

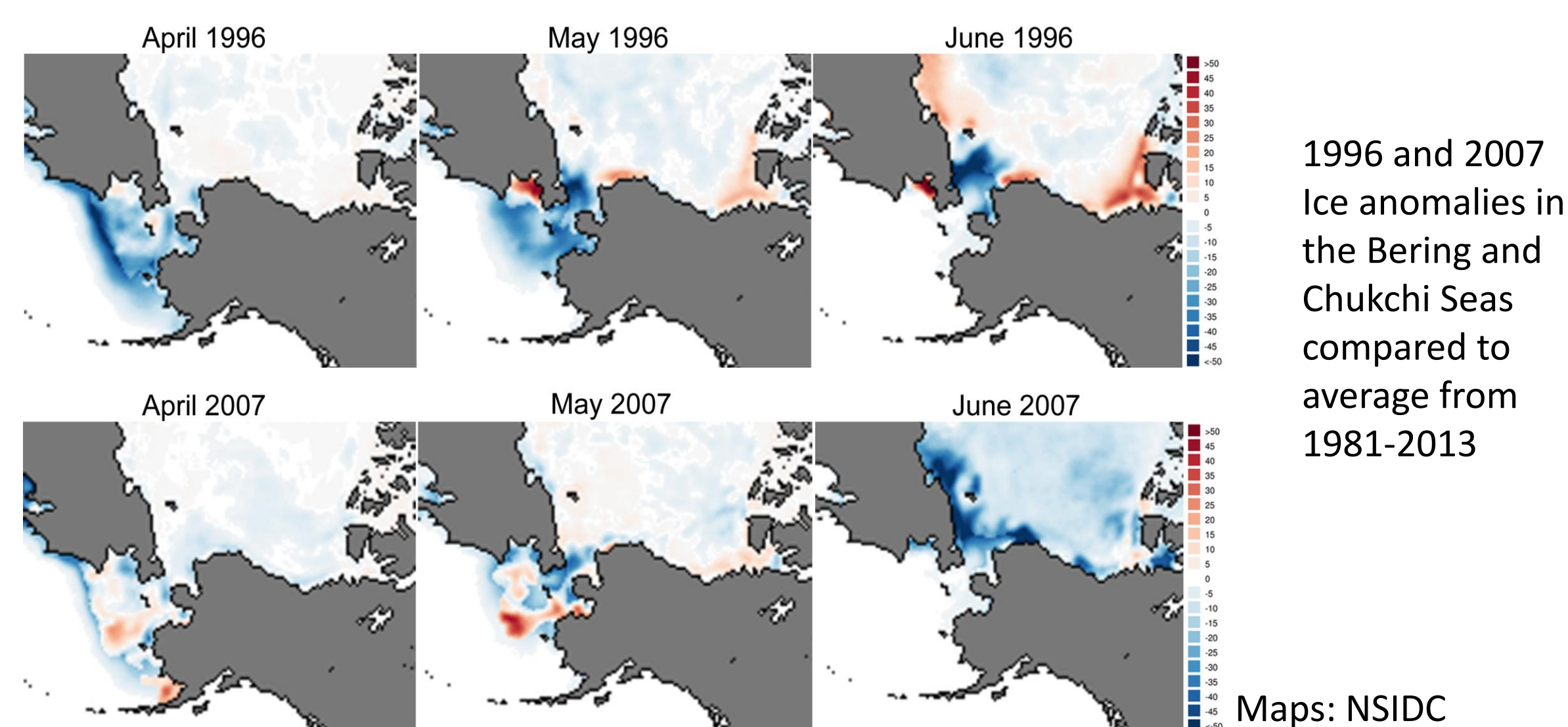
# Genetic investigation of multi-decadal shifts in beluga whale behavior in a changing Arctic

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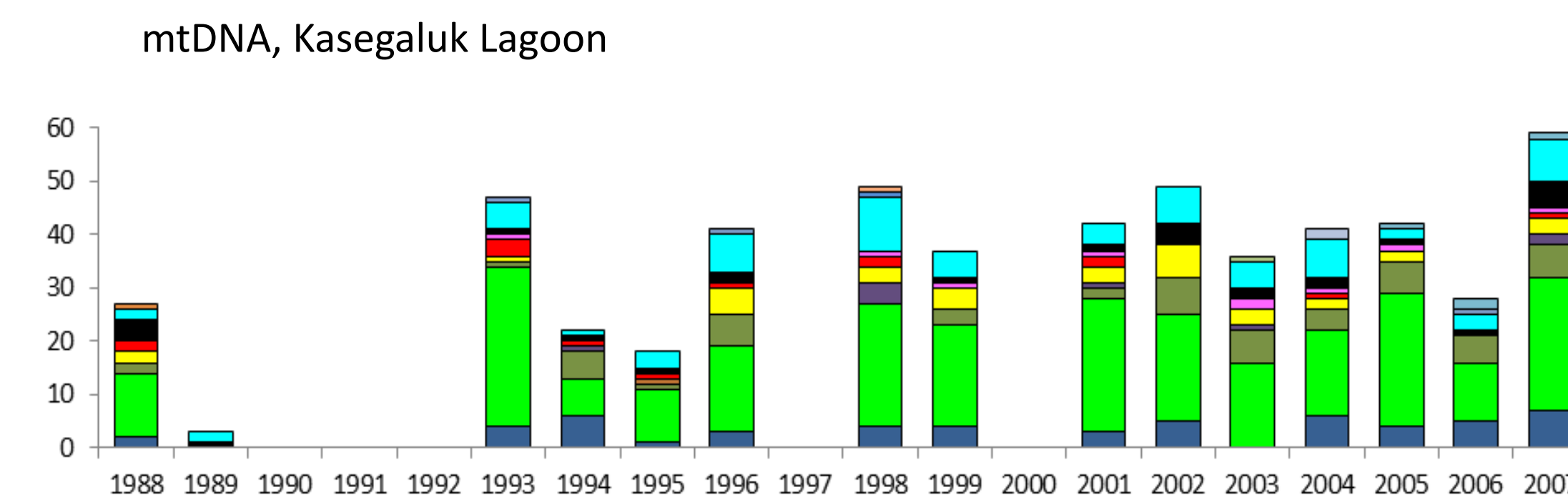
## ABSTRACT

In Arctic species, natal homing, dispersal and settlement and their ultimate influence on population subdivision are believed to be primarily shaped by seasonal fluctuations in sea-ice and resource availability and by changing climatic and oceanographic conditions over several time scales. We investigated population structure, dispersal and migration patterns in the beluga whale, *Delphinapterus leucas*, in the western Nearctic, a region that has witnessed dramatic sea-ice loss in recent decades. Genetic profiling of 1,252 whales from multiple geographically discrete populations, summering concentrations and migrating herds across 20 years (1988-2007) revealed phylogeographic structuring within mtDNA ( $F_{st} = 0.40$ ) and 8 microsatellite loci ( $F_{st} = 0.112$ ) that indicate the geographically discrete population in Cook Inlet, Alaska has been effectively isolated, demographically and reproductively, from populations in the Bering, Chukchi and Beaufort Seas (BCB) for such time that the evolution of distinct genetic signatures in the small, declining Cook Inlet population is likely and rescue via immigration is remote. Genetic heterogeneity ( $F_{st\ mtDNA} = 0.104-0.613$ ,  $F_{st\ nDNA} = 0.005-0.071$ ), Bayesian cluster analysis ( $K=4$ ) and likelihood-based assignment methods revealed limited dispersal and restricted gene flow by both sexes among four geographically discrete summering concentrations in the BCB region; Bristol Bay, Norton Sound, the eastern Chukchi Sea and the eastern Beaufort Sea, despite few physical barriers to movement and the potential co-occurrence of separate summering groupings during the winter-spring breeding season. This philopatry to migration destinations likely reflects behavioral adaptations to spatially patchy but seasonally predictable resources and is facilitated by the extended period of postnatal care by females. Gene flow, when it did occur, was mediated predominantly by adult males, either via interbreeding on a common wintering ground or overlapping migration route or via limited individual transfer ( $F_{st\ m.v.f} P = 0.043$ ,  $r_{m.v.f} P = 0.042$ ). Finally, temporal analysis across 20 years of sample collection confirmed inter-generational philopatry but also detected behavioral shifts in annual migration patterns that coincided with anomalous ice years. These shifts may represent behavioral responses to climate-induced ecosystem change the ecological and evolutionary consequences of which will depend on their frequency and duration

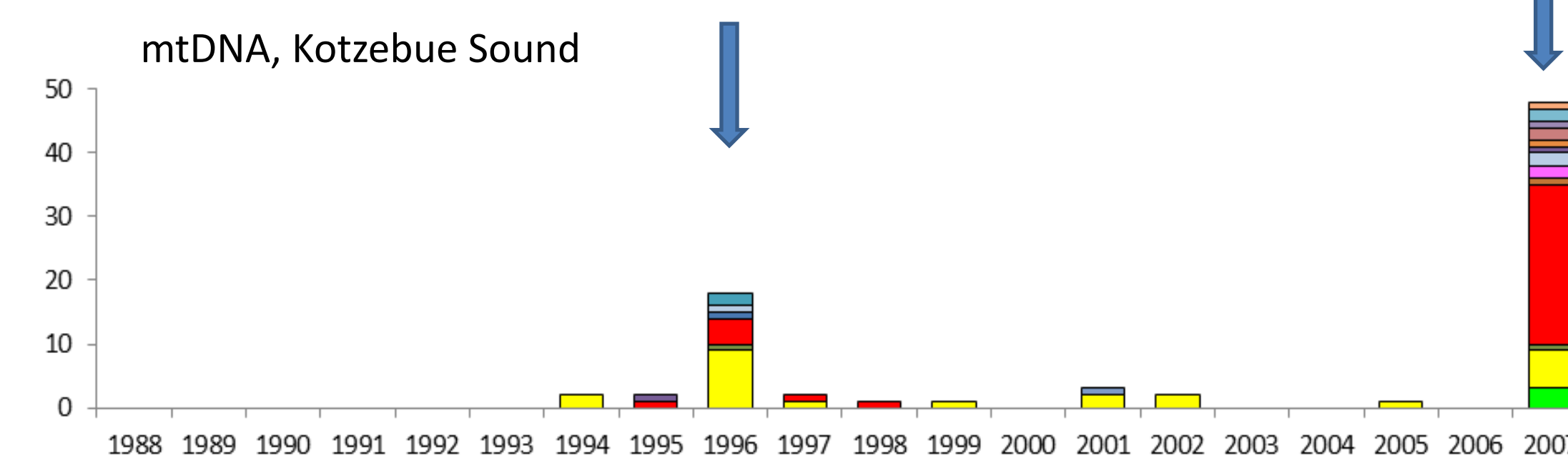


Record low ice years in 1996 and 2007 influence spring migration patterns in some locations but not in others

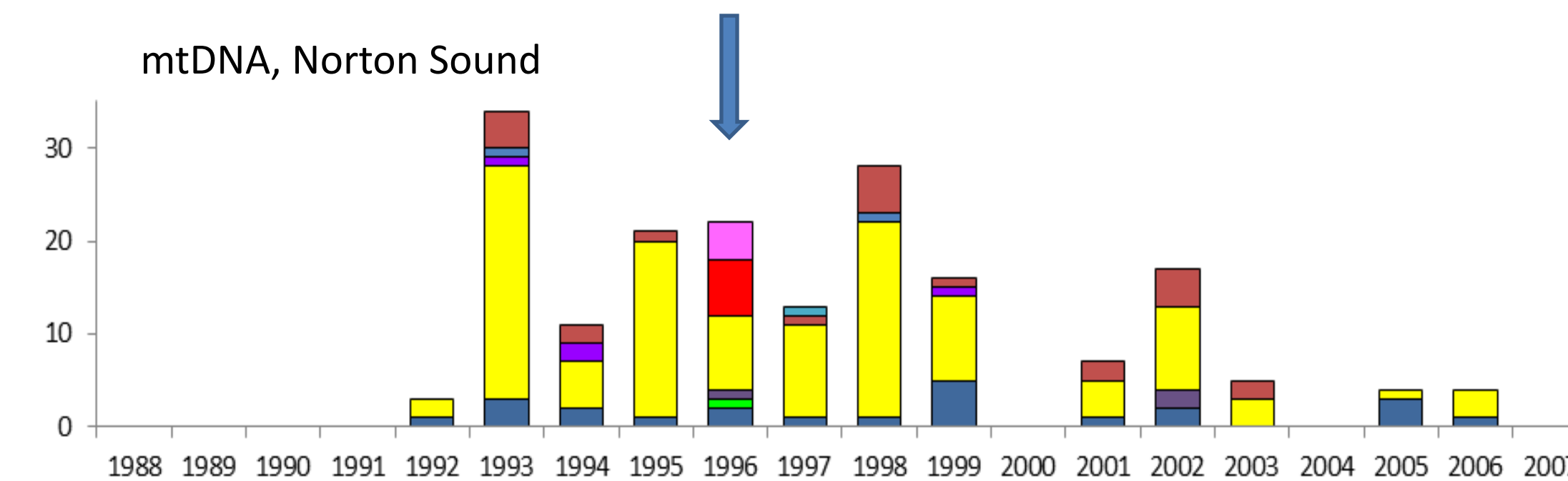
The timing of return to Kasegaluk Lagoon, and the genetic composition of the migrating herds did not change (1988-2007)



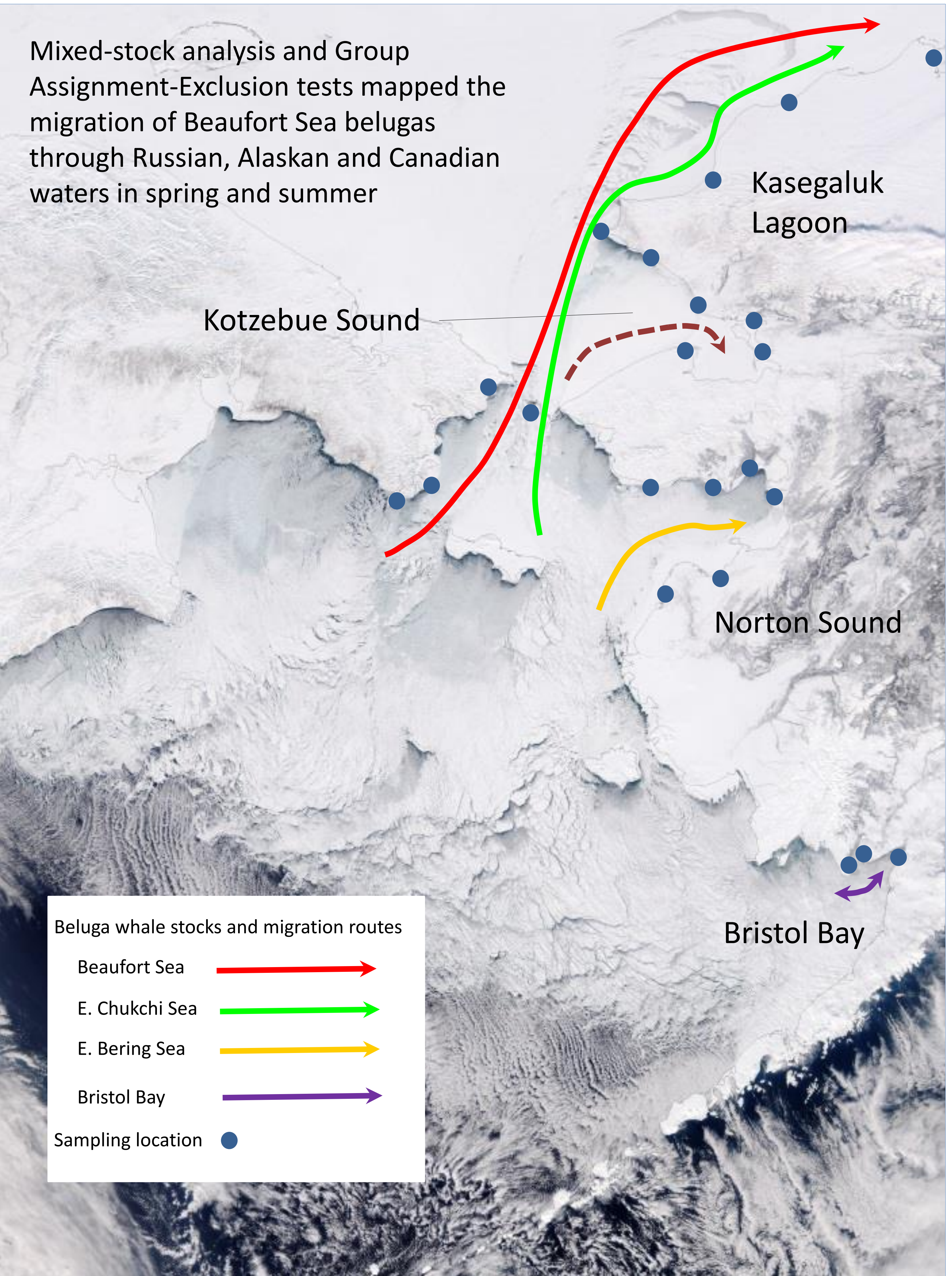
The return of large number of whales to Kotzebue Sound coincides with two of the lowest ice years in the past two decades



An unusual genetic make-up of whales in Norton Sound in 1996, coincides with the lowest ice year in the 1990s and a rare occurrence of whales in Kotzebue sound



Mixed-stock analysis and Group Assignment-Exclusion tests mapped the migration of Beaufort Sea belugas through Russian, Alaskan and Canadian waters in spring and summer



## METHODS

A total of 1,252 beluga whales were sampled from over 40 locations across Alaska, northwest Canada and eastern Chukotka. Each sample was screened for variation within 410bp of the mtDNA control region and 8 independent hypervariable microsatellite loci. Moment and likelihood-based statistics, including assignment and exclusion tests, were used to assess population subdivision and patterns of dispersal and gene flow. We used mixed-stock analysis (Bayes) and a novel Group Assignment-Exclusion test (Gelato) to map migration routes.

## CONCLUSION

Traditional and novel analysis of both mtDNA and nDNA data in large sample sizes collected from multiple locations across a 20 yr timespan confirmed that strong behavioral philopatry in beluga whales to both migration route and destination is the basis of population subdivision in this species.

It also revealed that changes in the physical environment, including patterns of sea ice cover and breakup may have immediate and substantial effects on beluga whale migratory behavior. Future research will focus on the impacts of these behavioral shifts.

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