STATE OF THE POLAR BEAR REPORT 2019

Susan J. Crockford

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Foreword

From 1972 until 2010,[1] The Polar Bear Specialist Group (PBSG) of the International Union for the Conservation of Nature (IUCN) published comprehensive status reports every four years or so, as proceedings of their official meetings, making them available in electronic format. Until 2018 – a full eight years after its last report – the PBSG had disseminated information only on its website, updated (without announcement) at its discretion. In April 2018, the PBSG finally produced a standalone proceedings document from its 2016 meeting,[2] although most people would have been unaware that this document existed unless they visited the PBSG website.

This *State of the Polar Bear Report* is intended to provide a yearly update of the kind of content available in those occasional PBSG meeting reports, albeit with more critical commentary regarding some of the inconsistencies and sources of bias present in the corpus of reports and papers. It is a summary of the state of polar bears in the Arctic since 2014, relative to historical records, based on a review of the recent and historical scientific literature. It is intended for a wide audience, including scientists, teachers, students, decision-makers and the general public interested in polar bears and Arctic ecology.

About the author

Dr Susan Crockford is an evolutionary biologist and has been working for 35 years in archaeozoology, paleozoology and forensic zoology.[3] She is a former adjunct professor at the University of Victoria, British Columbia and works full time for a private consulting company she co-owns (Pacific Identifications Inc). She is the author of *Rhythms of Life: Thyroid Hormone and the Origin of Species*, *Eaten: A Novel* (a polar bear attack thriller), *Polar Bear Facts and Myths* (for ages seven and up, also available in French, German, Dutch, and Norwegian), *Polar Bears Have Big Feet* (for preschoolers), and the fully referenced *Polar Bears: Outstanding Survivors of Climate Change* and *The Polar Bear Catastrophe That Never Happened,*[4] as well as a scientific paper on polar bear conservation status.[5] She has authored several earlier briefing papers, reports, and videos for GWPF on polar bear and walrus ecology and conservation.[6] Susan Crockford blogs at www.polarbearscience.com.

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Executive summary

- Reports have yet to be published for polar bear population surveys of M'Clintock Channel and Viscount Melville (completed 2016), Southern Beaufort and Gulf of Boothia (completed 2017) and Davis Strait (completed 2018), yet all were promised for 2019 or sooner. These may show increases in polar bear numbers or they may show stable or even declining numbers – but we won't know until we see the results.
- At present, the official IUCN Red List global population estimate for the polar bear (2015) is 22,000–31,000 (about 26,000) but surveys conducted since then would raise that average to about 29,500.
- Despite having to deal with the greatest change in summer sea ice habitat since 1979 of all Arctic regions, according to Norwegian biologists polar bears in the Svalbard area of the Barents Sea showed few negative impacts from the low sea ice years of 2016 through 2019.
- Despite repeated claims that the Southern Beaufort subpopulation is declining and nutritionally stressed, a summer survey of the coast of Alaska in 2019 documented 31 fat healthy polar bears onshore in July, compared to only three in 2017, when sea ice retreat had been similarly early.
- Contrary to expectations, in 2019 freeze-up of sea ice in Western Hudson Bay came as early in the autumn as it did in the 1980s (for the third year in a row) and sea ice breakup in spring was like the 1980s as well, with the result that polar bears onshore were in excellent condition.
- If the public are to take seriously repeated claims of harm to polar bear health and survival due to climate change, data collected since 2004 on cub survival and weights of female polar bears in Western Hudson Bay must be made available: it has now been more than 25 years since the last publication of such data, and polar bear specialists continue to cite decades-old figures to support their statements that lack of sea ice is causing declines in body condition and population size.
- Since polar bear researchers acknowledge that there has been no negative trend in either freeze-up or breakup dates for sea ice in Western Hudson Bay since at least 2001, the failure to report current data on cub survival and weights of female bears suggests that body condition and cub survival have not declined over the last two decades as claimed.
- Two separate incidents at opposite ends of the Russian Arctic at the beginning and the end of 2019 made this the year of the polar bear 'invasion'. Belushya Guba in the Barents Sea over the winter of 2018/2019 and Ryrkaypiy, Chukotka in December 2019 were each besieged by more than 50 bears, which terrified local residents. Although tragedy was ultimately averted, this is likely to be an on-going problem for Arctic settlements in the future: not because there is not enough sea ice but because there are now so many polar bears roaming Arctic coastlines.

1. Introduction

The US Geological Survey estimated the global population of polar bears at 24,500 in 2005.[7] In 2015, the IUCN Polar Bear Specialist Group estimated the population at 26,000 (range 22,000–31,000)[8] but additional surveys published in 2015–2017 brought the total to near 28,500.[9] However, data published in 2018 brought that number to almost 29,500,[10] with a relatively wide margin of error, and arguably as high as 39,000.[11] This is the highest global estimate since the bears were protected by international treaty in 1973.[12] While potential measurement error, lack of recent surveys, conflicting methodologies, and unpublished data mean it can only be said that the global population has likely been stable since 2005 (but may have increased slightly to moderately), it is far from the precipitous decline polar bear experts expected given summer sea ice levels as low as they have been in recent years.[13]

Between 2007 and 2015, summer sea ice on average dropped about 38% from 1979 levels, an abrupt decline to within measurement error of the reduced coverage expected to occur by mid-century (Figure 1).[14] Christine Hunter and colleagues[15] proclaimed in 2007 that such reduced summer sea ice by 2050, if present for eight out of ten years (or 4 out of 5 years), would generate a massive drop in polar bear numbers: ten vulnerable subpopulations out of 19 would be extirpated, leaving fewer than 10,000 animals worldwide (a 67% decline). Even though summer sea ice from 2016–2019 has continued this pattern, recent research shows such a decline in polar bear abundance has not occurred. This indicates summer sea ice levels are not as critical to polar bear

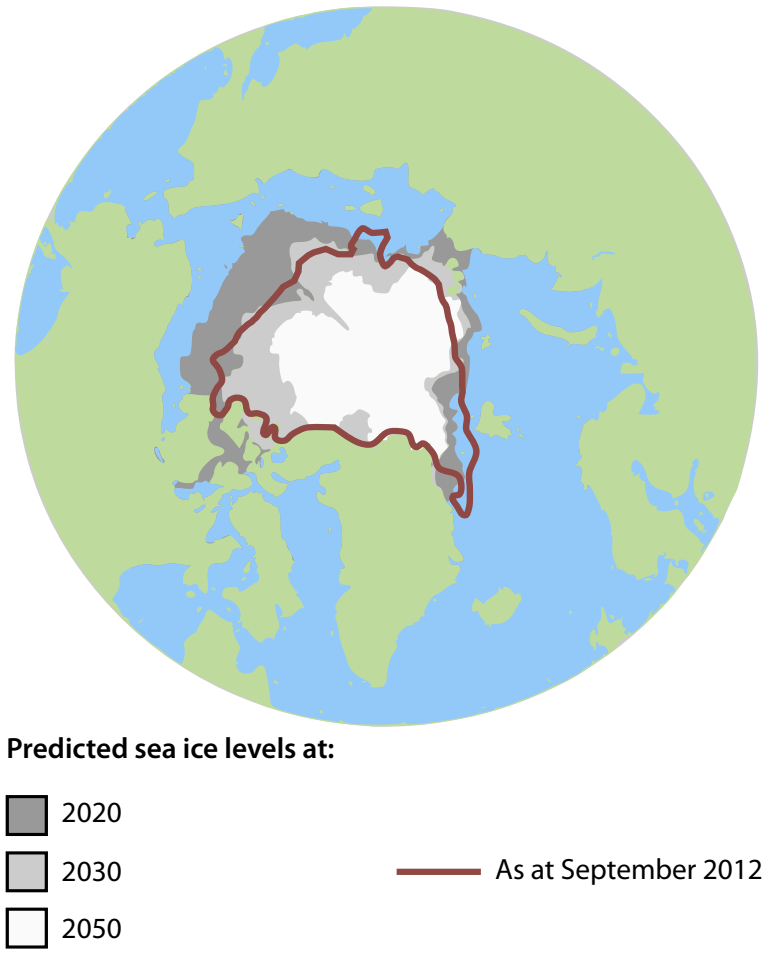


Figure 1: Predicted sea ice changes versus observations.

Sea ice predictions, based on 2004 data,[438] were used in 2007 to predict a 67% decline in global polar bear numbers. The brown line indicates the approximate situation at 10 September 2012, an example of sea ice extent experienced since 2007.[439]

survival as USGS biologists assumed.[16]

Despite marked declines in summer sea ice, Chukchi Sea polar bears continue to thrive, and reports from a survey of Wrangel Island bears in the fall of 2019 showed bears were abundant, healthy and reproducing well, as bears in the US portion were in 2016.[17] Similarly, according to Jon Aars, a senior Norwegian biologist, polar bears in the Svalbard area show no impact of the particularly low sea ice years of 2016–2018, and 2019 has proven no different.[18]

2. Conservation status

The International Union for the Conservation of Nature (IUCN), in their 2015 Red List assessment, again listed the polar bear as 'vulnerable' to extinction, just as it did in 2006.[19] Similarly, in 2016, the US Fish and Wildlife Service upheld its 2008 conclusion that polar bears were 'threatened' with extinction under the US Endangered Species Act (ESA).[20] In both of these instances, polar bear conservation status is based on computer-modelled future declines predicted to exceed standard threshold levels (i.e. a population decline of 30% or more expected within three generations), not observed declines.

Polar bears currently have a relatively large population size, and their historical range has not diminished due to habitat loss since 1979. If assessed on current observations, the polar bear would qualify for a status of 'least concern' in the IUCN Red List in 2015 (as they would have done in 2006) and the ESA would not have included polar bears on its list of threatened and endangered species in 2008.[21] Thus, concerns about the conservation status of polar bears are all about 'the potential response of the global population of polar bears to projected sea ice declines'[22], not their current population size.

The polar bear was the first species assessed by the IUCN and the ESA to use predicted population declines based on climate models, although all other species (with only a few recent exceptions) are assessed based on population declines already observed. As a consequence, the public and the media often logically assume that polar bear numbers must be currently declining because they have been listed as 'threatened' or 'vulnerable': this would be true for all other species listed by the IUCN or the ESA, with only a few exceptions. This confusion is understandable because it appears contradictory. But the peculiar way in which polar bear conservation status has been defined by these organizations means it is entirely correct to state that polar bears are currently thriving, and to insist that such a statement is not at odds with a conservation status based on possible *future* declines in population size.

In contrast to the IUCN and the ESA, in 2018 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) decided to continue to list the polar bear as a species of 'special concern', as it has done since 1991, rather than upgrade the status to 'threatened.'[23] Since roughly two thirds of the world's thriving polar bear population lives in Canada, the recent COSEWIC decision (full report published June 2019) means that most of the species is still managed with an overall attitude of cautious optimism. This is a refreshing spark of rationality in the world of polar bear conservation assessment.

3. Population size

Global

Despite the fact that one of the primary objectives of the PBSG, when appointed in 1973, was to generate a global population estimate[24], this portion of their mandate has proven particularly difficult to attain. Despite more than 50 years of dedicated research, several subpopulations have never been comprehensively surveyed for population abundance (East Greenland, the Canadian portion of the Arctic Basin, Laptev Sea) and several others have had only one survey conducted over that time period (Chukchi Sea, Kara Sea, the eastern portion of the Barents Sea, Viscount Mel-

ville, Lancaster Sound, M'Clintock Channel, and Norwegian Bay).

In 1993, the PBSG estimated polar bear abundance as about 21,470–28,370 (rounded to 22,000–27,000 in 1997). This number was 'adjusted' to 21,000–25,000 in 2001 and 'further simplified' to 20,000–25,000 in 2005; the apparent decline since 1993 comes from the fact that some estimates used prior to 2001 were deemed to be not scientific enough and were dropped from the totals.[25] In contrast, in 2005 the US Geological Survey put the global population of polar bears at 24,500, a mid-point estimate used to support the US Fish and Wildlife Service Endangered Species Act listing in 2008.[26]

In 2014, the PBSG mid-point estimate was listed as 'approximately 25,000' (no range given), which was still the figure listed on their website at 15 January 2020.[27] This is rather odd, since the 2015 IUCN Red List assessment, written by PBSG members,[28] used a mid-point estimate of 26,000 (but not 26,500, the true mid-point of the stated 22,000–31,000 range, apparently due to potential estimate errors). In September 2019 a new status assessment was added to the PBSG website as a downloadable document (along with a new status table) and that document gives the 22,000–31,000 global estimate. However, the PBSG webpage that discusses 'global polar bear population estimates' still has the very much out-of-date information provided in 2014: readers would not find the updated material unless they clicked the link to the polar bear status tables.[29]

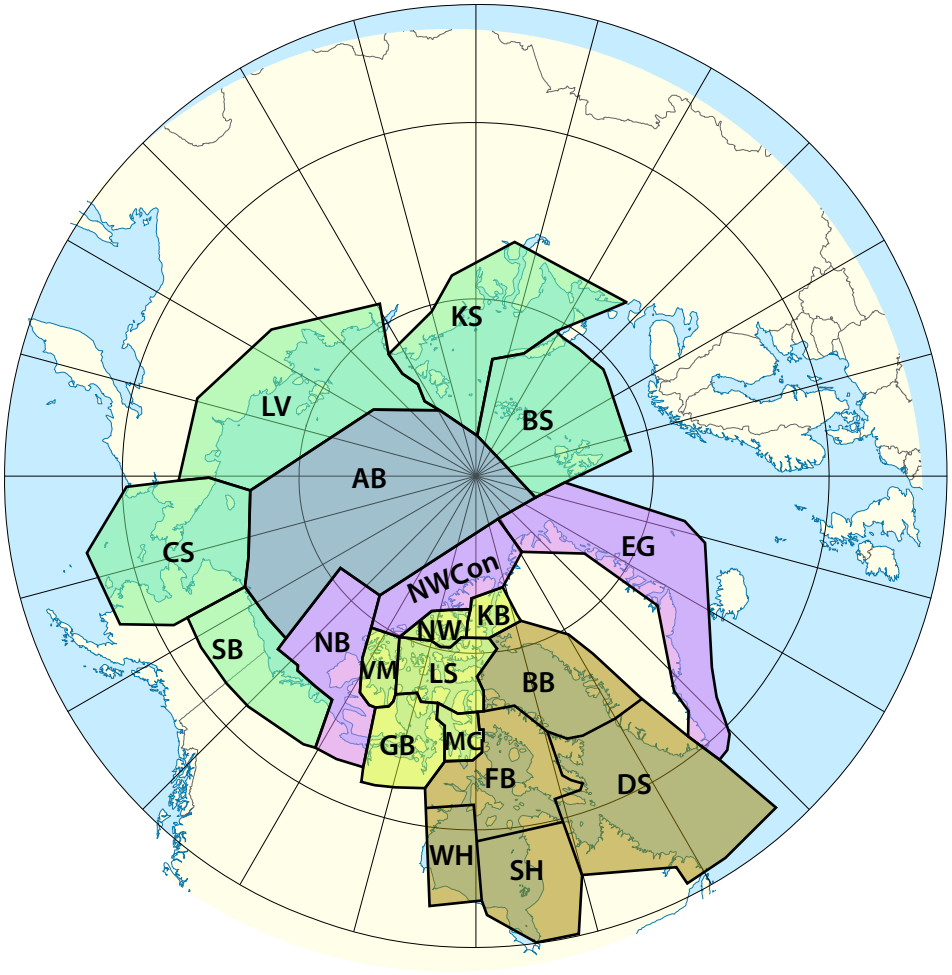
That said, additional survey results published since the 2015 Red List assessment was prepared brought the mid-point total at 2015 to near 28,500, with a similar wide margin of error (see Section 4 for more detail). However, in 2018, new estimates for Southern Hudson Bay and the Chukchi Sea, based on surveys completed in 2016, added about 1,000 to that total. Moreover, surveys of the Gulf of Boothia, Viscount Melville, M'Clintock Channel, the Southern Beaufort and Davis Strait were completed by 2019 and although the results have not yet been published, their updated counts would likely put that global mid-point estimate above 30,000. While there is a wide margin of error attached to the most recent mid-point estimate of 29,500, this is a far cry from the 7,493 (6,660–8,325) bears we were assured would be all that would remain[30] given the sea ice levels that have prevailed since 2007.[31] It has been argued that a plausible and scientifically defensible 'best-guess' estimate at 2018, extrapolated from 'known' to 'unknowns' subpopulations within sea ice ecoregions (see next section), would be about 39,000 (range 26,000–58,000), although a more pessimistic best-guess based on a greater variety of ecosystem traits (including prey diversity and sea ice cover) came out much lower, at 23,315 (range 15,972–31,212).[32]

Subpopulations by ecoregion

In 2007, the US Geological Survey defined four Arctic sea-ice 'ecoregions' as part of their current and future assessments of polar bear population size and health (Figure 2).

- The 'Seasonal' ecoregion represents all the subpopulation regions where sea ice melts completely during the summer, stranding polar bears onshore.
- The 'Divergent' ecoregion includes all subpopulation regions where sea ice recedes from the coast into the Arctic Basin during the summer, leaving bears the option of staying onshore or remaining with the sea ice.
- The 'Convergent' ecoregion is the subpopulation regions where ice formed elsewhere drifts towards shore all year long.
- The 'Archipelago' ecoregion represents subpopulations in the Canadian Arctic archipelago.

The ecoregion concept now appears to have been accepted as a useful assessment methodology.[33] However, it is important to note that the inclusion of the Southern Beaufort (SB) in the 'Divergent' ecoregion is potentially misleading. Thick sea ice conditions occur in the SB every ten years or so and persist for 2–3 years. They have a severe impact on polar bear health and survival, and thus population size. The most devastating and well-documented thick spring ice events occurred in 1974–1976 and 2004–2006,[34] with evidence of perhaps less severe events in the early 1960s,



AB	Arctic Basin	**FB**	Foxe Basin	**MC**	M'Clintock Channel		Seasonal
BB	Baffin Bay	**GB**	Gulf of Boothia	**NB**	Northern Beaufort		Archipelago
BS	Barents Sea	**KB**	Kane Basin	**NW**	Norwegian Bay		Convergent
CS	Chukchi Sea	**KS**	Kara Sea	**SB**	Southern Beaufort		Divergent
DS	Davis Strait	**LV**	Laptev Sea	**SH**	Southern Hudson Bay		
EG	East Greenland	**LS**	Lancaster Sound	**VM**	Viscount Melville		
				WH	Western Hudson Bay		

Figure 2: The four Arctic sea ice ecoregions.

The Arctic Basin (AB) is not considered to be a sea ice ecoregion. The Convergent region 'NWCon' (also known as 'Queen Elizabeth – Convergent') is not a recognized polar bear subpopulation.

mid-1980s, early 1990s, and the mid-2010s.[35] This makes the SB region almost unique, although something similar happens on a less regular basis off Greenland and in Hudson Bay due to thick ice and/or changes in snow depth over ice.[36] SB might therefore be better thought of as an ecoregion of its own.

It should also be noted that Canadian polar bear authorities (i.e. COSEWIC) have recently changed the boundary between the Southern and Northern Beaufort regions. This is meant to make management easier, but if the changes are adopted by the PBSG (and proceedings from their 2016 meeting indicated this has been only provisionally done),[37] accurately tracking long-term changes in population size and the effects of thick spring ice events could become extremely difficult. It has been proposed (and accepted by COSEWIC) to resolve this by taking about 20% of bear numbers (at 2006) away from SB and adding them to the NB subpopulation.[38]

Baffin Bay – Seasonal

A comprehensive survey of Baffin Bay (BB) polar bears undertaken in 1993–1997[39] generated an estimate of 2,074±226. The government report for the latest survey, completed in 2013, confirmed what local Inuit and some biologists had been saying for years: contrary to the assertions of PBSG scientists that bear numbers have been affected by over-hunting, the subpopulation has not declined since 1997.[40] BB bear abundance in 2013 was found to be 'considerably larger' than the previous estimate, but the authors assert that differences in sampling design preclude direct comparison between the two. Still, the polar bear subpopulation estimate at 2013 for BB was 2,826±767 (95% CI = 2,059–3,593), a 36% increase over 1997 (2,074; 95% CI = 1,553–2,595). While all other metrics of life history and habitat were subject to statistical significance testing,[41] the abundance estimate was not, because of the claimed methodological issues (a position refuted by Mitchell Taylor, the author of the 1997 report).[42] In 2019, the PBSG considered the BB trend 'data deficient' despite the recent survey, but aboriginal traditional knowledge assessed the population in 2018 as 'stable'.[43]

Davis Strait – Seasonal

The Davis Strait (DS) subpopulation include those bears that visit Newfoundland and southern Labrador in the spring. The first population count was completed in the late 1970s, and generated a figure of 726 bears. That figure has been subject to repeated post-hoc adjustments. The first was upwards, to 900.[44] That estimate was then subjectively increased by the PBSG to 1,400 bears and then, at the turn of the millennium, to 1,650 (without additional field surveys) to account for certain biases and assumptions in the original estimate as well as more sightings of bears and an increase in their harp seal prey.[45] A comprehensive survey completed in 2007 generated a new estimate of 2,158 (range 1,833–2,542), a substantial increase over the previous estimates.[46]

The density of Davis Strait bears in 2007 (5.1 bears/1,000 km^2) was found to be higher than other seasonal sea-ice subpopulations, such as Hudson Bay. Karyn Rode and colleagues recorded a slight decline in body condition of DS polar bears between 1977 and 2010, but there was no indication this had affected survival or reproduction.[47] By 2012, the harp seal population had grown even further,[48] providing the potential for a further increase in polar bear numbers; this is probably reflected in the 2018 Environment Canada status assessment as 'likely increasing'.[49] As a consequence, it is highly likely that the actual population size at 2018 (eleven years after the last survey) is well above 2,500. However, the results of recent surveys of both polar bears and harp seals have yet to be made public[50] and the PBSG in 2019 listed DS bears as 'likely stable' rather than increasing.[51]

Foxe Basin – Seasonal

The first survey of Foxe Basin (FB), conducted in 1994, generated an estimate of 2,197 bears (1,677–2,717), but in 2004 this was adjusted by the PBSG to 2,300 bears (1,780–2,820).[52] An aerial survey in 2009–2010 – the first aerial surveys performed in Canada after mark-recapture studies were effectively banned by the Nunavut government – generated an estimate of around 2,580 bears.[53] While the two methods (aerial survey and mark-recapture) are not directly comparable, the population was considered 'stable' by Environment Canada in 2014, as well as by the PBSG in 2014 and 2019, while traditional knowledge considered numbers to be increasing.[54]

Western Hudson Bay – Seasonal

The first comprehensive survey of Western Hudson Bay (WH) for the period 1978–1992 generated a population estimate of 1,000±51, which was adjusted by the PBSG in 1993 to 1,200 to account for areas not surveyed.[55] Regehr and colleagues estimated the abundance in 2004 as 935 (range 794–1,076), a statistically significant decline of 22% from the 1987 count of bears in the same core area of 1,194 (range 1,020–1,368).[56] This result was used as persuasive evidence that polar bears should be listed as 'vulnerable' and 'threatened' (by the IUCN Red List in 2006, and the US Fish and Wildlife Service in 2008, respectively). A mark-recapture study in 2011, again of the core region

only because this was assumed to include all WH bears, generated an estimate of 806 (653–984). This looked like a further decline, but the same year an aerial survey that encompassed the entire subpopulation area generated an estimate of 1,030 (range 754–1,406). This was the figure used by the PBSG in 2016 and 2017, when they concluded that this subpopulation was 'stable.'[57]

Another aerial survey in 2016 generated an estimate of 842 (range 562–1,121).[58] However, because the 2011 and 2016 WH aerial surveys used rather different methods and covered different portions of the region, the authors of the 2016 report emphasized that only two estimates can be reliably compared: for 2011, the partial estimate of 949 (range 618–1280) and for 2016, the estimate of 842 (range 562–1121). This decline between the 2011 and 2016 partial estimates of 11% was not statistically significant.[59] Therefore, it is not scientifically supportable to suggest that the estimate for 2016 of 842 bears represents an 18% decline from the 2011 estimate of 1,030 bears. Moreover, neither of these estimates is statistically different from the estimate of 935 calculated in 2004, which means there is no scientific justification for suggesting the WH population has declined since 2004. Although it continues to be done, it is similarly unsupportable to suggest there has been a 30% decline from the 1987 estimate: the differences in method between the 2016 aerial survey and the 1987 mark-recapture study are simply too great to allow valid comparison.[60]

Claims by polar bear specialists that the body mass of females, survival rates of cubs, and the frequency of triplet litters in fall have all declined since 2004 due to sea ice changes have not been substantiated because no data of this nature have been published.[61] In a late-2018 interview with UK journalist David Rose, WH polar bear researcher Andrew Derocher would only concede that there has been 'a recent period of stability'.[62] But WH polar bears may be doing even better than just holding their own: the Nunavut Government insisted in late 2018 that several indicators point to the conclusion that the WH population has increased in size.[63] However, in 2019 the PBSG listed the WH subpopulation as 'likely decreased'.[64]

Southern Hudson Bay – Seasonal

The first population size assessment for Southern Hudson Bay (SH) was made during 1984–1986, and generated an estimate of 763±323 bears.[65] Some adjustments, re-analyses and new surveys indicated that by 2005 the subpopulation had been stable since the mid-1980s at about 1,000 animals.[66] A subsequent aerial survey in 2011–2012 generated an estimate of 943 bears (range 658–1350), a non-significant change from 2005. It also indicated that the body condition of SH bears had changed very little since the 1980s.[67] The small decline in body condition index found by SH researchers (no raw data provided) correlated only with very late freeze-up dates. Results of a more recent aerial survey, completed in 2016, showed a 17% decline in population size, from 943 to 780 (range 590–1,029), which was not statistically significant.[68] However, something called a 'Monte Carlo simulation' (a technique never used before in polar bear population size estimates, as far as can be determined) was applied '*to better inform managers about the status of the subpopulation*' and since this test determined that the decline could be real, the authors reported an actual drop in abundance for the first time in SH. However, Martyn Obbard and colleagues also conceded that the decline in the percentage of yearling cubs they documented (from 12% in 2011 to 5% in 2016), which indicated low survival of cubs born in 2015, did not correlate with adverse fall or summer sea ice conditions because freeze-up was relatively early in 2015 and breakup was relatively late. They offered no alternative explanation for the poor survival of yearlings, which they noted was similar to that seen for Western Hudson Bay bears the same year. Furthermore, in contrast to their 2011/2012 survey, as of 31 December 2019 they have released no additional information on the body condition of bears they documented in 2016, nor have they reported sea ice conditions up to 2016.[69] Traditional knowledge indicates an increase in SH bear numbers, while the PBSG in 2019 considered it 'likely decreased'.[70]

Barents Sea – Divergent

The first count of Barents Sea (BS) polar bears was undertaken in August 2004, using a combination

of mark-recapture and aerial survey over both Norwegian and Russian territories. This survey generated an initial estimate of 2,997, which was later amended to 2,650 (range 1,900–3,600) for the entire region.[71] Researchers found 2.87 times as many bears in the Russian sector of the Barents Sea as in the Norwegian sector in 2004.[72] In August 2015, a planned recount of the entire subpopulation had to be restricted to the Norwegian sector because Russian authorities refused to issue the necessary permits. However, while the published paper that reported the results of the Svalbard survey confirmed that a 42% increase in abundance had occurred (from 685 bears in 2004 to 973 bears in 2015), due to the large uncertainty (broad error ranges) in the estimates involved, that 42% increase was not statistically significant.[73] Authors Jon Aars and colleagues had this to say about the Svalbard survey:

> There is no evidence that the fast reduction of sea-ice habitat in the area has yet led to a reduction in population size. The carrying capacity is likely reduced significantly, but recovery from earlier depletion up to 1973 may still be ongoing.[74]

The same authors also concluded that only a few hundred bears now use Svalbard routinely as a denning area or summer refuge, and that most individuals seen around the area live in the pack ice offshore. This confirmed their previous finding that most Barents Sea polar bears live in the Russian sector of the region, around the archipelago of Franz Josef Land.*

Zoologist Susan Crockford pointed out in 2017[75] that if the results of the 2015 survey were extrapolated to the entire region using the ratio for the Russian and Norwegian sectors taken from the 2004 survey, the 2015 population size for the Barents Sea would be about 3,749 (an increase of about 1,109 bears). This extrapolated size increase might not be statistically significant but it accounts for the high probability that the polar bear population in the Russian sector increased between 2004 and 2015 by at least as much as the Norwegian sector (and perhaps by even more, because sea-ice conditions there have been less seasonally volatile).[76] However, the researchers who undertook the 2015 Svalbard survey did not extrapolate their estimate to the entire region, in contrast to Chukchi Sea researchers, who based their estimate on a survey of only two portions of the entire region.[77] The proceedings document from the 2016 PBSG meeting published in July 2019 also did not extrapolate the Svalbard result and argued that because there was no statistically significant increase between 2004 and 2015, it could not conclude that the population had grown.[78] As a consequence, the official BS population size remains at 2,650 (range 1900–3600); in 2019 the PBSG considered it 'likely stable'.[79]

Kara Sea – Divergent

A first-ever Kara Sea (KS) population estimate, completed in late 2014, potentially added another 3,200 or so bears to the global total.[80] This estimate (range 2,700–3,500), derived by Russian biologists from ship counts, was included in the official global count published in 2015 by the IUCN Red List.[81] An earlier estimate, of about 2,000 bears at 2005, was used by American biologists to support the 2008 ESA status assessment, but this was an unofficial figure and does not appear in any document.[82] However, if it was accurate at the time, it may indicate a population increase has taken place. Despite this, the PBSG in 2016 and 2019 still listed the Kara Sea status as 'unknown' and did not mention the 2014 Russian estimate.[83]

Laptev Sea – Divergent

The Laptev Sea (LS) was given a population size of about 1,000 (range 800–1,200) based on den counts between the 1960s and 1980s.[84] The PBSG included this estimate in its 2005 assessment,[85] but the LS status was changed to 'data deficient' in 2013 and 'unknown' in 2014 due to the estimate being out of date.[86] 'Unknown' was also the LS status issued by the PBSG in 2016 and 2019.[87]

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* Note that a frequent claim made by the media, that 'polar bears outnumber people in Svalbard', is quite wrong. It seems to have originated from a statement on the website of the Svalbard Tourism Board ('Visit Svalbard'), and resulted from a mistaken equating of the Barents Sea subpopulation region with the Svalbard study area.

In contrast, the 2015 IUCN Red List assessment required population size numbers for its models projecting future status and used the out-of-date estimate of 1,000 for LS.[88] However, there has not been legal hunting in the region since 1957, and sea ice declines in all seasons have been less than in the neighbouring Kara and Barents Seas,[89] which suggests the population size for LS is almost certainly three or more times as large as the estimate used for the latest Red List assessment.[90] Despite this, the PBSG in 2019 listed this subpopulation as 'data deficient' and the population size as 'unknown'.[91]

Chukchi Sea – Divergent

An existing Russian estimate of 3,000–5,000 bears for the Chukchi Sea (CS) subpopulation, based on den counts and estimated numbers of females in the population, became 2,000–5,000 in the 1993 PBSG report and 2,000 in the 2005 report.[92] Considered 'declining' by the PBSG in 2009, based on existing and projected sea ice losses,[93] that changed to 'data deficient' in 2013 and 'unknown' in 2014–17.[94] However, because a number was required for predictive models, the long out-of-date estimate of 2,000 was used for the 2015 Red List assessment.[95]

However, a capture-recapture survey was conducted by US researchers over a small portion of the sea ice west of Alaska from 2008–2016 (during mid-March to early May). The numbers of bears captured –166 males and 135 females – were then extrapolated to provide a population estimate for the whole.[96] Even though the critical Wrangel Island denning region was not surveyed for the study, litter sizes of family groups on the sea ice off Alaska in spring were found to be much higher than average for both cubs of the year (2.18) and yearling cubs (1.61). These large litter sizes were seemingly driven by an incidence of triplet litters (3/39 of yearling litters or 7.7%)[97] formerly seen only in Western and Southern Hudson Bay in the 1970s and 1980s.[98] This 2016 estimate supports evidence reported up to 2016 that suggested CS bears were in good condition and reproducing well.[99] For example, research conducted from 2008–2013 showed that CS polar bears were doing better than they were in the 1980s, and body condition was better than any other subpopulation except the bears of Foxe Basin (who were doing exceptionally well).

It was also reported that bears spending the summer on Wrangel Island, the region's main terrestrial denning area, had increased dramatically, from about 200–300 individuals in 2012 and 2013 to 589 in the fall of 2017,[100] although about 550–600 were counted in 2007.[101] Preliminary reports from a 2019 fall survey of the northern part of the island counted 367 bears, and while it is unknown how many were counted in the south, the bears seen in the north were reported to be in good condition, with at least one litter of four cubs photographed.[102] All indicators suggest this subpopulation is productive and healthy despite recent changes in summer sea ice that led to bears coming ashore for the summer about 20 days earlier than they did in the 1980s.[103] Poaching is no longer considered an issue, and in 2019 the PBSG listed the subpopulation as 'likely stable'.[104]

Even though the Bering Sea is considered part of the range for CS bears, few individuals venture further south than St Lawrence Island while hunting for seals in winter and early spring, which means that year-to-year variations in Bering Sea ice cover in winter and spring has little impact on Chukchi Sea bears.[105]

Southern Beaufort Sea – Divergent

As noted above, although officially categorised as a subpopulation in the Divergent ecoregion, there are good reasons to believe that the sea ice conditions in the Southern Beaufort Sea (SB) are unique. The first survey of the region took place in 1986, and generated an estimate of about 1,800 individuals. The survey attempted to take into account known movements of bears to and from the Chukchi Sea to the west and the Northern Beaufort Sea to the east.[106] Such movements were what prompted a change in the SB/NB boundary in 2014 by Canadian wildlife managers; a similar change in the western boundary (near Barrow, Alaska) has been discussed but not implemented.[107] Mark-recapture studies in 2001–2006 generated a statistically insignificant decline, to about 1,526 bears (range 1,211–1,841), which was subsequently blamed on reduced summer ice.[108] However,

it was clear from other studies that a series of thick spring sea ice episodes from 2004–2006, as severe as had occurred in 1974–1976, was ultimately responsible for the poor survival of cubs, poorer body condition of adults and subadults, increased spring fasting, reduced abundance of ringed seals, and movement of bears into NB.[109]

Additional mark-recapture survey data from 2007–2010 were added to previously collected data from 2001–2006 and analysed using a new statistical method. This showed that survival picked up in 2007 (just as overall summer sea ice hit a record low) and increased through 2009, resulting in a revised estimate of 907 (range 548–1,270) at 2010, a statistically significant decline of roughly 25–50% (often wrongly cited as '40%') over the 1980s count.[110] The PBSG pointed out in 2016 that the latest survey may not have sampled the entire geographic range adequately, and that this may have negatively skewed the 2010 population estimate; they did not, however, make an adjustment to the population estimate as they had previously done for other subpopulations when such problems with estimates later became evident (e.g. Davis Strait).[111]

The COSEWIC report on polar bears published in June 2019 acknowledges concerns that the 2010 estimate was lower due to 'annual variability in ice conditions' (see Section 5) resulting in bears shifting to the NB.[112] It therefore proposed an 'equally valid' estimate for SB of 1,215 bears at 2006 (arrived at by taking 311 bears away from the 2006 SB estimate of 1,526 and adding it to NB subpopulation estimate).[113] This figure is currently the one used by the joint Inuvialuit/government body charged with managing SB and NB subpopulations in Canada.[114] For management purposes in Canada, the SB subpopulation is considered 'likely decline' and the PBSG considers it to be 'likely decreased'.[115] However, many Inuit in the Canadian portion of the region feel that polar bear numbers have been stable or increased within living memory.[116]

Northern Beaufort Sea – Convergent

The last population count for the Northern Beaufort Sea (NB) was made in 2006, so is now more than ten years out of date. It generated an estimate of 980 (range 825–1,135), although the lead author of the study suggested a more accurate estimate would be 1,200–1,300 due to non-sampling of northern areas.[117] At that time, the population appeared to have been relatively stable over the previous three decades. The boundary with SB has been moved east, to near Tuktoyaktuk, for Canadian management purposes, a change provisionally accepted by the IUCN PBSG in 2017.[118] Updated maps from Environment Canada now incorporate this boundary change.[119] The current population estimate suggested to account for the boundary change with SB is 1,291 (980 plus 311, see discussion in SB above), but the estimate used for management purposes is 1,710 (an adjustment for unsampled areas of the region during the 2006 count); the population is considered stable or 'likely stable' by Inuit and Canadian government authorities; it is listed as 'likely decreased' by the PBSG.[120]

East Greenland – Convergent

Although there has been no comprehensive survey of the East Greenland (EG) subpopulation, in 2001 the PBSG gave it an estimate of 2,000 bears (in part based on harvest records that indicated a fairly substantial population must exist).[121] However, in 2013 the group credited the region with only about 650 bears, with no reason given for the change in opinion,[122] and by 2014 EG numbers were simply said to be 'very low.' It is simply not true that the PBSG has never provided an estimate for EG, as they now claim on their website.[123] In fact, the 2001 estimate of 2,000 bears was considered adequate for the 2015 IUCN Red List assessment.[124] The first comprehensive population survey should be completed by 2022.[125] Traditional ecological knowledge gathered from hunters in northeast Greenland in 2014 and 2015 suggested an increase in numbers of bears coming into communities compared to the 1990s,[126] and in southeastern Greenland, one representative of the local hunters' association said that there are more healthy bears causing trouble in the area because abundant seals have meant abundant bears.[127] In 2019, the PBSG listed EG as 'data deficient' with an 'unknown' population size.[128]

Arctic Basin – a designated subpopulation but not an ecoregion

In the original classification of the sea-ice ecoregions, a narrow portion of the Arctic Basin (AB) north of Greenland and Ellesmere Island was at first called 'Queen Elizabeth – Convergent' and later 'Northwest – Convergent' (NWCon; Figure 2), but that nomenclature now seems to have been abandoned, probably because it is not a distinct subpopulation region for polar bears.[129] The PBSG treats AB as a 'catch-all' region because it contains bears moving between regions and those from peripheral seas (such as the Southern Beaufort and Barents Sea) who use it as a summer refuge during the ice-free season. Both single bears and family groups have been seen feeding on ringed seals during the summer, and both ringed seals and their fish prey have been documented as being present.[130] AB is given a population size estimate of zero, but there is some evidence that the productivity in some areas of this region is higher than previously assumed and it is thus possible that a small number of polar bears may live there year-round.[131]

Kane Basin – Archipelago

A 2013 survey of Kane Basin (KB) polar bears confirmed what local Inuit and some biologists have been saying for years: that contrary to the assertions of PBSG scientists, KB polar bear numbers have not been declining.[132] Until recently, the KB polar bear subpopulation, located between northwest Greenland and Ellesmere Island, was assessed with confidence by the PBSG to be declining due to suspected over-hunting. In 2014, Environment Canada's assessments were 'data deficient' for the area. But the 2013 survey generated an estimate of 357 (range 221–493), a 118% increase over the 1997 estimate of 164 (range 94–234) and a 59% increase over the estimate recalculated in 2016 as 224 (range 145–303), indicating a 'stable to increasing' population.[133] However, the survey authors expressed concerns with sampling methodology and differences in the areas surveyed, and suggested 'some caution in interpretation of population growth' was necessary.[134] While all other metrics of life history and habitat were subject to statistical significance testing, the authors did not state conclusively whether the 59% increase was statistically significant or not. However, traditional knowledge says numbers have increased, and the PBSG assessment for 2019 concluded that the population had 'likely increased'.[135]

M'Clintock Channel – Archipelago

The first population size estimate generated for M'Clintock Channel (MC) was about 900 bears in the mid-1970s. A mark-recapture study in 2000 generated an estimate of 284±59 bears, a significant decline, which was blamed on over-hunting.[136] Hunting was subsequently halted but later resumed at a much-reduced level, after which the population was presumed to be increasing. Results of a three-year genetic mark-recapture study that began in 2014 were still not available at the end of 2019, but traditional knowledge in 2018 considered this subpopulation had declined in recent years, probably due to overhunting. Surprisingly, the PBSG assessed it as 'very likely increased' in 2019.[137]

Viscount Melville – Archipelago

The first survey to determine the population size of the Viscount Melville (VM) subpopulation was completed in 1992 and generated an estimate of 161±40.[138] This estimate is now over 25 years old; while a new genetic mark-recapture survey was completed in 2014, the results had still not been made public by the end of 2019; traditional knowledge indicates the population is stable or increasing, while the PBSG in 2019 considered it 'data deficient'.[139]

Gulf of Boothia – Archipelago

The Gulf of Boothia (GB) is in the middle of the Canadian Arctic. In terms of geographic area, it is one of the smallest of all 19 subpopulations worldwide, covering an area of only 170,000 km^2; only the Norwegian Bay and Kane Basin regions are smaller, at 150,000 and 155,000 km^2 respectively.[140] The first population survey was done in 1986 and generated an estimate of about 900 bears. This was updated in 2000 with an estimate of 1,592±361 bears, a significant increase.[141] The new density

was calculated as 18.3 bears per 1000 km^2, well above the 5.1 bears per 1000 km^2 found in Davis Strait, the 1.9 bears per 1000 km^2 in M'Clintock Channel, and the 6.5 bears per 1000 km^2 found in the Northern Beaufort Sea.[142] A new estimate for the area has been completed based on genetic mark-recapture but, as of the end of 2019, the results have not been made public. However, the last preliminary report stated that 'polar bears remain relatively abundant and in good condition'; the PBSG in 2019 list this subpopulation as 'likely stable', while traditional knowledge considers it to have increased.[143]

Lancaster Sound – Archipelago

The Lancaster Sound (LS) subpopulation, in the middle of the Canadian Arctic archipelago, has one of the highest population counts of polar bears anywhere, although it is one of the smaller regions. The latest population surveys were conducted from 1995 to 1997, and in 1998 an estimate of 2,541±391 bears was generated, a significant increase over the previous estimate (from 1977) of 1,675 bears.[144] The eastern portion of LS is generally clear of ice by late summer (hence the Northwest Passage), but the western third of the region not only retains pack ice later in the season, but some multiyear ice remains throughout the year. The proximity of LS to Baffin Bay and the eastern Northwest Passage undoubtedly exposed polar bears there to hunting by European whalers during the 1800s and early 1900s,[145] but the population appears to have recovered since then. Traditional knowledge says numbers in the region have increased while the Polar Bear Technical Committee assessed it as 'likely stable' in 2018.[146] In 2017, the PBSG considered the population to be stable but changed this to 'data deficient' in 2019.[147]

Norwegian Bay – Archipelago

The last population count for Norwegian Bay (NB) was done in 1993–1997 in conjunction with the Lancaster Sound survey, and is therefore well out of date.[148] It generated a population estimate of 203±44.[149] Several studies suggest this may be a genetically distinct subpopulation.[150] Norwegian Bay is either part of, or adjacent to, what has been called the 'Last Ice': a refugium of sea ice over shallow continental shelf waters expected to remain even if summer sea ice drops to near-zero levels (<1 million km^2), depending on the model used.[151] The PBSG in 2019 listed this subpopulation as 'data deficient' while traditional knowledge considered it stable.[152]

4. Population trends

In 2018, the Government of Canada published a global polar bear population status and trend map, based primarily on IUCN PBSG data (Figure 3),[153] which showed the following classification totals:

- three 'likely declined'
- two 'increased' or 'likely increased'
- three 'stable' or 'likely stable'
- eleven 'data deficient'

New population surveys published since then would likely change the classification for the Chukchi, Barents, and Kara Seas from data deficient to at least 'likely stable.' However, as noted in Section 3, the PBSG has so far refused to acknowledge either the Kara Sea or Barents Sea survey results in their status tables and the Chukchi Sea estimate was not available at the time the Canadian status table was published. In addition, given conditions over the last two decades, it is highly likely that bear numbers in the Laptev Sea (once estimated at 1,000) and in East Greenland (previously estimated at 2,000) have also increased or at least remained stable.

Inexplicably, Western Hudson Bay and Southern Hudson Bay both were considered to be 'likely declined' even though (as noted in Section 3), neither registered statistically significant declines at their most recent counts: both should have been considered 'stable.' Also, only the Southern Beaufort (SB, Divergent sea ice ecoregion) registered a statistically significant decline at its last

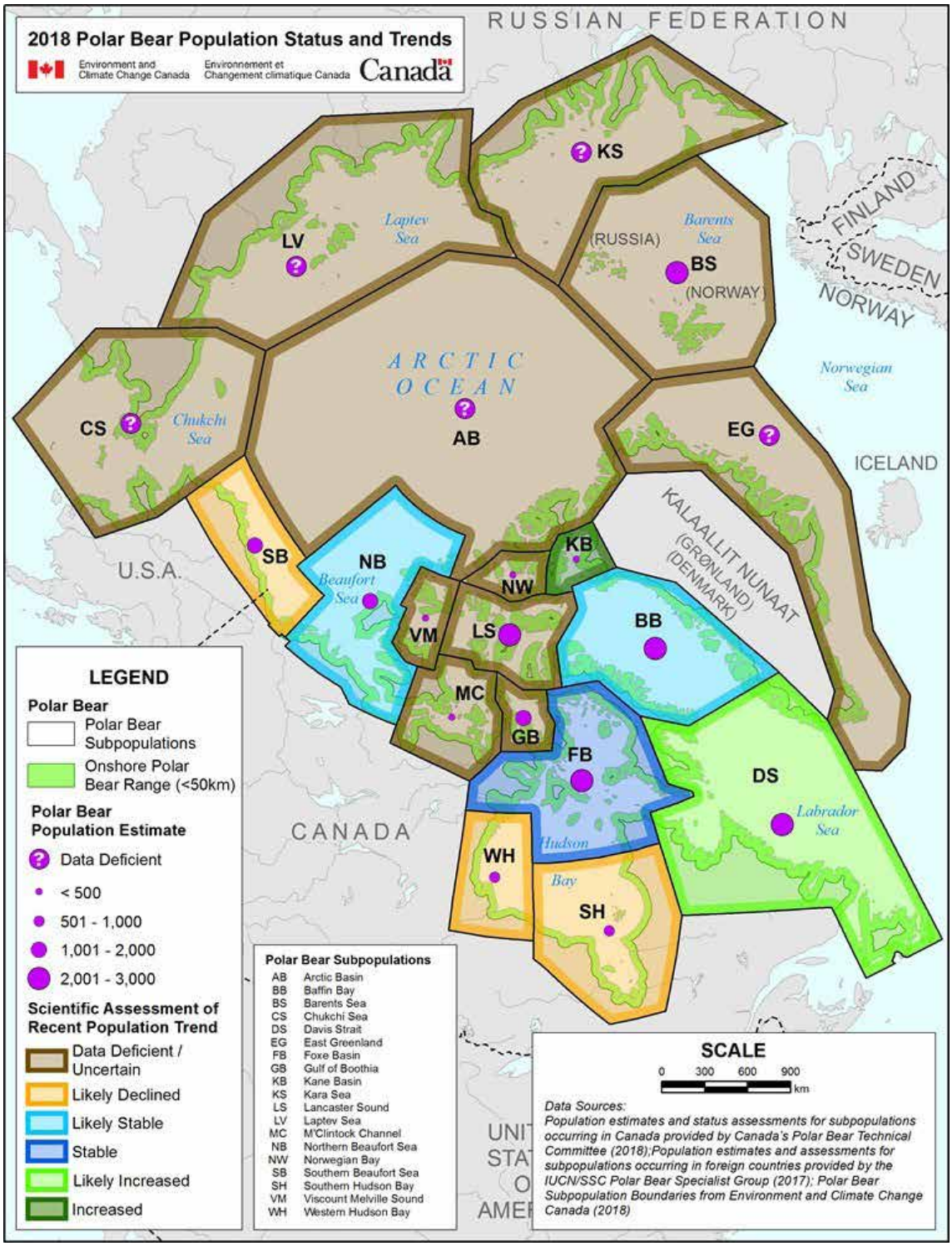


Figure 3: Trends in polar bear subpopulations at 2018, according to the Government of Canada.

The Canadian government considers the polar bear a species of 'Special Concern.' Note KB is 'increased' which is difficult to discern from 'data deficient' because of the color scheme chosen. The 'likely declined' status for WH and SH is not supported by statistically significant population declines.

population count, but, as noted above, this region has special circumstances that make it an outlier: the proximate cause of the apparent decline was thick sea ice, which temporarily drove seals and therefore bears out of the region.[154] A more realistic assessment of the SB nine years after the last population survey would therefore be 'likely stable.'

Although the PBSG listed population trends in their population status table in 2014 (when they considered four populations to be declining), by early 2017 they no longer included these

hitherto important numbers. However, by mid-2019 they had added them back in.[155] Nevertheless, their 2019 assessments show the same pessimistic bias as found in their 2014 status tables and in the Environment and Climate Change Canada status trend map.

Accordingly, Figure 4 shows a more realistic representation of current polar bear population trends, which gives the following classification totals at 2018 (not changed in 2019): [156]

- two 'increased' or 'likely increased' [KB, DS]
- three 'stable or likely stable' [WH, SH, AB]
- fourteen 'presumed stable or increasing' [EG, LS, AB, VM, NB, GB, MC, LS, BB, BS, KS, CS, NB, FB]

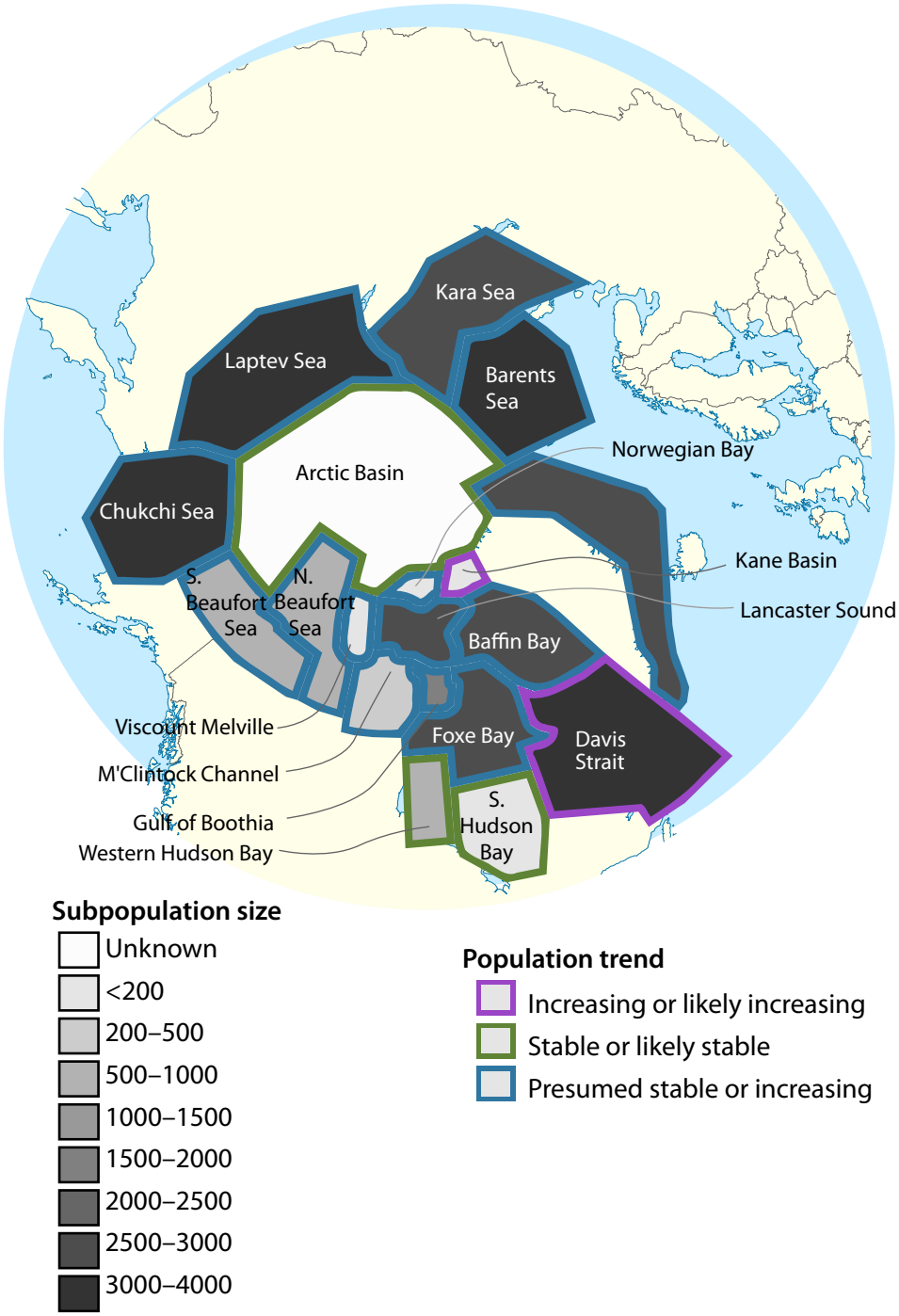


Figure 4: Trends in polar bear subpopulations at 2018 (no changes at 2019).

Number of bears per subpopulation. Former 'data deficient' regions are marked 'likely stable or increasing' to reflect current research on studied populations.

The problem of statistical confidence

Virtually all recent population size estimates for polar bear subpopulations have such wide margins of error (statistical confidence intervals) that even quite large changes in size are unlikely to be statistically significant. For example, in its most recent population count in 2015, the Svalbard portion of the Barents Sea saw an increase of 42%, but this was not statistically significant.[157] The authors, Jon Aars and colleagues, could conclude only that recent large declines in sea ice habitat in the Svalbard area had not yet led to a reduction in population size and that recovery from previous overhunting might still be ongoing.

In addition, differences in survey methodology have led to numbers that are not considered comparable, so a trend cannot be established. Such problems have recently been claimed for the 2012–2013 estimate for Baffin Bay bears compared to one conducted in 1997, even though the more recent estimate was 36% larger.[158] Similarly, the most recent Western Hudson Bay surveys, conducted in 2016, generated an estimate about 30% smaller than the one for 1987, but differences in methodology and areas surveyed mean the two figures cannot be used to derive a trend.[159] Two estimates for WH, for 2004 and 2016, could be compared, and these suggested a statistically insignificant decline of about 11%.

In short, changes in survey methods and/or mathematical formulae used to derive population estimates over time have generally increased statistical confidence intervals to such an extent that a decline or increase in abundance would likely need to be 50% or more to be considered real and valid. This means that the ESA and Red List definitions of 'threatened' or 'vulnerable' to extinction – based as they are on the likelihood of a population decline of 30% or more over the next three generations[160] – are using a mathematical threshold that is very likely statistically invalid for polar bears.[161] The IUCN Red List assessment for 2015 apparently dealt with this issue by concluding that there was a reduced probability (only 70%) that a decline of 30% or more would occur by 2050, which is a rarely discussed but significant caveat to their prediction.[162]

I have dealt with this issue in this report by replacing old subpopulation sizes with new ones generated since the 2015 Red List assessment was published (for Barents Sea, Baffin Bay, Kane Basin, Western Hudson Bay),[163] but acknowledge that the margin of error remains large and note the apparent increase in global population size is likely not statistically significant. The rationale for this approach is to emphasize that the anticipated decline in global numbers since 2005 has not taken place.

5. Habitat status

Global sea ice

Summer sea ice (at September) has declined markedly since 1979 but winter ice levels (at March) have declined very little and have been essentially flat since 2004 (Figure 5).[164] March extent in 2019, when atmospheric CO_2 levels were about 411 parts per million (ppm), was tied with 2007, when CO_2 was about 387 ppm, as the seventh lowest extent since 1979.[165] There has been no research done on what effects, if any, the slight decline in winter ice extent has had on polar bears overall, but a cursory examination suggests that since 1979 there has been enough sea ice in winter to meet the needs of polar bears and their prey. In part, this is because most of the change in winter ice extent has occurred in the Sea of Okhotsk and the Gulf of St. Lawrence (where polar bears do not live) as well as in the southern Bering and southern Labrador Seas (where few polar bears venture in winter and early spring).[166] This was especially relevant in 2018 and 2019 for the Bering Sea because of reports that the low extent of winter ice cover had broken historic records:[167] Bering Sea ice has been extraordinarily variable since 1979, and in 2012 – the year the summer extent hit its lowest level – reached by far the highest level since 1979 and broke the record at the other end of the range.[168]

As far as is known, record low extents of sea ice in March 2015, 2017 and 2018,[169] which were

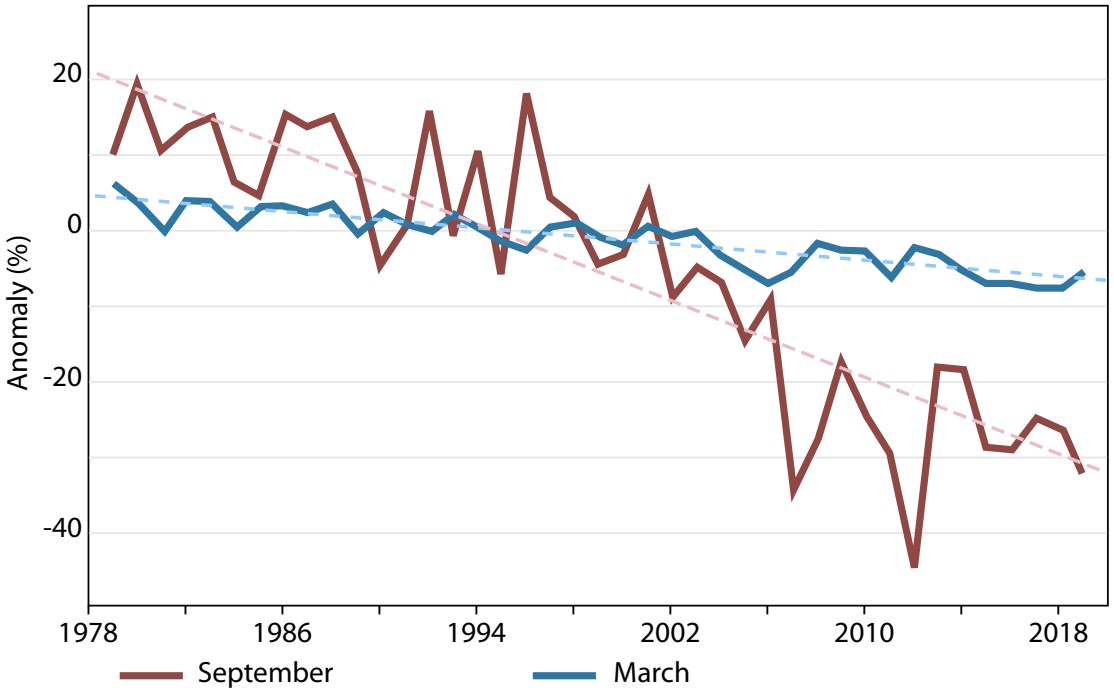


Figure 5: Sea ice extents, 1979–2019.

Anomalies against mean for 1981–2010. From NOAA's Arctic Report Card 2019.[440] A recent paper tracking sea ice levels back to 1850 shows a similar pattern.[441]

so similar to 2006, had no impact on polar bear health or survival (Figure 6a), and ice cover at March 2019 was higher than all three of those years. For example, adult male bears captured around Svalbard, Norway in spring showed no statistically significant change in body condition from 2015 through 2019, compared to those captured since 1993; however, in 2019, the condition of males was the best it had been since 1995 and average litter size (2.0) reached a level not seen since 1993.[170]

The most pessimistic predictions of March sea ice extent at the end of the 21st century is about 12.0 mkm^2, equal to the average extent of ice for May 2019 and May 2016 (Figure 6b).[171] Polar bears and their prey could survive without a precipitous decline in population size if March sea ice dropped this low, even before 2100, because there would be enough ice in all regions where these animals reside to meet their minimum spring requirements.

Sea ice extent in June has declined, on average, from just over 12 mkm^2 in the 1980s to just over 11 mkm^2 from 2004–2018.[172] By late May to early June, there has therefore been lots of sea ice throughout the Arctic to act as a feeding and mating platform for polar bears (Figure 6c): even the 10.5 mkm^2 available in June 2019 was ample habitat for late spring (Figure 6d).[173] In part, this is because the young seals that form the bulk of polar bear diets in spring take to the water to feed and are no longer available on the ice, leaving only predator-savvy adults and subadults hauled out as potential prey.[174] This means few seals are actually caught and consumed by polar bears after about mid-June in Seasonal and Divergent sea ice ecoregions, or by mid-July in Convergent and Archipelago regions (see Section 6).

Sea ice thickness has declined in some regions of the Arctic, and this has been especially pronounced in the Arctic Basin. In March 2019, it was reported that just 1.2% of the mobile pack ice in this region was 'old', thick ice (> 4 years and 4–5 m thick), compared to 33% for the same month in 1985.[175] However, by and large, this has been a net benefit for polar bears and their prey, whose preferred habitat is first-year ice less than 2 m thick, which was always the dominant ice type in the Divergent and Seasonal ecoregions but is now increasingly common in the Archipelago and Convergent regions as well.[176] For example, during the 1980s, sea ice in Kane Basin, west of Northern Greenland, was predominantly permanent, multi-year ice, even in summer, and this poor seal habitat supported few polar bears. But now that the ice is mostly seasonal first-year ice, the population

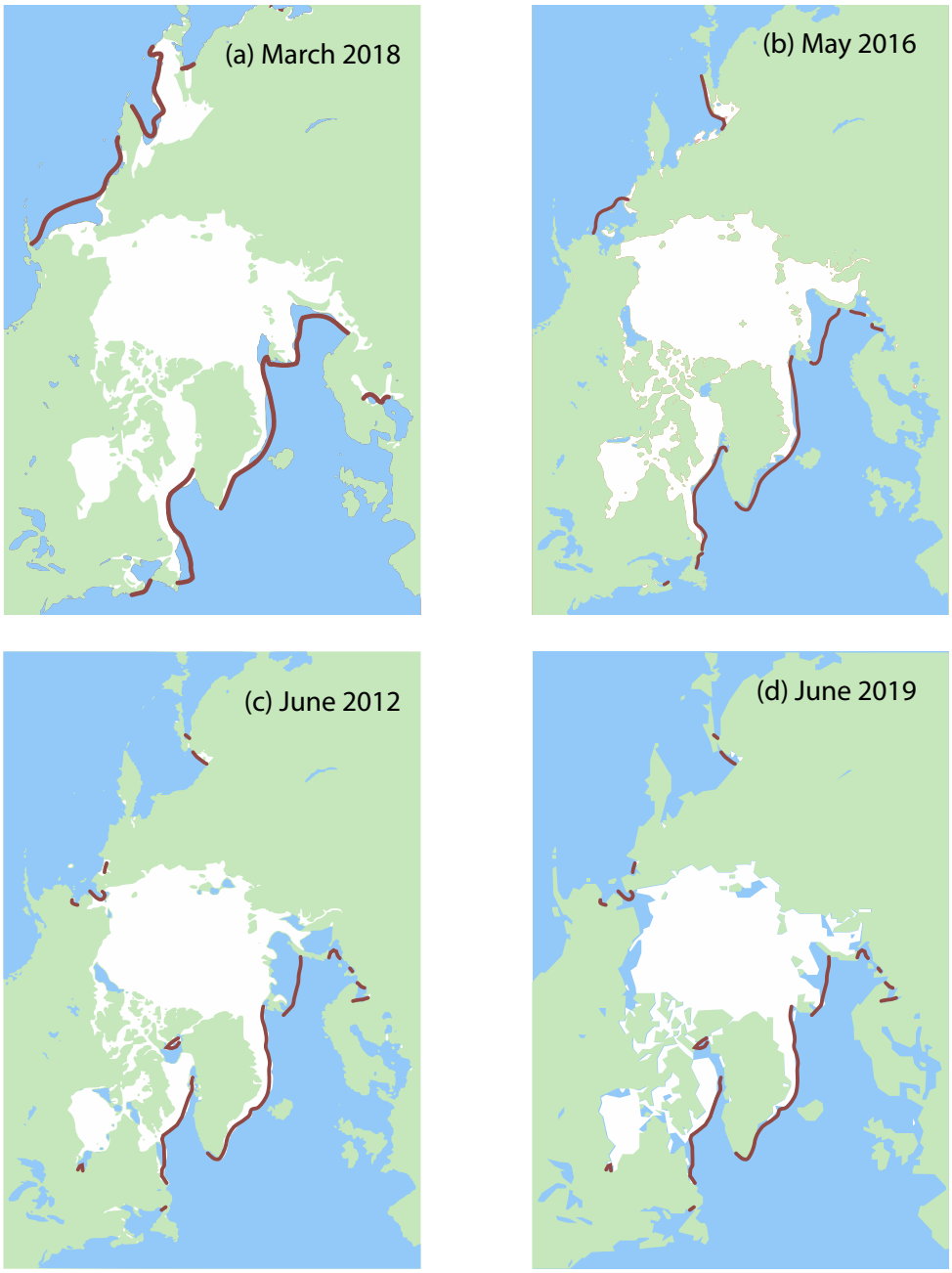


Figure 6: Average sea ice extents.

The brown lines indicate the median extent for 1981–2010. Courtesy US National Snow and Ice Data Center.

of bears has grown remarkably.[177]

In contrast, a 2016 report of Southern Beaufort Sea bears having difficulty finding prey in 2014–2016[178] indicated that the thick spring ice events that have temporarily impacted the region every ten years or so since the 1960s – when multi-year ice compresses first year ice along the shore until it becomes a mass so thick and buckled that it forces Arctic seal species to leave – have continued despite reduced summer sea ice, although authors Anthony Pagano and colleagues did not draw that conclusion.[179] The scientific literature has many papers and reports that show what past episodes of thick spring sea ice have done to polar bears, ringed seals, and bearded seals that live in the Southern Beaufort Sea.[180] The Pagano study is evidence that the phenomenon occurred again in 2014–2016, right on schedule, ten years after the 2004–2006 episodes, although researchers and the media[181] blamed the effects on reduced summer sea ice.[182] Fortunately, as happened following all previous episodes of thick spring ice, polar bear numbers and their physical condition appear to have improved since 2016, something which was especially evident in 2019, when doz-

ens of fat, healthy polar bears were seen onshore in July during a NOAA survey of the Alaskan coast (the highest concentration seen on or near shore since 2012, when larger numbers were observed in August and September during a US Fish and Wildlife Service survey).[183]

The devastating effects that heavy ice cover has had on polar bear health and survival in the Beaufort Sea has been documented for 1974–1976, 1984–1986, and 2004–2006, with similar events inferred from anecdotal information for 1964, 1992, and now 2014–2016.[184] Susan Crockford argued a few years ago that Arctic sea ice is not the stable habitat that polar bear experts currently assume,[185] and that population numbers in some regions will vary naturally in response. This was a conclusion reached by polar bear specialist Ian Stirling in 1982, and warrants repeating here:

> 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.*[186]*

While polar bear specialists have for years insisted that polar bears prefer sea ice of 50% or more over continental shelves, regardless of season, recent research has shown bears utilise sea ice during the melt season that is well below this threshold. In the Southern Beaufort Sea and Western Hudson Bay, bears were found to use ice of 0–20% concentration; in some cases SB bears were tracked to areas registered by satellites as open water.[187]

Sea ice varies between seasons, of course, but it is often highly variable from year to year within an ecoregion and across the Arctic as a whole. Over longer periods (decades, centuries, millennia), Arctic sea ice has also been quite variable, at times more extensive than today and at others, less extensive.[188] For example, the abrupt decline in sea ice extent that came at the end of the Younger Dryas cold period (ca. 10,000–12,500 years ago), especially in the Eastern Arctic, where ice had extended into the North and Baltic Seas in summer, meant an abrupt contraction of range: most of the polar bear fossils of the Younger Dryas come from Denmark, southern Sweden and southern and western Norway.[189] The Younger Dryas ended abruptly, perhaps as a result of a comet strike,[190] over a 40-year period; the change took place in a series of steps, each of about five years' duration.[191] Polar bears and their prey species – ringed and bearded seals, walrus, beluga, and narwhal – have survived these and other changes with no apparent negative effects.[192] Their inherent flexibility in dealing with changing ice conditions past and present mean that evolutionary adaptation, as it is usually defined, has not been necessary.

Sea ice loss by subpopulation

Eric Regehr and colleagues[193] provide details of the amount of sea ice loss (reduction in number of days with ice cover of >15% concentration) per year for the period 1979–2014 per polar bear subpopulation (see Figure 7). This metric varied from a high of 4.11 days per year in the Barents Sea to a low of 0.68 in the southernmost region, Southern Hudson Bay. Most subpopulations have lost about one day per year since 1979, although a few have lost somewhat more or less.[194] Surprisingly, despite the Barents Sea having the greatest loss of ice since 1979, polar bear numbers there grew between 2004 and 2015. Similarly, bear numbers in Southern Hudson Bay, with the least amount of ice loss, have remained stable since the 1980s.[195]

Freeze-up and breakup date changes for Hudson Bay

Contrary to predictions, freeze-up of sea ice along Western and Southern Hudson Bay came as

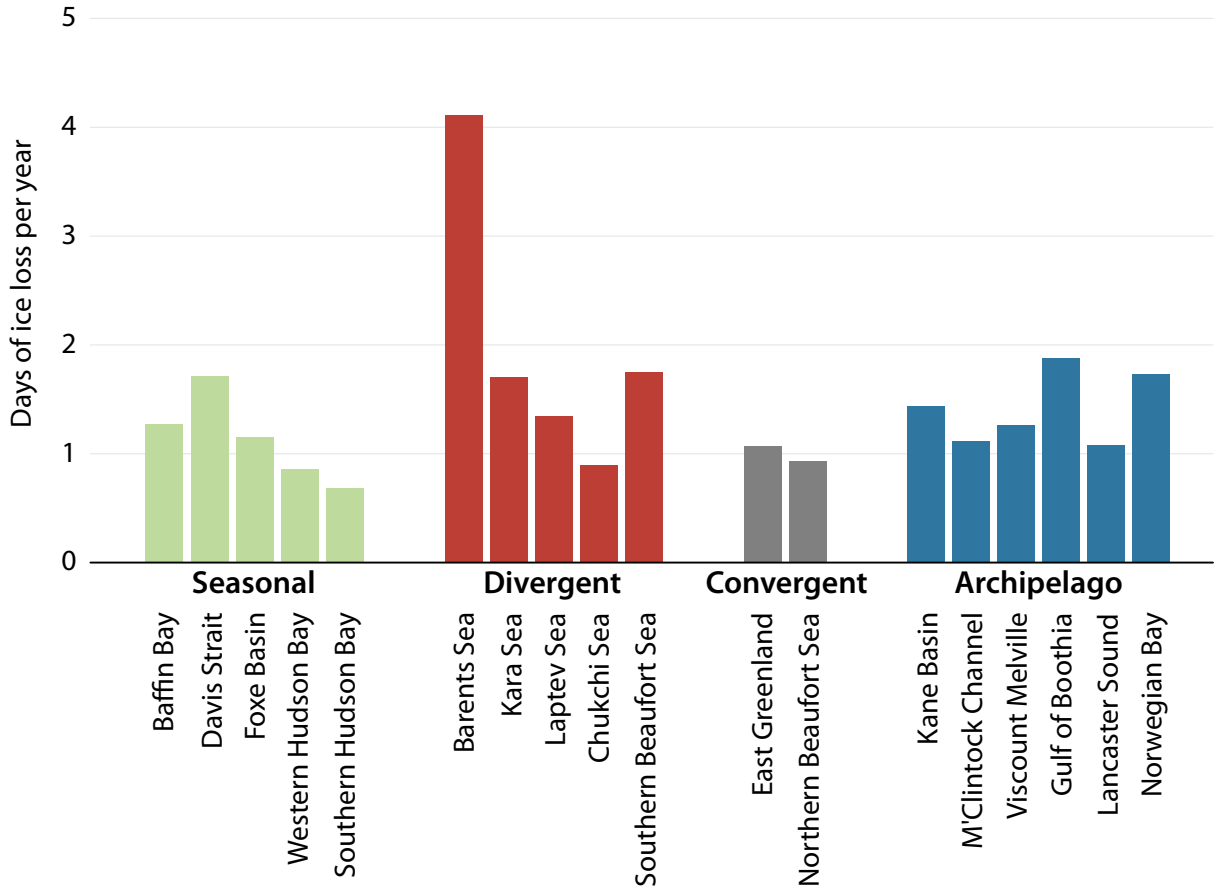


Figure 7: Sea ice loss per subpopulation.

Change in number of days with ice cover of >15% per year. Arctic Basin not included. Data from Regehr et al. (2016).

early in 2017, 2018, and 2019 as it did in the 1980s; in addition, breakup in 2019 was as late as it was in the 1980s – making 2019 a phenomenally good year for Hudson Bay polar bears – even though this information has not yet been incorporated into the scientific literature.[196] These ice conditions allowed most WH and SH bears to resume seal hunting four weeks earlier in 2019 than in 2016 (when freeze-up was quite late) and has meant five good seasons in a row for these bears (with the last being very good).[197] Even though sea ice was a bit slower to develop over the entire bay after polar bears left shore in November, there is no evidence to suggest this would have had a negative impact on feeding success, since bears in the fall feed at the developing ice edge whether close to shore or well offshore.[198] Although year-to-year variability is quite normal for Hudson Bay, a return to 1980s-like freeze-up dates three years in a row was not only unexpected but could not be explained by an external forcing, such as the June 1991 volcanic eruption of Mount Pinatubo, which seemed to cause a later-than-average breakup in 1992 and earlier-than-usual freeze-ups in 1991 and 1993.[199] In fact, polar bear specialists have implied that natural variation was to blame for these three early freeze-up dates in a row for WH.[200]

WH bears leave the shore within about two days of sea ice concentration reaching 10% along the shore, although SH bears leave when it reaches about 5%.[201] In other words, the bears leave shore as soon as they possibly can. In 2017, there was enough ice by 8 November for many bears to leave shore, and by 10 November most bears were on their way; in 2018, these same thresholds were reached on 12–14 November and in 2019, by 10–12 November. According to data for 1979–2015, in the 1980s the mean date that bears left the ice at freeze-up (10% sea ice coverage in WH) was 16 November ± 5 days, while in recent years (2004–2008) the mean date of leaving was 24 November ± 8 days, a difference of 8 days.[202] Even in the 1970s, bears leaving shore by 8 November was considered 'early.'[203] As a consequence, not only have freeze-up dates since 2017 been like

those of the 1980s, but freeze-up dates of 10–12 November for 2017 and 2019 and 12–14 November for 2018 were some of the earliest freeze-up dates since 1979 (the earliest being 6 November in 1991 and 1993). Churchill's *Polar Bear Alert Program* reported in 2018 that all bears in holding had been released on 13 November, remarking on the very early date of freeze-up; in 2017 bears were not released from the holding facility until 22 November, even though most bears had left shore at least two weeks earlier.[204] In 2019, Churchill Alert reports confirmed bears were leaving for the ice by 10–12 November.[205] Even though development of sea ice over the entire bay was a bit slower than usual in 2019, there is no evidence this would negatively affect the seal hunting success of polar bears.[206]

Despite the overall drop in ice-covered days since 1979, there has been no statistically significant change in either breakup or freeze-up dates for WH since the mid-1990s.[207] Most of the change, an increase in the total ice-free period of about three weeks, came about 1998. Note that the figure is three weeks total, not three weeks at breakup and another three weeks at freeze-up, as is sometimes claimed.[208] The ice-free season has increased in SH by about 30 days too, but, as for WH, most of the change came in the late 1990s, with much yearly variation in breakup and freeze-up dates since then.[209]

6. Prey base

Polar bears, seals, and sea ice

Ringed and bearded seals, and particularly their pups, are the primary prey of polar bears worldwide.[210] In some regions, other seal species make up varying proportions of the diet: harp seals for Davis Strait and East Greenland bears, and ribbon seals for Chukchi Sea bears, for example. Walrus, beluga, and narwhal make up a small proportion of the diet in some areas. Polar bears also sometimes scavenge fat and meat remaining on beached whale carcasses (whether left due to natural death or aboriginal hunting),[211] and it has even been proposed that polar bears survived the Eemian Interglacial, a period of warmth about 115,000–130,000 years ago, by switching to feeding on whale carcasses in summer rather than Arctic seals in spring.[212] However, the authors, Kristin Laidre and colleagues, provided no evidence to support this idea.

Arctic seals have their pups in the spring on the sea ice. Most ringed and bearded seals, as well as several less-common species, are born from mid-March to mid-April or a bit later, depending on the location; harp seals are born earlier (February to mid-March) in less consolidated pack ice than the others.[213] While it is true that some Arctic ringed seals give birth in stable fast ice close to shore,[214] many others give birth well offshore in thick pack ice where polar bears also live and hunt in the spring.[215] Although not often mentioned, there is documented evidence of pack ice breeding ringed seals in the Bering Sea, Sea of Okhotsk, Chukchi Sea, Davis Strait, and the Barents Sea. This finding is supported by genetic evidence.[216] The presence of breeding ringed seals in the pack ice suggests strongly that polar bear spring hunting habitat includes all Arctic sea ice of suitable thickness over continental shelf waters, not just shorelines and fjords.[217]

Seal pups are preyed upon by polar bears from the moment they are born. However, those that survive gain weight rapidly and are weaned after a short nursing period. They can more than double their birth weight by the time they are weaned, and can reach 50% fat by weight. They then remain on the ice for three or four weeks, before taking to the water to feed. During this period, the pups are a particularly important food source for fat-craving polar bears. Polar bears consume two-thirds of their yearly food supply in the spring (Figure 8). In some areas, polar bears can kill up to 44% of new born seal pups each spring if conditions are right.[218]

From May to July, adult and subadult seals of all varieties haul out on sea ice while they moult their fur, but are harder for polar bears to catch than youngsters because they are predator-savvy.[219] However, even though summer sea ice has routinely declined to less than 5 mkm^2 in recent years, there has still been plenty of ice remaining to act as a hunting platform for polar bears until

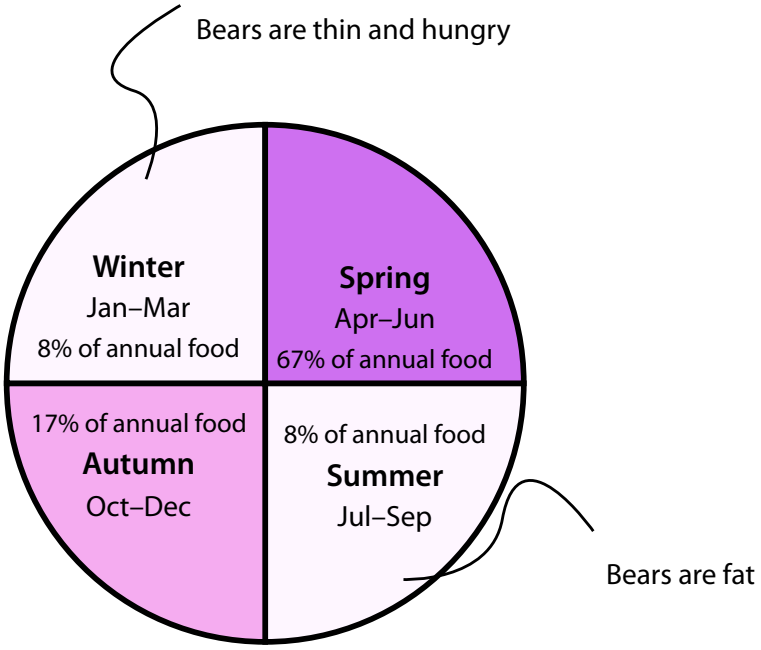


Figure 8: Polar bear feeding activity by season.

The most intensive feeding time is spring, followed by fall. Although some individuals have trouble eating enough in the spring due to inexperience, competition, old age, injury or disease, polar bears are usually hungriest in late winter, not summer as people have been told.[442] Based on data from the polar bear literature, seasons as defined by Pilfold and colleagues in 2015.[443]

the middle or the end of June or later, depending on the location.

Seal numbers

Ringed and bearded seals

While ringed seals and bearded seals were both listed as 'threatened' under the US Endangered Species Act (ESA) in 2012, there is no evidence that either species has declined in number or registered any other negative impact due to reduced summer sea ice.[220] The 'threatened' status is based exclusively on the presumption that future harm with be caused by further reductions in summer sea ice.[221] However, no other Arctic nation has taken this conservation step for ringed and bearded seals, and neither has the IUCN Red List, which lists both as 'least concern'.[222]

Chukchi Sea polar bears have been doing better in recent years – with an extended open-water season – than they did during the 1980s. This is because the ringed and bearded seals that are their primary prey do most of their feeding in ice-free summer waters.[223] More fat seals mean more fat seal pups the following spring for polar bears to eat. A recent study found that since 2007, with longer ice-free summers than occurred during the 1980s, the summer feeding period for seals was extended and they became extra fat. Well-fed female ringed seals produced fat, healthy pups the next spring, which meant more food for polar bears when they needed it the most. It seems likely this is also the case in many other peripheral regions of the Arctic with wide continental shelves (such as the Laptev, Kara and Barents Seas) but not the Southern Beaufort. Oddly, in March 2013, less than six months after ringed and bearded seals were listed in the USA as 'threatened' with extinction, seal biologists were reporting to their peers that the results of their Chukchi Sea research contradicted their dire predictions: less summer sea ice was actually better for ringed and bearded seals, not worse.[224]

In 2019, American biologists confirmed that data up to 2016 showed both species of seal are continuing to thrive in Alaskan waters of the Chukchi and Beaufort Seas: Alaska Department of Fish

and Game specialist Lori Quakenbush said that ringed and bearded seals are doing very well and are maturing earlier than in the past because they are so well fed.[225] Seals breeding at an earlier age due to reduced summer sea ice should result in a stable or growing population, not a declining one as was predicted. As a consequence of these studies, in March 2019 the State of Alaska and three Alaskan Indigenous organizations filed a petition to delist the Arctic ringed seal from the federal ESA.[226]

Harp and hooded seals

Harp seals are an important alternative prey for polar bears in Davis Strait, Foxe Basin, Hudson Bay, southern Baffin Bay, East Greenland, and the Barents Sea.[227] A survey in 2012 estimated there were 7.4 million harp seals in Atlantic Canada (range 6.5–8.3 m), an exponential increase over the early 1980s when perhaps only half a million remained.[228] Relatively few harp seals give birth and breed in the Gulf of St. Lawrence (where there are no polar bears), but in some years they have suffered substantial mortality due to reduced spring ice, something which has happened more often in recent years.[229] However, the seals that whelp off Labrador and Newfoundland (where they are the main prey of polar bears) appear to have been less vulnerable to such changes, in the past and in recent years. From 1950–1990, poor ice conditions were present in the Gulf about one year in every ten, but, as in the past, most animals today likely move to the 'front' ice off Newfoundland and Labrador to whelp when Gulf ice conditions are poor.[230] Although a count of harp seal pups off Newfoundland and Labrador was performed in March 2017, the results had still not been made public by 31 January 2020 even though they were promised by the end of 2019. [231] If the harp seal population has grown in size since 2012, it would provide an even larger spring prey base for polar bears in the Davis Strait subpopulation and perhaps also for some bears in Baffin Bay.

A 2019 report of harp seals in Svalbard revealed an interesting phenomenon: unlike ringed and bearded seals, adult harp seals hauled out on the ice do not show an immediate flight response when approached by a polar bear (even in summer), allowing polar bears to make multiple kills within a group of seals in a short space of time before beginning to feed.[232] That may explain why virtually all Davis Strait bears seen onshore in the spring in Labrador and Newfoundland in recent years have been in such good condition (see Section 9): they are able to put on the fat they need in a very short space of time when harp seals are so abundant.

In East Greenland, the current size of the harp seal stock is about three times as high as it was in the 1970s (estimated at more than 600,000 animals, range 470,540–784,280).[233] So, as for polar bears in the southern Davis Strait, there are lots of harp seal pups for East Greenland polar bears to eat in the spring. However, for unknown reasons, hooded seals in the same area (called the 'West Ice') appear to be declining (although those that live off Newfoundland and Labrador are doing well). There are only about half as many hooded seals in East Greenland now as there were in 1997, and far fewer than there were in the 1950s.[234] That's a huge *actual* decline, not a predicted one. The hooded seal in East Greenland was listed as 'vulnerable' to extinction by the IUCN in 2008 and again in 2015, but oddly, that fact hasn't been making headlines.

Walrus

As the USA stands out as the only nation that insists Arctic seals will be harmed by future declines in summer sea ice, as noted above, it was all the more surprising that in September 2017, the US Fish and Wildlife Service announced it would not pursue a plan to list Pacific walrus as 'threatened' with extinction under the Endangered Species Act. Walrus experts concluded there was no evidence of on-going harm or an imminent threat to walrus survival, a view that now concurs with the IUCN Red List assessment.[235] Although the litigious Center for Biological Diversity sued the US Fis and Wildlife Service in 2018 for failing to protect the walrus, the case was dismissed by an Alaskan Federal Court in September 2019.[236] More recently, Lori Quakenbush of the Alaska Department of Fish and Game stated in 2019 that, for unknown reasons, in recent years there have been far fewer stampede deaths of walrus calves at Alaskan beach haulouts than there were a few years ago, even

though haulout numbers have been just as high (25,000 and 40,000 reported at Point Lay in September 2018 and September 2019, respectively).[237] Although walrus are not often actively hunted by polar bears, walrus carcasses can be an important source of food in late summer and fall: in the western Arctic bears have learned that initiating a panic stampede of walrus into the water (while they are on a beach or on the top of a cliff) is an easy way to kill a large number of individuals with little effort.[238]

7. Health and survival

Body condition

There has been no increase in the percentage of starving or dying bears in recent years compared to the 1980s, despite the hungry bear photos and videos that have gone viral on the internet. While such images have been used to make points about human-caused global warming and loss of Arctic sea ice, none of the photos circulated to date show bears that were unequivocally harmed due to reduced sea ice and lack of prey. One photo distributed in 2015 showed a Svalbard-area bear with a badly injured leg; a 2017 *National Geographic* video of an emaciated Lancaster Sound (Somerset Island) bear,[239] which later went viral, almost certainly showed an animal suffering from cancer or another malady that caused profound muscle wasting preventing it from hunting and thus causing it to starve. Bears in Lancaster Sound normally spend the summer fasting on land and there is no reason to expect that bears on the west side of Baffin Island, in Lancaster Sound, were doing any worse than bears on the east side, which have recently been doing well.[240]

Indeed, by August 2018, pushback from viewers[241] apparently prompted *National Geographic* to make a well-publicized apology on their website and in their magazine for the misrepresentation in that video, saying it had gone too far with its claim that 'this is what climate change looks like'.[242] In fact, there was no factual basis to support a link between climate change or sea ice and the bear's condition: local sea ice had not been unusually low in 2017; most bears in that region come ashore in August, and no other starving bears were seen. Not only was the video seen as a blatant piece of propaganda, it made viewers angry that nothing had been done to help the bear. Activist Cristina Mittermeier, a colleague of the videographer Paul Nicklen, who shot the film, admitted the footage of the emaciated bear was specifically taken to convey a message about climate change, but blamed *National Geographic* for the bad publicity.[243] Mittermeier also revealed details about the event that showed an even greater indifference to the suffering of the animal than anyone had imagined. Apparently, Nicklen spotted the bear days before his camera crew arrived and told no one. In addition, after shooting the video, Nicklen and Mittermeier watched the bear swim away without alerting local conservation officers of its plight or the danger it presented to local residents (starving bears are desperate and extremely dangerous). Overall, the incident educated millions of people that starvation is the leading natural cause of death for polar bears and put the public on notice that even an organization they thought they could trust is willing to throw ethical practices out the window when climate change is involved.

Female body condition of polar bears has been reported to be somewhat worse in a few areas (SB, SH, DS, BB), but not below threshold levels necessary for reproduction.[244] A recent mark-recapture survey for WH did not report female body condition, which means this metric has not been updated since 2007.[245] However, in SH, Martyn Obbard and colleagues determined that in the 2000s (captured in 2000–2005 and 2007–2009), females were on average were about 31 kg lighter than they were in the 1980s and males 45 kg lighter. However, the number of bears in the population did not decline over the same period, which suggests that the small decline in body condition reported was not significant to survival. [246] Previous research on WH bears captured between 1982 and 1990 stated that the critical weight for pregnant females was about 189 kg (below this weight, they lost the pregnancy).[247] Obbard and colleagues did not mention finding any SH mature females at or near this critical point in the 2000s, and considering that females can be over

300 kg by the time they come ashore in late summer,[248] it is therefore understandable that an average weight loss of 31kg would not have had an appreciable effect on reproduction. However, a more recent SH survey (in 2016) registered a population decline of 17%, said to be associated with sea ice loss (see details in SH section above). However, it did not report data on body condition of SH females or the length of the SH ice-free season; by the end of 2019, this data had still not been published. [249] If the decline in population size in SH was indeed a reflection of reduced sea ice and poor body condition of females (as claimed), why has the data on sea ice and weights of bears not been made public?

This failure to publish data on body condition of polar bears in SH follows the longstanding refusal to release similar data for WH bears. There has been no data published on body mass of lone females since 2004 or of adult males and females with cubs in WH since 1998,[250] even though the declining weights of bears is said to be evidence of the impacts of sea ice loss due to human-caused global warming on bears in the region since 1985.[251] Even a 2016 paper that reported 'fasting rates' of polar bears in WH did not include average weights of the 152 bears captured around Churchill, Manitoba by the Polar Bear Alert Program from 2009–2014,[252] although in a CBC documentary filmed in 2014 called *The Politics of Polar Bears,* conservation officer Bob Windsor stated that, except for a few skinny bears one year (he did not say which year, but it may have been 2010), all problem bears captured and held in Churchill's 'polar bear jail' during that time had been in very good condition.[253] Recording body weight is part of standard protocol when polar bears are captured, but while mark–recapture studies have continued in WH since 2007, data on weights of bears have not been included in the reports.[254] Despite this lack of data, claims about weight loss and cub survival due to reduced sea ice are still being made by polar bear researchers. For example, in an April 2019 interview with *Maclean's Magazine*,[255] senior Canadian polar bear researcher Ian Stirling made the following statement about the response of WH polar bears to recent Arctic sea ice loss:

> They're losing body condition. Reproductive rates have dropped. Survival rates of young have plummeted. Every indication you would expect from a declining population is there.

No capture–recapture data on the size of WH litters or the proportion of independent yearlings has been published since 1998, and no additional data on cub survival has appeared since 1992.[256] There are some data on litter size and proportion of independent yearlings based on aerial surveys, which may be broadly comparable to capture–recapture study data (see discussion below). However, cub survival metrics cannot be determined from aerial survey data, which means that Stirling's claim that sea ice loss has negatively affected cub survival in recent years is not supported by published data.

A recent paper reported that polar bear females in Southern Beaufort were having difficulty catching prey, and noted a lack of seal pups in the diet in 2014–2016. This had resulted in an uncharacteristic spring weight loss, likely due to a predictable repeat of the thick spring ice events that have impacted the region every ten years or so since the 1960s. As noted in Section 3, a survey of near-shore habitat in Alaska found dozens of bears in excellent condition after the spring feeding period, suggesting that since 2017, SB bears are no longer struggling to find enough food.[257]

Lastly, in the Svalbard region of the Barents Sea, data collected by Norwegian researchers and posted online up to the spring of 2019 shows no trend in the body condition of adult males (the only sex/age class reported) since 1993, despite the fact that this region has seen the most dramatic decline in summer sea ice of all 19 subpopulations (Figure 7).[258]

Hybridization

Claims of recent widespread hybridization of polar bears with grizzlies, known for years from the Central Canadian Arctic,[259] were disproven in 2016 and 2017.[260] No further hybrids have been reported since 2014. This should have put to rest the hybridization-caused-by-global-warming myths, but it has not. For example, the January 2018 issue of *National Geographic* and the 10 February 2018 issue of *New Scientist* both repeated claims about grizzly/polar bear hybrids that disre-

In Svalbard, there is no trend in the body condition of adult males since 1993, despite a dramatic decline in summer sea ice

garded new evidence.[261] At least one other online article along similar lines followed later in the year but, fortunately, such claims all but disappeared in 2019.[262]

Effect of contaminants

Contaminants have been shown to be present in polar bears, but have not been shown to have done any harm. Most of the data are from Eastern Greenland, where there has never been a polar bear population count. Even if harm could be shown to have occurred, no impact on population size could be inferred. One researcher undertook a long and extensive review of all the toxicology research done on polar bears to that date[263] and noted that:

> …published polar bear data included in this review are correlative and descriptive and therefore do not directly demonstrate contaminant mediated cause and effect relationships.

While it is true that some biological effects have been recorded for a number of substances – sizes of male (but not female) skulls, changes in gene function, reduced penis bone density – it has not been demonstrated that any of the changes documented have negatively affected health or population size. For example, there is no evidence that any penis bones of polar bears in East Greenland have broken in recent years due to low bone density. There is only a suggestion that this could, theoretically, happen at some time in the future if the trend in density continues.[264] In short, all of the so-called 'evidence' for negative effects of organic pollutants on East Greenland polar bears is currently circumstantial and inconclusive.[265] Similarly, a report in 2018 that found 'hundreds' of previously unknown toxins in polar bear blood received much media attention but nevertheless provided no evidence that these chemicals had or would present health risks to bears (or to those who consume polar bear meat).[266] Lastly, a 2019 study examined more than 300 publications on contaminants and toxins in polar bears and found that while many compounds had been shown to have biological effects, none of the studies proved evidence that contaminants had effectively harmed polar bear health or survival.[267]

Swimming bears

There have been no further reports of polar bear deaths due to drowning during the open water season between 2005 and 2019, and no evidence has been presented to show that long-distance swims are detrimental to the health or survival of polar bears.[268] One group of researchers found that bears in Hudson Bay made few long-distance swims (>50 km) in 2007–2012, and 60% of those started on pack ice and ended on land during sea ice breakup in July; more Beaufort Sea bears undertook swims than Hudson Bay bears, but 80% of BS swims took place before the September sea ice minimum, and bears started and ended their swims in the pack ice as they moved north with the retreating ice edge.[269] The media were impressed with the weight lost during a single long-distance swim made by a BS female and cub in 2008.[270] This feat was reported in 2011 and promoted again in 2017.[271] However, a comparison of the numbers show the female lost slightly less weight during her 63-day swim and subsequent walk over the ice (49 kg or 109 lbs) than a typical bear sitting on the shore of Western Hudson Bay in the summer (54 kg or 119 lbs or 0.85 kg per day).[272]

Furthermore, a study published in 2018 found that some Svalbard females – including a female with cubs –made notable long-distance swims and had astonishing diving capabilities.[273] These new data called into question the prediction made by Ian Stirling just a few years ago that because of their apparently limited diving abilities, polar bears would be unable to evolve rapidly enough to deal with the abrupt sea ice changes predicted for the future.[274]

Denning on land

There has been no statistically significant change in the proportion of Southern Beaufort females that make their dens on the sea ice (51%) versus on land or near-shore ice (49%) between the mid-1980s and 2013, despite marked increases in the length of the ice-free season.[275] Karyn Rode

and colleagues[276] examined factors that might have been responsible for the higher reproductive success of both Southern Beaufort and Chukchi Sea females that made their dens on land rather than sea ice, but considered only spring and fall snow fall amounts, autumn ice conditions, and spring and fall air temperatures; in other words, they looked at everything except sea ice thickness in spring and availability of newborn prey in spring, conditions which are known to have had a very strong negative effect on survival of bears in the Southern Beaufort from 2004–2006, almost certainly impacting near-shore or land-denning bears more than ice-denning bears.[277]

Ice-free period on land

In recent years, the SB has been virtually 100% covered by sea ice between June and November, and the majority of bears stay on the ice as it retreats north in the summer; only a small fraction (17.5%) stay on land.[278] Bears that spend all or a part of the summer on land seem to benefit from scavenging on the carcasses of bowhead whales that have been legally harvested by aboriginal residents,[279] although it is primarily males and mothers with cubs (not pregnant females) that use these resources.

Threats from oil exploration and extraction in Alaska

In 2018, renewed concerns were expressed regarding the risks to polar bears from planned oil exploration and extraction activities in the National Wildlife Refuge area of Alaska (ANWR).[280] However, less than half of the female portion of the SB population makes maternity dens along this area of the coast,[281] where they would be most at risk of disturbance. And biologists have found that while females are generally loyal to either land or sea for denning, as well as to a particular stretch of coast, they were not loyal to a specific place. Such flexibility is probably necessary because annual variations in weather, sea ice conditions and prey availability have always impacted bears' choice of where to den.[282] In other words, there is strong evidence to suggest that if drilling or other activities were to disturb a pregnant female at a particular den location one year, she simply would not try to den in that spot again. Moreover, it is unlikely she would den in the same spot even if she was *not* disturbed. In addition, the small proportion of the polar bear population that spends some part of the summer on land are concentrated at the whale bone piles at Kaktovik and a few lesser known beach sites, which should be easy for drilling and exploration crews to avoid. [283]

It is worth mentioning that earlier oil exploration and extraction activities – from the 1990s in the Eastern Beaufort (around Tuktoyaktuk in Canada) and from the 1970s in the Canadian High Arctic – were expected to cause a marked increase in the number of defense kills and unacceptable disruptions to denning.[284] But impacts on polar bears have been so minimal that we've heard virtually nothing about them.[285] Similarly, there has been the potential for oil-related activities to cause disruption to denning outside the ANWR, a little further west along the Alaskan coast at Prudhoe Bay in the National Petroleum Reserve (the largest oil field in the USA). But since exploration and extraction began at this site in the 1960s,[286] there have been virtually no problems with polar bears (either from disruption of feeding and denning activities or due to excessive defence of life or property kills).[287] More specifically, biologist Steven Amstrup looked at 20 polar bear dens located within the ANWR between 1981 and 1992 and found that, contrary to expectations, virtually all females were exceptionally tolerant of the kind of human activities associated with oil exploration and drilling (including aircraft, snow machines, seismic surveys, and oil field operations).[288] Overall, documents show the oil industry in Alaska and western Canada has a very good track record of dealing responsibly with polar bears through a combination of education and precautionary practices.[289] Despite this evidence, in March 2019 Amstrup (a former US Geological Survey biologist who now works for *Polar Bears International*) presented written testimony to the US House of Representatives that oil and gas development on the ANWR 'will accelerate the decline of the region's already imperiled polar bear population'.[290] Nevertheless, sales of oil leases were ultimately approved and are expected to go ahead in 2020.[291]

Table 1: Litter sizes estimated from recent autumn surveys.

Subpopulation	Litter size	Year	Reference
WH	1.63	2016	Dyck et al. 2017
WH	1.43	2011	Dyck et al. 2017
WH	1.50	1985–1992	Derocher and Stirling 1995
WH	1.62	1980–1984	Derocher and Stirling 1995
WH	1.56	1966–1979	Derocher and Stirling 1995
SH	1.56	2011	Dyck et al. 2017
SH	1.46	2016	Obbard et al. 2018
FB	1.54	2009/2010	Dyck et al. 2017
BB	1.55	2011–2013	SWG 2016:301, 321
KB	1.60	2012–2014	SWG 2016:552
KB	1.67	1992–1997	SWG 2016:552

Litter sizes

Within the three Hudson Bay subpopulations, litter sizes estimated from recent autumn surveys of cubs-of-the-year varied only slightly up to 2016 (Table 1). No trends in autumn litter sizes over time were found for BB bears between 1997 and 2013, and the mean 2011–2013 litter size (1.55) was was similar to FB in 2009/10 and to SH in 2011, where populations were considered stable.[292] For Kane Basin, mean autumn litter size in 2012–2014 was similar to WH in 1980–1984 and 2016. SH litter size had declined between 2011 and 2016 by a lesser amount (1.56 to 1.46) than WH litter size had increased over the same period (1.43 to 1.63). Does this indicate WH could be increasing in size and SH decreasing? That is presently unclear, in part because there were about twice as many SH females with litters in both 2011 and 2016 as there were in WH. No explanation for such differences in litter sizes have been suggested, but one point is abundantly clear: recent litter sizes have been nowhere as low as they were in WH in 1985–1992 (Table 1), except for WH in 2011 and SH in 2016.

Not included in Table 1 are data for Chukchi Sea litters reported by Eric Regehr and colleagues. This is because they were collected in the spring rather than autumn (2.18 for cubs-of-the-year and 1.61 for yearlings).[293] As noted in the CS status section, however, the rate of triplet litters in 2016 was almost 8%,[294] a frequency seen previously only in WH during the 1970s and 1980s (and rarely elsewhere). [295] Although polar bear specialist Nick Lunn claimed in 2018 that there had been no triplet litters since 1996 in WH (later he said he meant few, but that none had been seen in fall),[296] in fact two photos of triplet litters in fall have been posted on the internet in recent years: one in 2011 and another in 2018.[297] There are likely others that have not been seen or photographed.

Also not included in Table 1 are data for the Svalbard portion of the Barents Sea that have been collected by Norwegian Polar Institute biologists since 1993. These are collected in spring and also reflect only a portion of the entire Barents Sea subpopulation. However, in 2019, litter size for cubs of the year in Svalbard was found to be as high (2.0) as it had been in 1993, which was the highest litter size recorded over the 1993–2019 period.[298] The lowest litter sizes reported for Svalbard were in 2014 (1.33) and 1997 (1.43).

8. Evidence of flexibility

Den locations

In the Barents Sea, where in some recent years the sea ice has not returned to the east coast of Svalbard in time for pregnant females to access traditional denning areas in fall, it appears that the

bears affected have been sufficiently flexible to use the much colder, but still productive, islands of the Franz Josef Land archipelago instead.[299]

In Baffin Bay, females in 2009–2015 entered land dens a bit later in the autumn than they did in 1991–1997 (about 5 October vs 5 September) and made the dens at higher locations, but they emerged at similar times in both periods. However, no negative effects of these changes were noted.[300] According to one study conducted in 2013, while females that made maternity dens on land in the Southern Beaufort (about 51%) and the Chukchi Sea (about 84%) had a higher survival rate of cubs than those that made dens on the sea ice, it was not clear precisely why this was so.[301] Overall, however, flexibility in choosing where and when to enter a den is evidence that polar bear females have the biological plasticity necessary to survive changing environmental conditions.

Feeding locations

In 2013, fewer Baffin Bay females were traced moving south into Davis Strait in winter/spring to pursue harp and hooded seals than in 1997. Similarly, in summer, fewer bears visited Lancaster Sound – where there is often remnant sea ice to use as a hunting platform – than did so in the 1990s. More BB females in 2013 remained in the northern portion of their range during the ice-covered seasons than did so previously.[302] These changes in distribution of female bears appear to relate to feeding behaviour. While the authors of the study attempted to correlate changes in bear movements with changes in sea ice coverage between the early 1990s and the 2009–2015 period, there appears to have been no attempt to consider potential changes in prey availability, especially of harp seals, that may have taken place over that time.[303]

An older example of this kind of flexibility was the documented movement of bears and seals into the Chukchi Sea during the catastrophic 1974 and 1975 episodes of thick spring ice in the Eastern Beaufort.[304] In the 1960s, Christian Vibe also described seals and bears moving in response to decadal cycles of change in sea ice cover along the Greenland coast.[305]

More recently, feeding on whale carcasses left from Inuit subsistence hunting has been shown to benefit the small proportion of the subpopulation of polar bears that spend the summer on shore rather than on sea ice in the Southern Beaufort Sea.[306] However, aside from whale carcasses, there is little evidence that terrestrial foods make a difference to the body condition or survival of bears that spend all or part of the summer onshore in the ice-free season.[307] While polar bears have been documented eating a variety of foods while onshore, from ground-nesting birds and bird eggs to caribou, grasses, berries, and seaweed,[308] there is little evidence this makes any difference to body condition or survival over the short or long term.

Although the reasons for long-distance moves are often not clear, they do happen. A four-year-old female who had not yet given birth traveled from the Canadian area of the Southern Beaufort Sea to Wrangel Island in the Chukchi Sea after being captured and tagged in late April 2009.[309] Previously, another bear, an adult female with two cubs of the year, who was tagged in late May 1992, moved from off Prudhoe Bay in the Southern Beaufort Sea, crossed the Arctic Basin to within 2 degrees of the North Pole, and ended up in northern Greenland.[310]

Genetics

One recent, widely publicised genetics paper suggested there is evidence that polar bears have already started moving from the periphery of the Arctic towards a sea ice 'refugium' in the Canadian Archipelago region in response to recent declines in summer sea ice. However, a follow-up analysis that did not get any media attention found that 'methodological shortcomings' (including small and unbalanced sample sizes) and 'errors of interpretation' undermined the conclusions of the first study.[311] The second study did not find evidence of recent widespread movement towards the Canadian Archipelago, but did confirm the existence of a genetically unique cluster of bears in Norwegian Bay, as previously identified by other researchers.[312] Norwegian Bay is located at the north end of the Canadian Archipelago and, while it is dominated by multiyear ice, it has two large polynyas that have a few ringed seals and also support walrus and bearded seal populations.[313]

Anecdotal accounts from local Inuit suggest that Norwegian Bay bears are 'different' from those in the surrounding area,[314] thus corroborating the two independent genetic studies. It is possible this subpopulation contains descendants of a previous population since gone into decline.[315]

One of the most recent genetic studies[316] emphasized that the polar bear, as a species, survived more than one previous warm period when there was virtually no summer sea ice.[317] Sea ice has varied both over the short term (i.e. decades-long climate oscillations) and the long term (glacial-to-interglacial cycles of thousands of years). Over the last 1.5 million years, for example, there have been periods of much less ice than today (including ice-free summers), but also periods with much more ice but no biological extinctions.[318]

Polar bear population numbers may have fluctuated up and down somewhat in conjunction with these sea ice changes, but the polar bear as a species survived, and so did all of the Arctic seal species they depended on for food, including Pacific walrus.[319] The survival of polar bears through these large changes in sea ice cover indicates that these Arctic marine mammals, in an evolutionary sense, have the necessary built-in flexibility (called '*plasticity*' in biology jargon) to survive in their highly-variable habitat.[320] Although some have suggested that the low genetic diversity of polar bears makes them especially vulnerable to extinction,[321] there is little support for this notion in the scientific literature.[322]

A study published in 2019 found a few genetic differences (gene copy numbers) between polar bears and brown bears that were interpreted as reflecting the evolutionary shift by polar bears to an extremely carnivorous diet.[323]

9. Human/bear interactions

Attacks on humans

A major 2017 scientific summary of polar bear attacks on humans (1880–2014), authored by biologist James Wilder and colleagues,[324] concluded that such attacks are extremely rare and that the threat to human safety from polar bears is exaggerated. However, this may be because they essentially ignored attacks on Inuit and other indigenous people that live and hunt in the Arctic. By attempting to generate information that could be assessed with statistical methods, the authors ended up with data so skewed and incomplete that it does not provide a plausible assessment of the risk to humans of attacks by polar bears. Acknowledging that well-reported attacks on Europeans (or recorded by them) make up the bulk of the data used in the paper does not adequately address the weakness of the authors' conclusion that polar bears are not particularly dangerous.

This means that, except for well-reported incidents in the last few decades, virtually all attacks on the people most likely to encounter polar bears were not included in this study and the authors discount the almost perpetual danger that Inuit and other indigenous people endured – and still endure in many areas – because those people in the past existed in 'relatively low numbers.'[325] As discussed below, two Inuk hunters in Canada who were mauled to death by polar bears in 2018 are prime examples of these shortcomings.

The Wilder paper focused much attention on the potential for increases in polar bear attacks on humans due to sea ice loss blamed on human-caused global warming,[326] but ignored totally the increased risk stemming from the relatively larger proportion of adult males in polar bear populations nowadays, a fact of life in growing populations, but also a function of hunting restrictions. Adult males dominate younger ones, and frequently steal their kills,[327] which can cause young bears to become nutritionally stressed and at risk of attacking humans. In fact, Ian Stirling warned in the early 1970s that a complete hunting ban, such as Norway had just imposed in Svalbard, might increase polar bear–human conflicts.[328]

The drive to put on fat means that polar bears are always looking for food, and even well-fed bears have been known to initiate a predatory attack (as the discussions below show). Bears are

attracted by caches of frozen meat, cemeteries, odours of cooking food, food fed to dogs and the dogs themselves, livestock, stored food, garbage and sewage, as well as man-made petroleum products and other industrial material (such as oils and lubricants, vinyl seats and plastic-coated cables), antifreeze and insulation.[329]

Unusual sightings, problem bears and attacks

The incidents mentioned in the following subsections – separated into winter/spring (January–March and April–June) and summer/autumn (July–September and October–December), by geographic region – are anecdotal, and are not part of any comprehensive survey that would make them scientifically significant. However, until such a survey is undertaken, they are noted here for perspective on the reports of unusual sightings of bears, problems with bears and bear attacks on humans that often garner wide media attention.[330]

Winter/spring

Winter is the leanest time of year for polar bears (Figure 8), since fat Arctic seal pups won't be available for another 2–3 months and food is therefore hard to come by; this makes the bears especially dangerous when they come into contact with humans.[331] By spring, they are in hunting-mode, as they pack on as much fat as possible to aid their survival over the summer months of fasting, and humans do well to avoid being the focus of these hunts.[332] Even well-fed bears continue to seek out sources of food.

Although, over the last few decades, winter and early spring incidents have been relatively rare, there are now larger numbers of polar bears than there were in the 1970s as well as more people living in coastal Arctic communities. This means that problems with bears in the coldest months are likely to increase. More bears out on the ice in winter and spring will almost certainly create more competition for the available seals. As a result, some bears – especially young bears or females with cubs – might look for alternative sources of food.

Alaska 2019 problem bears winter/spring

In early January 2019, a trapper from Arctic Village, which lies about 100 miles south of the Beaufort Sea coast, arrived at his trap-line cabin to find that a polar bear had damaged much of his winter camp and destroyed the vinyl seat of a snow machine.[333] The next morning, the bear returned and came at the man when he opened the door of the cabin. Fortunately, he was able to get to his rifle in time and shot the young female (estimated at about 2 years old) as it advanced on him in the dark. The condition of the bear was not reported. Although it is unusual to encounter a polar bear so far inland in Alaska (even pregnant polar bears looking for denning sites do not usually travel so far south), sightings of polar bears were noted to have occurred in 2002 (Toolik Lake) and 2008 (Fort Yukon). However, as the 2019 incident occurred in January, it could not be blamed on lack of sea ice.

Russia problem bears winter/spring

In February 2016, a female and two cubs in good condition were filmed rooting through garbage bins in an unidentified coastal community in Chukotka (Russian Far East) before being chased away with a truck.[334]

In February 2019, an invasion by more than 50 polar bears was reported in the Western Russian town of Belushya Guba, on the southwestern coast of Novaya Zemlya. However, as this incident began in December (still autumn in the Arctic), I discuss the details in the summer/autumn section.

On 17 June 2019, a thin polar bear wandered more than 1000 km south of the eastern Kara Sea into the Siberian town of Norilsk. This had happened at least once before, in the 1970s. Charts issued by the US National Snow and Ice Data Center for early June (around Julian day 155) show abundant ice in the eastern Kara Sea, which means this incident cannot be blamed on lack of sea ice. It was reported the bear would likely be moved to the zoo in Krasnoyarsk.[335]

Svalbard 2017–2019 problem bears winter/spring

In late January 2017, a polar bear female with two cubs (possibly two-year-olds) were reported near the community of Longyearbyen on the west coast of Svalbard, where there was no sea ice. The bears probably traveled overland from the east coast where spare sea ice existed. The bears were not reported to have been thin, starving, or in poor condition, and had thus far not caused any problems aside from frightening people. Helicopters and snowmobiles were used to chase them away from the community but, even so, the bears remained in the vicinity for several weeks.[336]

In 2018, by early January, ice extended as far south as Hopen Island, a remote location used by females for denning in favourable ice years.[337] In March, a meteorologist stationed on Hopen reported seeing a total of fourteen bears, including females with cubs, during a 24-hour cross-country ski trip to a small cabin 7 km from where he worked. Two bears looked into the window of the cabin while he was inside and another followed him as he skied back to his work station, coming so close to him and his two dogs that he had to fire a warning shot to make it move off.[338] Although ice surrounded Hopen Island by mid-February in 2019, no polar bear sightings were reported.

In early March 2019, a polar bear in good condition was photographed on Bear Island (Bjørnøya) in the southern Barents Sea by the crew at the meteorological station. The last time the workers had seen a bear was in 2011, but in 2019 extensive winter ice brought at least this bear to the northern part of the island (others may not have been seen). Ice extent had not been so extensive in winter since before 2007 and it persisted in 2019 for several weeks.[339] Lastly, in the final days of 2019, a polar bear in excellent condition repeatedly entered the downtown core of Longyearbyen between Christmas and New Year. It was shot for safety reasons in the early hours of New Year's Day 2020, because there were no qualified personnel available to relocate it.[340]

S. Hudson Bay/Foxe Basin 2017–2019 problem bears winter/spring

A 'very fat' polar bear was reported outside the community of Inukjuak, on the east coast of Hudson Bay, on Saturday 25 February 2017.[341] Inukjuak lies within the boundary of the Southern Hudson Bay polar bear subpopulation. This was a rare occurrence: according to the mayor, the community had not seen a bear onshore in nearly 30 years. The bear was a young, subadult female in excellent condition, but it was shot for safety reasons. Its condition was surprising, as subadults are likely to be in poorer condition than adults at any time of year, due to their lack of hunting experience and competition with adult males.[342] Polar bears in Hudson Bay travel with the retreating ice to the western and southern shores so, with some exceptions, they usually only have access to the east coast during winter through spring.

A few weeks later, in early March 2017, there was a late-night encounter with a thin and hungry polar bear in the northern Quebec community of Ivujivik on the eastern edge of Hudson Bay (within the Foxe Basin polar bear subpopulation region). The bear involved was thin and obviously dangerous, but had to eliminated before anyone was hurt. It became the fourth defence kill of 2017 (and the second that month) for this community, coming after a large number of bear sightings by residents that winter.[343]

In 2018, on the 4 March, a young polar bear, perhaps only two years old, came ashore and wandered about the village of Puvirnituq, on the northwest coast of Hudson Bay in northern Quebec (Foxe Basin).[344] It was shot for safety reasons by a local hunter. This was the first time a bear had ever come into the community in living memory and residents suggested a big storm the night before may have caused the animal to become lost.

In 2019, further north in the Foxe Basin region, a female and her cub were shot in the small community of Igloolik on 4 January. After a fatal attack the previous August outside the nearby community of Naujaat (see next section) had shown that females with cubs do sometimes make predatory attacks, a resident shot the bears when they entered the settlement. It was considered a defence kill.[345]

Labrador and Newfoundland 2017–2019 problem bears winter/spring

After only about a half dozen sightings in 2016, in 2017 there were well over a dozen reports of polar bears onshore in Newfoundland and Labrador,[346] as unusually cold conditions and heavy sea ice offshore persisted late into June.[347] Considering Newfoundland alone, one or two bears have been reported every spring since about 2012, but they were rare back until at least 1880.[348] However, there were more than half a dozen sightings in Newfoundland (involving at least nine bears) from March onward in 2017,[349] and sightings and problems with bears were even higher in the spring of 2018, although there were fewer Labrador incidents (especially in January and February). March 2018 was particularly busy:

- on the 6th, a bear in good condition strolled through the streets of St. Lunaire-Griquet on the Northern Peninsula of Newfoundland;[350]
- on the 7th, police in Elliston (outside Bonavista in northeastern Newfoundland) found footprint evidence of an onshore visit;[351]
- on the 8th, four bears in good condition (likely a mother with a triplet litter of almost-grown cubs) were spotted on shore outside of Red Bay on the Labrador coast;[352]
- from the 10–14th, perhaps as many as seven (but at least four) bears in good condition were spotted in or around communities on the Northern Peninsula;[353]
- on the 14th a bear was spotted on Fogo Island off Newfoundland.[354]

On the 2nd of April, 2018 another bear in good condition was spotted onshore outside of Bonavista, Newfoundland.[355] After that incident, there were several others later in the season: assisted by lingering ice offshore, a bear in good condition came ashore near St. Lunaire-Griquet on the tip of the Northern Peninsula on 10 June (perhaps delivered by an iceberg),[356] at least three bears including a mother and cub (and perhaps four altogether) were spotted around St. Anthony (also on the tip of the Northern Peninsula) between 21 and 24 June,[357] and lastly, a bear was removed from the community of Makkovik on the coast of Labrador for safety reasons on 5 July.[358]

On 1 January 2019, the winter polar bear season in Labrador began when one of two bears sighted near the garbage dump used by the coastal community of Makkovik was tranquillised and airlifted out of town; its condition was not reported.[359] A few weeks later, another bear was reported in Black Tickle and, at the end of February, a bear spent a few days on the prowl around the towns of St. Lewis and nearby Charlottetown, right at the time the only road in and out of St. Lewis was closed due to heavy snow.[360] There were no more reports of bears in Labrador until 15 April, when about ten bears were spotted prowling around the town of Black Tickle: photos of a few of the bears show animals in excellent condition. More worrying was the report on 17 April of a bear (one of four spotted in the area at the time) that aggressively circled a small summer cabin in Batteau (outside Black Tickle), growling and hissing through the window at the occupants and unfazed by gunshots in the air. A neighbour finally managed to drive the bear off, but not before it had destroyed the vinyl seat of one of the snow machines parked nearby.[361] In early May, a resident of Natuashish (north of Makkovik) took some photos of a female bear with fat cubs he encountered on a snow machine trip to one of the coastal islands nearby: all were in excellent condition and non-threatening.[362] The final sighting of the season came on 22–23 May, when a fat bear was photographed several times around the community of Blanc-Sablon near the Labrador border with Quebec at the south end of the Strait of Belle Isle (which was still choked with ice).[363]

In Newfoundland, the first report of 2019 came on 15 April, when a bear was spotted around Wesleyville and nearby Newtown (in the Bonavista area, on the northeastern coast); photos of the bear taken by residents show it was in excellent condition.[364] A week or so later, on 23 April, one bear in good condition was sighted swimming around Cook's Harbour on the tip of the Northern Peninsula and prowling the town, while another fat bear was spotted on the northeast coast of Newfoundland, at Carmanville (across from Fogo Island).[365] On 5 May a bear in good condition was spotted swimming about 2 km off the north-central coast (at Harry's Harbour), headed north to an ice floe about 40 km away.[366] By the third week in May, there was only a remnant of ice remaining around the tip of the Northern Peninsula, but on 21 May a bear in good condition was spotted on

the shore near Fleur de Lys on the Baie Verte Peninsula, Newfoundland, well south of the remaining ice, perhaps delivered there by an iceberg.[367] However, it wasn't the last: on 11 June, a sighting of a bear was confirmed near Cook's Harbour on the Northern Peninsula well after sea ice had cleared the area (perhaps having arrived on an iceberg), and it is not known if the bear made it successfully to ice lingering off the Labrador coast.[368]

Therefore, a minimum of twelve polar bears were spotted onshore in Newfoundland in 2018 – and perhaps as many as sixteen– not counting those seen in Labrador (which may not always make the news). This figure surpassed the nine bears recorded in 2017 and the six spotted in 2019. Sea ice around Newfoundland and southern Labrador was somewhat less persistent in 2018 and 2019 than in 2017: ice cleared the northern peninsula of Newfoundland by late May in 2018 and 2019, compared to about the middle of June in 2017. [369] However, variable ice conditions are unlikely the reason for the marked increase in polar bear sightings over the last three years compared to previous years; 2007 was a heavy ice year like 2017, yet no polar bears were reported ashore in Newfoundland that spring.[370] A larger population of bears is the most plausible explanation.[371] It is known that the Davis Strait subpopulation was heavily impacted by commercial whalers in the late 1800s and early 1900s[372] and is still recovering.[373] Abundant prey in the form of harp and hooded seals,[374] as well as competition among a thriving population of bears for those seals, may only now be encouraging individuals to wander to the southern limits of the region.

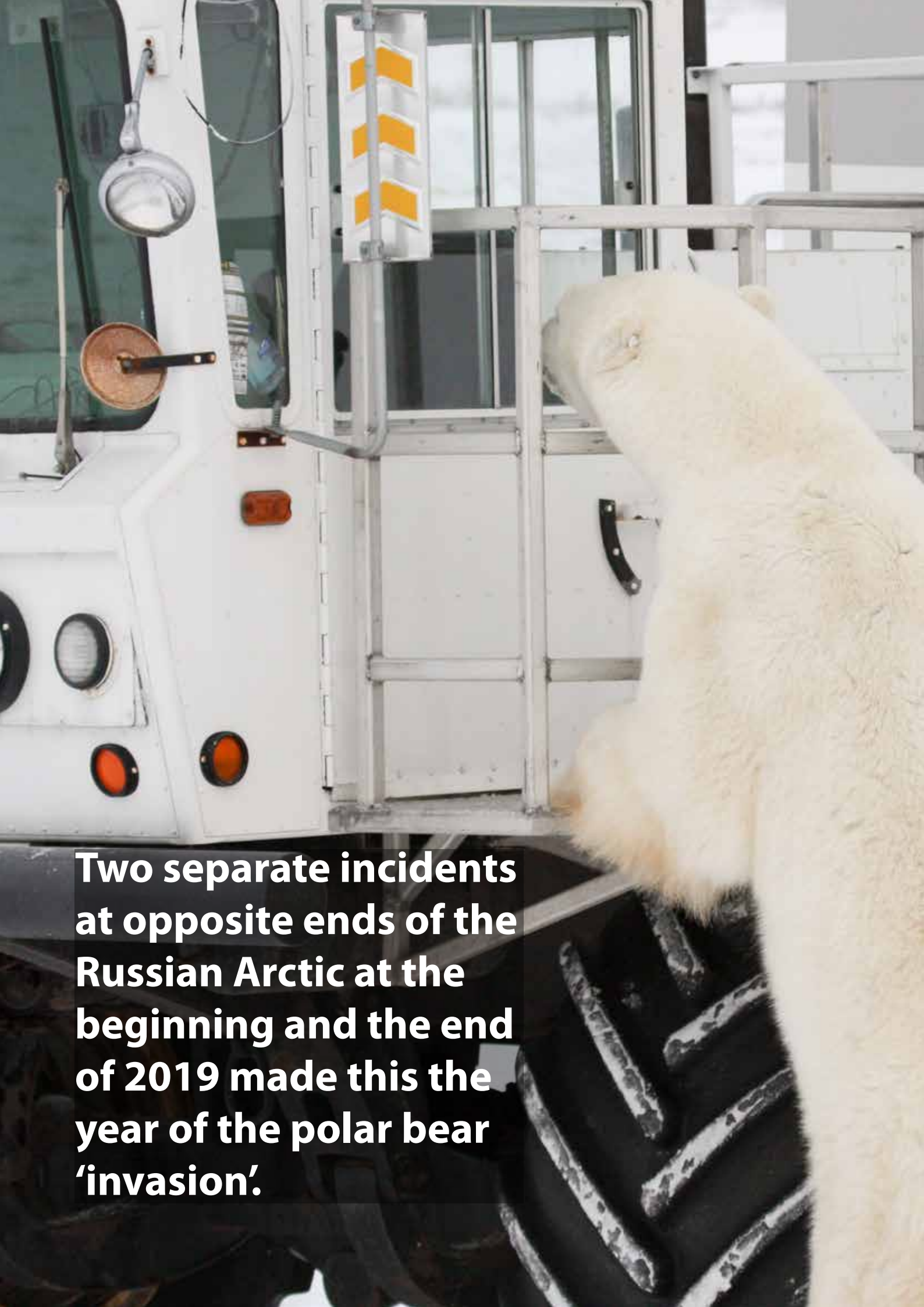
Summer/autumn

In areas where all or a portion of the subpopulation comes ashore during the ice-free season, the usual dynamic between polar bears and humans is different to what is seen in winter. For five months or so in some regions, but less in others, encounters between bears and people are much more likely in summer and autumn. Compared to sixty years ago, when hunting restrictions were put in place, there are many more bears and also more people. While serious attacks have always been relatively rare in summer, the number of bears shot or removed before tragedy strikes (especially in remote regions) have only recently been closely tracked.[375] For example, since polar bears have been protected in Canada, defence kills in Nunavut have been counted as part of the yearly quota of bears that a community is allowed to hunt, so they were rarely reported as something other than a legal harvest. The same may be true in Greenland, where bears are also hunted by native residents. In contrast, in the 1960s and early 1970s, many 'problem' bears in the community of Churchill, Manitoba were shot every year in defence of life or property, but presumably all were officially reported.[376]

There were two fatal attacks in 2018 in the Canadian Arctic at the height of summer, with a third near-fatal mauling in Svalbard shortly after. [377] These attacks put Arctic communities on edge, and people were perhaps more cautious afterwards, which may explain why there were no fatal or near-fatal attacks in 2019. However, in Russia two mass congregations of bears near small coastal communities in late autumn threatened the safety of local residents: one began in December 2018 and continued into February 2019, and the other occurred in early December 2019. Overall, there were fewer incidents in Churchill, Manitoba in 2019 than in 2017 or 2018 even though ice conditions were similar.

Russia 2017–2019, problem bears in summer/autumn

In Western Russia, in early December 2018, more than 50 polar bears congregated in the Russian military town of Belushya Guba on the southwest coast of Novaya Zemlya on the Barents Sea. By early February 2019 they presented a real threat to human safety.[378] The bears, which included mothers with cubs, were likely members of the Kara Sea subpopulation and had traveled across the narrow island from the east coast where sea ice is more persistent. Photographs showed bears in good or excellent condition congregated at the town dump, wandering through the streets, and entering buildings. People reported being attacked or threatened and the usual deterrents employed to drive them off were not successful.[379] Town officials were refused permission to shoot



Two separate incidents at opposite ends of the Russian Arctic at the beginning and the end of 2019 made this the year of the polar bear 'invasion'.

any of the animals, as in Russia polar bears are strictly protected. Although lack of sea ice was blamed by many for the invasion, ice charts demonstrated that these habituated garbage bears had failed to return to the sea ice present on the Kara Sea coast in late November and did not leave of their own accord in early February when ice had formed off the southwest end of the island.[380] By 18 February, a few days of persistent harassment, including help from the army, drove all or most of the bears out onto the ice offshore (it was unclear from the reports if any of the bears were killed in the process).[381] There had been no media reports of such massive 'invasions' of bears before this one at Belushya Guba, although it is likely that similar problems involving fewer bears have been an issue for years, given the obvious attractant of a garbage dump adjacent to a town within prime polar bear territory and a totally protected polar bear population.

In early December 2019, in Ryrkaypiy, Chukotka, in the Russian Far East, up to 72 polar bears came ashore for the summer and descended on the town to scavenge fat from the accumulated carcasses of hundreds of walrus that had died naturally in September and October. This was not a new phenomenon but the large number of bears involved in 2019 was a surprise and, in contrast to the problem in Belushya Guba, the attractants were natural rather than human-generated. Ryrkaypiy is similar to Churchill, Manitoba: both human settlements are about the same size and are situated close to where many polar bears wait for sea ice to form in the autumn. Sea ice advances from the west along the Chukotka shore and bears that have spent the summer onshore east of Ryrkaypiy move toward the village to intercept the first ice that forms offshore so that they can resume hunting seals (although relatively few Chukchi Sea bears spend the summer on the coast of Chukotka).[382] Ryrkaypiy is also within a few kilometres of a haulout site for thousands of Pacific walrus, known historically since the late 1800s.[383] Since 2007, large herds of walruses – mostly mothers and calves, and in some years numbering close to 50,000 – have spent a few weeks or more resting on the beaches at the base of the impressive rocky headland of Cape Schmidt.

The polar bears – initially reported to number 56 invididuals (then 63, then 72), including adults, females with cubs, and subadults – were photographed feeding on the carcasses of dead walruses.[384] Problems arose because some of the bears left the walrus feeding area and wandered into town only a few kilometres away; it was later revealed that the bears causing problems within the village were young, subadult animals driven away from the walrus carcasses by bigger, older bears.[385] Sea ice charts show the ice along the coast at Ryrkaypiy by the end of November (day 334)[386] was as thick and concentrated as ice is along Western Hudson Bay when polar bears take to the ice to resume hunting in autumn,[387] suggesting the bears were motivated to stay ashore by the presence of abundant walrus carcasses. The photographs that accompanied these reports showed virtually all the bears were fat and healthy. A similar congregation of polar bears occurred in early November 2018, but only about 25 bears were involved, with perhaps half that number entering the village; the army was called in to help move some of the walrus carcasses further away from the community.[388] In September 2017, about 20 bears near Ryrkaypiy were reported to have driven a number of walrus over the Cape Schmidt cliff and that hundreds of walrus were killed in the resulting stampede to the water; the carnage was eventually made public in a BBC documentary in late 2019.[389] The report that a bear had confronted another team of filmmakers at the top of the Cape Schmidt cliff in September 2019, plus the December 2019 congregation near Ryrkaypiy by three times as many polar bears feeding on numerous recently-dead walrus carcasses, suggests that the hunting strategy used by polar bears on walrus at Cape Schmidt and captured on film by the BBC in 2017 remains in use.

Research on land use of Chukchi Sea polar bears in summer provides no insight into this phenomenon (probably due to small sample sizes); there appears to have been a marked *decrease* in the proportion of bears spending the summer on land in Chukotka since the 1980s (0% of bears captured in 2008–2013 compared to 15% in 1986–1995).[390] However, the walrus carcasses at Ryrkaypiy are so plentiful that it is simply not necessary for the bears to leave land, even if sea ice is present. As a consequence, the autumn polar bear problem at Ryrkaypiy is unlikely to go away un-

less the carcasses of all walrus that die in September and October are removed, and this may prove impractical.

Alaska 2019 problem bears summer/autumn

The small hamlet of Kaktovik on the north coast of Alaska has an annual problem with polar bears attracted to the butchered carcasses of bowhead whales discarded by local residents. Although these 'bone piles' are not quite a completely 'natural' food attractant like the walrus carcasses of Ryrkaypiy, indigenous people of this area have hunted bowhead for millennia. In August 2019, there was a close call when a bear approached two young girls playing in their yard. It was chased away without further trouble. Bears were spotted as early as May and June in 2019, compared to mid-August most previous years (ahead of the whaling season in September).[391]

W. Hudson Bay/Foxe Basin 2018 fatal bear attacks in summer/autumn

The first 2018 fatal attack by a polar bear occurred in early July outside the community of Arviat, an Inuit hamlet of more than 2,600 residents that sits 250 km (about 155 miles) north of Churchill on the northwest shore of Hudson Bay. On the evening of 3 July 2018 (about 7:30 pm), 31-year-old Aaron Gibbons was mauled to death by a polar bear on Sentry Island, a barrier isle about 10 km offshore from Arviat ('Eskimo Point' on old maps). The attack occurred when a polar bear started to stalk one of Gibbons' three young children, who were on the island with their father to collect Arctic tern eggs. Gibbons put himself between the kids and the bear so they could run to the safety of their boat. Gibbons was subsequently mauled to death while his children watched and his terrified daughter called for help on the boat's radio. Unfortunately, he did not have his gun at hand at the time and died soon afterward from his injuries. Another person on the island heard the screams from Gibbons and his children and ran over to shoot the bear. It was an adult male and conservation officers who later examined the body described it as in 'fair' condition.[392]

In contrast, the last fatal attack in WH also happened in early July 1999, near Rankin Inlet. Two people were seriously injured and another mauled to death by a young bear, about one and a half years of age, which had probably just left the care of its mother.[393] Bears weaned in their second spring were less common in WH by 1998 compared to previous decades, but still made up between 15–20% of all yearlings captured.[394] Young bears 2–4 years old are notoriously unpredictable and dangerous.[395]

And while the bear that killed Aaron Gibbons must have left the sea ice much earlier than usual, perhaps as early as the third week of May, he was not forced ashore by receding ice. There was still abundant ice remaining on Hudson Bay in late May. But for some reason, the bear chose to leave the ice near Arviat in the northwest portion of Hudson Bay rather than continue hunting seals until late June or early July as most other WH bears did that summer (when they left the ice near Churchill or points south).[396] According to local informants, perhaps as many as a dozen other bears were in the general area of Arviat at the time of the attack, suggesting some attractant – perhaps the tern eggs sought by the Gibbons family, perhaps eggs and fledglings of other waterfowl that nest in the area – gave these bears a reason to come ashore much earlier and much further north than the rest of the population.[397] Shortly after the fatal attack, another bear was shot because it repeatedly approached a group staying in cabins outside Arviat and refused to be deterred by warning shots.[398]

The second fatal attack of 2018 occurred a bit further north, at the southwest edge of the Foxe Basin polar bear subpopulation region, on the morning of August 23. A party of three Inuit hunters from the community of Naujaat had boat trouble on the first day of a planned three-day hunting trip on 21 August. They took refuge on nearby White Island, but hours later, wind blew extensive ice onshore and they were prevented from leaving. On the morning of the attack, as they awaited rescue (knowing they would soon be reported overdue), the three were having their morning tea when an adult female polar bear accompanied by a yearling cub came at them. Leo Ijjangiaq fired a warning shot but the bear grabbed Laurent Uttak by the head. But when Darryl Kaunak tried to

run away, the bear turned on him instead. She mauled Kaunak until he was nearly dead. Ijjangiaq's rifle had jammed after the warning shot but as soon as he found another rifle, he shot the bear dead, then the cub. His friends administered first aid, but Kaunak died a few hours later. Attracted by the carnage of three bodies on the ground, more bears came around and threatened the survivors; Ijjangiaq killed two of them. The Canadian Coast Guard icebreaker sent to rescue the men could not get through the thick ice to their location but they were eventually spotted by the ship's helicopter and taken to safety – three long days after the attack.[399]

Conservation officers later said three of the four bears found at the site after the rescue were in good condition (the carcass of the fourth could not be located). There had been an abundance of sea ice in the region at the time: the bears were not 'forced' off the ice, nor were any of them starving. The men were not near a community full of attractants, nor were they surrounded by meat or refuse from hunting activities (since they had not yet been hunting). The fact that this was an attack by an adult female made this incident especially disturbing, since most polar bear attacks are initiated by young males in poor condition.[400] This female appeared to be fearless, and the presence of a cub almost old enough to fend for itself was not likely a factor, since polar bears are not especially protective of cubs older than newborns just out of the den.[401]

Local Inuit blamed both attacks on an increased abundance of bears and, perhaps, bears habituated to the tourists that flock to the Churchill area to see bears up close. However, at least three polar bear specialists said the attacks were caused by lack of sea ice.[402] But trends of generalized sea ice decline do not explain local conditions at the times the attacks took place: state of the sea ice was not a plausible factor in either incident. However, because of the wide margins of error involved in estimating population sizes, it is entirely possible that the Inuit are right: that actual numbers of WH bears on the ground have increased since 2012 or so (about the time Arviat noticed more bears), even if the reported 'mean' of official counts had declined slightly (see Section 3). At the same time, or alternatively, a redistribution of WH bears may have occurred, with more bears now spending most of their time to the north of Churchill (and thus active close to Arviat and Rankin Inlet) than did so in 2004.[403]

Western Hudson Bay problem bears in summer/autumn

All Western Hudson Bay polar bears are forced ashore by melting ice in the summer and Churchill, Manitoba is located near a primary staging area for many dozens of bears that wait for the ice to form in the autumn. Churchill's problems with polar bears extend back to the 1960s and it took time and money for them to become as well-managed as they are today.[404] Here are tallies made public by the Polar Bear Alert Program at the end of the season for 2015–2019:

- 2019 (week of 11–17 Nov), 138 incidents
- 2018 (week of 5–11 Nov), 246 incidents
- 2017 (week of 20–26 Nov), 148 incidents
- 2016 (week of 5–11 Dec), 386 incidents
- 2015 (week of 16–22 Nov), 333 incidents.

Some of the differences between years for reported polar bear incidents may be due to the fact that the numbers of bears that congregate around Churchill inexplicably vary from year to year, a fact noted as early as the 1970s.[405] While a late freeze-up of sea ice, as occurred in 2016 (and also in 1983), understandably boosts the number of problem bear encounters and the potential for fatal maulings (as occurred in 1983), the large number of incidents in 2015 occurred in part because of a newly-initiated 'zero-tolerance' policy for bears near town after a serious mauling in 2013.[406]

Southwest Greenland 2019 bear attacks in summer/autumn

In mid-September 2019, three hunters were attacked by a polar bear near Ummannaq in south-

west Greenland (across from Baffin Island) as they were butchering a musk ox they had hunted. The skinny bear attacked each of the hunters, one by one, until one of them managed to get to a rifle and scare the bear off. Another bear was shot the week before in a nearby community when it was deemed to be a threat. A third was sighted in another community.[407] These events in southwest Greenland are unusual: virtually all Baffin Bay bears spend the ice-free season on Baffin Island or near Melville Bay in northwest Greenland, where the ice lingers longer in summer and returns sooner in the fall. [408]

Svalbard 2018 bear attacks in summer/autumn

A serious attack occurred on 28 July 2018 when a contingent of four polar bear guards from the German cruise ship *MS Bremen* went ashore on a remote island in the Sjuøyene group north of Svalbard to check for the presence of bears before tourists from the ship would be allowed ashore to watch birds; the shore leave was not for observing polar bears, as bears were only viewed from aboard the ship.[409] One of the guards was ambushed and disabled by a bear before he could protect himself. Warning shots from his colleagues did not deter the animal, which was subsequently shot by one of the other guards but not before the victim suffered serious head injuries.[410] Pictures of the bear showed he was an emaciated adult male, age undetermined, in much the same condition as the Canadian bear promoted in the *National Geographic* video that caused so much trouble a year earlier – which shows just how dangerous a starving bear can be.

Even by December 2019, as far as is known, no details of the necropsy of the Sjuøyene bear have been released. However, it seems likely that if he hadn't been shot, the bear would have died a natural death from starvation within weeks of the attack. Most bears are in their best condition at that time of year and the fact that he was so very thin suggested he had not been in good condition when he came ashore or had been ashore for many months. Lack of sea ice due to climate change cannot be blamed for his pitiful condition (although some have tried),[411] because most bears in this region choose to remain on the ice throughout the summer and autumn months, where they can continue to try to hunt seals. The bear made a poor decision to leave the ice because he became stranded when the ice retreated.

The enormous hue-and-cry generated by environmentalists and anti-hunting factions on social media and in the news over the death of the Sjuøyene bear in 2018 dwarfed the media responses to the deaths of two Inuk hunters in Western Hudson Bay and Foxe Basin described above.[412] Most of the people who got angry about the Svalbard mauling were simply misinformed: based on early but incomplete reports of the incident, they thought, incorrectly, that ecotourists had come to the island to view polar bears and shot a bear that came too close. However, the accusation from some of the Inuit in Nunavut that people care more about polar bears than they do about people whose lives are threatened almost daily by their presence[413] seemed substantiated by the disproportionate outrage prompted by the death of the Svalbard bear. Inuit residents of Nunavut were also angry that their lives were being put at risk from polar bears all year round, in the here and now, while scientists continue to focus on protecting bears from becoming extinct decades from now.[414]

Svalbard 2018–2019 problem bears summer/autumn

In late spring 2018 (3 June), a bear in good condition broke into the storage cabin of a remote luxury hotel about 90 km west of Longyearbyen (on the tip of the fjord) by pushing open a newly-installed garage door that somehow closed behind it. The bear ripped into garbage stored there and consumed bags and boxes of food and chocolate. He finally left through one of the many windows he had broken. According to the hotel manager, the garage door used to gain entry to the storage area needed replacing because a visit by another bear in February had destroyed the old one.[415] Near the small community of Ny-Ålesund a single bear was responsible for breaking into at least ten cabins between July and October 2018: it broke windows and doors, broke through a wall and destroyed mattresses, although no food was stored in any of the cabins.[416] And in September

2018, a bear destroyed tents at a youth camp at Ymerbukta but no one was hurt.[417]

In August and September 2019, there were numerous reports of problem polar bears near Longyearbyen: bears vandalised a large number of local cabins, others threatened a local dog kennel at least twice, and another bear severely damaged a motorboat and its rubber dingy. None of the bears involved were described as skinny or thin and the bear that destroyed the boat was shown by photographs to be in good condition.[418] The local perception from media reports seemed to be that problems with bears in the summer had increased over previous years, although records of all incidents are not publicly available.

Labrador and Newfoundland 2017–2019 problem bears summer/autumn

In 2019, there was a rare late autumn (or early winter) visit of a polar bear to northern Newfoundland at Green Island Cove, just north of the ferry port of Saint Barb on the Northern Peninsula, on New Year's Eve. This was surprising because sea ice extent along the Labrador coast had been scarce up to that time. The bear left the area without incident.[419]

10. Discussion

Table 2: Counts not yet delivered.

	Count completed	Previous count
M'Clintock Channel	2016	284
Viscount Melville	2014	161
Southern Beaufort	2017	907 or 1215*
Gulf of Boothia	2017	1592
Davis Strait	2018	2158

*See p.10

Despite the fact that in 2019, summer sea ice levels declined no further than 3–5 mkm^2, as they have since 2007, it is not yet clear if global polar bear numbers continued to increase (albeit slowly) or not.[420] Studies published in 2018 put the mid-point estimate at about 29,500 bears, with a wide margin of error, although much higher and lower estimates have been presented.[421] However, by the end of 2019 the results of five subpopulation surveys completed by 2018 had not been published (Table 2), which means that the most up-to-date total could be even higher.[422]

A report is also overdue on a 2017 survey on the abundance of harp seals off eastern Newfoundland and Labrador, an important food source for Davis Strait and southern Baffin Bay polar bears. The population was estimated at 7.4 million in 2012, but it may now be even higher, and thus able to support an even larger population of polar bears.[423]

The Western Hudson Bay polar bear subpopulation is the best-studied in the world and what happens to these bears is often presented as a barometer for the global population. Declining weights of female bears and low cub survival are routinely cited as evidence that sea ice declines due to climate change have harmed WH bears and caused their population numbers to decline.[424] However, it has now been more than 25 years since data has been published on cub survival and weights of female polar bears in Western Hudson Bay, even though the data has been collected as part of the standard protocol when bears are collared or ear-tagged. Instead, decades-old figures are cited as if they were current and relevant to recent climate change effects and population counts. This practice is especially disturbing given the well-documented evidence that sea ice conditions on Hudson Bay (freeze-up and breakup dates) unexpectedly showed no declining trend between 2001 and 2015, [425] and for the last three years (since 2017), freeze-up dates have been like the 1980s. Surprisingly, in 2019 both breakup *and* freeze-up dates were virtually identical

to conditions in the 1980s (see discussion in Section 5). It seems inconceivable that such benign sea ice conditions up to 2015 could have caused polar bear population numbers to decline due to negative effects on female body condition and cub survival – as researchers claim – and even more implausible for such effects to be a current concern after three good ice years. As it is, the failure to publish the data on body condition and cub survival collected between 2004 and 2019 makes it look like that information is being deliberately withheld because it does not support the claims being made.[426] Only complete transparency will resolve this appearance of misconduct.

Despite having to deal with the greatest change in summer sea ice habitat since 1979 of all Arctic regions, polar bears in the Svalbard area of the Barents Sea showed very little negative impact from the low sea ice years of 2016 through 2019, according to Norwegian biologists.[427] On the other side of the Arctic, Chukchi Sea bears are still in better condition than they were in the 1980s, and are reproducing well.[428] And despite repeated claims that the Southern Beaufort is still a declining and nutritionally stressed population based on data collected between 2001 and 2010 (see Sections 3 and 5 for some problems with that research), a summer aerial survey of the coast of Alaska in 2019 suggests otherwise: it documented 31 fat healthy polar bears onshore in July compared to only three in 2017 (when sea ice retreat had been similarly early).[429]

Finally, two incidents at opposite ends of the Russian Arctic at the beginning and the end of 2019 made this the year of the mass polar bear 'invasion'.[430] In the winter of 2018/2019, garbage and other human-associated food attractants were the impetus as more than 50 bears descended on the town of Belushya Guba on the south end of Novaya Zemlya in the Barents Sea and refused to leave. And in December 2019, competition among the more than 60 bears feeding on the carcasses of Pacific walrus that had died naturally over the previous few months at Cape Schmidt in Chukotka encouraged some young bears to enter the nearby village of Ryrkaypiy looking for food. Both incidents left local residents terrified of being attacked, although in the end no one was hurt. Contrary to media reports and comments from some academics, these 'swarms' of bears were not forced to find food near human habitations because of a lack of sea ice; in both cases, details show the bears were highly attracted to these sources of food (garbage in the one case, a natural food source in the other) and that there was more than enough ice nearby on which to hunt for seals.[431] In fact similar sea ice conditions have existed at both locations in recent years, as have the village garbage dumps and walrus carcasses, yet only in 2019 did so many bears congregate to cause distress at these villages.

Large congregations of polar bears near remote Arctic settlements are to be expected as a natural consequence of the current large global population of bears. This is a problem that simply has not existed for more than 100 years. Lack of sea ice isn't the problem. Between the slaughter of polar bears by commercial whalers and sealers that went on in the late 1800s and early 1900s and the carnage of unregulated sport hunting in the 1940s through to the early 1970s, Arctic residents have simply never had to deal with polar bear problems on the scale that they do now. Both Belushya Guba ('Beluga Whale Bay') and Ryrkaypiy ('the limit of walrus moving' or simply 'place of the walrus') didn't exist the last time polar bears were as abundant as they are now.[432] Ryrkaypiy was built in the early 1930s as a collective reindeer farm and Belushya Guba grew from a tiny encampment in the late 1800s into a large Soviet naval base in 1944 that expanded during the 1950s as indigenous Nenets from the rest of Novaya Zemlya were moved in.[433] Both towns are much smaller now than they were in their glory days, before bears were as numerous as they are today. This is also true for Dikson and Amderma, two towns on the Kara Sea that have had serious problems with polar bears in the last two years,[434] as well as Churchill, Manitoba, which had its worst problems with bears in the late 1960s. But these settlements are still large enough to produce abundant garbage, which is attractive to polar bears. In contrast, other Arctic settlements have grown tremendously into real towns: Arviat, on the northwest coast of Hudson Bay, is more than three times the size of Churchill and has recently had many problems with bears but has not had the financial resources to construct an incinerator as Churchill did.[435] However, it's not just garbage or

dead walrus (or whales) that attract polar bears: lots of other accoutrements of Arctic living bring the bears in close, including dogs, cabins with interesting odours, harvested seals and whales, and even snow machines (because of their vinyl seats and oily smell), as the litany of problem bear reports in Section 9 attest.

Despite predictions that polar bear numbers might decline decades into the future, so far that hasn't happened. Garbage dumps are not going to go away and few villages have the funds to build an incinerator.[436] Many other attractants, like the carcasses of walrus that appear at Cape Schmidt in Russia almost every year, are a different kind of problem, and are almost impossible to eliminate. It's possible that the easiest and most cost-effective solution, as one Russian biologist suggested, is to move the village.[437] The simple truth is that right now, Arctic residents and visitors face a much greater risk of having a deadly encounter with a polar bear at almost any time of year than they did 60–70 years ago, and this is because polar bear populations are so much larger. Predictions of future calamity do not change the present reality that polar bears are thriving.

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151. Amstrup et al. 2007; Folger 2018; Wang and Overland 2012.
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157. Aars et al. 2017.
158. SWG 2016b.
159. Dyck et al. 2017; Lunn et al. 2016; Regehr et al. 2007; Stapleton et al. 2014.
160. Amstrup et al. 2007, 2008; Wiig et al. 2015; Regehr et al. 2016.
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167. Kaufman 2019a; Perovich et al. 2018, 2019; https://climate.nasa.gov/news/2726/historic-low-sea-ice-in-the-bering-sea/ and https://uaf-iarc.org/2018/04/09/new-summary-available-on-bering-strait-winter-2018-sea-ice-conditions/. See also http://nsidc.org/arcticseaicenews/2018/04/2018-winter-arctic-sea-ice-bering-down/ and http://nsidc.org/arcticseaicenews/2019/04/spring-arrives-in-the-arctic/.
168. Brown et al. 2011; Wendler et al. 2014. See also http://nsidc.org/arcticseaicenews/2012/04/arctic-sea-ice-enters-the-spring-melt-season/.
169. http://nsidc.org/arcticseaicenews/2017/04/another-record-but-a-somewhat-cooler-arctic-ocean/ and http://nsidc.org/arcticseaicenews/2018/04/2018-winter-arctic-sea-ice-bering-down/.
170. Aars 2018; See also http://www.mosj.no/en/fauna/marine/polar-bear.html.
171. Stroeve et al. 2007, Stroeve et al. 2014.
172. http://nsidc.org/arcticseaicenews/.
173. While polar bears usually mate while on the sea ice from late March to early May during the intensive period of feeding on young seals (and rarely as late as June), they will also mate on land if it is close by, which suggests that sea ice is not strictly necessary for breeding (Laidre et al. 2013; Ramsay and Stirling 1986; Stirling et al. 1980b, 1984; Wiig and Thornassen 1992).
174. Obbard et al. 2016.
175. Lang et al. 2017; Perovich et al. 2019; Scott 2019; See also https://www.climate.gov/news-features/featured-im-

ages/2019-arctic-report-card-old-thick-ice-barely-survives-today%E2%80%99s-arctic and https://www.livescience.com/arctic-ice-refuge-vanishing.html.

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177. SWG 2016.

178. Pagano et al. 2018.

179. DeMaster 1980; Bromaghin et al. 2015; Ramseier et al. 1975; Stirling 2002, Stirling and Lunn 1997; but see Rode et al. 2018a, 2018b.

180. Bromaghin et al. 2015; Burns et al. 1975; Cherry et al. 2009; DeMaster 1980; Harwood et al. 2012, 2015; Pilfold et al. 2012, 2015; Rode et al. 2010, 2014; Smith 1987; Stirling 1997, 2002; Stirling et al. 1975a, 1975b, 1980b, 1981, 1982, 1985, 1988, 1993, 2008; Stirling and Lunn 1997.

181. https://news.nationalgeographic.com/2018/02/polar-bears-starve-melting-sea-ice-global-warming-study-beaufort-sea-environment/.

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183. Beaver 2019; Bromaghin et al. 2015; USFWS 2013.

184. DeMaster 1980; Bromaghin et al. 2015; Ramseier et al. 1975; Stirling 2002, Stirling and Lunn 1997.

185. Crockford 2015; Derocher et al. 2004; Laidre et al. 2008; Vongraven et al. 2012 .

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187. Amstrup et al. 2007; Durner et al. 2007, 2009; Pilfold et al. 2017; Pongracz and Derocher 2007.

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193. Regehr et al. 2016.

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195. Aars et al. 2017; Obbard et al. 2016; Crockford 2019b.

196. Kaufman 2019b; 'Brian Keating: Polar bears in Churchill Manitoba' (13 November 2017, CBC Radio episode 300312418) http://www.cbc.ca/player/play/1095183939998 and https://twitter.com/AEDerocher/status/1144015795598454784. See also https://polarbearscience.com/2017/11/13/w-hudson-bay-freeze-up-one-of-earliest-since-1979-not-closer-to-average/ and http://polarbearscience.com/2018/11/10/w-hudson-bay-freeze-up-earlier-than-average-for-2nd-year-in-a-row-polar-bear-hunt-resumes/ and http://polarbearscience.com/2019/09/05/western-hudson-bay-polar-bears-in-great-shape-after-five-good-sea-ice-seasons/.

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198. Polar Bears International 2019; See also https://twitter.com/AEDerocher/status/1207333275619823616 and https://twitter.com/AEDerocher/status/1200445698337988608 and http://polarbearscience.com/2019/09/05/western-hudson-bay-polar-bears-in-great-shape-after-five-good-sea-ice-seasons/.

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203. Stirling et al. 1977.

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205. According to the Polar Bear Alert Program report for 11–17 November 2019, there was enough ice to release all bears from the holding facility on 13 November 2019; See http://churchill.ca/p/polar-bear-stats and https://twitter.com/TownofChurchill/status/1196473808057700352.

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217. Aars et al. 2017; Descamps et al. 2017; Fauchald et al. 2014.
218. Hammill and Smith 1991.
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220. Kelly et al. 2010; Cameron et al. 2010.
221. USFWS 2012a--b.
222. COSEWIC 2018; Kovacs 2016b; Lowry 2016.
223. Crawford et al. 2015; Rode et al. 2018b.
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225. Adam et al. 2019; Eurich 2019.
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249. Obbard et al. 2018.
250. Stirling et al. 1999:296; Stirling and Parkinson 2006:265.
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252. Pilfold et al. 2016.
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