Stomach content analysis reveals temporal changes in ice seal diets: Climate change or regime shift?

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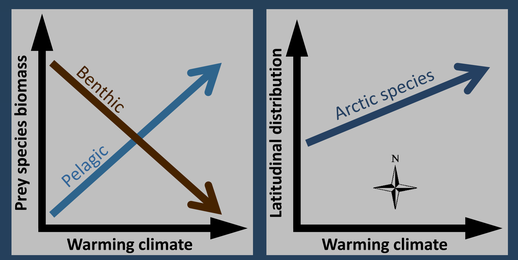
Introduction

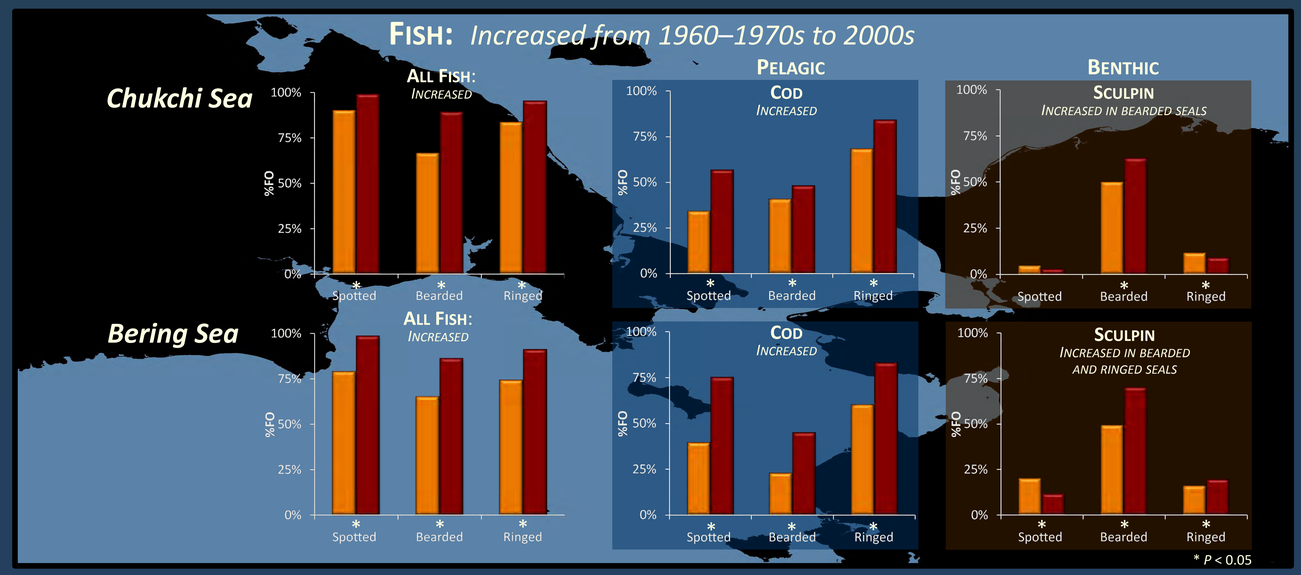
Recent studies have predicted how changes related to climate warming may impact Arctic marine food webs. Declining sea ice coverage, earlier ice melt, and increased water temperatures may lead to increases in pelagic biomass and decreases in benthic biomass (Bluhm and Gradinger 2008; Grebmeier et al. 2006). Early sea ice retreat and warming of the Bering Sea may also be responsible for a northward shift in distribution of some arctic species (e.g., arctic cod (*Boreogadus saida*)) (Mueter and Litzow 2008). Given recent concerns regarding the status of ice seals and walruses due to climate change, long-term diet data will be an increasingly valuable source of information for assessing how changes in prey distributions affect pinniped diet. Although recent changes in prey species availability are being attributed to climate warming, changes in the past likely were caused by other factors such as those responsible for regime shifts. Understanding how prey availability affects ice seal diets will allow us to better predict how changes in prey distribution may influence seal feeding ecology in the future.

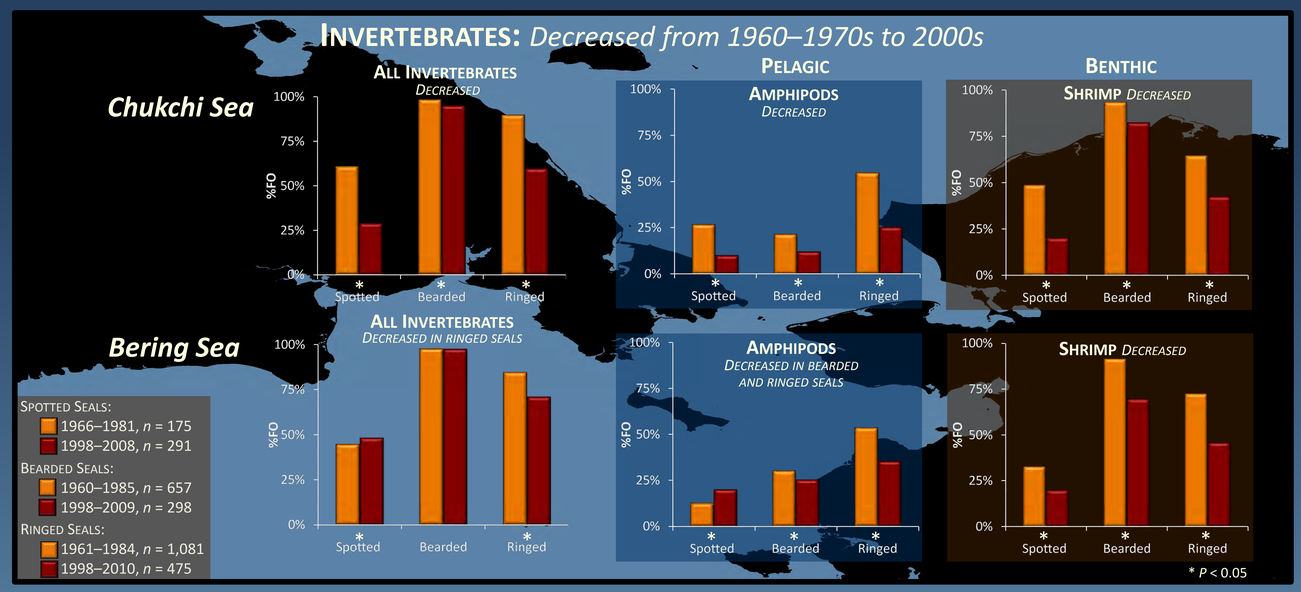


Conceptual models of predicted and observed changes in fish and invertebrates as a result of changing climate.

Methods

- Stomachs from spotted (*Phoca largha*), bearded (*Erignathus barbatus*), and ringed seals (*Phoca hispida*) harvested by Alaskan Natives and during scientific cruises were collected and frozen from 1960–2010.
- Stomachs were thawed in the laboratory and the contents were rinsed with freshwater through two sieves with mesh sizes of 1.0 mm and 0.5 mm.
- Prey items were identified to the lowest taxonomic level, grouped by taxa, and compared by time period.
- We calculated the **Frequency of Occurrence** (FO_i) for each prey item.
  - FO_i is the percentage of stomachs that contained one or more individuals of the prey item *i* out of the number of stomachs with digested material.
- To determine if seal diets have changed over time, we used **logistic regression** to test for differences in the presence of prey items. Variables of interest included:
  - **Time period** (1960–1985: *n* = 1,913, and 1998–2010: *n* = 1,064)
  - **Region** (Bering and Chukchi seas)
  - **Season** (spring-summer and fall-winter)
- Models were fit using SAS software (PROC LOGISTIC) and the best model was selected using a backward elimination procedure ($\alpha = 0.05$).





Results

- We identified changes in diet for all seal species between time periods, regions, and seasons for fish and invertebrate prey items.
  - ***Fish*** were consumed ***more*** frequently during the 2000s than the 1960s and 1970s.
    - Specifically, benthic flatfish (Pleuronectidae) and pelagic arctic cod (*Boreogadus saida*), saffron cod (*Eleginus gracilis*), and walleye pollock (*Theragra chalcogramma*) were consumed more frequently by all species in the 2000s. Bearded and ringed seals consumption of benthic sculpins also increased.
  - ***Invertebrates*** were consumed ***less*** frequently during the 2000s than the 1960s and 1970s.
    - Specifically, benthic shrimp (Caridea) and crabs (Anomura and Brachyura), and pelagic mysids (Mysida) and amphipods (Amphipoda) were consumed less frequently in the 2000s. Consumption of benthic mollusks, however, increased.

Discussion

- Contrary to predictions regarding decreases in benthic and increases in pelagic biomass, in seal diets we detected:
  - Increases in benthic and pelagic fish
  - Decreases in invertebrates, except benthic mollusks
- Contrary to predictions regarding northward shifts in arctic species, in seal diets we detected:
  - Increases in arctic cod in the Bering Sea
- If seals prefer specific prey, the availability of preferred prey may need to be further reduced before changes can be detected in seal diets; alternatively, benthic sampling efforts may not be representative of benthic prey availability for areas where seals feed.

Conclusions

- Our analysis demonstrates that significant changes in seal diet can be detected by analyzing stomach contents through time and that some of those changes do not fit the expected changes given the recent measured reductions in benthic biomass and arctic cod.
- We recommend continued monitoring of diet and body condition in ice seals to further determine when shifts in prey species availability influence changes in prey selection by ice seals.

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