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'Arctic Crashes:' Revisiting the Human-Animal Disequilibrium Model in a Time of Rapid Change

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Abstract
The paper introduces a new vision advanced by the recent project, Arctic People and Animal Crashes: Human, Climate and Habitat Agency in the Anthropocene (2014–2015) developed at the Smithsonian Institution. Unlike earlier top-down models of polar animal-climate-people connections that tied changes in Arctic species' abundance and ranges to alternating warmer and cooler temperatures or high ice/low sea-ice regimes, rapid animal declines ('crashes') may be better approached at regional and local scales. This approach is close to Arctic peoples' traditional vision that animals, like people, live in 'tribes' and that they 'come and go' according to their relations with the local human societies. As the Arctic changes rapidly and climate/sea-ice/ecotone boundaries shift, we see diverse responses by Arctic people and animals to environmental stressors. I examine recent data on the status of three northern mammal species – caribou/reindeer, Pacific walrus, and polar bear—during two decades of the ongoing Arctic warming. The emerging record may be best approached as a series of local human-animal disequilibria interpreted from different angles by population biologists, indigenous peoples, and anthropologists, rather than a top-down climate-induced 'crash.' Such new understanding implies the varying speed of change in the physical, animal, and human domains, which was not factored in the earlier models of climate–animal–people's interactions.

Keywords Arctic · Climate change · Disequilibrium · Human-animal relations

Introduction

The year 2017 marked the 50th anniversary of the publication of a seminal book by Danish zoologist Christian Vibe (1913–1998), *Arctic Animals in Relation to Climatic Fluctuation* (1967), his doctoral thesis at the University of Copenhagen based on 30 years of research on various marine and terrestrial species inhabiting Greenland and the adjacent seas (Meldgaard and Born 1998; Born 2005). Vibe's monograph transformed our vision of Arctic animals' interaction with their habitat, climate, and the peoples who hunt them. It offered compelling evidence on the role of climate and sea ice regime shifts in polar animal distribution and abundance, and on the highly unstable access of indigenous people to their food resources.

Vibe's research has been cited in numerous later studies on scores of polar species, including caribou, bowhead whale, polar bear, walrus, musk-ox, common eider, Greenlandic cod, and others (e.g., Born *et al.* 2017; Derocher *et al.* 2004; Dick 2001; Gunn *et al.* 1991; Kovasc and Lydersen 2008; Reeves 1980; Stirling and Derocher 1993). It became a mainstay reference and an inspiration to many researchers on the early peopling and human habitation of the Arctic during the 1970s and 1980s (e.g., Bockstoce 1976; Damas 1984; 1996; Fitzhugh 1972; Gilberg 1974-1975; Krupnik 1983, 1989, 1990; McCartney 1980; McGhee 1970, 1984; McGovern 1991; Minc 1986; Schledermann 1976; see also http://www.worldcat.org/title/arctic-animals-in-relation-to-climatic-fluctuations/oclc/459845).

Vibe's pioneer vision was a product of the mid-twentieth century natural sciences. Following Charles Elton's seminal research on animal cycles in northern North America based on the Hudson Bay Company's and other historical records (Elton 1942) and similar biological studies of the time (Braestrup 1941; Elton 1924; Elton and Nicholson 1942; Keith 1963; Siivonen 1948), Vibe used Greenlandic hunting statistics from the early 1800s onward, specifically, on the amount of traded animal pelts, tusks, down, blubber, and fish

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at various trading stations across Greenland as proxy indicators of high (or low) abundance of respective wildlife species. He linked such peaks (or drops) to climate fluctuations caused by the recurring historical phases of the polar ice pack roughly 50–100 years in duration. Vibe also referenced the then-popular 11-year sunspot cycle, with a rather tenuous association with the longer ice regime shifts (Vibe 1967, 1970) and projected it back in time roughly to 1100 AD, using historical Icelandic saga and documentary records on the drift ice distribution around Iceland construed by Lauge Koch (1945). He also referred to a much-longer 1800-year climate cycle advanced 10 years earlier by Russian geographer, Arsenyi V. Shnitnikov (1957), without citing his monograph.

The result was Vibe's cyclical model of the *recurrent Arctic disequilibrium* that implied periodic transitions from animal scarcity to abundance, and back, according to the climate and sea-ice phase of the time. The model, first outlined in 1950 (Vibe 1950a, 1950b), introduced the recurring 'warming-cooling' cycles in Greenlandic history and domino-like responses along the chain of actors – from sea ice to climate to animals to people. The model posits that when there is more (or less) drifting ice around Greenland, the climate gets colder (or warmer), to which the animals react by shifting their habitats, normally by migrating south or north (Vibe 1967). Arctic people, similarly, responded by moving or by switching to economic activities best suited to the then predominant animal species. They had no alternative responses to such periodic shifts in game animal fluctuations other than scarcity or starvation.

Vibe's model was a top-down general paradigm based on sets of proxies from different areas in Greenland and elsewhere in the Arctic. Yet it produced a powerful argument *against* the then-popular concept that early hunter-gatherers and other so-called 'small-scale' societies lived in a sort of self-controlled balance or 'equilibrium' with their home ecosystems (e.g., Birdsell 1968; Hardesty 1977; Hayden 1972; Moran 1979; Rappaport 1968; and others – see Morgan *et al.* 2017). It provided strong evidence that such equilibrium was hard, if not impossible to maintain, as the polar environment was too unstable for any static human-animal relations (Krupnik 1990, 1993).

Human-Animal Disequilibrium in the Time of Climate Change

Today, we live with rapid climate change that is happening twice as fast in the Arctic than elsewhere (Larsen *et al.* 2014). Modern scholars have unprecedented access to troves of new data on sea-ice, temperature, weather, and ecosystem shifts (e.g., ACIA 2005; Chapin *et al.* 2014; Richter-Menge *et al.* 2016; Taylor *et al.* 2017). Over the past 40 years of satellite observation, scientists have recorded a 50% reduction of the summer Arctic sea-ice area and a 75% reduction of the total ice volume (Larsen *et al.* 2014; Perovich *et al.* 2015; Stroeve *et al.* 2007; see Fig. 1). The continuing thinning and shrinking of Arctic sea ice has triggered massive coastal erosion during the ice-free summer and fall seasons and caused increased storm activity in the wintertime. The percentage of thick, solid 5-year or older pack ice has declined from 20% in the 1980s to barely 3% today (Perovich *et al.* 2015:35). High temperatures, river and storm floods, thawing permafrost, and forest fires have produced similar drastic effects in terrestrial ecosystems.

Current climate-change researchers have developed new models and paradigms to address disequilibrium in human-natural systems (e.g., the Resilience and Vulnerability approach, the Adaptive Capacity building approach, and the Community-based risk assessment approach) that invariably favor local perspectives rather than the grand scenarios of the past (Carson and Peterson 2016; Ford *et al.* 2012; Ford and Smit 2004; Hovelsrud and Smit 2010; McDowell *et al.* 2016; Reid *et al.* 2009; Rosales and Chapman 2015; Smit and Wandel 2006). They repeatedly emphasize that every change is *local* and each case of disequilibrium has its own causes besides overall climate fluctuations.

At the same time, biologists are increasingly adopting an approach to large Arctic animal species as complex systems (meta-populations) composed of several geographically isolated or overlapping sub-populations (Heide-Jørgensen *et al.* 2013; Hinkes *et al.* 2005; Nagy *et al.* 2011; Ray and McCormick-Ray 2014; Regehr *et al.* 2016). Such local 'stocks' or 'herds' are exposed to varying sets of regional stressors and often have individual population trajectories (Meltofte 2013; Reid *et al.* 2013**)**. Today's researchers also rely on regional synopses of Arctic ice and climate change (Grebmeier *et al.* 2006, 2009; Wood *et al.* 2015), as well as on extensive historical datasets for many documented animal collapses, caused by both indigenous and Euro-American populations, particularly for caribou, bowhead whale, and walrus (Allen and Keay 2006; Bergerud *et al.* 2008; Bockstoce and Botkin 1980, 1982, 1983; Meldgaard 1986; Ross 1979, 1993; Stewart *et al.* 2009; Witting and Born 2014). Following the new 'historical herd' approach (Burch 2012), ranges and past dynamics of several species of *individual* animal groups can be construed whenever adequate historical or genomic data are available.

Because of this new high-resolution approach vision of local geography - environmental, animal, and human - researchers are better equipped to address cases of animal crashes at sub-population, even local scale. Fifty years after Vibe's pioneering study, we may revisit Arctic climate-people-animal relations using new datasets and improved research tools, and observe in real time animal and human responses to environmental stressors that were either not anticipated or not addressed in the 1960s and 1970s. I attempt to reassess such relations through overviews of recent data on the status of 3 northern

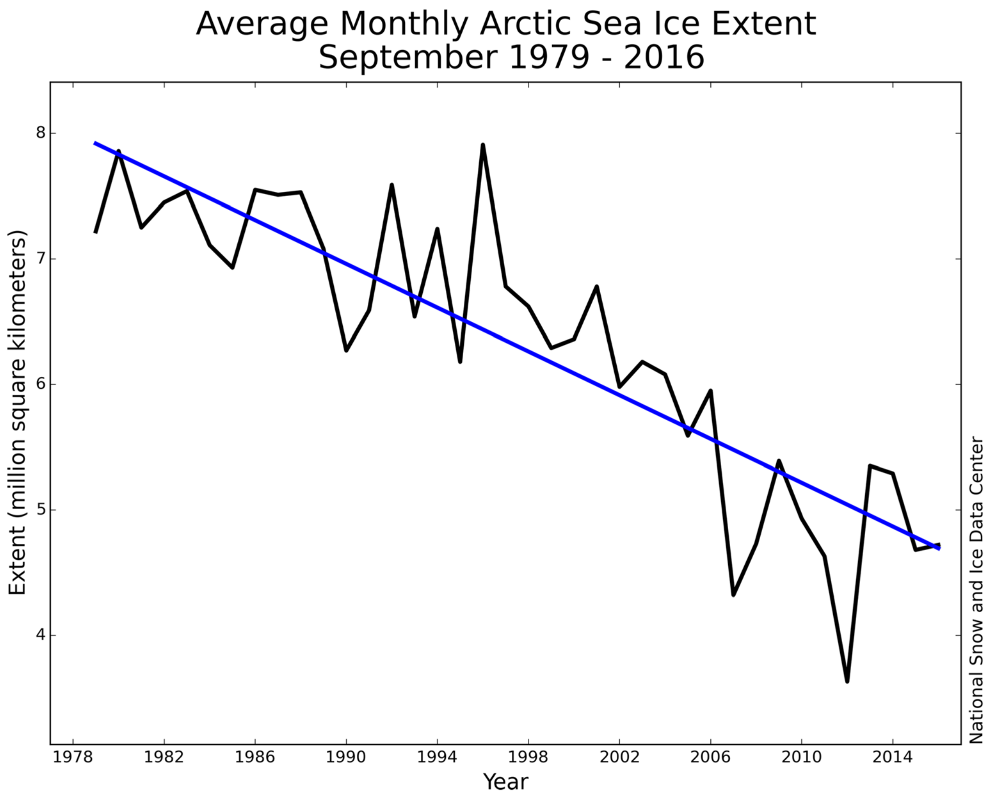

Fig. 1 Decline in seasonal minimum (September) Arctic sea ice extent, 1979–2016 – http://nsidc.org/arcticseaicenews/2016/10/

mammal species – caribou/reindeer, Pacific walrus, and polar bear - and by introducing new insights, primarily from Arctic indigenous knowledge holders collected during two decades of the ongoing Arctic warming.

Contemporary Crashes: Three Cases

Reindeer/Caribou

Rangifer tarandus is the most common and abundant ungulate species across the world's northern regions, with wide circumpolar distribution and a prime role in Arctic peoples' economies, past and present (Fig. 2). Within the species circumpolar range, besides the general distinction between the domesticated versus wild reindeer ('caribou' in North America, 'wild reindeer' in Eurasia), biologists identify 14 individual subspecies and numerous local 'herds' (Wilson and Reeder 2005).

Populations of caribou/reindeer are known to undergo dramatic fluctuations and to be significantly affected by climate and habitat change and by human predation. Vibe (1967:153–180) described wild reindeer crashes in Greenland. Numerous summaries of population cycles, for both domesticated and wild reindeer are available for Alaska, Arctic Canada, northern Scandinavia, and the Russian Arctic (e.g., Bergerud 1980; Bergerud *et al.* 2008; Burch 2012; Klokov 2012; Meldgaard 1986, 1987; Syroechkovskyi 1982). The common approach is that reindeer/caribou populations experience dramatic fluctuations in range and numbers due to many factors but primarily in response to the changing climate. Cooling climate phases may be generally more favorable to the species, as the increase in winter freezing-rain events and heat stress in the summertime caused by climate warming often trigger catastrophic crashes of both domesticated and wild stocks of Rangifer (Krupnik 1993:143–147).

Current climate warming coupled with the rapid industrial development in the Arctic placed reindeer/caribou in the center of climate change debates and reindeer/caribou dynamics are now researched both globally (Gunn and Russell 2011; Russell 2008) and at the level of individual stocks or herds. At least 34 regional caribou herds have been identified in North America and over two dozen in Northern Eurasia (CARMA n.d.; Nagy *et al.* 2011; Russell and Gunn 2013). The number of major herds of domestic reindeer should be in the hundreds, spread widely in Northern Eurasia and in smaller clusters in North America. For many local herds detailed population histories are available, often going back decades, even centuries (Bergerud *et al.* 2008; Burch 2012; Meldgaard 1986; Syroechkovskyi 1982; Valkenburg *et al.* 1994; Whitten 1996).

The increase in knowledge on the dynamics and diversity of the *Rangifer* meta-population has revealed certain correlations, even among isolated areas (such as North Alaska and Labrador-Ungava in the late 1990s and early 2000s), but also strong regional variation in trajectories of individual herds

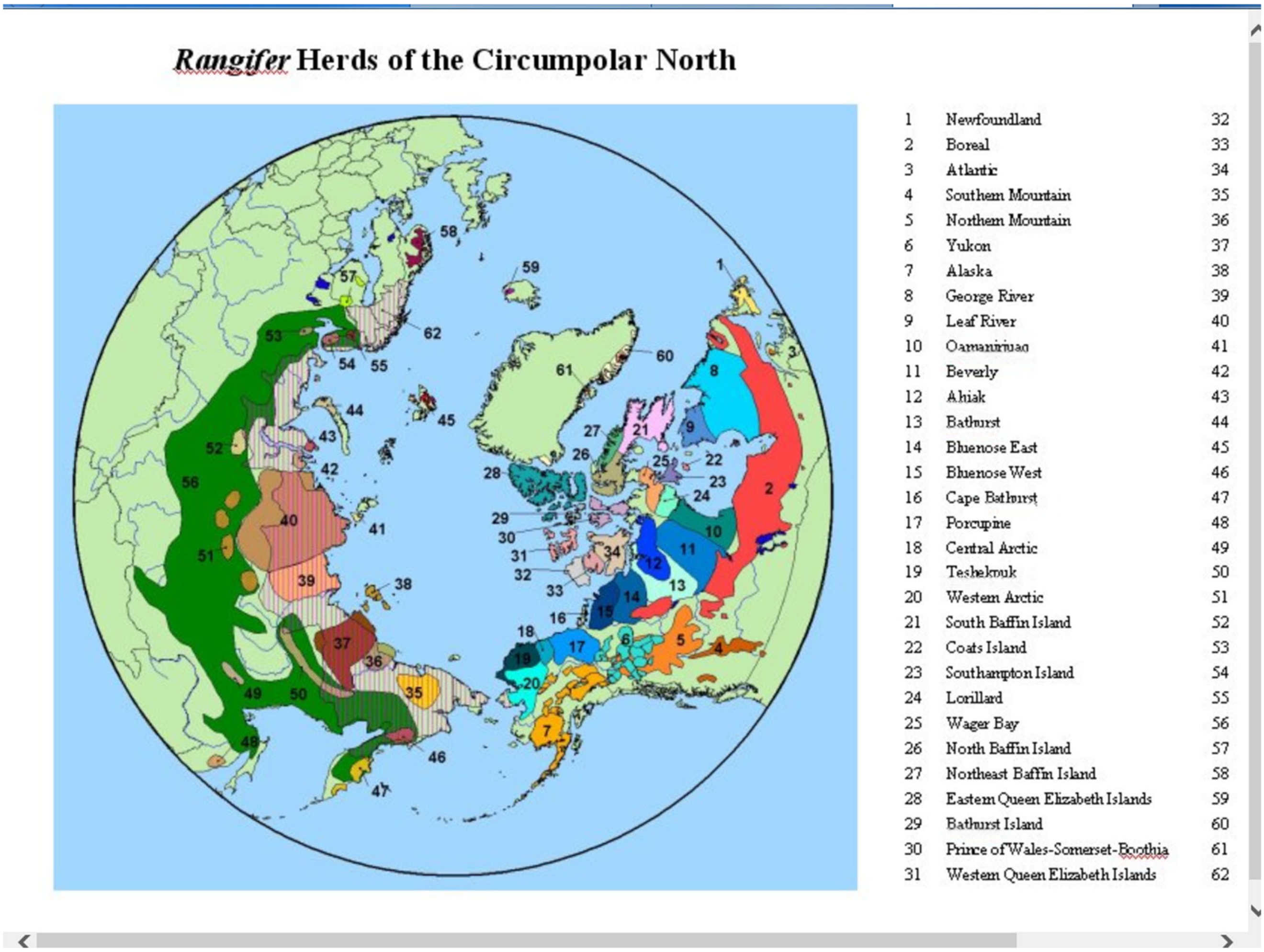

Fig. 2 Rangifer herds of the Circumpolar North. https://www.caff.is/images/_Organized/CARMA/Welcome_to_CARMA/Map/Circumpolar%20herds.jpg

(subpopulations). Many are indeed declining, but some are either increasing or stable despite of the ongoing warming of their habitat. In summer 2013, four North Alaskan caribou herds, the Western Arctic (WAH), Teshekpuk Lake (TLH), Central Arctic (CAH), and Porcupine (PCH), were counted for the first time. Three to 4 years later, the PCH has grown to a record high since its population monitoring started in the 1970s; the CAH is shrinking, also fast; whereas the WAH and the smallest TLH have stabilized after previous declines (Anonymous 2016–2017, 2018; Parrett et al. 2014; Parrett 2016). According to the statistics for 23 regional herds compiled by the CircumArctic Rangifer Monitoring and Assessment Network (CARMA)—out of 60+ herds featured on its circumpolar map—14 are declining, 6 are increasing, 2 are stable, and the status of one is uncertain (CARMA n.d.). There are too many gaps in data concerning the individual herds' dynamics post-2010, although recent rapid decline ('crash') of certain herds, such as the Leaf River and the George River herds in Labrador–Ungava since 2010, is indisputable (Anonymous 2015; UPCART 2017).

Some authors claim that the numbers of caribou/reindeer are growing slightly, at least in Northern Eurasia, whereas others insist that *Rangifer* species are experiencing global decline because of fragmentation of its habitat (Post and Forchhammer 2008; Post *et al.* 2008; Vors and Boyce 2009). Even neighboring herds often follow different trends in responding to different climate cycles affecting their range, such as the North Atlantic Oscillation (NAO), Arctic Oscillation (AO), and the Pacific Decadal Oscillation (PDO – see Jolly *et al.* 2011).

Initially, new data did not directly confirm past scenarios that strongly linked reindeer/caribou population declines to the Arctic warming phases (e.g., Krupnik 1975, 1993). Also, the role of extreme weather events, particularly of winter freezing rains (rain on snow) seemed ambiguous, if not exaggerated. Such events may indeed cause occasional catastrophic declines in the affected areas, such as the Yamal Peninsula in West Siberia in winter 2013–2014 (Forbes *et al.* 2016; Golovnev 2016); but many crashes took place without ice or even snow on the ground, and many herds have survived numerous crashes caused by 'rain on snow' events and successfully recovered (Tyler 2010). Even the most vulnerable populations, such as the Peary caribou of the Canadian Arctic islands and several local herds on the Norwegian Svalbard archipelago that shrank by up to 80–98% in the recent weather-caused crashes, managed to recover (Hansen *et al.* 2011; Vors and Boyce 2009).

Lastly, recent studies illustrate that indigenous knowledge and forms of management of caribou/reindeer are critically important in responding to climate change for both domesticated reindeer and wild reindeer/caribou (Golovnev 2016, n.d.; Klokov 2002; Magga *et al.* 2009; Oskal *et al.* 2009; Parlee and Caine 2017; Thorpe *et al.* 2001; UPCART 2017). Other social factors, such as range fragmentation due to industrial development, increased demand for reindeer meat (Stammler 2005; Uboni *et al.* 2016), too many hunters in certain areas, man-made disasters (such as the post-Chernobyl slaughter of domesticated reindeer in Sweden – Bell 1999), and economic disruption work as powerful local drivers. Our current knowledge does not yet provide definitive clues to whether reindeer/caribou populations ever have a common response to climate change, including present-day Arctic warming (Gunn and Skogland 1997; Klokov 2012; Krupnik 1993; Mallory and Boyce 2017; Rees *et al.* 2008; Russell 2008) or, rather, fluctuate according to individual population cycles based on changing reproduction, status of the pastures, or other factors (Bergerud *et al.* 2008; Bergerud 2014).

Pacific Walrus

The Pacific walrus (*Odobenus rosmarus divergens* Illiger) is a large ice-associated Arctic marine mammal and a keystone upper-trophic component of marine ecosystems across the northern Bering Sea and most of the Chukchi Sea (Ray *et al.* 2014). It has been a cornerstone of indigenous cultures and local economies for the past 2500 years (Krupnik 2003; Hill 2011). The U.S. Fish and Wildlife Service (FWS), the main U.S. agency in charge of monitoring and managing the Pacific walrus stock, considers it a single panmictic population (Anonymous 2010; MacCracken 2012). A more realistic approach is to view it as a *meta-population* composed of several discreet groupings that may constitute separate breeding associations (Fay 1982; Jay *et al.* 2008; Krupnik and Ray 2007; Ray *et al.* 2014 – Fig. 3).

The dependence of Pacific walrus on a particular ice regime during its seasonal cycle has long been known to scientists and Native hunters (Arsen'iev 1935; Krupnik and Bogoslovskaya 1999; Ray and Hufford 1989). Presently, the Pacific walrus population is showing signs of stress caused primarily by changes in its summer and winter sea-ice habitats. The former are triggered by the continuing northward retreat of the polar pack ice into the Arctic Basin (Jay *et al.* 2012; Garlich-Miller *et al.* 2011). The latter evidently result from a reconfiguration of winter-spring icescapes in the northern Bering Sea, due to the sea ice thinning, diminishing, and increased storm activity (Ray *et al.* 2014, 2016). The sea ice change caused by climate warming is increasingly viewed as a major threat to the long-term sustainability of the Pacific walrus (Kochnev 2004; MacCracken 2012). In the 'low-ice' years, such as 2007, 2011, 2012, 2014, 2016, and 2017, the summer edge of the Arctic pack ice retreated to roughly 80°N, far beyond the continental shelf zone where walruses feed. In recent years, hardly any summer drift ice was left in the eastern (Alaskan) and western (Russian) portions of the Chukchi Sea and in the East-Siberian Sea (MacCracken 2012). As a result, enormous coastal haul-out aggregations, often of 30–100,000 animals form annually along the Chukchi Sea shores in Alaska and Russian Chukotka Peninsula (Chakilev and Kochnev 2014; Chakilev *et al.* 2015; Kochnev 2010).

Even with strong regulatory protection, at such enormous concentrations that are obviously beyond carrying capacity of the coastal feeding sites walrus are at high risk of human disturbance and food depletion (Kochnev 2004; MacCracken 2012; MMC 2014). In 2011, the FWS argued that: "…after review of all of the available scientific and commercial information, listing the Pacific walrus as endangered or threatened is warranted" (Anderson 2013). The listing was delayed pending another review in 2017; eventually the FWS decided that Pacific walrus does *not* require protection and is currently *not* threatened or endangered. The population appears to be stable and the species has reportedly demonstrated an ability to adapt to changing conditions (MacCracken *et al.* 2017; US FWS 2017). Nonetheless, managers, environmentalists, and scientists continue to press for the Pacific walrus to be listed under the Endangered Species Act of 1973, due to quite evident changing climate and sea ice conditions (cf. Anderson 2013; Ristroph 2017).

In the meantime, the aboriginal subsistence catch of the Pacific walrus has dropped dramatically in the past few years. In spring 2013, in the two largest walrus hunting communities in Alaska, Gambell and Savoonga on St. Lawrence Island, hunters landed just a fourth of their usual spring catch during 1960–2002 (Krupnik and Benter 2016). In August 2013, both tribal councils asked for emergency government assistance in the form of a declaration 'economic disaster' that was granted by the Governor. Other walrus hunting communities in the area fared even worse, indicating that a population 'crash' is perhaps in the making.

In the following 3 years (2014–2016), the catch remained low. The overall Alaskan annual subsistence walrus harvest has dropped four-fold: from an average of 1600–2000 in 2003–2007 to 479 in 2015 (Krupnik and Benter 2016). It has subsequently increased slightly, according to local hunters (Koonooka N.d.; Krupnik and Crowell N.d.), but still remains much lower than 5–7 years ago. Aboriginal subsistence catch

Fig. 3 Walrus at land haul-out site at Cape Serdze-Kamen, Chukotka, Russia. Photo by Anatoly Kochnev, September 2009. https://www.usgs.gov/media/images/walruses-resting-shore-cape-serdtse-kamen-haulout-area. https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/styles/full_width/public/thumbnails/image/Kochnev-Serdtse-Kamen-2.JPG?itok=XTmG6qcy

in Russia has also remained lower than in previous years. Subsistence hunting communities in Alaska and Chukotka may be on a path to painful adjustment of their seasonal calendar, food habits, and local cash economy (Krupnik and Benter 2016).

Nonetheless, Native hunters argue strongly against any new protective measures stressing that their catch is now less than a half of what it used to be and that it poses no threat to walrus health. The situation clearly requires careful monitoring, *locally*-based assessments, and a dialogue with subsistence users before any new protective strategy is put in place. Notably, no similar concerns have been expressed regarding the much smaller population of the Atlantic walrus (*Odobenus rosmarus rosmarus*), actually a set of isolated subpopulations or stocks across Arctic Canada, Greenland, and Western Russian Arctic (Anderson *et al.* 1998; NAMMCO n.d.; Stewart and Robert Stewart 2008). In spite of Vibe's claim that Atlantic walrus abundance around Greenland was similarly determined by the shifting historical sea ice phases (1967:80), current researchers believe it is influenced more by the size of regional subsistence catch quotas, other protective regimes, and a slow pace of recovery from previous population crashes inflicted by unregulated commercial hunting (Born *et al.* 2017; COSEWIC 2017; Wiig *et al.* 2014; Witting and Born 2014).

Polar Bear

The Polar bear (*Ursus maritimus*) is the largest ice-associated Arctic carnivore with a circumpolar distribution. Vibe (1967:57–61) was the first scholar to link phases of polar bear's historical abundance in Greenland to changes in ice regime in the adjacent seas. Yet it was Stirling and Derocher (1993) who made a critical step in arguing that if the Arctic Ocean becomes seasonally ice free due to global warming, it is likely that polar bears will be extirpated (see also, Derocher *et al.* 2004; Stirling and Derocher 2012). Some biologists have predicted that the global polar bear population may decrease by 30% during the next 45 years and its range would contract significantly (Amstrup *et al.* 2008; Durner *et al.* 2009; Regehr *et al.* 2016). Over the past 20 years, the image of a polar bear stranded on a shrinking ice floe has become a logo for a battle cry from environmentalists to protect the Arctic and its ecosystems.

The plight of certain local groups of polar bears, particularly along the shores of Hudson Bay and the southern Beaufort Sea (Bromaghin *et al.* 2015; Obbard *et al.* 2016; Regehr *et al.* 2006; Stirling *et al.* 1999) and sightings of drowned polar bears in north Alaska (Monnett and Gleason 2006) have been widely used as evidence of polar bear endangerment due to the sea ice loss. In 2008, polar bears were added to the list of 'threatened species' under the U.S. Endangered Species Act of 1973. In fact, the future of the polar bears depends on many factors and will almost certainly differ by region and local groupings.

The Polar Bear Specialist Group (PBSG) of the International Union for the Conservation of Nature (IUCN) presently recognizes 19 'subpopulation units' of polar bears across the Arctic (Obbard *et al.* 2010; Reid *et al.* 2013; Fig. 4).[1] As of 2014, three of these units are declining, seven are stable or increasing, and there is not enough data for the rest to assess their status (http://www.polarbearsinternational.org/status-and-threats/polar-bear-status-report). The once endangered grouping in the western Hudson Bay is now considered 'stable' (Dyck *et al.* 2007; Obbard *et al.* 2010; see also Obbard *et al.* 2016 and Reid *et al.* 2013).

Indigenous Arctic residents staunchly disagree with biologists and environmentalists' assessment. They argue that there are plenty of polar bears, asserting that the Elders have never

[1] Whether these are regional groupings selected for management purposes or actual subpopulations with a specific genetic 'footprint' (cf. Paetkau *et al.* 1999), is beyond the scope of this paper.

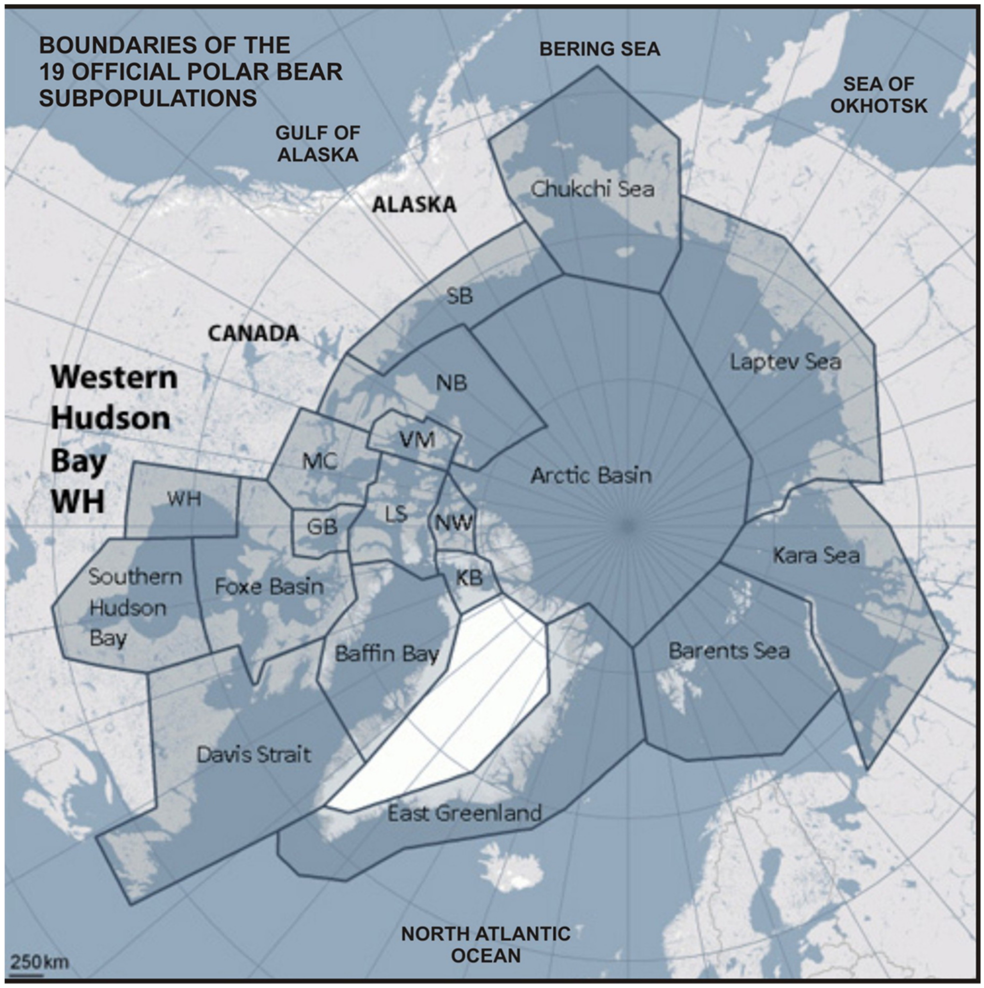

Fig. 4 Map of polar bear subpopulations ('units') – https://polarbearscience.com/2012/11/

seen 'that many polar bears in their life,' that the animals are in good condition (Dowsley and Wenzel 2008; Freeman and Foote 2009; IJS 2015; Voorhees and Sparks 2012), or that 'they periodically move to other areas' (Voorhees *et al.* 2014). These indigenous observations are not unanimous, but they cannot be ignored. The most recent assessments of 3 regional polar bear stocks (subpopulations) in the Baffin Bay and Kane Basin (SWG 2016) and in the northern Bering and Chukchi Sea (Regehr *et al.* 2016; Rode *et al.* 2014) indicate that they are all increasing, certainly stable, in spite of limited subsistence hunting and drastic change in their habitat due to the warming Arctic and shrinking polar ice.

This brief overview provides some general insights as to how a widely distributed meta-population responds to climate stressors. First, the link among polar bears' health, abundance and sea ice conditions may not be as strong as Vibe and many biologists some 20 years ago believed. Polar bears are increasingly going on land to explore new resources, particularly in the summertime (Rode *et al.* 2015; Voorhees *et al.* 2014). Second, all 3 parameters—sea ice, bears' health, and numbers—fluctuate over time and, reportedly, have always fluctuated. Third, modern warming does not necessarily produce the same 'domino' effect across the entire polar bear range due to variety in local conditions, resources, human disturbance, and other factors. Thus, the observed decline in sea ice alone could not explain the variations in polar bear health and survival.

Most importantly, not all polar bears are 'born equal' and some sub-populations demonstrate higher resilience to climate-induced change than others. Rode *et al.* (2014) compared physical status of polar bears from the neighboring southern Beaufort and Chukchi Sea-northern Bering Sea sub-populations and found the former to be in obvious physical decline, whereas the latter were among the largest and healthiest reported. Evidently they are able to maintain their status according to the availability of *new* sources of food on land in the absence of sea ice, such as trampled walruses at new haul-out sites (see above) and beached carcasses of dead bowhead whales – as reported by indigenous hunters (Voorhees and Sparks 2012; Voorhees *et al.* 2014). The alleged polar bear population crash appears to be more of a local phenomenon and a product of multiple drivers; and indigenous perspectives offer a much needed insight to game managers' predictions based on general population and climate models.

Native people's Insight to 'Arctic Crashes'

Northern indigenous peoples, who have perfected impressive ecological and spiritual knowledge about the animals they hunt, generally believe that animals' availability and human success in hunting are predicated on mutual respect and deep spiritual connections between people and animals (Fienup-Riordan 2014; Loring 1997; Martin 1978; Nelson 1973, 1983; Tanner 1979; Watanabe 1994; Willerslev 2007). They believe that animals, like people, live in 'tribes' that interact as equals with various local human groups. Climate or general physical change in habitats is not an element in understanding people's relations with the animals, according to numerous descriptions of northern people's environmental ontologies. Indigenous hunters actively, often aggressively, target many northern mammal species, as well birds and fishes, but have not driven their prey to extirpation, via rational or irrational checks (Burch 1994) – with the rare exception of the Steller's sea cow *(Hydrodamalis gigas)* along the Aleutian Islands (Betts *et al.* 2011; Maschner *et al.* 2009; Yesner 1988) and the great auk (*Pinguinus impennis*) in certain areas of Greenland (Meldgaard 1988).

One of the strongest new assets in today's reanalysis of Arctic climate–people–animal relations is a record of indigenous observations of modern environmental change assembled over the last two decades of collaborative work in northern communities (Born *et al.* 2017; Eicken *et al.* 2014; Gearheard Fox *et al.* 2013; Huntington *et al.* 2005, 2017; Krupnik and Jolly 2002; Krupnik *et al.* 2010; Oozeva *et al.* 2004; Rosales and Chapman 2015; Salomon *et al.* 2011; Voorhees and Sparks 2012). Arctic indigenous residents detected changes in their home environments in the mid-1990s and made their observations known to scientists (McDonald *et al.* 1997; Krupnik 2000; Weller and Anderson 1999), who initially remained skeptical about the nature of the trend (Serreze 2008/2009:1–2). Since then, we have witnessed at least 20 years of noticeable climate change in the polar regions. From a human perspective, it is a lifetime of a generation, a difference in knowledge between an elder and a young adult.

Native experts generally concur with scientists about the ongoing rapid climate and sea ice shifts in their home areas. Nevertheless, they strongly disagree with biologists and game managers about its immediate impact on animal populations. They generally do not share scientists' and environmentalists' concerns that the advent of the era of the human-induced global warming has ushered the new threat of imminent extinction of many polar species. As certain northern mammals, like polar bear, Pacific walrus, ribbon, ringed, and harp seal, narwhal, and caribou have been declared 'threatened' because of the climate-caused habitat change (Derocher *et al.* 2004; Garlich-Miller *et al.* 2011; Jay *et al.* 2012; MacCracken 2012; MMC 2014; Post and Forchhammer 2008; Stirling and Derocher 1993, 2012; Vors and Boyce 2009; Womble *et al.* 2010; https://alaskafisheries.noaa.gov/pr/ice-seals), indigenous people have generally stuck to their own vision of animal health and causes of population dynamics. This disagreement has created an arena of conflict between indigenous users and environmentalists and biologists, as illustrated in the cases of polar bear, caribou, and walrus. More polar species are certain to join this list soon.

Native perspectives on Arctic animals and habitat change generally rest on 3 main arguments. First, *the animals do not go 'down;' it is we who fail them*. In numerous personal statements and interviews, indigenous experts claim that the animals are 'healthy,' in good condition, and, when they show up, they come in strong numbers. Poor hunting is usually an outcome of unpredictable weather, people's unpreparedness, or of various other factors such as high cost of gasoline for boats, new wildlife regulations, pollution and noise, particularly from ships and seismic testing, and 'lack of respect' and other disturbances, including biologists' efforts to tag, count, or monitor the animals (Dowsley and Wenzel 2008; Fienup-Riordan 1999; Freeman and Foote 2009; Voorhees and Sparks 2012; Voorhees *et al.* 2014).

The second common indigenous argument is that if the animals are scarce they *are somewhere (elsewhere) and other people are having plenty of them,* in stark contrast to biologists' perspectives. To game managers, a shortage of animals (or birds or fishes) in the area of their jurisdiction is a sign of 'low' population, and a common response is a new regulation or a ban on human use of the stock presumed 'endangered.' Indigenous users generally believe that with proper human behavior the animals will return in good numbers. If they are absent now, someone else is using them and, therefore, any effort to limit hunting is counter-productive.

The third popular indigenous belief is that *if the animals are rare or absent in their usual time they will make themselves available otherwise or will send other animals 'in their turn'– again, following a proper human behavior.* It is somewhat akin to biologists' concept of successive or expanding species. It also helps explain why indigenous users are so adaptive in exploiting new or old species when they appear at an unusual time or season, as they are treated as 'offered replacements.' For example, the Yupik people of St. Lawrence Island, Alaska have recently shifted to late-fall and early winter hunting of bowhead whales, in addition to their usual spring whaling season. Since 1995, 40% of all whales harvested on St. Lawrence Island have been taken in November–January (Noongwook *et al.* 2007:51), something unheard of in living memory. It is also a cause of great delight because of the recent drop in walrus catch.

The above-mentioned case of the Pacific walrus is a pointed illustration why local hunters disagree with biologists about the overall status of the walrus population and the need for its stronger protection. According to hunters, their catches are lower not because of fewer walruses, but due to poor ice/wind conditions, high gasoline prices, and lower hunting effort (*'we fail them'*). As subsistence catch south of Bering Strait has dwindled, it remains stable, even increasing along the Chukchi Sea shore (*'the animals are elsewhere'*). New coastal walrus haul-outs at Point Lay in Alaska and along the Russian shore have created an abundance of meat, food for dogs and for roaming polar bears, and ivory from trampled animals (*'other people have plenty of walrus now'*). Lastly, other game resources are still available and walrus have started showing in large numbers during the wintertime, which is highly unusual (*'they will send other animals in their turn'*). Even if an eventual Pacific walrus crash is in the making it is unfolding more according to indigenous interpretations rather than biologists' scenarios of climate 'endangerment,' due to the sea ice decline (Jay *et al.* 2011, 2012; MacCracken 2012).

Another lesson from indigenous perspectives is that *all change is local,* and this helps explain why indigenous experts are so reluctant to extrapolate their knowledge to other areas or make long-term predictions about future climate or animal abundance (Bates 2007; Voorhees and Sparks 2012; Voorhees *et al.* 2014). Climate, sea ice, and animal health and population changes vary widely, as do peoples perceptions of them, often within the same area (cf. Rosales and Chapman 2015). In 2003, residents of the Alaskan villages of Wales and Diomede in the Bering Strait reported a full-month shift to earlier spring break-up and walrus migration, whereas hunters on St. Lawrence Island, 150 miles to the south, denied any change in the timing of walrus spring run due to warmer weather (Metcalf and Krupnik 2003).

Lastly, the main lesson learned from the past two decades of work with indigenous communities on climate/environmental change is about the *value of alternative interpretation*. We know that indigenous experts generally do not follow scientists' explanations and often strongly disagree with them; instead, they rely on their own reasoning – observational, spiritual, and moral.

Discussion

It is clear from the previous discussion that the new body of data on the abundance, range, and health status of most Arctic wildlife species since the beginning of Arctic warming in the 1990s *does not* support earlier models that forecasted a rapid restructuring of animal ranges in response to climate and sea ice shifts. Except for some cases of local declines, such as the alleged endangerment of the South Beaufort polar bear subpopulation, or the 85–90% drop of the Northeast Atlantic stock of harp seal (*Pagophilus groenlandicus*), which breeds on the pack ice off East Greenland (Johnston *et al.* 2012), few recent Arctic mammal crashes could be unequivocally associated with the reported 2.3 °C increase in annual temperature, accompanied by almost 50% reduction of summer sea ice and dramatic change in its seasonal dynamics and stability. Even some 'model' recent crashes, such as the collapse of the George River caribou herd in Labrador-Ungava since 2000 and the fall of the harbor seal stocks in the Gulf of Alaska, have been attributed to scores of factors, of which climate change was perhaps one of many (cf. Bergerud 2014; Mathews and Pendleton 2006; UPCART (Ungava Peninsula Caribou Aboriginal Round Table), 2017; Womble *et al.* 2010).

The response of Arctic wildlife to climate change appears to be more complex than the once-projected north- or south-bound shifts of prime habitats for major species. Although we possess ample records of such range moves, particularly for fishes, some marine and terrestrial mammals, birds, and benthic communities (e.g., Grebmeier *et al.* 2006, 2009), animal response more often occurs via what biologists call *phenological mismatches*, that is, temporary (or long-term) discords in species' established reproductive and migration cycle (Cushing 1990; Miller-Rushing *et al.* 2010). There is also increasing evidence of seasonal and/or systemic replacements of species in a complex web of trophic relations within ecosystems (Durant *et al.* 2007; Ray *et al.* 2016).

Though the 20-some years of warming may not be sufficient to determine how the 'new Arctic' will look like in terms of future animal ranges and species composition, no one would have predicted in the 1970s that among its most visible symbols would be the land-roaming polar bears and many thousand walruses hauling out on the beaches of Northwest Alaska and Arctic Chukotka. No one would have thought that across the spectrum of ice-associated marine mammals the most vulnerable would be the ribbon, harp, and hood seals, whereas bowhead whale, narwhal, beluga whale, and ringed seal would be more resilient, with walrus, polar bear and caribou in between. It is as yet unclear how species could be ranked in terms of their vulnerability to the warming climate and shrinking ice, as evidently they all need different times to respond (adapt?) to change, other than simply collapse in numbers or move to other areas, according to Vibe's model.

Today, most of the large Arctic animal and bird species are under various protective and co-management regimes; many no longer constitute the primary food or material resource to local communities. Limited human predation may spare the animals the worst crashes scenarios and offer much needed time to adapt to new climate and ice conditions, in spite of the increased human presence across the polar regions. From the perspective of 20+ years of observable Arctic change, the destructive human impacts on animal habitats—via industrial development, range fragmentation, increased disturbance—*and* extreme weather events are more likely to produce wildlife crashes than the general climate/temperature/sea-ice trends. It may also explain why so many more recorded Arctic crashes happened during the era of rapid commercial expansion and uncontrolled animal exploitation, first in the North Atlantic in the 1600s and 1700s, and, later, in the

North Pacific-Chukchi-Beaufort Sea area in the 1700s and 1800s, including several documented overkills perpetuated by local indigenous people (Allen 1880; Allen and Keay 2006; Bockstoce and Botkin 1980, 1982, 1983; Crowell 2016; Krech III 1999; Krupnik 1993; Martin 1978; Meldgaard 1986; Mowat 1984; Reeves 1980; Ross 1979, 1993; Vibe 1967).

Therefore, as the Arctic warming progresses, we should resist the lure of simplistic domino-like (cascade) scenarios, e.g., warmer climate–less ice–shrinking food sources–altered habitats–animal decline–population crash or extinction. Not every rapid climate or sea ice change results in a crash, and many Arctic societies, early and modern, have demonstrated high resilience in the face of climate and animal fluctuations (cf. Friesen 2015; Hamilton *et al.* 2016). Several other impacts are prominent among indigenous peoples' concerns besides the rising temperatures or thinning ice, such as increased coastal erosion, river and beach floods, or violent storms (Rosales and Chapman 2015).

Local observers keep pointing to new forces that often shape their life far more than climate change, such as limited economic opportunities, high gasoline prices, lack of markets for subsistence products, language and culture loss, among many more. A number of recent studies (e.g., Cameron 2012; Collings 2011, 2014; Hovelsrud and Smit 2010; Krupnik, N.d.; Marino and Schweitzer 2009; Tejsner 2013) challenge a common vision that all current discourse in Arctic indigenous communities is dominated by environmental change. It also indicates that in the earlier phases of climate change social factors, such as inter-tribal wars, intimidation by powerful neighbors, and unequal status in local social and trade networks could have similarly affected people's life besides warming temperatures or melting ice (Krupnik and Chlenov 2009). One wonders how much of this past complexity in responding to change by polar animals and people is missing from current explanations of historical Arctic crashes.

Lastly, in their narratives about today's rapid changes, Arctic residents commonly refer to unpredictable weather, high temperatures, strong winds, unsafe ice, or little snow. These natural trends, however, are neither the only drivers of people's behavior nor even the main ones. People of the 'climate change era' often worry more about other aspects of change and tend to internalize climate in a matrix of numerous other factors (Tejsner 2013). They also remain persistent, if not conservative in trying to preserve their way of life – which is a normal human response and, perhaps, has always been.

This new understanding of the varying speed of change—in the physical, animal, and human domains—is definitely the main outcome of the ongoing reassessment of the earlier models of climate–animal–people interactions. Climate may shift quickly and polar ice shrinks even faster, whereas the animals lag behind, and people tend to stick to their familiar ways of life ("culture") against all odds. The emerging narrative of Arctic 'crashes' is less a coarse-brush shift of the earlier models, like warming or cooling, but more a tapestry of local disequilibria that produces highly varied changes at societal and animal subpopulation level. The latter conclusion may be of special interest to researchers working on peoples' and animals' responses to change in other regions or other times, particularly in the distant past.

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References

ACIA (Arctic Climate Impact Assessment) (2005). Arctic climate impact assessment, Cambridge University Press, Cambridge and New York.

Allen, J. (1880). History of north American pinnipeds: A monograph of the walruses, sea-lions, sea-bears and seals of North America, G.P.O, Washington, DC.

Allen, R., and Keay, I. (2006). Bowhead whales in the eastern Arctic, 1611–1911: Population reconstruction with historical whaling records. Environment and History 12: 89–113.

Amstrup, S., Marcot, B., and Douglas, D. (2008). A Bayesian network modeling approach to forecasting the 21st century range wide status of polar bears. In DeWeaver, Bitz, C., and Tremblay, L.-B. (eds.), Arctic Sea ice decline: Observations, projections, mechanisms, and implications. Geophysical monograph series, 180, pp. 213–268.

Anderson, B. (2013). Will Pacific walrus be next species protected due to shrinking sea ice? *Alaska Dispatch* March 11. http://www.alaskadispatch.com/article/20130311/will-pacific-walrus-be-next-species-protected-due-shrinking-sea-ice. Accessed November 13, 2016

Anderson, L., Born E., Gjertz, I., Wiig, Ø., Holm, L., and Bendixen.C. (1998). Population structure and gene flow of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in the eastern Atlantic Arctic based on mitochondrial DNA and microsatellite variation. Molecular Ecology 7(10): 1323–1336.

Anonymous (2010). Pacific walrus (*Odobenus rosmarus divergens*): Alaska stock. http://www.fws.gov/alaska/fisheries/mmm/stock/final_pacific_walrus_sar.pdf. Accessed November 13, 2016.

Anonymous (2015). George River caribou information update. Department of environment and conservation, Wildlife Division. Happy Valley-Goose Bay. http://www.torngatsecretariat.ca/home/files/pg/grc_info.pdf. Accessed November 15, 2016.

Anonymous (2016–2017). Central Arctic caribou herd news. Alaska Department of Fish and Game, (winter). Accessed January 21, 2018. http://www.cookinletarchers.com/central_arctic_caribou_herd_news_winter_2016_2017.pdf

Anonymous (2018). Porcupine caribou herd grows to record high numbers. Alaska Department of Fish and Game Press Release. (Accessed January 21, 2018) http://www.adfg.alaska.gov/index.cfm?adfg=pressreleases.pr&release=2018_01_02

Arsen'iev, V. (1935). Sea mammal hunting in the Chukchi and east Siberian seas. Sovetskii Sever 3-4: 106–112 (Russian).

Bates, P. (2007). Inuit and scientific philosophies about planning, prediction, and uncertainty. Arctic Anthropology 44(2): 87–100.

Bell, S. (1999). Radioactive reindeer: The Chernobyl legacy. Ecologist 29(7): 413–422.

Bergerud, A. (1980). A Review of the population dynamics of caribou and wild reindeer in North America. In Proceedings of the Second Reindeer/Caribou Symposium, 17–21 September, 1979. Reimers, E., Gaare, E., and Skjenneberg, S. (eds.). Trondheim, pp. 556–581.

Bergerud, A. (2014). The decline of the cyclic George River caribou herd, 1989–2012: rabies, wolves and hunters. (Accessed January 20, 2018) https://atbergerud.weebly.com/uploads/4/2/5/6/42560127/bergerud_2014_final__1_.pdf

Bergerud, A., Luttich, S., and Camps, L. (2008). The return of the caribou to Ungava, McGill-Queen's University Press, Montreal and Kingston.

Betts, M., Maschner, H., and Leach, V. (2011). A 4,500-year time-series of Otarid abundance on Sanak Island, western gulf of Alaska. In Braje, T., and Rick, T. (eds.), Human impacts on seals, sea lions, and sea otters. Integrating archaeology and ecology, University of California Press, Berkeley and Los Angeles, pp. 93–110.

Birdsell, J. (1968). Some predictions for the Pleistocene based on equilibrium systems among recent hunter-gatherers. In: Man the hunter. Lee, R. and DeVore, I. (eds.). Aldine, Chicago, pp. 229–240.

Bockstoce, J. (1976). On the development of whaling in the western Thule culture. Folk 18: 40–46.

Bockstoce, J., and Botkin, D. (1980). The harvest of Pacific walrus by the pelagic whaling industry, 1848–1914. Unpublished report, 33 pp.

Bockstoce, J., and Botkin, D. (1982). The harvest of Pacific walrus by the pelagic whaling industry, 1848 to 1914. Arctic and Alpine Research 14(3): 183–188.

Bockstoce, J., and Botkin, D. (1983). The historical status and reduction of the western Arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry, 1848–1914. Report of the International Whaling Commission, Special Issue 5: 107–141.

Born, E. (2005). Christian Vibe. Encyclopedia of the Arctic. Nuttall, M. (ed.). Vol. 3. Routledge, New York, pp. 2127–2128.

Born, E. Heilmann A., Kielsen Holm L., Laidre, K., and Iversen, M. (2017). Walruses and the walrus hunt in West and Northwest Greenland: An Interview survey about the catch and the climate. Meddelelser om Grønland 355, Man & Society 44.

Braestrup, F. (1941). A study on the arctic fox in Greenland. Immigration, fluctuations in numbers based mainly on trading statistics. Meddelelser om Grønland 131: 1–101.

Bromaghin, J., McDonald, T., Stirling, I., Derocher, A., Richardson, E., Regehr, E., and Amstrup, S. (2015). Polar bear population dynamics in the southern Beaufort Sea during a period of sea ice decline. Ecological Applications 25(3): 634–651.

Burch, E. Jr. (1994). Rationality and resource use among hunters. In Irimoto, T., and Yamada, T. (eds.), Circumpolar religion and ecology. An anthropology of the north, University of Tokyo Press, Tokyo, pp. 163–186.

Burch, E. Jr. (2012). Caribou herds of Northwest Alaska, 1850–2000, University of Alaska Press, Fairbanks.

Cameron, E. (2012). Securing indigenous politics: A critique of the vulnerability and adaptation approach to the human dimensions of climate change in the Canadian Arctic. Global environmental change 22(1): 103–114.

CARMA (CircumArctic Rangifer Monitoring and Assessment Network. (n.d.) Rangifer herds of the Circumpolar North. (interactive map – Accessed July 11, 2016) http://www.caff.is/images/_Organized/CARMA/Welcome_to_CARMA/Map/Circumpolar%20herds.jpg

Carson, M., and Peterson, G. (eds.) (2016). Arctic resilience report, Stockholm Environment Institute and Stockholm Resilience Centre, Stockholm. http://www.arctic-council.org/arr. Accessed January 24, 2018.

Chakilev, M., and Kochnev, A. (2014). Abundance and distribution of Pacific walrus *Odobenus rosmarus divergens* in the vicinity of cape Serdtse-Kamen in 2009–2013. Izvestiya TINRO 179: 1–10 (Russian).

Chakilev, M., Baiderin, A., and Kochnev, A. (2015). Pacific walrus (*Odobenus rosmarus divergens*) haul-out site at cape Serdtse-Kamen' (Chukchi Sea) in 2013. In Morskie mlekopitayushchie Golarktiki. Vol. 2, Moscow, pp. 270–274.

Chapin, F. I. I. I., Trainor, S., Cochran, P., Huntington, H., Markon, C., McCammon, M., McGuire, A., and Serreze, M. (2014). Alaska. In Climate change impacts in the United States: The third National Climate Assessment, Melillo, J., Richmond,T. And Yohe, G. (eds.): U.S. global change research program, Washington DC, pp. 514–536. https://doi.org/10.7930/J00Z7150.

Collings, P. (2011). Economic strategies, community, and food networks in Ulukhaktok, NT, Canada. Arctic 64(2): 207–219.

Collings, P. (2014). Becoming Inummarik: Men's lives in an Inuit community, McGill-Queen's University Press, Montreal.

COSEWIC (2017). COSEWIC assessment and status report on the Atlantic walrus, *Odobenus rosmarus rosmarus*: High Arctic population, central-low Arctic population and Nova Scotia-Newfoundland-gulf of St. Lawrence population in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa (Accessed January 21, 2018) http://www.sararegistry.gc.ca/default.asp?lang=En&n=7F497605-1#_doc.

Crowell, A. (2016). Ice, seals, and guns: Late 19th century Alaska native commercial sealing in Southeast Alaska. Arctic Anthropology 53(2): 11–32.

Cushing, D. (1990). Plankton production and year-class strength in fish populations—An update of the match mismatch hypothesis. Adv. Mar. Biol. 26: 249–293.

Damas, D. (ed.) (1984). Arctic. Handbook of north American Indians vol 5, Smithsonian Institution, Washington DC.

Derocher, A., Lunn, N., and Stirling, I. (2004). Polar bears in a warming climate. Integrative and Comparative Biology 44: 163–176.

Dick, L. (2001). Muskox land. Ellesmere Island in the age of contact, University of Calgary Press, Calgary.

Dowsley, M., and Wenzel, G. (2008). "The time of the most polar bears": A co-management conflict in Nunavut. Arctic 61(2): 177–189.

Durant, J., Hjermann, D., Ottersen, G., and Stenseth, N. (2007). Climate and the match or mismatch between predator requirements and resource availability. Climate Research 33(3): 271–283.

Durner, G., Douglas, D., Nielson, R., Amstrup, S., McDonald, T., Stirling, I., et al (2009). Predicting 21-st century polar bear habitat distribution from global climate model. Ecological Monographs 79: 25–58.

Dyck, M., Soon, W., Baydack, R., Legates, D., Baliunas, S., Ball, T., and Hancock, L. (2007). Polar bears of western Hudson Bay and climate change: Are warming spring air temperatures the "ultimate" survival control factor? Ecological Complexity 4(3): 73–84.

Eicken, H., Kaufman, M., Krupnik, I., Pulsifer, P., Apangalook, L., Apangalook, P., Weyapuk, W. Jr., and Leavitt, J. (2014). A framework and database for community sea ice observations in a changing Arctic: An Alaskan prototype for multiple users. Polar Geography 37(1): 5–27. https://doi.org/10.1080/1088937X.2013.873090.

Elton, C. (1924). Periodic fluctuations in the numbers of animals: Their causes and effects. Journal of Experimental Biology 2: 119–163.

Elton, C. (1942). Voles, mice, and lemmings; problems in population dynamics, Oxford University Press, New York and London.

Elton, C., and Nicholson, M. (1942). The ten-year cycle of numbers of lynx in Canada. Journal of Animal Ecology 11: 215–244.

Fay, F. (1982). Ecology and biology of the Pacific walrus, *Odobenus Rosmarus Divergens Illiger*. North American Fauna 74, U.S. Dept. of Interior, Washington, D.C.

Fienup-Riordan, A. (1999). *Yaqulget Qaillun Pilartat* (what the birds do): Yup'ik Eskimo understanding of geese and those who study them. Arctic 52(1): 1–22.

Fienup-Riordan, A. (ed.) (2014). Nunamta Ellamta-llu Ayuqucia, What our land and world are like. Lower Yukon history and oral traditions. Alaska Native Language Center, Fairbanks.

Fitzhugh, W. (1972). Environmental archaeology and cultural systems in Hamilton Inlet, Labrador. Smithsonian Contributions to Anthropology, 16., Government Printing Office, Washington DC.

Forbes, B., Kumpula, T., Meschtyb, N., Laptander, R., Macias-Fauria, M., Zetterberg, P., Verdonen, M., Skarin, A., Kwang-Yul, K., Boisvert, L., Stroeve, J. C., and Bartschet, A. (2016). Sea ice, rain-on-snow and tundra reindeer nomadism in Arctic Russia. Biological Letters 12: 20160466. https://doi.org/10.1098/rsbl.2016.0466.

Ford, J., and Smit, B. (2004). A framework for assessing the vulnerability of communities in the Canadian Arctic to risks associated with climate change. Arctic 57(4): 389–400.

Ford, J., Kenyon, B., Shirley, J., Pearce, T., Tremblay, M., and Westlake, M. (2012). Research on the human dimensions of climate change in Nunavut, Nunavik, and Nunatsiavut: A literature review and gap analysis. Arctic 65(3): 289–304.

Freeman, M., and Foote, L. (eds.) (2009). Inuit, polar bears and sustainable use, CCI Press, Edmonton.

Friesen, M. (2015). The Arctic CHAR project: Climate change impacts on the Inuvialuit archaeological record. Les Nouvelles de l'archéologie (141): 31–37.

Garlich-Miller, J., MacCracken, J., Snyder, J., Meehan, R., Myers, M., Wilder, J., Lance, E., and Matz, A. (2011). Status review of the Pacific walrus (*Odobenus rosmarus divergens*). U.S. Fish and Wildlife Service, Anchorage, (Accessed November 10, 2016). www.fws.gov/fisheries/mmm/walrus/pdf/review_2011.pdf, 163 pp.

Gearheard Fox, S., Kielsen, H. L., Huntington, H., Leavitt, J., and Mahoney, A. (eds.) (2013). The meaning of ice People and sea ice in three Arctic communities, International Arctic Institute, Hanover.

Gilberg, R. (1974–1975). Changes in the life of the polar Eskimos resulting from a Canadian immigration in the Thule District, North Greenland, in the 1860s. Folk 16–17: 159–170.

Golovnev, A. (2016). The risks and maneuvers of the Yamal nomads. Sibirskie etnograficheskie issledovaniia 4: 154–171 (Russian).

Golovnev, A. (n.d.). Challenging Arctic nomadism: Yamal Nenets vs current calamities. Arctic Anthropology (in press)

Grebmeier, J. M., Overland, J., Moore, S., Farley, E., Carmack, E., Cooper, L., Frey, K., Helle, J., McLaughlin, F., and McNutt, S. (2006). A major ecosystem shift in the northern Bering Sea. Science 311: 1461–1464.

Grebmeier, J., Overland J., Moore S., Farley E., Carmack E., Cooper L., Frey K. 2009. Impact of warming temperatures on marine life and fisheries in the Bering Sea. http://www.akmarine.org/our-work/address-climate-change/fisheries-and-warming-oceans (Accessed September 25, 2016).

Gunn, A., and Russell, D. (2011). Northern caribou population trends. In Canadian Biodiversity: Ecosystem Status and Trends, 2010 Technical Thematic Report Series No. 10. Canadian Councils of Resource Ministers. Ottawa, iv+55 p.

Gunn, A., and Skogland, T. (1997). Response of caribou and reindeer to global warming. In Global change and Arctic terrestrial ecosystems. Oechel, W., Callaghan, T., Gilmanov, T., Holten, J., B. Maxwell, B., Molau, U., and Sveinbjömsson, B. (eds.). Ecological Studies 124: 189–200.

Gunn, A., Shank, C., and McLean, B. (1991). The history, status and management of muskoxen on Banks Island. Arctic 44(3): 188–195.

Hamilton, L., Saito, K., Loring, P., Lammers, A., Richard, B., and Huntington, H. (2016). Climigration? Population and climate change in Arctic Alaska. Population and Environment 38(2): 115–133.

Hansen, B., Aanes, R., Herfindal, I., Kohler, J., and Bernt, E. (2011). Climate, icing, and wild arctic reindeer: Past relationships and future prospects. Ecology 92(10): 1917–1923.

Hardesty, D. (1977). Ecological anthropology, John Wiley & Sons, New York.

Hayden, B. (1972). Population control among hunter/gatherers. World Archaeology 4(2): 205221.

Heide-Jørgensen, M., Richard, P., Dietz, R., and Laidre, K. (2013). A metapopulation model for Canadian and West Greenland narwhals. Animal Conservation 16: 331–343.

Hill, E. (2011). The historical ecology of walrus exploitation in the North Pacific. In Human impacts on seals, sea lions, and sea otters; integrating archaeology and ecology in the Northwest Pacific. Braje, T., and Rick, T. (eds.). University of California Press, Oakland. Pp, pp. 41–64.

Hinkes, M., Collins, G., Van Daele, L., Kovach, S., Alderman, A., Woolington, J., and Seavoy, R. (2005). Influence of population growth on caribou herd identity, calving ground fidelity, and behavior. Journal of Wildlife Management 69(3): 1147–1162.

Hovelsrud, G., and Smit, B. (eds.) (2010). Community adaptation and vulnerability in Arctic regions, Springer, Dordrecht.

Huntington, H., and Fox, S., lead authors, Berkes F., and Krupnik, I., contributing authors (2005). The changing Arctic: Indigenous perspectives. In: Arctic climate impact assessment, chapter 3. Pp. 61–98. Cambridge University Press, Cambridge and New York.

Huntington, H., Quakenbush, L., and Nelson, M. (2017). Evaluating the effects of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge. Frontiers in Marine Science 4. https://doi.org/10.3389/fmars.2017.00319.

Inuvialuit Joint Secretariat (IJS). (2015). Inuvialuit and Nanuq: A polar bear traditional knowledge study. Joint Secretariat, Inuvialuit Settlement Region, Inuivik. http://www.wmacns.ca/pdfs/394_polar-bear-tk-report-low-res.pdf. Accessed January 24, 2018.

Jay, C., Outridge, P., and Garlich-Miller, J. (2008). Indication of two Pacific walrus stocks from whole tooth elemental. Polar Biology 31: 933–943.

Jay, C., Marcot, B., and Douglas, D. (2011). Projected status of the Pacific walrus (*Odobenus rosmarus divergens*) in the twenty-first century. Polar Biology 34: 1065–1084. https://doi.org/10.1007/s00300-011-0967-4.

Jay, C., Fishbach, A., and Kochnev, A. (2012). Walrus areas of use in the Chukchi Sea during sparse sea ice cover. Marine Ecology Progress Series 468: 1–13.

Johnston, D., Bowers, M., Friedlaender, A., and Lavigne, D. (2012). The effects of climate change on harp seals (*Pagophilus groenlandicus*). PLoS ONE 7(1): e29158. https://doi.org/10.1371/journal.pone.0029158).

Jolly, K., Klein, D., Verbyla, D., Raupp, S., and Chapin, S. III (2011). Linkages between large-scale climate patterns and the dynamics of Arctic caribou populations. Ecography 34: 345–352.

Keith, L. (1963). Wildlife's ten-year cycle, University of Wisconsin Press, Madison.

Klokov, K. (2002). Reindeer husbandry in Russia. In Jernsletten, J.-L., and Klokov, K. (eds.), Sustainable reindeer husbandry. Arctic council 2000–2002. University of Tromsø, Tromsø, pp. 23–72. http://www.reindeer-husbandry.uit.no/online/Final_Report/russia.pdf.

Klokov, K. (2012). Changes in reindeer population numbers in Russia: An effect of the political context or of climate? Rangifer 32(1): 19–32.

Koch, L. (1945). The East Greenland ice. Meddelelser om Grønland vol. 130, 3.Copenhagen

Kochnev, A. (2004). Warming of eastern Arctic and present status of the Pacific walrus (*Odobenus rosmarus divergens*) population. In Belkovich, V. (ed.), Morskie mlekopitayushchie Golarktiki, Marine Mammal Commission, Moscow, pp. 284–288 (Russian).

Kochnev, A. (2010). The haulout of Pacific walruses (*Odobenus rosmarus divergens*) on cape Serdtse-Kamen, the Chukchi Sea. In Boltunov A. (comp.). Morskie mlekopitayushchie Golarktiki. Marine Mammal Commission, Kaliningrad, pp. 281–285.

Koonooka, M. (N.d.). Observing marine mammals in Gambell, Alaska in the time of change. In Krupnik, I., Crowell, A. (eds.). Arctic crashes: People and animals in the changing North. Smithsonian Institution Scholarly Press, Washington (in preparation)

Kovasc, K., and Lydersen, C. (2008). Climate change impacts on seals and whales in the North Atlantic Arctic and adjacent shelf seas. Science Progress 91(2): 117–150.

Krech, S. III (1999). The ecological Indian, Myth and history. W.W, Norton, New York and London.

Krupnik, I. (1975). The natural environment and the evolution of tundra reindeer economy. In Chlenov, M. (ed.), Karta, schema i chislo v etnicheskoi geografii, Geographical Society, Moscow, pp. 26–47 (Russian).

Krupnik, I. (1983). Le chasseur traditionnel dans les écosystemes du Subarctique (l'Example des Esquimaux Asiatiques). Inter-Nord 17:105–110. Paris

Krupnik, I. (1989). Arctic ethno-ecology. Models of traditional subsistence economy of maritime hunters and reindeer herders in northern Eurasia, Nauka, Moscow (Russian).

Krupnik, I. (1990). The aboriginal hunter in an unstable ecosystem: A view from subarctic Pacific. In Yen, D., and Mummery, J. (eds.), Pacific production systems. Approach to economic prehistory. Australian National University, Canberra, pp. 18–24.

Krupnik, I. (2000). Native perspectives on the climate and sea-ice change. In Huntington, H. (ed.), Impacts of changes in sea ice and other environmental parameters in the Arctic. Marine Mammal Commission, Washington, pp. 15–29.

Krupnik, I. (2003). The walrus in native marine economies. In Ray, C., and McCormick-Ray, J. (eds.), Coastal-marine conservation: Science and policy. Blackwell publishing, Oxford, pp. 196–197.

Krupnik, I. (2016). Two 'Arctic crashes' symposia introduce and summarize project research. Arctic studies center. Newsletter 23: 28–31.

Krupnik, I. (n.d.). At the frontline or very close: Living with climate change on St, Lawrence Island, Alaska, pp. 1999–2017 (in review).

Krupnik, I., and Benter, B. (2016). A disaster of local proportion: Walrus catch falls for three straight years in the Bering Strait region. Arctic studies center. Newsletter 23: 34–36.

Krupnik, I., and Bogoslovskaya, L. (1999). Old records, new stories. Ecosystem variability and subsistence hunting pressure in the Bering Strait area. Arctic Research of the United States 13: 15–24.

Krupnik, I. (1993). Arctic adaptations. Native whalers and reindeer herders of Northern Eurasia, University Press of New England, Hanover and London.

Krupnik I., and Chlenov, M. (2009). Distant lands and brave pioneers: Original Thule migration revisited. In Grønnow, B. (ed.). On the Track of the Thule Culture from Bering Strait to East Greenland. Publications from the National Museum. Studies in Archaeology and History, Vol. 15, Copenhagen, pp. 13–24.

Krupnik, I., and Crowell, A. (eds.) (N.d.) Arctic crashes: People and animals in the changing North. Smithsonian Institution Scholarly Press, Washington (in preparation).

Krupnik, I., and Jolly, D. (eds.) (2002). The earth is faster now. Indigenous observations of Arctic environmental change. ARCUS, Fairbanks.

Krupnik, I., and Ray, C. (2007). Pacific walrus, indigenous hunters, and climate change: Bridging scientific and indigenous knowledge. Deep-Sea Research. Part II 54: 2946–2957.

Krupnik, I., Apangalook, L., and Apangalook, P. (2010). It's cold, but not cold enough: Observing ice and climate change in Gambell, Alaska in IPY 2007-2008 and beyond. In Krupnik, I., Aporta, C., Gearheard, S., Laidler, G., and Kielsen Holm, L. (eds.), SIKU: Knowing our ice. Documenting Inuit Sea ice knowledge and use. Springer, Dordrecht, pp. 81–114.

Larsen, J., Anisimov, O., Constable, A. Hollowed, A., Maynard, N., Prestrud, P., Prowse, T., and Stone, J. (2014). Polar regions. In: Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp. 1567–1612.

Loring, S. (1997). On the trail to the caribou house: Some reflections on Innu caribou hunters in Ntessinan (Labrador). In Jackson, L., and Thacker, P. (eds.), Caribou and reindeer hunters of the northern hemisphere. Avebury press, London, pp. 185–220.

MacCracken, J. (2012). Pacific walrus and climate change: Observations and predictions. Ecology and Evolution 2(9): 2072–2090. https://doi.org/10.1002/ece3.381.

MacCracken, J., Beatty, W., Garlich-Miller, J., Kissling, M., and Snyder, J. (2017). Final species status assessment for the Pacific Walrus (*Odobenus rosmarus divergens*). U.S. Fish and Wildlife Service, Anchorage.

Magga, O., Mathiesen, S., Corell, R., and Oskal, A. (eds.) (2009). Reindeer herding, traditional knowledge and adaptationto climate change and loss of grazing land, International Centre for Reindeer Husbandry, Kautokeino.

Mallory, C., and Boyce, M. (2017). Observed and predicted effects of climate change on Arctic caribou and reindeer. Environmental Reviews. https://doi.org/10.1139/er-2017-0032.

Martin, C. (1978). Keepers of the game; Indian–animal relations and the fur trade, University of California Press, Berkeley.

Marino, E., and Schweitzer, P. (2009). Talking and not talking about climate change in Northwestern Alaska. In Crate, S., and Nuttall, M. (eds.). Anthropology and climate change. From encounters to actions. Left Coast Press, pp. 209–217.

Maschner, H., Finney, B., J. Jordan, J., Misarti, N., Tews, A., Knudsen, G. (2009). Did the North Pacific ecosystem collapse in AD 1000? In Maschner, H., Mason, O., and McGhee, R. (eds.). The northern world AD 900–1400. University of Utah Press, pp. 33–57.

Mathews, E., and Pendleton, G. (2006). Declines in harbor seal (*Phoca vitulina*) numbers in Glacier Bay National Park, Alaska, 1992–2002. Marine Mammal Science 22(1): 167–189.

McCartney, A. (1980). The nature of Thule Eskimo whale use. Arctic 33(3): 517–541.

McDonald, M., Arragutainaq, L., and Z. Novalinga, Z. (comps.) (1997). Voices from the bay: Traditional ecological knowledge of Inuit and Cree in the Hudson Bay bioregion. Canadian Arctic Resources Committee, Ottawa.

McDowell, G., Ford, J., and Jones, J. (2016). Community-level climate change vulnerability research: trends, progress, and future directions. Environmental Res. Lett. 11 (2016) 033001

McGhee, R. (1970). Speculations on climatic change and Thule culture development. Folk 11-12: 173–184.

McGhee, R. (1984). Thule prehistory of Canada. In Damas, D. (ed.), Arctic. Handbook of north American Indians. Vol vol 5, Smithsonian Institution, Washington, pp. 369–376.

McGovern, T. (1991). Climate, correlation, and causation in Norse Greenland. Arctic Anthropology 28(2): 77–100.

Meldgaard, M. (1986). The Greenland caribou: zoogeography, taxonomy and population dynamics. Meddelelser om Grønland. Bioscience 20. Copenhagen.

Meldgaard, M. (1987). Human implications of Arctic animal population fluctuations: Caribou in Greenland. In Nelson, J., Needham, R., and Norton, L. (eds.), Arctic heritage: Proceedings of a symposium. Banff, pp. 243–251.

Meldgaard, M. (1988). The great auk, *Pinguinus impennis* (L.) in Greenland. Historical Biology 1: 145–178.

Meldgaard, M., and Born, E. (1998). Videnskab med vision og hjerte, Afd. for Eskimologi og Arktiske studier. Københavens universitet. Copenhagen, pp. 60–68 (Danish).

Meltofte, H. (ed.) (2013). Arctic biodiversity assessment. Status and trends in Arctic biodiversity. Conservation of Arctic Flora and Fauna, Akureyri.

Metcalf, V., and Krupnik, I. (eds.) (2003). Pacific walrus. Conserving our culture through traditional management. Eskimo Walrus Commission, Kawerak, Inc., Nome.

Miller-Rushing, A., Høye, T., Inouye, D., and Post, E. (2010). The effects of phenological mismatches on demography. Philosophical Transactions of the Royal Society B 365: 3177–3186.

Minc, L. (1986). Scarcity and survival: The role of oral tradition in mediating subsistence crises. Journal of Anthropological Archaeology 5: 39–113.

MMC (Marine Mammal Commission) (2014). Annual report to congress, Marine Mammal Commission, Bethesda, p. 2012.

Monnett, C., and Gleason, J. (2006). Observations of mortality associated with extended open-water swimming by polar bears in the Alaskan Beaufort Sea. Polar Biology 29: 681–687.

Moran, E. (1979). Human adaptability. An introduction to ecological anthropology, Westview Press, Boulder.

Morgan, C., Tushingham, S., Garvey, R., Barton, L., and Bettinger, R. (2017). Hunter-gatherer economies in the old world and new world. Oxford Research Encyclopedia of Environmental Science. https://doi.org/10.1093/acrefore/9780199389414.013.164.

Mowat, F. (1984). The Sea of slaughter. Atlantic Monthly Press, (n. l.).

Nagy, J., Johnson, D., Larter, N., Campbell, M., Derocher, A., Kelly, A., Dumond, M., Allaire, D., and Croft, B. (2011). Subpopulation structure of caribou (*Rangifer tarandus* L.) in Arctic and subarctic Canada. Ecological Applications 21: 2334–2348.

NAMMCO (North Atlantic Marine Mammal Commission). (n.d.) The Atlantic walrus. http://iea-archive.uoregon.edu/indicators/NAMMCOWalrus1994-2001Data.pdf

Nelson, R. (1973). Hunters of the northern forest. Designs for survival among the Alaskan Kutchin, University of Chicago Press, Chicago.

Nelson, R. (1983). Make prayers to the raven. A Koyukon view of the northern forest, University of Chicago Press, Chicago.

Noongwook, G., The Native Village of Savoonga, The Native Village of Gambell, Huntington, H., and George, J. (2007). Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. Arctic 60(1): 47–54.

Obbard, M., Thiemann, G., Peacock, E., and DeBruyn, T. (eds.) (2010). Polar bears: Proceedings of the 15th working meeting of the IUCN/SSC polar bear specialist group, 29 June – 3 July 2009, Copenhagen, Denmark. Occasional paper of the IUCN species survival commission, no. 43. International Union for Conservation of nature and natural resources (IUCN), Gland, Switzerland.

Obbard, M., Cattet, M., Howe, E., Middel, K., Newton, E., Kolenosky, G., and Abraham, K. and Greenwood, C. (2016). Trends in body condition in polar bears (*Ursus maritimus*) from the southern Hudson Bay subpopulation in relation to changes in sea ice. Arctic Science 2: 15–32. https://doi.org/10.1139/as-2015-0027.

Oozeva, C., Noongwook, C., Noongwook, G., Aloowa, C., and Krupnik, I. (2004). Watching ice and weather our way, Sikumengllu eslamengllu esghapalleghput, Arctic Studies Center and Savoonga Whaling Captains Association, Washington.

Oskal, A., Turi, J., Mathiesen, S., and Philip Burgess, P. (2009). EALÁT. Reindeer herders voice: Reindeer herding, traditional knowledge and adaptation to climate change and loss of grazing lands, International Centre for Reindeer Husbandry, Kautokeino/Guovdageadnu.

Paetkau, D., Amstrup, S., Born, E., Calvert, W., Derocher, A., Garner, G., et al (1999). Genetic structure of the world's polar bear populations. Molecular Ecology 8: 1571–1584.

Parlee, B., and Caine, K. (eds.) (2017). When the caribou do not come: Indigenous knowledge and adaptive Management in the Western Arctic, UBC Press, Vancouver.

Parrett, L. (2016). Western Arctic caribou herd update. Alaska Fish and Wildlife News 9. http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=794

Parrett, L., Dau, J., and Nedwick, M. (2014). Four North Slope caribou herds counted. Behind the numbers: How are the caribou? Alaska Fish and Wildlife News 8 (August). http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=678

Perovich, D., Meier, W., Tschudi, M., Farrell, S., Gerland, S., and Hendricks, S. (2015). Sea ice. In Arctic report card 2015. Jeffries, M., Richter-Menge, J., and Overland, J. (eds.), pp. 33–40. http://www.arctic.noaa.gov/reportcard.

Post, E., and Forchhammer, M. (2008). Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch. Philosophical Transactions of the Royal Society B 363: 2369–2375.

Post, E., Pedersen, C., Wilmers, C., and Forchhammer, M. (2008). Warming, plant phenology and the spacial dimension of trophic mismatch for large herbivore. Proceedings of the Royal Society B 275: 2005–2013.

Rappaport, R. (1968). Pigs for the ancestors: Ritual in the ecology of a new Guinea people, Yale University Press, New Haven.

Ray, C., and Hufford, G. (1989). Relationships among Beringian marine mammals and sea ice. Rapport Processverbal Reunion Conseil International Exploration de la Mer 188: 22–39.

Ray, C., and McCormick-Ray, J. (eds.). (2014). Marine conservation. Science policy and management. Wiley Blackwell, Oxford.

Ray, C., Hufford, G., Laughlin, T., and Krupnik, I. (2014). Bering Sea seals and walruses: Responses to environmental stress. In Ray, C., and McCormick-Ray, J. (eds.), Marine conservation. Science policy and management. Wiley Blackwell, Oxford, pp. 171–199.

Ray, G., Hufford, G., Overland, J., Krupnik, I., McCormick-Ray, J., Frey, K., and Labunski, E. (2016). Decadal Bering Sea seascape change: Consequences for Pacific walruses and indigenous hunters. Ecological Applications 26(1): 24–41.

Rees, W., Stammler, F., Danks, F., and Vitebsky, P. (2008). Vulnerability of European reindeer husbandry to global change. Climatic Change 87: 199–217.

Reeves, R. (1980). Spitsbergen bowhead stock: A short review. Marine Fisheries Review 42: 65–69.

Regehr, E., Amstrup, S., and Stirling, I. (2006). Polar bear population status in the Southern Beaufort Sea. U.S. Geological Survey, Open-File Report 2006–1337. https://pubs.usgs.gov/of/2006/1337/pdf/ofr20061337.pdf Accessed January 24, 2018.

Regehr, E., Laidre, K., Akçakaya, R., Amstrup, S., Atwood, T., Lunn, N., Obbard, M., Stern, H., Thiemann, G., and Wiig, Ø. (2016). Conservation status of polar bears (*Ursus maritimus*) in relation to projected sea-ice declines. Biology Letters 12(12). https://doi.org/10.1098/rsbl.2016.0556.

Reid, H., Cannon, T., Berger, R., Alam, M., and Milligan, A. (eds.) (2009). Community-based adaptation to climate change. Participatory Learning and Action vol 60, Nottingham, UK.

Reid, D., Berteaux, D., and Laidre, K., lead authors. (2013). Mammals. In Arctic biodiversity assessment. Status and trends in Arctic biodiversity. Meltofte, H. (ed.). Conservation of Arctic Flora and Fauna, Akureyri, pp.79–141.

Richter-Menge, J., Overland, J., and Mathis, J. (eds.) (2016). Arctic Report Card 2016. http://www.arctic.noaa.gov/Report-Card.

Ristroph, B. (2017). Pacific walrus protection and management in a changing climate. Findings from the 2016 Arctic Science Summit Seminar. San Francisco: Pacific Environment. http://www.pacificenvironment.org/wp-content/uploads/2017/02/walrus-mgmt-report_final_gl.pdf. Accessed January 20, 2018.

Rode, K., Regehr E., Douglas D., Durner, G., Derocher, A., Thiemann, G., and Budge, S. (2014). Variation in the response of an Arctic top predator experiencing habitat loss: Feeding and reproductive ecology of two polar bear populations. Global Change Biology 20: 76–88. https://doi.org/10.1111/gcb.12339.

Rode, K., Wilson, R., Regehr, E., St. Martin, M., Douglas, D., and Olson, J. (2015). Increased land use by Chukchi Sea polar bears in relation to changing sea ice conditions. PLoS ONE 10(11): e0142213. https://doi.org/10.1371/journal.pone.0142213.

Rosales, J., and Chapman, J. (2015). Perceptions of obvious and disruptive climate change: Community-based risk assessment for two native villages in Alaska. Climate 3(4): 812–832. https://doi.org/10.3390/cli3040812.

Ross, G. (1979). The annual catch of Greenland (bowhead) whales in waters north of Canada, 1719–1915: A preliminary compilation. Arctic 32(1): 91–121.

Ross, G. (1993). Commercial whaling in the North Atlantic. In The bowhead whale. Burns, J., Montague, J., and Cowles, C. (eds.). Lawrence, KS: Society for Marine Mammology Lawrence, pp. 511–561.

Russell, D. (2008). State of wild reindeer herds. In Arctic Report Card 2008, pp. 37–38. ftp://ftp.oar.noaa.gov/arctic/documents/ArcticReportCard_full_report2008.pdf. Accessed January 18, 2018.

Russell, D., and Gunn, A. (2013) Migratory Tundra Rangifer. In Arctic Report Card 2013. Jeffries, M., Richter-Menge J., and Overland J. (eds), pp.96–101 www.arctic.noaa.gov/reportcard. (Accessed March 28, 2018).

Salomon, A., Tanape, N., and Huntington, H. (2011). Imam Cimiucia: Our changing sea, University of Alaska Press, Fairbanks.

Schledermann, P. (1976). The effect of ecological/climate changes on the style of Thule culture winter dwellings. Arctic and Alpine Research 8(1): 37–47.

Serreze, M. (2008/2009). Arctic climate change: Where reality exceeds expectations. Witness the Arctic 13(1): 1–4.

Shnitnikov, A. (1957). Fluctuations in humidity of the continents in the northern hemisphere. In Zapiski Geograficheskogo obshchestva SSSR 16:1–336, Leningrad, Moscow and (Russian).

Siivonen, L. (1948). Structure of short-cyclic fluctuations in numbers of mammals and birds in the northern parts of the northern hemisphere. Riistatieellisiä Julkaisuja (Papers on Game Research) 1, Helsinki, Finnish Game and Fisheries Research.

Smit, B., and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. Global Environmental Change 16: 282–292.

Stammler, F. (2005). Reindeer nomads meet the market: Culture, property, and globalization at the end of the land, Litverlag, Münster.

Stewart, R. (2008). Redefining walrus stocks in Canada. Arctic 61(3): 292–308.

Stewart, B., Higdon, J., Reeves, R., and Stewart, R. (2009). A catch history for Atlantic walruses (*Odobenus rosmarus rosmarus*) in the eastern Canadian Arctic. NAMMCO Scientific Publications 9: 219–313.

Stirling, I., and Derocher, A. (1993). Possible impacts of climatic warming on polar bears. Arctic 46(3): 240–245.

Stirling, I., and Derocher, A. (2012). Effects of climate warming on polar bears: A review of the evidence. Global Change Biology 18: 2694–2706.

Stirling, I., Lunn, N., and Iacozza, J. (1999). Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climatic change. Arctic 52: 294–306.

Stroeve, J., Holland, M., Meier, W., Scambos, T., and Serreze, M. (2007). Arctic Sea ice decline: Faster than forecast. Geophysical Research Letters 34: L09501. https://doi.org/10.1029/2007GL029703.

SWG [Scientific Working Group to the Canada-Greenland Joint Commission on Polar Bear]. (2016). Re-assessment of the Baffin Bay and Kane Basin polar bear subpopulations: Final report to the Canada-Greenland joint commission on polar bear. 31 July 2016: X + 636 pp.

Syroechkovskyi, E. (ed.) (1982). Wild reindeer in the USSR, Sovetskaia Rossiia, Moscow (Russian).

Tanner, A. (1979). Bringing home animals: Religious ideology and mode of production of the Mistassini Cree hunters, St. Martin Press, New York.

Taylor, P., Maslowski, W., Perlwitz, J., and Wuebbles, D. (2017). Arctic changes and their effects on Alaska and the rest of the United States. In climate science special report: Fourth National Climate Assessment Vol. 1. Washington DC: U.S. global change. Research Program: 303–332. https://doi.org/10.7930/J00863GK.

Tejsner, P. (2013). Living with uncertainties: Qeqertarsuarmiut perceptions of changing sea ice. Polar Geography 36(1–2): 47–64.

Thorpe, N., Hakongak, N., Eyegetok, S., and Elders, K. (2001). Thunder on the tundra: Inuit Qaujimajatuqangit of the Bathurst caribou, Generation Printing, Vancouver.

Tyler, N. (2010). Climate, snow, ice, crashes, and declines in populations of reindeer and caribou (*Rangiger tarandus* L.) Ecological Monographs 80(2): 197–219.

U.S. FWS (U.S. Fish and Wildlife Service). (2017). After comprehensive review, Service determines Pacific walrus does not require Endangered Species Act protection. News release (October 4, 2017). https://www.fws.gov/alaska/fisheries/mmm/walrus/esa.htm.

Uboni, A., Horskotte, T., Kaarlevjärvi, E., Seveque, A., Stammler F., Olofsson J., Forbes, B., and Moen, J. (2016). Long-tern trends and role of climate in the population dynamics of Eurasian reindeer. PLoS One 11(6): https://doi.org/10.1371/journal.pone0158359.

UPCART (Ungava Peninsula Caribou Aboriginal Round Table). (2017). A long time ago in the future: Caribou and the people of Ungava. 2017–2117. http://www.gcc.ca/pdf/UPCART-STRATEGY-October-17-2017.pdf. Accessed January 20, 2018.

Valkenburg, P., Kellyhouse, D., Davis, J., and Ver Hoef, J. (1994). Case-history of the Fortymile caribou herd, 1920-1990. Rangifer 14: 11–22.

Vibe, C. (1950a). Dyrelivet (Animal life). In Grønlands bogen. Birket-Smith, K., Mentze, E., and Møller, F. (eds.). Vol. 1, pp. 181–204. Copenhagen (Danish).

Vibe, C. (1950b). The marine mammals and the marine fauna in the Thule District (Northwest Greenland) with observations on the ice conditions in 1939–41. Meddelelser om Grønland 150: 1–115.

Vibe, C. (1967). Arctic animals in relation to climatic fluctuations. Meddelelser om Grønland 170(5).

Vibe, C. (1970). The Arctic ecosystems influenced by fluctuations in sunspots and drift-ice movements. In Productivity and Conservation in

Northern Circumpolar Lands. Fuller, W., and Kevan, P. (eds.). International Union for Conservation of nature and natural resources publications, new series, 16:115–120. Morges.
Voorhees, H., and Sparks, R. (2012). Nanuuq: Local and traditional ecological knowledge of polar bears in the Bering and Chukchi seas, Alaska Nanuuq Commission, Anchorage.
Voorhees, H., Sparks, R., Huntington, H., and Rode, K. (2014). Traditional knowledge about polar bears (*Ursus maritimus*) in northwestern Alaska. Arctic 67(4): 23–36.
Vors, L., and Boyce, M. (2009). Global decline of caribou and reindeer. Global Change Biology 15: 2626–2633.
Watanabe, H. (1994). The animal cult of northern hunter-gatherers: Patterns and their ecological implications. In Irimoto, T., and Yamada, T. (eds.), Circumpolar religion and ecology. An anthropology of the north, University of Tokyo Press, Tokyo, pp. 47–68.
Weller, G., and Anderson, P. (eds.) (1999). Assessing the consequences of climate change for Alaska and the Bering Sea region. Proceedings of a workshop (29–30 October 1998), University of Alaska Fairbanks, Fairbanks.
Whitten, K. (1996). Ecology of the Porcupine caribou herd. Rangifer, Special Issue 9: 45–51.
Wiig, Ø., Born, E., and Stewart, R. (2014). Management of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in the arctic Atlantic. NAMMCO Scientific Publications 9. https://doi.org/10.7557/3.2855.
Willerslev, R. (2007). Soul hunters. Hunting, animism, and personhood among the Siberian Yukaghirs, University of California Press, Berkeley.
Wilson, D., and Reeder, D. (eds.) (2005). Mammal species of the world — A taxonomic and geographic reference, Johns Hopkins University Press, Baltimore.
Witting, L., and Born, E. (2014). Population dynamics of walruses in Greenland. NAMMCO Scientific Publications 9: 191–218. https://doi.org/10.7557/3.2612.
Womble, J., Pendleton, G., Mathews, E., Blundell, G., Bool, N., and Gende, S. (2010). Harbor seal (*Phoca vitulina richardii*) decline continues in the rapidly changing landscape of Glacier Bay National Park, Alaska 1992-2008. Marine Mammal Science 26(3): 686–697.
Wood, K., Bond, N., Danielson, S., Overland, J., Salo, S., Stabeno, P., and Whitefield, J. (2015). A decade of environmental change in the Pacific Arctic region. Progress in Oceanography 136: 12–31.
Yesner, D. (1988). Effect of Aleut exploitation on sea mammal populations. Arctic Anthropology 25(1): 28–43.