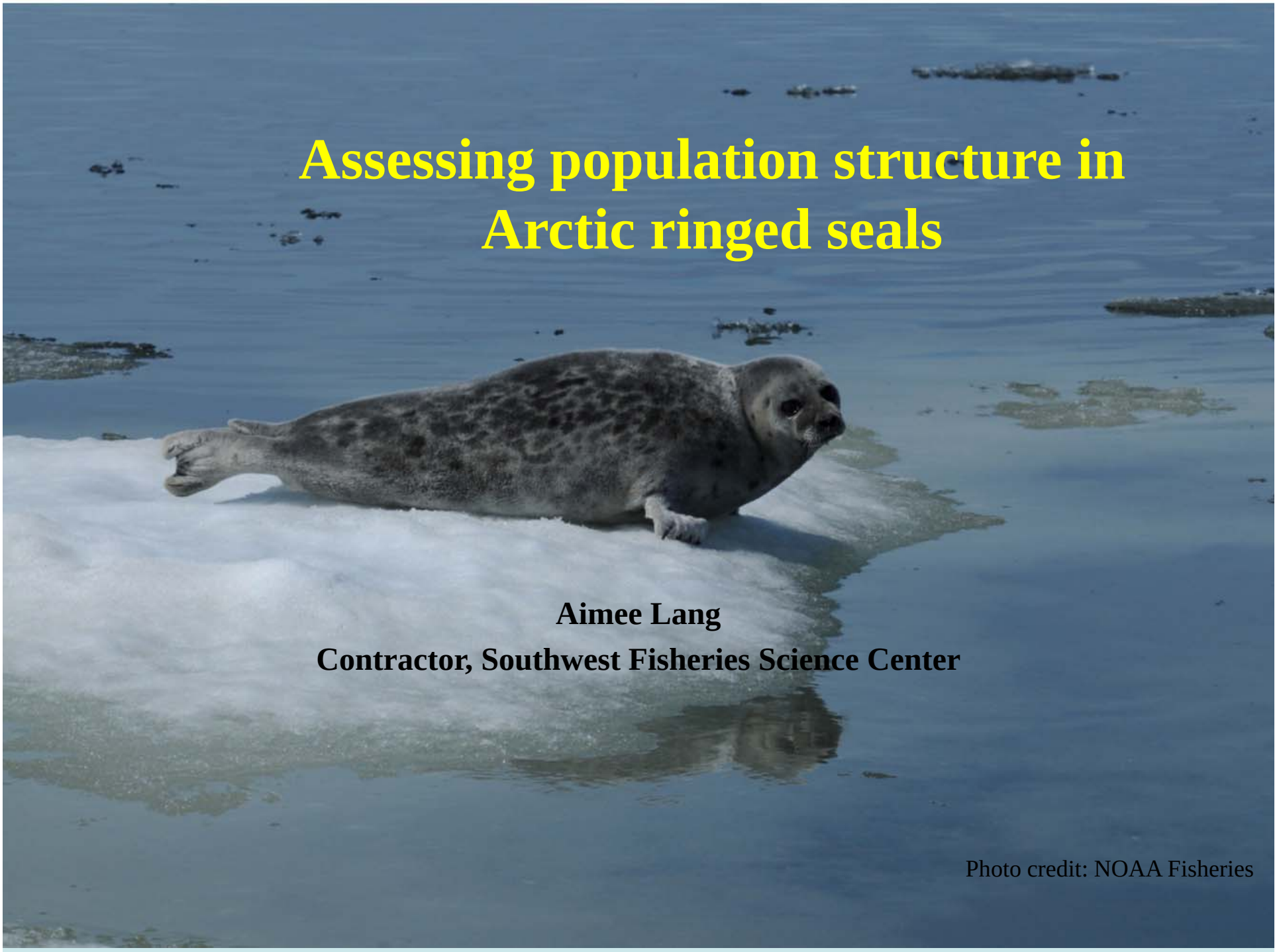


Assessing population structure in Arctic ringed seals

Aimee Lang

Contractor, Southwest Fisheries Science Center

Photo credit: NOAA Fisheries

- **Collaborators/Contributors**
  - Peter Boveng and Heather Ziel, AFSC
  - Lori Quakenbush and the Ice Seal Biomonitoring Program, ADFG
  - Barb Taylor, Kelly Robertson, and Morgane Lauf, SWFSC
  - Karyn Rode, USGS

Taxonomy and status:

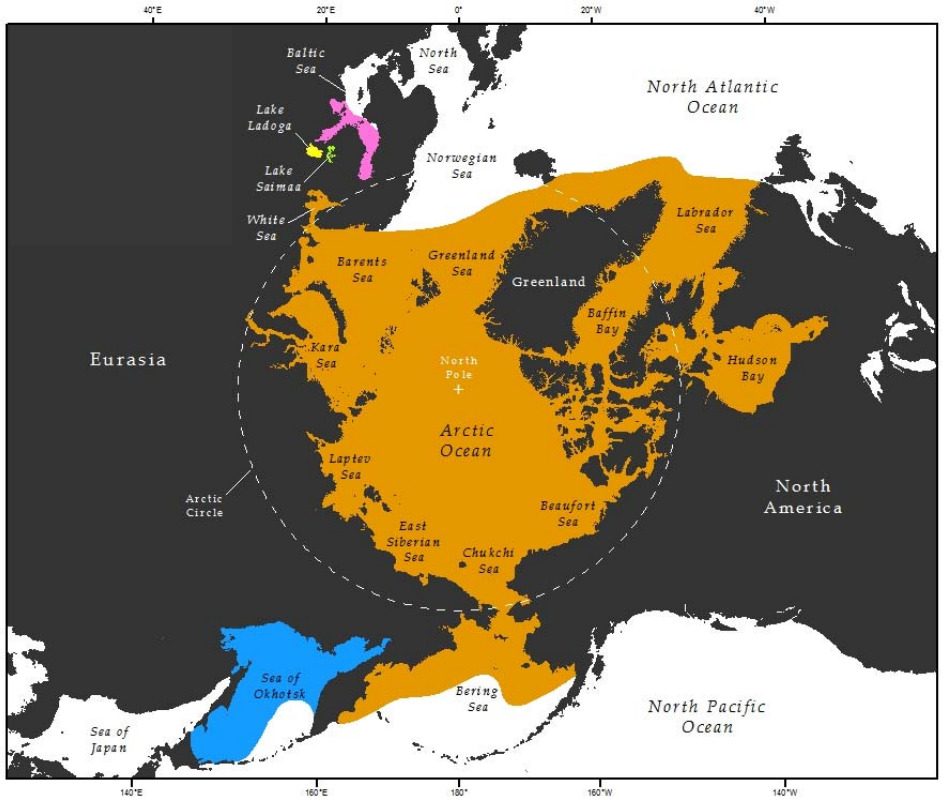
Arctic ringed seal (P. h. hispida)
IUCN: Least Concern
ESA: Threatened

Okhotsk ringed seal (P. h. ochotensis)
IUCN: Least Concern
ESA: Threatened

Baltic ringed seal (P. h. botnica)
IUCN: Least Concern
ESA: Threatened

Ladoga ringed seal (P. h. lagodensis)
IUCN: Vulnerable
ESA: Endangered

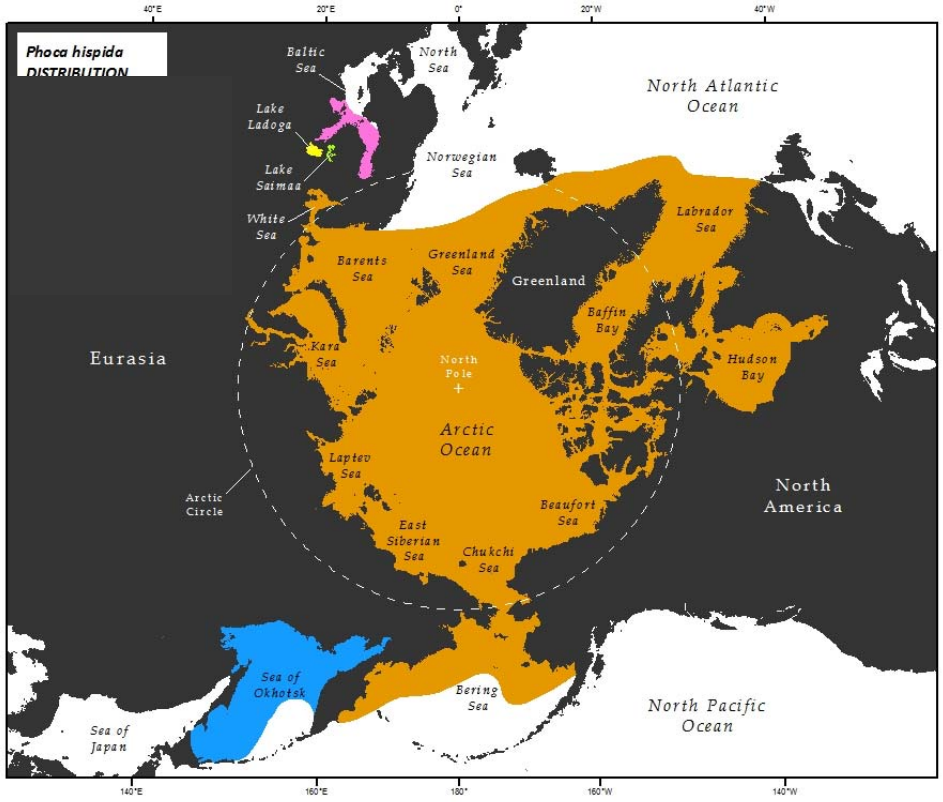
Saimaa ringed seal (P. h. saimensis)
IUCN: Endangered
ESA: Endangered



NOAA FISHERIES

Within the Arctic:

- Widely distributed and abundant
  - ~3 million across range (Laidre et al. 2015)
  - ~300,000 in the Alaskan Chukchi and Beaufort (Kelly et al. 2010)
- Within U.S. waters, only a single Alaskan stock is recognized
  - Co-managed by NMFS and the Ice Seal Committee



Conservation and management concerns:

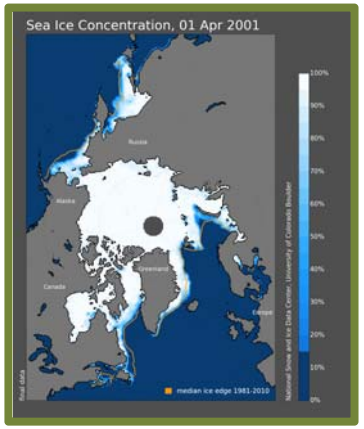
- Ringed seals depend on sea ice and snow cover for survival and reproduction
- Sea ice extent, thickness and seasonal duration is declining
- Declines in body condition, reproductive rates, pup survival, and foraging behavior have been reported in some areas[1]

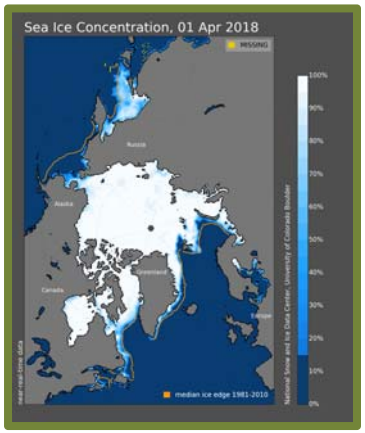
Photo credit: Shawn Dahle, NOAA
Permit #15126

[1] Ferguson *et al.* 2005, 2012, 2017; Stirling 2005, Harwood *et al.* 2012b, Hamilton *et al.* 2016, Yurkowski 2016)

Why do we need to understand population structure?

- Some regions of the Arctic are impacted by climate warming more severely than others
  - If no population structure exists, then seals that have previously used impacted areas will move to other areas where suitable habitat remains
  - If seals return to breed in the same area where they were born (i.e., natal philopatry), localized depletion may occur





Images:nsidc.org

Population structure: What do we know so far?

- Satellite tagging:
  - Seals range widely during the foraging season
  - Movements more restricted during the winter-spring months
  - Tagged seals have been shown to return to the same wintering areas in subsequent years
- Genetics:
  - Genetic analyses have failed to detect population structure throughout most of the range of the Arctic subspecies (Davis et al. 2008, Martinez-Bakker et al. 2013)
    - These studies have relied on mtDNA sequence data and a small number of nuclear markers (9-11 microsatellites)

Photo credit: Michael Cameron, NOAA
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Population structure: What do we know so far?

- Genetics:
  - But ....
    - Genetic differences accumulate slowly in large populations
    - Traditional markers may have little power to detect low, but potentially biologically significant, levels of differentiation
- Recent technological advances ("Next Generation Sequencing") allow large numbers of SNPs to be genotyped
  - Cost-effective
  - Genome sequence data not required
- Such extensive datasets have been shown to substantially increase the power of genetic analyses even with limited sample sizes

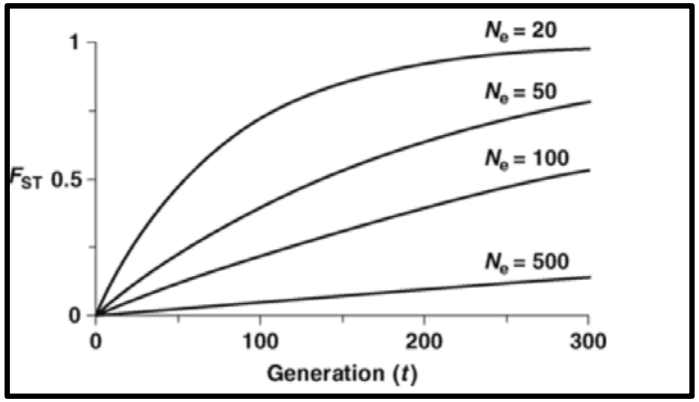


Fig 14.8. Relationship between FST, effective population size (Ne), and time (in generations). From Allendorf et al. 2010

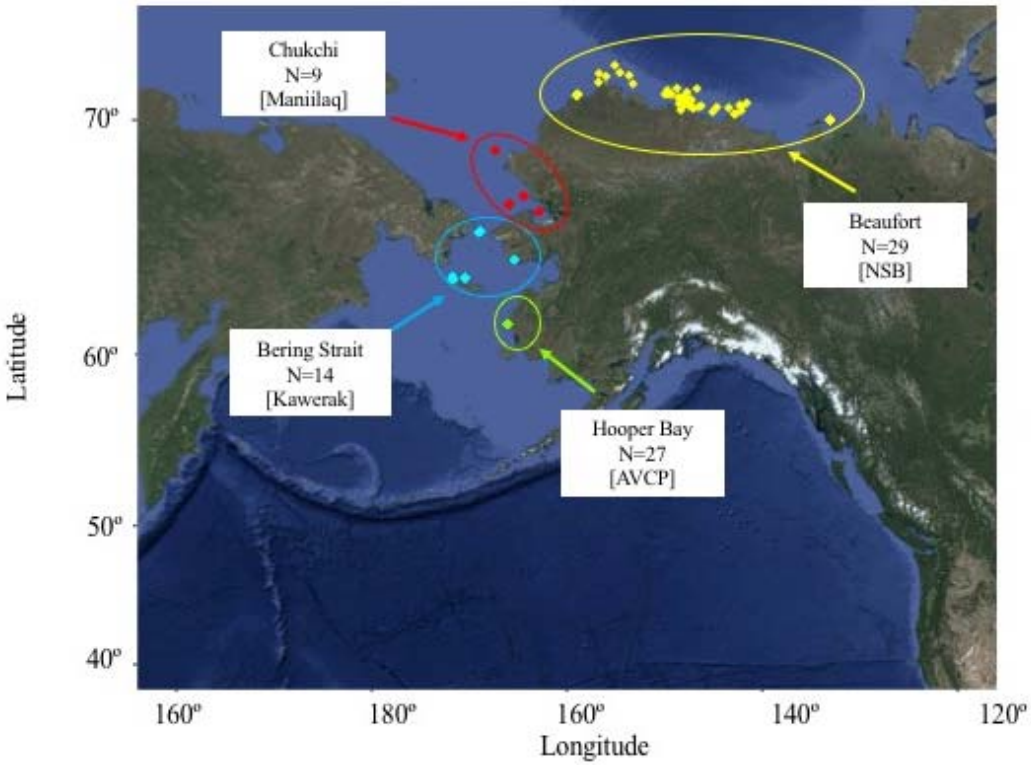
Objective: Evaluate whether population structure can be detected in Arctic ringed seals using a large genome-wide dataset of SNP markers

- SNP discovery and genotyping approach: DArTseq
  - Diversity Arrays Technology Pty Ltd
  - ddRADseq-like approach

Get a bigger hammer!

Samples:

- Samples from 90 individuals
- All collected between March – May (breeding season)
- Majority from harvested seals; remainder from seals killed by polar bears

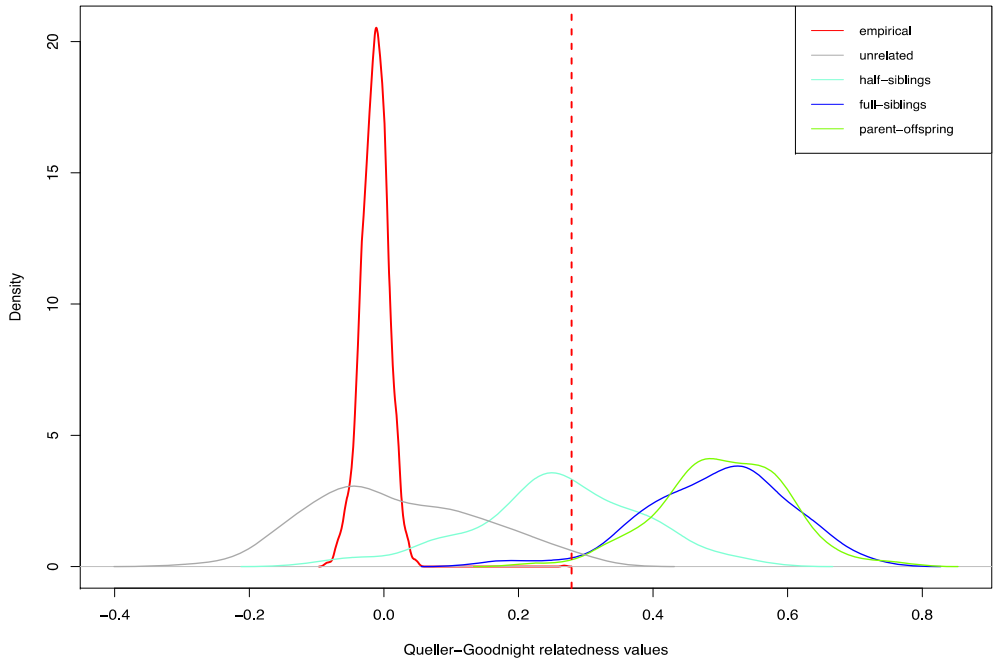


Results: Quality control

Filtering Criterion	# of individuals	# of loci removed	# of loci remaining
Unfiltered dataset	90	100,281	100,281
Multiply aligned	90	660	99,621
Avg read count < 15	90	34769	64,852
Avg read count > 100	90	2697	62155
Monomorphic*	85	12760	49395
Call rate =< 0.8	85	11402	37993
Reproducibility < 0.95	85	253	37740
Secondary loci	85	12927	24813
Individual coverage <0.8	83	132	24681
Minor allele frequency <0.05	83	16632	8049

Results: Relatedness

- Two samples collected in Hooper Bay in the spring of 2008 appear to be paternal half-siblings
- Based on the harvest data, one individual was ~8 mos old and the other ~12 mos
- Provides evidence of a single male mating with multiple females within a given season
- Highlights need to understand more about movements of seals during their first year



Results: Genetic Differentiation

Little to no genetic differentiation between a priori defined geographic strata was detected, although the comparison of samples collected in Hooper Bay and those from the Beaufort Sea were close to significance.

Strata compared:	**F_{ST} (p-value)**	**X^2 p-value**
Hooper Bay (n=27) v. Bering Strait (n=14)	-0.001 (p=0.755)	0.638
Hooper Bay (n=27) v. Chukchi (n=9)	0.001 (p=0.199)	*0.056*
Hooper Bay (n=27) v. Beaufort (n=29)	*0.001 (p=0.081)*	**0.035**
Bering Strait (n=14) v. Chukchi (9)	0.000 (p=0.423)	0.468
Bering Strait (n=14) v. Beaufort (n=29)	0.000 (p=0.445)	0.341
Chukchi (n=9) v. Beaufort (n=29)	0.000 (p=0.638)	0.638

What's next?

- Clustering analyses (e.g., STRUCTURE, DAPC)
  - A priori stratification of samples not required
- Detecting loci under selection
  - May allow for detection of adaptive variation

Photo credit: Michael Cameron, AFSC
MMPA permit 15126

Implications (so far):

- Despite greatly increasing the power of the analyses, the results are generally consistent with previous studies suggesting little to no population structure is present within the Arctic
  - Suggests that the loss of sea ice habitat may not result in the loss of genetic diversity
- However, small, but statistically significant, differences were seen between the most geographically distant strata
  - Genotyping additional samples could be valuable
    - Increase power by increasing sample sizes
    - Fill in sampling gaps

Thank you to the Marine Mammal Commission for funding this work!

Photo credit: Shawn Dahle, AFSC
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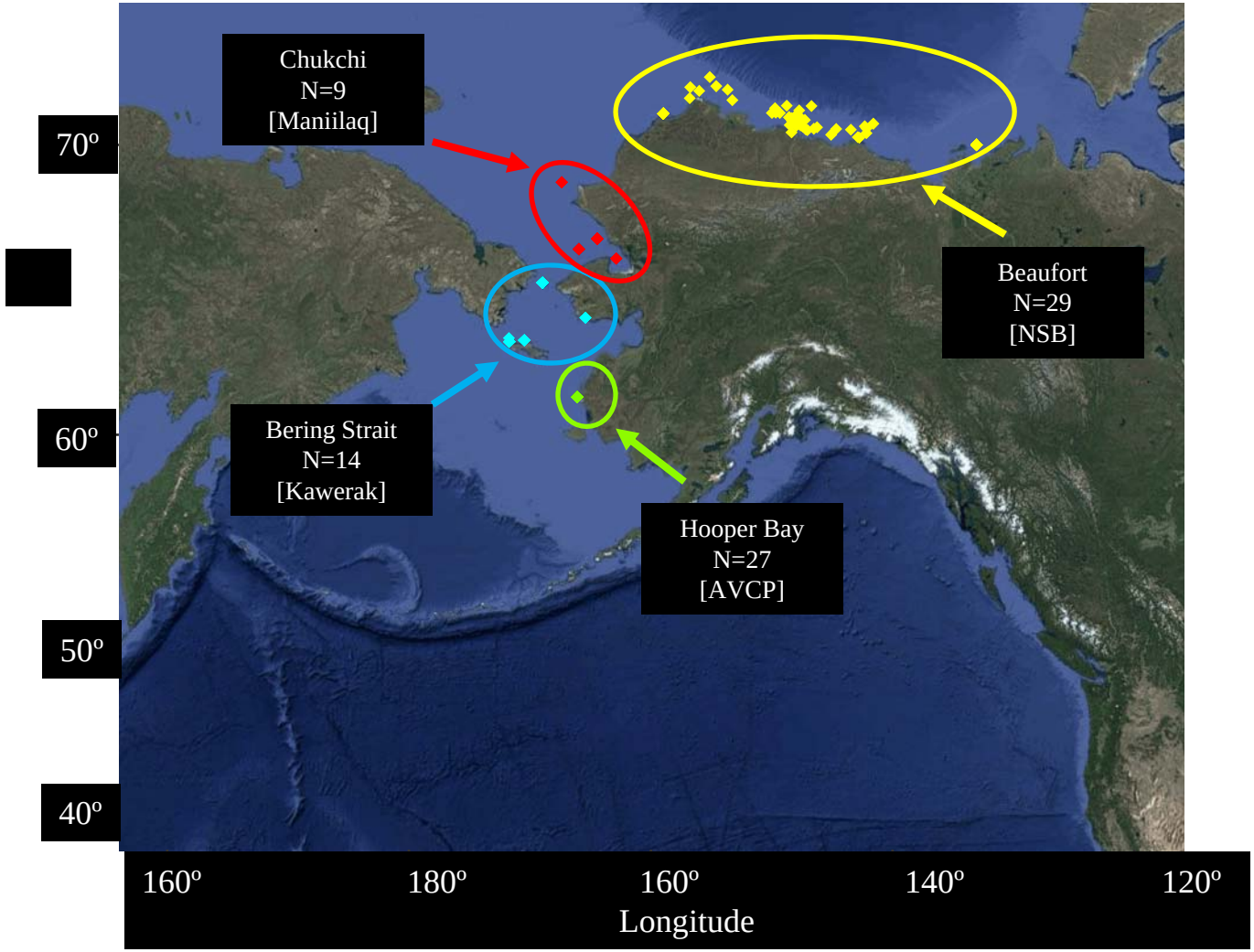

Chukchi
N=9
[Maniilaq]
Beaufort
N=29
[NSB]
Bering Strait
N=14
[Kawerak]
Hooper Bay
N=27
[AVCP]
70º
60º
50º
40º
160º
180º
160º
140º
120º
Longitude

Management:

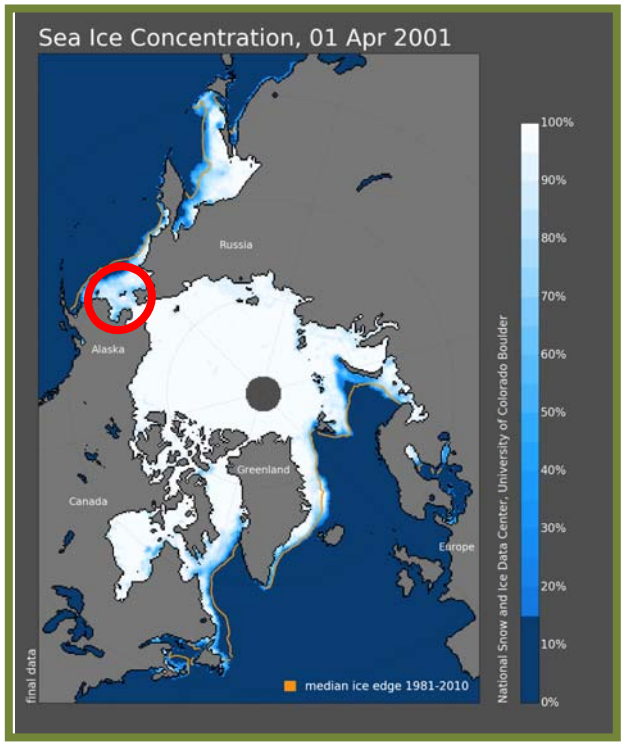
- Objectives of the ISC:
  - Maintain healthy ice seal populations in AK waters
  - Provide for adequate subsistence harvest of ice seals
  - Protect hunting privileges for AK Native subsistence hunters

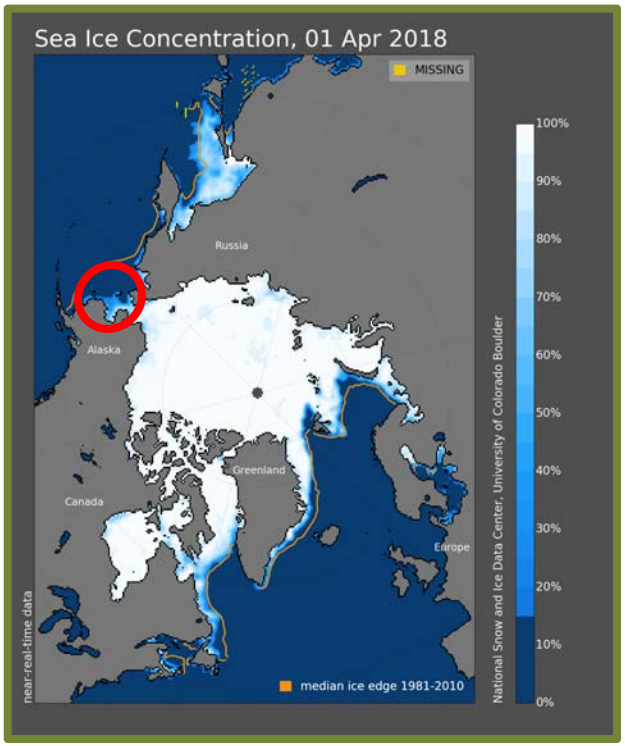
Results: mtDNA

Little to no genetic differentiation between geographic strata was detected, although the comparison of samples collected in the Bering Strait region and those from the Beaufort Sea were statistically significant.

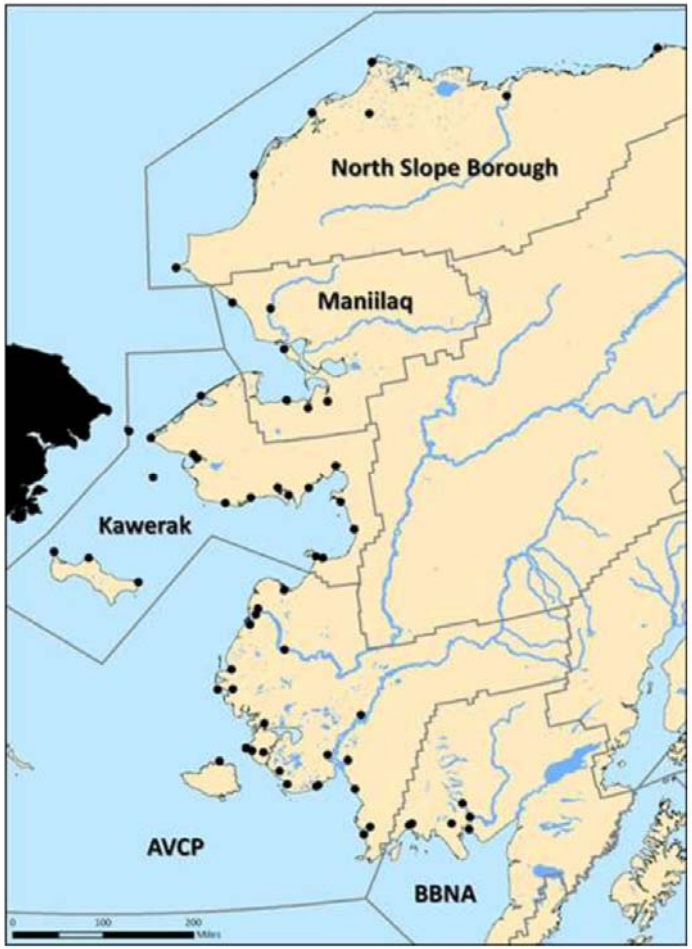
Strata compared:	**Φ_{ST} (p-value)**
Hooper Bay (n=39) v. Chukchi (n=34)	0.003 (p=0.363)
Hooper Bay (n=39) v. Bering Strait (n=105)	-0.003 (p=0.604)
Hooper Bay (n=39) v. Chukchi (n=34)	0.003 (p=0.311)
Hooper Bay (n=39) v. Beaufort (n=116)	0.007 (p=0.130)
Bering Strait (n=105) v. Chukchi (n=34)	0.010 (p=0.118)
Bering Strait (n=105) v. Beaufort (n=116)	**0.009 (p=0.024)**
Chukchi (n=34) v. Beaufort (n=116)	0.007 (p=0.148)

Unstable **habitat?**





Images courtesy of nsidc.org


North Slope Borough
Maniilaq
Kawerak
AVCP
BBNA