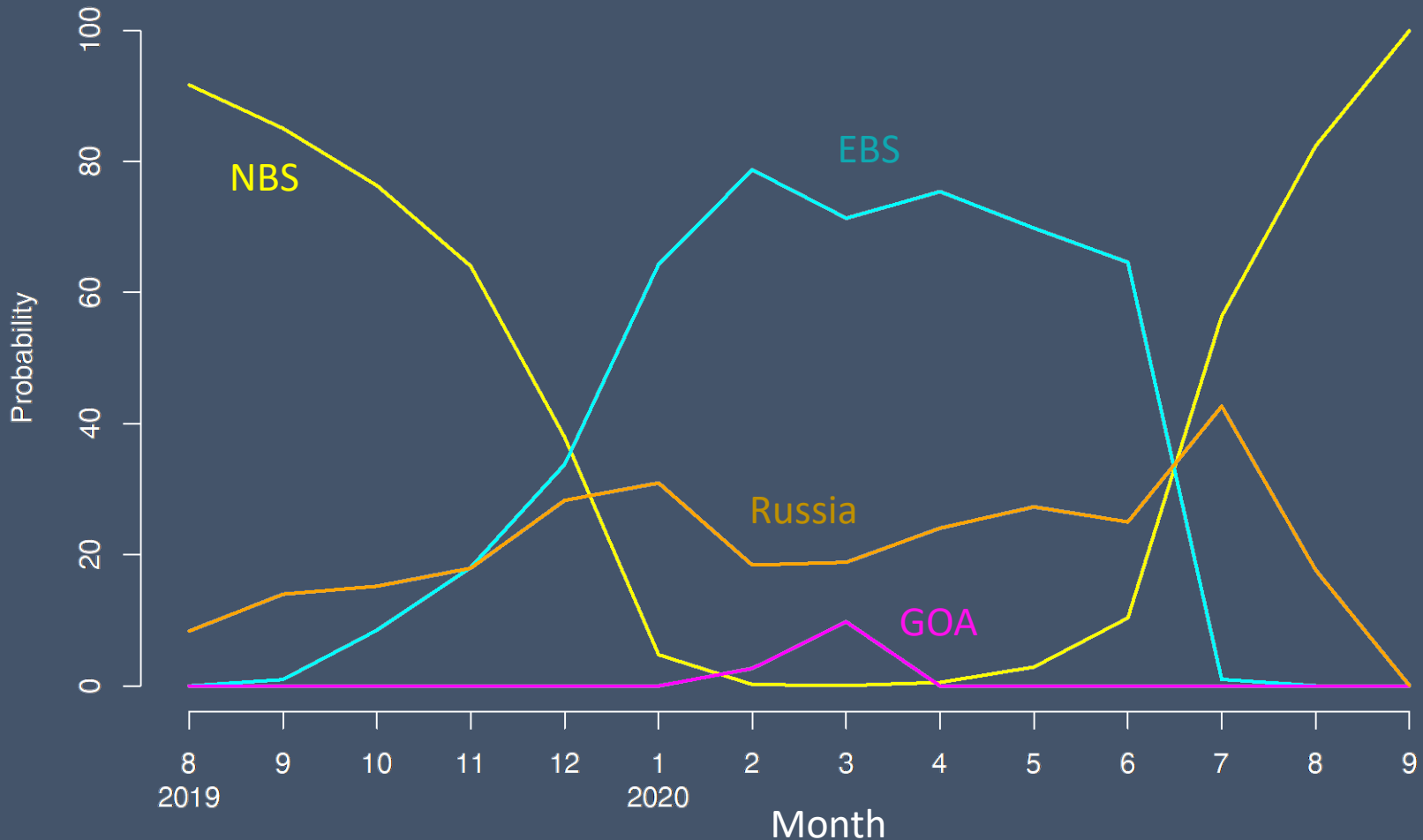
Known spawning locations



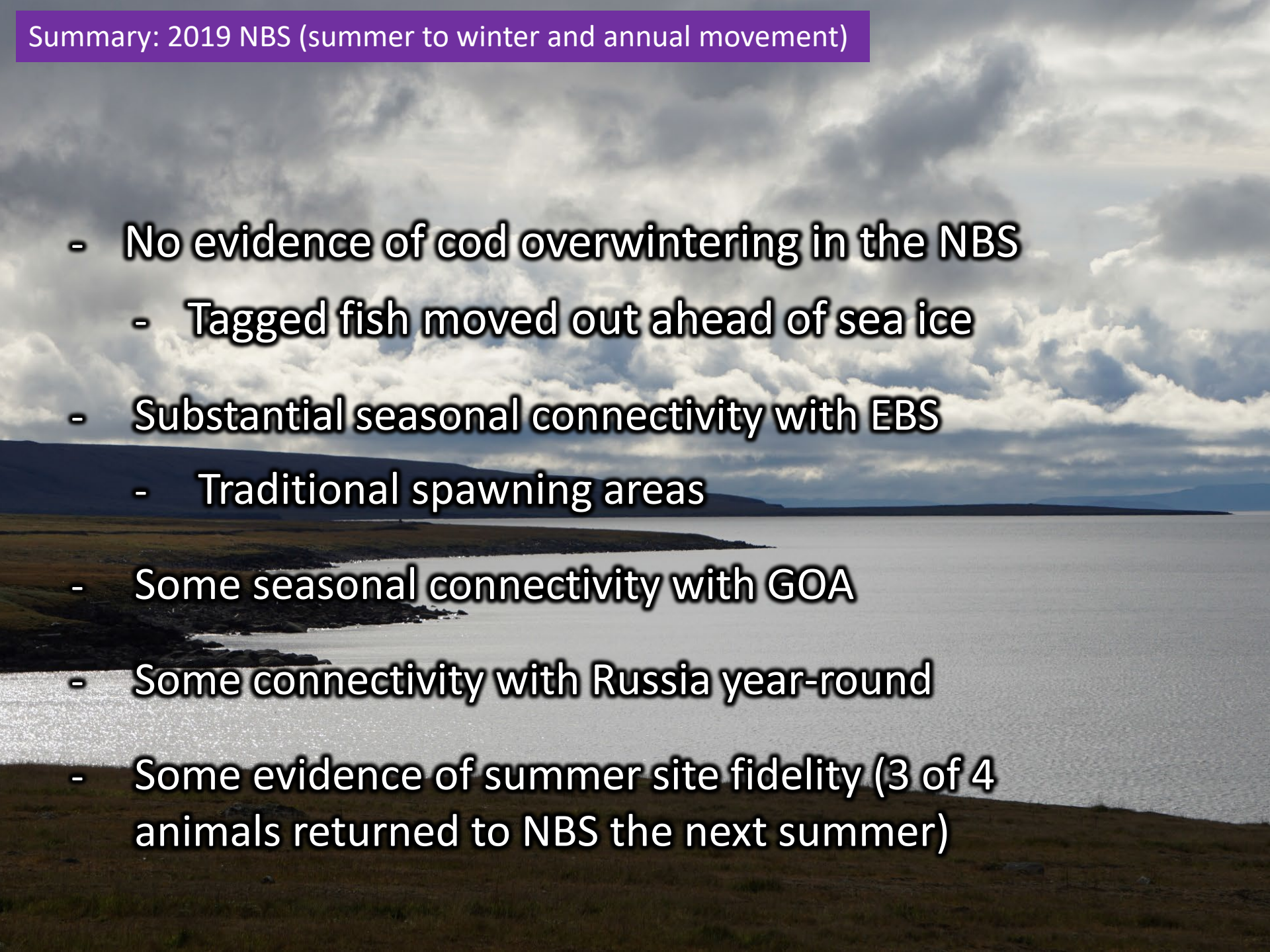
Neidetcher et al., 2014. Spawning phenology and geography of Aleutian Islands and eastern Bering Sea Pacific cod (*Gadus macrocephalus*). Deep Sea Research.

Monthly probability by region

tags: 24 31 29 27 20 17 12 10 3 3 3 1 1 1



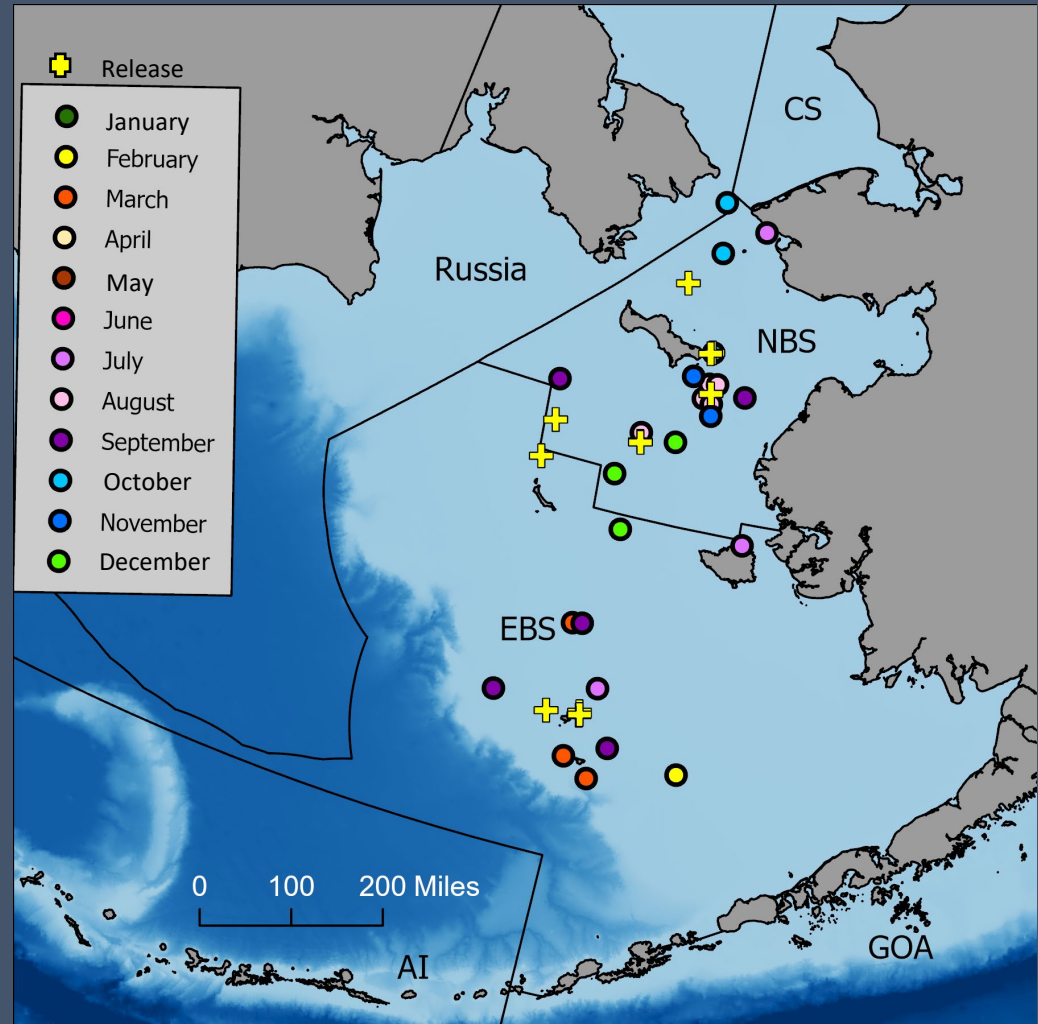
Summary: 2019 NBS (summer to winter and annual movement)

- No evidence of cod overwintering in the NBS
 - Tagged fish moved out ahead of sea ice
 - Substantial seasonal connectivity with EBS
 - Traditional spawning areas
 - Some seasonal connectivity with GOA
 - Some connectivity with Russia year-round
 - Some evidence of summer site fidelity (3 of 4 animals returned to NBS the next summer)
- 
- A coastal landscape with a body of water, a grassy shore, and a cloudy sky. The water is calm, reflecting the light from the sky. The shore is covered in low-lying vegetation. In the distance, there are hills or mountains under a sky filled with large, white clouds.

2021 tag releases in Bering Sea

2021: n = 26 (7 from FLC)

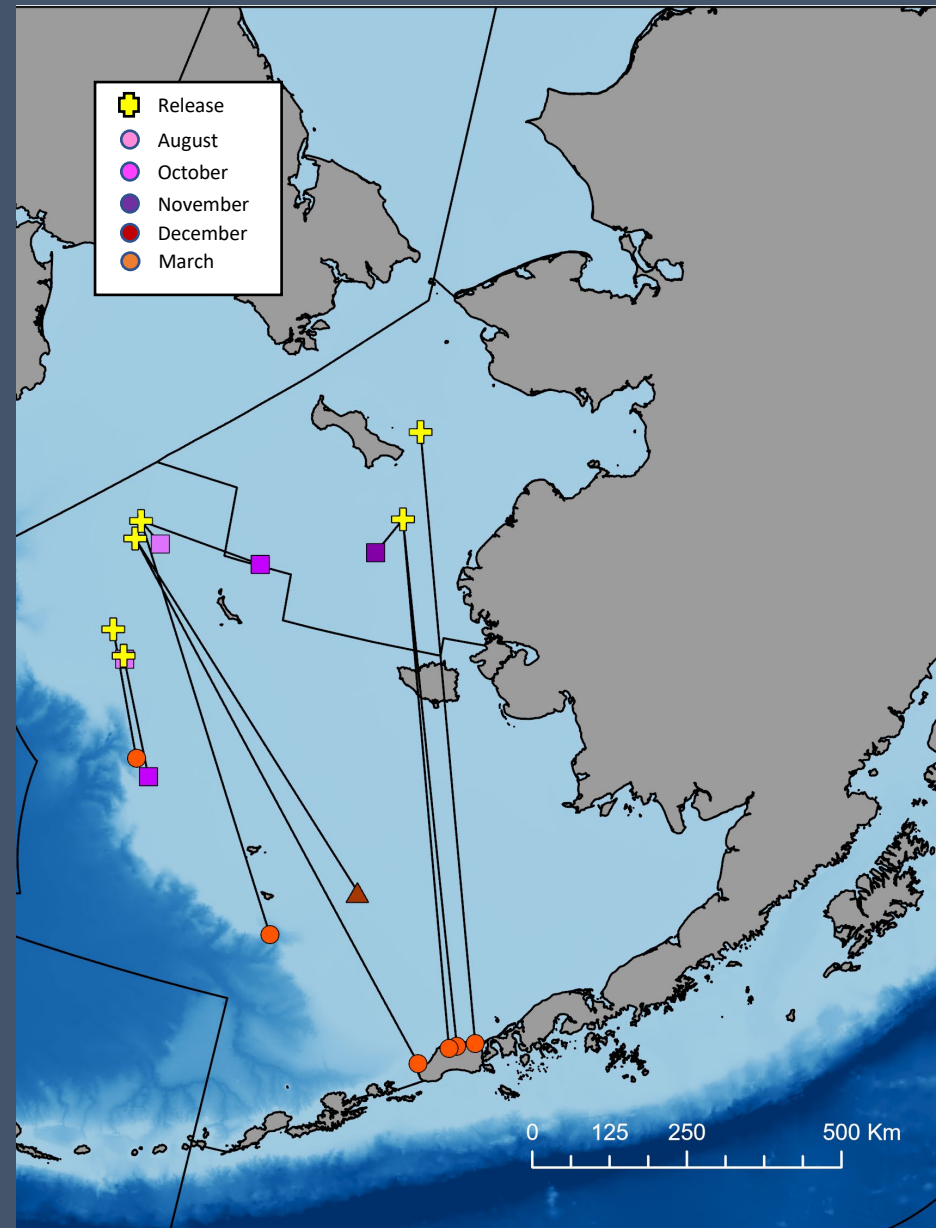
- EBS: 8
- NBS: 18
- Tagging associated mortality: 5
- Early releases (predation, unknown events): 6
 - Range 32 – 353 days at liberty
- On-time pop-ups
 - 90 days: 8
 - 215 days: 2
 - 365 days: 2
- Fisheries recapture: 3
 - 226, 263, 358 days at liberty



2022 tag releases in Bering Sea

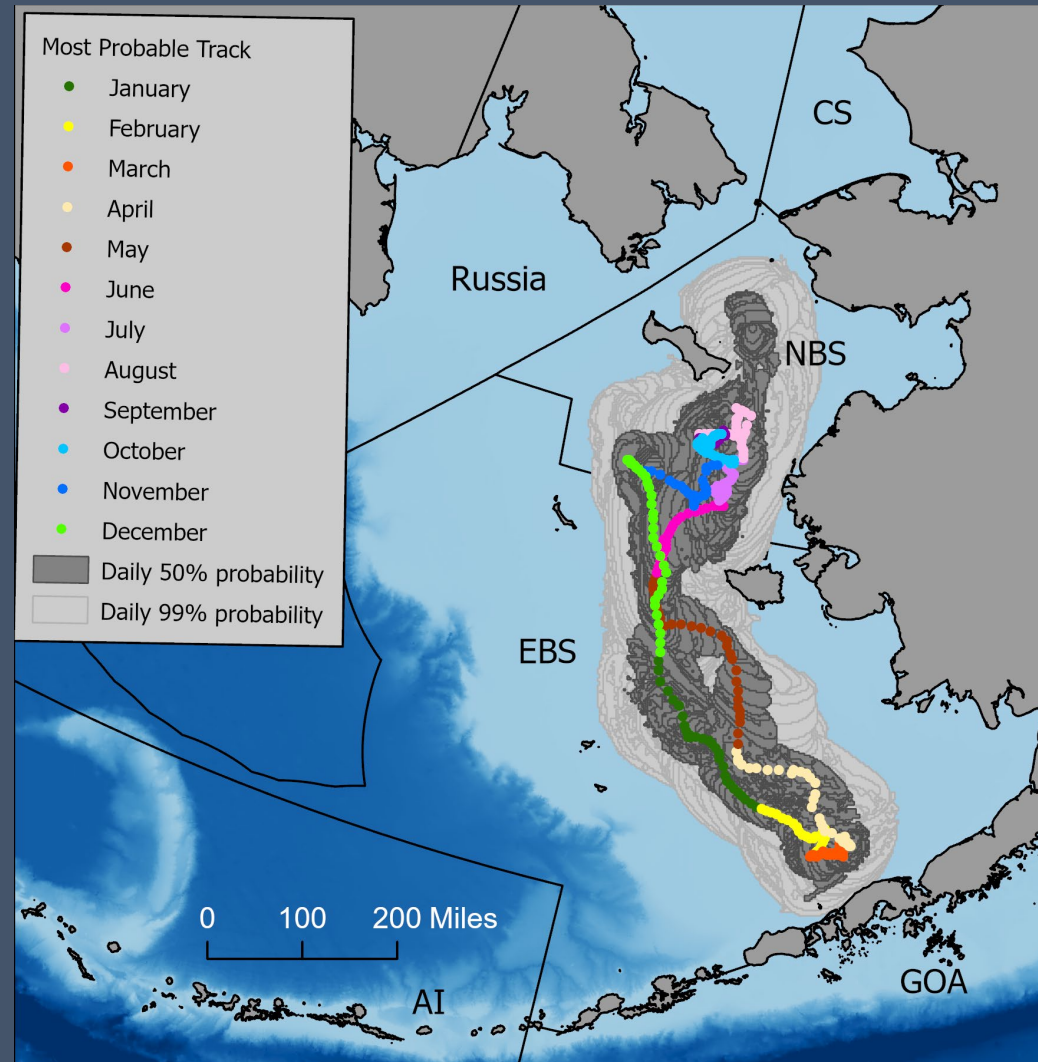
2022: n = 14 (all from FLC)

- One tag not deployed
 - Will go out this summer in EBS
- EBS: 9
- NBS: 5
- Pop-ups:
 - Tagging-associated mortality: 2
 - On-time pop-ups
 - 90-day: 2
 - March 15: 6
 - Fisheries recaptures: 2
 - (90 and 147 days at liberty)
- Did not hear from 2 tags
 - 1 expected in October
 - 1 expected in March



2021-2022 Bering Sea preliminary results

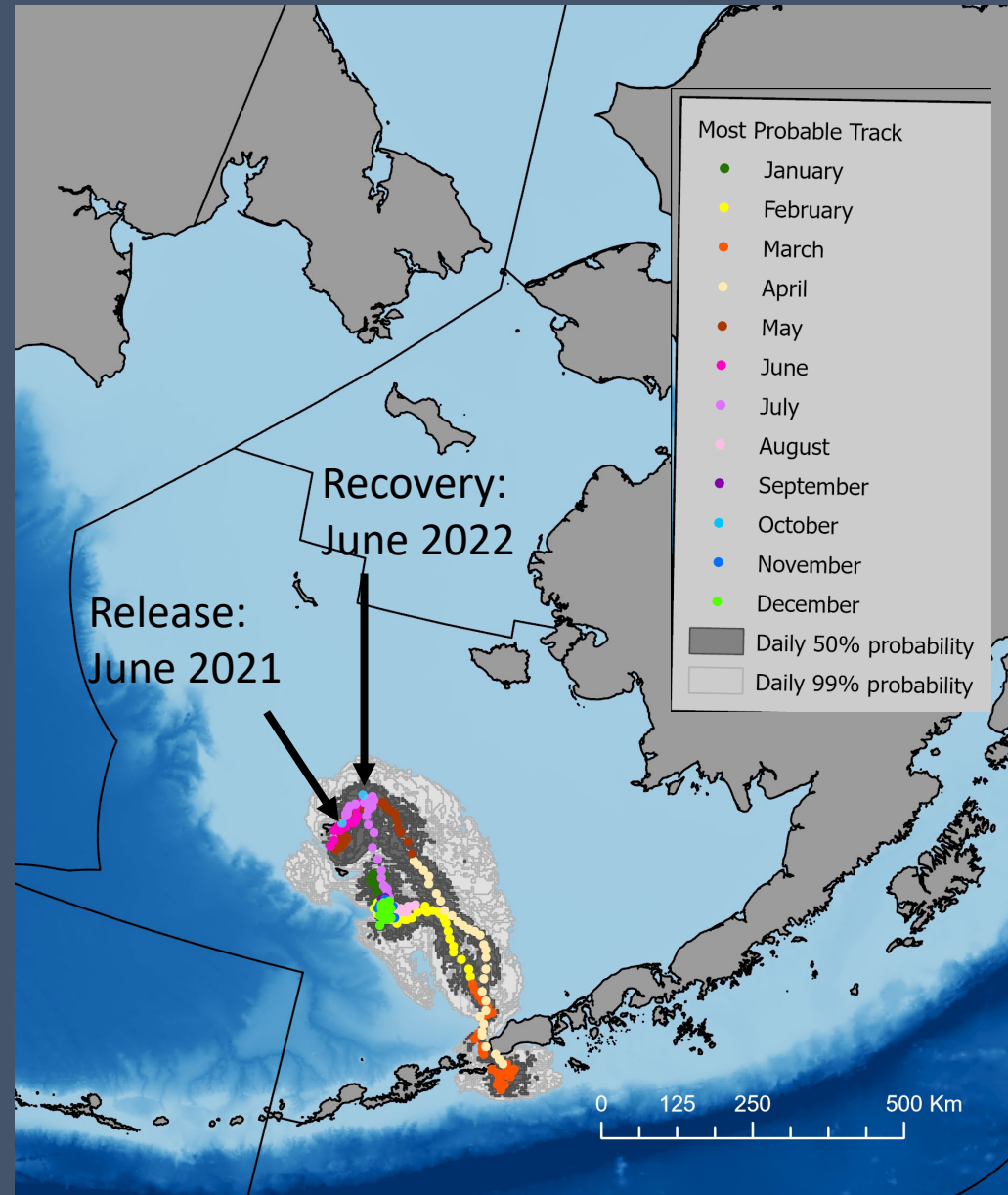
- **NBS:**
 - Confirm previous tagging results (movement out of NBS during winter)
 - Additional evidence of annual summer site fidelity



2021-2022 Bering Sea preliminary results

- **EBS:**

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



2021 Western GOA capture and tagging

(Winter spawning to summer foraging)

March release



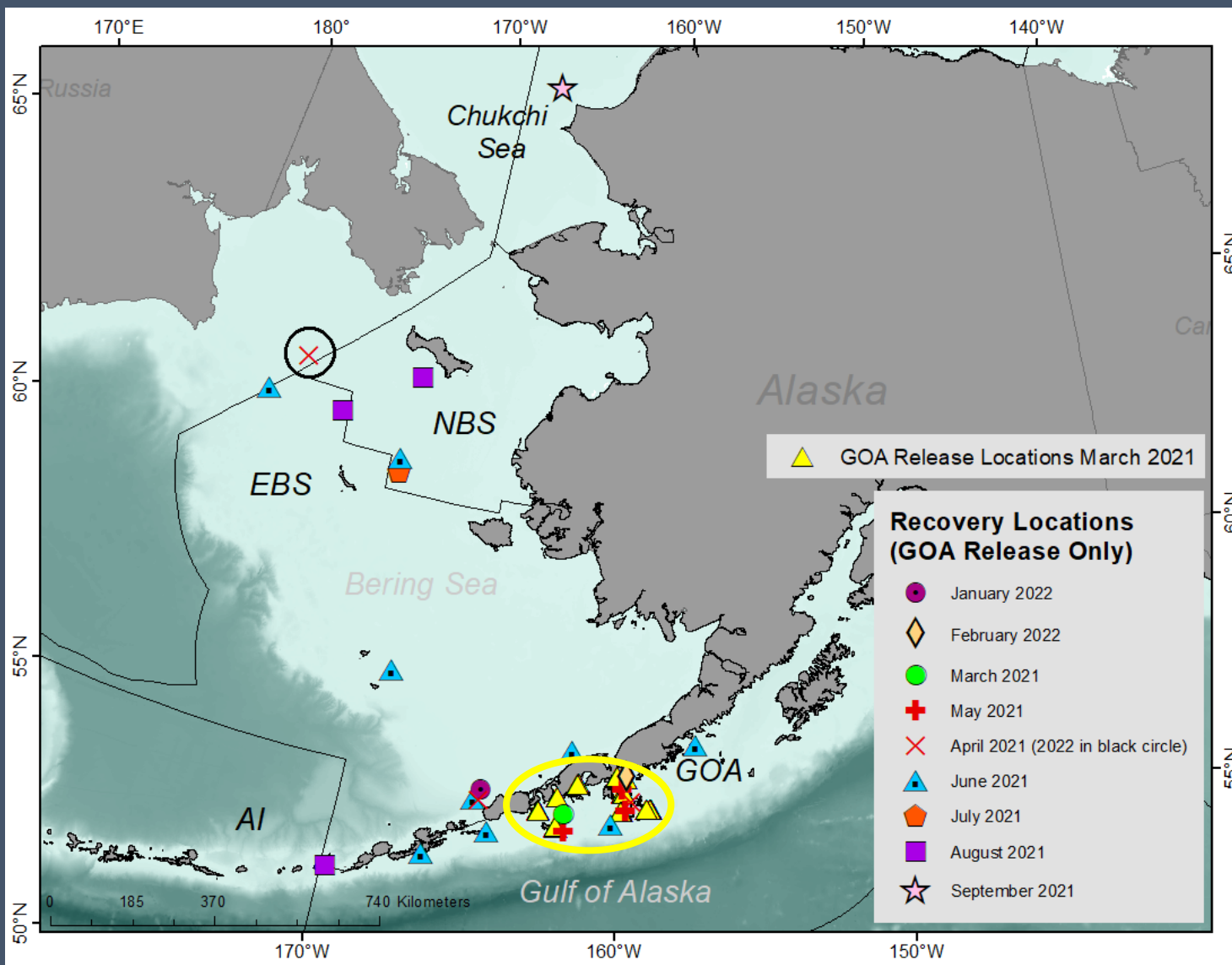
Chartered survey:
F/V Decision

n = 25



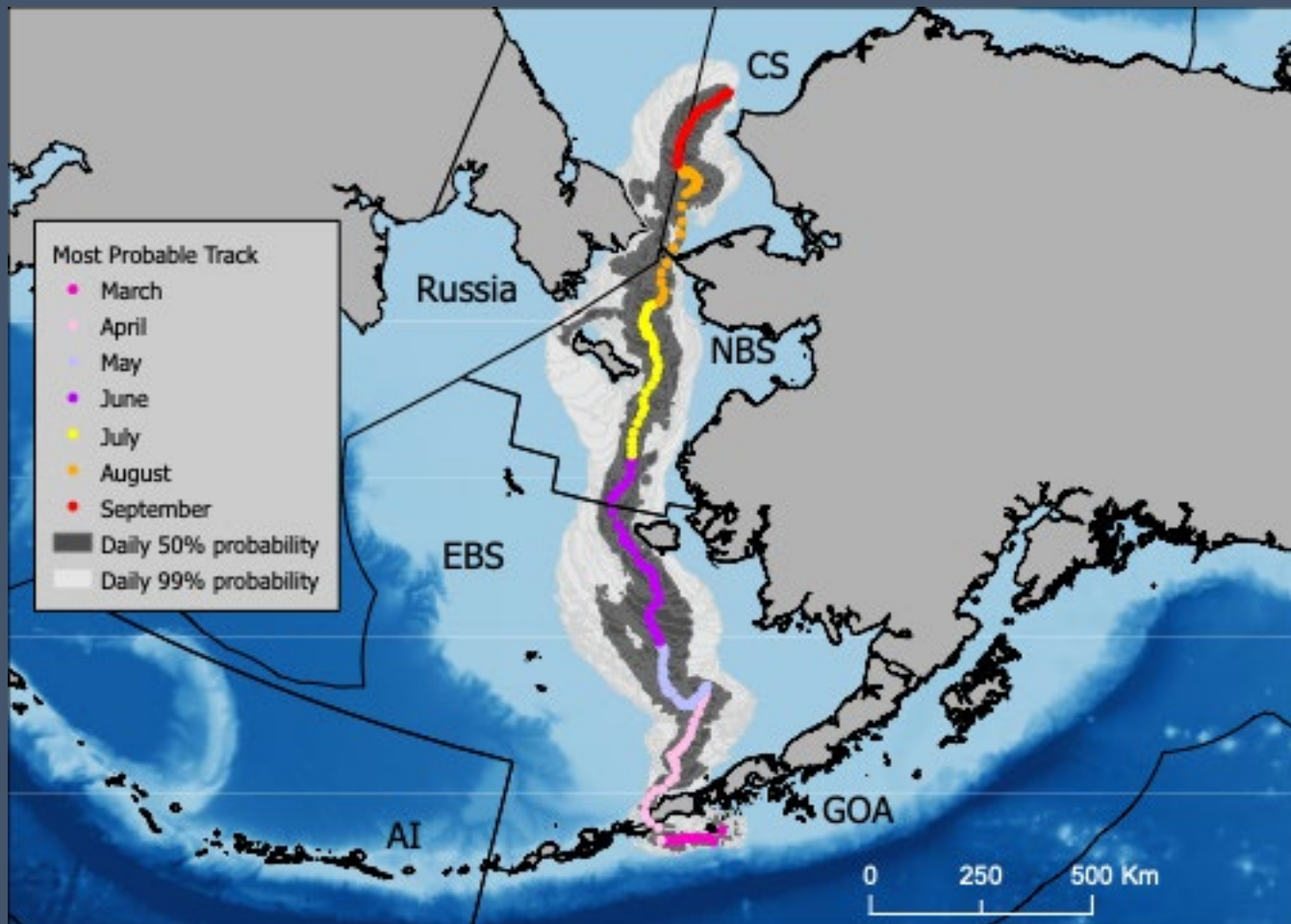
- Capture in pots and brought to surface in 4 stages
- Depths < 100 m
- Released with descender
- Biological samples collected
- Conventional tags released

Pop-up locations



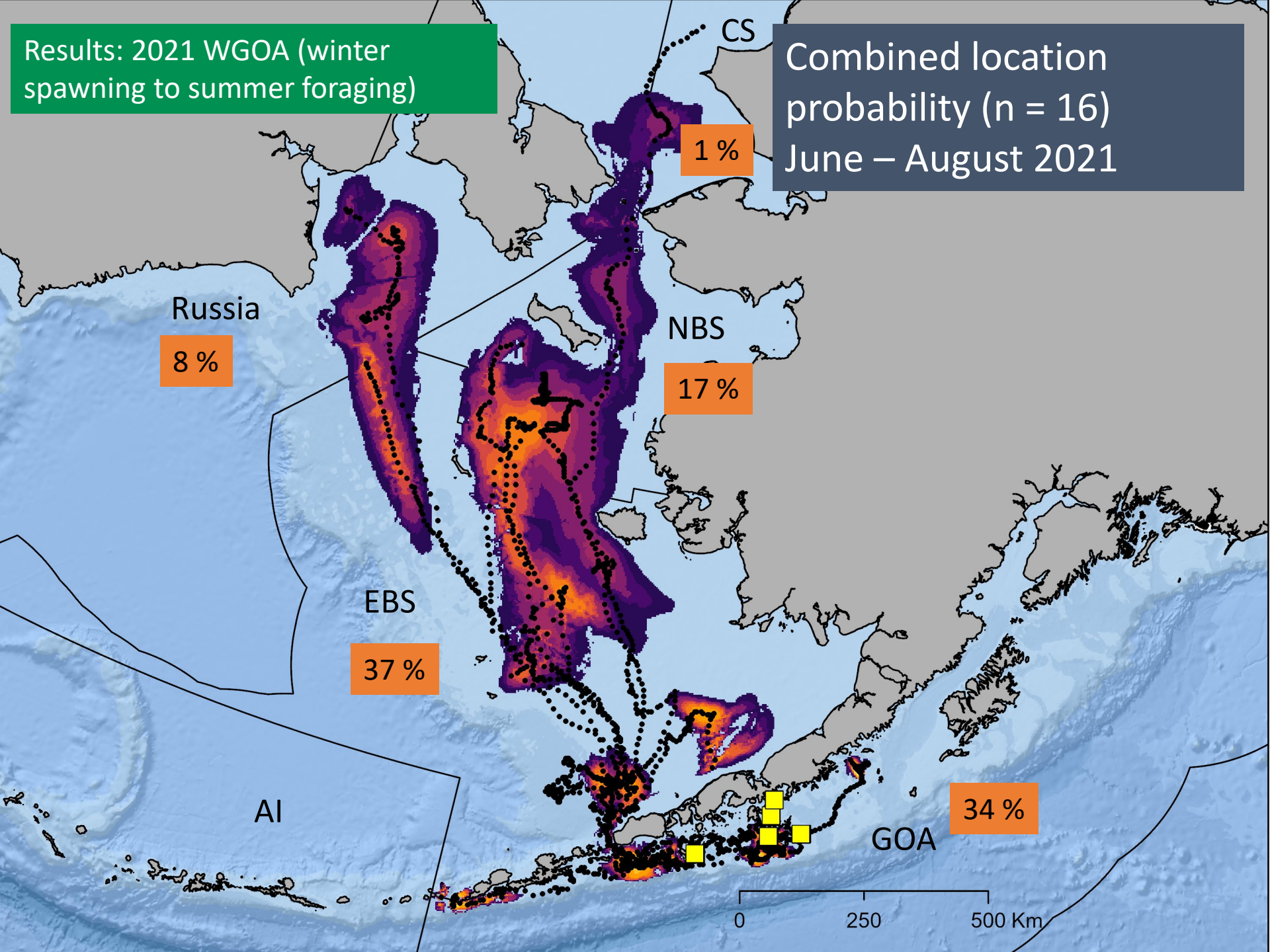
- 23 of 25 tags
- 3 recovered in fishery
- No tagging mortality
- Geolocation for 23 fish

Estimated pathways



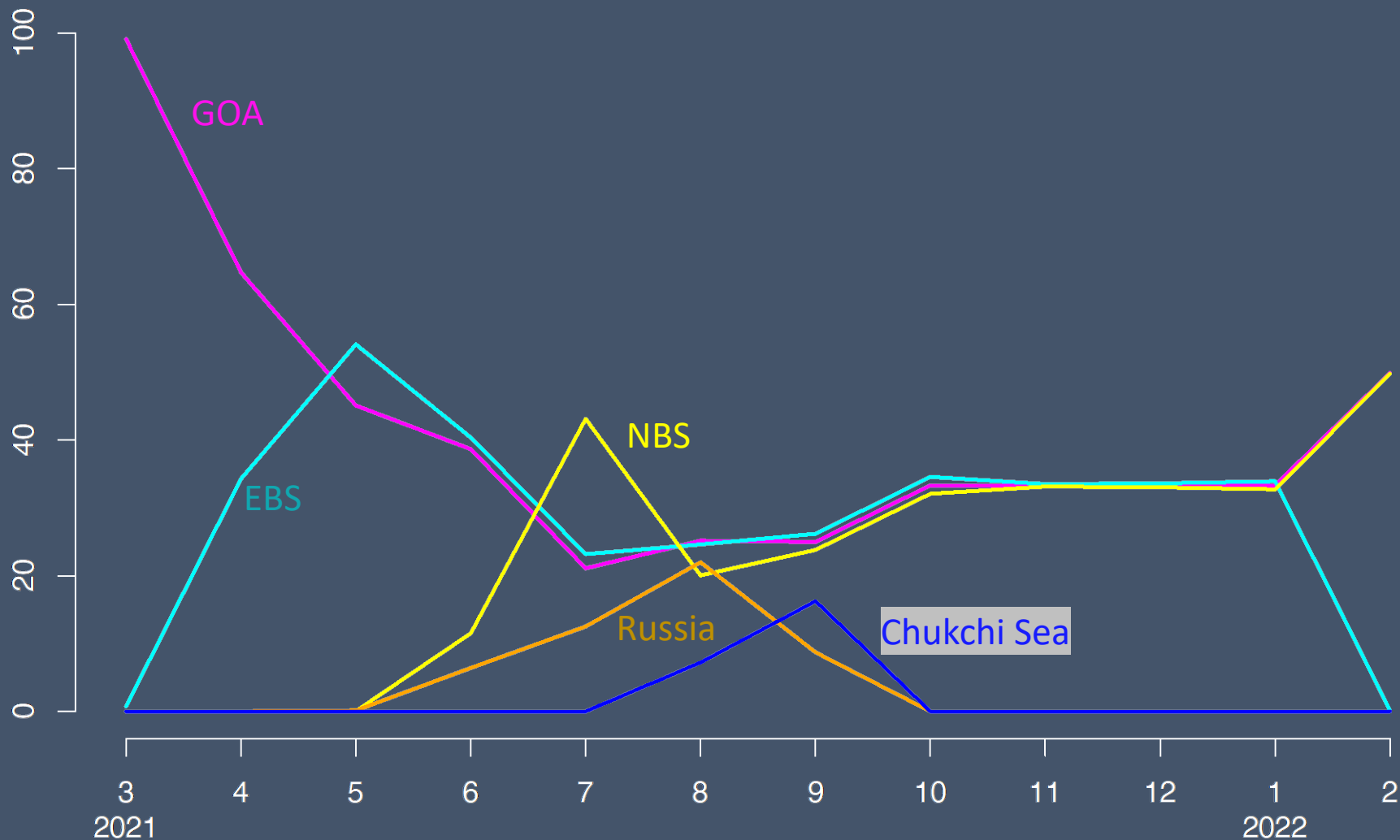
Results: 2021 WGOA (winter spawning to summer foraging)


Combined location probability (n = 16)
June – August 2021

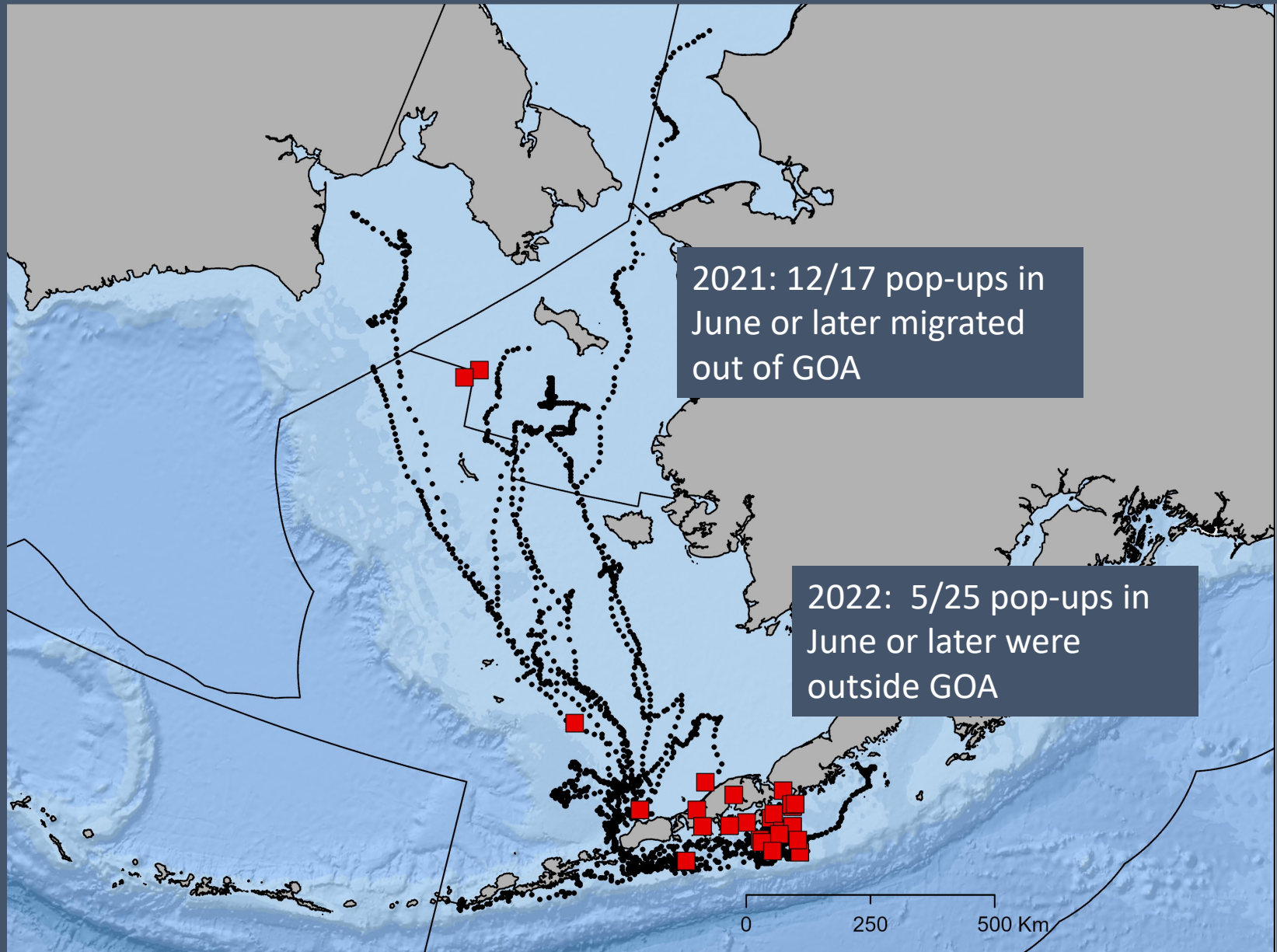


Results: 2021 WGOA (winter spawning to summer foraging) Monthly probability by region

tags: 23 22 20 16 8 6 4 3 3 3 3 2



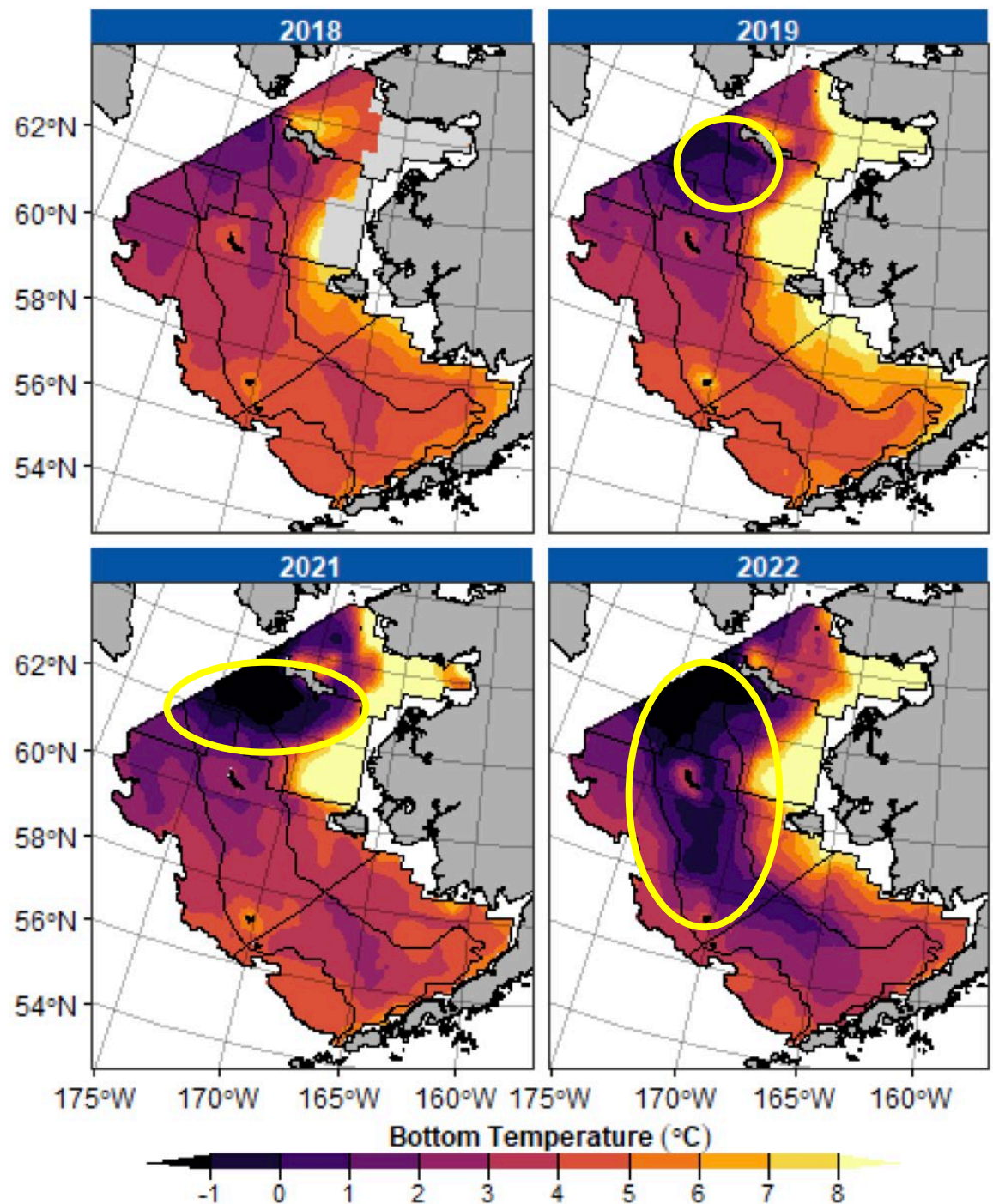
- 
- Extensive seasonal connectivity between WGOA and Bering Sea
 - Some seasonal connectivity between WGOA and Russia/Chukchi sea



Bering Sea bottom temperature

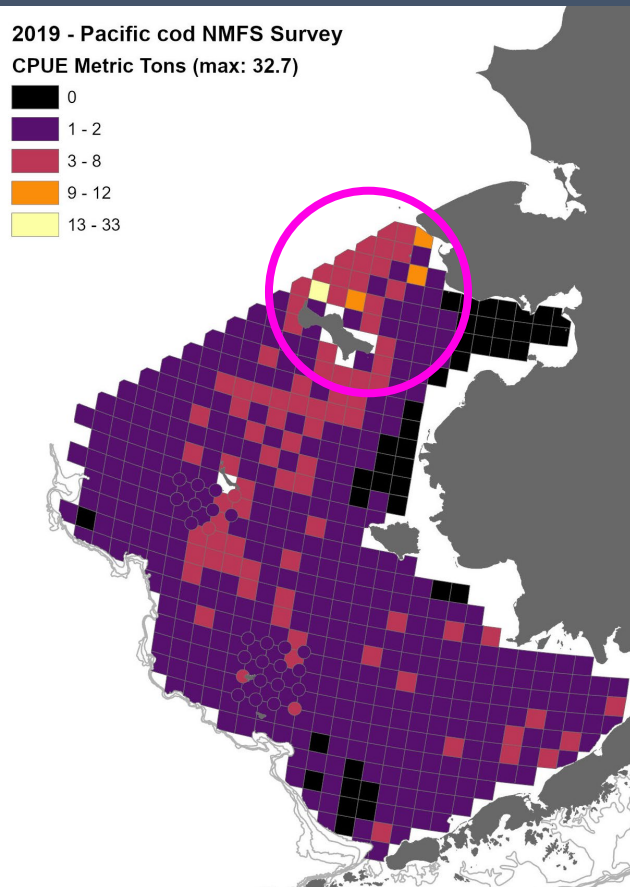
Courtesy of Sean
Rohan, NOAA AFSC

2022: colder in
Bering Sea and
western GOA

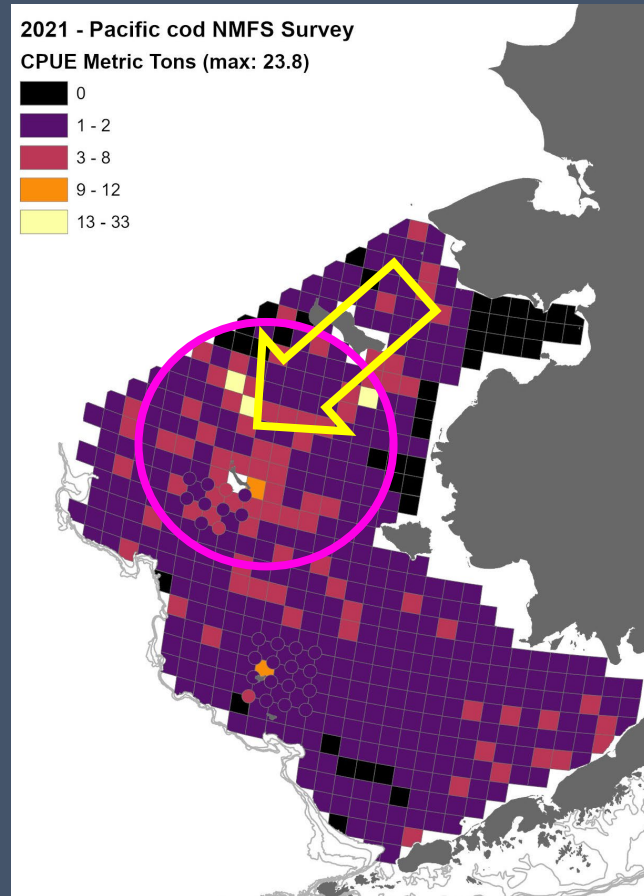


Pacific cod distribution in summer survey

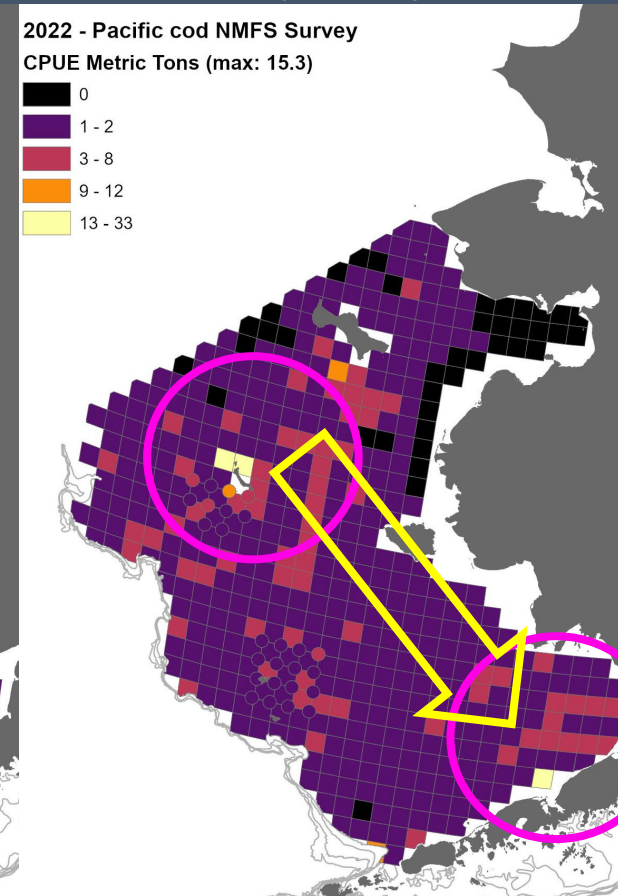
2019 (very warm!)



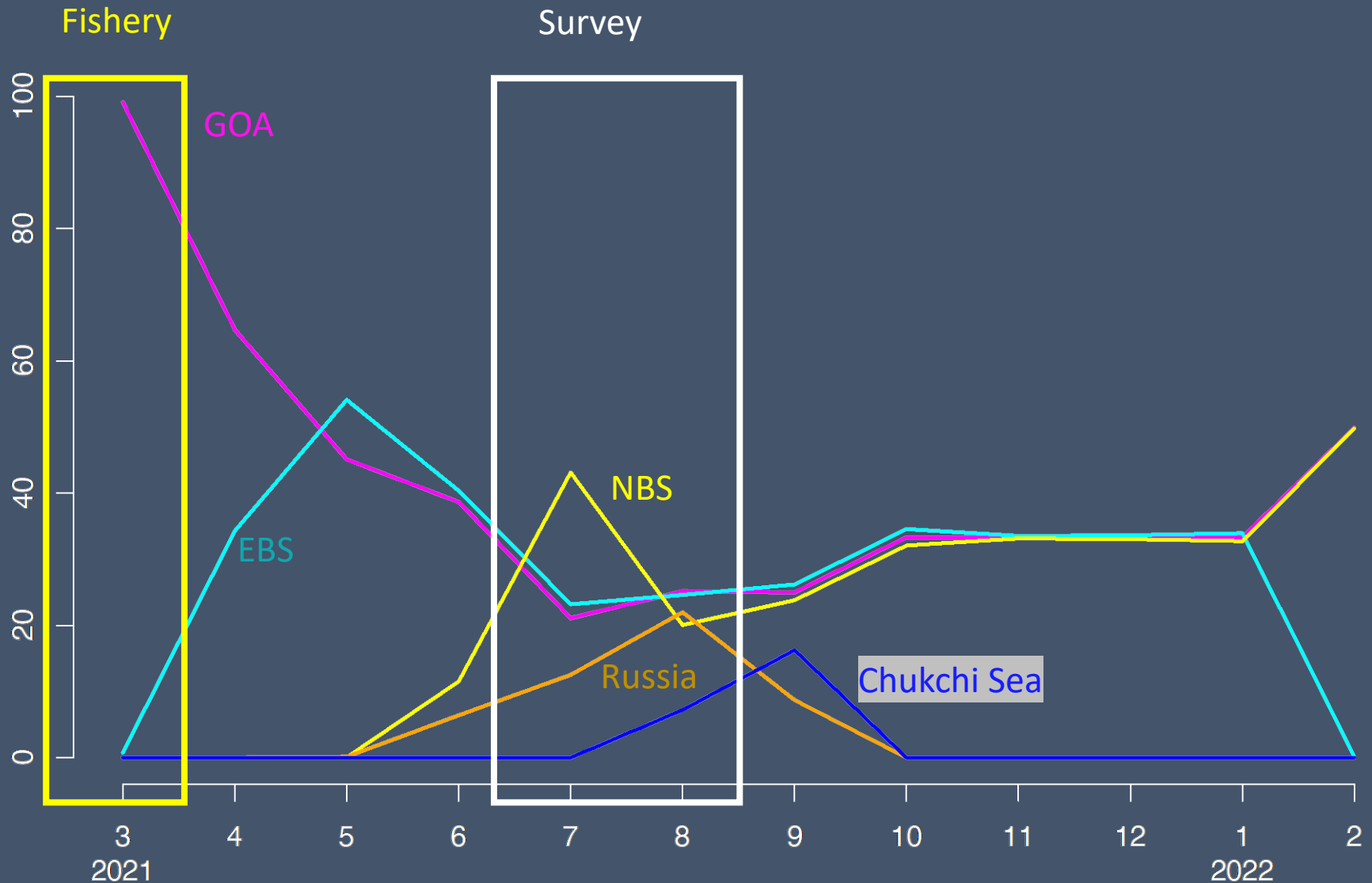
2021 (still warm)



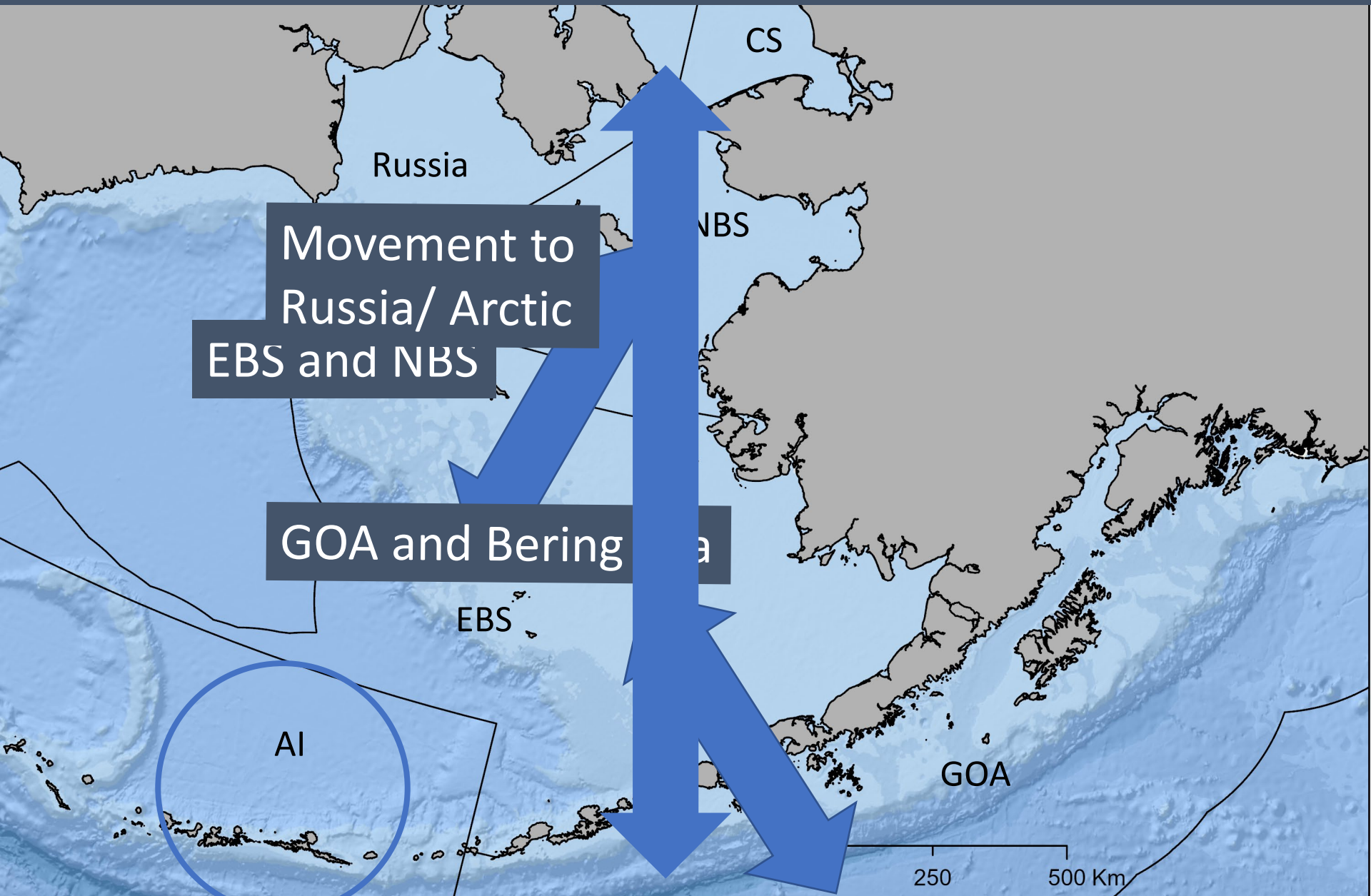
2022 (colder)



Management implications: seasonal change in distribution



Management implications: seasonal connectivity



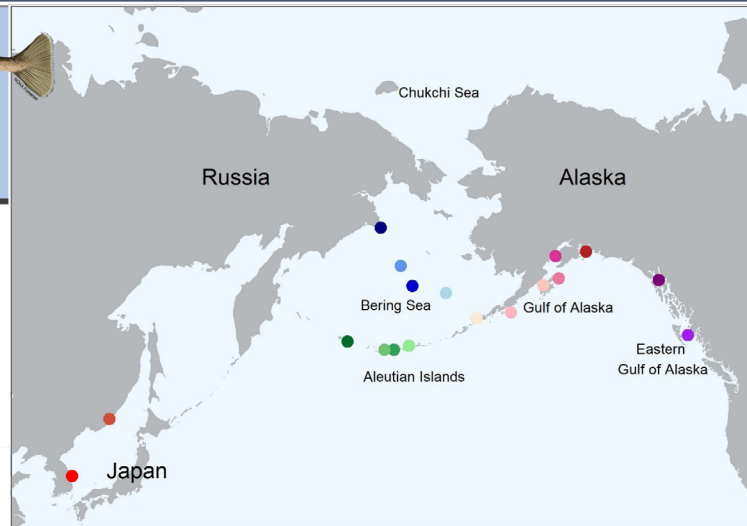
Comparative Genomics of Pacific Cod and Walleye Pollock

Sara Michele Schaal¹, Wes Larson², Ingrid Spies¹

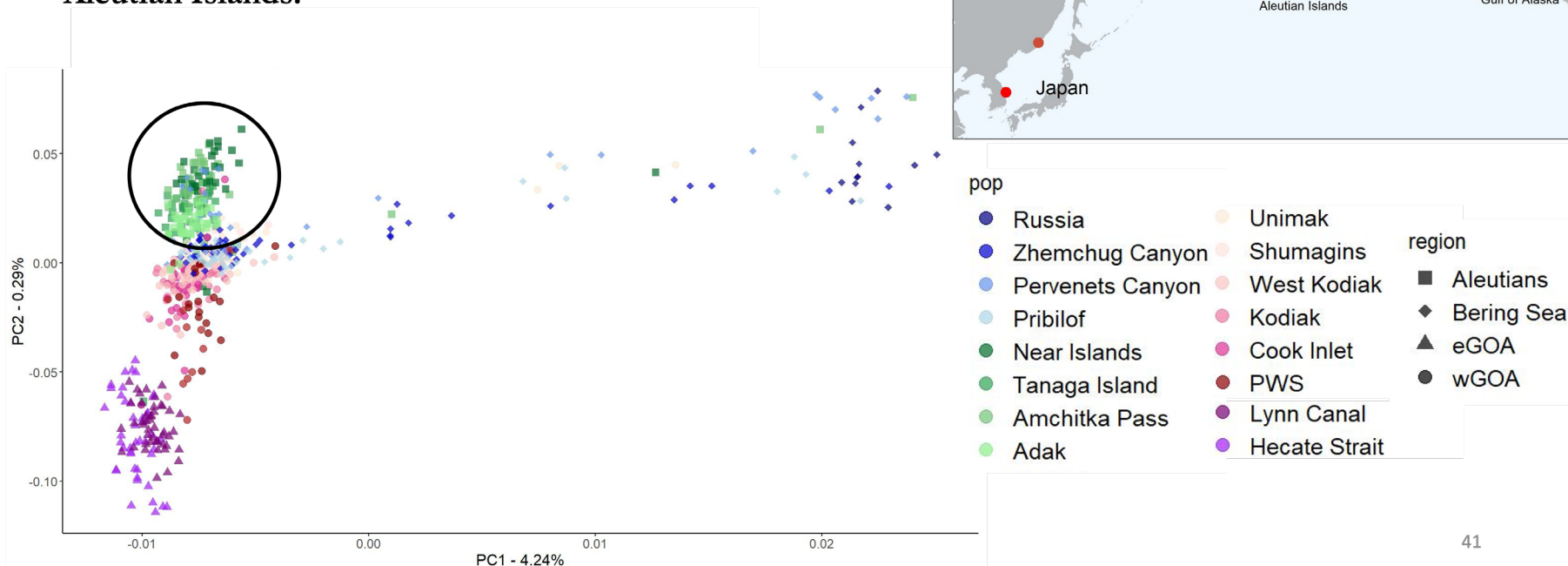
¹Alaska Fisheries Science Center, Seattle, WA

²Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, AK

Low-coverage whole genome sequencing (lcWGS)



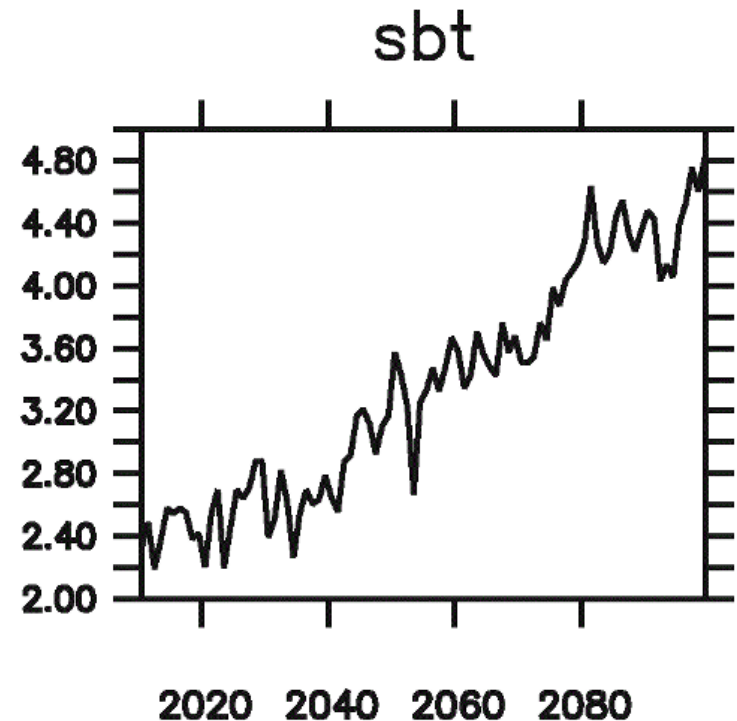
Genetic Break due to adaptive differences in the Aleutian Islands.



Management implications: connectivity may vary with temperature regime

- Increasing temps = increasing connectivity with Russia and Arctic?
 - Trans-boundary stock issues
 - Movement out of surveyed areas
- More research in different years to determine mechanisms and predict connectivity under different scenarios
 - Sea ice extent?
 - Prey distribution?
 - Cold pool temps not a physiological barrier....

Bering Sea bottom temperature predictions under “no change” scenario



JOURNAL ARTICLE

Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios

Albert J Hermann , Georgina A Gibson, Wei Cheng, Ivonne Ortiz, Kerim Aydin, Muyin Wang, Anne B Hollowed, Kirstin K Holsman

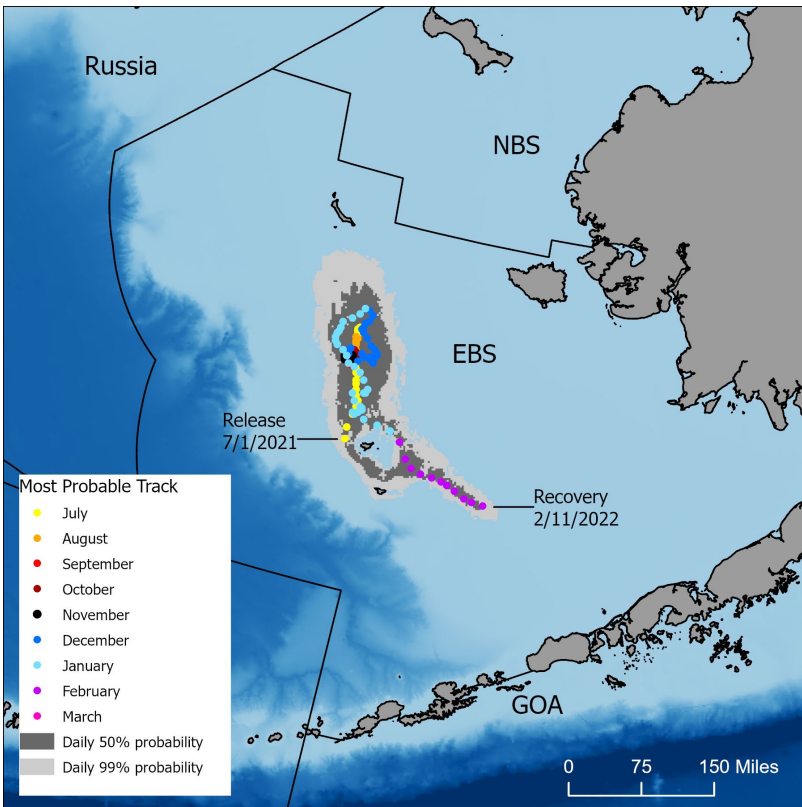
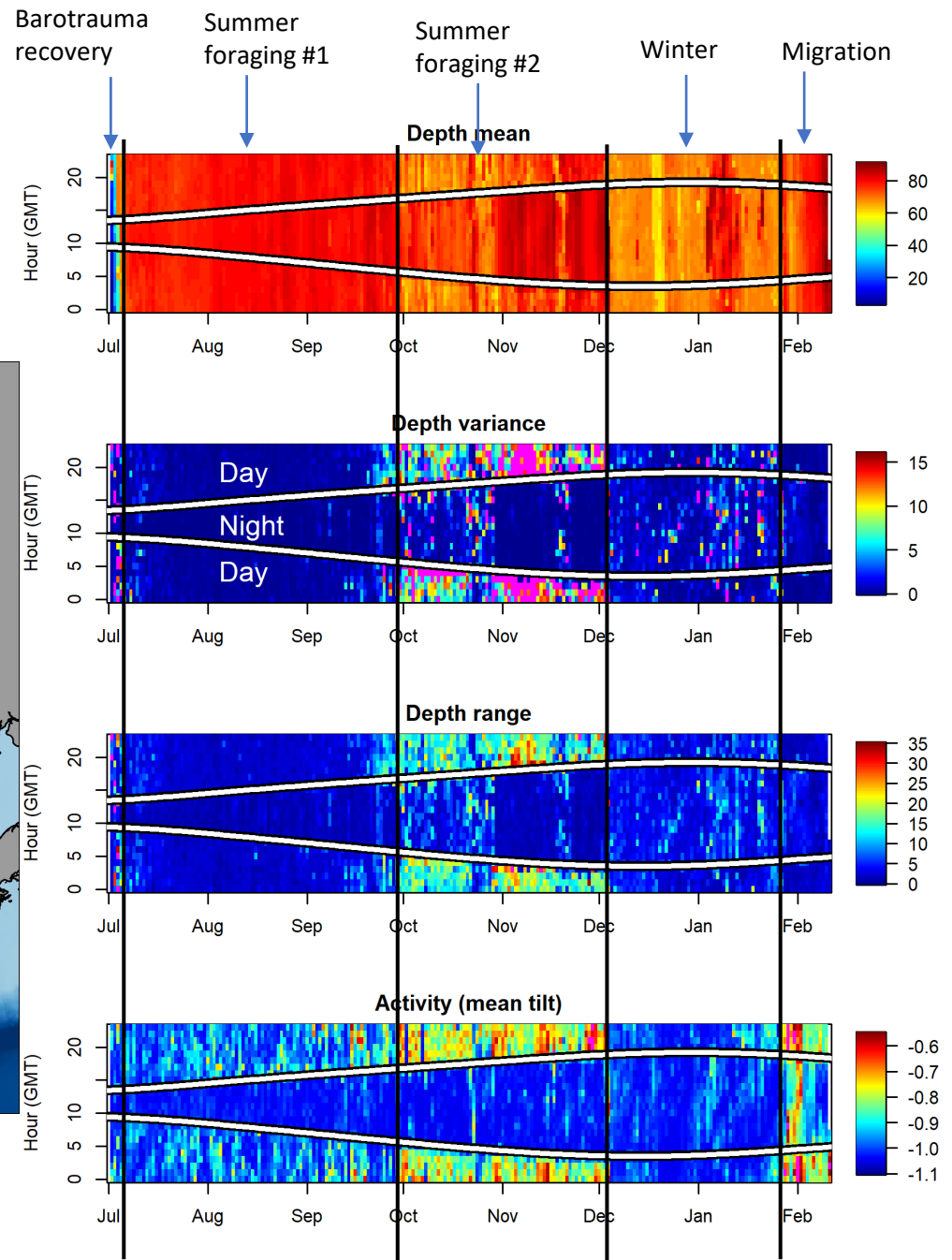
ICES Journal of Marine Science, Volume 76, Issue 6, November-December 2019, Page 1937, <https://doi.org/10.1093/icesjms/fsz111>

Published: 09 June 2019

Behavior

90-day tags and fisheries recaptures

Example: US Intrepid



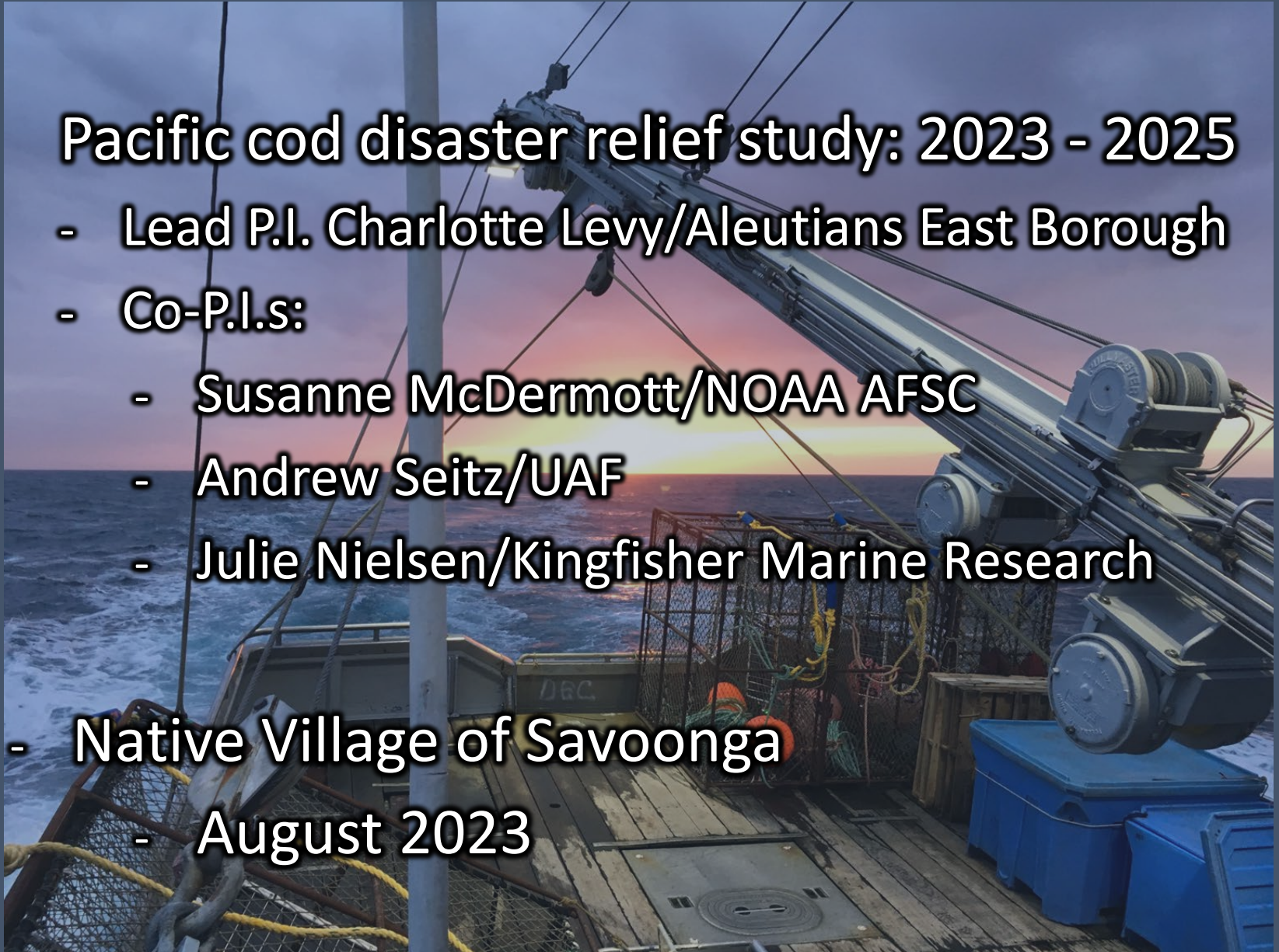
Current satellite tagging research

- Seasonal and annual movement patterns
- Behavior
- Genetics
- Diet
- Spawning phenology
- Movement modeling with habitat preference
- “Conceptual model” of Pacific cod seasonal movement
 - Mechanisms of seasonal movement
 - Allow predictions for future climate scenarios

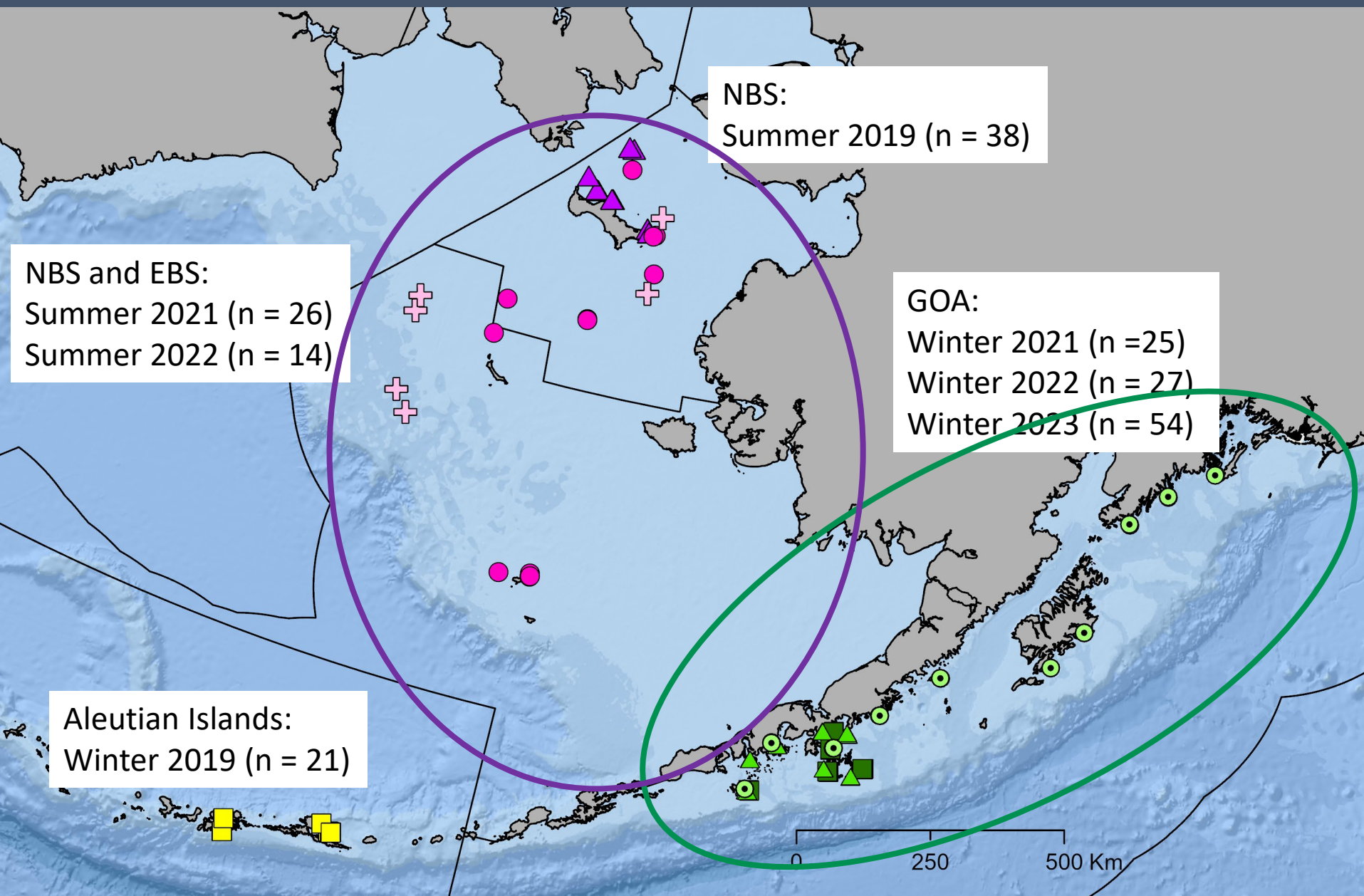
Current and future research

Pacific cod disaster relief study: 2023 - 2025

- Lead P.I. Charlotte Levy/Aleutians East Borough
- Co-P.I.s:
 - Susanne McDermott/NOAA AFSC
 - Andrew Seitz/UAF
 - Julie Nielsen/Kingfisher Marine Research
- Native Village of Savoonga
 - August 2023



Disaster relief satellite tag releases:



Thank you!

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

Savoonga fishermen and plant personnel

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

Cooperative Partners:

Aleutians East Borough

Norton Sound Economic Development Corporation

Freezer Longline Coalition

Pacific Cod Harvesters



Comments? Questions?

Julie.Nielsen@gmail.com

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NMFS Scientific personnel:

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Jennifer Gardner

Cynthia Yeung

Reyn Yoshioka

Lukas DeFilippo

Chris Long

Emily Ryznar

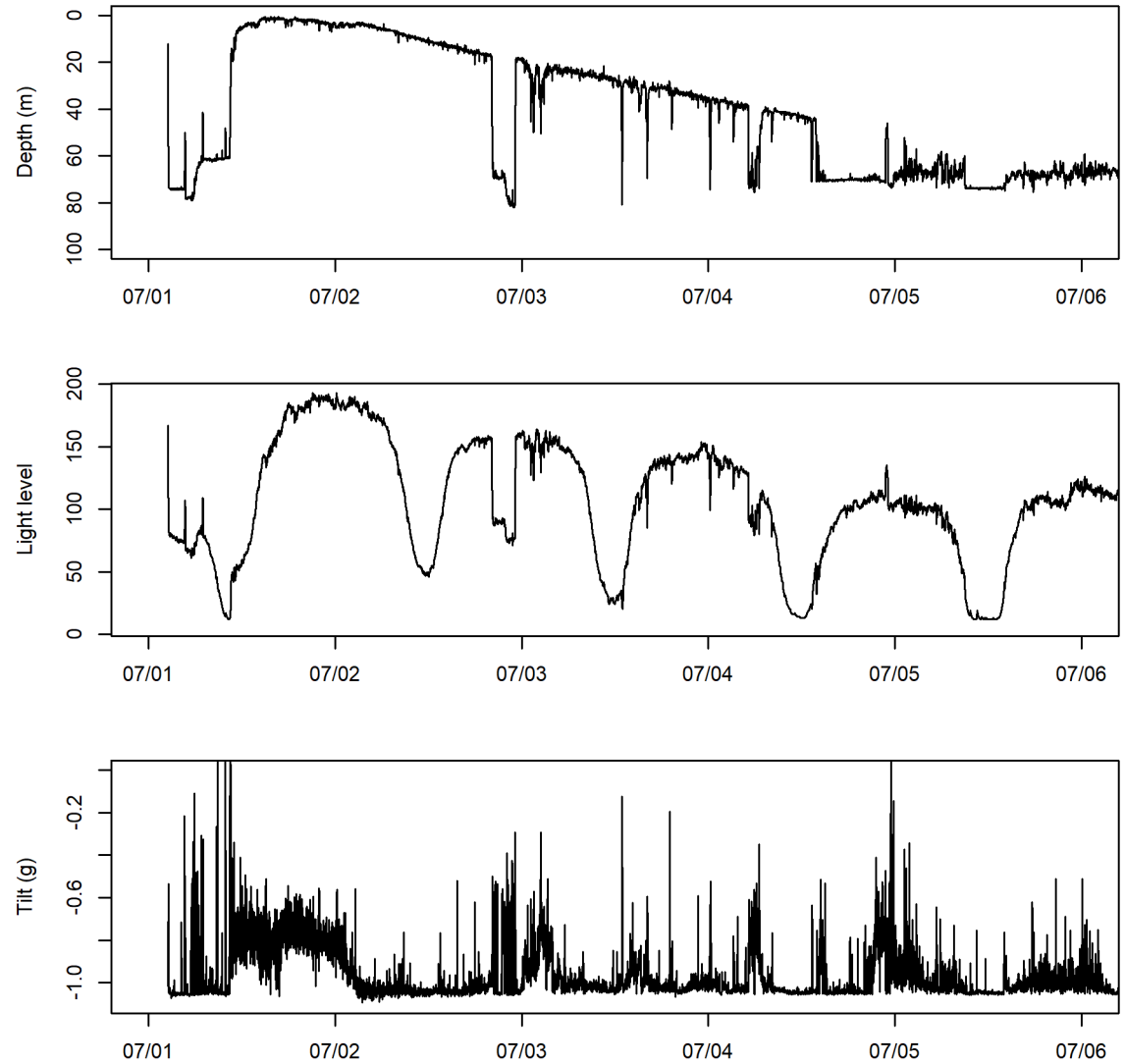
Emily Markowitz

Rebecca Haehn

Stan Kotwicki

Behavior

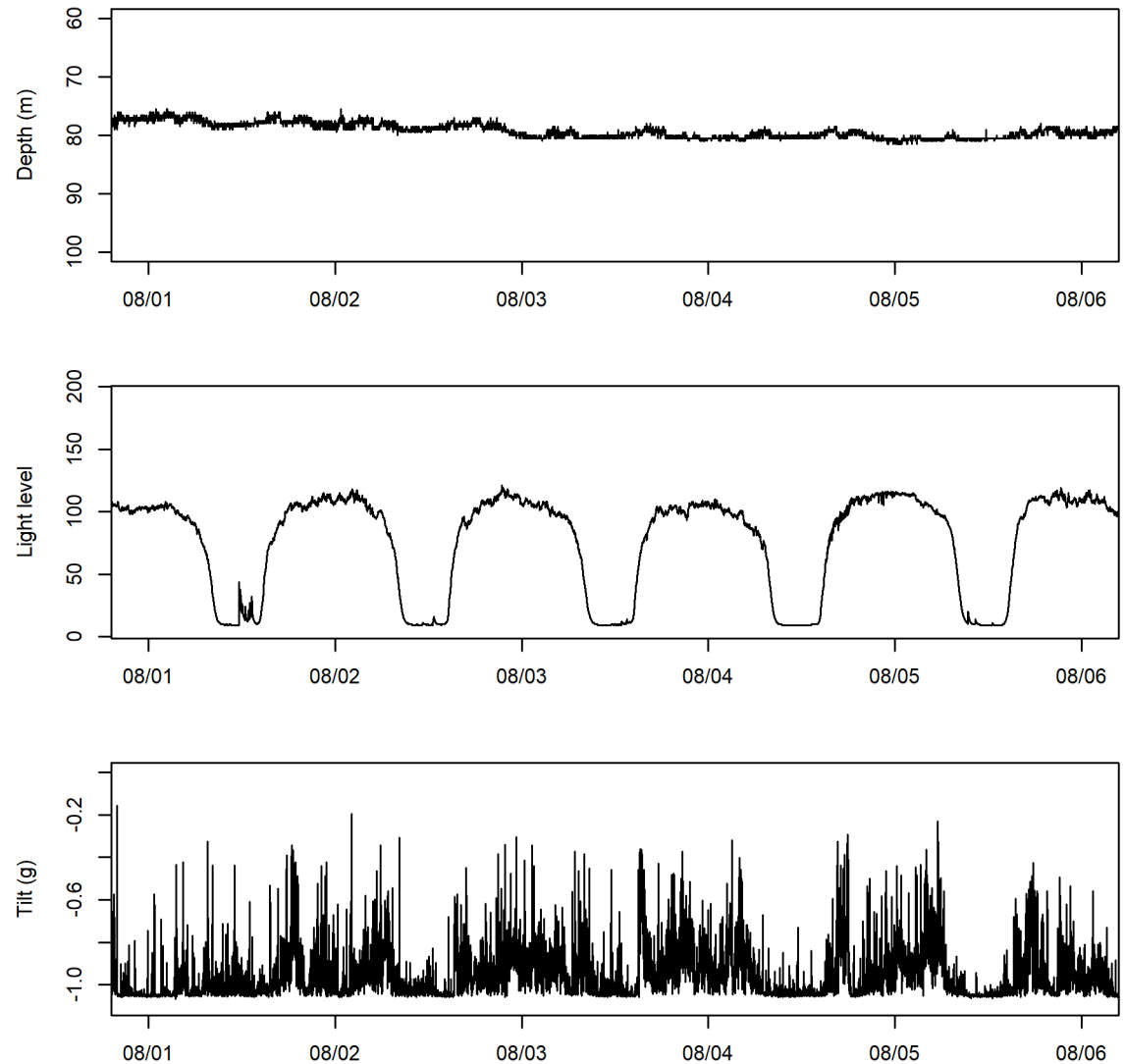
Barotrauma recovery



Behavior

Summer foraging #1:

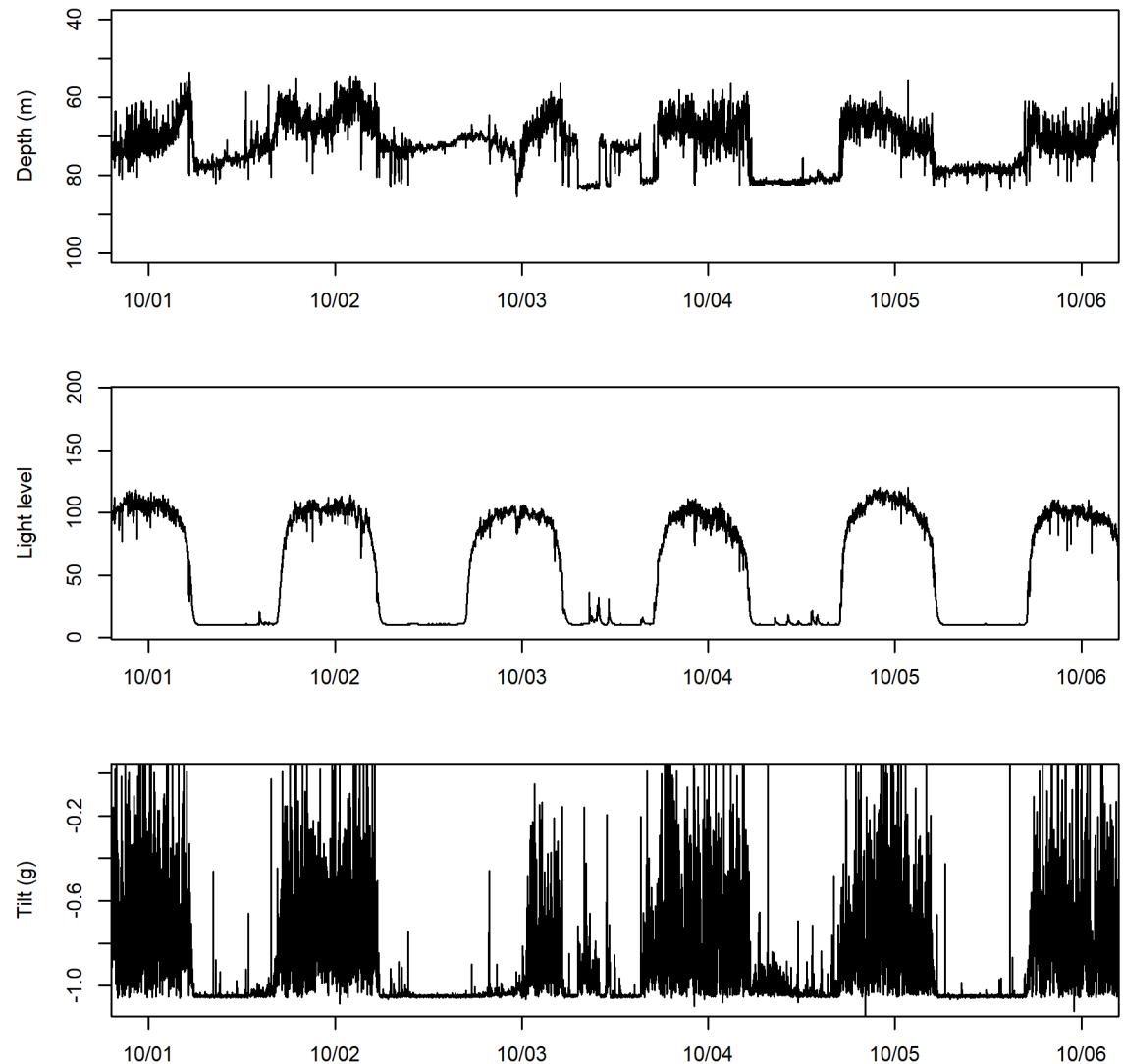
- July - September
- Moderate activity during daytime
- Very little change in depth



Behavior

Summer foraging #2:

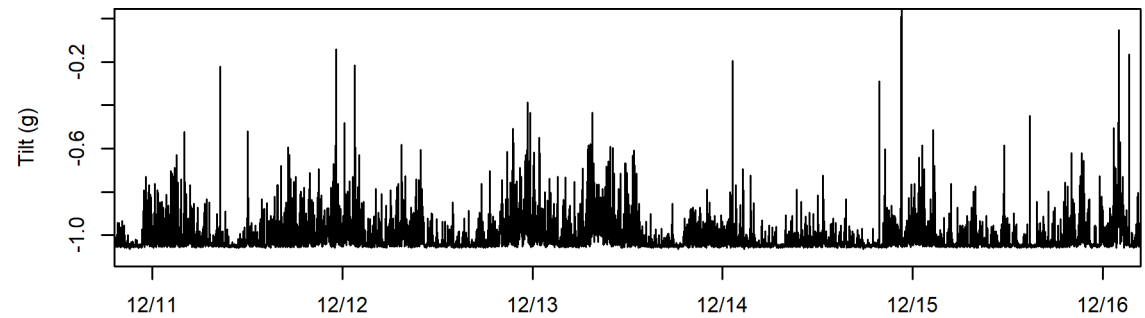
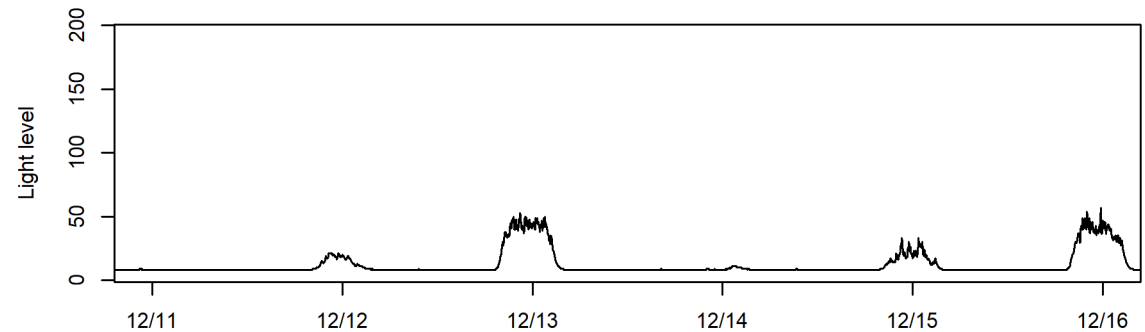
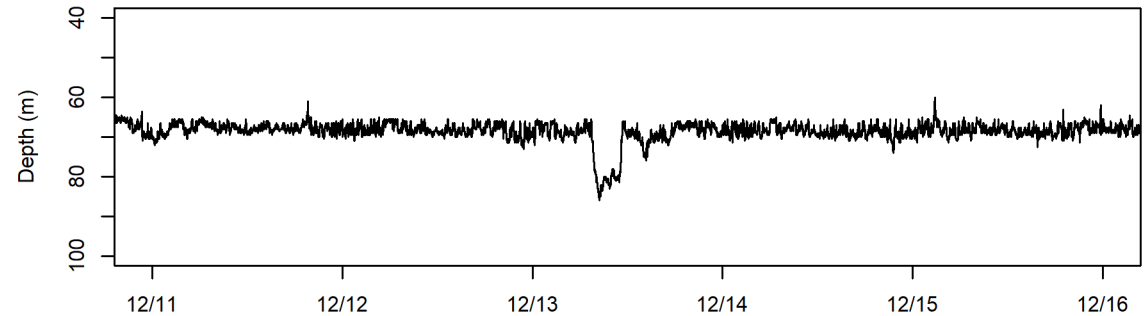
- October - November
- Considerable activity during daytime
- Hourly change in depth up to 35 m



Behavior

Winter :

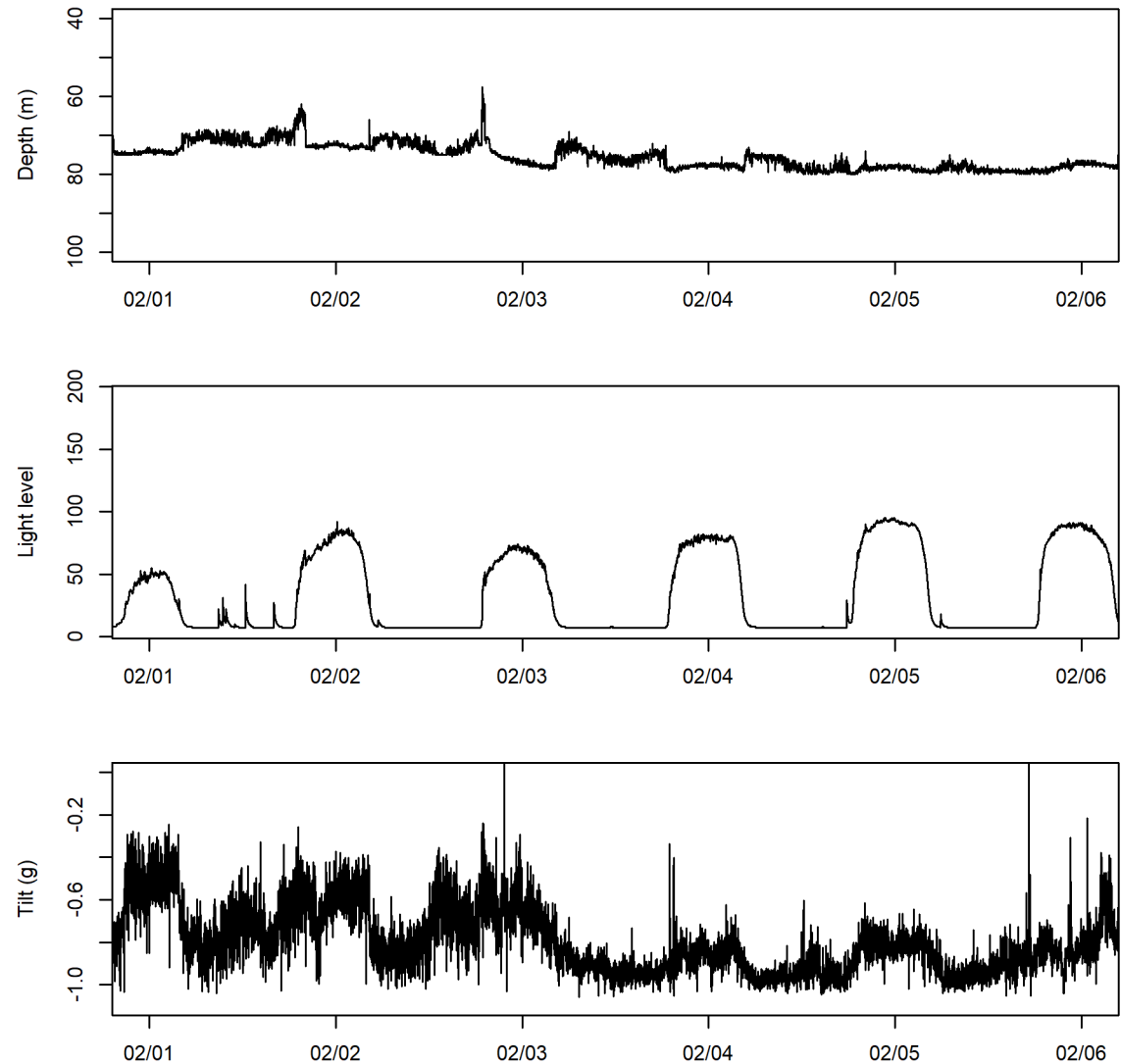
- December - January
- Low – moderate activity
- Tidal instead of diel



Behavior

Migration :

- February
- High activity
- Both tidal and diel
- Little change in depth

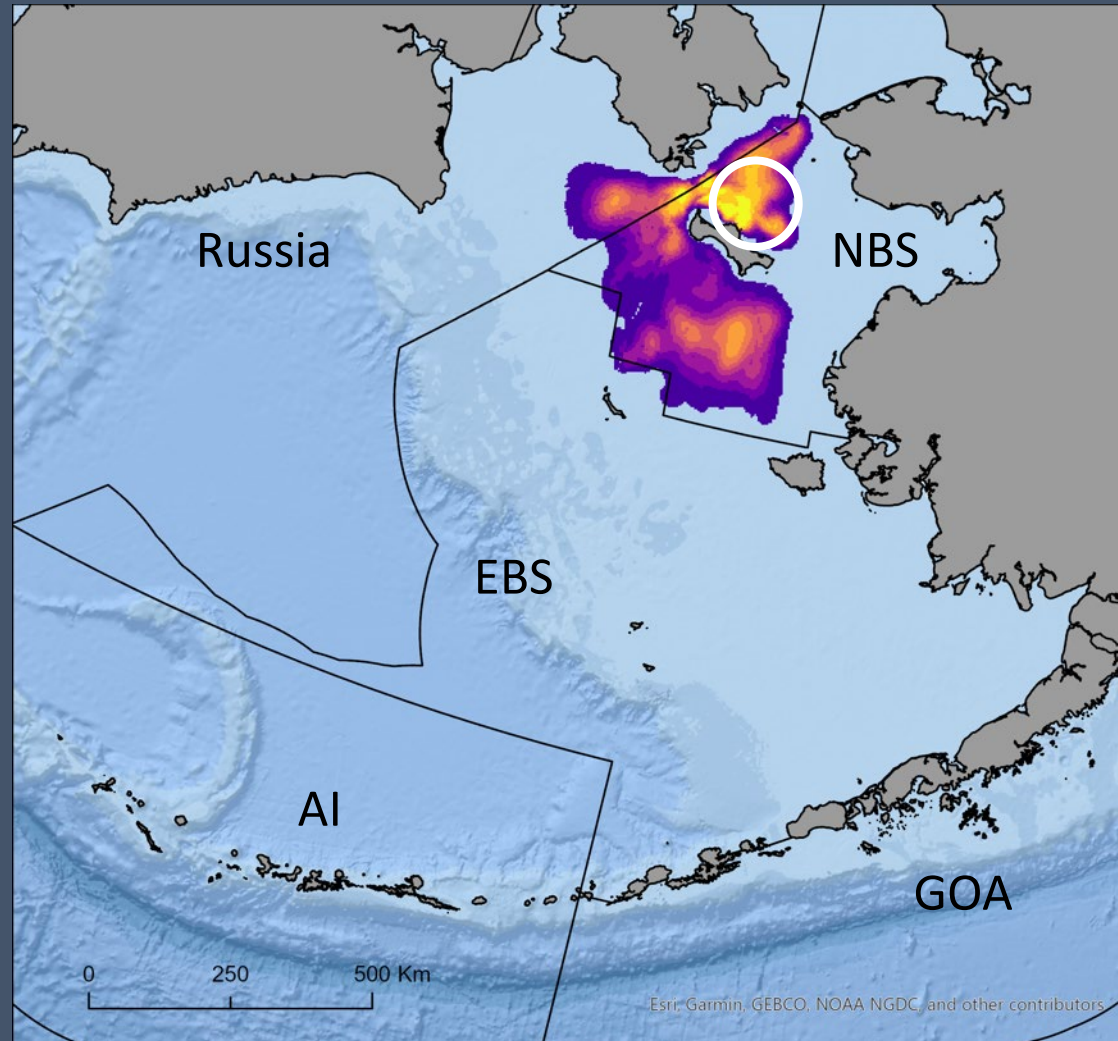


Month

September 2019

Sample size

n = 31



Month

April 2021 .1

Sample size

n = 22

