Evidence for increasingly rapid destabilization of coastal arctic foodwebs

Douglas Causey[1,2]
dcausey@alaska.edu

Ashley Stanek[2]
Kate Sheehan[2,3]
Kurt Burnham[4]

[1] *University of Alaska Fairbanks, College of Fisheries and Ocean Sciences, Fairbanks, Alaska*
[2] *University of Alaska Anchorage, Department of Biological Sciences, Anchorage, Alaska*
[3] *Scripps Institution of Oceanography, La Jolla, California*
[4] *High Arctic Institute, Orion, Illinois*

Abstract

Understanding the complex dynamics of environmental change in northern latitudes is particularly critical for arctic avian communities, which are integral components that maintain biological connections between the mid- and northern latitudes. We report on studies done in 2010 – 2015 in Northwest Greenland as part of a larger effort focused on understanding the population dynamics of High Arctic marine bird communities. We use several data sources and analysis techniques, including diet data, stable isotopes, and Bayesian inference, to identify the potential relationships between ecological response of coastal marine birds and rapid environmental change such as increased freshwater runoff from glacier melt, inshore oceanographic change, and cascading trophic perturbations. Our preliminary results indicate that community-wide spatial and temporal dynamics of this high Arctic marine bird community are far greater during our study period than was evident in past decades. We also find that the magnitude of change is greater here in the high Arctic (eg., 78 °N) compared to low Arctic coastal marine ecosystems (eg., western Aleutian Islands, 53 °N). In particular, we show that the ecological patterns observed within such widespread arctic species as Dovekie (*Alle alle*), Thick-billed Murres (*Uria lomvia*), and Black-legged Kittiwakes (*Rissa tridactyla*) indicate diets are strongly perturbed from a decade earlier. Moreover, we find that the variance in environmental and ecological parameters is increasing over relatively small temporal and spatial scales. We hypothesize that these fine-scale changes are related to oceanographic and trophic-level responses to increased freshwater injection into coastal waters, in addition to larger- scale perturbations possibly related to a cascade of climate-related factors.

Introduction

It seems now indisputable that the Arctic is undergoing dramatic changes in climate, accompanied by a cascade of effects associated with warming temperatures and consequent environmental change. Coastal arctic ecosystems are particularly vulnerable given that they are at the interface of marine and terrestrial environments of the Arctic, and recent evidence suggests that change is accelerating in these regions compared to coastal systems outside of the Arctic. Coastal marine ecosystems are strongly influenced by fluxes of freshwater, nutrients, and organic matter from river inputs, a factor particularly important in the Arctic (Fig. 1).

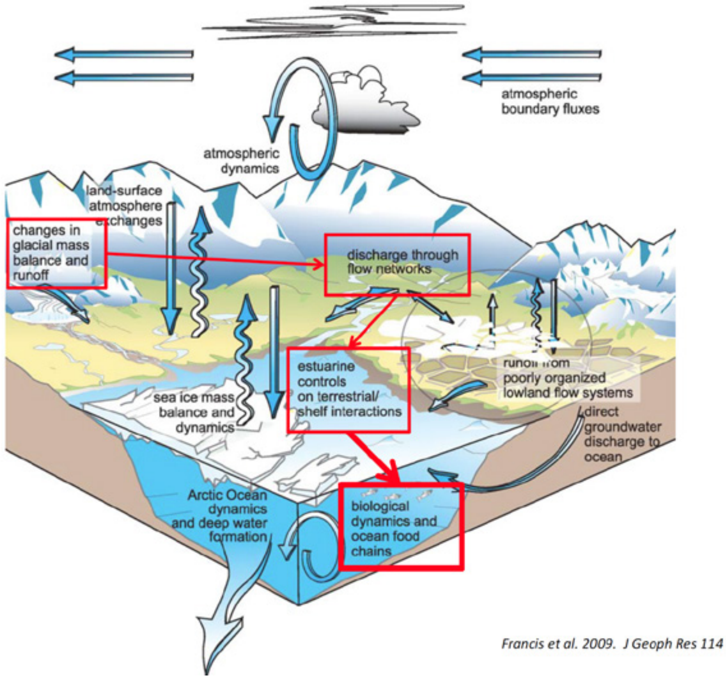


Figure 1. Interconnection of hydrology and oceanography in coastal Arctic systems.

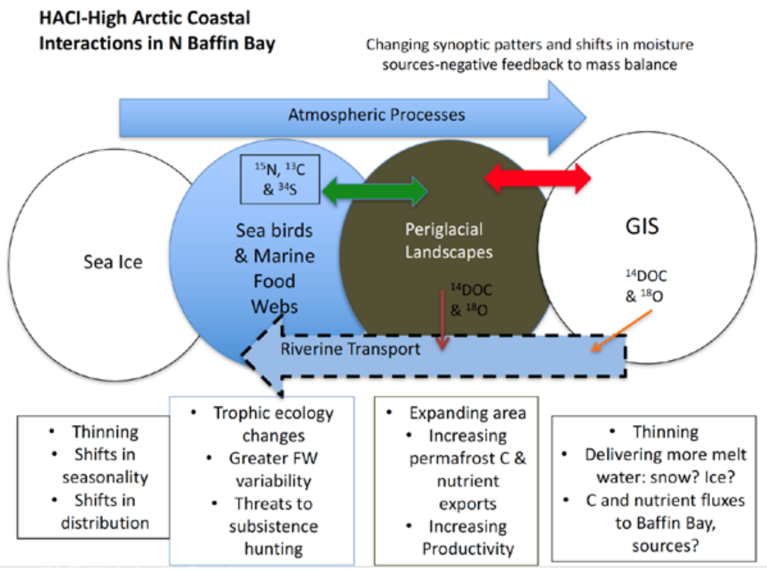


Figure 2. Dynamic interactions among coastal hydrographic systems and food webs.

Overall, the Arctic Ocean receives about 10% of the global river discharge but only comprises about 1% of the global ocean volume. Consequently, Arctic coastal ecosystems are strongly influenced by the terrestrial environment, which often imparts estuarine features at large and small scales (Fig. 2).

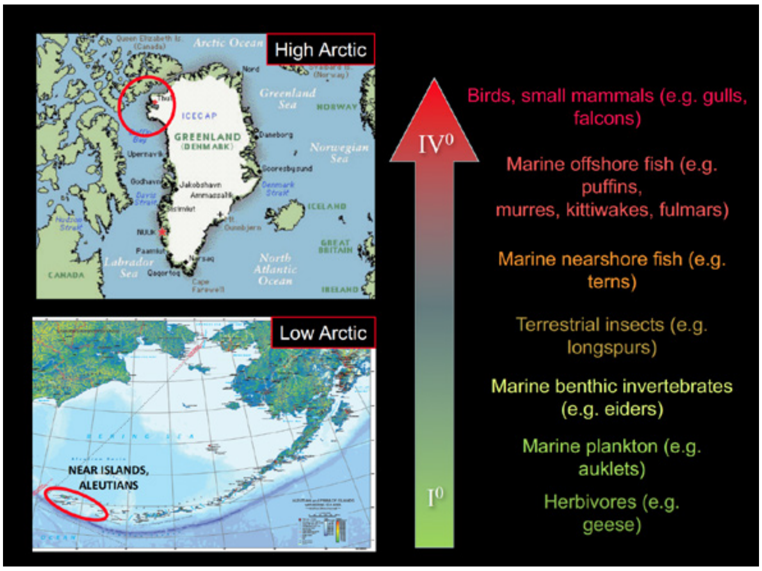


Figure 3. Trophic levels of marine birds in coastal Low Arctic and High Arctic regions.

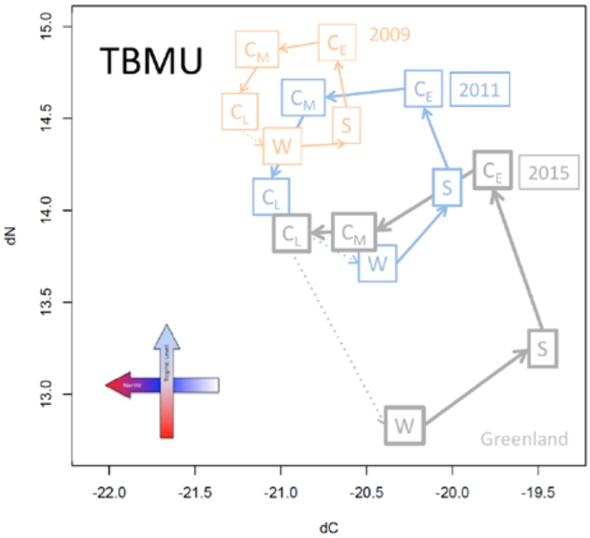
Marine food webs are strongly influenced by physical oceanographic factors as described above, and it is well known that primary and secondary productivity in Arctic shelves are often controlled by these changes, with consequent cascading effects upward into upper trophic levels (Fig. 3.)

In order to better understand Arctic foodweb dynamics on fine temporal and spatial scales, we are utilizing the foraging ecology of breeding seabirds as an indicator of oceanographic conditions and local prey availability in coastal northwest Greenland. Seabirds serve well as indicators of foodweb dynamics because they are accessible during breeding season and their diets span many trophic levels. Different prey species, especially plankton, are adapted to different oceanographic conditions, and the strong link between distribution/abundance and hydrography can help inform us on the complexity of food web dynamics. We are utilizing changes in the proportion of stable isotopes of carbon $\delta^{13}C$ and nitrogen $\delta^{15}N$ as proxy indicators of diet. We are particularly interested in understanding how stochasticity and variability in climate through hydrography may affect food web stability and dynamics.

Results

Stable isotope values from whole blood and feathers collected from Thick-billed Murres in the central region of the NOW area are shown in Figure 4. The centroids of the temporal range of stable isotope values of Carbon and Nitrogen vary seasonally, but the key aspect shown here is the decreasing nitrogen ratios (indicating feeding at lower trophic levels) and the increasing variance in values.

Figure 4. Stable isotopic biplot of dN and dC obtained from Thick-billed Murres through time. All samples were collected from the Central region of the NOW area. Squares indicate centroids of the 95% confidence ellipses of data values. C_E=Central region, early (July 1-15); C_M=Central region, mid-season (July 1-15); C_L=Central region, Late (July 1-15); S= Spring (~March – May); W = Winter (~ November – February).



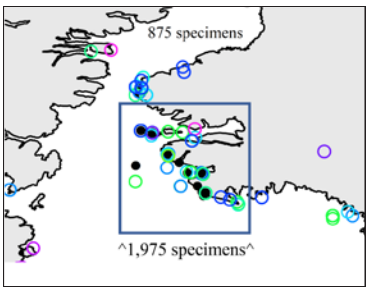
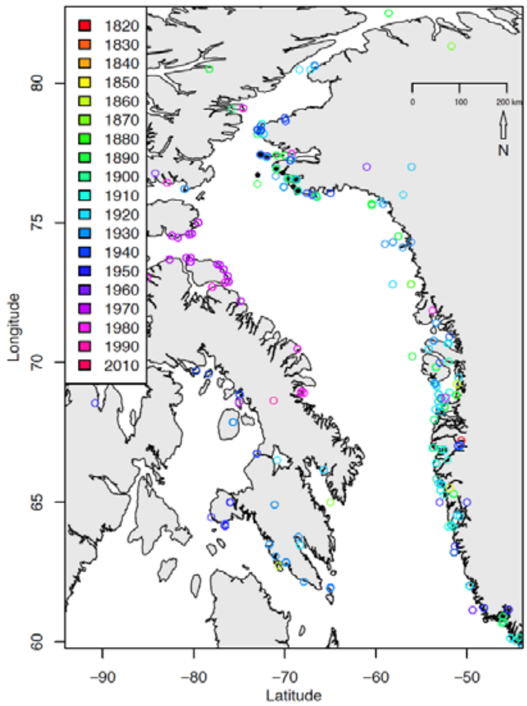


Figure 5. Total number of archival bird specimens since 1820. Specimens are curated throughout the world's natural history museums.



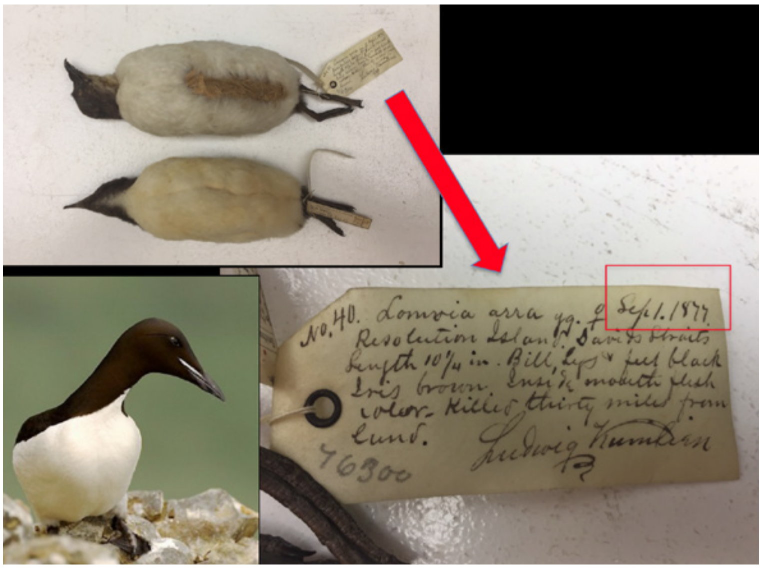


Figure 6. Thick-billed murre specimens collected from Resolution Island, Davis Straits by Leonard Stejneger on September 1, 1877.

Next Steps

We plan to continue investigations into using stable isotopes as indicators of temporal changes in diet using archival specimens collected from the 19th and 20th centuries (Fig. 5). Data from these early specimens can provide insights into the dynamics of change during periods of relative stability by comparison to the present times. Scientific specimens are relatively free of contaminating substances, and distinguished by an abundance of collection data relevant to identify locality, dates, and ecological correlates (Fig. 6.)

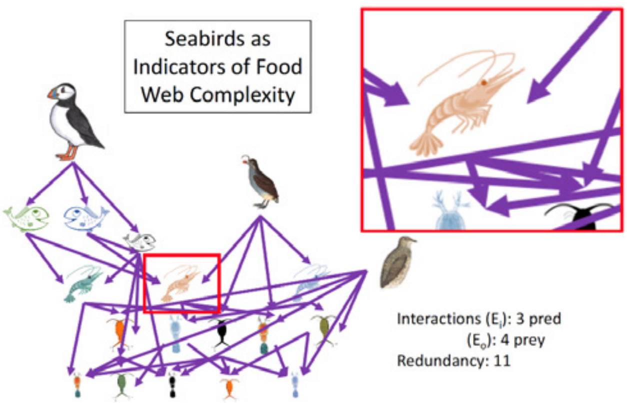


Figure 7. Diagram of the interconnectivity of seabird diet items in a localized foodweb.

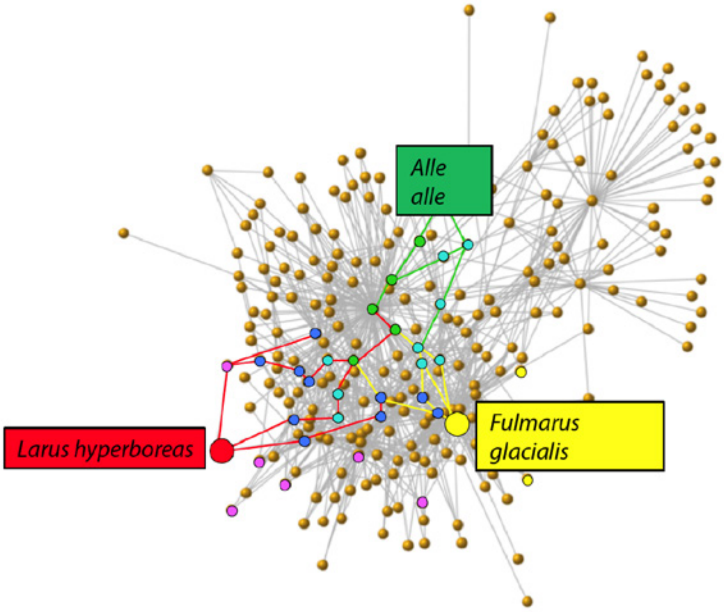


Figure 8. Conceptualized network diagram of the NOW region of Northwest Greenland.

These data, combined with correlative information relating to abundance and distribution, are particularly useful for utilizing seabirds as indicators of food web complexity. Natural history data on seabird diets, obtained by many researchers over time and space, provide fairly comprehensive lists of prey items. All the marine species are interconnected through localized food webs, which means that seabirds feeding at the top of the foodwebs are ultimately connected through lower trophic levels. This feature means that patterns observed in one seabird species is simultaneous reinforced by patterns in other seabirds by their interconnection (Fig. 7).

References

Aagaard K & Carmack E (1994). The Arctic ocean and climate: a perspective. In: Johannessen J, Muench RD & Overland JE (Eds.). The Polar Oceans and Their Roles in Shaping the Global Environment. Geophysical Monograph vol. 85: 4-20. Amer. Geophys. Union.

Abraham CL & Sydeman WJ (2006). Prey-switching by Cassin's auklet *Ptychoramphus aleuticus* reveals seasonal climate-related cycles of *Euphausia pacifica* and *Thysanoessa spinifer.* Mar. Ecol. Prog. Ser. 313:271-283.

Arimitsu ML, Piatt JF, Madison EN, Conaway JS & Hillgruber N (2012). Oceanographic gradients and seabird prey community dynamics in glacial fjords. Fish. Oceanogr. 21:148-169.

Bearhop S, Adams CE, Waldron S, Fuller RA & MacLeod H (2004). Determining trophic niche width: a novel approach using stable isotope analysis. J Anim. Ecol. 73:1007-1012.

Beaugrand G, Reid PC, Ibanez F, Lindley JA & Edwards M (2002). Reorganization of North Atlantic marine copepod biodiversity and climate. Science 296:1692-1694.

Carmack E & Wassmann P (2006). Food webs and physical-biological coupling on pan- Arctic shelves: unifying concepts and comprehensive perspectives. Prog. Oceanogr. 71:446-477.

Carmack E, Barber D, Christensen J, Macdonald R, Rudels B & Sakshaug E (2006). Climate variability and physical forcing of the food web and the carbon budget on panarctic shelves. Prog. Oceanogr. 71:145-182.

Caut S, Angulo E & Courchamp F (2009). Variation in discrimination factors ($\delta^{15}N$ and $\delta^{13}C$): the effect of diet isotopic values and applications for diet reconstruction. J. Appl. Ecol. 46:443-453.

Drew GS, Piatt JF & Hill DF (2013). Effects of currents and tides on fine-scale use of marine bird habitats in a Southeast Alaska hotspot. Mar. Ecol. Prog. Ser. 487:275-286.

Dunton KH, Schonberg SV & Cooper LW (2012). Food web structure of the Alaskan nearshore shelf and estuarine lagoons of the Beaufort Sea. Estuaries and Coasts 35:426- 435.

References

Frederickson M, Edwards M, Richardson AJ, Halliday C & Wanless S (2006). From plankton to top-predators: bottom-up control of a marine food web across four trophic levels. J. Anim. Ecol. 75: 1259-1268.

Harding AMA, Hobson KA, Walkusz W, Dmoch K, Karnovsky NJ, Van Pelt TI & Lifjeld JT (2008). Can stable isotope ($\delta^{13}C$ and $\delta^{15}N$) measurement of little auk (*Alle alle*) adults and chicks be used to track changes in high-Arctic marine foodwebs? Polar Biol. 31:725-733.

Hobson KA (1993). Trophic relationships among high Arctic seabirds: insights from tissue- dependent stable-isotope models. Mar. Ecol. Prog. Ser. 95:7-18.

Hobson KA (2008). Applying isotopic methods to tracking animal movements. In: Hobson KA & Wassenaar LI (Eds.). Tracking Animal Migration Using Stable Isotopes, pp. 45-78. Academic, London

Hobson KA & Bond AL (2012). Extending an indicator: year-round information on seabird trophic ecology from multiple-tissue stable-isotope analyses. Mar. Ecol. Prog. Ser. 461:233-243.

Hobson KA, Gilchrist G & Falk K (2012). Isotopic investigations of seabirds of the North Water Polynya: contrasting trophic relationships between the Eastern and Western sectors. Condor 104: 1-11.

Holmes RM, McClelland JW, Peterson BJ, Tank SE, Blyugina E, Eglington TI, Gordeev VV, Gurtovaya TY, Raymond PA, Repeta DJ, Staples R, Striegl RG, Shulidov AV & Zimov SA (2012). Seasonal and annual fluxes of nutrients and organic matter from large rivers to the Arctic Ocean and surrounding seas. Estuaries and Coasts 35:369-382.

Jackson AL, Inger R, Parnell AC & Bearhop S (2011). Comparing isotopic niche widths among and within communities: SIBER–Stable Isotope Bayesian Ellipses in R. J Anim. Ecol. 80:595-602.

Karnovsky NJ, Hobson KA & Iverson SJ (2012). From lavage to lipids: estimating diets of seabirds. Mar. Ecol. Prog. Ser. 451:263-284.

Layman CA, Araujo MS, Boucek R, Hammerschlag-Peyer CM, Harrison E, Jud ZR, Matich P, Rosenblatt AE, Vaudo JJ, Yeager LA, Post DM & Bearhop S (2012). Applying stable isotopes to examine food-web structure: an overview of analytical tools. Biol. Rev. 87:545-562.

McClelland J, Holmes RM, Dunton KH & MacDonald RW (2011). The Artic Ocean estuary. Estuaries and Coasts doi:10.1007/s12237-010-9357-3.

McPhee MG, Proshutinsky A, Morison LH, Steele M & Alkire MB (2009). Rapid change in freshwater content of the Arctic Ocean. Geophys. Res. Lett. 36.

Moody AT, Hobson KA & Gaston AJ (2012). High-arctic seabird trophic variation revealed through long-term isotopic monitoring. J Ornithol 153:1067-1078.

Mote TL (2013). Greenland daily surface melt 25km EASE-Grid 2.0 climate data record. http://climate.rutgers.edu/measures/snowice/greenland-daily-surface-melt

Parnell AC, Inger R, Bearhop S & Jackson AL (2010). Source partitioning using stable isotopes: Coping with too much variation. PLoS ONE 5(3):e9672.

Quillfeldt P, McGill RAR & Furness RW (2005). Diet and foraging areas of Southern Ocean seabirds and their prey inferred from stable isotopes: review and case study of Wilson's storm-petrel. Mar. Ecol. Prog. Ser. 295:295-304.

Scott CL, Kwasniewski S, Falk-Petersen S & Sargent JR (2000). Lipids and life strategies of Calanus in late autumn, Svalbard. Polar Biol. 23: 510-516.

Serreze MC, Barrett AP, Slater AG, Woodgate RA, Aagaard K, Lammers RB, Steele M, Moritz R, Meredith M & Lee CM (2006). The large-scale freshwater cycle of the Arctic. J. Geophys. Res. 111: C11010.