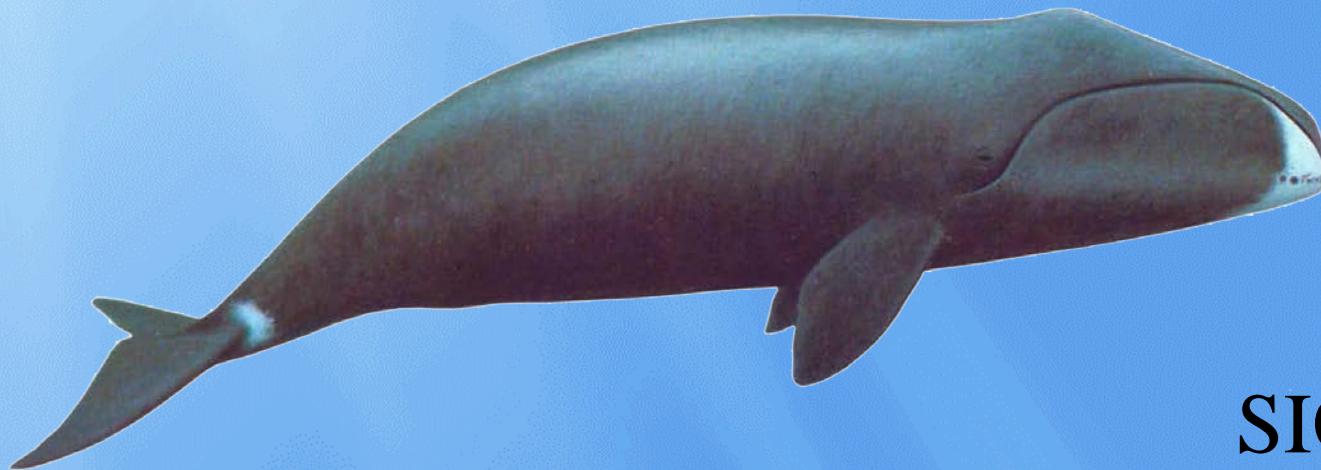




Marine Mammals on Ice

Douglas Krause (with content from SIO 133), NOAA Fisheries



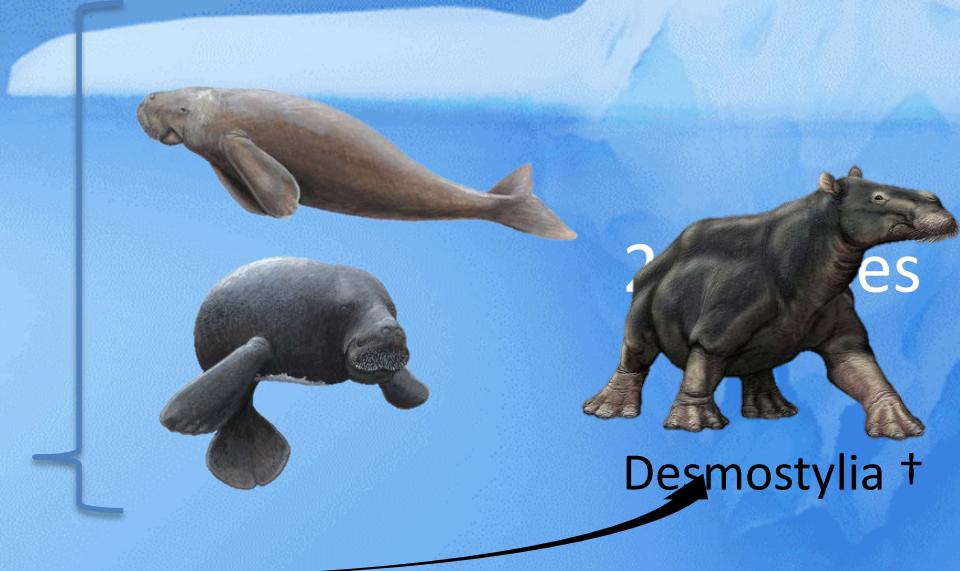
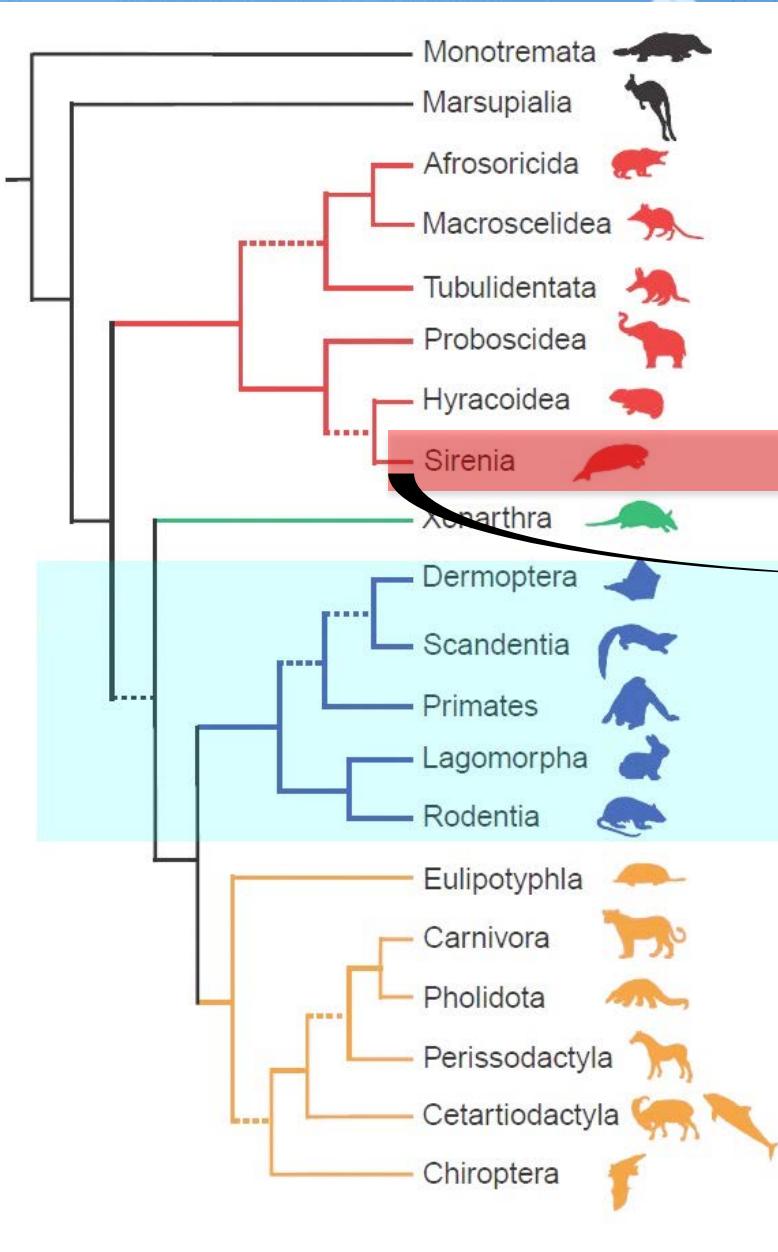
SIO 121



Classification

- Domain: Eukarya
- Kingdom: Animalia
- Phylum: Chordata
- Class: Mammalia
 - lactation, endothermy, hair, 7 cervical vertebrae, dyphodont teeth, night vision

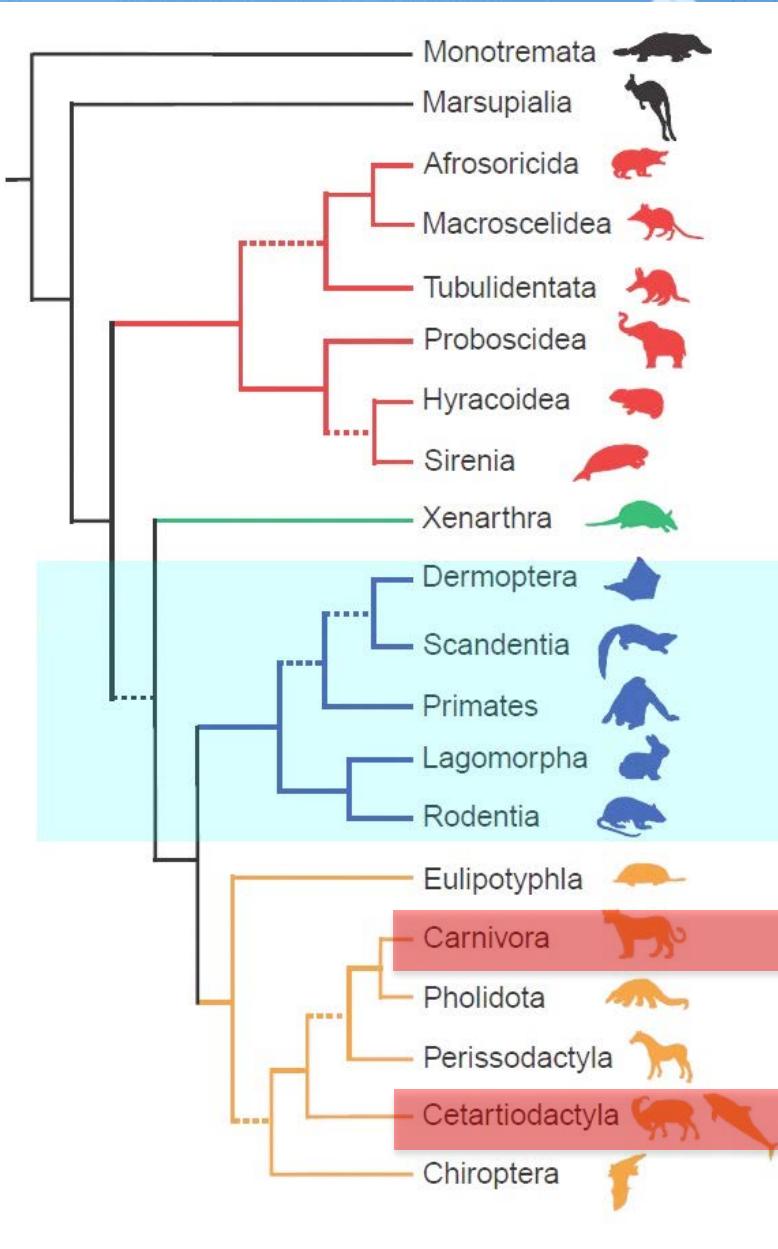
Mammalia



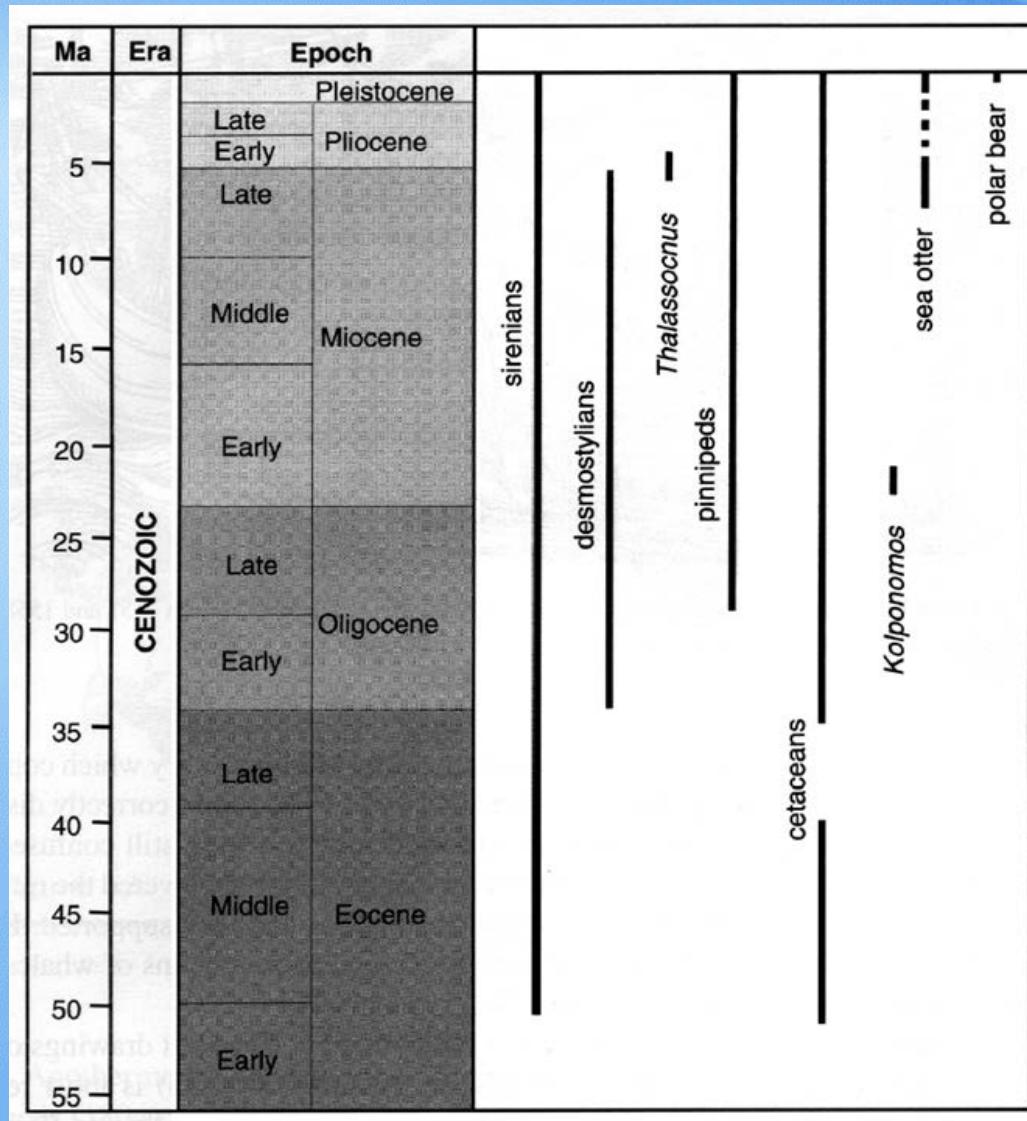
SIO



Mammalia



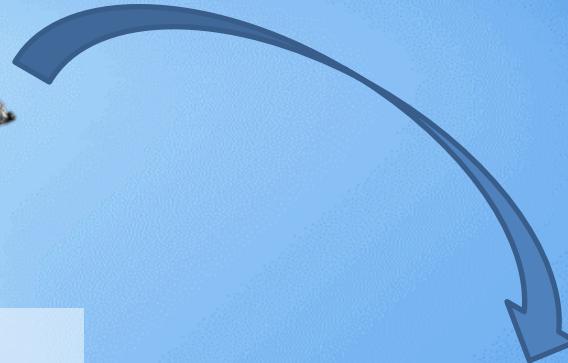
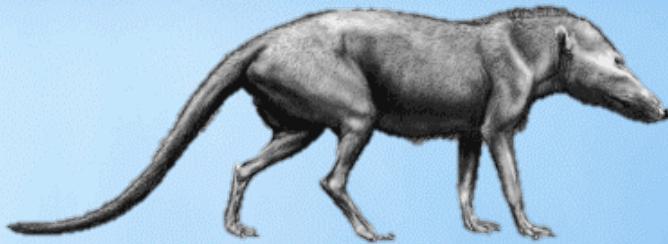
MM Evolution



SIO



Marine Mammal Evolution

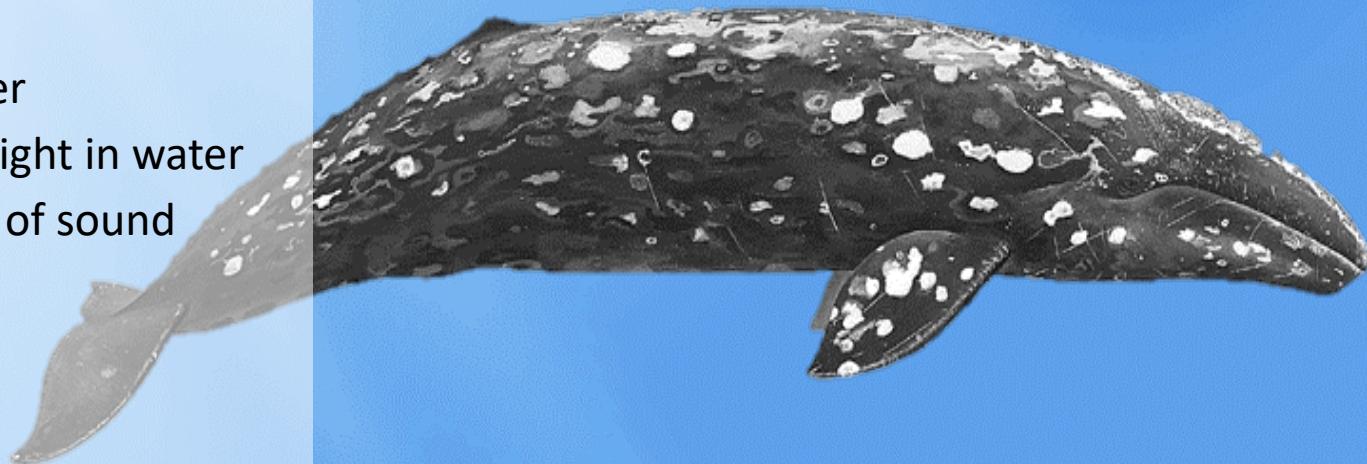


Physical properties of water:

- Density
- Heat capacity of water
- Low transmission of light in water
- Efficient propagation of sound

Consider changes in:

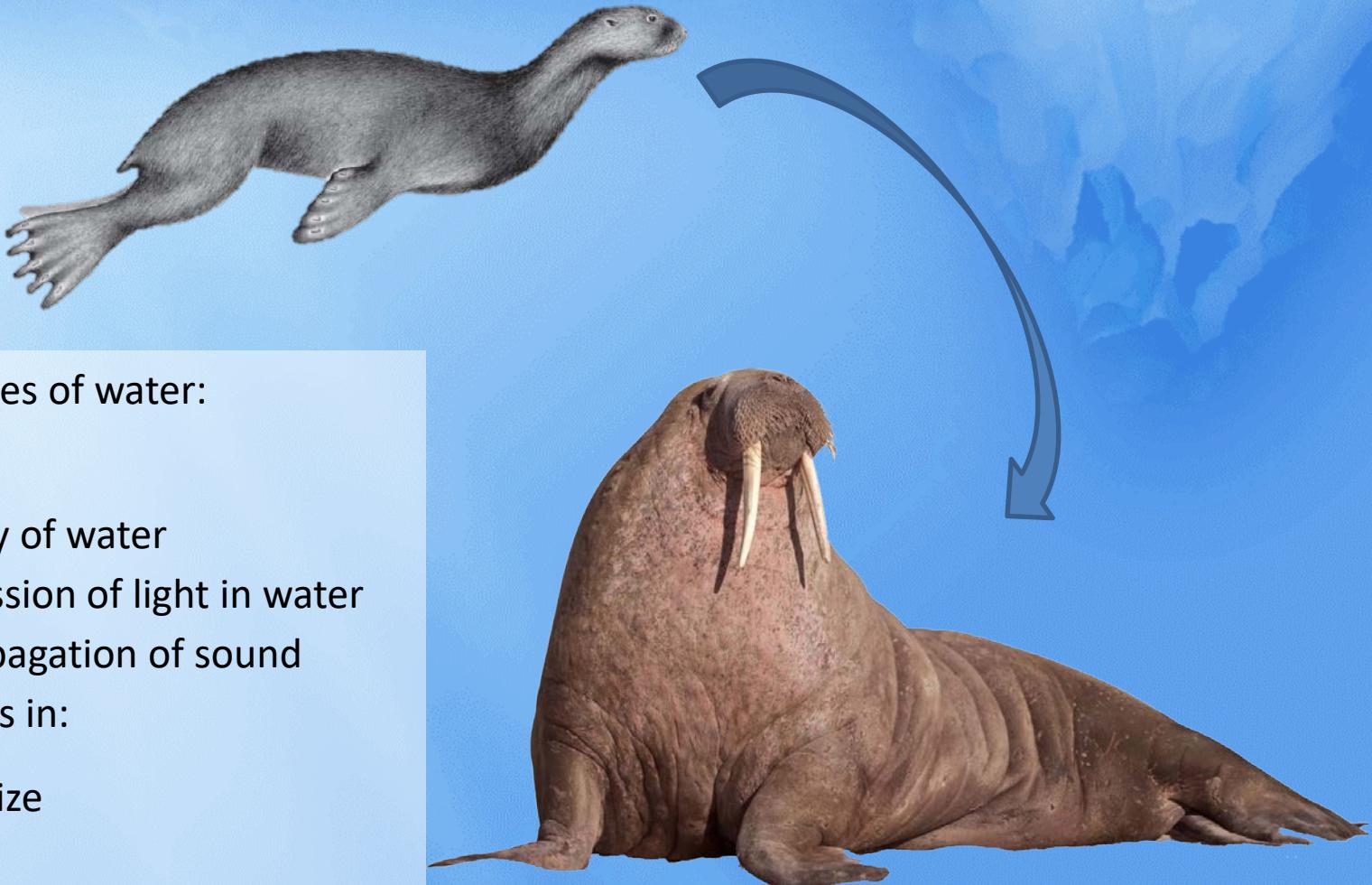
- Body Form/size
- Appendages
- Locomotion
- Diet



SIO



Marine Mammal Evolution



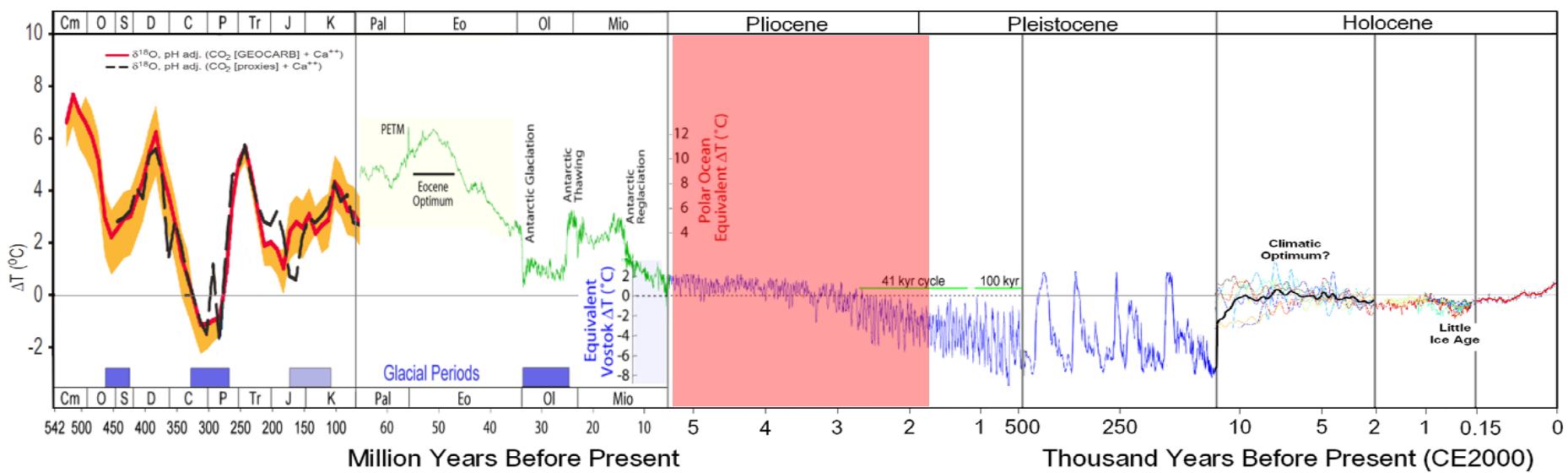
Physical properties of water:

- Density
- Heat capacity of water
- Low transmission of light in water
- Efficient propagation of sound

Consider changes in:

- Body Form/size
- Appendages
- Locomotion
- Diet

MM Evolution



Pliocene (7 – 1.8 Ma)

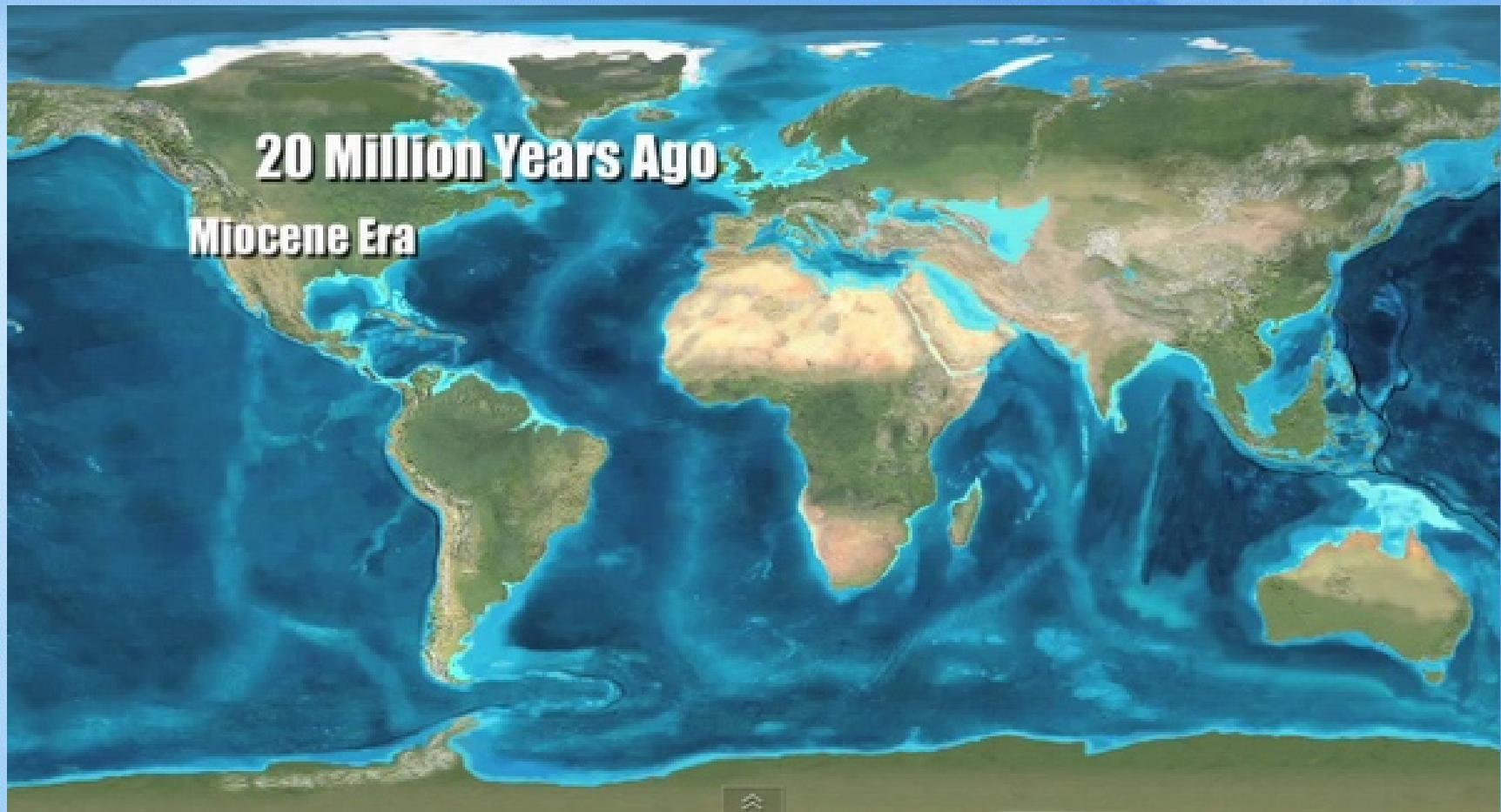
- Continued global cooling, increased seasonality
- Formation of modern climates and ocean circulation
- Central American Seaway (Panama) closes
- Arctocephalus (fur seals) appear

Adapted from M. Goebel

SIO



MM Evolution



SIO



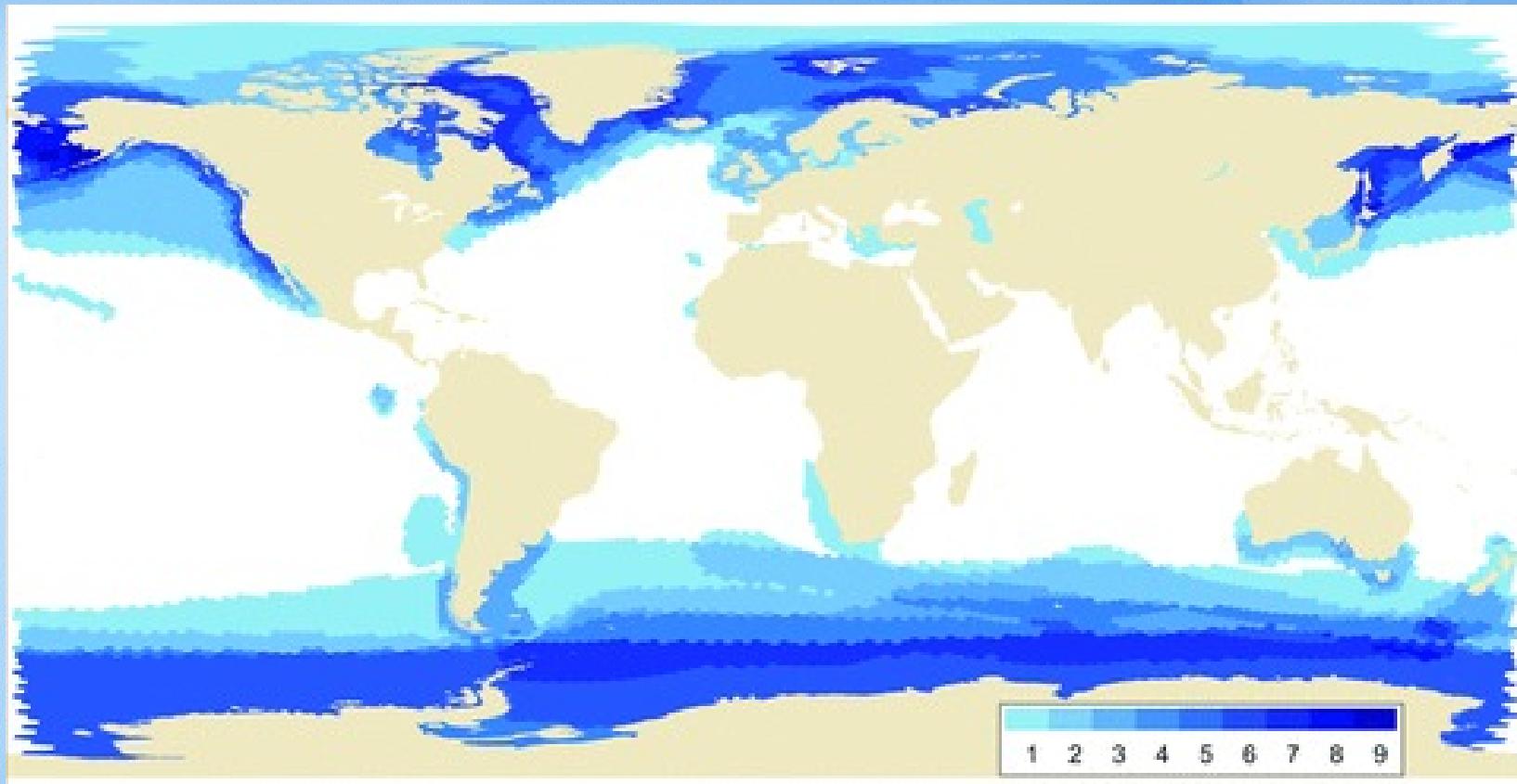
MM Evolution



SIO



MM Evolution



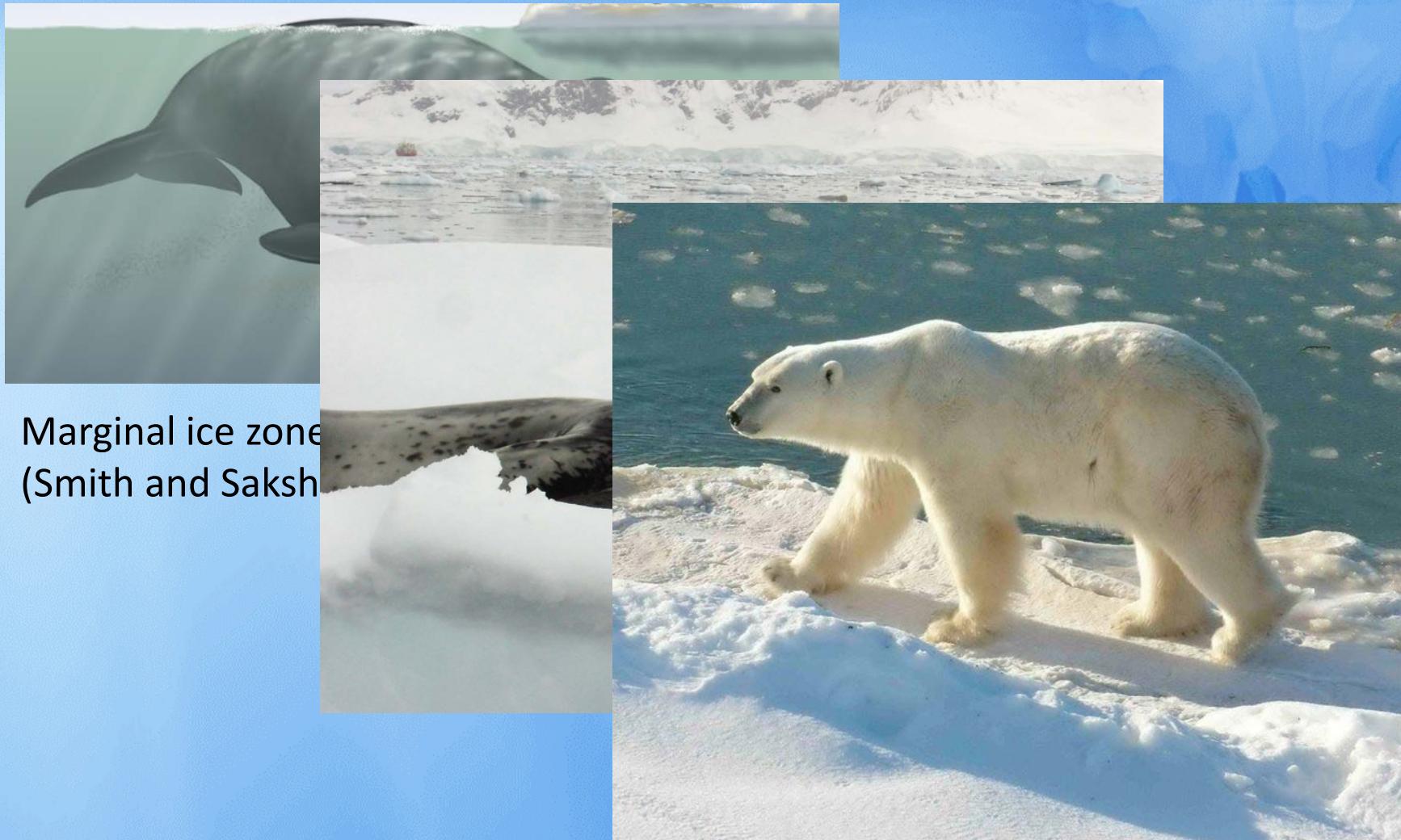
Global Pinniped Distribution

Kovacs et al. 2012

SIO



MM Evolution

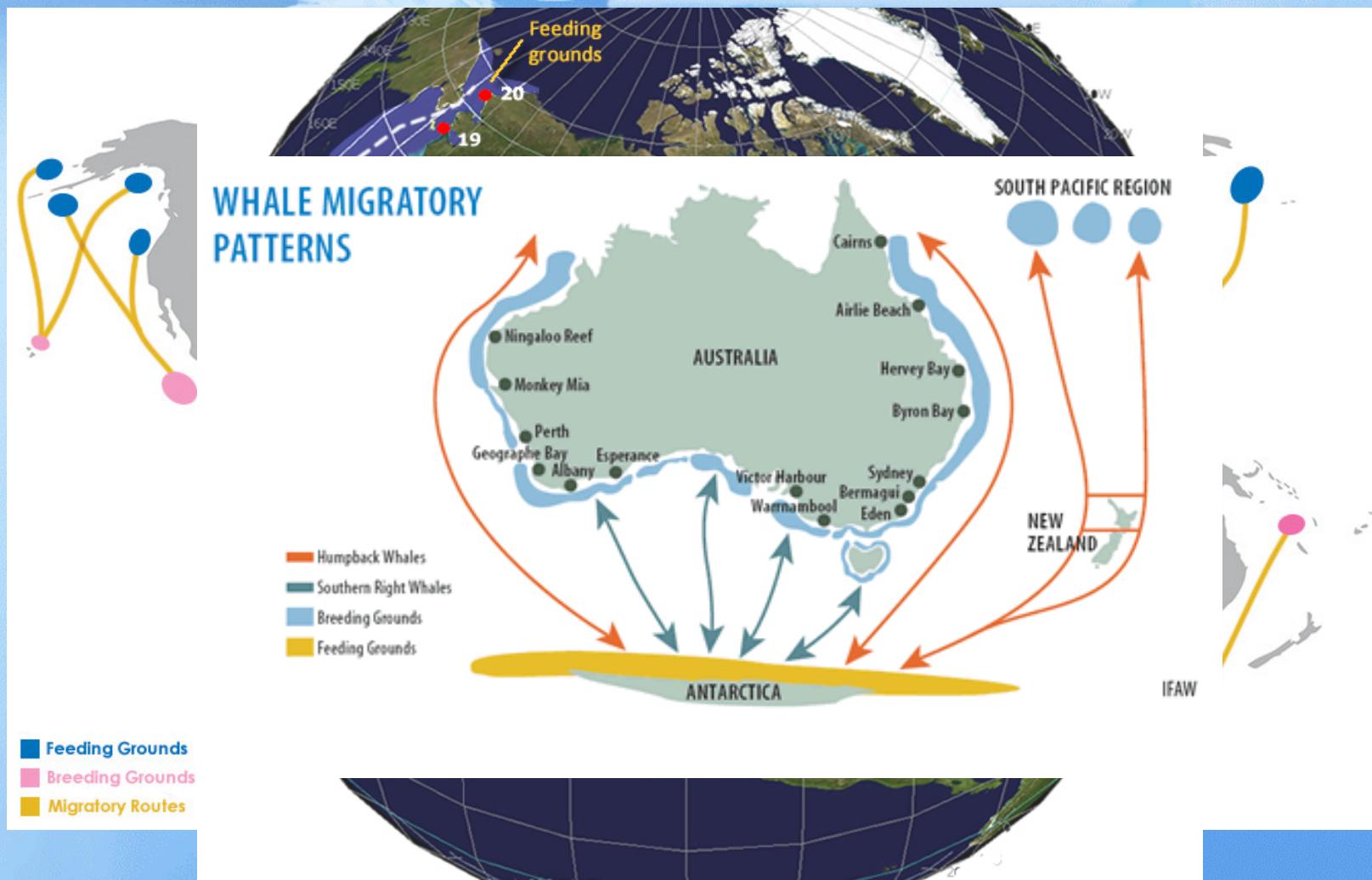


Marginal ice zone
(Smith and Sakshaun)

SIO



MM Evolution



True Migrators: large mysticete whales

MM in Ecosystems

- Large numbers of sharks reported among KWs attacking HBs



*Remains of ~9m humpback (yearling?)
<60 h after kill - "dozens of sharks"*

“All of this largesse ultimately derives from the Southern Ocean where Antarctic krill (*Euphausia superba*) is shape-shifted into Area IV humpbacks and injected annually into the relatively oligotrophic, littoral marine ecosystem of Western Australia, where killer whales do their part in making it available to local consumers.”

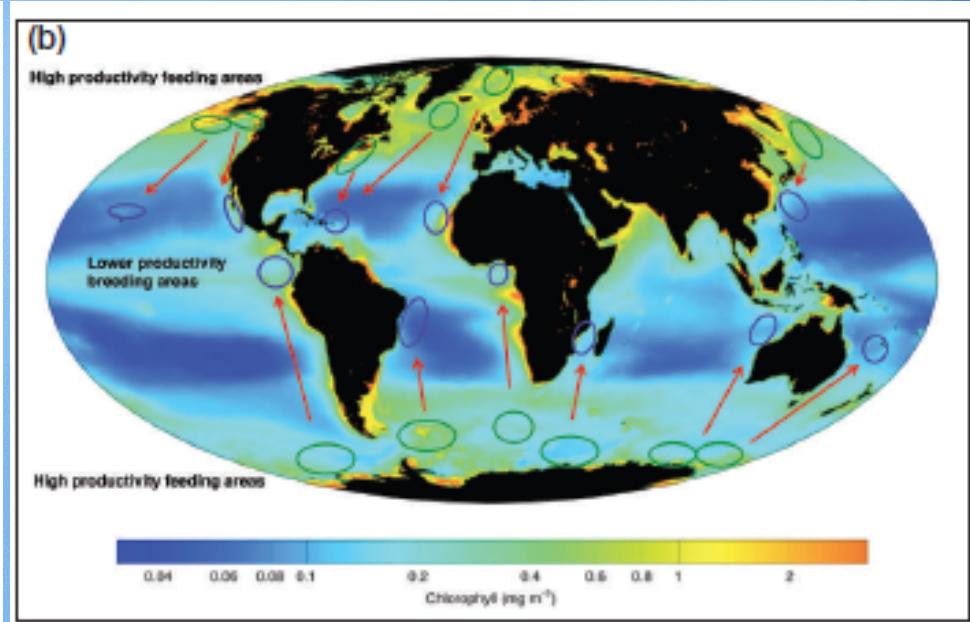
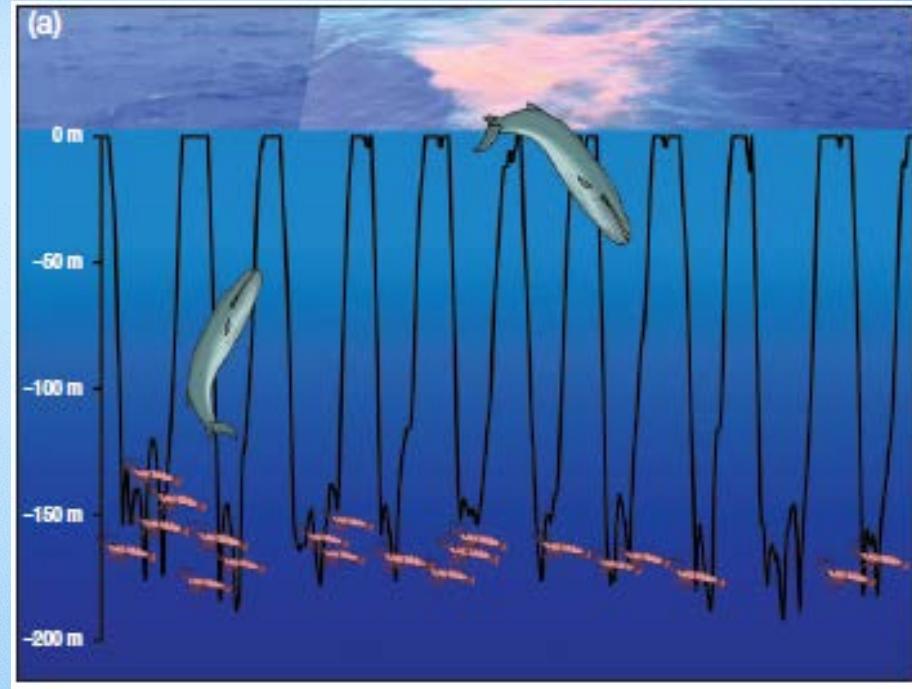
Marine Mammals as Bioengineers: “whale pump”

The amazing thing about whale poop.



Vertical and horizontal transfer of Fe and nutrients enhance productivity, prolong blooms, and increase C sequestration
(Lavery et al. 2010, Roman and McCarthy 2010)

Marine Mammals as Bioengineers: “whale pump”



“With primary production held constant, reducing baleen whale populations lowers the potential for marine ecosystems to retain carbon” (Roman and McCarthy 2010, Pershing et al. 2010)

Marine Mammals as Predators



Nellis et al. 1968, Kruuk 1975, Bertram 1979, Ripple and Beschta 2012

SIO



Marine Mammals as Predators

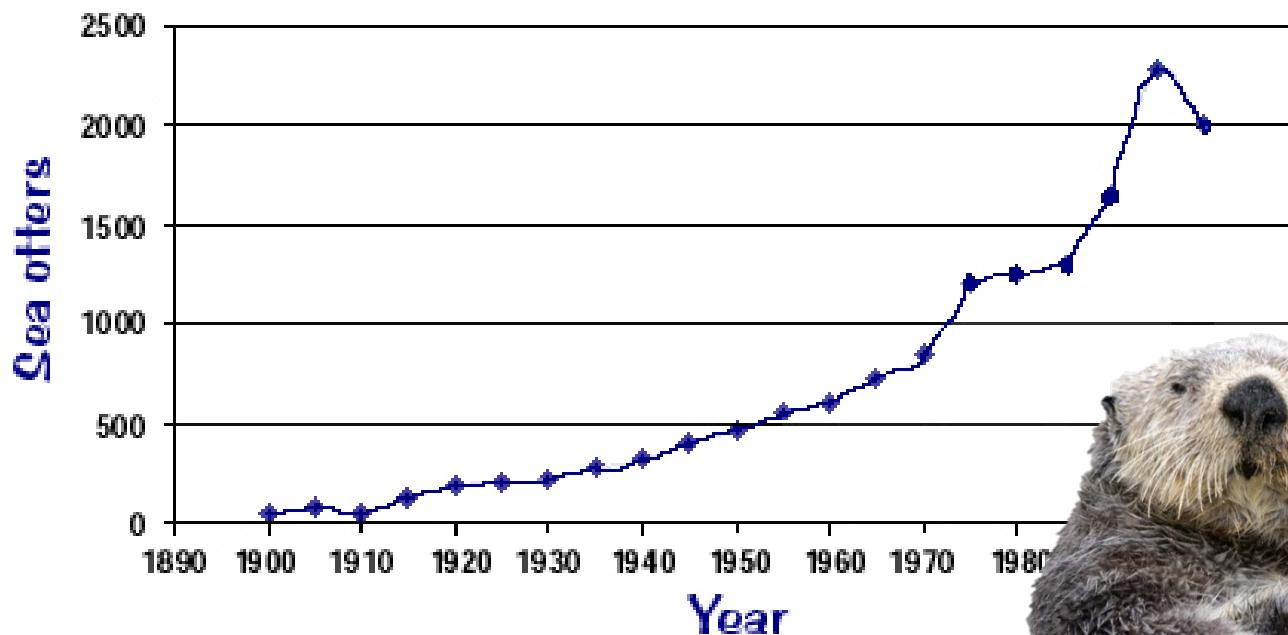


Thompson 1983, Albins and Hixon 2008,
Post et al. 2008, Smith et al. 2010



Marine Mammals as Predators

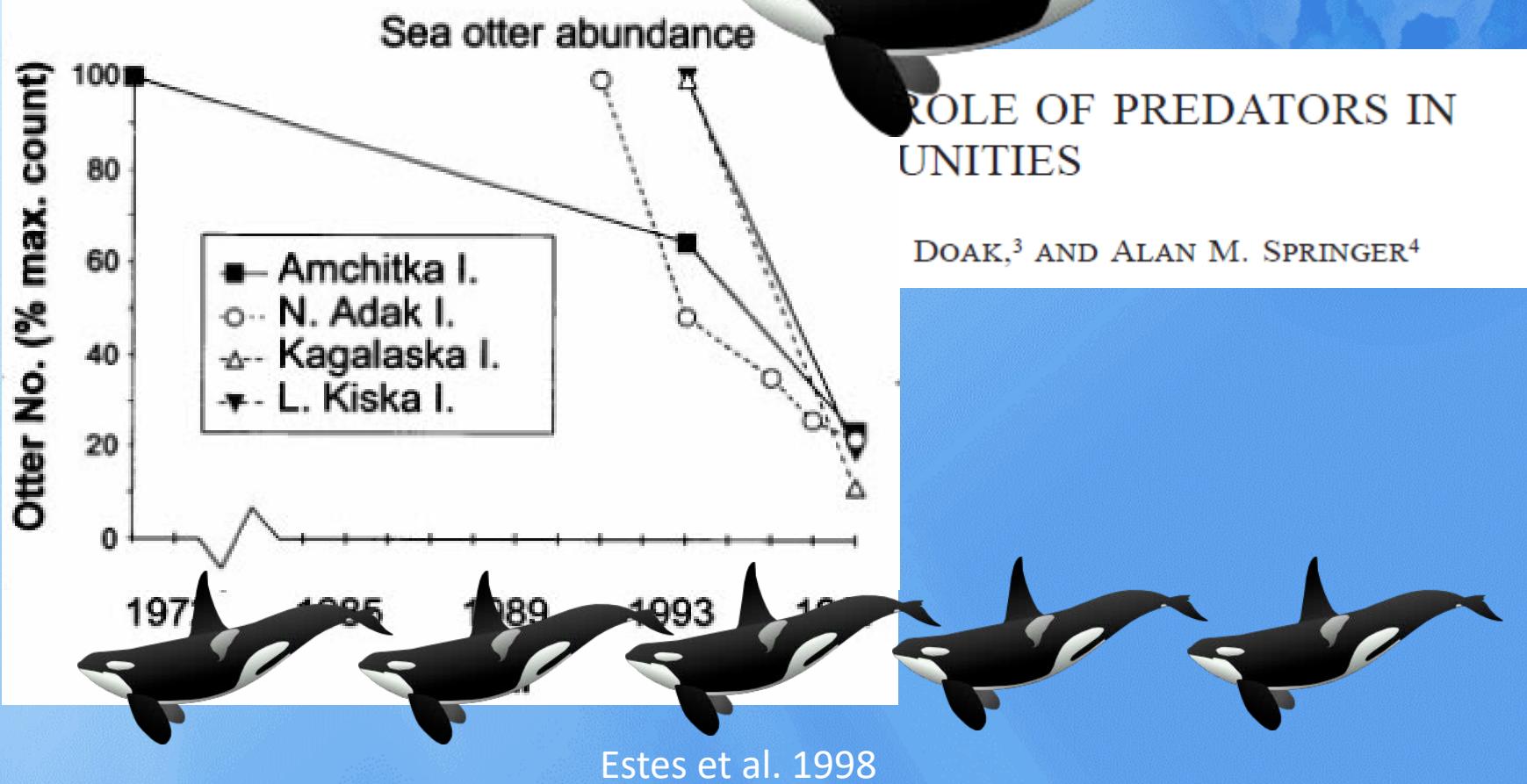
Number of sea otters in Monterey Bay National Marine Sanctuary since 1900



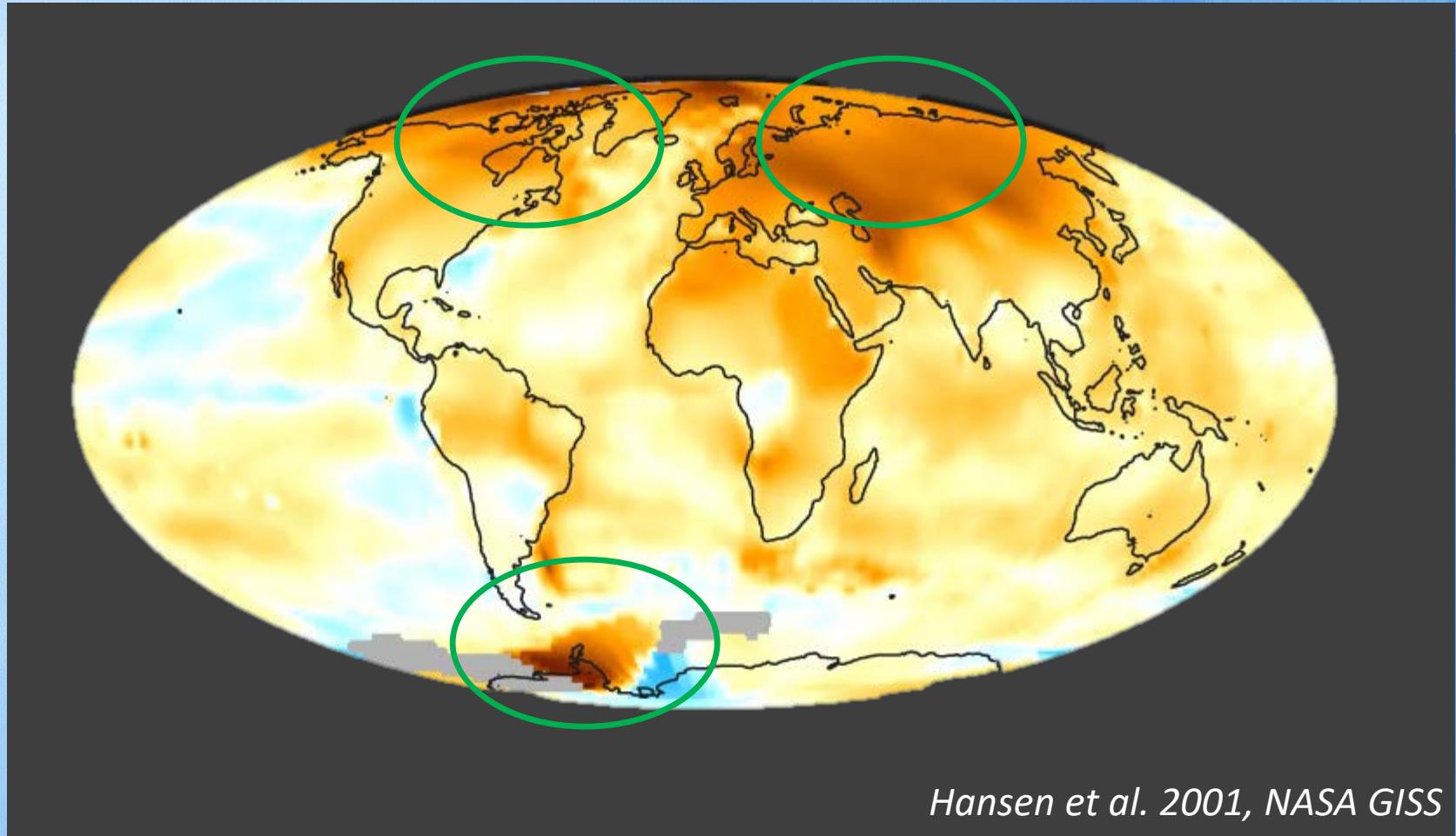
Marine Mammals as Predators



Sea otter abundance



Climate Change: Effects



Hansen et al. 2001, NASA GISS

SIO



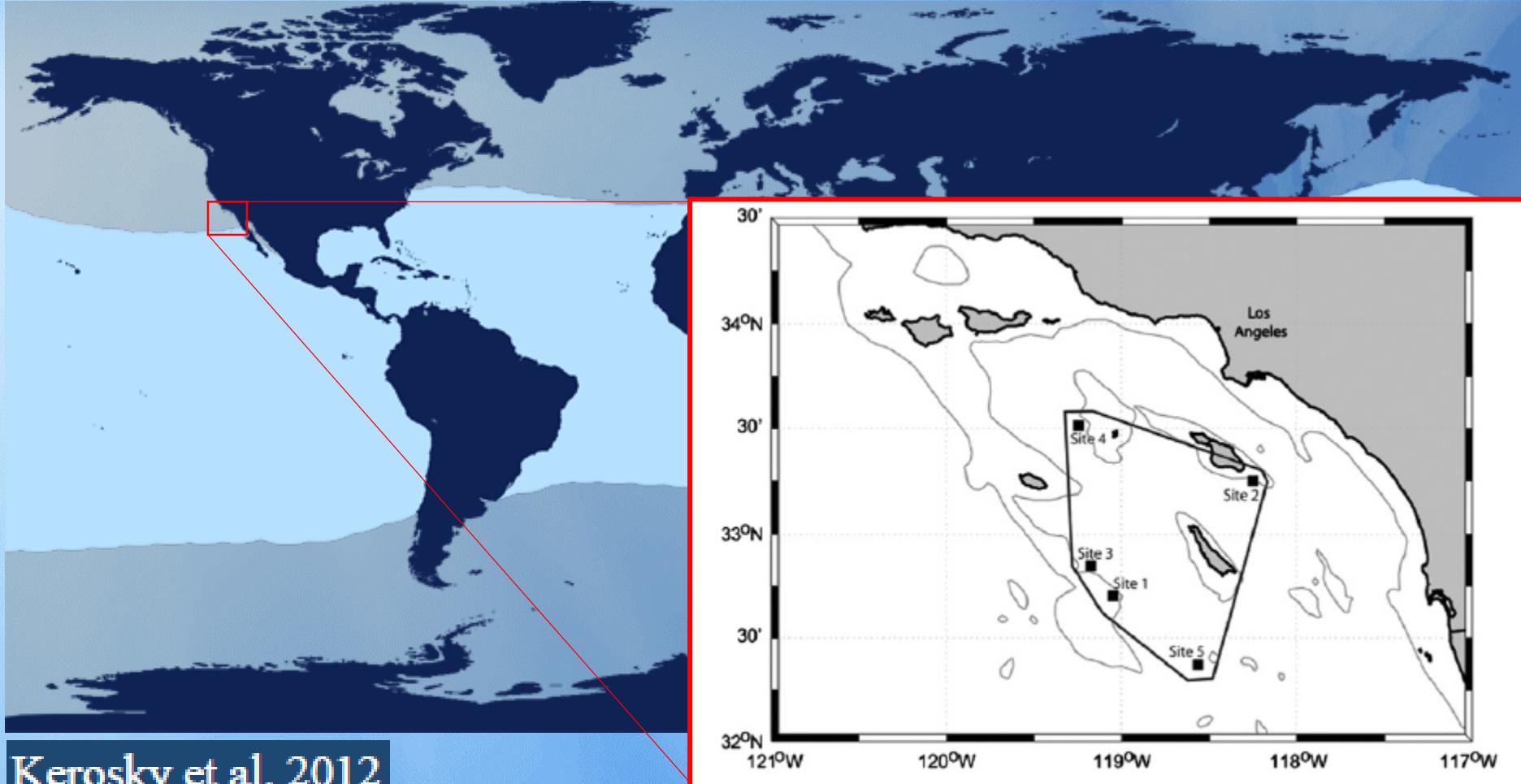
Prey-driven Distribution Shifts



e.g., Bryde's whale *Balaenoptera brydei*



Prey-driven Distribution Shifts

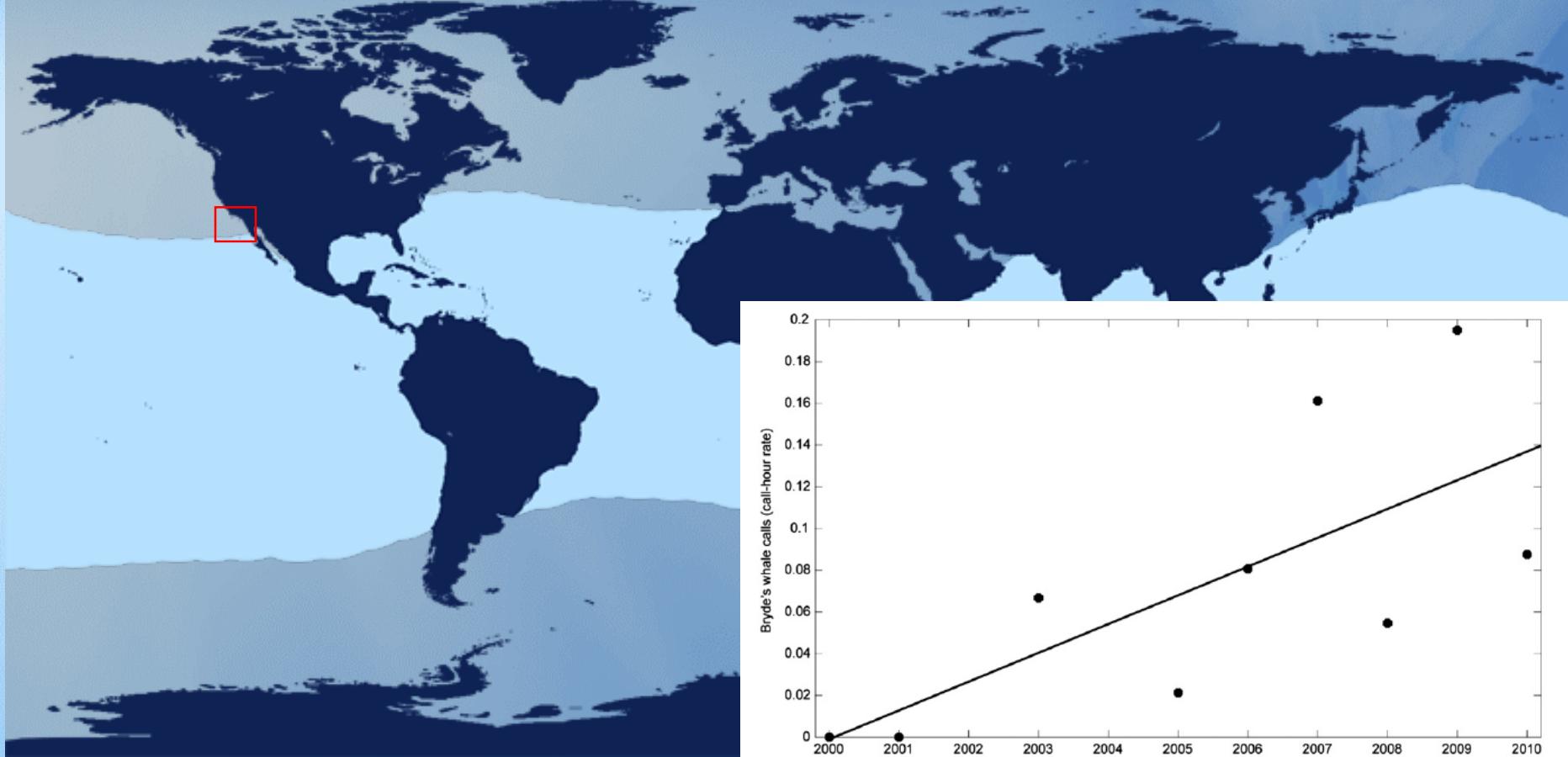


Kerosky et al. 2012

e.g., Bryde's whale *Balaenoptera brydei*



Prey-driven Distribution Shifts

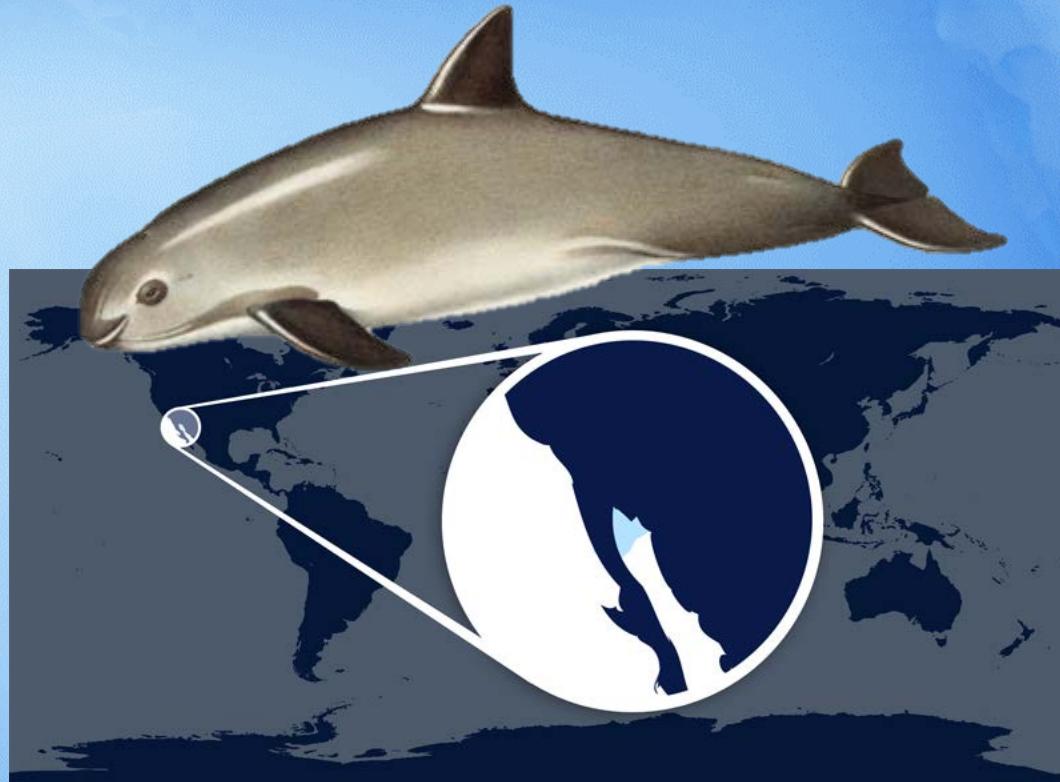


Kerosky et al. 2012

e.g., Bryde's whale *Balaenoptera brydei*



Prey-driven Distribution Shifts



e.g., Vaquita (*Phocoena sinus*)

Prey-driven Distribution Shifts



e.g., Leopard seal (*Hydrurga leptonyx*)



SIO

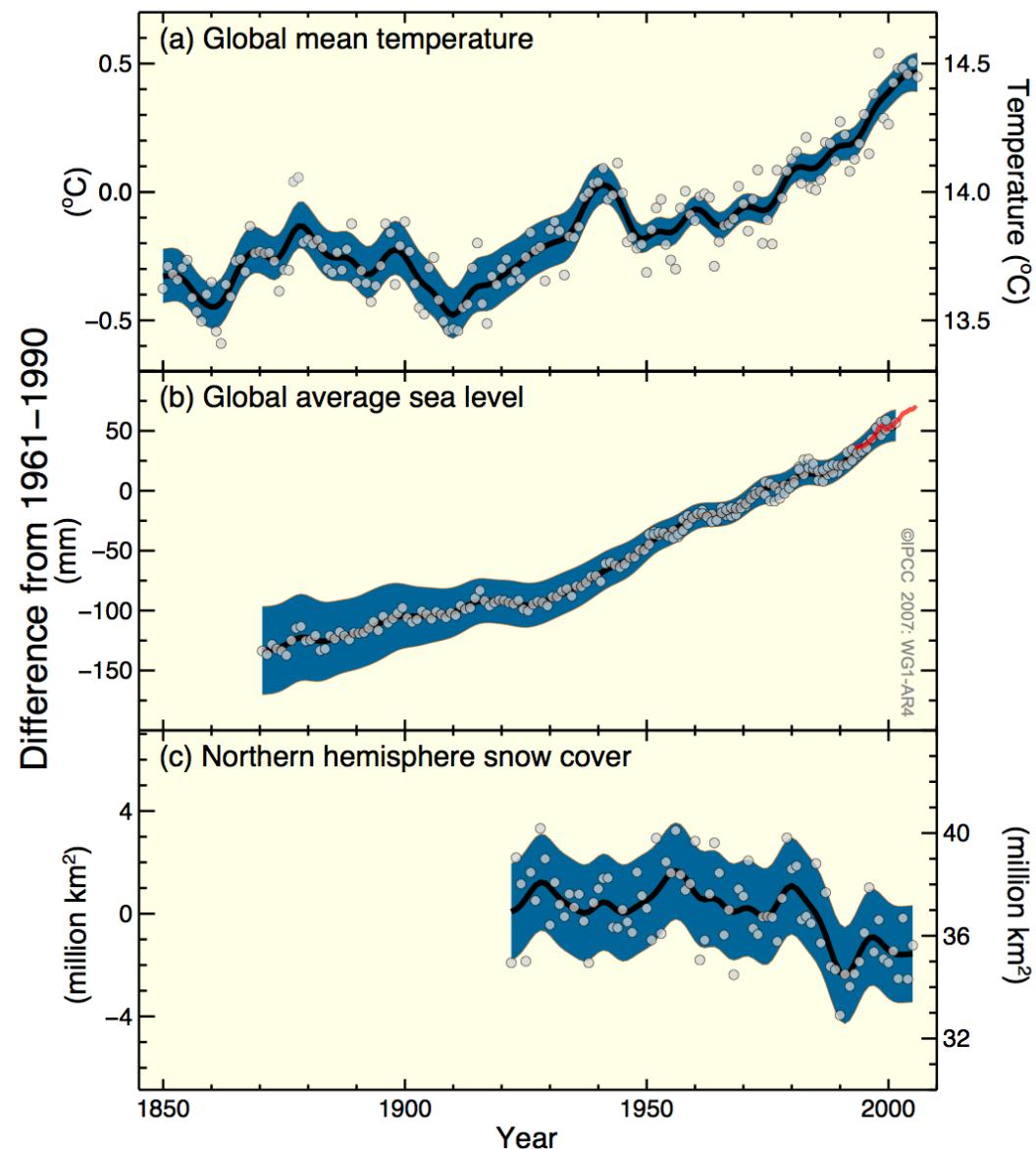


Climate Change: Effects

Global mean temperature

Global average sea level

Northern hemisphere snow cover



Climate Change: Effects

“The rate of climate change is outside of the evolutionary experience of marine mammal species.”

Simmonds & Isaac 2007

Sea Ice Reduction

- Migration Impacts
- Habitat loss
- Anticipated versus Unanticipated effects



Sea Ice Reduction



SIO



Sea Ice Reduction

Seasonal extent
of Arctic sea ice

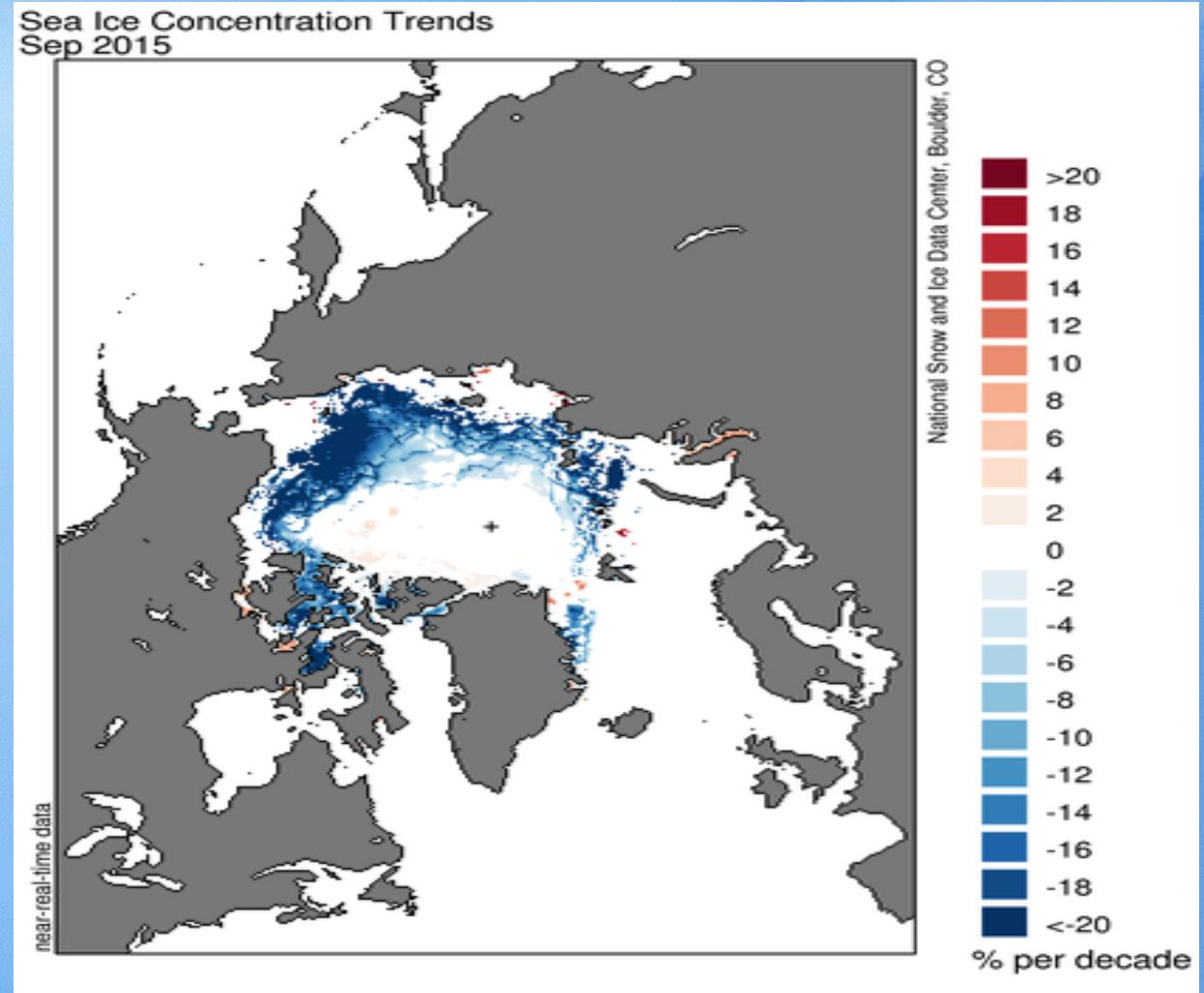
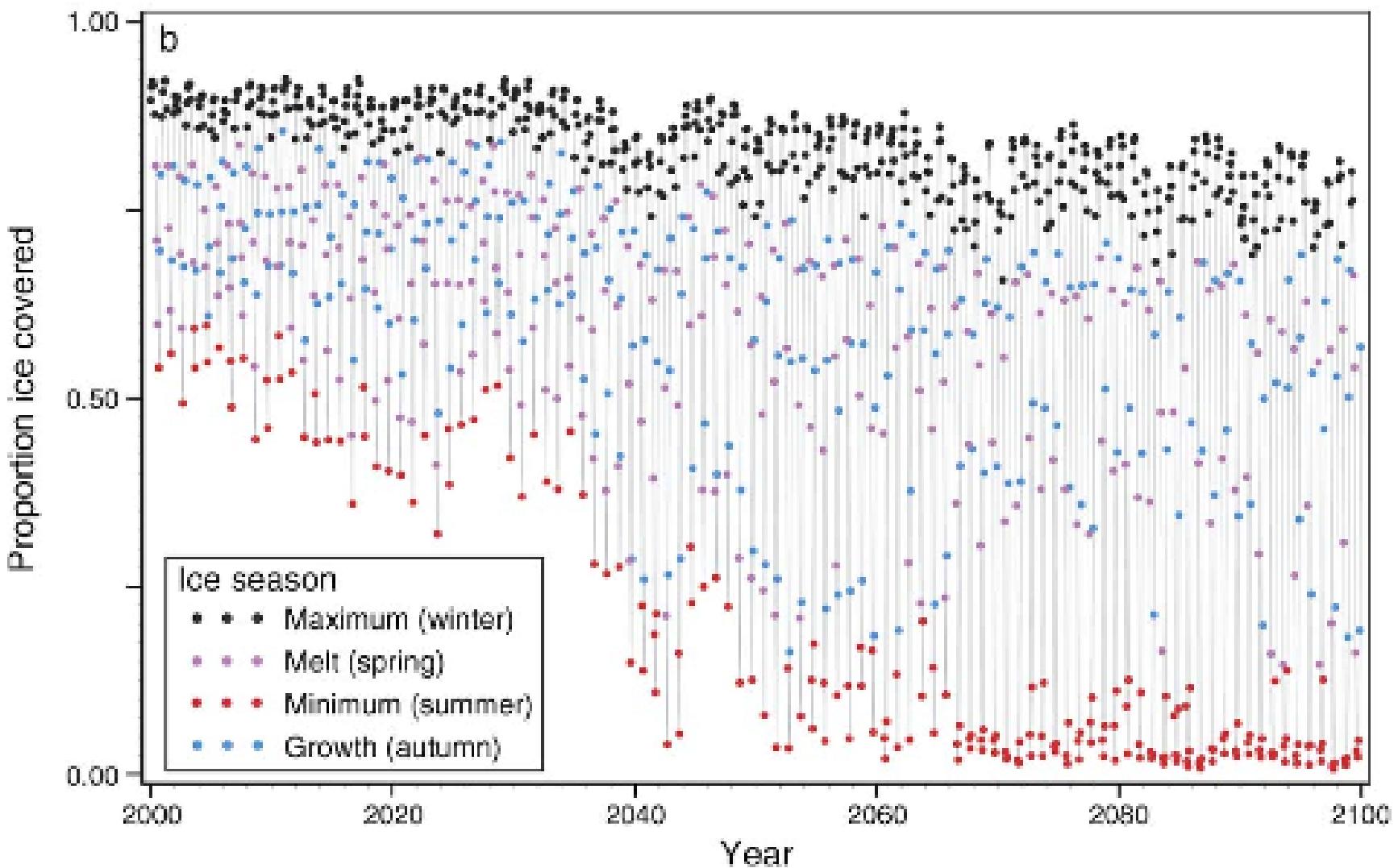


Figure. 1979-2015 Sea ice conc. Trends NSIDC, 2015)

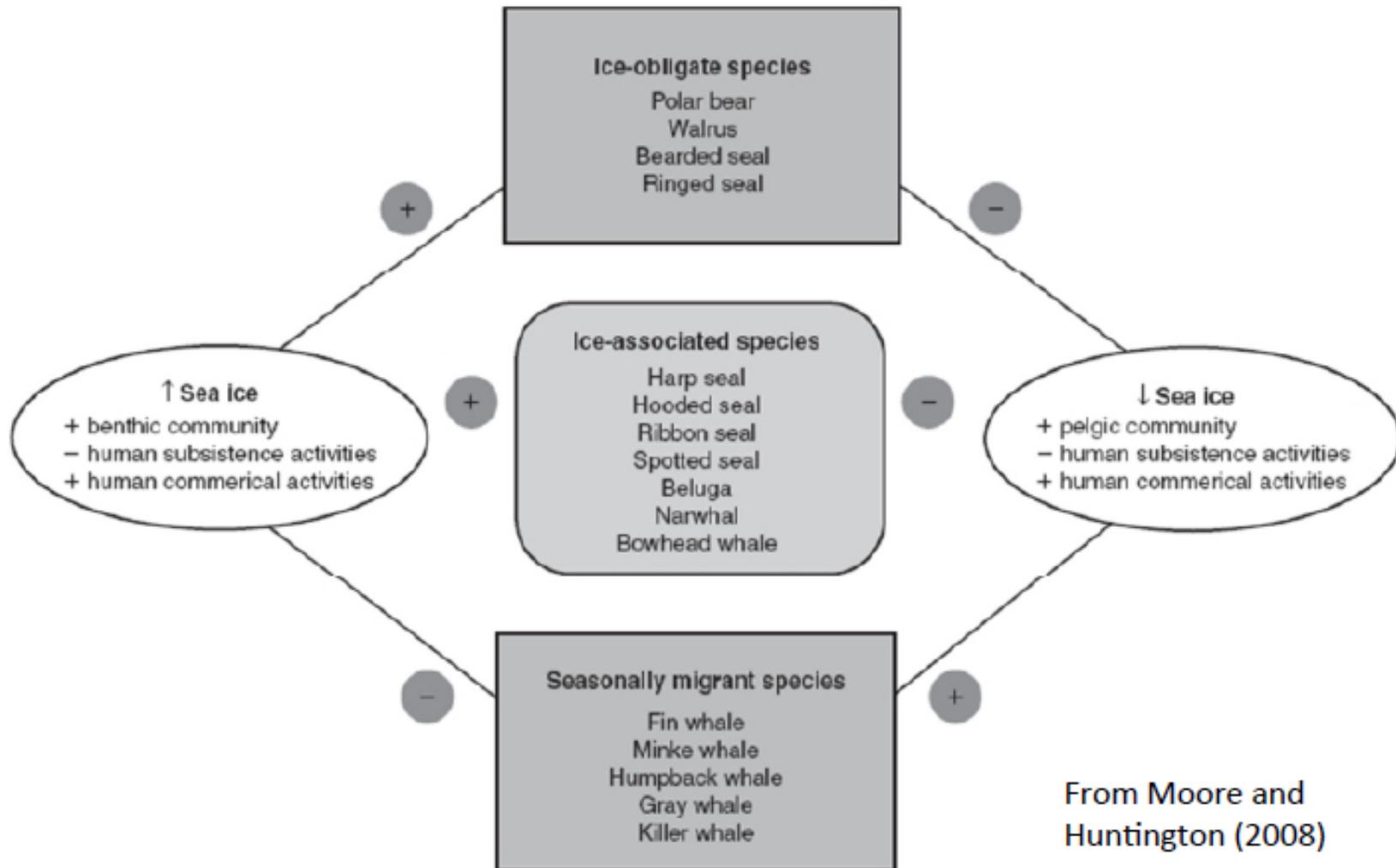
Sea Ice Reduction

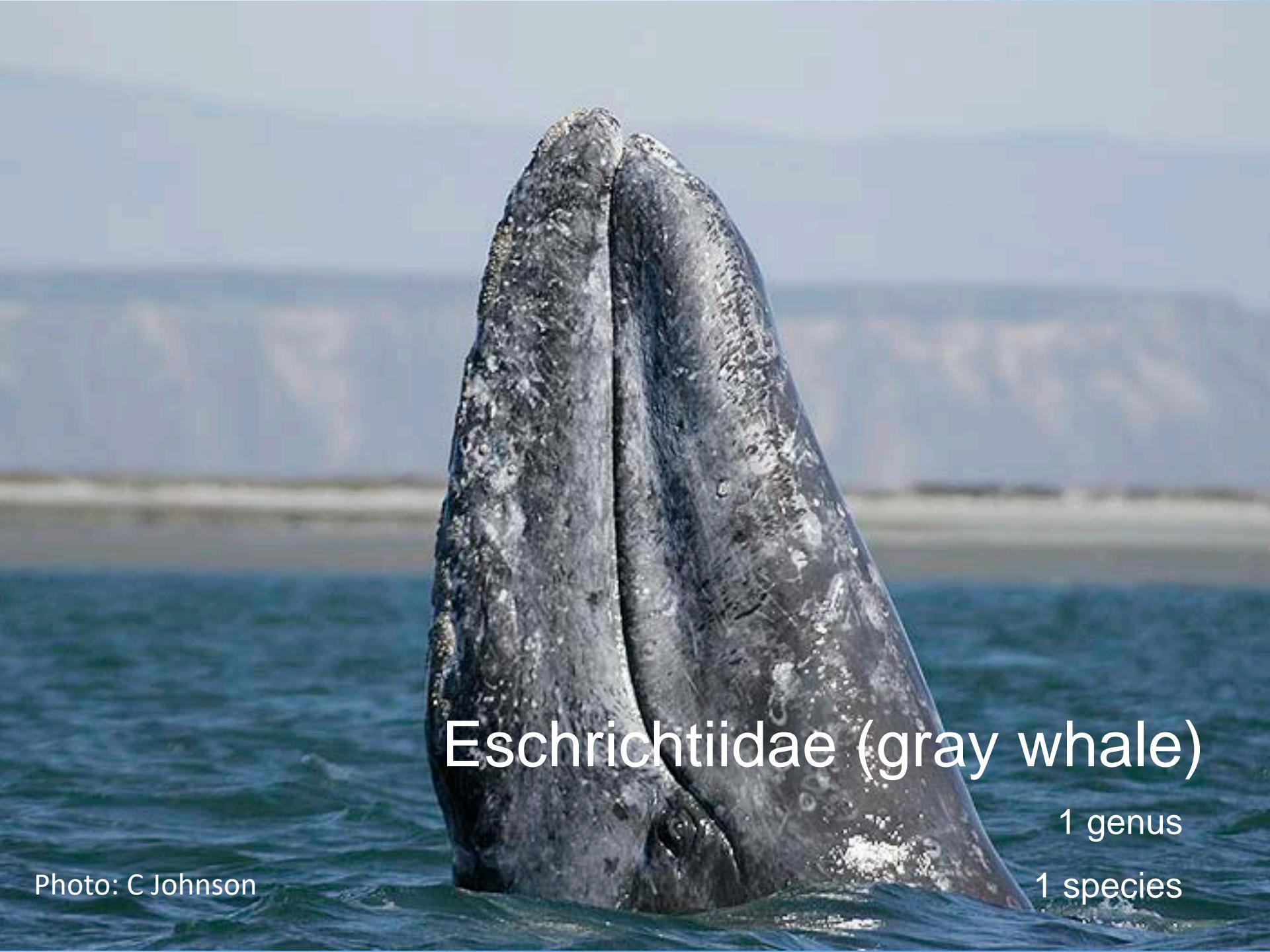




Sea Ice Reduction

Anticipated Effects



A close-up photograph of a gray whale's head and upper body as it breaches out of the ocean. The whale's dark, mottled skin is visible against the bright blue water. In the background, a distant shoreline with hills or mountains under a clear sky is visible.

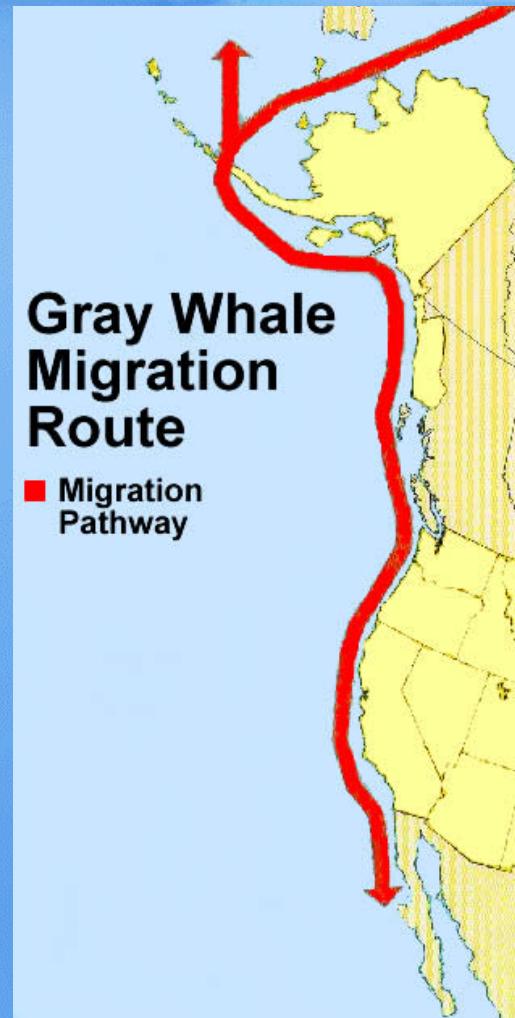
Eschrichtiidae (gray whale)

1 genus

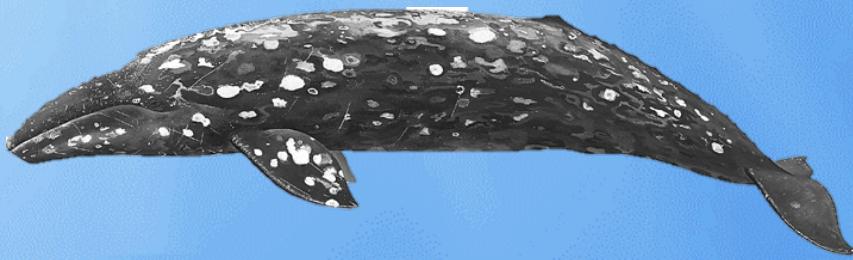
1 species

Photo: C Johnson

Migration Impacts



As Arctic ice extent retreats northward, gray whales **depart later** and have to **travel further**.



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Balaenidae (right whales)

2 genera

4 species

Bowhead whale (*Balaena mysticetus*)



Migration Impacts



With open, ice-free water available, Bowhead whales linger later into fall.

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Sea Ice Reduction

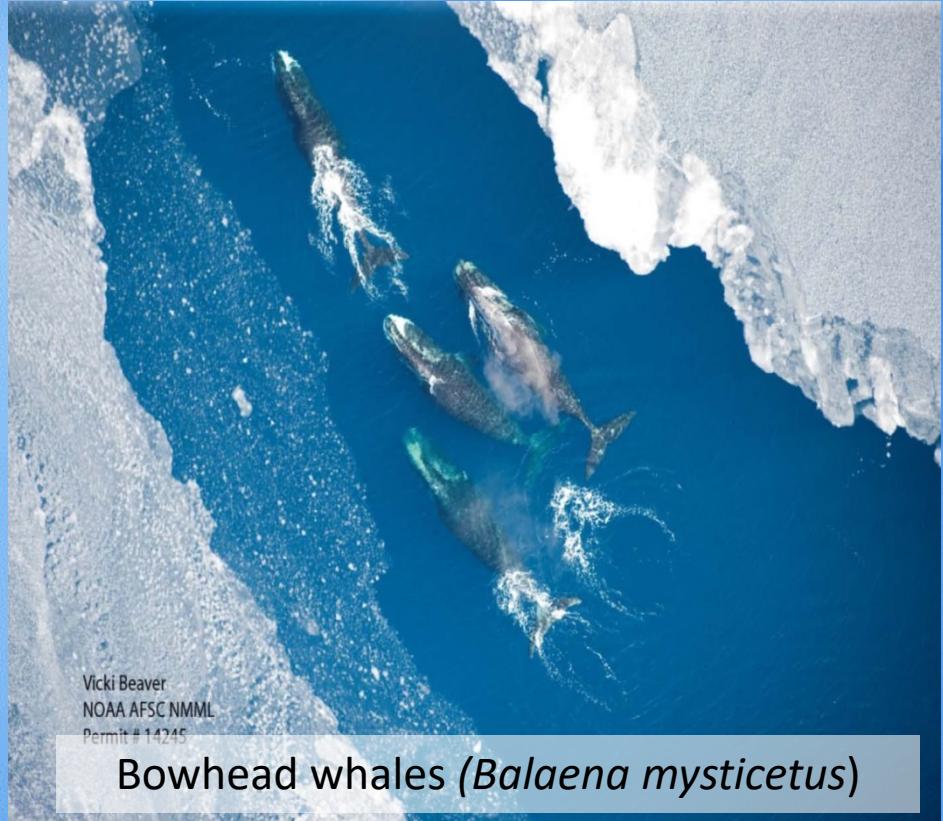
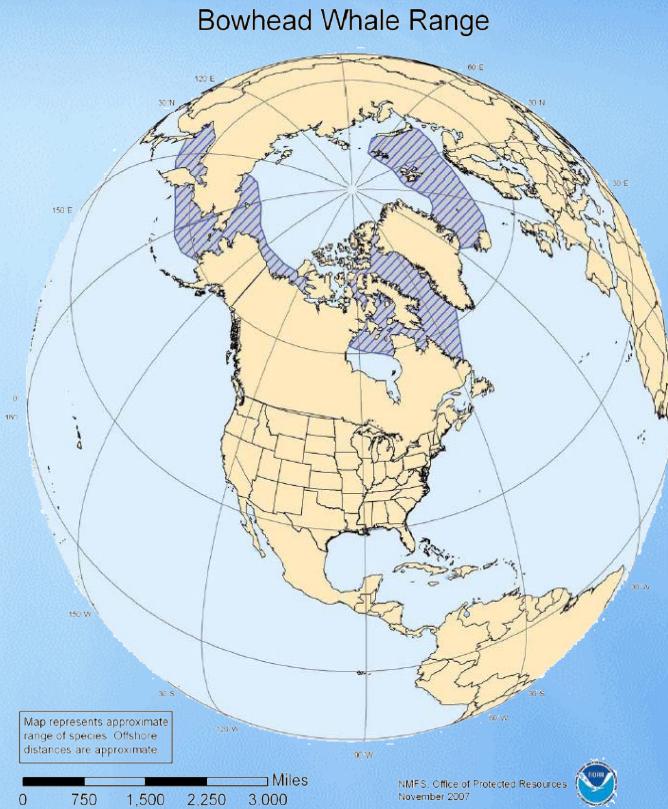
Two copepod spp.
represent majority of
zooplankton biomass.

- *Calanus hyperboreus*
(slopes and basins)
- *Calanus glacialis*
(shelves)

Primary prey spp. for
bowhead whales



Sea Ice Reduction



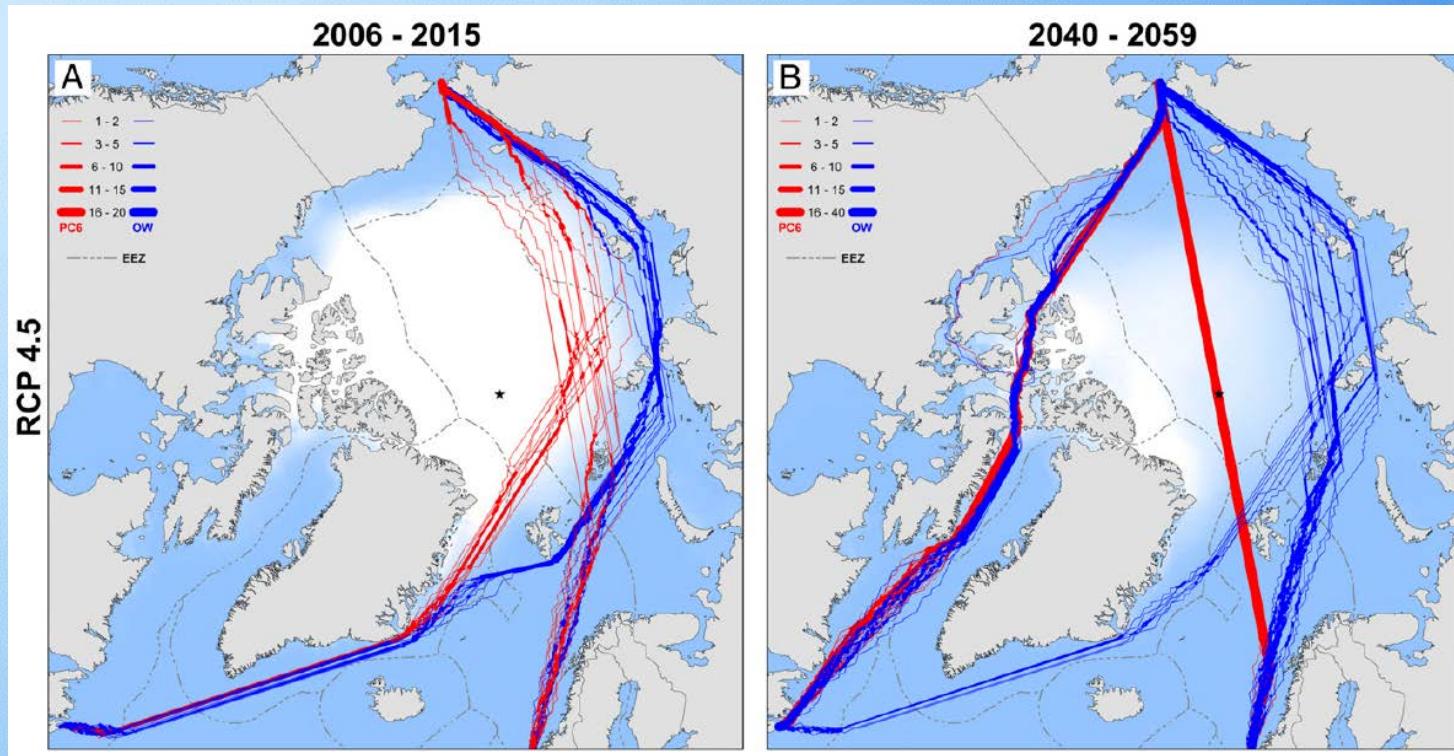
Reduction in sea ice has recently **IMPROVED** body condition of bowhead whales by allowing wind-driven upwelling, and associated plankton blooms (George et al. 2015)

SIO



Sea Ice Reduction

Predicted Effects: Climate change winner



Actual Effects: complicated by human ice-reduction effects (like expanded shipping lanes)

SIO



Sea Ice Reduction

Arctic phocid seals: Differing adaptations to sea ice

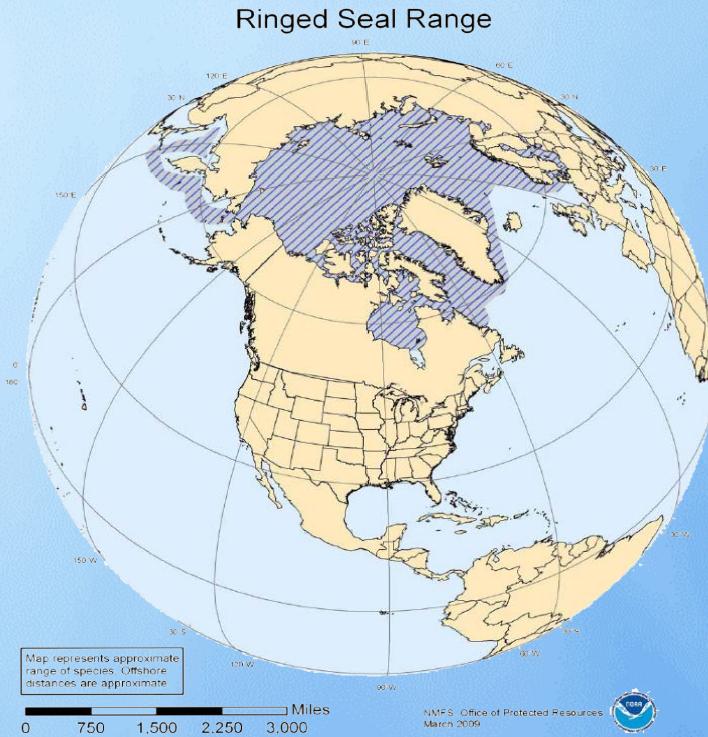


Photo: Paul Nicklen

SIO



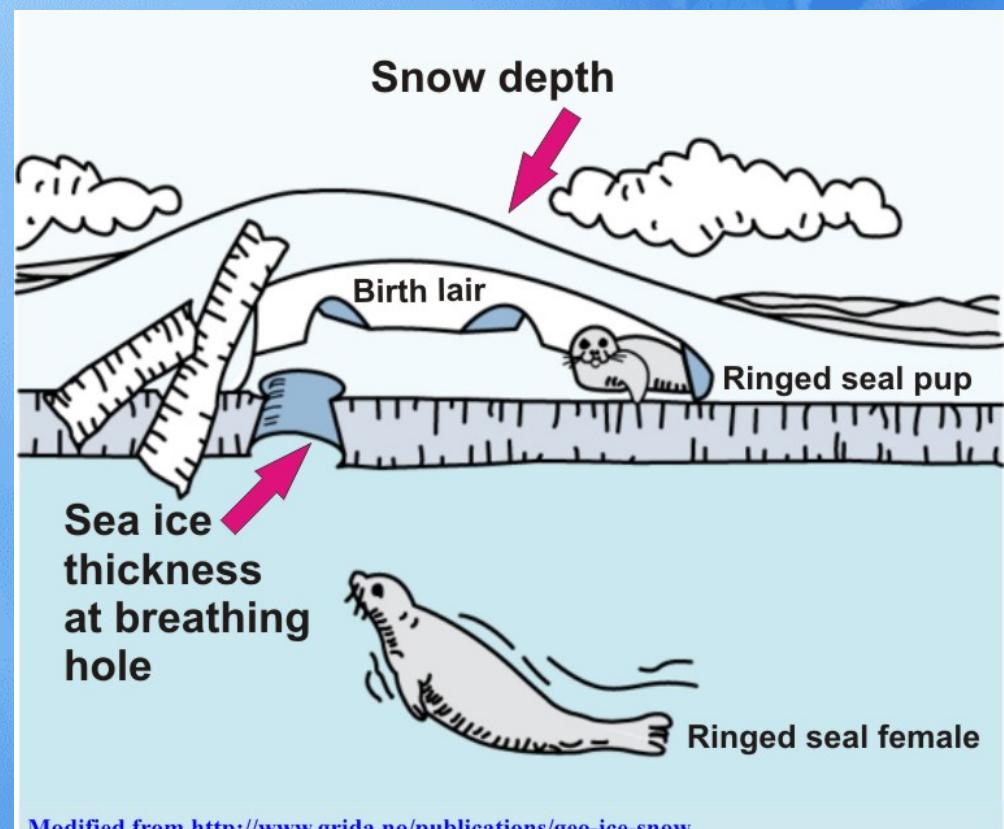
Phocidae: ringed seal

Ecology/Behavior

- Dependent upon sea ice to rest and breed
- Solitary in the water and on ice
- Piscivorous (esp. cod, herring, also eats shrimp)
- Pupping season March or April, nursing for 1 month
- Unique breeding layer in ice cut with claws

Morphology

Smallest phocid
1.4 – 1.6 m
50-70 kg ♂ ♀

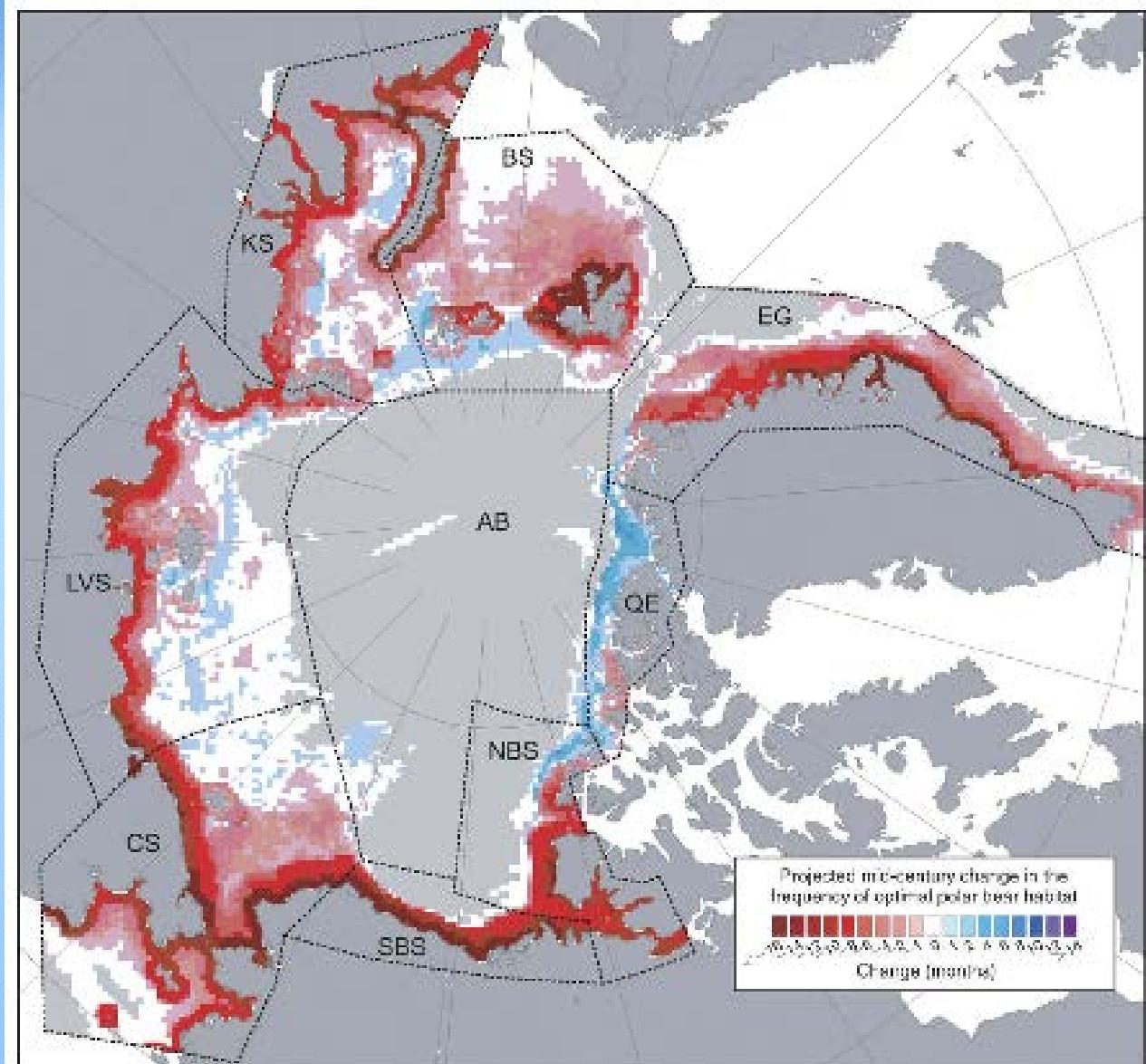


Family Ursidae

Ursus maritimus - Polar bear



Polar Bear Predicted Change Optimal Habitat



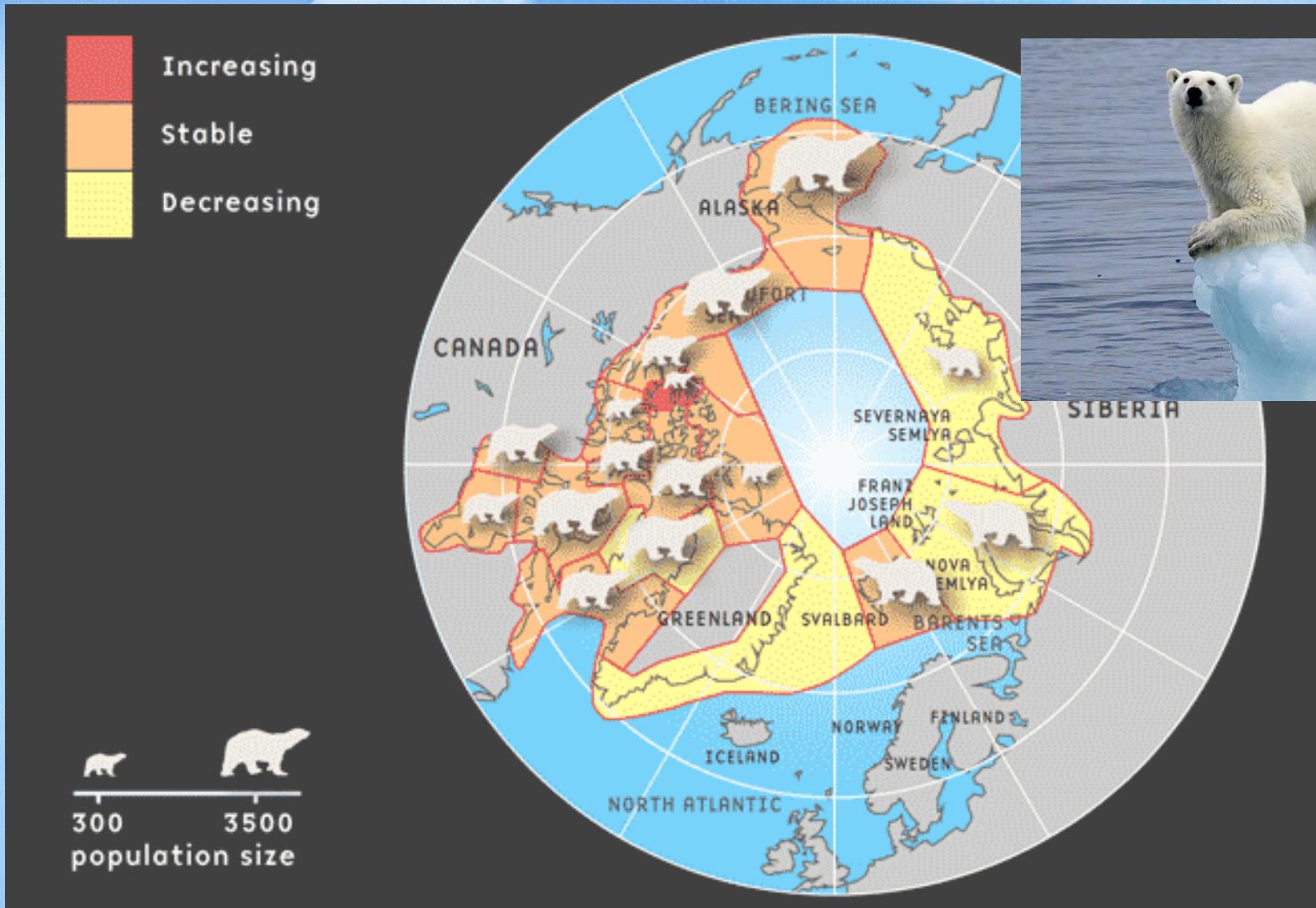
2001-2010
to
2041 - 2050

Durner et al. 2009 Ecological Monographs Vol 79



SIO

Family Ursidae



SIO



Sea Ice Reduction

Polar bear body mass decreasing

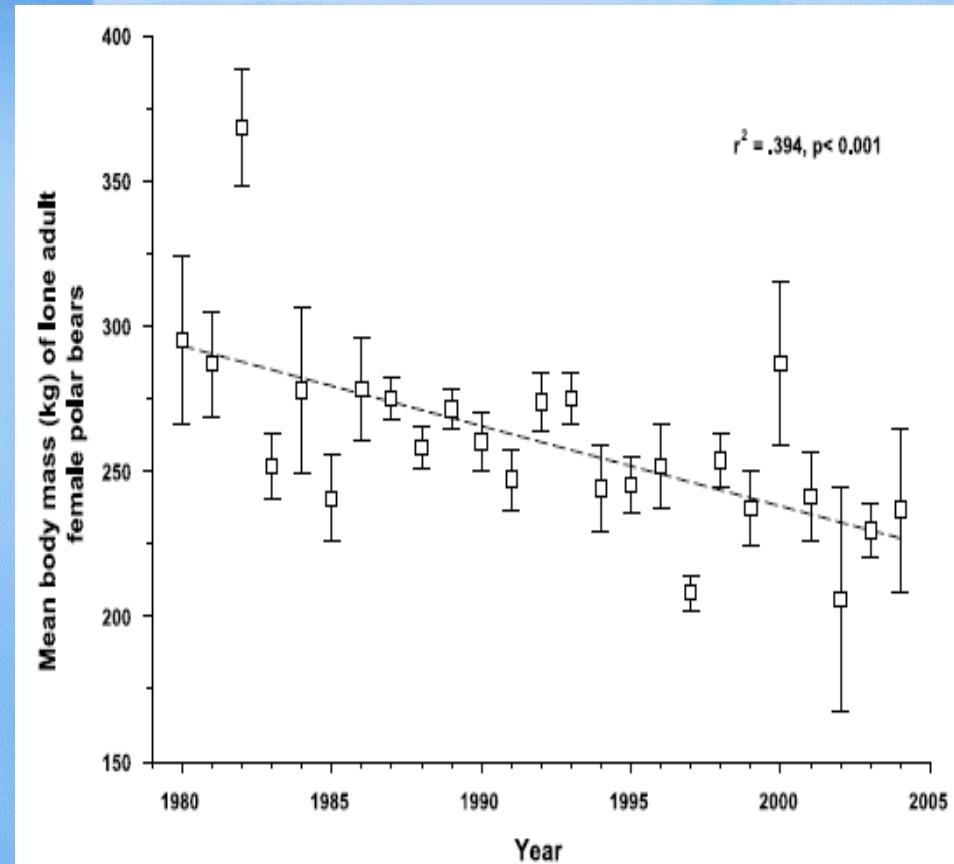


FIG. 3. Mean estimated mass of lone (and thus possibly pregnant) adult female polar bears in Western Hudson Bay from 1980 through 2004 (dashed line indicates fit of linear regression).

(Stirling and Parkinson, 2006)

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Sea Ice Reduction

Polar bear-human interactions increasing

Significant relationship with timing of sea ice breakup

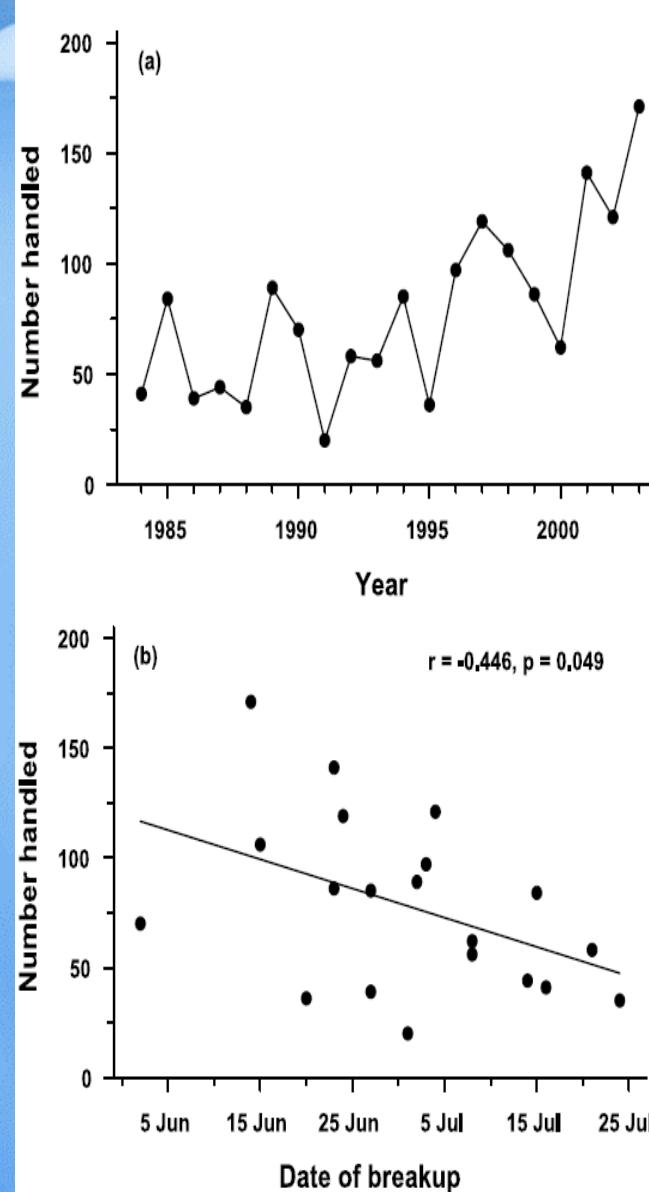


Figure. Stirling and Parkinson (2006)

SIO

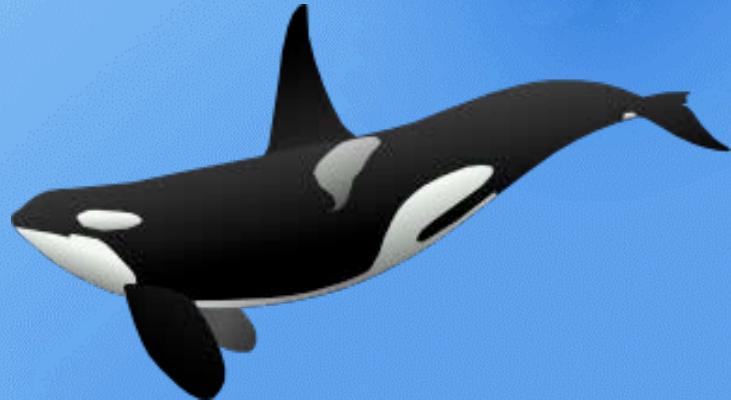


Polar Comparison

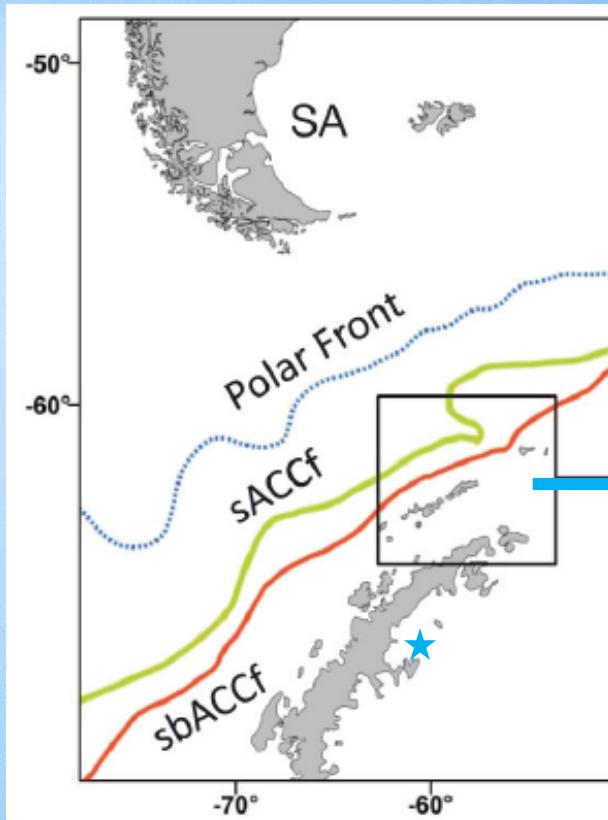
Arctic



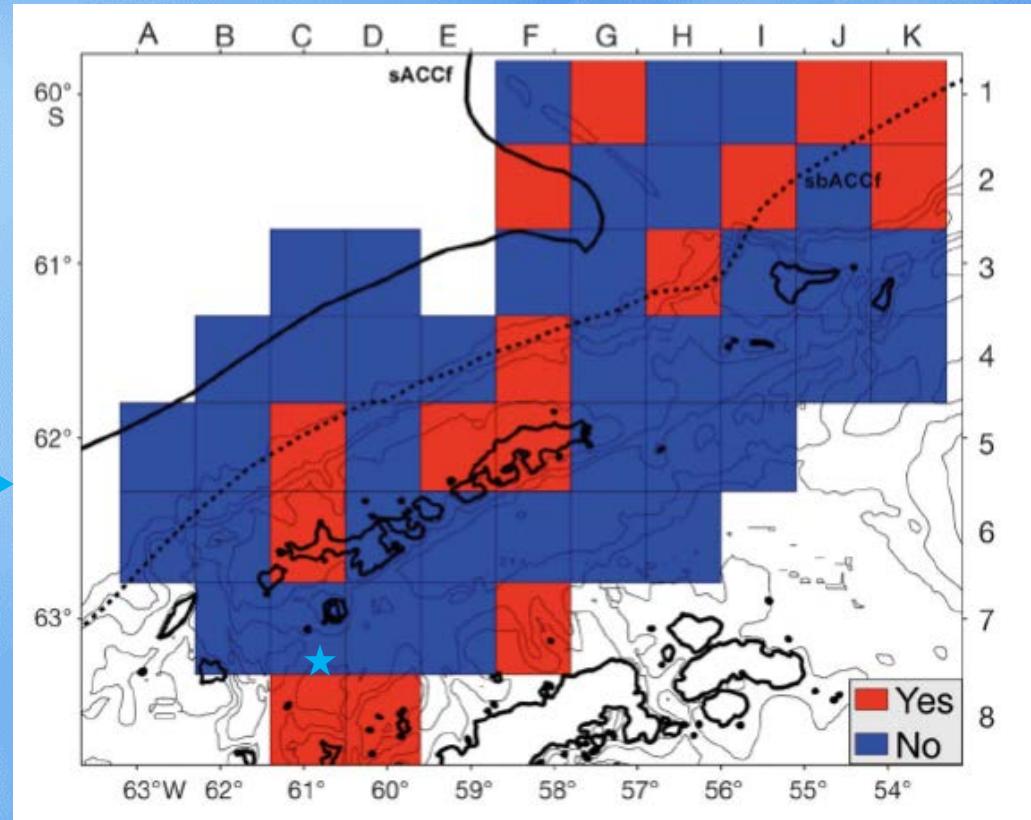
Antarctic



Polar Comparison



Orsi et al. 1995



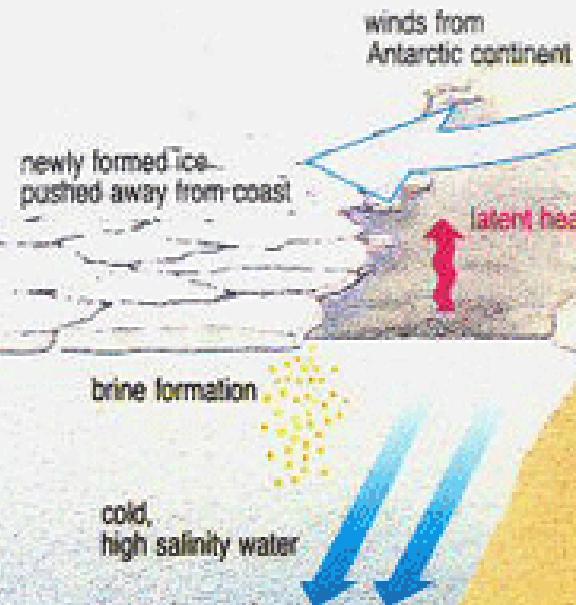
Santora and Veit 2013

Polar Comparison

OPEN OCEAN POLYNYA
(SENSIBLE-HEAT POLYNYA)



COASTAL POLYNYA
(LATENT-HEAT POLYNYA)



Phocid Breeding Behavior

Hooded seal (*Cystophora cristata*)



Crabeater seal (*Lobodon carcinophagus*)



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Killer whale (*Orcinus orca*)



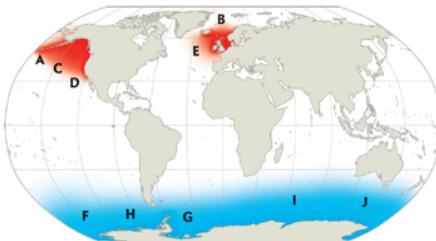
Photo: P Wa



A Resident
Preferred prey: fish,
especially salmon

Kinds of Killers

Killer whales live in all the world's oceans, without any geographical barriers to keep their populations from interbreeding. Yet studies show that in various regions distinct forms, or ecoregions, have arisen despite living in close proximity to one another. These separate groups, which do not interbreed, differ in their prey choices and how they hunt. They also differ in their physical features, such as body size and coloration, eye patch size, and the shape of the dorsal fin and the saddle patch behind it. The whales choose mates that share their customs rather than foreigners from other ecoregions. Culture appears to keep the ecoregions apart, promoting speciation.



Southern Hemisphere Forms

The Antarctic and sub-Antarctic waters harbor at least five killer whale varieties. Their cultural traditions probably differ depending on their preferred prey. For instance, members of the type B pack ice ecoregion have developed a unique strategy called wave washing to push seals off ice floes and into the water, where they are easier to nab. DNA studies indicate that the majority of these forms most likely diverged while living in the same geographical region.



Northern Hemisphere Forms

At least five killer whale ecoregions inhabit the Northern Hemisphere, each with its own hunting traditions.

For example, the type 1 individuals, which focus on herring and mackerel, herd the small fish into a tight ball for easier killing—a tactic not seen in other ecoregions. Whether the northern ecoregions began to diverge while living in the same region or whether they started to differentiate at a time earlier in the evolutionary history when they lived apart is unclear based on current evidence.

C Offshore
Known prey:
Pacific halibut
and sleeper sharks

D Transient
Preferred prey:
marine mammals

E Type 2
Preferred prey:
seals

I Type D
Known prey:
Patagonian toothfish

J Type C
Preferred prey:
Antarctic toothfish

Wave washing - “Large Type B”

Pitman & Durban 2011



R Pitman, NOAA SWFSC

Hydrurga leptonyx - leopard seal

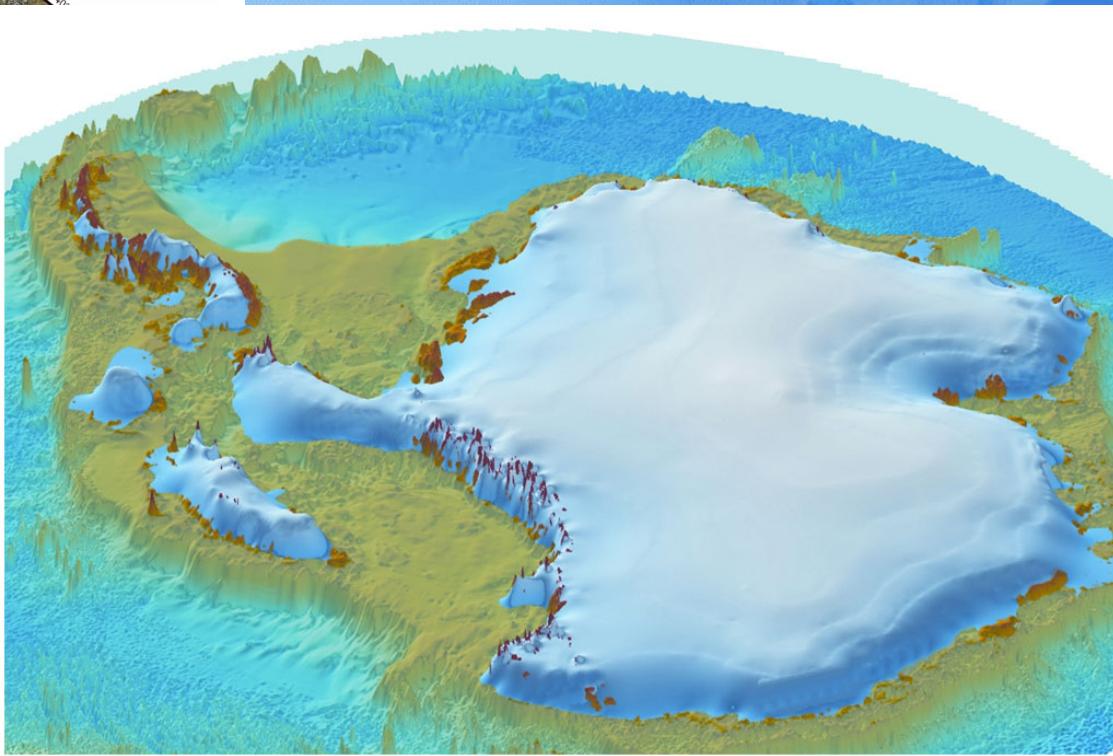
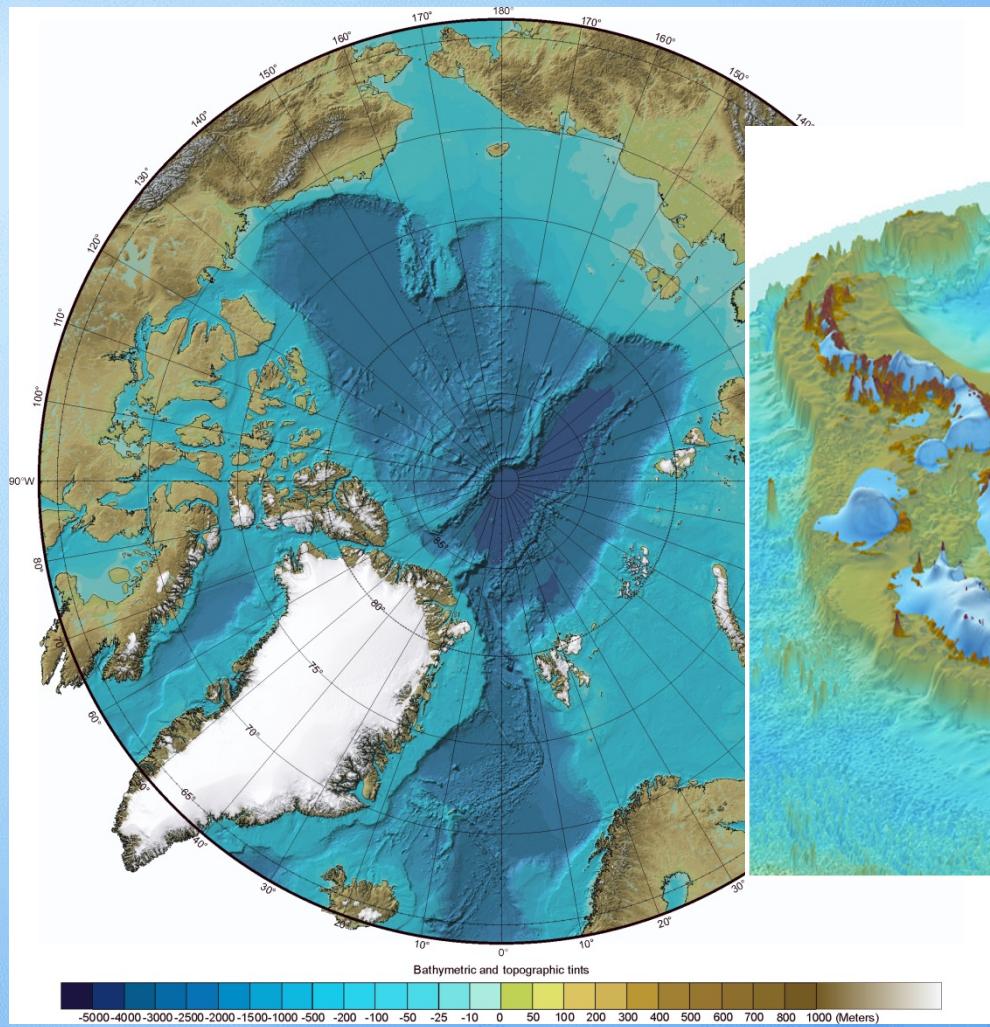


SIO



Arctic

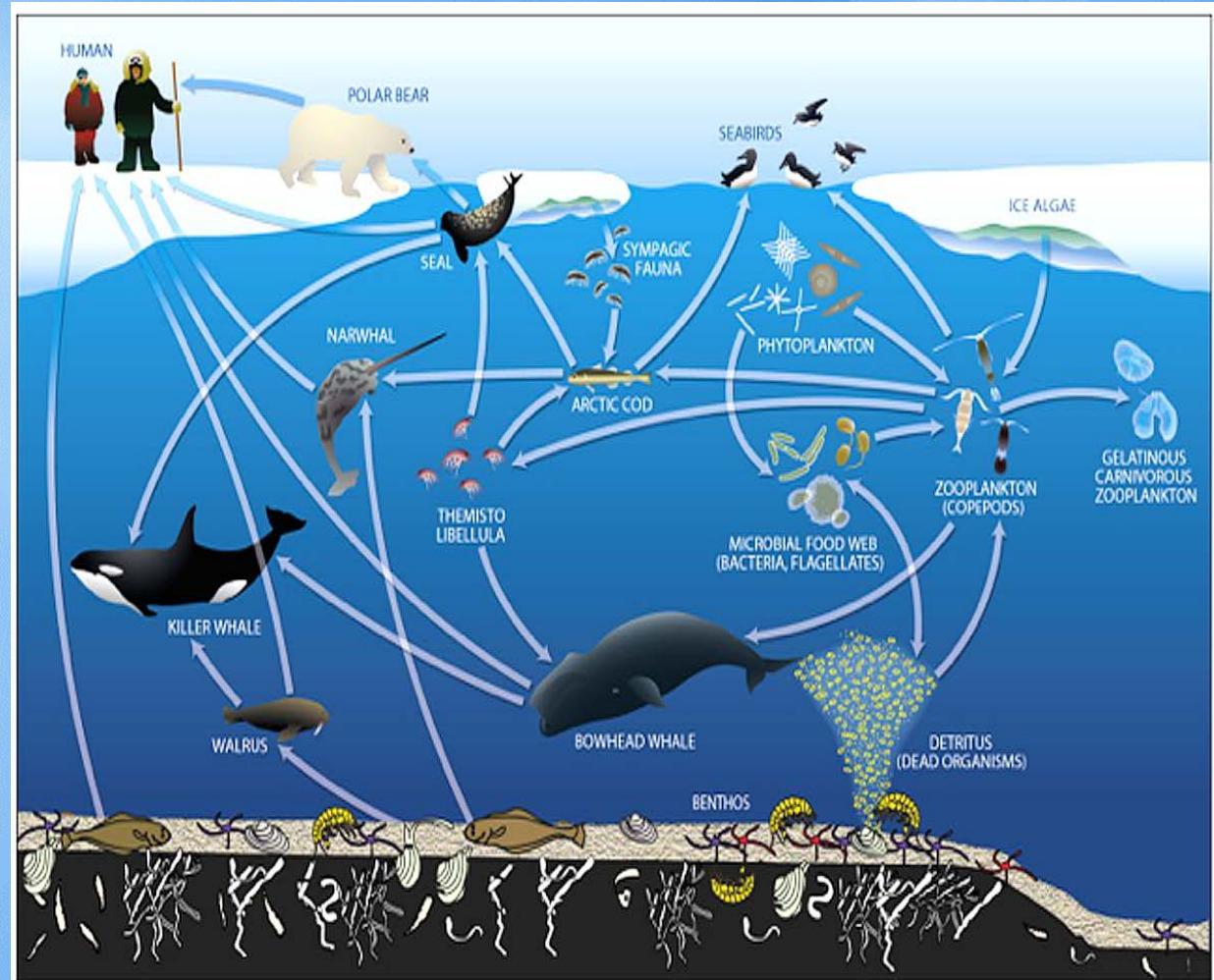
Antarctic



Sea Ice Reduction

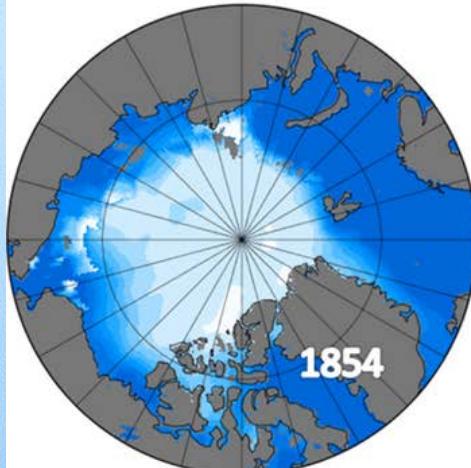
Arctic

- Short growing season
- Intense ice algal and phytoplankton blooms
- High zooplankton biomass (esp. copepods)
- High benthic biomass (shallow shelves)

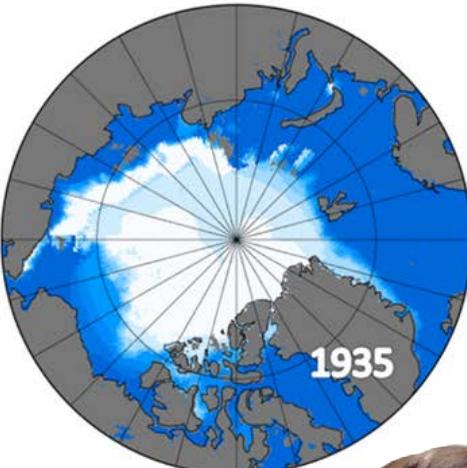


Minimum Ice Areas

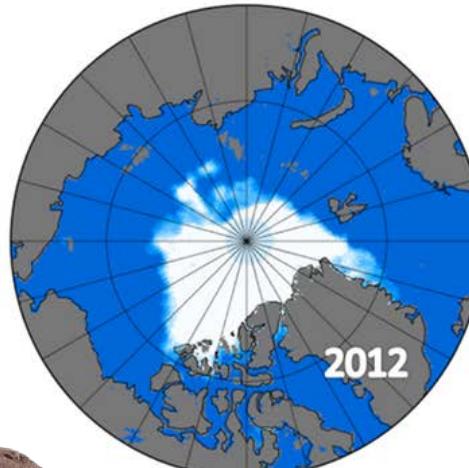
1850-1990



1901-1950

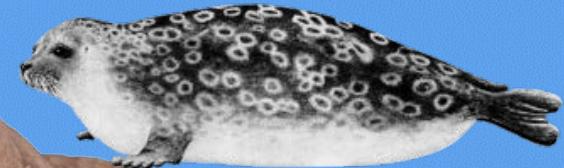
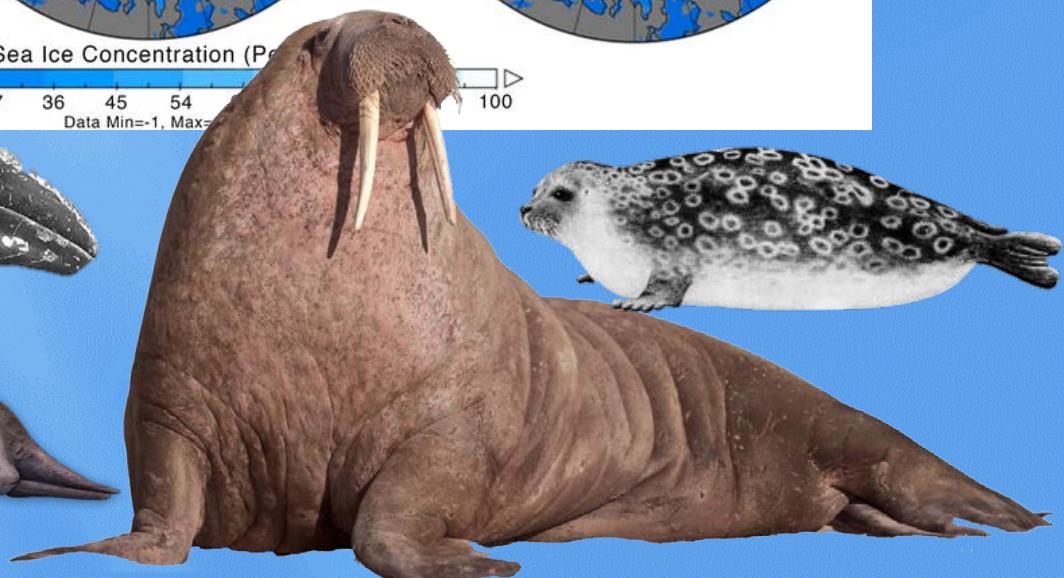
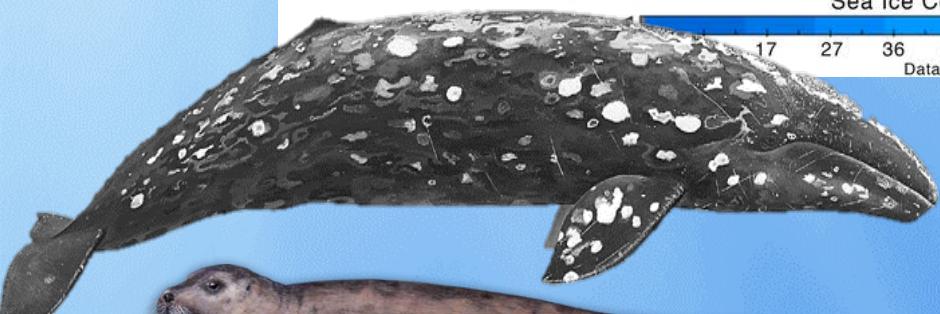


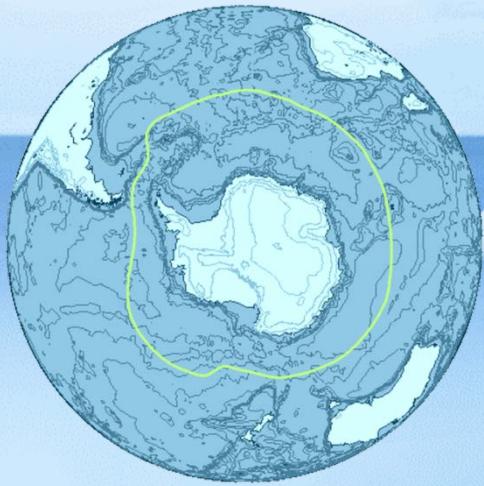
1951-2014



Sea Ice Concentration (Per Cent)

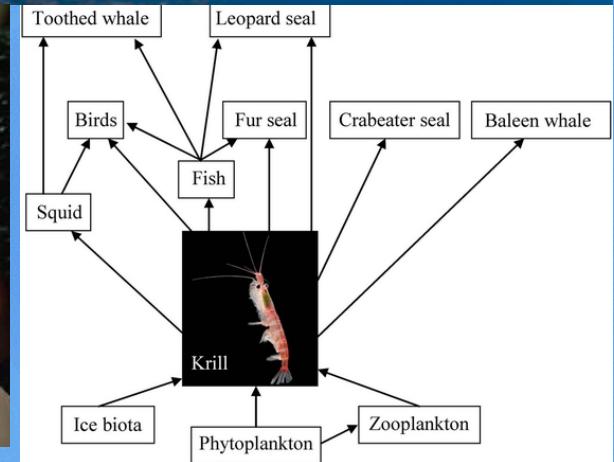
Data Min=-1, Max=100





Krill

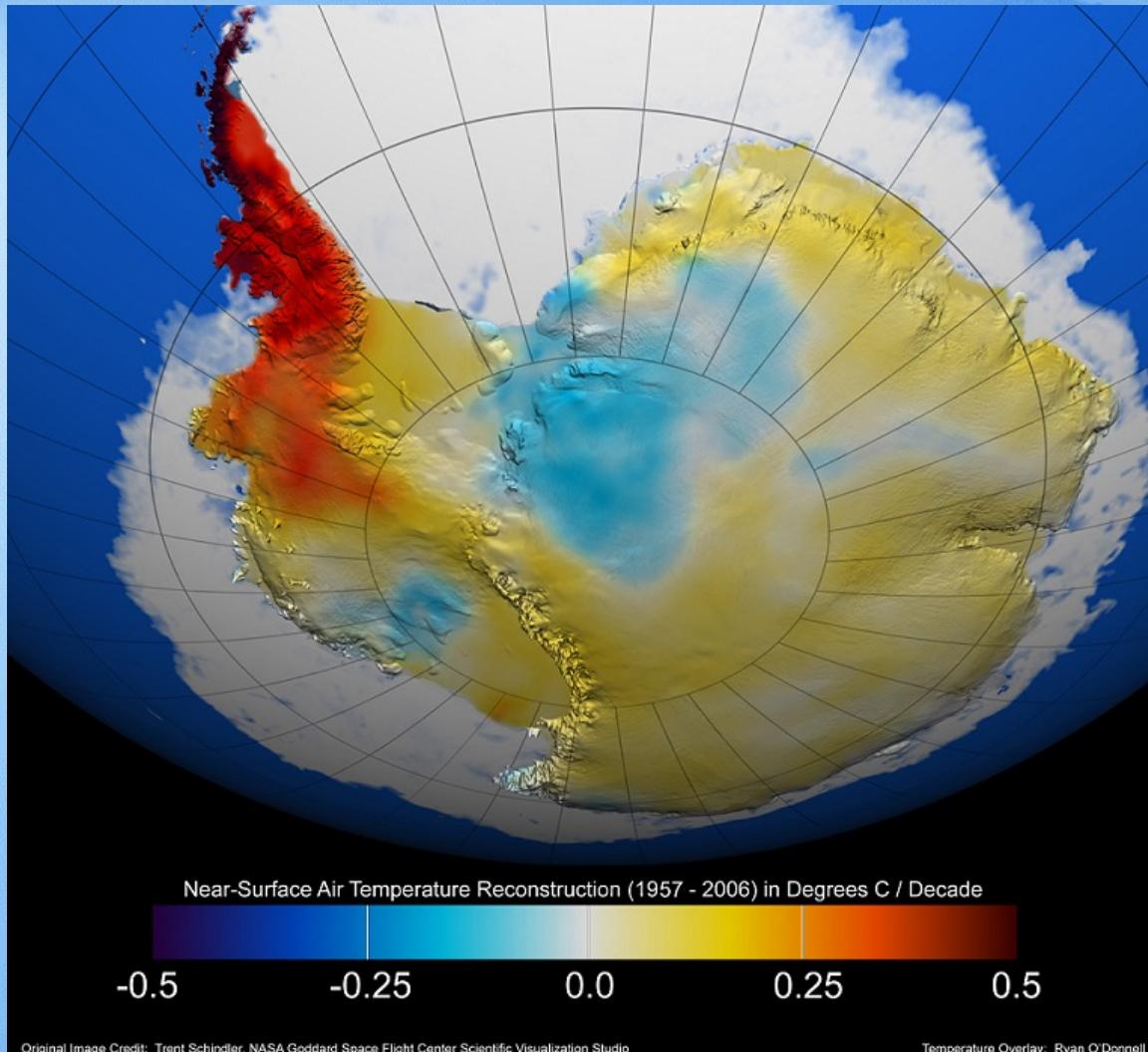
Euphausia superba



Lobodontine Seals



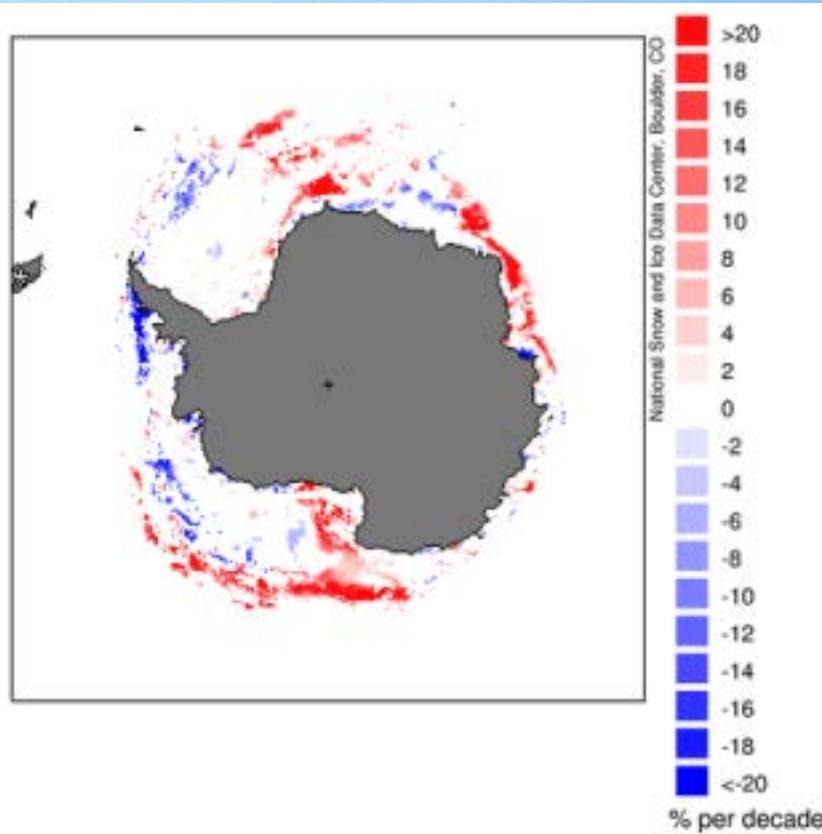
Sea Ice Reduction



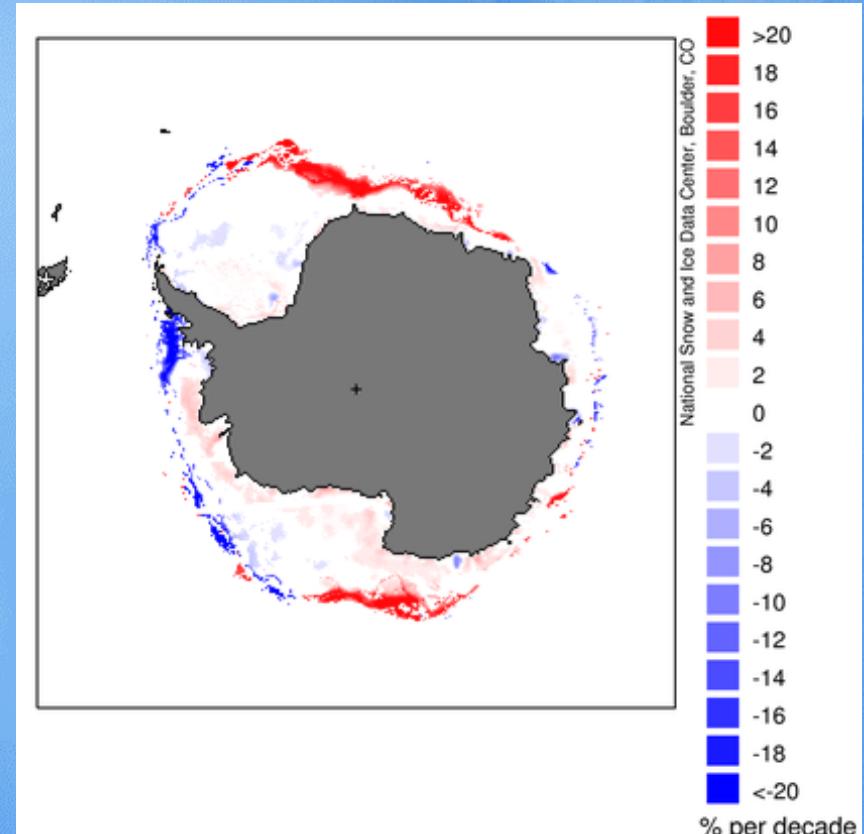
SIO



Sea Ice Reduction



Summer



Winter

Fetterer et al. 2002

SIO



Sea Ice Reduction



Sea Ice Reduction

Arctocephalus gazella Antarctic fur seal



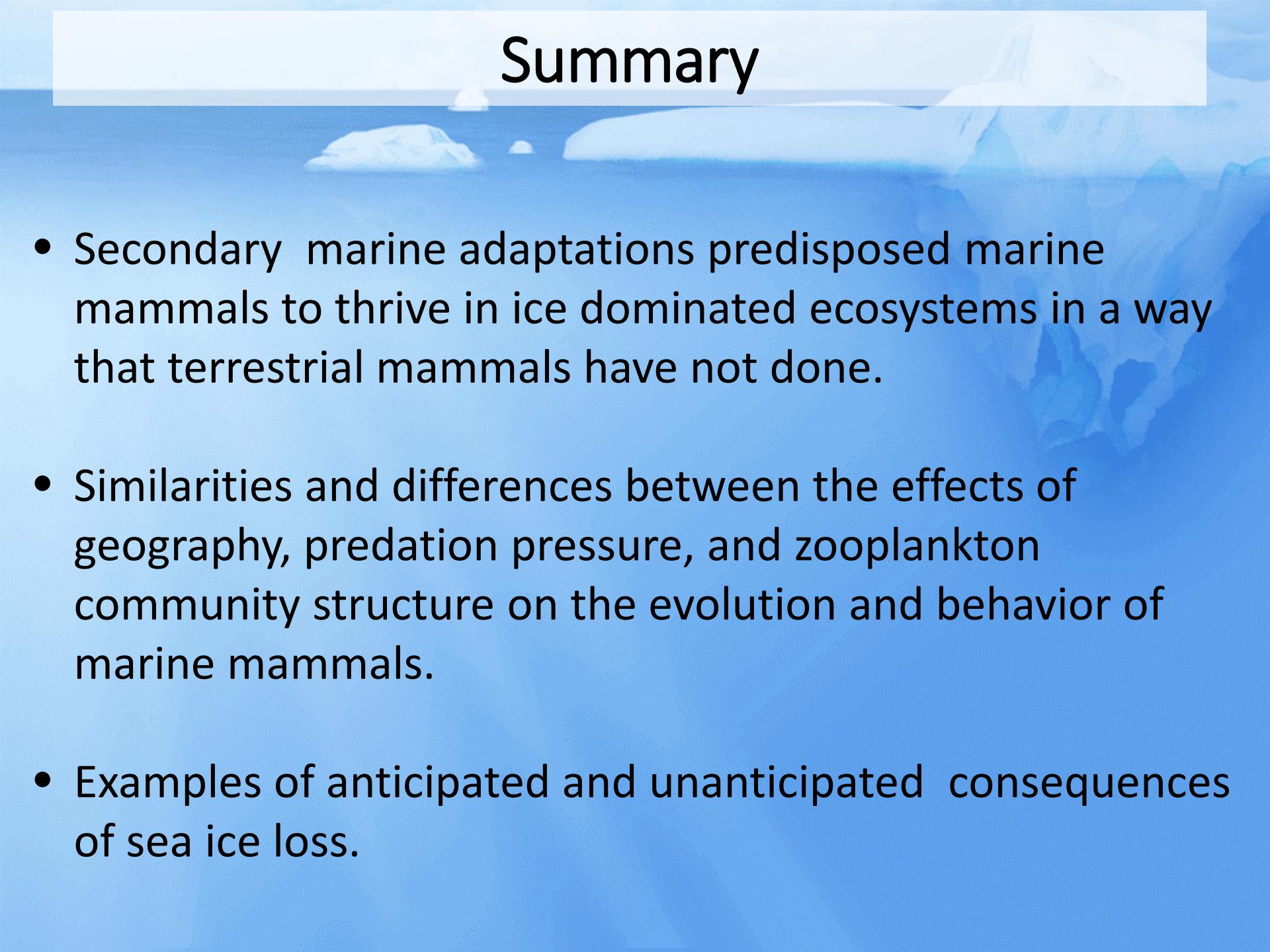
"climate change winner" (paraphrase, Mcclintock et al. 2007)

Sea Ice Reduction

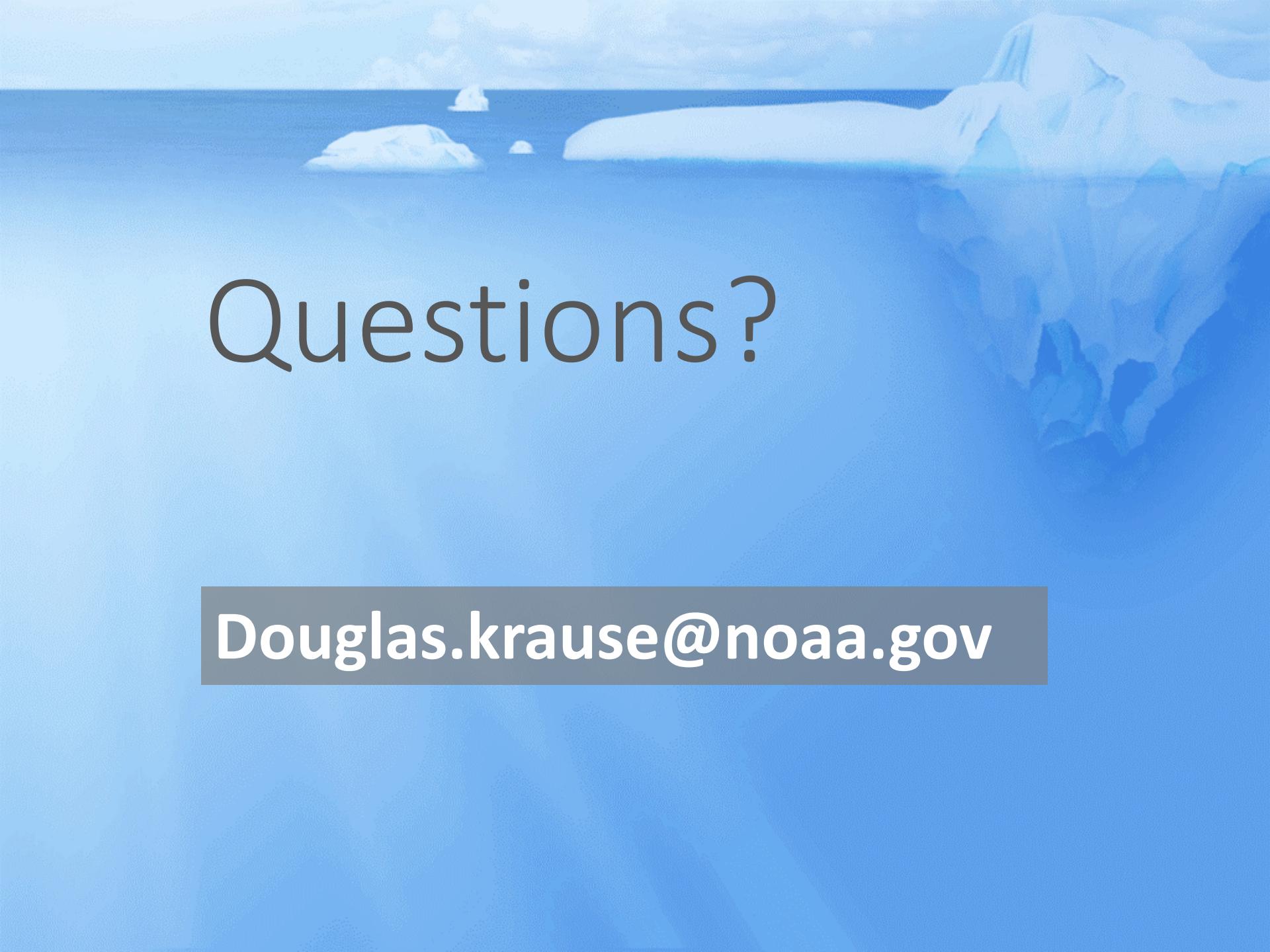


1997

Summary



- Secondary marine adaptations predisposed marine mammals to thrive in ice dominated ecosystems in a way that terrestrial mammals have not done.
- Similarities and differences between the effects of geography, predation pressure, and zooplankton community structure on the evolution and behavior of marine mammals.
- Examples of anticipated and unanticipated consequences of sea ice loss.

The background of the slide features a large, white iceberg floating in a deep blue ocean under a cloudy sky. The iceberg is positioned on the right side of the frame, with its massive bulk and intricate internal structures visible.

Questions?

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