Seasonal movement patterns of Pacific cod in Alaska indicate connectivity between management areas

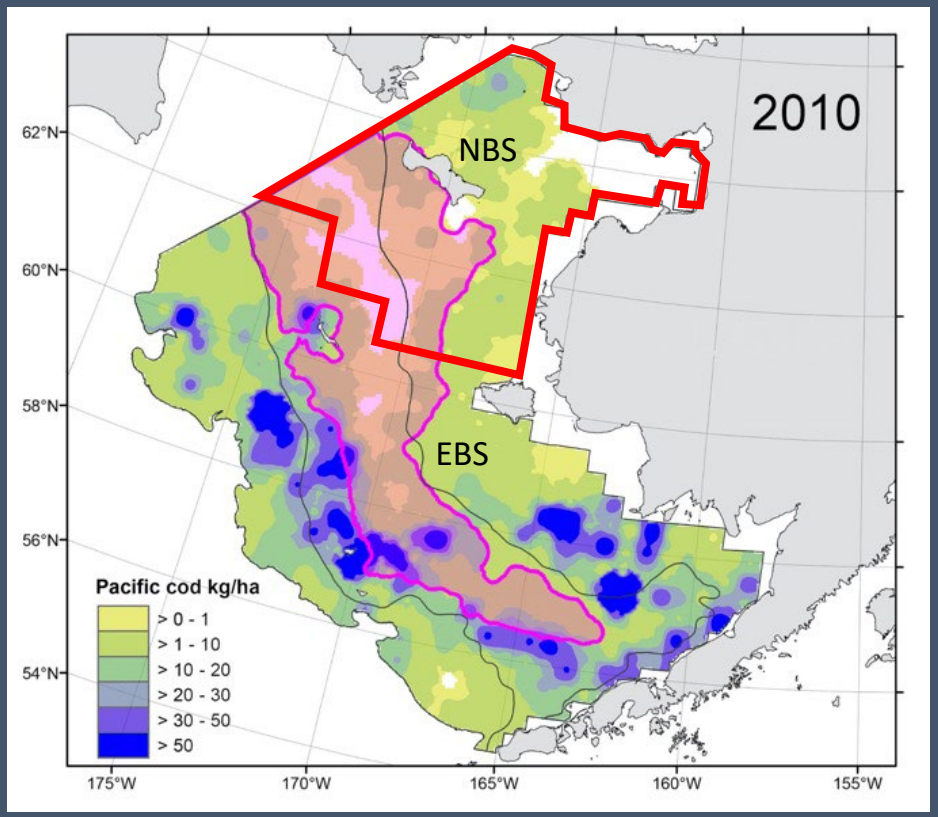
Julie Nielsen[1], Susanne McDermott[2], Charlotte Levy[3], Kimberly Rand[4], Liz Dawson[2]

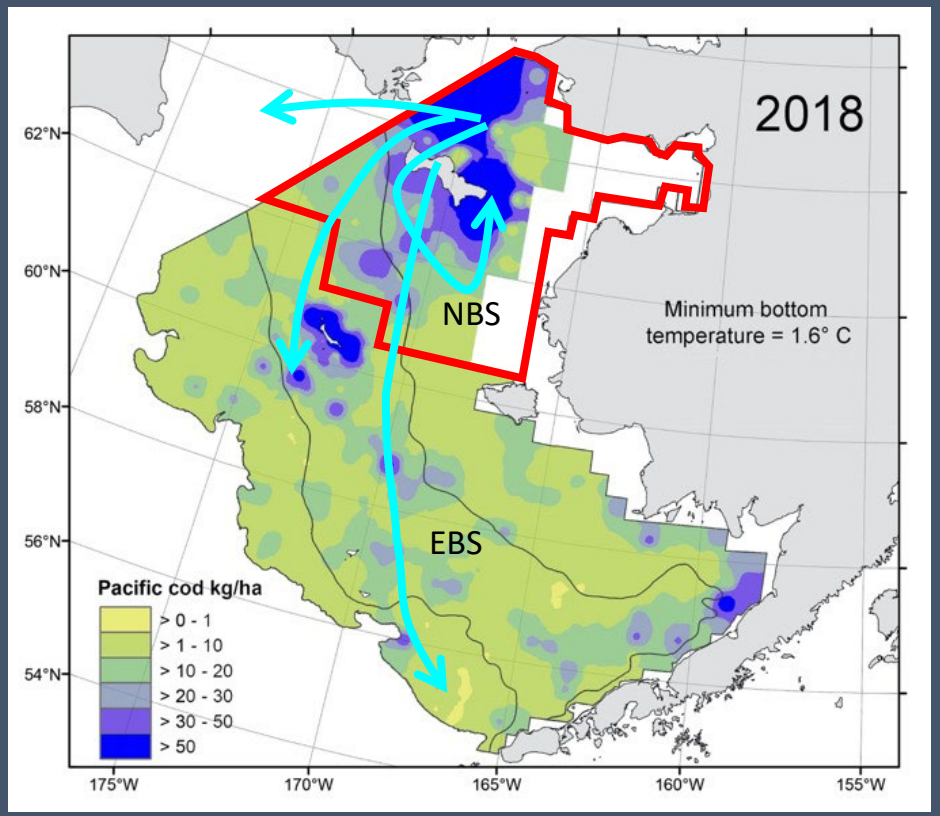
[1]Kingfisher Marine Research, [2]Alaska Fisheries Science Center, [3]Aleutians East Borough, [4]Lynker Technologies

Pacific cod (*gadus macrocephalus*)

- High-value commercial fishery
- Ecologically important predator
- Migrates between winter spawning and summer foraging areas

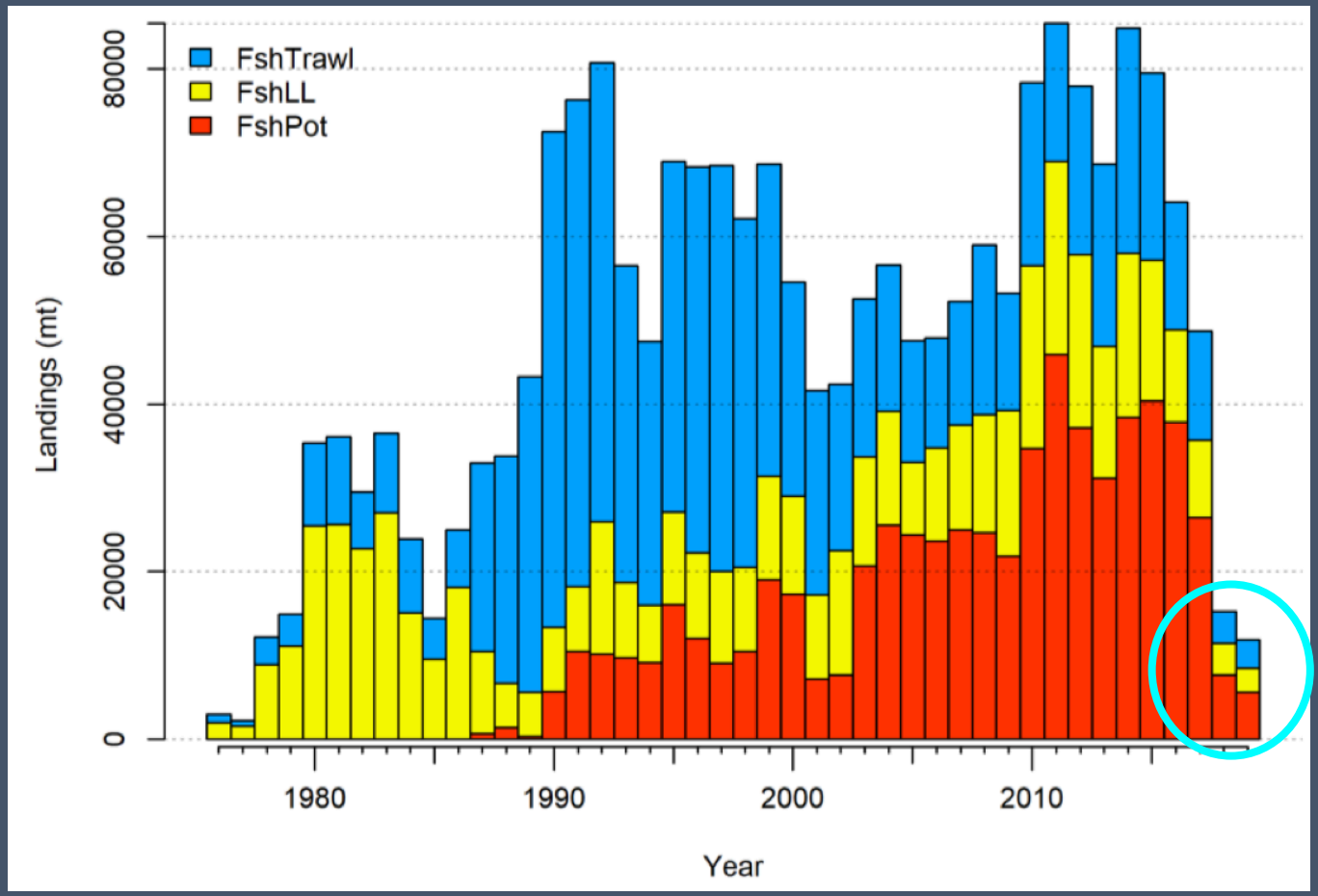
Pacific cod distribution in Bering Sea





Stevenson and Lauth, 2019. Bottom trawl surveys in the northern Bering Sea indicate recent shifts in the distribution of marine species. Polar Biology.

Pacific cod catch in the Gulf of Alaska



2018 , 2019

Barbeaux et al. 2019. Assessment of Pacific cod in the Gulf of Alaska. Figure 2.11. Gulf of Alaska Pacific cod catch from 1977 – 2019. Note that 2019 catch was through October 2.

2019: Studying seasonal movement Pacific cod with Pop-up Satellite Archival Transmitting tags (PSATs)

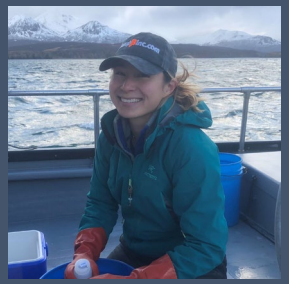
PSATs

- Fishery independent locations

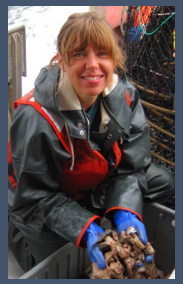
- Detailed information on migrations

The Pacific Cod Tagging (PACT)Team

Susanne McDermott
NOAA AFSC

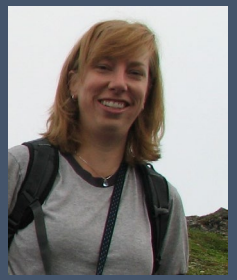


Charlotte Levy
Aleutians East Borough



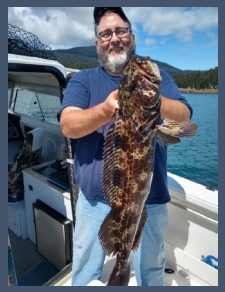
Julie Nielsen
Kingfisher Marine Research

Liz Dawson
NOAA AFSC



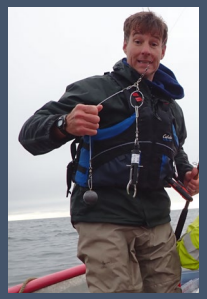
Kim Rand
Lynker Technologies

Bianca Prohaska
NOAA AFSC

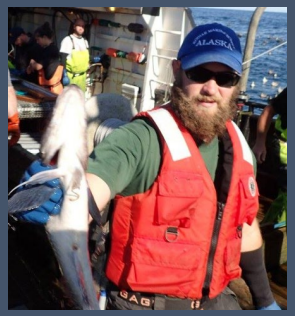


Steve Barbeaux
NOAA AFSC

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

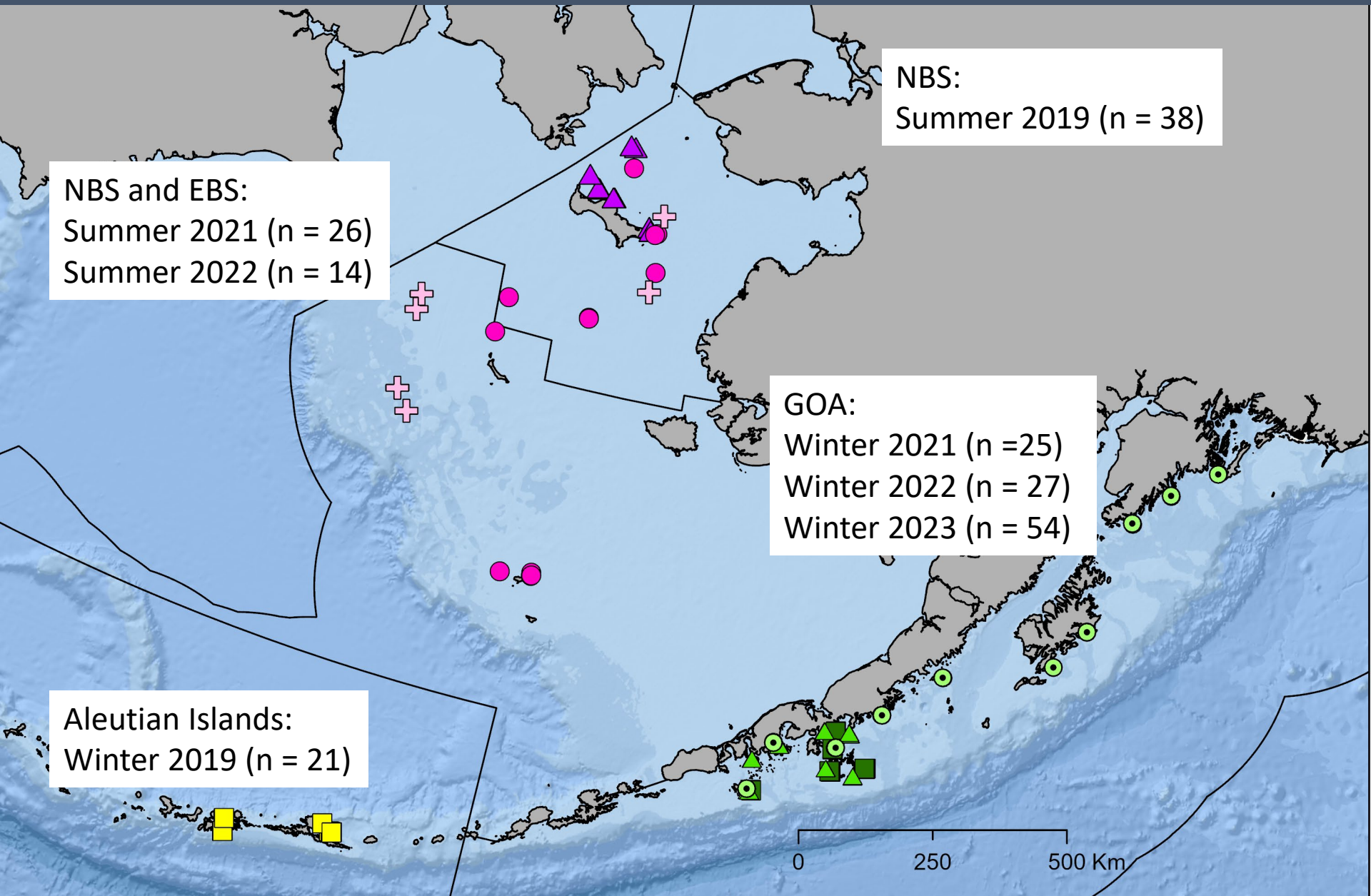
Collaborators:

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

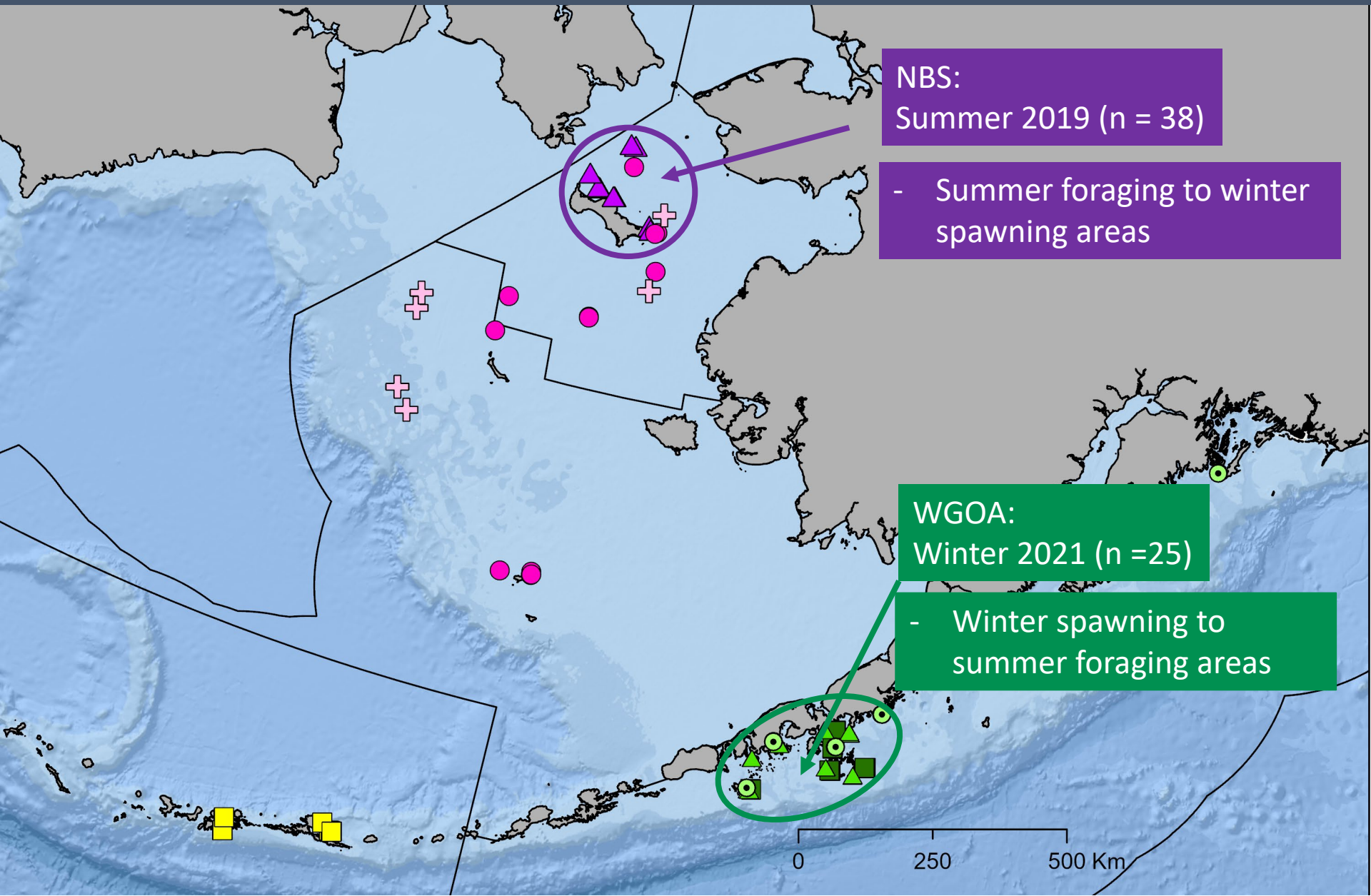
Other Funding Sources:

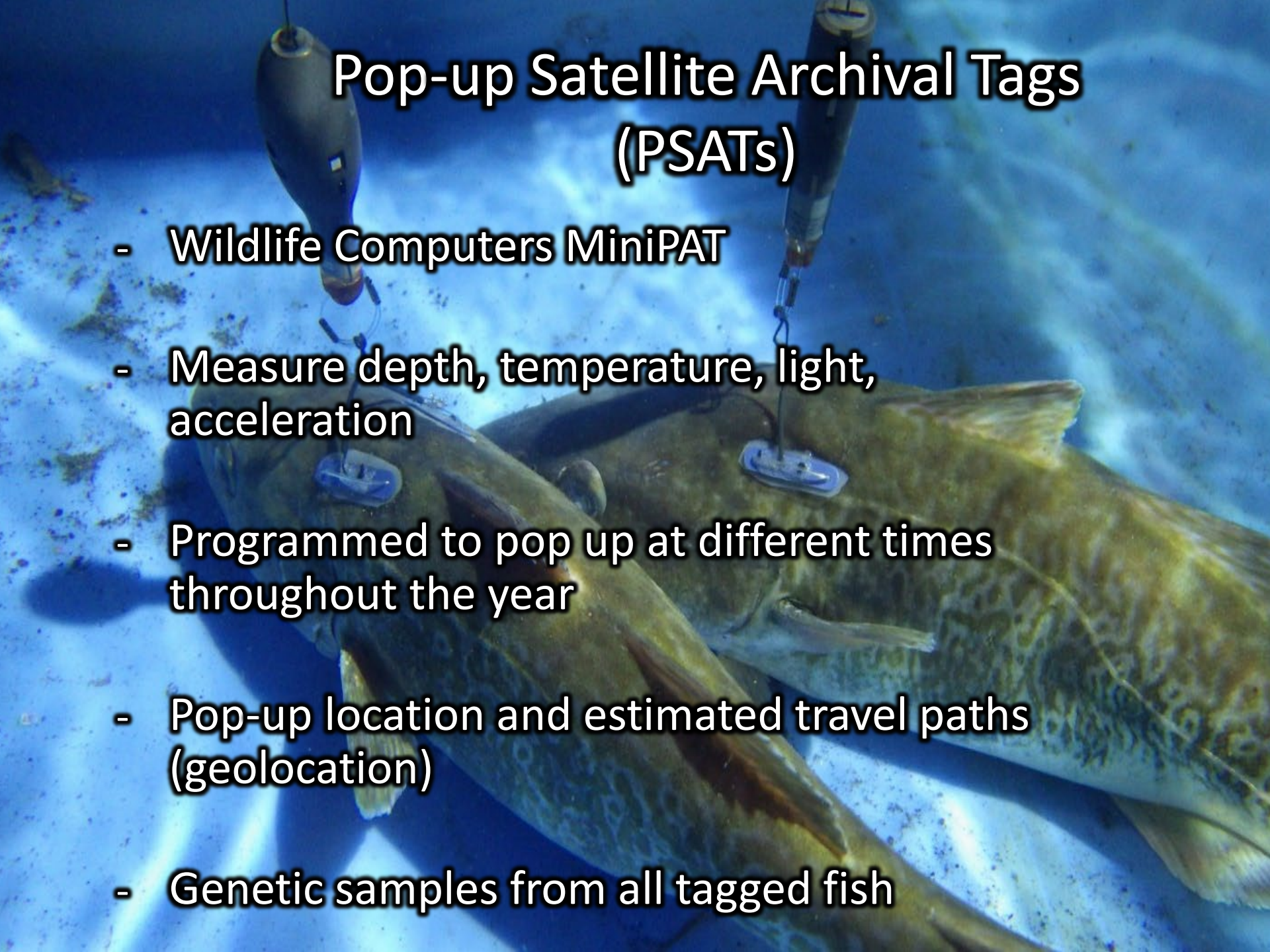
- North Pacific Research Board
- National Cooperative Research Program
- MSA funding
- Pacific States Marine Fisheries Commission

Pacific cod PSAT releases to date: n = 201



Pacific cod seasonal movement examples





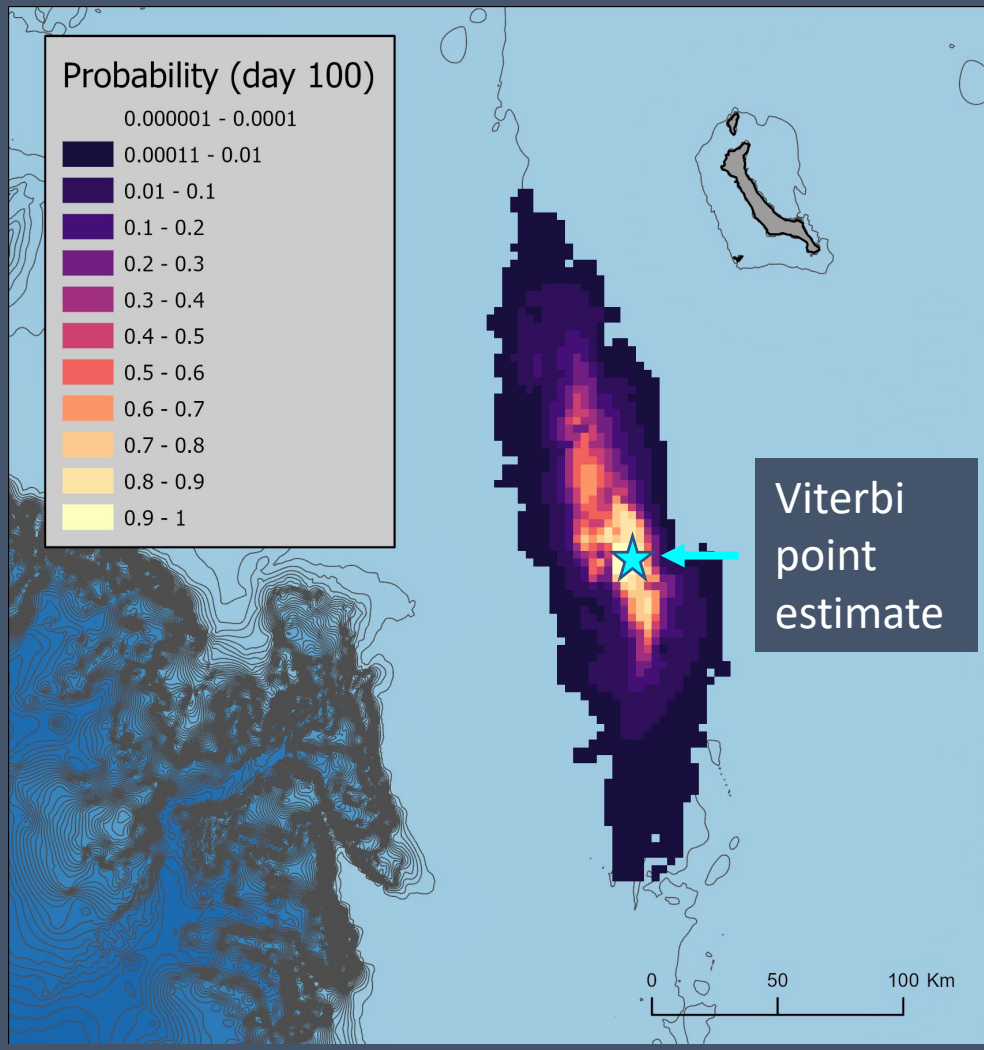
Pop-up Satellite Archival Tags (PSATs)

- 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)*

- Geolocation based on maximum daily depth and light-based longitude
- Study area: 3 km grid
- Individuals:
  - Probability in each study area grid cell each day
    - Viterbi point estimates: most probable sequence of grid cells occupied
- All tags: combine probabilities cell-wise for the same time period:
  - Spawning/foraging areas
  - Monthly probabilities by region



*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.

2019 Northern Bering Sea (NBS) capture and tagging

(Summer foraging to winter spawning)

August/September release

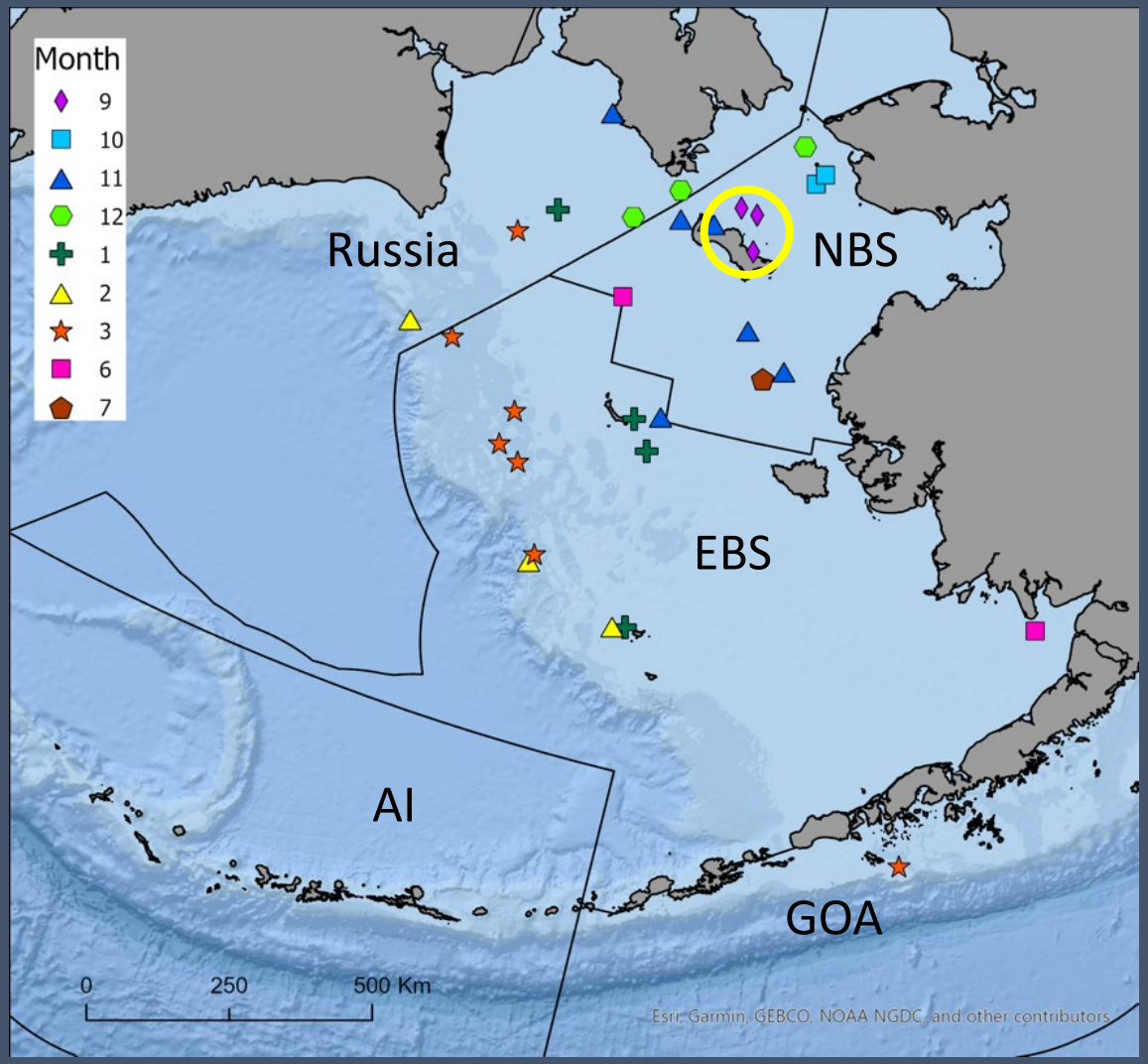
NOAA summer survey:
F/V Alaska Knight
F/V Vesteraalen
- Capture by rod and reel
- n = 30

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



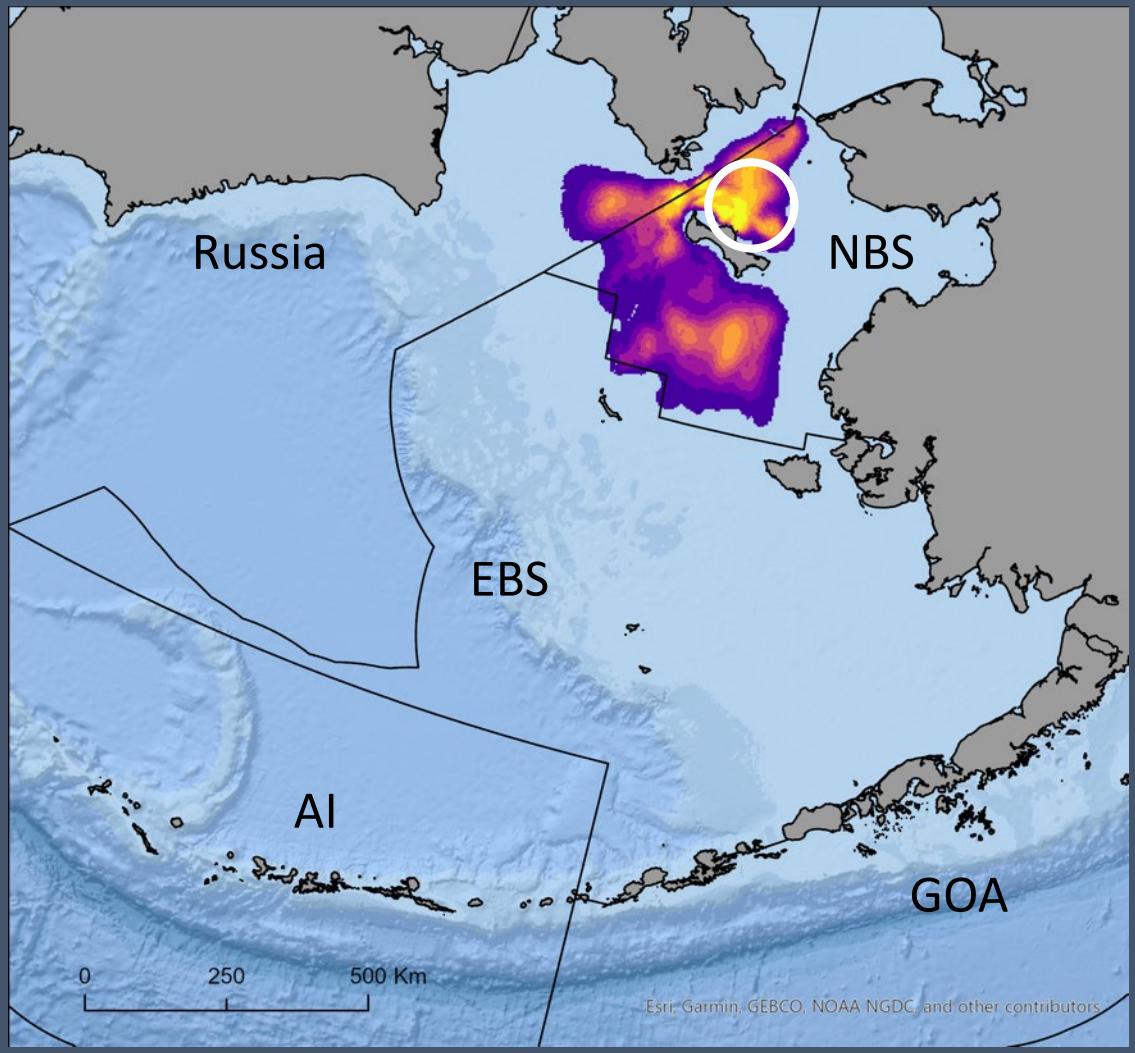
- 33 of 38 tags
- 6 recovered in fishery
- No tagging mortality
- Geolocation for 31 fish

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

Monthly combined probability

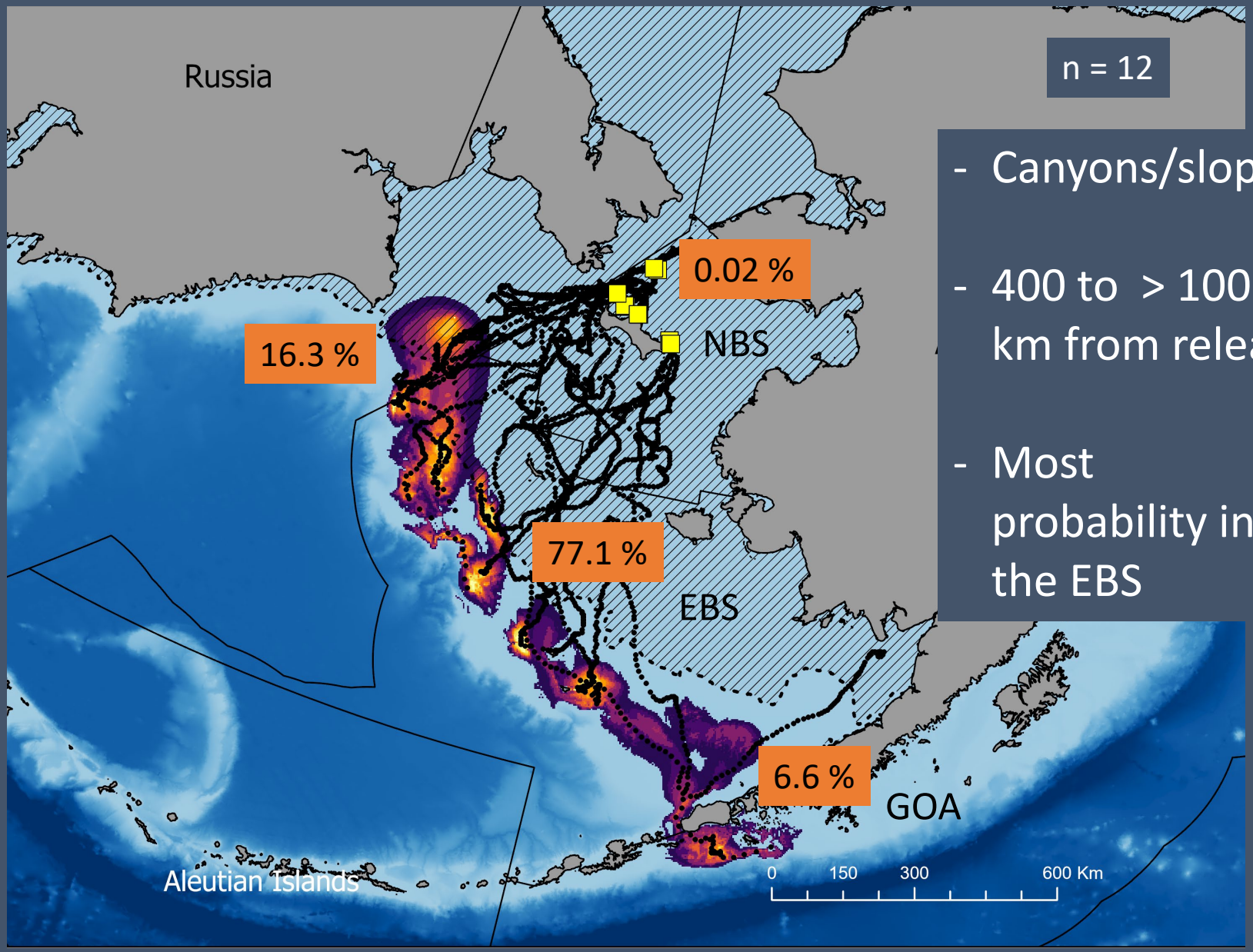
Month **September 2019**

Sample size **n = 31**



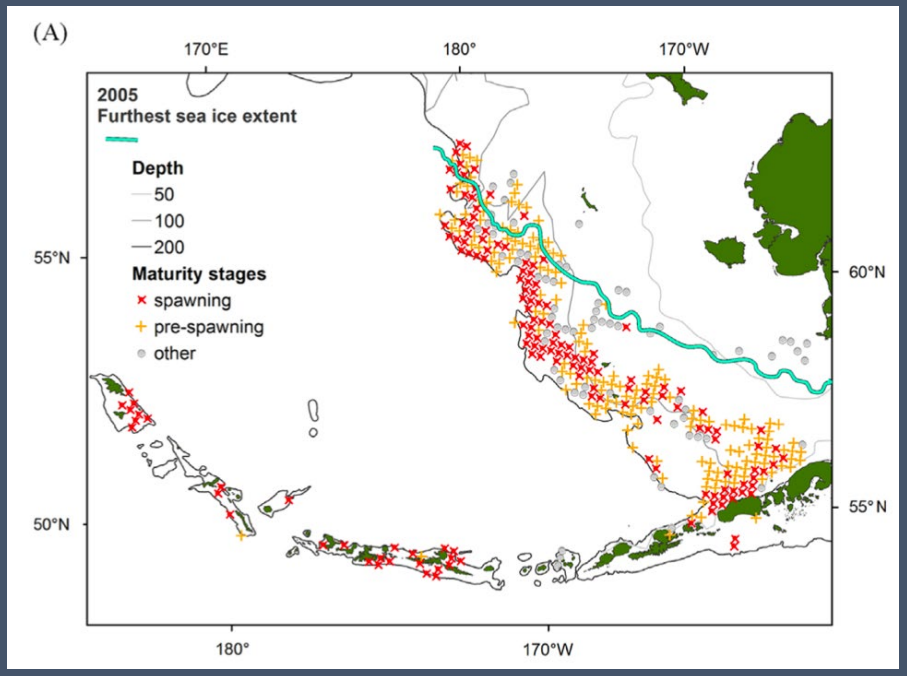
Results: 2019 NBS (summer to winter and annual movement)

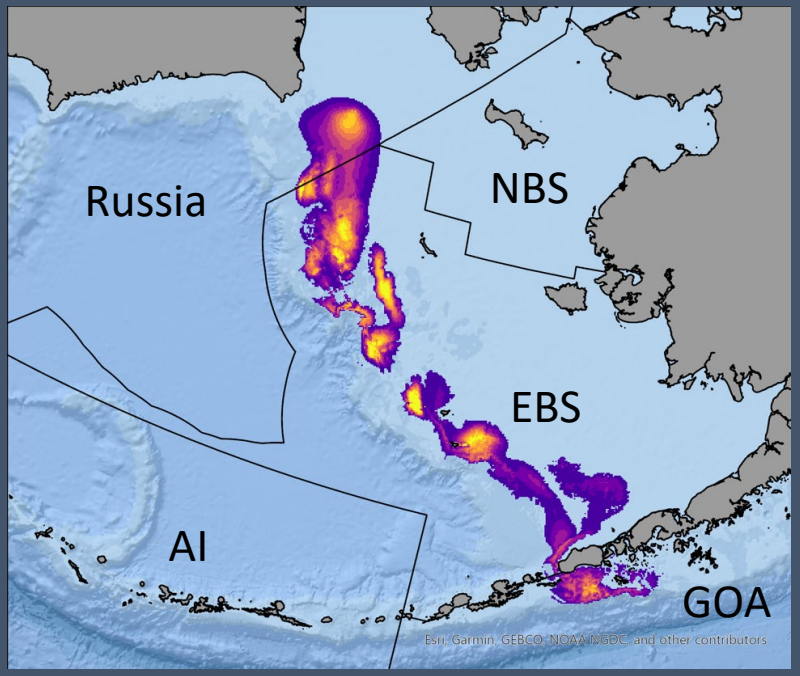
Probability during spawning (Feb 14 – March 31)



- Canyons/slopes
- 400 to > 1000 km from release
- Most probability in the EBS

Known spawning locations

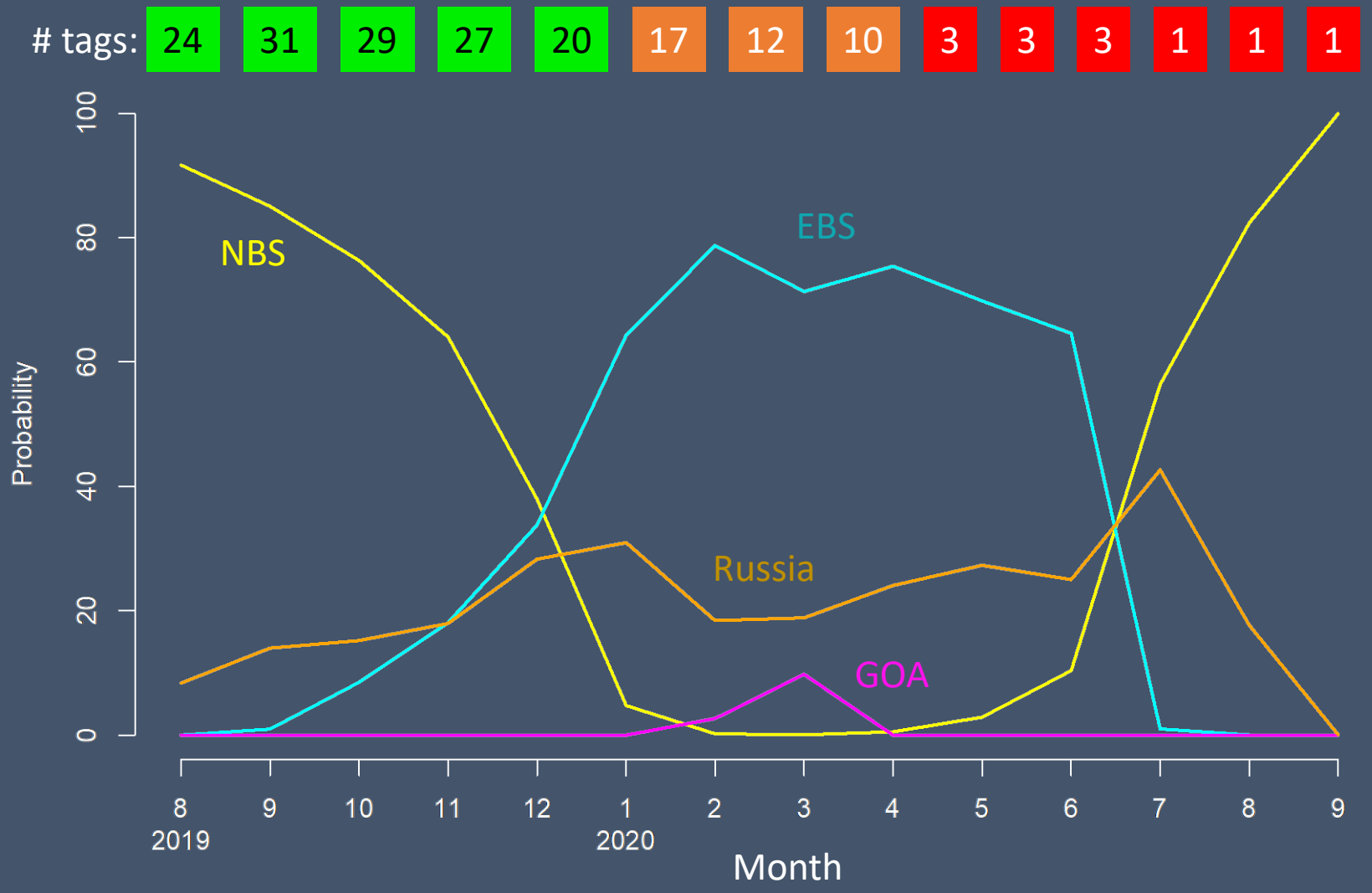




Neidetcher et al., 2014. Spawning phenology and geography of Aleutian Islands and eastern Bering Sea Pacific cod (*Gadus macrocephalus*). Deep Sea Research.

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

Monthly probability by region



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
- 2021/2022 preliminary results similar

2021 Western GOA capture and tagging

(Winter spawning to summer foraging)

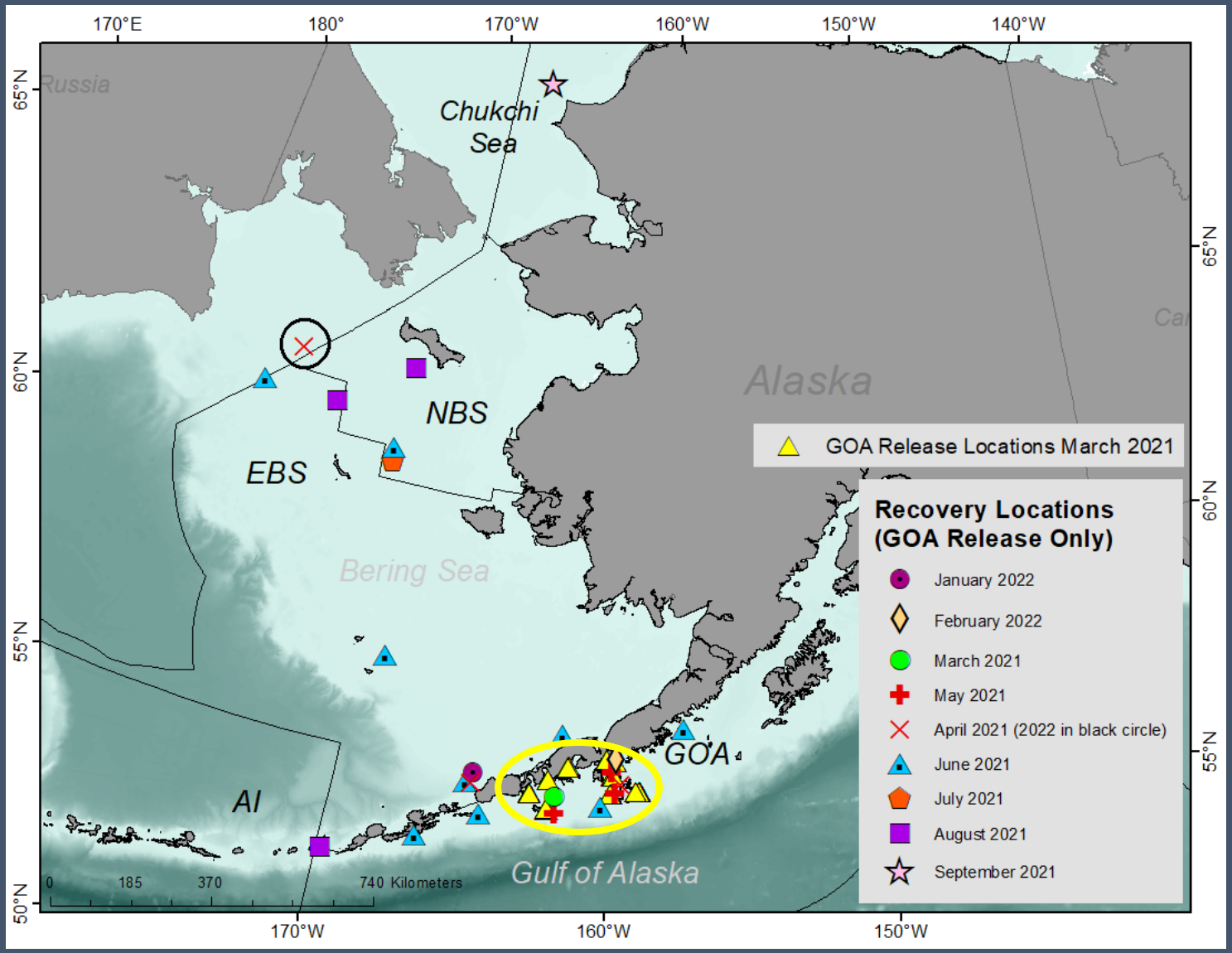
March release

Chartered survey:
F/V Decision

n = 25

- Capture in pots
- Allowed to off-gas
- Depths < 100 m
- Released with descender
- Biological samples collected
- Conventional tags released

Pop-up locations

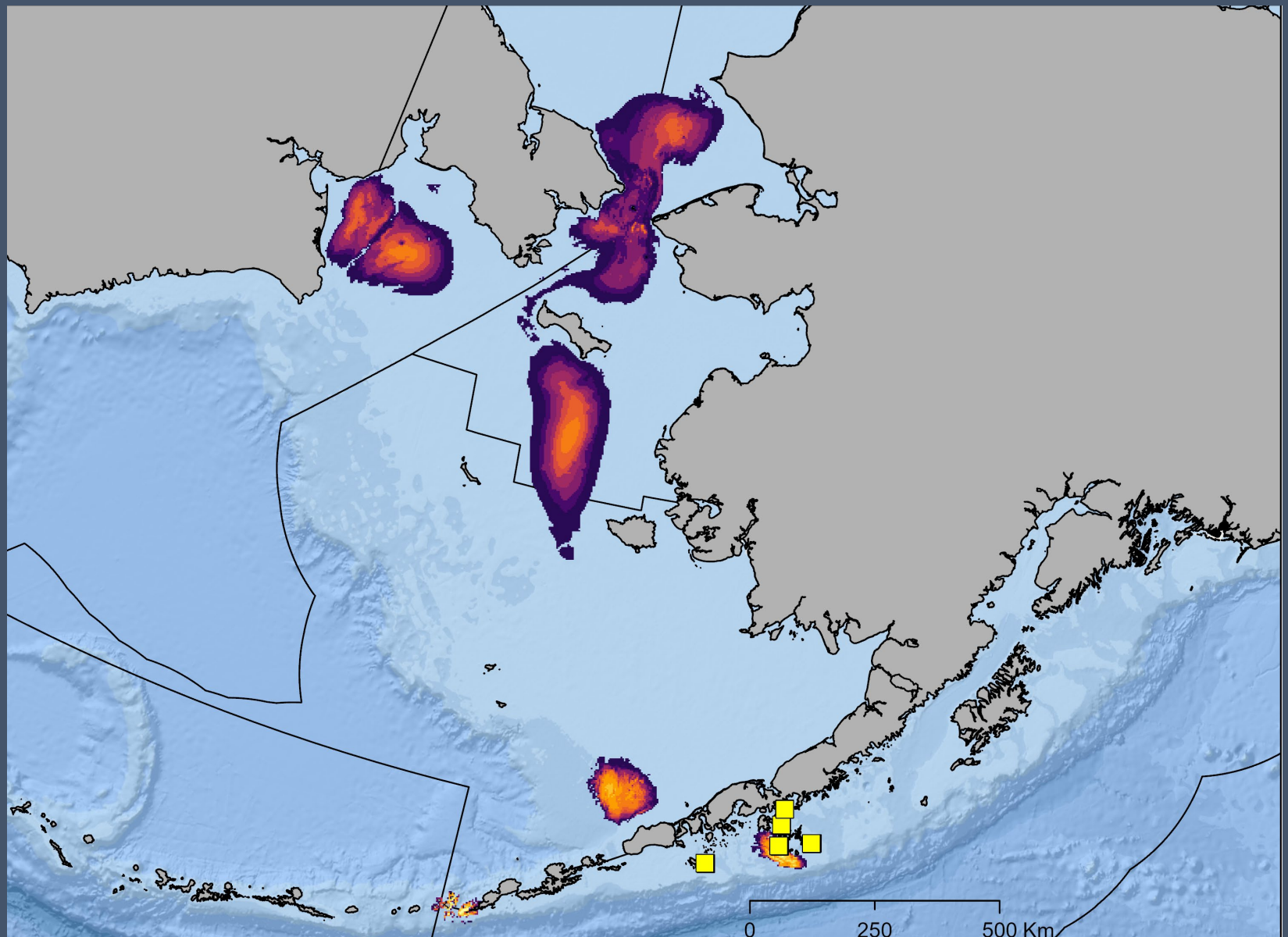


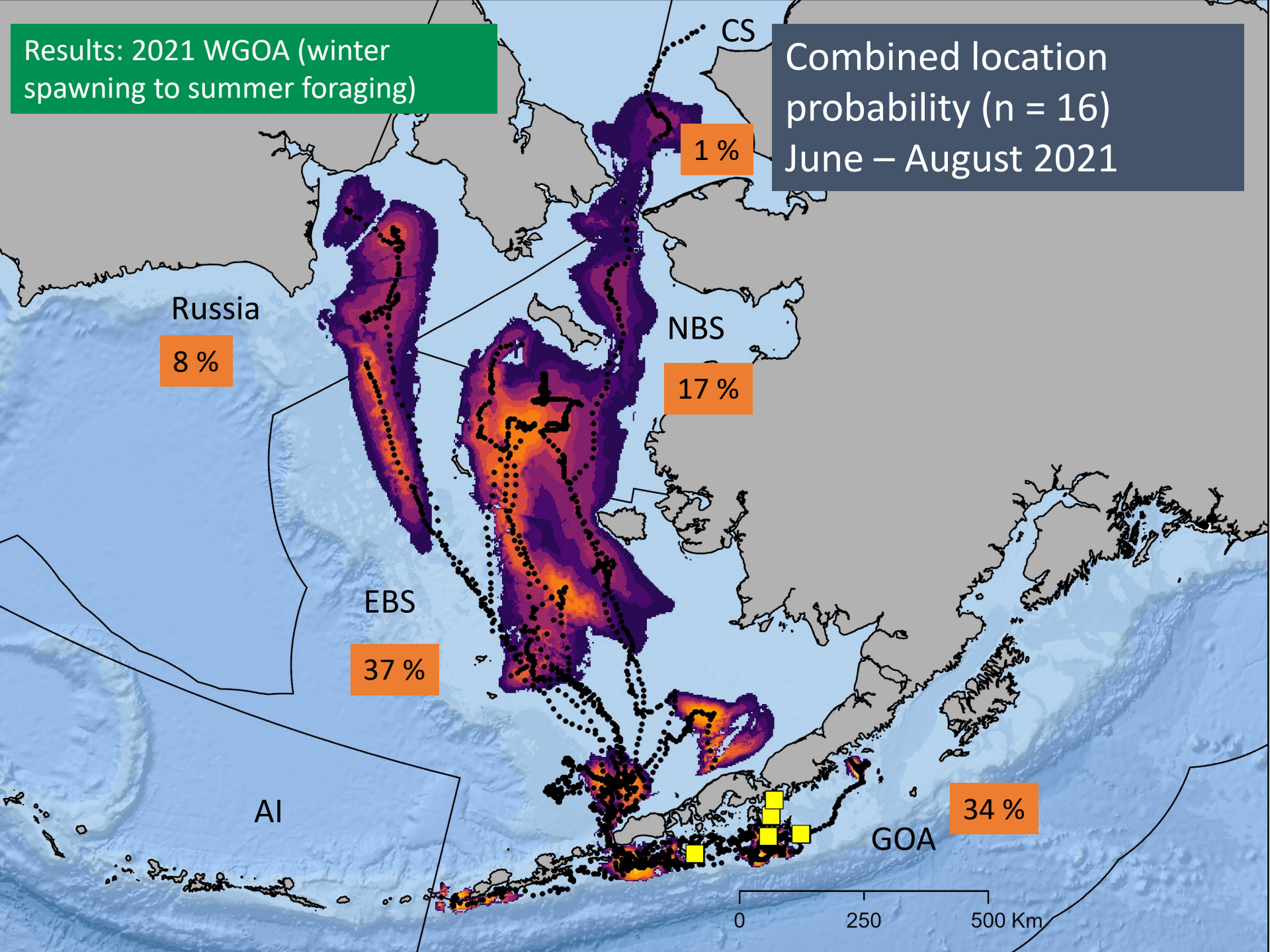
- 23 of 25 tags
- 3 recovered in fishery
- No tagging mortality
- Geolocation for 23 fish

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

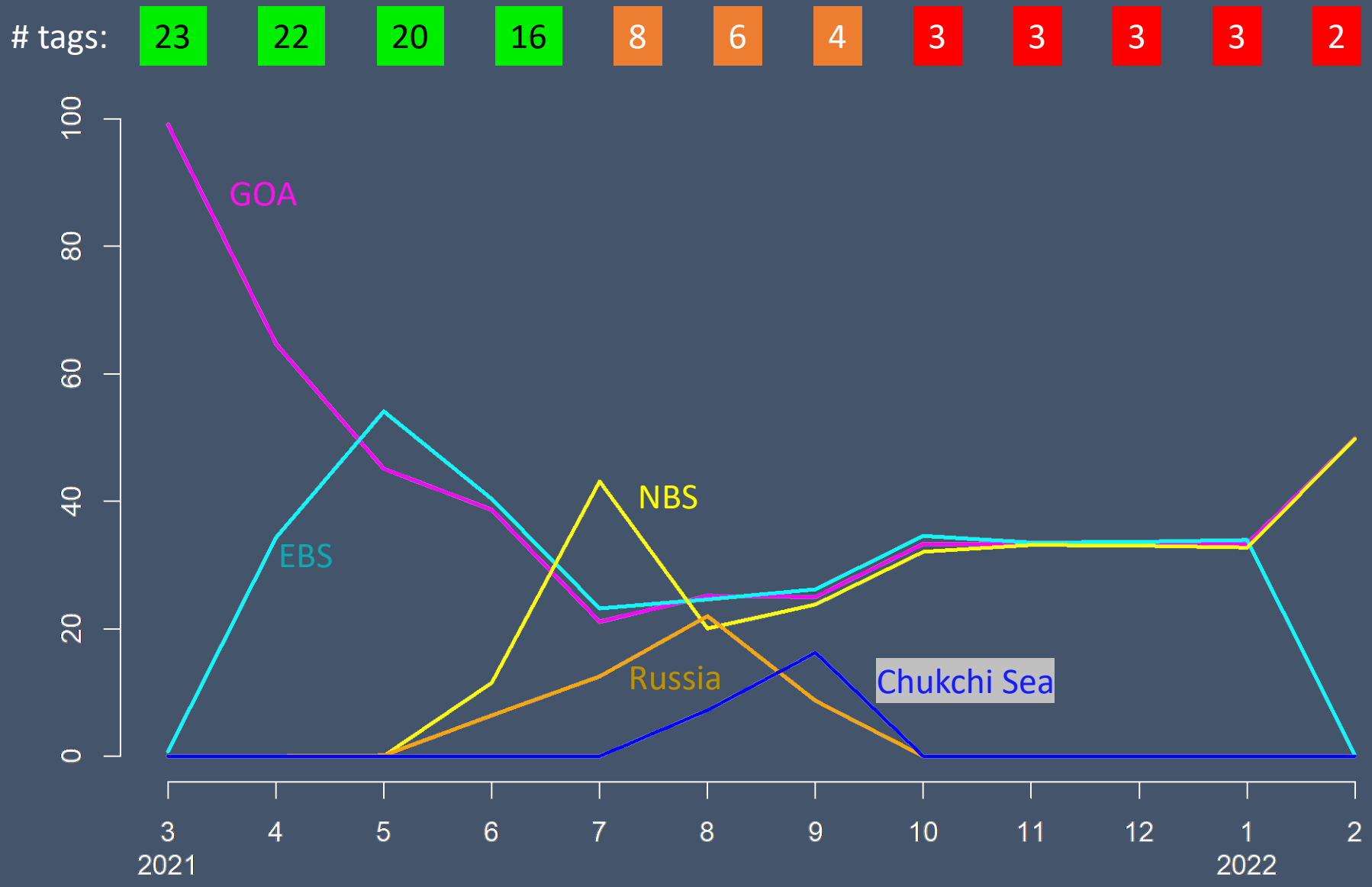
Month April 2021 .1

Sample size n = 22




Results: 2021 WGOA (winter spawning to summer foraging)
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



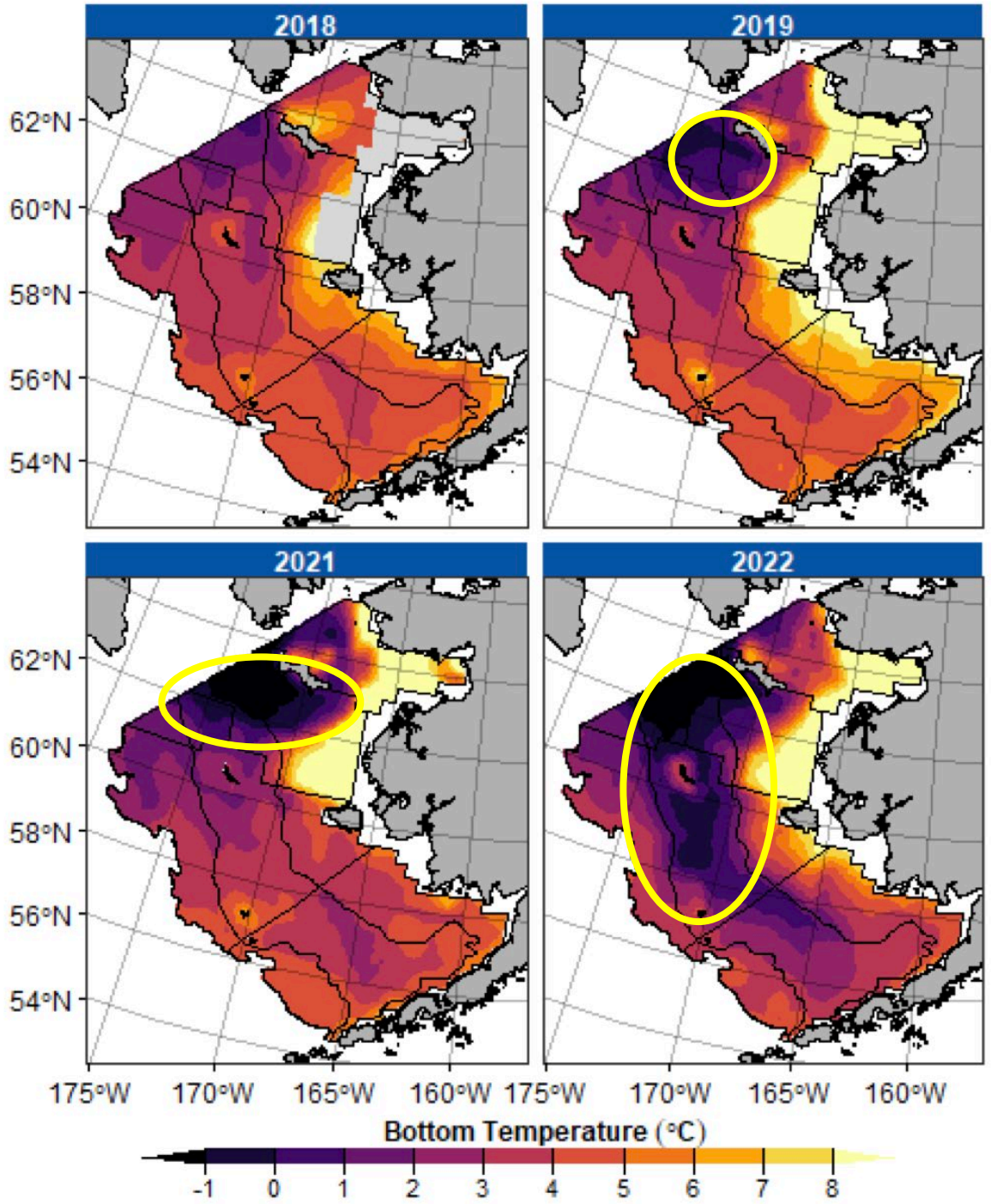
Summary: 2021 WGOA (winter spawning to summer foraging)

- Extensive seasonal connectivity between WGOA and Bering Sea

- Some seasonal connectivity between WGOA and Russia/Chukchi sea

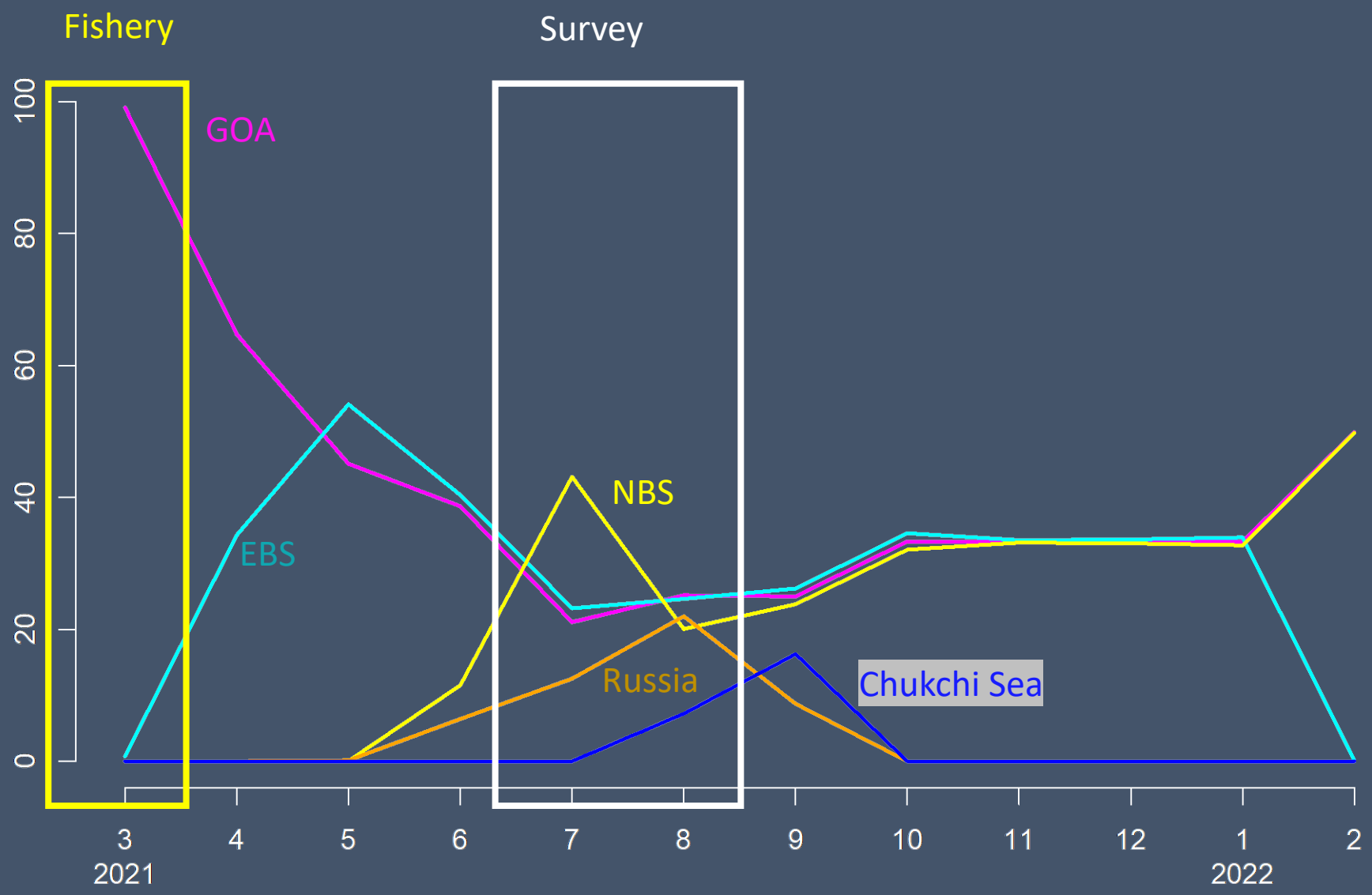
- Preliminary 2022 results tell a different story!
  - 2021: 12/17 (70%) fish at liberty longer than June migrated out of GOA
  - 2022: 5/25 (20%)

Bering Sea bottom temperature

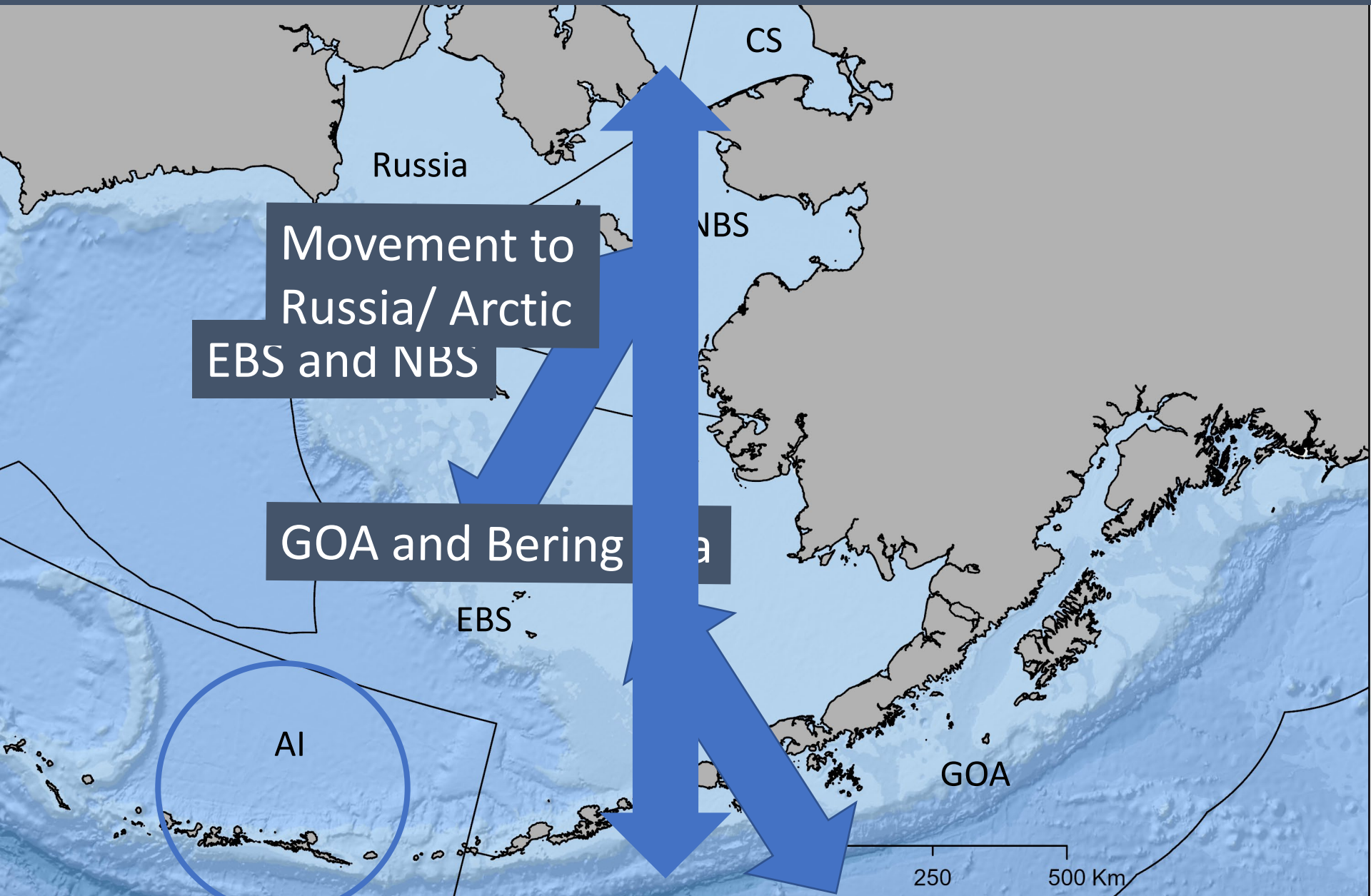


Courtesy of Sean Rohan, NOAA AFSC

Management implications: seasonal change in distribution



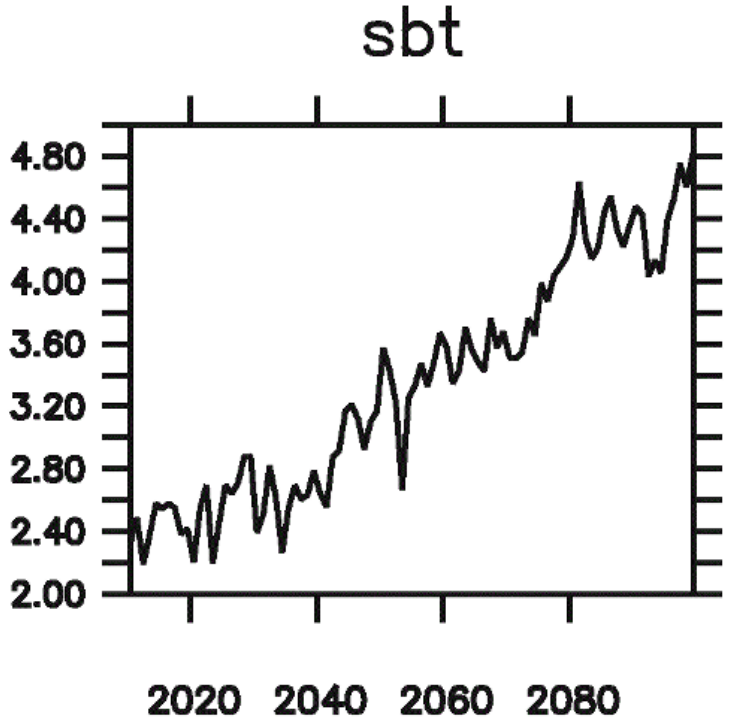
Management implications: seasonal connectivity



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

Current and future research

- Current:
  - Annual movement (site fidelity)
  - Behavior
  - Genetics
  - Diet
  - Spawning phenology
  - Movement modeling with habitat preference

- Future:
  - GOA releases during summer
  - Another winter survey in WGOA/CGOA in 2024
  - More summer releases in Bering 2023/2024

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

NMFS Scientific personnel:

Duane Stevenson

Cecilia O'Leary

Ned Laman

Adriana Meyers

Sean Rohan

Bianca Prohaska

Nicole Charriere

Jennifer Gardner

Cynthia Yeung

Reyn Yoshioka

Lukas DeFilippo

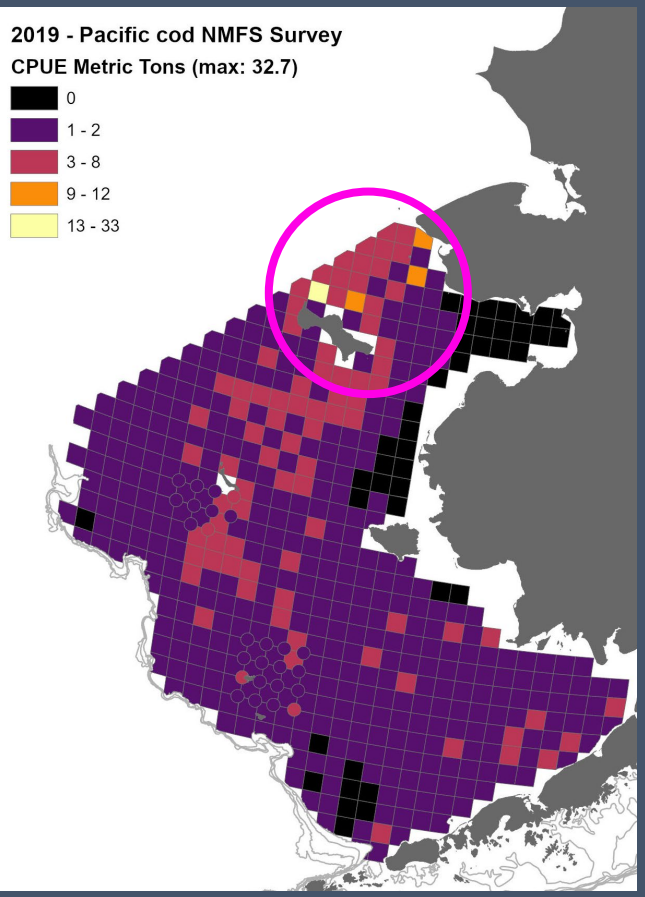
Chris Long

Emily Ryznar

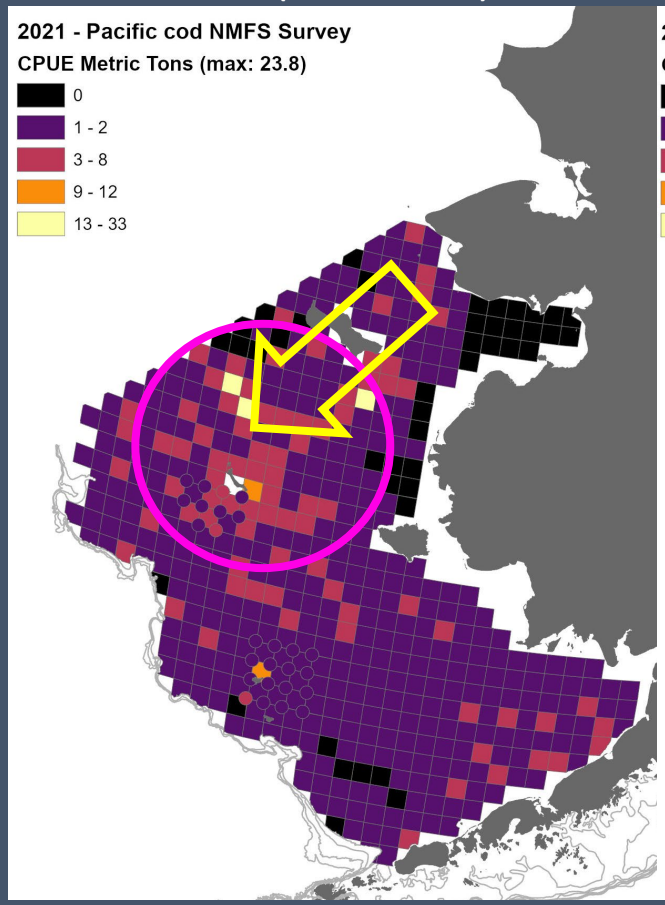
Comments? Questions?
Julie.Nielsen@gmail.com
Susanne.McDermott@noaa.gov

Pacific cod distribution in summer survey

2019 (very warm!)



2021 (still warm)



2022 (colder)