



THE ARCTIC FALLACY

Sea ice stability and the polar bear

Susan Crockford

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About the author

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Foreword

by Matthew A. Cronin

This same practice of Lysenkoism has long been under way in western science in regard to the politically correct theory of man caused, catastrophic, global warming.

Peter Ferrara, Forbes ¹

Harsh words indeed. Ferrara's insights got my attention because, as a geneticist, I am quite familiar with the tragedy of Trofim Lysenko's science in the Soviet Union in the 1900s. Lysenko insisted that agricultural science be consistent with communist doctrine, and he rejected western science, most notably Mendelian genetics. This resulted in persecution of dissenting scientists, and the failure of Soviet agriculture, which in turn resulted in massive famines at a time when western science was giving us the Green Revolution of greatly increased agricultural production.

The reason Lysenko was so influential was because he used the government to force his science, and farming policy derived from it, onto the entire Soviet Union. The author Michael Crichton MD also saw the parallel of Lysenkoism and global warming:

Lysenko... dominated Russian biology. The result was famines that killed millions, and purges that sent hundreds of dissenting Soviet scientists to the gulags or the firing squads... Now we are engaged in a great new theory... that has drawn the support of politicians, scientists, and celebrities around the world... Once again, critics are few and harshly dealt with... ²

Ferrara and Crichton believe that global warming has now become a politicized science similar to Lysenkoism, in which dissenting views are not allowed. Cries of 'The science is settled' on global warming and persecution of so-called 'deniers' are unsettling echoes of this era. The similarities of global warming and Lysenkoism described by these authors should serve as a warning to scientists and laymen alike.

Undeterred by such a politically-charged climate, Susan Crockford has addressed an important aspect of the global warming issue: the status of polar bears. Her thorough analysis convincingly argues that the science on polar bears has been presented in a one-sided way to support predictions of impacts from global warming and makes the point that we must consider data whether or not it supports predictions. Scientists know that predictions are basically hypotheses that need to be tested with observations, not accepted as conclusions.

I have experience with such wildlife issues including impacts of oilfields on caribou in northern Alaska (the population grew tenfold during the period of oilfield development and operation but only negative impacts are emphasized by wildlife biologists), and the arbitrary classification of subspecies and populations for Endangered Species Act (ESA) listings. My work and that of others with DNA and fossils have also

shown that polar bears likely have been a species for at least several hundred thousand years and thus survived previous interglacial periods in which there likely was little or no Arctic summer sea ice. I pointed out that if the bears survived one such period perhaps they could survive another, with the logic that if we can predict the polar bear's future we can also infer its past. This has been ignored (and denigrated) by the polar bear research community although it is a legitimate finding. This is presumably because it does not support predictions (i.e. hypotheses) of polar bears' extinction.

Crockford's work is similar in presenting data that do not support declines of polar bear numbers caused exclusively by loss of summer sea ice. She uses her broad background in several scientific fields to question the basic assumption that sea ice is a stable environment in all seasons, even over short time periods. The loss of stable sea ice is a basic assumption of the models used to predict declines in polar bear numbers to the point of being threatened with extinction (being threatened or endangered with extinction is the criterion for ESA listing).

Scientists know that the assumptions used in a model are critical to its validity. For example, assumptions in genetic models that I use (e.g. mutation rates or species divergence times) are estimates, not known quantities, making model results uncertain. It is legitimate to use models with uncertain assumptions, but the uncertainty of the model results must be openly acknowledged and alternatives considered. Crockford demonstrates that this has not been done for polar bears and that the basic assumption of stable sea ice is not valid. She strengthens her argument with revelations that there is a consensus that winter sea ice is expected to persist despite global warming, and that heavy spring ice, not absence of summer ice, has a negative impact on seals and thus polar bears. These points could change the entire argument about the future survival of polar bears.

The constant chorus declaring crises for high-profile wildlife (snail darters, spotted owls, wolves, bears, etc.) has led to what I call the 'pan-impact' paradigm: there is always a human impact on wildlife, and scientific information will be found to support a preconceived conclusion. This has resulted in many of us now having a skeptical 'boy who cried wolf' attitude regarding wildlife: everything people do will be claimed to have a negative impact on some critical species, and must be corrected by top-down government regulation (of which the ESA is a preferred mechanism in the USA). This is dangerous, not only to science and economics, but because we might not pay attention when real threats arise.

I appreciate that global warming is potentially very important. But, we should not stifle the open discussion and debate that is integral to science. Crockford's article is a valuable contribution to the scientific discourse on polar bears, and I hope it gets a fair hearing. I encourage readers on both sides of the climate debate to engage in civil discourse on these issues, and not prejudge any work without thoughtful consideration.

Matthew Cronin is Professor of Animal Genetics at the University of Alaska Fairbanks.

Summary

Since the late 1960s, Arctic marine mammal conservation has been based on the assumption that sea ice provides a stable, predictable environment for polar bears and Arctic seals: today, it underpins their 'threatened with extinction' status. A stable environment, the oversimplified K-selection theory goes, should support populations at relatively high levels over time, without marked variation in size due to habitat change. This idealized concept was strongly promoted by the most popular university-level ecology textbooks of the 1970s and was embraced by early polar bear biologists, who began their careers at a time when polar bears were truly threatened with extinction by overhunting.

Observations since then, however, have shown the assumption of sea ice as a stable habitat over short timescales is false. Spring sea-ice thickness has been naturally variable over timescales of a few years to decades in the Beaufort Sea, East Greenland, and Hudson Bay; spring ice extent has been naturally variable in the Barents Sea for centuries and spring snow depth on sea ice is known to vary over short periods. Marked declines in polar bear and ringed seal survival in response to thick spring sea ice and reduced snow depth have been documented. These two variables are closely tied because spring (April–June) is the period of on-ice birth and nursing for ice-dependent seals and is also when polar bears consume two-thirds of their annual prey. Apparently expecting stable or increasing populations, despite their own evidence to the contrary, Arctic biologists now surprisingly attribute virtually every downturn in population size of Arctic species to declines in summer sea ice blamed on human use of fossil fuels. Shifting the blaming for the devastation caused by thick spring ice onto recent summer ice declines, biologists portray summer ice changes as manifestations of unprecedented, human-caused habitat instability.

Regardless of such willful blindness to the facts, the assumption that Arctic sea ice is a naturally stable habitat over short time frames is a biological fallacy. Predictive population models based on this myth are flawed, their results illusory. Yet, the International Union for the Conservation of Nature and the US government have, for the first time, accepted modelled (future) population declines of Arctic species based on modelled (future) summer sea ice changes as valid threats to their survival, all built upon this fallacy. Given what we now know about the animals and their naturally changing habitat, it is time to concede that data do not support predictions that polar bears, walrus, and Arctic seals are threatened with extinction due to habitat instability.

1 Introduction

Research used to support polar bears' status as 'threatened' under the American Endangered Species Act (ESA), and 'vulnerable' by the International Union for the Conservation of Nature (IUCN)³ is based on the concept that Arctic sea ice is such a stable habitat that no profound fluctuations in population size ever take place naturally as a result of seasonal changes in sea ice. In other words, unlike terrestrial habitats such as grasslands or deserts, where periodic heavy winter snowfall or summer drought may cause animal populations to crash,⁴ the inherent stability of sea ice in all seasons is assumed to buffer polar bears and Arctic seals from such natural population fluctuations. How did such a bizarre idea – that sea ice habitat never varies naturally, even over short time periods – come to underpin a declaration that a species was 'threatened'?⁵

In the 1960s, some biologists who studied animal populations looked for an overarching pattern of interaction between animals and their habitats. One ecological feature of particular interest was the ability of the habitat to support populations of animals over time, the habitat's so-called 'carrying-capacity', referred to as 'K'.

By the early 1970s, when research on Arctic seals, walrus and polar bears began in earnest, a popular yet short-lived paradigm had emerged. This divided all species into so-called 'r-selected' or 'K-selected' groups. The category of r-selected animals includes those with 'many offspring, short gestation, less parental care, and a short time until sexual maturity' and which live in unstable or unpredictable habitats. Examples include bacteria or mice. K-selected species are those with 'few offspring, long gestation, long parental care, and a long period until sexual maturity' and which live in stable, predictable habitats. Examples include whales and humans.⁶ This concept was strongly promoted by the most popular university-level ecology textbooks of the 1970s.⁷

Polar bears and walrus were then, and still are today, considered to be classic K-selected species⁸ by the specialists who study them, as shown by this statement made more than a decade ago by Derocher and colleagues:⁹

Polar bears (*Ursus maritimus*) are a classic K-selected species having delayed maturation, small litter sizes, and high adult survival rates.

While unbridled human predation on walrus and polar bears in the 19th and early 20th centuries temporarily made the notion of a 'balanced' Arctic ecosystem invalid, Arctic biologists believed that recovered populations should reach and then maintain a constant level in their stable habitat: populations would not decline due to naturally-occurring changes in their habitat because such environmental changes would not happen, even over the short term. For carnivores such as polar bears, the theory that stable habitats support stable population numbers over short timescales also assumed the presence of a relatively constant number of animals to feed upon – in other words, a stable prey base of Arctic seals, primarily ringed and bearded seals.

As Moore and Huntington (2008) have stated:

...the fitness of Arctic marine mammals will be influenced by change to the dynamic balance among sea ice's effects on ecosystem structure and prey availability, as well as its role as a barrier or platform. In the ice-obligate category, the polar bear provides the clearest example: reductions in sea ice remove their hunting and resting platforms and likely reduce survivorship of ringed seals, their primary prey.

What is this 'dynamic balance' within which the Arctic is assumed to operate? It is a relatively modern notion that eminent ecologist Daniel Botkin¹⁰ calls the 'nature in balance' concept:¹¹

The idea that nature can be restored to a single best condition is also part of a modern nature-myth, the belief in nature as a machine. According to this belief, developed in the nineteenth century, nature was like a watch or steam engine. It could be operated to run steadily.

Botkin also described a specific example of the fallacy of this out-of-date concept in this excerpt from his 1995 book,¹² in which he discusses modern grizzly bear populations compared to what explorers Lewis and Clark observed in the western United States in the early 1800s:

...this old view of nature also carried with it the belief that each creature existed at its carrying capacity – at the maximum number that could be sustained by its environment. Such a belief, while consistent with the idea of a perfect balance of nature, contradicts the inherent changeableness of the environment, which Lewis and Clark came to know all too well in their travels on the Missouri. And scientists know now that populations of grizzlies and other animals and plants are, like the Missouri River, always changing. There is no single 'natural' abundance.

There is a range of abundances, all of which are 'natural' in the sense that the population was at that level at some time during the past, prior to the effects of modern civilization.

The ecological concept of 'stability' is thus an idealised state, a theoretical condition that often does not apply to real animal populations and the environments they occupy in the real world.¹³ For example, amongst terrestrial mammals, drought or heavy snow can impact populations profoundly over the short term by decreasing critical food supplies or access to them.¹⁴ For polar bears and Arctic seals, sea ice has only been 'stable' in the sense that the habitat has been available, although variable in seasonal extent, over hundreds of thousands of years, through glacial ice ages and interglacial warm periods alike,¹⁵ but this is not how polar bear biologists use the term.

It is clear from the literature that polar bear specialists believe that polar bears, until recently, lived in ideal stable habitats that *never* varied and maintained stable or increasing population numbers that *never* declined due to natural environmental

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factors. For example, Peacock et al. (2010), in a book chapter on polar bear conservation in Hudson Bay, provided a list of four reasons they thought sea ice habitat had not been explicitly protected over the last four decades and the fourth reason given was that:

...sea ice as a habitat has been considered stable in quantity and quality.

This assumption of sea ice as a naturally stable habitat over short time periods was also demonstrated in a 2014 BBC web essay,¹⁶ which quoted Dr. Steven Amstrup, a former polar bear biologist for the US Geological Survey and now 'chief scientist' for *Polar Bears International*, as saying the following:

It is important to remember that wild animals, if they have a stable healthy habitat, are a renewable resource and they can be managed sustainably. The problem with polar bears is that, right now, their habitat isn't stable.

Computer models used in 2008 to predict the likely response of polar bears to predicted sea ice changes over the next 100 years in support of listing polar bears as 'threatened' under the Endangered Species Act assumed population starting points were stable or increasing.¹⁷ In addition, any negative habitat changes in any year were assumed to be due to unnatural increases in the length of the ice-free period in summer (i.e. due to human-caused global warming). For example, in one of the nine USGS reports supporting the 2008 polar bear listing document, Hunter and colleagues¹⁸ divided five years worth of Southern Beaufort Sea population data into 'good' ice summers (2001–2003) and 'bad' ice summers (2004–2005) for the purpose of projecting future population responses to predicted summer sea ice declines.¹⁹ They assumed that 'bad' ice summers were caused by unnatural (human-caused) influences while 'good' ice summers reflected normal, stable sea ice conditions, and thus should support a stable or increasing population. This assumption is reflected in a short statement from page 19 of their conclusions:

If conditions were to remain similar to 2001–2003, the population would increase over the next 45–100 years.

Similarly, Stirling and colleagues,²⁰ in their comparison of survival of cubs-of-the-year (bears born that spring; COYs) between Southern Beaufort and Northern Beaufort relative the amount of open water (similar to the 'good'/'bad' summer ice conditions described above), had this to say;

...the marked reduction in survivorship for COYs noted in [the Southern Beaufort] in 2005 and 2006 (Regehr et al. 2006) was not observed in [the Northern Beaufort]. It is possible the drop in survivorship in [the south] was related to ecological changes resulting from several years of successively more extensive and extended open water (Regehr et al. 2007a) while, in comparison, ice conditions have remained relatively stable in [the north].

Regarding the prey of polar bears, the government document that laid out the argument for listing polar bears as threatened had this to say²¹:

... polar bears are uniquely adapted to hunting on ice and need relatively large, stable seal populations to survive.

It is abundantly clear that the new 'instability' apparently faced by polar bears and their prey refers to summer sea ice coverage alone, a habitat variability that can only be considered unprecedented if the wealth of data on *spring* sea ice habitat changes are ignored.²²

All of these factors contribute to the conclusion that Arctic biologists stand out amongst colleagues doing research in other regions. For the most part, ecologists and biologists using ecological principles have moved beyond the simplistic, 1970s notion of r-selected versus K-selected population/habitat dynamics and most have developed more realistic methods of analysis.²³ In contrast, virtually all Arctic biologists remain idealistic in regards to their outmoded assumptions that sea ice is a naturally stable habitat over short timeframes and that stable (or increasing) populations are the only natural trends expected for Arctic marine mammals. This attitude is especially disturbing because the strongest evidence refuting these assumptions comes from their own research.

2 Evidence that sea ice is not a stable habitat

Although long-term records of sea ice thickness and snow depth over sea ice are not available on a global basis, observations from several regions have shown that sea ice across the Arctic is not a naturally stable habitat over decadal time scales, especially in winter through spring.²⁴ Due to their dependence on specific winter/spring sea ice conditions, Arctic seal populations have varied over time at a number of locations. As a consequence of the variability in seal numbers during the spring, when polar bears consume two-thirds of their annual prey, polar bear population numbers have likewise fluctuated over decades. Survival and production of young for both seals and polar bears are inextricably linked to prevailing sea ice conditions from January through June.²⁵

Eastern Beaufort

Take, for example, the Beaufort Sea – the area north of Alaska's Arctic coast and west of the Central Canadian Archipelago. The USA and Canada share management of polar bears in this area. Too much thick spring ice in this region has had detrimental short-term consequences for both ringed seal and polar bear numbers approximately every 10 years since at least the early 1960s. However, numbers have quickly recovered.²⁶ The first of these population declines was described in the proceedings of the 1979 IUCN Polar Bear Specialist Group (PBSG meeting).²⁷ The following statement from

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that report reveals the surprise that biologist Ian Stirling and colleagues felt at the instability they had witnessed in the field:

However, it was apparent from the studies of both polar bears and seals that their populations had undergone marked declines in numbers, productivity, and survival of young in 1974 and 1975. The decline apparently occurred because of natural causes that are not completely understood.

Up until the present, the numbers of seals and bears in relation to the marine ecosystem have been regarded as being fairly static. This is the first time that major changes in numbers and reproductive parameters caused by natural influences have been documented in populations of arctic seals and polar bears.

A few years later, Stirling and colleagues²⁸ made the following statement about the same mid-1970s Southern Beaufort phenomenon, which impacted both ringed and bearded seals as well as polar bears, and shows they understood its implications for assessing environmental impacts:

Until recently, management of marine mammals in the Canadian Arctic, to the extent that they are managed at all, seems to have been based on the assumption that ecological conditions show little variability. Thus, once populations are counted or quotas are established, little change in population management takes place for long periods. The results of this study have clearly shown that ice conditions in the eastern Beaufort Sea can be highly variable, can influence other ecological parameters, and can cause changes in the distribution and abundance of ringed and bearded seals. We expect that similar variability will be documented in other areas of the Arctic when comparable studies have been completed.

What this means in terms of environmental assessment is that, because conditions are so variable, the consequences of possible man-made detrimental effects will vary depending on the status of the seal populations at the time.

In 2008, Stirling and colleagues²⁹ summarized the decadal nature of polar bear and ringed seal population fluctuations in relation to another episode of the phenomenon that occurred in 2004–2006. They noted that population declines of both seals and bears were always associated with thick spring ice conditions but recovered afterward:

The 1960s, 1970s, and 1980s each experienced a two- to three-year decline in seal productivity in the eastern Beaufort Sea and Amundsen Gulf, associated with heavy ice conditions, around mid-decade. Each was followed by a decline in polar bear reproduction and condition, after which both seal and bear populations recovered (Smith, 1987; Harwood et al., 2000; Stirling, 2002). The beginning of each of those three periods was

associated with heavy ice conditions through the winter before the reproductive decline of the seals, followed by a late spring breakup.

These authors also noted that the spring sea ice conditions in 2004–2006 (the most recent documented incident) were as bad as they had been in 1974, when Ian Stirling and Nick Lunn recorded some of the worst cases of starvation they had ever witnessed in the Arctic:³⁰

...in the spring of 1974, when ringed seal pups first became scarce, we captured two very thin lone adult female polar bears that had nursed recently, from which we deduced they had already lost their litters. A third emaciated female was accompanied by two cubs which were so thin that one could barely walk. We have not seen females with cubs in this condition in the Beaufort Sea, or elsewhere in the Arctic, before or since.

In the early 1970s, many ringed seals and polar bears were known to have moved out of the south-east Beaufort Sea and into the Chukchi Sea,³¹ probably to escape thick spring ice conditions. This may have occurred in other thick-ice years but has not been documented. The few ringed seal pups that were born in the south-eastern Beaufort during any thick-ice spring would have been hard for polar bears to locate within the deformed near-shore ice. With few naïve, fat newborns to be had, predation-savvy adult seals and young subadults would have been the primary prey available to polar bears in heavy ice years, regardless of when they occurred, making successful seal hunts a much greater challenge than usual.

In their recently-published paper, Bromaghin and colleagues³² said this about the recurring sea ice phenomenon in the Southern Beaufort (SBS), one of which occurred during their study (2004–2006):

Extensive ice rubble and rafted floes during winter and spring are thought to have led to past declines in polar bear productivity in the SBS (Stirling et al. 1976, Amstrup et al. 1986, Stirling 2002), as well as during our investigation (Stirling et al. 2008).

Unfortunately, the precise amount of polar bear population decline during the 1974–1975 thick-ice events has never been calculated: the drop in numbers was only noted as being ‘marked’. The thick ice coverage in those years primarily affected ringed seals by reducing almost to zero the number of pups born,³³ resulting in the starvation and reduced survival of polar bears, especially cubs. For the mid-2000s event, however, a newly formulated model³⁴ was used to estimate that numbers of polar bears had declined by 25–50%.³⁵ Since the response of ringed seals to conditions in 2004–2006 were virtually identical to 1974–1976, with virtually no seal pups born,³⁶ and lacking other information, it is reasonable to assume that in the mid-1970s, the polar bear

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population would have declined by similar amounts as in the mid-2000s, due to a combination of reduced cub survival and movement of bears out of the region. In both periods, polar bear numbers rebounded to pre-thick-ice levels within 3–6 years.³⁷

Other incidents in that region are not as well documented because polar bear research in the 1960s, 1980s, and 1990s was rather limited. However, ringed seal researchers noted that seal pup production fell to almost zero in 1963, 1984–1986, and in 1992–1994, suggesting that local polar bear populations probably faced starvation-related declines in survival or forced-relocation pressure in those decades also.³⁸ That makes a total of two well-documented periods of significant declines in polar bear and ringed seal populations caused by natural changes in sea ice quality during the spring, with three additional events that may or may not have been as severe.

Stirling and Lunn³⁹ concluded the following in their 1997 paper:

From the results presented above, it seems clear that the most critical factor affecting reproductive success, subsequent condition and probably survival of polar bears is the availability of ringed seal pups from about mid-April through to breakup sometime in July.

What they did not add is that availability of ringed seal pups in spring varied with spring sea ice conditions, especially ice thickness: that insight came a bit later.⁴⁰ Oddly, Stirling and others now link polar bear survival and population declines in the Southern Beaufort to sea ice conditions in late summer/fall (August to October),⁴¹ although Nick Pilfold and colleagues⁴² recently conceded:

Because polar bears may acquire as much as two-thirds of their energetic intake in spring (Stirling and Øritsland 1995), a significant reduction in kill biomass could have population level consequences. Spring is the mating season for polar bears, and successfully mated females can avoid implantation or abort fetuses before denning if fat stores are inadequate (Derocher et al. 1992). Additionally, Bromaghin et al. (2014) reported lower survival rates between 2004–2006 for the southern Beaufort sub-population and suggested measures of ice-availability were insufficient in explaining the decline. We suggest that poor hunting conditions in spring 2005–2006 could have negatively affected polar bear survival.

Eastern Arctic: effects of the Atlantic Multidecadal Oscillation

Similar evidence of spring sea ice habitat instability comes from Hudson Bay and the Barents Sea. In Hudson Bay in the early and late 1990s, production and survival of ringed seal pups declined markedly.⁴³ The low number of pups in 1991 and 1992 was correlated with heavy spring sea-ice conditions and a

much shortened open-water period. Ringed seal researcher Magaly Chambellant and colleagues blamed the thick spring ice on natural conditions and events⁴⁴:

The combined effect of a strong positive phase of the North Atlantic Oscillation [aka the Atlantic Multidecadal Oscillation, AMO⁴⁵] and a strong El Niño event in 1991–1992, and the eruption of Mount Pinatubo in June, 1991, created colder than average conditions in the eastern Arctic, including Hudson Bay, in the early 1990s.

Similarly to thick-spring-ice events in the Southern Beaufort, it was noted that some of the decline in seal populations in Hudson Bay during the 1990s may have been due to seals leaving the region during heavy ice years, although reduced pup survival in other years was correlated with spring snow depths being less than 32 cm. Overall, Steve Ferguson and colleagues⁴⁶ summarised the variation in survival of ringed seals between the 1971 and 2001 this way:

The pooled survivorship curve for the western Hudson Bay sample (1999–2001) showed considerable annual variability... suggesting that survival of seals born in any given year was not constant. However, a decadal pattern emerged suggesting poor ringed seal recruitment, 1971–1978 (7 of 8 yr below average); better than average recruitment, 1979–1988 (8 of 10 yr); followed by poor recruitment in later years, 1989–2000 (8 of 12 yr).

Due to the reliance of polar bears on abundant ringed seal pups in spring, survival of Western Hudson Bay cubs between spring and the following summer between 1980 and 1992 dropped to a low of 39% in 1991 (from 70–100% some years) when low seal pup production was noted due to thick spring ice. Polar bear cub survival was also low (41–47%) in 1988–1990,⁴⁷ when low snow depths reduced seal pup survival.⁴⁸ In 1992, polar bears were reportedly in good condition when they left the ice in late summer. They had been feeding for about three weeks longer than average, apparently compensating for the lower availability of seal pups.

Negative polar bear cub survival clearly impacted overall population size: the largest sustained drops in western Hudson Bay occurred in the late 1980s and early 1990s (see Fig. 1) and again in 1999. These impacts were associated with documented declines in ringed seal pup production, which were blamed in turn on heavy ice conditions and/or low snow depths.⁴⁹

The 30-year trend towards earlier breakup dates in western Hudson Bay does correlate with overall population declines since the 1980s but rarely do specific early breakup dates correlate with short-term declines in population size. For example, breakup was apparently early in 1990 (Fig. 2) but, as noted above, low ringed seal production that year was blamed on shallow winter

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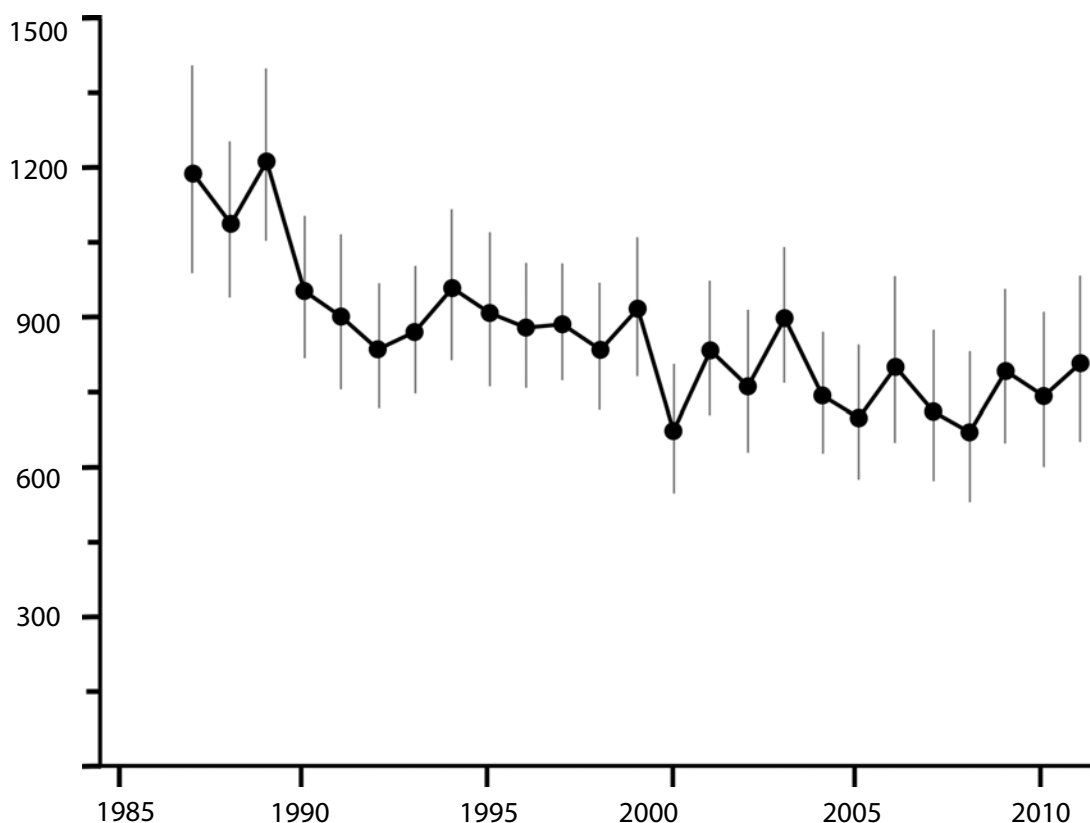


Figure 1: Polar bear population in western Hudson Bay

Redrawn from Lunn et al. 2013: 40.

snow depths and there was not unexpectedly an associated decline in polar bear numbers (Fig. 1).

In 2003, breakup was very early (Fig. 2) and was associated with only a modest decline in polar bear numbers over the next few years (Fig. 1).⁵⁰ Lunn and colleagues found no trend in breakup or freeze-up dates between 2001 and 2010; breakup dates were not getting earlier over time nor were freeze-up dates getting later.⁵¹ In contrast, seal pup production and polar bear cub survival were both low in 1991 (Fig. 2), but both were blamed on the relatively late breakup of sea ice that year and its associated short open-water season. Unfortunately, spring snow depths over sea ice and spring ice thickness for Hudson Bay do not appear to be reported independently of ringed seal research reports, which means polar bear biologists are lacking a long-term, detailed record of these critical winter and spring sea ice habitat characteristics to include in their analyses and predictive models.

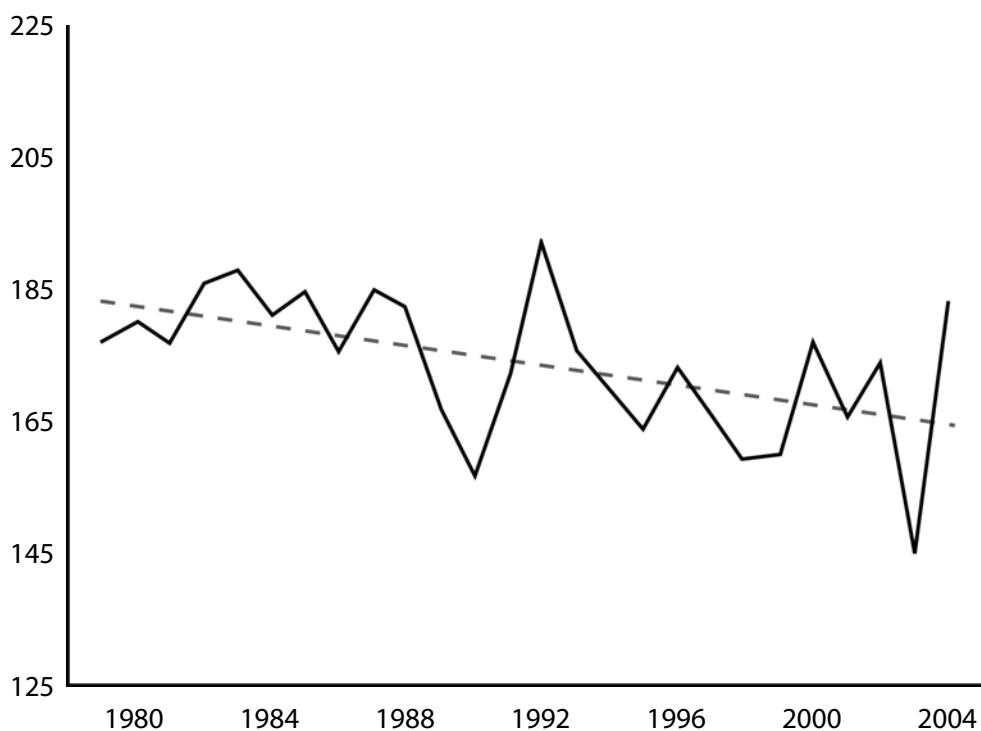


Figure 2: Breakup dates for Western Hudson Bay

The figure uses the 50% ice cover threshold for 'breakup' and Julian calendar days. Dashed line is the authors' trend line fit by linear regression. Redrawn from Stirling and Parkinson (2006: 265).

Multidecadal variability in winter sea ice thickness has also been reported from the late 1700s to the mid-1900s by Danish biologist Christian Vibe⁵² for northwest Greenland (i.e. Baffin Bay) as well as the north coast of East Greenland (Fig. 3). The variability correlated strongly with changes in availability of ringed seals and polar bears. Bears and seals apparently moved out of areas when thick winter/spring ice conditions dominated but returned when normal ice conditions resumed.⁵³ In contrast, around the Svalbard Archipelago in the eastern Arctic, the condition of polar bears has been linked to the relative coverage of sea ice in spring, which varies naturally with the state of the AMO. In this case, the variation has not been in ice thickness, but ice extent (Fig. 3). At the end of February 2014,⁵⁴ the US National Snow and Ice Data Center noted that ice in the Barents Sea was below the seasonal average due to natural variations driven by the AMO, a factor that had been mentioned previously in relation to Hudson Bay ice variation. The AMO (Fig. 4), according to one source:

...is a coherent pattern of basin-wide sea surface temperature (SST) vari-



Figure 3: Sea ice around Greenland and the Barents Sea at 8 March 2014

NSIDC MASIE sea ice product.

ations with a period of roughly 60–90 years...Paleoenvironmental studies suggest that the AMO has persisted through previous centuries...and even millennia...⁵⁵

Norwegian biologists Jon Aars and Magnus Andersen of the Norwegian Polar Institute have pointed out in their online polar bear research updates⁵⁶ that around Svalbard the body condition of adult males, number of females with cubs-of-the-year, and litter size varied with the AMO and sea-ice levels in spring (April–June). Miles and colleagues concluded, regarding the AMO's

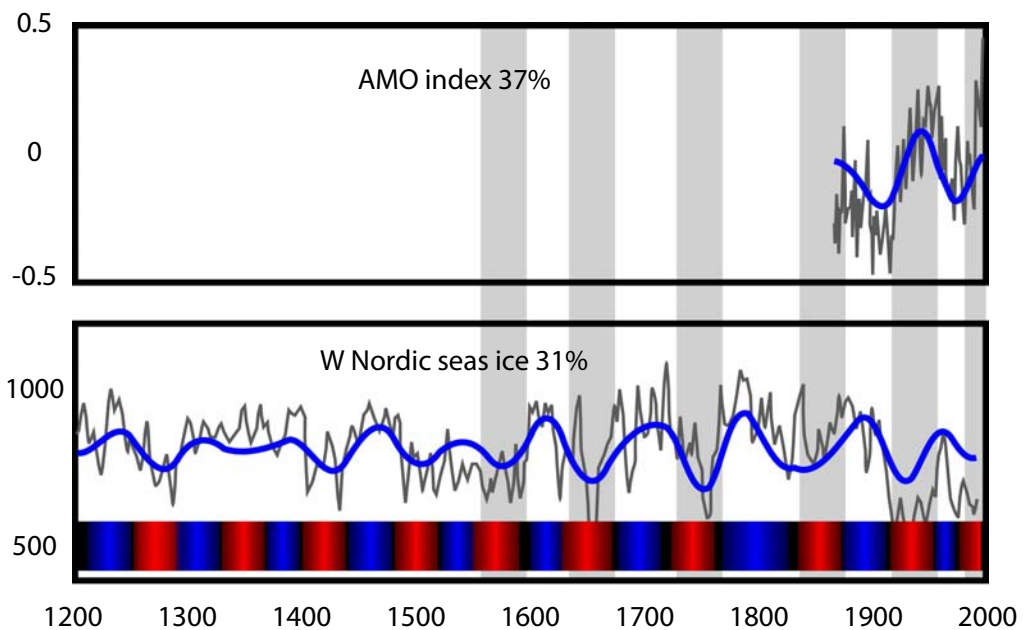


Figure 4: Persistent multidecadal fluctuations in sea ice linked to the AMO

Top, AMO modern index for the North Atlantic sea surface temperature anomaly; bottom, the extended record going back 400 years for sea ice extent (based on proxy reconstructions) for the East Greenland Sea. The color bar indicates periods with reduced ice (red) and periods with increased ice (blue) inferred from the wavelet-filtered signal. The reduced ice periods are seen to correspond to warm AMO periods. Source: Redrawn from Miles et al. (2014).

influence on sea ice:⁵⁷

The pervasive multidecadal variability in observed sea ice is here not considered to represent truly oscillatory cycles but rather irregular, broadly multidecadal fluctuations between warmer (colder) periods with less (more) ice that are related to [Atlantic multidecadal variability].

Polar bear biologist Andrew Derocher looked for correlations of climate with polar bear body condition in spring (1988–2002) in a study of Svalbard bears. He focused on the Arctic Oscillation (AO)⁵⁸ rather than the AMO, but in comparing his Barents Sea results to those from similar studies in western Hudson Bay, he stated that:⁵⁹

The stronger correlation [found] between the Arctic Oscillation index in the spring for both females and males suggests that climate influences affect polar bears more during this period.

Canadian Arctic Archipelago

Another example of the effects of variable spring snow depth and sea ice on both ringed seal and polar bear survival comes from the work of Mike Hammill and Tom Smith⁶⁰, who studied polar bear predation on ringed seals in the Lancaster Sound region of the central Canadian Arctic (known as Barrow Strait). They encountered significant variability in sea ice conditions and snow cover over a three-year period in the mid-1980s. Working in March and April (late winter/early spring), they noted:

...in 1986, extensive open water conditions forced us to survey different plots...

They also recorded that mean snow depth declined from 23 cm in 1984 to 10 cm in 1985. The decline in snow depth between years coincided with an increase in predation success by polar bears on newborn ringed seals, suggesting that deep spring snow offered ringed seals more protection from polar bear attack. As to the importance of spring as a feeding period for polar bears, they had this to say:⁶¹

Prior to late April, we found little evidence of predation in Barrow Strait. In late spring, polar bears enter a period of intense feeding (Stirling and McEwan 1975, Ramsay and Stirling 1988), which begins with the onset of the ringed seal pupping season...Feeding on young seals continues throughout the spring and early summer as bears replenish depleted fat reserves. After ice breakup, bears move ashore and begin another period of little feeding (Stirling and McEwan 1975, Ramsay and Stirling 1988).

Ian Stirling and Andrew Derocher reiterated this essential point in their recent summary paper:⁶²

Stirling & Øritsland (1995) estimated that in most areas, polar bears likely accumulate two thirds or more of the energy they will need for the entire year during the late spring and early summer before breakup. The long open water season in much of the Arctic necessitates accumulation of fat reserves.

In other words, the spring feeding period is critical for polar bears because they eat so little during the rest of the year. A review of the literature shows little documented evidence for polar bears hunting seals successfully in late summer:⁶³ in most regions they do not eat much, regardless of whether summers are spent on shore or on the sea ice.⁶⁴ In fact, many of the effects of a longer open-water period have been unexpectedly positive for polar bears. For example, polar bear condition and reproduction in the Chukchi Sea (between Russia and Alaska) was much better over a recent period with a long open-water season than it was in the 1980s, when there was a short open-water season. Ringed seals flourished during the recent long open-water sea-

son: they had a longer time to feed and consequently reproduced well. Similarly, in the southern Davis Strait (off Labrador), polar bears have flourished despite longer ice-free seasons in recent years because harp seal numbers increased exponentially over the same period (due to collapse of commercial seal hunting). In both cases, more healthy seals meant more food for polar bears in spring. Polar bears that have plenty of seals to eat in spring are fat by early summer, and that fat serves as an essential energy buffer over the summer months, when bears in most regions fast or eat very little. While the timing of ice breakup or extent of summer sea ice is also variable, well-fed bears are prepared for a summer fast of variable length.

In conclusion, it is critical to note that in the Barents Sea/East Greenland region we have evidence of marked natural variability in winter/spring sea ice conditions going back at least 400 years. Variability in spring sea ice and snow conditions has been shown to affect polar bear and ringed seal condition and reproduction over the short term, and may initiate movements of animals between regions. The most deadly of these variations for both species appears to be thick spring ice, although shallow snow cover over spring ice may be nearly as detrimental. As a result, both polar bear and ringed seal population size and reproduction have varied considerably in several regions over the last 20–60 years. So far, few of the marked declines documented in polar bear populations over the last 40 years discussed here can be plausibly blamed on reduced summer sea ice – apparent correlations are spurious or coincidental. Therefore, the evidence is strong that the ‘natural’ state for Arctic sea ice habitat in the winter and spring is *not* stable over short time frames. Consequently, neither are polar bear and ringed seal population numbers.

3 Sea ice and Arctic marine mammal conservation

Polar bear conservation started several decades before other Arctic marine mammals, with the exception of whales.⁶⁵ In the late 1950s, Russia banned all polar bear hunting. By the late 1960s, it was recognized internationally that polar bear populations around the Arctic had been seriously depleted by wanton slaughter and unregulated hunting⁶⁶ and that they were at risk of extinction unless coordinated steps were taken to halt the process. In 1973, an international treaty was signed by Arctic nations⁶⁷ to ensure the protection of polar bears against the over-hunting that threatened their survival.

The PBSG, formed in conjunction with that treaty, had from its inception a unique international authority to inform Arctic policymakers regarding the

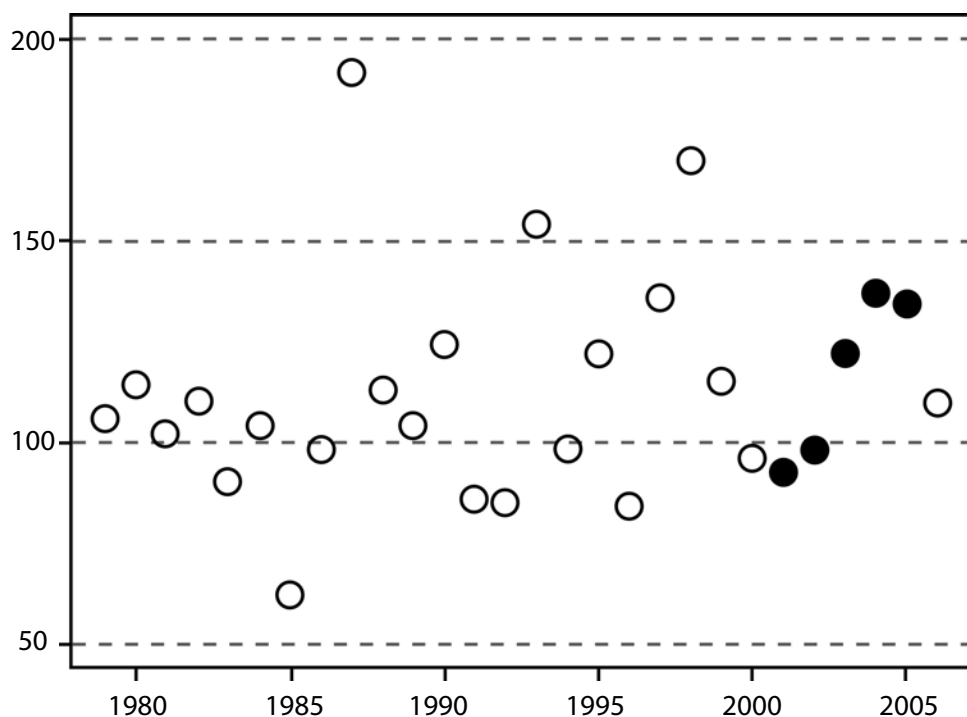


Figure 5: Ice-free days in the southern Beaufort Sea

Number of ice-free days. Solid circles are the years used in the polar bear population survival vs sea ice study. Note that 'good' summer ice years are those below 125 ice-free days and 'bad' summer ice years (those blamed on global warming) are above 125 days. Redrawn from Regehr et al. 2007a: 26.

status of polar bear research and the relative health of polar bear populations. It took until 1988 for the IUCN to gather enough information to formally classify polar bears as 'vulnerable' (equivalent to the term 'threatened' under other schemes). Just eight years later in 1996, polar bear population numbers had sufficiently recovered for the status to be boosted to 'least concern.'⁶⁸ International protection from over-hunting had done its job: the polar bear had been saved.

Fast-forward to 2005. That year, the PBSG recommended that the IUCN return polar bears to 'vulnerable' status on the basis of future risks due to predictions of summer sea ice declines associated with man-made global warming.⁶⁹ The justifications offered for this recommendation were weak, to say the least. Little to no mathematically supported data or model results had been provided. For example, a glossy overview document (with no references to original research and sea ice projection models based on only 19 years of data – less than a single period for what is considered to be 'climate'⁷⁰), was

all that was offered regarding future polar bear habitat changes.⁷¹ The professional opinion of polar bear specialists, namely that a population reduction of more than 30% within the next 35–50 years was foreseen,⁷² was apparently enough for the IUCN to accept the PBSG recommendation. As a consequence, in 2006, the polar bear was upgraded to ‘vulnerable’ on the IUCN Red List.⁷³ Using a similar approach, in 2008 the US Fish and Wildlife Service listed polar bears as ‘threatened’ under the Endangered Species Act, a status equivalent to the IUCN category of ‘vulnerable.’⁷⁴ This was the first time that a *predicted* threat based on computer models had been accepted under the terms of the Act as evidence for a ‘threatened’ listing.⁷⁵ Even though the USA possessed the smallest proportion of the world’s polar bear habitat, the Act pronounced a global endangerment finding. Supported by eight internal government reports commissioned by the US Fish and Wildlife Service and prepared by the US Geological Survey rather than peer-reviewed academic papers,⁷⁶ the justification for this listing hinged on what are called ‘Bayesian Network’ model results. The models relied upon the opinions of a single expert regarding how polar bears might respond to predicted sea ice changes.⁷⁷ The same complex Bayesian Network model approach was recently used to assess walrus responses to predicted sea ice declines, using four expert opinions.⁷⁸ However, the use of such complex but data-poor Bayesian Network models has been strongly criticized for this purpose,⁷⁹ a point that will be discussed in more detail below.

The 2007 polar bear model has since been revised to include the expert opinions of four additional biologists,⁸⁰ but still does not include any population size estimates, any discussion of naturally occurring variations in population, or changes in polar bear health due to naturally occurring shifts in sea-ice conditions, particularly in the critical spring season. The complex ‘second generation’ model produced in 2014 by Atwood and colleagues assumes the only sea ice change that ‘threatens’ polar bear health or population size is the predicted decline in summer ice extent blamed on human-caused global warming. The well-documented variations in spring ice thickness in the Southern Beaufort, and their associated repercussions on seal and polar bear populations, have been glossed over in favor of spurious correlations with summer-ice declines (Fig. 5).

The focus of American biologists on opinion-heavy but data-light Bayesian Network models, based on the fallacy that sea ice is a stable habitat (see Section 2), has led to a peculiar international conservation bias: the USA, alone amongst all Arctic nations, has listed bearded seals, ringed seals, and spotted seals as ‘threatened’ based on predicted sea ice declines due to global warming.⁸¹ A similar listing for the Pacific walrus is pending.⁸² However, a court-ordered review of the bearded seal ESA listing is underway⁸³ and a petition

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to list the Pacific ribbon seal under the same 'future threats' criteria was rejected.⁸⁴ The USA has been uniquely aggressive amongst Arctic nations in assigning 'threatened' status to Arctic seals based on predicted population declines blamed on human-caused global warming. Most other countries, as well as the IUCN, list Arctic seals as either being of 'least concern' or have not assessed them at all.⁸⁵

There are indications that this situation may change in the next few years, at least for the IUCN Red List status of polar bears. The first-generation predictive model used to support the US listing of polar bears as 'threatened'⁸⁶ recently came under heavy criticism from the chairman of the IUCN Standards and Petitions subcommittee, a biological modeling expert.⁸⁷ Almost certainly because of those concerns, the next IUCN polar bear assessment, due in June 2015,⁸⁸ will have to meet strict new IUCN standards for using predicted climate change threats as criteria for recommending a 'vulnerable' or 'endangered' status.⁸⁹ However, none of those new IUCN standards acknowledge that sea ice is a naturally variable habitat over short timescales. That suggests the next IUCN Red List assessment for polar bears will be just as biologically flawed as the American judgment.

A close examination of the models developed to predict future population changes for polar bears, walrus, and ice-dependent seals reveals they all assume the fallacy that under 'natural' conditions – without human-caused global warming – sea ice provides a stable habitat. The models also assume, of course, that populations living in such stable habitats should grow or remain stable. As a consequence, the computer models that project population risks over the next 30–45 years focus on the end of summer,⁹⁰ the only season for which recent declines in sea ice have been pronounced (see Fig. 6). Projected declines in winter ice are insignificant, and those for spring ice are generally slight.⁹¹ For example, Amstrup et al. (2007:9) stated:

...all GCMs project extensive winter sea ice through the end of the 21st century in most ecoregions (Durner et al. 2009).⁹²

Negative effects on populations of short-term natural variations in spring sea ice or spring snow cover on ice have been entirely ignored in these predictions and the focus, both in academic reports and media stories, has been on summer ice extent. *More disturbing is that population declines that were clearly caused by thick sea ice conditions in spring are now blamed on summer sea-ice declines.* I repeat: population declines that were clearly caused by thick sea ice conditions in spring are now blamed on summer sea ice declines. These claims are based on spurious statistical correlations, and are used as 'evidence' that the predicted declines of sea ice in the future will have more pronounced effects.

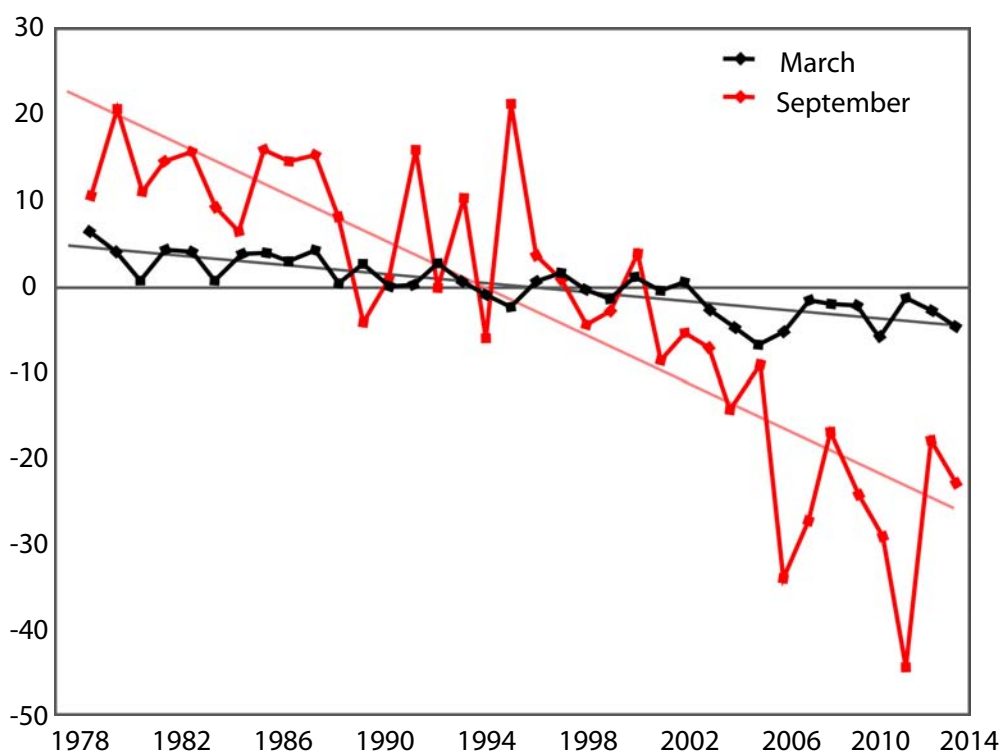


Figure 6: September and March sea-ice declines

Source: NOAA, Arctic Report Card 2014.

4 Consequences of recent sea ice declines in summer

Surprisingly, negative changes to polar bear and ringed seal populations in response to summer sea-ice declines since 2006 have so far not materialized, despite many confident pronouncements based on expert opinion.⁹³ Unfortunately, the Bayesian models that were published in 2007 to support the ESA ‘threatened’ listing generated only ‘probabilities of extinction’ at 2045, 2075, and 2100. These dates were too far in the future, and the concept too mathematically vague, to allow the models to be tested against observations.⁹⁴ The few marked population declines that have been documented since the 1980s, such as in the Southern Beaufort and Western Hudson Bay, were actually associated with short-term episodes of thick spring ice and/or low spring snow depth rather than long-term declines in summer ice coverage. Only one incident of summer sea ice decline – the early breakup of sea ice in Western Hudson Bay in 2003 – was clearly associated with a documented drop in polar bear

numbers, although the decline was small compared to earlier ones associated with variable spring habitat conditions.

Contrary to predictions, reduced summer ice in the Chukchi Sea in the 21st century has proven to be a huge benefit to ringed seals⁹⁵ because they do most of their feeding during the ice-free season: more food for ringed seals in summer has meant more pups the following spring for hungry polar bears. Similarly, marked increases in the ice-free period in the southern Davis Strait⁹⁶ have been offset by abundant harp seal in the spring – so much so that the population has increased despite dramatic summer sea ice declines.⁹⁷ Most recently, reports on field work into 2013 suggests that Southern Beaufort polar bear populations have not been negatively affected by the remarkable decline of sea ice in late summer of 2012 (Fig. 6). The western Arctic was particularly severely affected in 2012, and saw the highest number of ice-free days since 1987 (Fig. 5).⁹⁸ Reduced summer ice has apparently not been accompanied by reduced spring snow depth over sea ice in any region, as biologists expected⁹⁹ – no such snow depth declines have been reported.

While it is true that there have been moderate increases in the length of the ice-free season in regions of the Arctic where the ice usually melts completely in the summer – for example Hudson Bay and the Davis Strait – this has so far changed gradually and polar bear populations are either stable or increasing.¹⁰⁰ The most recent research calculated breakup dates in relation to ice-cover levels corresponding to when polar bears actually left the ice in summer and returned to it in the fall, rather than an arbitrary 50% cut-off. It found that breakup dates for Western Hudson Bay over the last 20 years have so far had little or no impact on the critical feeding period. In other words, breakup has so far not come before mid-June, which means most bears have come on-shore in early July or later, although some individuals may come ashore before then.¹⁰¹ And as noted previously, it is apparent that no matter where polar bears spend the summer – on shore or on the ice – they generally consume little during the open-water season.¹⁰² Bears that have hunted successfully between March and June under suitable spring conditions will have stored enough fat to see them through a summer fast of 2–6 months, whether they spend that time on land or out on the sea ice.

5 Conclusions

The notion that declines in summer sea ice are the most serious threat to Arctic marine mammals is based on the biological fallacy that under natural conditions Arctic sea ice is a stable habitat and leads to stable or increasing populations, and that summer sea ice stability is necessary to prevent extinctions.

This flawed ecological concept has led to the present pessimistic attitude of most polar bear biologists and to the formal, legal listing by the USA of polar bears, walrus, ringed seals, bearded seals and spotted seals as 'threatened'. The sea ice constancy fallacy was taught to leading polar bear experts years ago and accepted as fact, but to their credit – even though they believed sea ice *should* be a stable habitat, even over short timescales – they spent years collecting evidence to the contrary. Eventually, the concept of human-caused global warming provided a rationale for deferring to what they had been taught over what they had personally discovered, and they convinced themselves that reduced summer ice coverage could potentially pose as large a threat to polar bear and Arctic seal survival as reckless overhunting.

However, there is well documented evidence that natural changes in sea ice during the critical spring period over the last 60 years have been profound and resulted in marked declines followed by marked increases in polar bear and Arctic seal numbers. Rather than climate change leading to extinction or near-extinction of these species, they appear to persist well, despite such environmental variation, even during the critical spring period. Historical documents and paleoclimatic research suggests similar changes have occurred for at least the last few hundred years.

Since the 1960s, thick spring ice has been more prevalent, and affected more Arctic regions, than scarce summer ice. Most important, since the thick ice phenomenon is caused by natural forces rather than presumed man-made ones – and will almost certainly continue into the future – conservation policies currently in place cannot prevent populations from fluctuating. Like other temperate marine mammal species, such as the humpback whale,¹⁰³ polar bears are thriving in a world that has finally protected them from relentless slaughter. Their populations are now free to respond to natural variations in sea-ice habitat and food supply, as they have done for hundreds of thousands of years. Pretending that natural fluctuations in populations don't happen in the Arctic won't prevent them from happening.

The fallacy of sea ice stability is biologically unsupportable, and means that predictive population models based on this premise are not using the best available science. Some would argue they are not based on accepted scientific practice at all. The IUCN and the US government, in accepting predicted sea-ice changes as valid threats to species survival, have allowed a myth to masquerade as 21st century science. A model built on a flawed premise is itself flawed. Until such time as predictive models are modified to reflect the reality of Arctic sea ice as a naturally variable habitat – and populations of polar bears and their prey acknowledged as highly variable over time due to natural habitat changes in spring – the notion that the population impact of one particular kind of habitat change ('human-caused' summer sea-ice cov-

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erage) can be predicted within a biologically meaningful time frame must be abandoned. Given what we now know about the animals and their naturally changing habitat, it is time to concede that data do not support predictions that polar bears, walrus, and Arctic seals are threatened with extinction due to habitat instability.

Notes

1. <http://www.forbes.com/sites/peterferrara/2013/04/28/the-disgraceful-episode-of-lysenkoism-brings-us-global-warming-theory/2/>
2. Michael Crichton. 2004. *State of Fear* (Appendix I Why politicized science is dangerous). Harper Collins, New York.
3. US Fish and Wildlife Service 2008; Schliebe et al. 2008.
4. For example Martinka 1967; Anthony 1976.
5. <http://www.scientificamerican.com/article/polar-bears-threatened/> See also Adler 2008; Akçakaya et al. 2006.
6. http://en.wikipedia.org/wiki/R/K\protect_selection\protect_theory.
7. Reznick et al. 2002: 1511.
8. Pianka 1970.
9. Derocher et al. 2004: 163; see also Vongraven et al. 2012: 2, 17; Laidre et al. 2008.
10. <http://www.danielbbotkin.com/2007/03/18/360-degrees-restoring-nature-in-a-naturally-changing-world/>. See also Wu and Loucks 1995.
11. See also Botkin's short video summary of his book, *The Moon in the Nautilus Shell* <https://www.youtube.com/watch?v=SyPKoJY23xU>.
12. Botkin 1995: 67–79.
13. For example Huggett 2004: 177.
14. Gillson and Hoffman 2007; Hambler et al. 2005; Reimers 1982; Martinka 1967. <http://yellowstoneinsider.com/2013/06/11/study-drought-not-wolves-impact-yellowstone-elk-reproductive-rates/>.
15. <http://polarbears-science.com/2015/04/21/polar-bears-barely-survived-the-sea-ice-habitat-changes-of-the-last-ice-age-evidence-suggests/>. See also Cronin et al. 2014; Polyak et al. 2010.
16. <http://www.bbc.com/earth/story/20141107-can-polar-bears-be-saved>.
17. Amstrup et al., 2007: 56; Amstrup et al. 2008, 2010; Amstrup 2011; Durner et al. 2009.
18. Hunter et al. 2007.
19. A 'good' ice year was defined as <125 days ice-free in 'preferred polar bear habitat' (defined as >50% ice coverage over the continental shelf, <300 m in depth), while 'bad' ice years were those with >125 days ice-free in preferred habitat.
20. Stirling et al. 2007: 12.
21. US Fish & Wildlife Service 2008: 28239.
22. <http://polarbears-science.com/2015/04/01/polar-bear-consumption-of-terrestrial-foods-new-paper-misses-the-point/>. See also Amstrup et al. 2007; Durner et al. 2009; Oakley et al. 2012; Wang et al. 2012.
23. Gillson and Hoffman 2007; Reznick et al. 2002: 1518; Wu and Loucks 1995.

24. Arctic Winter, January–March; Spring, April–June (Pilfold et al. 2015, in press).
25. Stirling and Lunn 1997: 176.
26. <http://polarbearsience.com/2014/11/18/s-beaufort-polar-bears-largely-recovered-from-known-2004-2006-decline-says-new-study/>. Review of Bromaghin et al. 2015; see also Polar Bear News 2013; Stirling 2002: 68.
27. Stirling et al. 1980: 52. See also <http://polarbearsience.com/2013/02/21/where-were-the-appeals-to-feed-starving-polar-bears-in-1974/>.
28. Stirling et al. 1982: 21.
29. Stirling et al. 2008: 21; see also Smith 1987; Harwood et al. 2000, 2012.
30. Stirling and Lunn 1997: 177.
31. Burns 1975: 77.
32. Bromaghin et al. 2014: 647.
33. Harwood et al. 2000, 2012.
34. Bromaghin et al. 2013.
35. Bromaghin et al. 2014.
36. Harwood et al. 2012.
37. Stirling and Lunn 1997: 176; Stirling 2002:68. See also (a) <http://polarbearsience.com/2014/11/19/polar-bear-researchers-knew-s-beaufort-population-continued-to-increase-up-to-2012/> (b) http://polarbearsience.files.wordpress.com/2014/03/miles-et-al-2014-sea-ice_amo_fig-2a-and-e.jpg and (c) <http://polarbearsience.com/2014/12/17/recent-s-beaufort-polar-bear-count-was-a-cherry-picked-result-new-evidence/>.
38. Stirling 2002; Stirling and Lunn 1997: 174,176.
39. Stirling and Lunn 1997: 176.
40. Stirling 2002; Stirling et al. 2008.
41. Stirling and Derocher, 2012; Peacock et al. 2010; IUCN PBSG status table <http://pbsg.npolar.no/en/status/populations/southern-beaufort-sea.html> [24 January 2015] and <http://polarbearsience.com/2013/07/04/great-polar-bear-red-herring-in-the-southern-beaufort/>.
42. Pilfold et al. 2015, in press. Their citation of Bromaghin et al (2014) was to an in-press paper, which has now appeared as Bromaghin et al. (2015). See bibliography.
43. Chambellant et al. 2012; Stirling and Lunn 1997.
44. Chambellant et al. 2012: 275.
45. Wyatt and Curry 2014.
46. Ferguson et al. 2005: 127 (Fig. 2). See also <http://polarbearsience.com/2015/05/14/snow-depth-over-spring-sea-ice-affects-polar-bear-feeding-success-and-ringed-seal-survival/>.
47. Derocher and Stirling 1996: 1247.

48. Ferguson et al. 2005: 127–128.
49. Regarding the final population estimate for 2011, Lunn et al. (2013:18) noted that they calculated a new estimate for 2004 using the same method they used for 2011, which gave 742 (range 630–872) for 2004 and 806 (653–984) for 2011, indicating no decline since the last estimate was calculated in 2004 by Regehr et al. (2007b).
50. According to Stirling et al. 2004 (Fig. 3, 'Area 5'), breakup in WHB near Churchill was also quite early in 1976 (ca. June 16) and in again in 1977 (ca. June 9) but number of bears counted did not show an associated decline (Fig. 4b): the lowest number of bears counted after 1975 occurred in 1979.
51. Lunn et al. 2013: 15, 21
52. Vibe 1965: 17–24.
53. <http://polarbears.com/2014/04/14/polar-bears-move-around-as-sea-ice-habitat-changes-this-is-what-resilience-looks-like/>.
54. (a) <http://seagrant.uaf.edu/conferences/2013/wakefield-arctic-ecosystems/program.php> (b) <http://nsidc.org/arcticseaicenews/2014/03/in-the-arctic-winters-might-doesnt-have-much-bite/>.
55. Miles et al. 2014.
56. (a) <http://onlinelibrary.wiley.com/doi/10.1002/2013GL058084/abstract> and (b) <http://mosj.npolar.no/en/fauna/marine/indicators/polar-bear.html>.
57. Miles et al. 2014: 468.
58. Ambaum et al. 2001.
59. Derocher (2005: 273).
60. Hammill and Smith 1991: 125.
61. Hammill and Smith 1991: 132.
62. Stirling and Derocher 2012: 2698; Stirling and Øritsland 1995. See also Stirling 1974.
63. Derocher et al. 2002; Hammill and Smith 1991; Stirling 1974; Stirling and Øritsland 1995.
64. (a) <http://pbsg.npolar.no/en/meetings/> (b) <http://polarbears.com/2015/02/09/polar-bears-out-on-the-sea-ice-eat-few-seals-in-summer-and-early-fall/>.
65. <http://iwc.int/history-and-purpose>. The International Whaling Commission was established in 1946.
66. <http://polarbears.com/2012/09/20/the-slaughter-of-polar-bears-that-rarely-gets-mentioned-ca-1890-1930/>.
67. Canada, Russia, Denmark for Greenland, Norway, and the United States of America.
68. <http://pbsg.npolar.no/en/issues/conservation/redlist.html>.
69. <http://polarbears.com/2012/12/26/did-the-pbsg-game-the-polar-bear-listing-process/>.

70. <http://bit.ly/1LNrcIP>.
71. Hassol 2004; <http://www.iucnredlist.org/details/full/22823/0>.
72. Aars et al. 2006: 31.
73. (a) <http://pbsg.npolar.no/en/issues/conservation/redlist.html> (b) <http://www.iucnredlist.org/initiatives/amphibians/analysis/2008-update>.
74. US Fish and Wildlife Service 2008.
75. <http://www.scientificamerican.com/article/polar-bears-threatened/>.
76. http://www.usgs.gov/newsroom/special/polar_bears/.
77. <http://polarbearsience.com/2013/09/08/how-and-why-great-news-about-chukchi-polar-bears-has-been-suppressed/>.
78. Jay et al. 2011: 1068; Oakley et al. 2012: 4; <http://polarbearsience.com/2015/03/30/us-biologists-used-same-flawed-models-for-listing-walrus-and-polar-bears-as-threatened/>.
79. Akçakaya et al. 2006; http://pbsg.npolar.no/en/meetings/stories/17th_meeting.html See also Karl et al. 2012.
80. Atwood et al. 2014.
81. US Fish and Wildlife Service 2012a and 2012b.
82. US Fish and Wildlife Service 2011.
83. <http://www.adn.com/article/20140725/judge-rules-beringia-bearded-seals-improperly-listed-threatened>.
84. <https://www.animallaw.info/case/center-biological-diversity-v-lubchenco>.
85. <http://polarbearsience.com/2014/12/31/threatened-arctic-species-comparison-shows-usa-most-assertive-about-global-warming/>.
86. Amstrup et al. 2008 http://alaska.usgs.gov/science/biology/polar_bears/forecasting.html.
87. <http://polarbearsience.com/2014/11/29/amstrup-knows-his-polar-bear-predictions-are-flawed-but-continues-to-promote-them/>.
88. <http://polarbearsience.com/2015/01/01/iucn-polar-bear-specialist-group-out-lived-its-usefulness-20-years-ago/>.
89. IUCN Standards and Petitions Subcommittee 2014.
90. Overland and Wang 2013; Swart et al. 2015; <http://www.thegwpf.com/arctic-ice-decline-a-new-pause/>.
91. See Durner et al. 2009: 44 for a general Arctic projection and Wang et al. 2012 regarding Chukchi Sea projections.
92. Steven Amstrup was the USGS biologist whose 'expert opinion' was used in the Bayesian Network models; he is employed as 'chief scientist' at the conservation organization Polar Bears International.
93. <http://polarbearsience.com/2015/01/12/if-summer-ice-was-critical-for-s-beaufort-polar-bears-2012-would-have-decimated-them/> See also Stirling and Derocher 2012; Obbard et al. 2010; Laidre et al. 2008.

94. Amstrup et al. 2007:92; Durner et al. 2009.
95. Crawford and Quakenbush 2013; Rode et al. 2014b; Rode et al. 2013. See also <http://polarbears.com/2013/07/07/chukchi-polar-bear-status-contradicts-the-message-new-details/> and <http://polarbears.com/2013/09/08/how-and-why-great-news-about-chukchi-polar-bears-has-been-suppressed/>.
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1	Andrew Turnbull	The Really Inconvenient Truth or 'It Ain't Necessarily So'
2	Philipp Mueller	The Greening of the Sahel
3	William Happer	The Truth about Greenhouse Gases
4	Gordon Hughes	The Impact of Wind Power on Household Energy Bills
5	Matt Ridley	The Perils of Confirmation Bias
6	Philipp Mueller	The Abundance of Fossil Fuels
7	Indur Goklany	Is Global Warming the Number One Threat to Humanity?
8	Andrew Montford	The Climate Model and the Public Purse
9	Philipp Mueller	UK Energy Security: Myth and Reality
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11	Susan Crockford	On the Beach
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