Polar Bears

Proceedings of the 18th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 7–11 June 2016, Anchorage, Alaska

Compiled and edited by George M. Durner, Kristin L. Laidre, and Geoffery S. York

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Cover photo: A polar bear and her two yearlings on the sea ice in southeast Greenland, March 2015. Photo by Kristin Laidre.

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Foreword

Following the First International Scientific Meeting on the Polar Bear which was held in Fairbanks, Alaska in 1965, the Polar Bear Specialist Group was formed to coordinate research and management of polar bears. Eight years following the First Scientific Meeting, the 'Agreement on the Conservation of Polar Bears and Their Habitat' was signed by the Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics, and the United States. Article VII of the Agreement states: "The Contracting Parties shall conduct national research programmes on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate coordinate such research with research carried out by other Parties, consult with other Parties on the management of migrating polar bear populations, and exchange information on research and management programmes, research results and data on bears taken."

As part of their commitment to fulfil the intent of the Agreement, representatives of all five signatory nations, together with invited specialists, attended the 18th Working Meeting of the IUCN/SSC Polar Bear Specialist Group that was held 7–11 June 2016 in Anchorage, Alaska, and hosted by the Alaska Unit of the United States National Park Service. In this regular working meeting, representing research and management efforts by the signatory nations for the years 2009–2016, the Specialist Group reviewed overall progress since the previous regular working meeting (Copenhagen, Denmark, 2009), and identified priorities for future studies.

As with the previous 17 proceedings, the 18th Proceedings of this regular working meeting demonstrate a continued international effort by representatives from each of the Range States to increase knowledge and inform management decisions needed to conserve polar bears in a changing Arctic. The group confirmed the conclusion from previous meetings that the greatest challenge to conservation of polar bears is ecological change in the Arctic resulting from climatic warming. Declines in the extent of the sea ice have accelerated since the last meeting of the group in 2009, unprecedented ice retreat in 2012. Habitat degradation and loss are already negatively affecting polar bears in some parts of their range, and unabated global warming will ultimately threaten polar bears everywhere. However, humand-induced threats to polar bears will occur at different rates and times across their range, meaning that conservation and management of polar bears will be even more challenging in the future. Previous proceedings included a Status Report for each of the world's subpopulations, which focused largely on the known or unknown status as it related to harvest. In the Status Report of these 18th Proceedings, we follow the path set by the 15th Proceedings in providing a comprehensive assessment of all threats to the status of each polar bear subpopulation.

A note on the use of the terms population and subpopulation

Following the usage adopted in the 14th Proceedings, we use the term population for all the polar bears in the Arctic. This decision is based on their biology, as polar bears roam over large areas and genetic structuring is low even between areas far apart. However, in earlier issues and in several publications, population has been used to term more local management units. Here those are termed subpopulations. The boundaries between these subpopulations will always be based on current knowledge, thus boundaries may change as more complete knowledge on their ecology becomes available. This is especially so in less studied areas such as the Russian Arctic, where our view of what the real subpopulations or management units are, and to what degree they interact or are a part of the neighbouring nations' subpopulations, may change in the future.

The Editors:
G.M. Durner
K.L. Laidre
G.S. York

Executive Summary

During 7–11 June 2016 members of the IUCN/SSC Polar Bear Specialist Group (PBSG), and invited specialists, including scientists and managers from Canada, Greenland, Norway, the Russian Federation, and the United States, met in Anchorage, Alaska, USA, for the 18th regular working meeting of the PBSG. The material within these Proceedings represents a summary for 2009–2016 on the state of knowledge and conservation concerns for polar bears throughout their range. The difficulties in studying a species that ranges widely, at low densities, and in one of the world's most remote and environmentally challenging regions is evident in these proceedings. Of the 19 polar bear subpopulations recognized by the PBSG, estimates of population size were available for 14. Of the 19 subpopulations, 5 appeared to be stable, 1 may be increasing, 2 were decreasing, and 11 had insufficient data to estimate a trend. However, information derived from field studies of polar bears and analyses of remotely-collected environmental data help fill gaps in our understanding of how they are responding to a changing Arctic. Since satellite imagery of sea ice extent began in 1978, the summertime extent of sea ice has declined from 2.3–20.5 % per decade, depending on the subpopulation. Empirical data collected from field efforts is revealing the mechanisms that climate warming driven sea ice loss is having on polar bears. The nature and timing of these mechanisms is not uniform across their pan-Arctic range. Neighboring subpopulations experiencing similar sea ice declines have responded differently, likely due to regional variation in productivity of the underlying biological oceanography, the energetic costs for occupying drifting sea ice, and sub-optimal habitats. Regardless, unabated sea ice declines as projected through the 21st century, are expected to negatively impact all polar bear subpopulations over the long-term. Other factors are also presented that must be considered when assessing the status of polar bears. Polar bears continue to be an important species for indigenous peoples of Greenland, Canada, the Russian Federation, and the United States, providing them with spiritual, nutritional, and economic subsistence resources. Increasing industry, tourism, and commerce in the Arctic brings humans and polar bears into closer proximity and increases the potential for negative interactions. Industrial and agricultural pollutants from southern latitudes show their far-reaching effects on the health of polar bears through atmospheric and oceanic transport of contaminants into their environment. Changing sea ice has also altered the behavior and distribution of bears, bringing them into increased contact with humans, terrestrial wildlife, and novel diseases. Few polar bear subpopulations occur entirely within one jurisdiction. Hence the challenges and benefits of co-management, as was recognized at the First International Scientific Meeting on the Polar Bears, is now more than ever an integral part of polar bear conservation. In the following pages, the reader will hopefully come to a better appreciation of the current and future challenges in understanding the response of polar bears to a warming Arctic, and the conservation efforts needed to ensure their survival.

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Agenda

of the 18th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 7–11 June 2016, Anchorage, Alaska

Meeting venue: United States National Park Service, Alaska Unit headquarters

Closed session

Tuesday, 7 June 2009

9:00	1	Opening welcome and call to order (D. Vongraven)
	2	Formal matters Media requests (discussion led by D. Vongraven)
		Press release (discussion led by D. Vongraven)
		Agenda and proceedings for the meeting (discussion led by D. Vongraven)
		Resolutions (discussion led by D. Vongraven)
	3	Report from the Range States meeting in 2015 (discussion led by D. Vongraven)
9:46	4	Requested Advice to the Range States (discussion led by D. Vongraven)
10:25		Break
10:57		More on PBSG's role with the Range States (discussion led by D. Vongraven)
	5	Capacity issues (discussion led by D. Vongraven)
		Funding for support of a program officer for the PBSG (discussion led by D. Vongraven)
	6	Terms of Reference (discussion led by D. Vongraven)
		Responsibilities of the co-chairs
		Nomination of the co-chairs
		Members
		Financial
		Other matters
11:45		Lunch break
	7	Website (discussion led by D. Vongraven)
13:17		Decisions on co-chairs, amending the TOR, electing chairs and members
15:15		Break
15:30		More discussion on financial matters

Wednesday, 8 June 2016

9:00	8	Status table (discussion led by E. Peacock)
9:00		Executive meeting on the PBSG website
10:45		Break
11:07		Continued discussions on the status table
12:41		Lunch break
14:00		Continued discussions on the status table
14:24	9	CITES (discussion led by D. Vongraven)
15:00	10	Effects of handling polar bears (presented by K. Rode)
	11	Discussion on elections and new members (discussion led by D. Vongraven)

Open session

Thursday, 9 June 2016

9:00		Arrival of invited specialists and observers
9:04	12	Nation reports on research Canada (presented by A. Derocher)
		Greenland (presented by K. Laidre)
		Norway (presented by J. Aars)
		Russia (presented by S. Belikov)
12:27		Lunch break
13:30		Continue nation research reports: United States (presented by E. Regehr, T. Atwood, G. Durner, K. Rode)
	13	Discussion of the boundary change in the Beaufort Sea (discussion led by invited specialist M. Branigen)

Closed session

		Nomination of chair and co-chair, Red List coordinator, members (discussion led by D. Vongraven)

Open session

Friday, 10 June 2016

9:00	14	Sea ice session Recent patterns of sea ice conditions (presented by invited specialist H. Stern)
		Assumptions and uncertainties associated with sea ice projections (presented by invited specialist D. Douglas)
		Climate change uncertainty and commitment (presented by invited specialist K. Armour)
12:00		Lunch break
13:00	15	Nation reports on management
		Canada (presented by N. Lunn)
		Greenland (presented by A. Jessen)
		Norway (presented by M. Ekker)
		Russia (presented by S. Belikov)
		United States (presented by E. Regehr)
	16	Putting the "eco" in eco-toxicology (presented by invited specialist T. Bechshøft)

Saturday, 11 June 2016

9:00	17	The Red List process (presented by E. Regehr)
	18	Human-polar bear conflict working group
		Update from the Range States
		Conflict Working Group (presented by V. Sahanatien and G. York)
		Efficacy of bear deterrent spray on polar bears (presented by J. Wilder)
		Bear attacks in North America (presented by invited specialist T. Smith)
13:30		Potential impacts of human recreation (presented by invited specialist J. Fortin)
	19	Updates from zoos and other facilities (presented by invited specialists R. Meyerson, M. Owen and N. Pilfold)

Closed session

15:22	20	Revisiting TOR and

		resolutions (discussion led by E. Regehr)	17:24	22	Closing remarks and adjournment (discussion led by D.Vongraven)
	21	Elections			

Minutes

of the 18th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 7–11 June 2016, Anchorage, Alaska

Closed sessions

Tuesday, 7 June

1. Welcome

Introductory remarks

The 18th Working Meeting of the IUCN/SSC Polar Bear Specialist Group (PBSG; hereafter Group) was called to order by D. Vongraven, Chair of the Group, at 09:00 in Room 309 of the Headquarters of the Alaska Unit of the National Park Service building in Anchorage, Alaska. No observers or invited specialists were present.

2. Formal matters

Request for media attendance

Chair Vongraven reported that there was one media request for permission to attend and report on the meeting (Erica Goode, New York Times). Ms. Goode had also contacted individual members about interviews as she is apparently working on an extended article about polar bears. A large majority of the members voted to allow her to attend the open sessions with the invited experts and observers.

Press releases

Chair Vongraven asked if members felt the PBSG should issue press releases. N. Lunn noted that in the past the Group has prepared press releases, but it was noted by others that these tended not to be widely picked up by the media. A. Derocher suggested it might be more effective for the PBSG to continue writing press releases on important topics but to then put them on the web site rather than using the traditional press release route. This would mean that the material could be readily available to both the press and the public for an extended period of time. There was general agreement on placing releases on the website.

Agenda and Proceedings for the meeting

Chair Vongraven asked for comments on the meeting agenda. No additional comments were made and the agenda, as distributed ahead of the meeting, was accepted and a schedule for rapporteurs was established. T. Atwood volunteered to coordinate the reports from the individual rapporteurs (J. Aars, S. Amstrup, A. Derocher, G. Durner, A. Jessen, N. Lunn, M. Obbard, E. Richardson, K. Rode, I. Stirling, G. Thiemann, F. Ugarte, J. Wilder, and G. York) from all the sessions into a single document for the Proceedings. At the special meeting in 2014 (Fort Collins, Colorado) it was agreed that the Proceedings of the PBSG meetings would include minutes, status table, and reports on research and management in a single document. It was also agreed that it would be most useful to continue publication of the Proceedings in the IUCN Occasional Paper series, as has been the practice following past meetings. The tentative goal for completion of the contents for the Proceedings was set for October. Additional material for possible inclusion in the final Proceedings, such as Resolutions, will be discussed as the issues come up through the meeting. G. Durner agreed to help with coordination of the final document for eventual publication as the Proceedings of the meeting.

Resolutions

Chair Vongraven asked whether there were any issues requiring a resolution from the PBSG. J. Wilder stated that the Range States occasionally needs reminded to act on aspects of the Circumpolar Action Plan, and perhaps a resolution from the PBSG would help to maintain their engagement. E. Regehr and

Chair Vongraven suggested revisiting the need for resolutions at the end of the meeting as additional issues are likely to come up in subsequent days.

3. Report from Range States meeting in 2015

A summary of the 2015 Range States meeting was presented. N. Lunn noted that the extensive list of tasks from the Range States comprised a huge commitment and is, in reality, the work of the Range States and not simply "advice" from the PBSG. The tasks are abundant in number and many are quite large (although there is some overlap) and it would require a very large effort on the part of individuals, or groups of individuals, to complete. As such, it would be better done by the Range States themselves and the PBSG could consider providing advice on how they might proceed, or possibly advise on the final product. K. Laidre noted that the Range States list is long but the PBSG did not formally agree to take on the tasks at the 2015 meeting.

4. Advice to the Range States

To date, the PBSG has been the official scientific advisor for the Range States, but members agreed the relationship needs revisiting in order to achieve positive results for both parties. With regards to the 2015 Range States meeting, several members felt the PBSG needs to prioritize tasks identified by the Range States and then suggest how to approach the most important ones. Specific knowledge gaps need to be identified as part of the prioritization exercise. J. Wilder, E. Regehr, K. Laidre, K. Rode, and E. Richardson agreed to form a subgroup to assess the work that would be needed to actually accomplish the tasks using the information base already in existence. Additionally, they will make a general estimate of how much work will be required to address the tasks. The Range States need to recognize that a high level of commitment will be required to achieve the highest priority goals, such as the need for specific contracts and prioritizing work formally into staff and agency annual plans. The objectives set forth by the Range States, while needed, are simply too large to expect individual scientists, or groups of scientists, to be able to achieve the tasks in their spare time. Successful completion of some goals will likely require new budgets and significant staff commitments. Several members commented that there needs to be communication to the Range States that the PBSG does not have the financial or staff capacity to take on unfunded tasks.

Two particular priorities the Range States sought advice on were further clarification of the so-called "Arctic Basin subpopulation", and an estimate of the costs of implementing the priorities in the Circumpolar Action Plan. In examining the Arctic Basin question, A. Derocher noted the importance of looking at data on movements of satellite collared bears from subpopulations such as the Northern Beaufort Sea, Southern Beaufort Sea, Chukchi Sea, and Barents Sea as it is clear that some of the time, bears are distributed well north of the presently recognized northern boundaries of those subpopulations. This suggests that the area of this hypothetical subpopulation is probably much smaller than shown on present maps and likely does not contain many, if any, resident bears. A. Derocher, G. York, and G. Thiemann will review the available information on the movements of bears from relevant subpopulations in order to provide a brief report on what might be needed to enhance our understanding of this issue. It is important to address this reasonably soon because there is an impression held by some groups outside of the PBSG that there are more bears within the Arctic Basin subpopulation than may be the case.

The subgroup reporting on human-polar bear conflicts has forwarded an interim report back to the Range States but the final report has not yet been completed.

It was agreed that, if practical, all the subgroup reports done in response to the Range States request should be parts of a single report back to Range States.

5. Capacity issues

Funding for support of a program officer for the PBSG

At the special meeting in 2014, members discussed whether there was a need for a Program Officer who could manage and do much of the important, but time-consuming, work required of the PBSG. It was noted that the PBSG membership simply does not have the capacity at the moment to address the numerous requests being made by the Range States. It was estimated that the total cost of a Program Officer would be in the vicinity of US$150,000/year for 5 years and a request for this support was made to the Range States. The Range States were able to commit to approximately US$20,000–30,000/year. It was noted that it may be difficult to convince the Range States of the need for a Program officer at the PSBG because it may be difficult to quantify the direct benefit to the Range States. There was discussion of the possibility of soliciting funding/sponsorships from the private sector. The general consensus was that several lines of funding would likely be needed to support a Program Officer position and acquiring those funds would require substantial effort.

G. York noted that a formal proposal identifying tasks that groups like non-governmental organizations (NGOs) might be interested in addressing was not drafted after the 2014 special meeting. He suggested that if the goal of a Program Officer is to be achieved, it will likely need to be shaped toward an NGO option rather than governments, and this may be a role for NGOs to help. Members expressed a need to more clearly identify the roles of this position in such areas as communications, coordination, and related tasks. Additionally, it was suggested that a working group be established to develop an outline for the position, using the previous working document as a starting point. A working group was not named.

A. Derocher suggested that a trust account managed through a non-profit organization or a university is a possibility for administering the position. Chair Vongraven noted that it will be difficult to both find a single sponsor for such a project or to find and administer a larger number of smaller supporting groups.

6. Terms of Reference

E. Regehr led a review of a document drafted in advance of the meeting that contained revisions to the current Terms of Reference (ToR; to add more structure and clarity). The redrafting was led by E. Regehr and involved a small group of members – J. Aars, A. Jessen, K. Laidre, N. Lunn, M. Obbard, I. Stirling, D. Vongraven, Ø. Wiig, and G. York.

Responsibilities of the chair and co-chair

The document drafted by E. Regehr included wording (replacement text to the existing ToR) that the PBSG would be led by a chair and a co-chair, where the co-chair would report to the chair and should be more appropriately called a deputy chair. The Group recognized the benefit of additional help for the chair but focused on whether this would be best met with a chair/deputy chair model or a co-chair model where both co-chairs had equal standing within the PBSG and also with IUCN.

The Group preferred the co-chair model (equal standing) but felt that there must be clear delineation of responsibilities/roles of each so that there was no confusion either between the co-chairs or among the members. It was agreed that the ToR would reflect a co-chair model but that wording should be retained to allow for a single chair to avoid having to redraft the ToR. It was also agreed that while the responsibilities of the co-chairs need to be clear, there should be a degree of flexibility retained to allow co-chairs to take on responsibilities for areas of particular interest to them rather than a structure that commits one co-chair to be responsible for "A", "B", and "C", and the other for "D', "E", and "F".

Nomination of the chair and co-chair

The members discussed proposed replacement text on the process and timing of nominations. There was a general view that the Group is small enough that it is not necessary to overly formalize processes to allow for some flexibility. While it was encouraged that nominations for co-chairs occur 14 days in advance of the meeting, there was agreement that there was no need to make this a strict requirement. There is an intention to allow members not present to be able to vote via email and thus there needs to be some cut-off point for nominations. There was consensus among the members that nominations would close at the start of the meeting.

There was discussion on the election process and whether there is a need for it to be organized by a subcommittee. It was considered important that the election process be run by a group of individuals that do not include nominated members. However, it was felt that this could be facilitated by an ad hoc subcommittee rather than by creating a formalized subcommittee.

While the members agreed that there should be a limit to consecutive terms that an individual could be co-chair, there was difference of opinions as to whether co-chairs should be limited to one consecutive term or two. There was agreement that this was a very important issue and a vote of members in attendance was held by a show of hands: a majority of members voted for co-chairs being limited to two consecutive terms.

Members

There was discussion on the PBSG membership regarding proportional representation of each country. A graph of members from each country was presented and it was suggested that the membership section of the ToR may need to be adjusted to consolidate requirements for membership, selection of new members, and participation.

The members reviewed new text for the ToR with respect to the process of new candidate members. There was a general view that there should not be a time limit with respect to identifying or appointing new members when vacancies exist. The entire membership is dissolved following the IUCN quadrennial cycle but there may be a need(s) for additional members outside of this 4-year cycle. The formation of a subcommittee to help identify/review potential candidates would be of benefit. While it was agreed that it would be important for a subcommittee to assist in the selection process of members, it was less clear whether this subcommittee should work with the co-chairs in advance of the meeting so that the incoming co-chairs have a list of candidates to appoint or whether this subcommittee and the new co-chairs start the process after the election of the co-chairs. There was general agreement that there would be benefit to having a list prepared in advance. It was recognized that only the outgoing co-chairs would fully know the contributions to the Group made by each member, thus there would need to be considerable reliance on the outgoing co-chairs for recommendations.

So long as individuals were qualified and the membership was not at maximum, it was agreed that new members could be added at any time and not be restricted to the IUCN quadrennial cycle.

While there was no language in the suggested new text, the members agreed it was important to include some wording to the effect that PBSG members are appointed because of their expertise and not to formally represent Range State countries. It was recognized that wording is critical because many of the current members are employees of Range State countries that support their participation. It was felt that a strong message of what the members represent in terms of their expertise and ability to contribute is far better than a statement of what jurisdiction the members represent.

E. Regehr indicated that he would revise the document to reflect the discussions and that the wording is not intended to change the fundamentals of the ToR but rather to tighten up the language. He planned to revise the language and recirculate the document during the meeting for the members to revisit on the final day.

Financial

A new ToR section regarding financial matters of the Group was discussed. While the co-chairs are responsible for the financial operations, it is important that all members know where funds come from and how they are spent. A financial subcommittee should be created that oversees financial matters. While the members agreed that they wanted to know about funds received/dispensed, there was some disagreement as to how the funds should be managed. Regardless of the host institution, the funds must be managed through an auditable account. The Group agreed that the financial subcommittee should review and provide recommendations on best option with respect to institutional options.

The Group discussed whether or not incoming funds from any source would need to be reviewed by the members in advance of acceptance. It was noted that we collectively do a lot of things on trust and collegial governance. It was felt that for most incoming sources there are unlikely to be issues that acceptance would compromise the Group's independence. It was felt that the financial subcommittee and co-chairs should be able to determine whether or not incoming funds need to be approved in advance by the members. Before the meeting, Ø. Wiig, who was unable to attend, sent an e-mail asking that financial details for use of all funds be provided in a transparent format, as such details so far have not been available to the members.

Other matters

The Group discussed additional suggested text with respect to observers and invited specialists. There was general consensus that while a number of individuals would like to attend and observe the meetings, the meetings of the PBSG are not public meetings or conferences. There was agreement that invited specialists are still important but that the language of the ToR should no longer include observers.

E. Regehr reiterated his intention of revising the document and circulating to the members during the meeting in order that it can be revisited while members are in Anchorage.

7. Website

Chair Vongraven reviewed the Group's website and changes that have been made. He noted that there will be a new domain name (www.iucn-pbsg.org) and that it has been redesigned and rewritten in new script. He described it as being more dynamic and using a modern platform but not yet ready for launch.

There were questions as to who was going to manage and maintain it in order for the site to remain active. It was noted that a website subcommittee had been formed during the special meeting in 2014 with the objective to modernize the site, and subcommittee members could help with keeping it active. Additional comments included that member blogs, especially when new papers come out, can make a significant contribution to activity on the site. It was suggested that some sort of rolling new science banner would be beneficial on the home page.

Wednesday, 8 June

8. Status table

L. Peacock led a discussion of the PBSG status table focused on the IUCN/SSC status table definitions from the Red List Criteria. There was general agreement from the members that the IUCN/SSC definition of subpopulation is sufficient for the purposes of the PBSG. Members agreed to remove "standard" and "conservation" from the definition for Methods. N. Lunn suggested that the detailed text accompanying the status table should include new information on how estimates are derived. L. Peacock advocated the removal of specifics on genetic exchange. Members discussed whether IUCN/SSC definitions should be followed to the word and the consensus was that the PBSG should use some flexibility on the interpretation of definitions.

There was extended discussion on whether the definitions of "Static", "Increasing", and "Declining" should be changed. The general feeling was that the definitions were reasonable because they are broad indices of subpopulation change that are not dependent on measures of lambda. Additional discussion focused on whether changes should be made to the removals columns. Some members felt that while harvest needs to be documented, 4 columns for various harvest metrics seem excessive. It was agreed that the 4 columns should remain.

It was noted that the status table estimate on abundance used by the PBGS includes all age classes of bears. This differs from the IUCN definition of abundance, which is the inclusion of only adult individuals.

There was discussion about how to reconcile the status of the Northern and Southern Beaufort Sea subpopulations given the movement of the eastern boundary separating the two to 133°W. No resolution was reached and this sparked a larger consideration of how and when subpopulation boundaries should be assessed.

The Status Table Subcommittee will distribute the draft status table and revised definitions to members and seek updates to subpopulation text sections. The deadline for comments to status table is 15 August 2016.

9. CITES

Chair Vongraven provided an update on recent developments regarding polar bears under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In May 2014, CITES conducted a Significant Trade Review and reached the conclusion that current international trade was considered to be sustainable. The Chair informed the Group that no new proposal would come from the United States to uplist polar bears to Appendix I at the 17th Conference of the Parties (COP17). A. Jessen informed the Group that the European Union is considering a motion that would ban international trade in all Appendix I and II species, including polar bears. The chair suggested the Group seek input from the IUCN on the matter. A. Jessen will obtain and circulate the draft resolution from the European Union (EU). The PBSG will consider submitting a letter to CITES pending review of the draft resolution.

10. Effects of handling polar bears

K. Rode provided a presentation on evaluating the short and long-term responses of polar bears to capture and collaring. She reviewed previous studies on polar bear movement rates (recovery to normal movements), body weight, body condition, and reproduction. A recent USGS-led study in the southern Beaufort Sea found that polar bear movement rates returned to near normal in 2–3 days and were fully normal within 5 days. There was no difference in body condition between bears caught once vs. those handled multiple times. Capture as cubs did not affect future body size and there were no effects of collars on reproduction of adult females. Since 1987, when tiletamine/zolazepam was adopted as the standard immobilizing drugs, capture-related mortality rate has been 0.1%. All mortality was related to predation and drowning of immobilized bears; no mortality was a direct result of the drug solely by itself.

There was agreement that the USGS study was valuable and important. The Group discussed the potentially mortal effects of capture on bears that are severely compromised by age or disease. There was consideration of individual animal welfare concerns vs. population-level impacts. The Group discussed the frequency of collaring injuries and the need for better collaring materials and sizing standards. E. Regehr suggested that researchers examine trap effects where possible, to explicitly model survival in the first interval after capture.

11. Elections

The Group sought nominations for the two new co-chair positions and Red List coordinator for the next quadrennial cycle. The Group discussed the implications of the draft revisions to the ToR and concluded that D. Vongraven was eligible for nomination because he has not served two full terms as chair. There was general discussion of how best to engage absent members in the nomination and election process.

The Group decided that the deadline for nominations of Chair/Co-Chair, Red List Coordinator and new members will be Thursday, 9 June, at the end of the open session. Voting will be open. The two candidates with the most votes will be elected as co-chairs.

F. Ugarte nominated E. Regehr for the position of IUCN Red List Coordinator. E. Regehr accepted the nomination. J. Aars nominated K. Laidre for co-chair. K. Laidre considered the offer and respectfully declined because of workload in upcoming 4 years; however, she noted she was willing to consider the position in the future. A decision was made to defer taking further nominations for co-chair until Thursday (9 June) so that an email could be sent to absent members to seek additional nominations.

A number of potential new members were identified. The Group discussed the possibility of expanding the size of the membership but decided, by majority vote, to maintain the current limit of 35. The chair suggested that the new co-chairs approach current members (especially those that are not active contributors) to affirm they want to continue their membership. G. York volunteered to contact absent members and invite them to vote on and add new suggestions for members.

Open sessions

Thursday, 9 June

The session started with a welcome and introduction to invited experts and observers. The first session consisted of oral presentations, the contents of which are given in the National Progress Reports chapter. Here follows a brief summary of the discussion following the presentations.

12. National reports on research

Canada

A. Derocher presented summaries of research in Canada by various institutions in the period 2009-2016. The presentation consisted of brief summaries of published papers.

After the presentation, S. Amstrup asked if there were observations from long term studies indicating that thinner ice is better polar bear habitat for hunting seals than multiyear ice. A. Derocher answered with an example from the Viscount Melville Sound area, where there were very few polar bears and seals over multiyear ice in 1991. The area today has less multiyear ice and more seasonal ice, but there are still very few seals and polar bears. I. Stirling added that the area's low density of seals and polar bears, despite having more seasonal ice and less multiyear ice could be due to the water being transported from the Polar Basin, where the productivity is low. E. Richardson commented that Viscount Melville Sound is still a desert compared with other areas in Arctic Canada. A. Derocher wrapped up the discussion about Viscount Melville Sound by mentioning that results from the Beaufort Sea show that old ringed seals are an important part of the polar bear diet. Therefore, if new habitat opens up, many years are probably needed to build up enough prey for polar bears.

K. Rode asked about the potential for bias in the diet study related to prey size and ability to detect kills. A. Derocher answered that there may be a bias, as a dead bearded seal with multiple bear tracks around it is easier to spot than a ringed seal pup.

Greenland

K. Laidre presented a summary of research in Greenland carried out by the Greenland Institute of Natural Resources, in collaboration with colleagues from Canada, USA, and Norway. Her presentation focused on the nearly finished assessments of Kane Basin and Baffin Bay, however detailed results were not presented for these subpopulations because they had not been publicly released at the time of the meeting. She also detailed new studies initiated in southeast Greenland including two seasons of captures in 2015–2016 and a local knowledge interview survey. Her presentation ended with summaries of pollution studies carried out by the University of Aarhus.

J. Wilder asked about the reason for lower densities of polar bears close to settlements in east Greenland. K. Laidre answered that this could be explained by bears trying to avoid areas where human activities like hunting are intensive. A. Derocher asked if the telemetry and genetic data were used to define the border between the subpopulations in

Baffin Bay and Davis Strait. K. Laidre answered that the assessment is using the current boundary, which is based on genetics and telemetry, and that there was no anticipation of changing the boundary. S. Amstrup referred to the various studies showing a high contaminant load for polar bears in east Greenland and asked if this is reflected in the condition of the bears handled in east Greenland in 2015 and 2016. K. Laidre answered that the bears she handled were generally in good condition and F. Ugarte added that the contaminant studies are from northeast Greenland, while the tagging effort the past two years was in southeast Greenland.

A question was posed as to whether the studies will provide information on the distribution of the East Greenland subpopulation. K. Laidre answered that work is ongoing, but there seems to be some segregation between polar bears offshore in the pack-ice in northeast Greenland and those in the fjords of southeast Greenland. A. Derocher asked if there were plans for genetic comparisons between polar bears in the northeast and southeast, and K. Laidre answered that the material for the analysis has been compiled and the analyses will be done soon.

A. Derocher wanted to know about prey items observed in southeast Greenland. K. Laidre explained that ringed seals, which were present at high densities in the fjords, were the most common prey. Prey items included also bearded seals. E. Regehr asked about sea ice models to look at living conditions in the fjords. A. Derocher and J. Aars expressed that it is difficult to obtain sea ice data with good resolution from fjords.

Norway

J. Aars summarized the research carried out in the Svalbard region by the Norwegian Polar Institute and their collaborators, mainly from Canada.

A. Derocher wondered if killed prey were seen during the aerial survey over the sea ice north of the Barents Sea. J. Aars explained that kills of harp seals were common, as were sightings of harp seals basking on the sea ice, at times several meters away from the ice edge. E. Richardson was interested in geo-locator tags and asked whether these have given information about early emergence from maternal dens. J. Aars answered that the data showed bears leaving dens, but it was hard to know if those were maternity or temporary dens. The geo-locator tags should provide up to 4 years of data, which may help to determine the frequency of use of temporary dens.

S. Amstrup asked for clarification regarding presence of polar bears in Karlsøya during years with little sea ice. J. Aars explained that on the island of Hopen, there are polar bears only when there is sea ice, while in Karlsøya there are always polar bears. E. Regehr wanted to know the distance swam by a female polar bear with two cubs, which was a repeat of the same route used by the female in years with and without cubs. J. Aars clarified that the female and her cubs swam about 20 km, at a third of the speed used by the female when she was alone.

G. Durner wanted to know about the density of bears observed during the aerial survey over the continental shelf and beyond. J. Aars explained that, contrary to what is usually assumed, not all deep-sea areas are characterized by low productivity; he has observed productive areas with abundant marine mammals over deep water. S. Amstrup asked a final question regarding the visibility during the aerial survey, compared with the previous survey from 2004. J. Aars answered that there were numerous days with fog and bad weather in both surveys, but he was not able to compare the two surveys yet.

Russia

S. Belikov explained that there are three different research groups in Russia. Unfortunately, the other Russian members were unable to attend, and the presentation only included the results of his research group. The others will hopefully be included later in the proceedings.

After the presentation, S. Amstrup mentioned that it was interesting to hear about observations of grey whale carcasses available for polar bears in Chukotka and asked if there has been an increase in whale strandings. S. Belikov did not have data on an increase of cetacean strandings, but local knowledge indicates that killer whale predation has increased and there are more stranded grey whales. A question was posed about the extent of interactions between brown bears and polar bears. S. Belikov answered that he has not personally observed interactions and believes that locals likely have more information. He has heard that when interactions occur, brown bears usually displace polar bears. He noted that there seems to be an increase of brown bears along the northern coast, and more interactions should be expected.

M. Ekker asked if there were Russian plans for aerial surveys in the Russian region of the Barents Sea, as Norway did not get permission to survey Russian waters in 2015. S. Belikov said that there is no opportunity to carry out projects with high financial costs. The Norwegian-Russian cooperative group will meet in the fall of 2016 and hopefully provide information about a future Russian survey in the Barents Sea.

United States

E. Regehr presented a summary of United States Fish and Wildlife Service (USFWS) studies. T. Atwood, G. Durner, and K. Rode presented summaries of United States Geological Survey (USGS) research.

With reference to the demographic model presented by E. Regehr, L. Peacock asked what types of density-independent effects may affect populations. E. Regehr answered that a density-independent effect could be simply that there isn't enough time on the ice regardless of density. S. Amstrup mentioned that density-dependent and density-independent effects are not necessarily completely separate.

A. Derocher asked if the demographic model can be used in areas other than the Beaufort- specifically in areas where there is less data available. E. Regehr responded that one of the primary advantages of the model is that the assumptions are explicit. Including density dependence in the models provided an opportunity to better understand population dynamics. E. Regehr noted that there are sufficient data from some subpopulations to adapt this model for application. S. Amstrup stated that, for populations with sufficient data, the model can help determine key indices to measure in areas where polar bears are very difficult to study.

On the topic of denning behaviour by Chukchi Sea bears on Wrangel Island, S. Belikov asked whether some denned on the Chukotkan and Alaskan coasts. K. Rode responded that 57–62% denned on Wrangel, 15% denned on the Chukotkan coast, 15% denned on the pack ice, and very few on the Alaska coast in recent years. K. Rode noted that the data presented were collected from 1986–1995 and 2008–2015 and should account for some annual variation in denning locations.

13. Discussion of the boundary change in the Beaufort Sea

M. Branigan (invited specialist, Northwest Territories Department of Environment and Natural Resources) gave a presentation titled "Canadian Beaufort Sea Boundary Change Process" to explain the background and data used to support the change of the eastern boundary separating the Northern and Southern Beaufort Sea subpopulations. The process of considering a boundary shift included community meetings to discuss recommendations and a discussion at the Polar Bear Technical Committee (PBTC) meeting in 2008, where 3 boundary options were identified based on available science. The 3 options were presented to communities and they chose the option that was furthest to the west (133°W), which corresponds to the 50/50% probability contour identified in the Amstrup *et al.* (2004) publication.

In 2009, an analysis was initiated that resulted in the Griswold *et al.* (2010) report used to adjust the 2004-2006 abundance estimate of the Southern Beaufort Sea subpopulation from 1,526 to 1,215 individuals. In 2014, the PBTC accepted the adjusted subpopulation estimate by including it in the status table. M. Branigan stated that the next step is for the PBSG to reflect the boundary change in the map associated with the PBSG status table. If new analyses indicate the need for more discussion about the boundary, it can be brought forward.

A. Derocher stated that data suggested the boundary should be further east. There was an apparent demarcation of the population near a polynya. M. Branigan replied that they used the best science available at the time and it took some time to get to a decision from the communities. Now there appears to be some change in where it is thought the boundary should be, but a large amount of effort went into getting to this decision. There is a lot of ambiguity in the boundary between the Southern and Northern Beaufort Sea subpopulations. E. Richardson mentioned that some information on bear movements may not have been weighted heavy enough in the options that were presented to communities.

E. Regehr stated that we do not have a consistent method for dealing with issues like adjusting boundaries. For example, what information do we bring to bear on boundary decisions? How do we deal with seasonality of movements? And how do we deal with consideration of how these boundaries get used relative to management versus science. These are important issues to consider. S. Amstrup noted that it may be the case that decisions about boundaries determined primarily from community involvement may not agree with boundaries that are based on other information. It's likely that none of the subpopulations currently fit the IUCN definition, and our thinking has to evolve in a climate change world.

P. Molnár (invited specialist, University of Toronto) asked if a 50% probability contour should be the place to draw a boundary between subpopulations? Is it possible that there may not be any boundary when it comes to management? Rather than assigning subpopulations based on where they move, base them how much they contribute to the population dynamics of a given subpopulation. He also noted that which subpopulation is harvested from is affected by seasonality. A. Derocher asked if, for consistency, the western boundary of the Southern Beaufort Sea subpopulation should be changed to the 50/50% probability contour – which is at Barrow? He noted that this is not where the PBSG boundary is, but it is the boundary used in the US-Russia treaty.

M. Branigan stated that if a new boundary is being considered on the western side, then a new analysis should be conducted. The eastern boundary change was based on the best available science at the time, but a new analysis should be conducted for any new boundary change being considered.

S. Amstrup noted that there was discussion previously about the western boundary. A. Derocher remarked that there was a situation in which a boundary shift was suggested in the absence of data to support it but that request was denied. M. Branigan showed a resolution by the PBSG in 2014 that stated Canadian officials had taken unilateral action to adjust the boundary. M. Branigan indicated that resolution failed to acknowledge that boundary adjustment was made using the best available science at the time and by working with affected communities.

K. Rode presented maps of bear locations in the Chukchi and Southern Beaufort Sea subpopulations relative to the northern PBSG boundaries of the populations. S. Amstrup noted that boundaries on maps are not relevant under all circumstances but in places where we have analyses that provide probabilities, it allows harvest to be allocated after the fact. A. Derocher mentioned that other forms of data can be used to inform the delineation of boundaries. For example, genetic and isotopic data that can help inform probabilities derived from spatial data. He noted that there are a lot of issues and we do not have a clear solution. In some instances, we do see geographic barriers that influence distribution. The boundary lines for subpopulations are not arbitrary, but rather are very much based on fidelity of bears to certain areas.

Co-Chair nominations

Per the decision made on Wednesday, 8 June, a final call was made to members to nominate candidates for the co-chair positions. The nominees were N. Lunn, D. Vongraven, and G. York.

Friday, 10 June

14. Sea ice session

Recent patterns of sea ice conditions

Harry Stern (invited specialist from the Polar Science Center, University of Washington) led off the session with a presentation on the history of sea ice observations and recent patterns of ice conditions. He noted that the historical record of ice observations dates back to the earliest explorers, with the modern record beginning with the advent of satellite-collected imagery in 1979. After 2001, ice began to change significantly in the Beaufort – Chukchi area in summer, which has led to an increase in ship transits. He also discussed a recent analysis of ice dynamics for the 19 PBSG subpopulations, which used National Snow and Ice Data Center data, 1979–2014. The analysis largely focuses on changes in the dates of sea ice retreat and advance. He noted that the Barents Sea has experienced the largest change (earlier melt and later freeze-up).

K. Rode asked a question about ice distribution in winter in Barents Sea. J. Aars responded that warm currents routinely affect ice in the Barents Sea, which is now several degrees warmer, which in turn, explains why fjords in west Svalbard are now open even in winter. V. Sahanatien (invited specialist, Nunavut Department of Environment) asked if the analysis also examined potential effects on polar bear subpopulations. H. Stern and K. Laidre both replied no, the analysis examined ice trends. E. Richardson asked if a break-point analysis was conducted on the trend data and whether variance in the metrics was examined. H. Stern replied that they did not conduct a break-point analysis, although others have done so. In some areas, the trend is linear, while others show a pronounced shift.

E. Regehr mentioned the importance of developing biologically relevant standard metrics, specifically those that include linkages to life history. Population projections need to evaluate effects of management actions and can bring biologically relevant sea ice metrics into analyses to test hypotheses. S. Klenzendorf (invited specialist, World Wildlife Fund) asked if analyses were conducted from an ecoregion perspective. H. Stern replied no, all analyses were focused on the subpopulation units. A. Derocher asked about challenges resolving low concentration ice during the melt and freeze-up periods. H. Stern discussed some of the issues associated with discriminating water from ice using satellite imagery.

Assumptions and uncertainties associated with sea ice projections

Dave Douglas (invited specialist, USGS) gave a presentation focused on projections of future ice extent and assumptions and uncertainties associated with those projections. He described work to model predictions to assess how polar bears will be distributed at the end of the 21st century, including which areas bears are likely to seek terrestrial refugia. Future distribution will be influenced by emissions of greenhouse gases (GHG), prey availability, food web integrity, the ability of bears to migrate seasonally, and the distribution of terrestrial food. He presented projections based on the main Representative Concentration Pathway (RCP) scenarios, which reflect a wide degree of possible futures and many possible outcomes. He reviewed the use of ice projections to model future polar bear population status in Amstrup *et al.* (2008, 2010) and in Atwood *et al.* (2015, 2016). These modelling efforts highlight the importance of mitigating GHG emissions for conserving sea ice habitat. He noted that several issues with sea ice models, including sometimes extensive variation between individual models and poor spatial resolution of models for some areas of the Arctic.

K. Laidre suggested that an important extent of the approach would be to examine the responses of different "ecotypes" of bears (e.g., those living in fjords). D. Douglas agreed. N. Lunn asked if Hudson Bay retains habitat through the end of the century under the most optimistic emissions scenario. D. Douglas responded that ice is projected to be absent for at least 4 months. A. Derocher asked about whether the approach was able to capture sufficient variation and, in particular, the potential for several sequential bad years. D.

Douglas replied that variation is captured by using a suite of models, and back-to-back bad years were not explicitly modelled.

Climate change uncertainty and commitment

Kyle Armour (invited specialist, University of Washington) gave a presentation that highlighted uncertainties associated with future conditions. Specifically, he discussed the sources of uncertainty, when critical ice habitat thresholds may be crossed, and when we may be committed to crossing those thresholds. He presented projections for western Hudson Bay using different warming scenarios and the role of aerosols in influencing those projections. He also discussed when we are likely to be committed to crossing a threshold of >180 ice-free days.

Questions addressed various issues pertaining to the role of aerosol forcing and uncertainty in general for the future.

15. National reports on management

Canada

N. Lunn presented the Canadian Management Report. He noted that the PBSG is now considered a permanent member of the PBTC. S. Belikov asked if it was correct that the polar bear hunters in Baffin Bay are from both Greenland and Canada, but the export of the harvested bears does not take place because of voluntary restrictions. N. Lunn replied that yes, it was a voluntary non-detriment (NDF) finding by Canada out of concern for the sustainability of the harvest. E. Regehr asked for clarity on the distribution of harvest numbers for the Western Hudson Bay subpopulation. N. Lunn responded that 4 go to Manitoba and 24 go to Nunavut. The allotment of 4 bears to Manitoba is for defence only; there is no harvest in Manitoba. A. Derocher asked if there was a switch from the 2:1 male:female sex ratio of harvest in Nunavut. N. Lunn replied that Markus Dyck would be the best person to contact regarding that question. F. Ugarte asked if Canada allowed the export of bears from the Kane Basin subpopulation. N. Lunn replied that while Canada does allow the export of hides from Kane Basin, Inuit from Nunavut have not harvested any bears from this subpopulation in the last several years. S. Klenzendorf asked if there is any land use planning going on in areas of the high Arctic that are likely to function as long-term ice refugia. N. Lunn responded that there is some land use planning in Nunavut, a proposal in Lancaster Sound for a Marine Protected Area, and several other initiatives.

Greenland

A. Jessen presented the Greenland Management Report. Greenland has decided on a Country total allowable harvest (TAH) of 140 bears across the subpopulations. A key challenge is that Greenland is a vast area to manage and resources are limited. With regards to human-bear conflict, the Ittoqqortoormiit/Scoresby Sound area is the most problematic. S. Belikov asked if defence of life and property kills are included in the quota. A. Jessen responded that they are not included in the quotas. Conflict situations are relatively new and if they appear to increase over time then they may be included in the quota. Currently, bears that are killed due to conflict are confiscated and the remains are burned or given to science. P. Molnár asked how often compliance officers discover issues and how non-compliance issues are handled. A. Jessen responded that fortunately problems are rare. When they occur all materials are confiscated and meat is given to a different community. Furthermore, serious infractions are referred to law enforcement. J. Wilder thanked Greenland for the progress on conflict work, particularly the testing of rubber bullets and bear spray. Quantitative evidence on deterrents will be a significant conservation benefit range-wide and he hoped the results spur other countries to broaden their current regulation of potential deterrents. L. Peacock asked what happens to cubs when sows are illegally taken or taken in defence. A. Jessen stated that it is exceptionally rare. Cubs under 2 years old are killed by law enforcement and older cubs are released.

Norway

M. Ekker presented the Norwegian Management Report. A new white paper has been released on the development of Svalbard that maintains ambitious environmental goals for the region. Information was provided on resource extraction activities, particularly that oil leases are offered every two years and Norway is in the process of updating sea ice maps and having discussions to restrict leases in areas of seasonal ice. Discussions are ongoing, but some leases have been offered in areas with historical winter ice. S. Amstrup mentioned that regarding resource extraction/exploration activity, there was quite a lot of talk in Moscow during the Range States of significant new studies funded by the oil and gas industry in Russia, and asked if there is a status update on those studies. M. Ekker responded that studies continue and Norway has a very strict protection and monitoring system. Currently, exploration activities have declined due to the low price of oil. Information on tourism activities were discussed, including the fact that the number of cruise passengers has doubled from approximately 15,000 passengers in 1997 to 30,000 in 2015. Additionally, winter tourism (including snowmobiling) has doubled over recent years. Human removal of polar bears from Svalbard has shifted dramatically from historic highs of 800–900 bears annually to few removals in recent years. When defence kills do occur, the skins are confiscated by the Governor for use by government agencies. A. Derocher asked if the strong increase in tourism traffic and landings has resulted in a trend towards increasing human-bear interactions. M. Ekker responded that was not his impression. He noted that in the white paper mentioned earlier, there is a discussion of the potential for human-bear conflict to increase as tourism increases. J. Aars mentioned that despite the increase in tourism, there has been a decrease in the number of conflict kills. This is for two reasons: people are behaving better and the Governor of Svalbard does not kill bears anymore. They put every effort into moving the bear, even if it breaks into cabins. This makes a big difference. Prior to 2000, they frequently killed bears involved in conflict with humans. J. Wilder noted that since 2008 there has been a marked increase in tourist landings and asked what is driving that increase. M. Ekker responded that it is clearly not price. J. Aars responded that it is probably due to more areas with no ice and increased landing opportunities for ships.

Russia

S. Belikov presented the Russian Management Report. Russia plans to split the Kara and Barents Sea subpopulations when the Russian Red Book is updated. The harvest moratorium is still in effect for all of Russia, including Chukotka. There are two areas where liquefied natural gas (LNG) is being produced and shipped across the Northern Sea Route to the east and west (through the southeast Barents Sea and the southwest Kara Sea). S. Amstrup asked for clarification on whether it is LNG or natural gas concentrate that is being produced and shipped. S. Belikov replied that it is LNG.

United States

E. Regehr presented the USFWS Management Report. The next meeting in support of the U.S.-Russia Bilateral Agreement will be in Anchorage, Alaska, in 2016. The USFWS recently published a polar bear deterrence manual. J. Wilder asked if the manual was in the public domain. E. Regehr responded that it is publicly available. The USFWS and the North Slope Borough Department of Wildlife Management co-fund polar bear patrols in coastal communities. A. Jessen asked what happens to bears that are killed due to self-defence concerns. E. Regehr responded that the animal is recovered by the USFWS and hides are typically used for education purposes. A. Jessen asked if there are no legal limits on polar bear take in the U.S. E. Regehr responded that there is no stated harvest limit as long as take is not wasteful. The Inuvialuit-Inupiat Joint Polar Bear Commission has a voluntary agreement on take but there is no legal mechanism to enforce that agreement. A quota for the Chukchi Sea is imminent. S. Klenzendorf asked if there will be a new aerial survey for the Southern Beaufort Sea subpopulation and whether there is a commitment by co-managers to abide by the new results of that effort. E. Regehr responded that a survey is being planned but he cannot speak to a commitment by the Inuvialuit-Inupiat Joint Polar Bear Commission. A. Derocher asked if there is a process to resolve which boundary to use under the U.S.-Russia agreement to delineate the Chukchi Sea and Southern Beaufort Sea subpopulations. E. Regehr responded that there are ongoing discussions regarding the boundary issue, and it may be possible to have a smaller management area under the agreement. S. Amstrup asked if the harvest limits in the Southern Beaufort Sea will remain voluntary and the quota in the Chukchi Sea will be legally binding. E. Regehr responded that yes, the Chukchi Sea quota will be legally binding and the Southern Beaufort Sea limit will not.

16. Putting the "eco" in eco-toxicology

Thea Bechshøft (invited specialist, University of Alberta) gave a presentation on the importance of emphasizing ecological processes and relationships when conducting eco-toxicology research. The presentation represents a summary of a paper that was submitted to a journal and should be out later this year. P. Molnár noted that per the presentation, 66% of studies published use samples from harvested bears and only 22% of studies use samples from bears caught for research. He asked if anyone has reported differences between those two groups. T. Bechshøft responded that is a topic of frequent discussion but, as yet, no one has assessed if differences exist. She noted that harvest has a male bias and dealing with potential differences between sexes and sample collection methods (i.e., harvest versus capture) remains a challenge.

Saturday, 11 June

17. The Red List process

E. Regehr gave a presentation on the most recent IUCN Red list Assessment. The last IUCN Red List Assessment for polar bears was done in 2008, and there is a long history of polar bears being listed as "vulnerable" under the Red List. A main goal of the recent assessment was to perform a data-based sensitivity analysis evaluating the response of the global population to sea ice loss. The analysis had three parts: i) estimate generation length from field data; ii) derive a habitat metric by summarizing remotely sensed sea ice data; and iii) use models and simulations to project polar bear abundance by subpopulation over three generations. A standardized sea ice metric was developed for use across all subpopulations (Stern and Laidre 2016).

The assessment projected polar bear response to sea ice changes starting in 2015 and extending out to three generation lengths. Three approaches were used to project outcomes, including one-to-one proportional relationship between ice and polar bear abundance for each subpopulation suggesting that declines in ice are linked to declines in carrying capacity. This approach has a basis in IUCN as it has been done for other species. The second approach was based on a global relationship between ice and population size using two estimates of abundance per subpopulation. The third approach was based on an ecoregion-specific relationship between ice and population size estimated from linear models using longer time series for well-studied subpopulations. The output of all 3 models was percent change in mean global population size which is what is needed to inform the categorization in the Red List assessment. The assessment used more liberal estimates of subpopulation size than in the PBSG status table for the purpose of informing this analysis.

All subpopulations exhibited declines in sea ice metrics. The first approach resulted in 30% decline in mean global population size; the second approach resulted in a 4% decline and the third approach resulted in a 43% decline. In approach 3, it appears that the well-studied subpopulations are driving the results. Those well-studied subpopulations are in decline, so they have a significant impact on the results for their respective ecoregion. Across scenarios, median probability of a mean global population size greater than 30% of 2015 abundance was 0.71.

The assessment highlights variability in the current status of polar bear subpopulations. Over near and mid-term, there is likely to be variability in the impacts of sea ice loss on polar bears. Over long-term, bears in all subpopulations will be negatively affected by sea ice loss. There was broad consistency in the outcome of these estimates and those of similar efforts (Amstrup *et al.* 2007, 2008, 2010; Atwood *et al.* 2015). As a result of this analysis, polar bears were listed as "vulnerable" under the IUCN Red List.

S. Amstrup stated that we owe E. Regehr a debt of gratitude for carrying the weight on this analysis, and noted that projections for sea ice loss and polar bear responses have higher variability in more recent time periods and greater certainty the further they are projected out. E. Richardson mentioned that for some populations like Western Hudson Bay, which is declining in relation to sea ice loss, really bad ice years seem to be the primary driver of decline. E. Regehr noted that the response of populations to variability is not balanced, and bears may need several good years to recover from one bad year. That said, we tend to think of polar bears as a long-lived K-selected species that are slow to recover, but from demographic modelling there are some surprisingly high population growth rates. Brown bears and black bears can survive relatively high harvest rates. This relates back to the potential that we may be underestimating the resilience of polar bear subpopulations.

A. Derocher complimented the work and asked if there is not non-linearity incorporated in this analysis. E. Regehr responded that the analysis did incorporate the potential for non-linear responses. P. Molnár asked what kind of delay in population response there might be in the approach used. E. Regehr stated that he felt any delay is unlikely to result in a meaningful difference in model outcomes. S. Amstrup noted that in the Bayesian models, he assumed that sea ice loss might be linear and that there would be thresholds for polar bear responses; this is a pattern seen across many species.

18. Human-polar bear conflict

Update from the Range States Conflict Working Group

G. York and V. Sahanatien gave a presentation on work conducted by the Range States Human Conflict Working Group. The Working Group was established in 2009 at Range States meeting in Tromsø, Norway. In 2015, a two-year implementation plan of the Conflict Working Group was endorsed. The group is currently working to finalize a data sharing agreement between countries, terms of reference for the functioning of the Working Group, and a requirements document describing the needs for the Polar Bear-Human Interaction Management System (PBHIMS) database. Challenges the Working Group face are a lack of a data sharing agreement, unfilled vacancies of delegates appointed to the group, and lack of financial resources.

The PBHIMS database is being used to document conflict, unusual occurrences, and natural mortalities. The respective countries have been working to enter relevant data into the database, with the intention that the information be shared across jurisdictions to address questions of how, when, and where human-polar bear conflict is occurring so that actions can be taken to mitigate future conflict. For example, all the data from Nunavut should be entered into PBIHMS by September of 2016. There appears to be increasing incidents of human-polar bear conflict in several areas and there is a need to understand the drivers of increasing conflict.

Efficacy of bear deterrent spray on polar bears

J. Wilder gave a presentation on the efficacy of bear deterrent spray on polar bears. He related a story of two people using bear spray to deter an adult female polar bear and her yearling at Pond Inlet, Nunavut. Although the evidence is limited, it provides further evidence that bear spray does appear to be effective on polar bears— bears were deterred in 14 of the 15 cases where bear spray has been used. The one unsuccessful case appeared to be a result of the wind carrying the spray away from rather than towards the bear. There was a discussion about the importance of being mindful of the expiration date of bear spray. The expiration date is typically 3 years, because the propellant use to spray the deterrent loses its strength over time. S. Belikov commented that on Wrangel Island, females with cubs most commonly came close to their base camp, and they used a variety of deterrents on those bears including turning on a motor from a four-wheeler. He recommended carrying multiple deterrents. There was discussion of the need for research to better understand the effectiveness of repeated use of deterrents on the same bear. For example, do chemical deterrents lose their effectiveness over time on bears that have experienced multiple exposures? This is a concern because in Churchill, Manitoba there are a number of bears that get captured every year for coming into conflict with people.

Bear attacks in North America

T. Smith (invited specialist, Brigham Young University) gave a presentation on the frequency of human-bear conflicts in North America. There were 682 bear conflicts documented from 1880-2015 (4.8 conflicts per year). These conflicts involved about 1500 people; 350 of the conflicts were non-contact incidents and 332 were attacks. Eighty-seven percent of attacks were by grizzly bears, 10.5% black bears, and 1.2% polar bears. Over time, there has been an increase in bear attacks that is correlated with human population growth. The majority of bear attacks on people involve injuries to the head and neck. Most incidents occur with groups of 2 or less individuals. There is a lot of conflicting information on how to respond to bear encounters and we need to develop a clear message based on what the data indicate. There was discussion as to whether the response to a bear should differ for children versus adults. T. Smith indicated that there have been no attacks on children by black, brown, or polar bears, but the potential for attacks on children should remain a concern.

Potential impacts of human recreation

J. Fortin (invited specialist, University of Montana) presented the details of a new research survey intended to examine the potential for conflict between human recreational activities and polar bears throughout their range. The PBSG members were invited to provide comments on the survey questions and to suggest potential survey participants.

19. Updates from zoos and other facilities

R. Meyerson (invited specialist, Association of Zoos and Aquaria (AZA), Bear Taxon Advisory Group, Polar Bear Lead) spoke to the Group about the AZA and their Species Survival Program (SSP) for polar bears. She provided an overview of the number of polar bears on exhibit in the United States and the opportunity for zoos to contribute to polar bear conservation, education, and research. She discussed several recent research collaborations and the role of the SSP in facilitating ex-situ research and in-situ applications.

M. Owen (invited specialist, Associate Director, Institute for Conservation Research, San Diego Zoo) described some recent captivity-based research in support of polar bear conservation and management. Research projects included the development of collar-based sensors to detect polar bear activities, seasonal dynamics of stress hormones, examination of sensory ability, metabolic studies, and estimation of isotopic discrimination factors between tissues and diet.

N. Pilfold (invited specialist, Institute for Conservation Research, San Diego Zoo) described a recent analysis of mass loss rates in polar bears held in a temporary holding facility near Churchill, Manitoba. The study used data from 142 management-related capture events carried out by Manitoba Conservation staff. Results showed that polar bears >2 years lose *ca.* 1 kg per day. Rates of mass loss for adult males held in temporary captivity were identical to those for free-ranging bears. Data were used to make inferences about the ecological relevance of terrestrial feeding, estimate the metabolic rates for fasting bears, and model the potential ability of bears to survive prolonged fasting periods.

At 15:03, the Chair announced the conclusion of the open part of the meeting and thanked the Invited Specialists for their contributions.

Closed session

20. Revisiting ToR and resolutions

The closed session resumed at 15:22, with a discussion led by E. Regehr about the revised ToR and how best to integrate them with the version developed at the 2014 meeting. A group of volunteers agreed to lead the process.

N. Lunn pointed out that according to the current ToR media are not allowed to attend meetings of the PBSG. Given that a reporter was present for the open part of this working meeting, there was discussion as to whether this stipulation should be revised. The Group agreed to revise the ToR to potentially allow media at the discretion of the (co-)chair(s) in consultation with the membership. The Group also recognized that both (co-)chair(s) will have equal ability to represent the Group in the media and elsewhere.

The following resolutions were discussed and adopted by consensus:

Resolution 1 – Convene a workshop to develop scientific criteria for the assessment and identification of subpopulation boundaries.

Resolution 2 – The PBSG will adopt interim use of the revised boundary for the purposes of the status table. The PBSG will also request the Government of the Northwest Territories make available the most recent telemetry data for use in developing a revised PBSG subpopulation boundary.

21. Elections

The Group conducted a closed vote (paper ballot) to elect D. Vongraven and N. Lunn as co-chairs and E. Regehr as the Red List Coordinator.

22. Closing remarks and adjournment

The Chair suggested that the Group aim to have products of the meeting available on the PBSG website by mid-October.

The Chair thanked all the participants for a thoughtful and productive meeting. Members thanked the National Park Service, Alaska Headquarters for hosting the meeting. The 18th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 7–11 June 2016, was adjourned at 17:24.

2016 Status Report on the World's Polar Bear Subpopulations

Status and distribution

Polar bears are neither evenly distributed throughout the Arctic, nor do they comprise a single nomadic population, but rather occur in 19 relatively discrete subpopulations (Figure 1). There is uncertainty about the discreteness of the less studied subpopulations, particularly in the Russian Arctic and neighbouring areas, due to a lack of capture and genetic data. The total number of polar bears worldwide is estimated to be 26,000 (95% CI=22,000–31,000; Regehr et al. 2016). The following subpopulation summaries are the result of discussions of the 18th Working Meeting of the IUCN/SSC Polar Bear Specialist Group held in Anchorage, Alaska, 7–11 June, 2016. The information on each subpopulation is based on the status reports given by each nation. We present estimated subpopulation sizes and associated uncertainty in those estimates, subpopulation trends, changes in sea ice habitat, recent human-caused mortality, and rationale for our determinations of status.

Status table structure

Subpopulation size

Table 1 presents subpopulation sizes and uncertainty in the estimates as 95% confidence intervals (CI). These estimates are based on scientific research using mark-recapture analysis or aerial surveys. The year of the estimate is presented to give an indication of the age of the data on which this estimate is based. For some subpopulations scientific data were not available to make population estimates.

Subpopulation trend

Qualitative categories of trend and status are presented for each polar bear subpopulation where recent data (i.e., after 2005) allowed a determination (Table 1). Status is an assessment of whether a subpopulation is not reduced or reduced relative to historic levels of abundance, or if there are insufficient data to estimate status (data deficient). Current trend is an assessment of whether the subpopulation is currently increasing, stable, or declining, or if there are insufficient data to estimate trend (data deficient).

Sea ice metrics

Because sea ice conditions are likely the most influential determinant of the future status of the world's polar bears (Atwood *et al.* 2016), we present the retrospective results of sea ice trends for all 19 subpopulations (Stern and Laidre 2016). Stern and Laidre (2016) showed a trend for earlier melt onset in spring and later freeze onset in fall, and overall decreasing extent of summer sea ice area, from passive microwave satellite imagery during the years 1979–2014. We provide these categories of trends in sea ice melt and freeze onset, and declines in the spatial extent of summer sea ice, as an index of trends in habitat loss due to climate change.

Human-caused mortality

For most subpopulations, particularly those in North America and Greenland, harvesting of polar bears is a regulated and/or monitored activity. In many cases, harvesting is the major cause of mortality for bears. In most jurisdictions, the total numbers of bears killed by humans in pursuit of subsistence and sport hunting, and in defense of life or property are documented. Where data allow, we present the five-year mean of known human-caused mortality for each subpopulation, as well as the data from the most recent year.

Polar bear subpopulations

Arctic Basin (AB)

The Arctic Basin subpopulation (AB) is a geographic catchall to account for polar bears resident in northern areas of the circumpolar Arctic that are not clearly part of other subpopulations. Polar bears occur at very low densities here, in part because of deep, cold, stratified, and less biologically productive water and, formerly at least, extensive coverage by multiyear ice. It is known that bears from several subpopulations may use the area (Durner and Amstrup 1993). As climate warming continues, it is anticipated that areas where some ice may still remain over the continental shelf may become important for polar bears as a refuge but a large part of the area is over the deepest waters of the Arctic Ocean and biological productivity is thought to be low. Polar bears with cubs have recently been observed from icebreakers in the region of this subpopulation (Ovsyanikov 2010), although it is not possible to determine whether or not these cubs were born in the AB, or make an assessment of possible total numbers on the basis of these anecdotal observations. Ovsyanikov (pers. comm.) reported that in 2015–2016 very few polar bears were seen along this route (i.e., from Svalbard to Chukotka) in July–August. The northernmost documented observation was made at 89°46 5'N, which is 25 km from the North Pole (van Meurs and Splettstoesser 2003).

Baffin Bay (BB)

Based on movements of adult females with satellite radio-collars and recaptures of tagged animals, the Baffin Bay subpopulation (BB) is bounded by the North Water Polynya to the north, Greenland to the east and Baffin Island, Canada to the west (Taylor and Lee 1995, Taylor *et al*. 2001, Laidre *et al*. 2012). A distinct southern boundary at Cape Dyer on Baffin Island in Nunavut, Canada is evident from the movements of tagged bears (Stirling *et al*. 1980, Peacock *et al*. 2012) and from polar bears monitored by satellite telemetry (Taylor *et al*. 2001). This boundary overlaps with the northern boundary of the Davis Strait subpopulation. Studies of microsatellite genetic variation have not revealed significant differences between polar bears in the BB and neighboring Kane Basin subpopulation, although there was significant genetic variation between BB polar bears and those in Davis Strait (Paetkau *et al*. 1999, Peacock *et al*. 2015, Malenfant *et al*. 2016, SWG 2016). However, BB polar bears occurred within the same genetic cluster as bears in northern Davis Strait (Peacock *et al*. 2015).

An initial subpopulation estimate of 300–600 bears in the BB subpopulation was based on mark-recapture data collected in spring 1984–1989, in which the capture effort was restricted to shore-fast ice and the floe edge off northeast Baffin Island. However, work in the early 1990s showed that an unknown proportion of the subpopulation was typically offshore during the spring and, therefore, unavailable for capture. A second study (1993–1997) was carried out during September and October, when all polar bears were thought to be ashore in summer retreat areas on Bylot and Baffin islands (Taylor *et al*. 2005). Taylor *et al*. (2005) estimated the number of polar bears in the BB subpopulation at 2,074 (SE = 226). A 3-year genetic mark-recapture survey (via biopsy darting) was completed in 2014 resulting in a new population estimate, survival rates, and habitat use analyses (SWG 2016). The mean estimate of total abundance of the BB subpopulation in 2012–2013 was 2,826 (95% CI: 2,059–3,593) polar bears. Due to evidence that the sampling design and environmental conditions resulted in an underestimate of abundance in the 1990s, these two estimates are not directly comparable and trend in abundance cannot be determined.

Satellite telemetry data and habitat selection studies in the 2000s indicate a number of ecological changes related to sea ice loss in Baffin Bay. There has been a significant reduction in the range of the BB subpopulation in all months and seasons when compared to the 1990s. The most marked reduction is a 60% decline in subpopulation range size in summer. Emigration from the BB subpopulation has declined since the 1990s, especially with a reduction of bears moving into Davis Strait and

Lancaster Sound. The total number of bears marked during studies in 2011–2012 in Baffin Bay was equivalent to ~34% of the estimated BB subpopulation size. Despite this, instances of emigration were ≤1% of the recaptures and recoveries of marks for the BB subpopulation.

Compared to the 1990s, adult female BB bears now use significantly lower sea-ice concentrations in winter and spring and spend 20–30 more days on land on Baffin Island in the summer ice-free season. Changes in maternity denning have been observed; entry dates into maternity dens are >1 month later in the 2000s than the 1990s. Furthermore, the first date of arrival on land by pregnant females is significantly earlier in the 2000s. Maternity dens in the 2000s occurred at higher elevations and steeper slopes than the 1990s, likely due to reduced snow cover.

Barents Sea (BS)

The size of the Barents Sea subpopulation (BS) was estimated to be 2,650 (95% CI: 1,900–3,600) in August 2004, using mark-recapture distance-sampling (MRDS) with data collected from aerial surveys (Aars *et al.* 2009). This analysis suggests that earlier estimates based on den counts and ship surveys (Larsen 1972) may have been too high. Ecological data supports that the BS subpopulation grew steadily during the first decade after all hunting ceased in 1973, and then either continued to grow or stabilized. A new survey in the Norwegian extent of the BS subpopulation was conducted in August 2015. The ice edge was located beyond an ice-free gap north of the Svalbard Archipelago. The number of bears encountered in Svalbard indicates that there is a local stock of ~200–300 bears (preliminary results), which did not differ much from the number detected in 2004. The results (J. Aars *et al.*, *in prep*.) also indicate, in accordance with the results from 2004, that more bears are off-shore in the pack ice in autumn. The total estimated for Norwegian Arctic was just under 1000 bears, considerably higher than the total for the Norwegian side in 2004, but with a confidence interval overlapping with the earlier estimate. During the new survey, the distribution of bears was clumped along the ice edge with most bears close to the Russian border, but access to the Russian portion of the BS subpopulation for an aerial survey was not permitted. Because of the overlapping confidence intervals, it cannot be concluded that the BS subpopulation has grown.

It is believed that excess hunting in the area before 1973 led to a population size far below the carrying capacity. Consequently, it could be that the current population size is still lower because of an ongoing decline in, carrying capacity. Thus, it is unclear what the trajectory of the subpopulation will be in near future; we do expect that habitat loss will continue. There have not been any dramatic time trends in reproduction or condition parameters in BS polar bears, although poor ice years seem to influence these parameters.

Subpopulation boundaries based on satellite telemetry data indicate that the BS subpopulation is a natural subpopulation unit, albeit with some overlap to the east with the Kara Sea (KS) subpopulation (Mauritzen *et al.* 2002). Overlap between the BS and the East Greenland (EG) subpopulations may be limited (Born *et al.* 1997), although to some degree home ranges of bears from the EG subpopulation overlap with those of bears from Svalbard in Fram Strait (Born *et al.* 2012). Genetically, polar bears from the BS subpopulation are similar to those in the EG, KS, and Laptev Sea (LP) subpopulations (Paetkau *et al.* 1999, Peacock *et al.* 2015). At a global level, BS polar bears belong to the Eastern Polar Basin genetic cluster (one of four global genetic clusters); substantial directional gene flow occurs from the Eastern Polar Basin to the Western Polar Basin (Peacock *et al.* 2015).

At a finer scale, there is evidence to support sub-structuring of polar bears of the BS subpopulation. Studies on individual movement using satellite telemetry and mark-recapture have been conducted in the Svalbard area since the early 1970s (Larsen 1972, 1985; Wiig 1995, Mauritzen *et al.* 2001, 2002). These data show that some bears associated with Svalbard are very restricted in their movements, but bears specifically from the Barents Sea range widely between Svalbard and Franz Josef Land in the western Russian Arctic (i.e., a 'pelagic' type; Wiig 1995, Mauritzen *et al.* 2001).

Within the BS subpopulation boundaries, substructure between local Svalbard bears and pelagic bears is likely increasing as sea ice around the islands disappears for longer durations. Fewer of the pelagic bears use maternity dens in the eastern part of Svalbard (Derocher *et al.* 2011, Aars 2013), in traditionally important denning areas, and it is likely that many of these bears now den more frequently on Franz Josef Land. Some bears of the pelagic-type from northern Svalbard, move north to the Arctic Ocean in the summer, and return to northern Svalbard in the winter, whereas bears from southeast Svalbard follow retreating ice to the east. Capture-recapture data also show that movement between northwest and southeast Svalbard is rare between springs of different years (Lone *et al.* 2013).

A new national park on Franz Josef Land was dedicated by the Russian Federation in 2016; this is an important summering area for polar bears.

Chukchi Sea (CS)

Studies in the late 1980s and early 1990s using satellite radio-telemetry revealed that polar bears in the Chukchi Sea subpopulation (CS), also known as the Alaska-Chukotka subpopulation (see: *Polar bear management and research in Russia, 2009–2016*, in these proceedings) are widely distributed on the pack ice of the northern Bering, Chukchi, and eastern portions of the East Siberian seas (Garner *et al.* 1990, 1994, 1995). Based upon these telemetry studies, the western boundary of the CS subpopulation was set near Chaunskaya Bay in northeastern Russia. The eastern boundary was set at Icy Cape, Alaska, which is also the western boundary of the Southern Beaufort Sea (SB) subpopulation (Amstrup and DeMaster 1988, Garner *et al.* 1990, Amstrup *et al.* 1986, 2004a, 2005).

Precise estimates of subpopulation size or status are not available. An approximate estimate of 2,000–5,000 animals was based on the number of maternity dens observed on Wrangel and Herald islands and the Chukotkan coast, and the assumed proportion of females in the subpopulation (Belikov 1993). In recent years the range occupied by the CS subpopulation has experienced longer ice-retreat seasons and more ice-free days over the biologically productive waters of the continental shelf (Durner *et al.* 2009, Rode *et al.* 2013). Sea ice loss is expected to continue (Douglas 2010). Rode *et al.* 2013 documented stable or improving body condition and reproduction for polar bears captured in the U.S. between 1986–1994 and 2008–2011, a period during which substantial sea ice loss occurred, suggesting the capacity for positive population growth. Autumn-based observations on Wrangel Island for the period 2004–2010, however, suggest relatively low cub production and reduced maternity denning (Ovsyanikov 2012).

Estimates of illegal take of CS polar bears in Russia are based on village interviews conducted 2010–2012, and the current level appears to be significantly lower than in the 1990s (Kochnev and Zdor 2016). Combined with legal subsistence harvest in the U.S., the overall level of human-caused removals for the CS subpopulation may exceed sustainable limits. Uncertainty in the level of human-caused removals, current population size, and population growth rate result in a designation of "Data deficient" for the status relative to historic abundance and the current trend of the CS subpopulation.

New studies have found that polar bears of the CS subpopulation have been increasingly using land during the summer, both in Russia, on Wrangel Island and the Chukotkan peninsula, and on the northwest Alaskan coast of the United States (Rode *et al.* 2015). However, Wilson *et al.* (2014, 2016) have found that despite large reductions in sea ice, particularly in summer, polar bears have not changed their habitat selection preferences in the Chukchi Sea.

Davis Strait (DS)

Based on the recapture or harvest of previously tagged animals and tracking adult female polar bears with satellite collars, the Davis Strait subpopulation (DS) occurs in Canada within the Labrador Sea, eastern Hudson Strait, Davis Strait south of Cape Dyer, and along a portion of southwest Greenland (Stirling *et al*. 1980, Stirling and Kiliaan 1980, Taylor and Lee 1995, Taylor *et al*. 2001). A genetic study of polar bears (Paetkau *et al*. 1999) indicated significant differences between bears from southern Davis Strait and both Baffin Bay and Foxe Basin; Crompton *et al*. (2008) found that individuals from northern portions of Davis Strait and those from Foxe Basin share a high degree of ancestry. Peacock *et al*. (2015) used samples from both northern and southern Davis Strait in an updated circumpolar genetic analysis, and found that the two regions are so distinct as to belong to two different global genetic clusters (i.e., southern Davis Strait in Southern Canada and northern Davis Strait in the Canadian Archipelago).

The initial estimate of 900 bears for the DS subpopulation (Stirling *et al*. 1980, Stirling and Kiliaan 1980) was based on a subjective correction from the original mark-recapture estimate of 726 bears, which was thought to be too low because of possible bias in the sampling. In 1993, the estimate was again subjectively increased to 1,400 bears and to 1,650 in 2005. These increases were to account for bias as a result of springtime sampling, the fact that the existing harvest appeared to be sustainable and not having negative effects on the age structure, and Traditional Ecological Knowledge (TEK) that suggested that more bears were being seen over the last 20 years. In addition, harp seals, an important prey species for that population, had increased dramatically over the same period, providing a much-enhanced potential prey base. Polar bears were seen and radio-tracked in the large pupping areas off the coast of southern Labrador in spring. The most recent inventory of the DS subpopulation was completed in 2007. With a resulting estimate of 2,158 (95% CI: 1,833–2,542) (Peacock *et al*. 2013), the DS subpopulation was assessed as stable. Polar bear survival in the DS subpopulation varied with time and geography, and was related to factors that included reductions in sea ice habitat and increases of harp seal (*Pagophilus groenlandicus*) numbers (Peacock *et al*. 2013). It was suggested that the observed lowered reproductive rates and declines in body condition of polar bears in the DS subpopulation were likely a result of habitat changes and/or polar bear density (Peacock *et al*. 2013, Rode *et al*. 2012).

East Greenland (EG)

Satellite-telemetry data show that polar bears range widely along the coast of eastern Greenland and in the pack ice in the Greenland Sea and Fram Strait (Born *et al*. 1997, 2009; Wiig *et al*. 2003, Laidre *et al*. 2012, 2015). Various studies have shown that there are resident groups in the region (Born 1995, Dietz *et al*. 2000, Sandell *et al*. 2001), and the East Greenland subpopulation (EG) is thought to have limited exchange with other subpopulations (Wiig 1995, Born *et al*. 2009). Although there is little evidence of genetic difference between subpopulations in the eastern Greenland and Svalbard-Franz Josef Land regions (Paetkau *et al*. 1999), satellite telemetry and movement of marked animals have detected minimal exchange between the EG and the Barents Sea (BS) subpopulations (Wiig 1995, Born *et al*. 1997, 2009; Wiig *et al*. 2003, Laidre *et al*. 2012). Polar bears of the EG subpopulation fall within the Eastern Polar Basin genetic cluster, one of 4 global genetic clusters of polar bears (Peacock *et al*. 2015). Laidre *et al*. (2015) showed that due to multi-decadal sea ice loss within the region of the EG subpopulation, there have been changes in bears' habitat use between the 1990s and 2000s. Adult females tracked in the 2000s used areas with significantly lower sea ice concentrations (10–15% lower) than adult females in the 1990s during winter. They were also located significantly closer (100–150 km) to open water in all seasons and spent approximately 2 months longer in areas with <60% sea ice concentration than bears in the 1990s. No inventories have been conducted to determine the size of the EG polar bear subpopulation, however pilot studies were initiated in southeast Greenland in 2015 to collect data to inform an assessment (Laidre, unpubl data).

Foxe Basin (FB)

Based on decades of mark-recapture studies and satellite tracking of female bears of the

Western Hudson Bay (WH) and Southern Hudson Bay (SH) subpopulations, the Foxe Basin subpopulation (FB) appears to occur in Foxe Basin, northern Hudson Bay, and the western end of Hudson Strait (Taylor and Lee 1995, Sahanatien *et al.* 2015). The most recent mapping of satellite telemetry data indicates substantial overlap with the WH and SH subpopulations and, to a lesser extent, with the DS subpopulation (Peacock *et al.* 2010; Sahanatien *et al.* 2015). During the ice-free season, polar bears are concentrated on Southampton Island and along the Wager Bay coast; however, significant numbers of bears are also encountered on the islands and coastal regions throughout the FB subpopulation area (Stapleton *et al.* 2015). A total subpopulation estimate of 2,197 ± 260 for 1994 was developed (Taylor *et al.* 2006) from a mark-recapture analysis based on tetracycline biomarkers where the marking effort was conducted during the ice-free season, and distributed throughout the entire area. TEK suggested the FB subpopulation of polar bears had increased (GN consultations in villages in Foxe Basin 2004–2012). During a comprehensive summertime aerial survey in 2009 and 2010 (based on distance sampling and double-observer estimation) covering about 40,000 km each year, 816 and 1,003 bears were observed, respectively (Stapleton *et al.* 2016). This most recent study of the FB subpopulation yielded an abundance estimate of 2585 (95% CI: 2,096–3,189) polar bears (Stapleton *et al.* 2016), which is not statistically different from the 1994 estimate indicating a stable population. Sea ice habitat for polar bears has decreased substantially for polar bears over the last several decades in Foxe Basin (Sahanatien and Derocher 2012).

Gulf of Boothia (GB)

The boundaries of the Gulf of Boothia subpopulation (GB) are based on genetic studies (Paetkau *et al.* 1999, Campagna *et al.* 2013, Peacock *et al.* 2015, Malenfant *et al.* 2016), movements of tagged bears (Stirling *et al.* 1978, Taylor and Lee 1995), radio telemetry in the Gulf of Boothia and adjacent areas (Taylor *et al.* 2001), and interpretations by local Inuit hunters of how local conditions influence the movements of polar bears in the area. The GB subpopulation belongs in the Canadian Archipelago global genetic cluster (Peacock *et al.* 2015). An initial subpopulation estimate of 333 bears was derived from the data collected within the boundaries proposed for the GB subpopulation, as part of a study conducted over a larger area of the central Arctic (Furnell and Schweinsburg 1984). Although population data from this area were limited, local hunters reported that numbers remained constant or increased since the time of the central Arctic polar bear survey. Based on TEK, recognition of sampling deficiencies, and polar bear densities in other areas, an interim subpopulation estimate of 900 was established in the 1990s. Following the completion of a mark-recapture inventory in spring 2000, the GB subpopulation was estimated to number 1,592 ± 361 bears (Taylor *et al.* 2009). Natural survival and recruitment rates were estimated at values higher than the previous standardized estimates (Taylor *et al.* 1987). Taylor *et al.* (2009) concluded that the GB subpopulation was increasing in 2000, as a result of high intrinsic rate of growth and low harvest. Harvest rates were increased in 2005 based on the 2000 population estimate and the population was believed to be stable. A three year (genetic mark-recapture) inventory study for the GB subpopulation began in spring of 2015.

Kane Basin (KB)

Based on the movements of adult females with satellite collars and recaptures of tagged animals, the boundaries of the Kane Basin subpopulation (KB) include the North Water Polynya to the south, the Kennedy Channel to the north and Greenland and Ellesmere Island to the east and west (Taylor *et al.* 2001). Polar bears in Kane Basin do not differ genetically from those in Baffin Bay (Paetkau *et al.* 1999, Peacock *et al.* 2015). The size of the KB subpopulation was estimated to be 164 (SE = 35) for 1994–1997 by Taylor *et al.* (2008). The intrinsic natural rate of growth for KB polar bears was estimated to be low at 1.009 (SE = 0.010) (Taylor *et al.* 2008), likely because of large expanses of multi-year ice and low population density of seals (Born *et al.* 2004). A genetic mark-recapture survey (via biopsy darting) and aerial survey were completed in 2014 resulting in a new population estimate, survival rates, and habitat use analyses (SWG 2016). Using genetic mark-recapture, the estimated abundance of the KB subpopulation was 357 polar bears (95% CI: 221–493) for 2013–2014. More bears were documented in the eastern regions of the KB subpopulation during 2012–2014 than during 1994–1997. The difference in distribution between the 1990s and 2010s may reflect differences in spatial distribution of bears, possibly influenced by reduced hunting pressure by Greenland in eastern Kane Basin but also some differences in sampling protocols. An estimate of abundance based on a springtime 2014 aerial survey for the KB subpopulation was 206 bears (95% lognormal CI: 83– 510). However, due to insufficient coverage of offshore polar bear habitat, this estimate is likely negatively biased. The total number of bears marked during studies in 2012–2013 in Kane Basin was equivalent to ~25% of the estimated size of the KB subpopulation. Despite this, documented cases of emigration comprised <4% of recaptures and recoveries in Kane Basin.

Changing sea-ice conditions have resulted in broad movement and habitat use patterns by bears of the KB subpopulation that are more similar to those of bears in seasonal sea-ice ecoregions. The size of the KB subpopulation range has expanded since the 1990s in all seasons, especially in summer (June–September) where ranges doubled between the 1990s and the 2000s. Land use by polar bears of the KB subpopulation during summer remains intermittent because some sea ice remains inside fjords and coastal areas. Reproductive metrics for bears of the KB subpopulation were comparable between the 1990s and 2010s sampling periods. Body condition of KB polar bears appeared to have slightly improved between sampling periods (see SWG 2016). Overall, the data on abundance when considered with data on movements, condition, and reproduction, suggest evidence that the KB subpopulation has increased.

Kara Sea (KS)

The Kara Sea subpopulation (KS) overlaps in the west with the Barents Sea subpopulation (BS) in the area to the east of Franz Josef Land and includes the Novaya Zemlya archipelago. Data from KS and BS subpopulations, in the vicinity of Franz Josef Land and Novaya Zemlya, are mainly based on dated aerial surveys and den counts (Parovshivkov 1965, Belikov and Matveev 1983, Uspenski 1989, Belikov *et al.* 1991, Belikov and Gorbunov 1991, Belikov 1993). Telemetry studies of movements have been done throughout the area, but data to define the eastern boundary are incomplete (Belikov *et al.* 1998, Mauritzen *et al.* 2002). Using polar bear samples from the KS subpopulation from the 1990s suggests that, at a global level, KS polar bears belong to the Eastern Polar Basin genetic cluster (together with polar bears from the BS and Laptev Sea subpopulations). Peacock *et al.* (2015) found substantial directional gene flow (29-fold difference) from the Eastern Polar Basin to the Western Polar Basin genetic clusters.

Lancaster Sound (LS)

Information on the movements of adult female polar bears monitored by satellite radio-collars, and mark-recapture data from past years, has shown that the Lancaster Sound subpopulation (LS) is distinct from the adjoining Viscount Melville Sound (VS), M'Clintock Channel (MC), Gulf of Boothia (GB), Baffin Bay (BB) and Norwegian Bay (NW) subpopulations (Taylor *et al.* 2001). Survival rates of the pooled NW and LS subpopulations were used in the PVA to minimize sampling errors; the subpopulation estimate of 2,541 (SE = 391) is based on an analysis of both historical and current mark-recapture data to 1997 (Taylor *et al.* 2008). This estimate is considerably larger than a previous estimate of 1,675 that included NW (Stirling *et al.* 1984). Taylor *et al.* (2008) estimated survival and recruitment parameters that suggest this subpopulation has a lower renewal rate than previously estimated. However, what effect this may or may not have on the present population is not known, especially under changing sea-ice conditions.

Currently, the population data are dated, but the population is thought to be stable based on local traditional information.

Laptev Sea (LP)

The Laptev Sea subpopulation (LP) area includes the western half of the East Siberian Sea and most of the Laptev Sea, including the Novosibirsk and possibly Severnaya Zemlya islands (Belikov *et al.* 1998). The 1993 estimate of subpopulation size for LP polar bears (800–1,200) is based on aerial counts of dens on the Severnaya Zemlya in 1982 (Belikov and Randla 1987) and on anecdotal data collected in 1960–1980s on the number of females coming to dens on Novosibirsk Islands and on the mainland coast (Kischinski 1969, Uspenski 1989). At present these estimates are not actual, and the size of the LP subpopulation is unknown.

M'Clintock Channel (MC)

The current population boundaries for the M'Clintock Channel subpopulation (MC) are based on recovery of tagged bears, movements of adult females with satellite radio-collars in adjacent areas (Taylor and Lee 1995, Taylor *et al.* 2001), and genetics (Paetkau *et al.* 1999, Campagna *et al.* 2013, Peacock *et al.* 2015, Malenfant *et al.* 2016). These boundaries appear to be a consequence of large islands to the east and west, the mainland to the south, and the multiyear ice in Viscount Melville Sound to the north. An estimate of 900 bears was derived from a 6-year study in the mid-1970s within the boundaries proposed for the MC subpopulation, as part of a study conducted over a larger area of the central Arctic (Furnell and Schweinsburg 1984). Following the completion of a mark-recapture inventory in spring 2000, the subpopulation was estimated to number 284 (SE = 59.3) (Taylor *et al.* 2006a). Natural survival and recruitment rates were estimated at values lower than previous standardized estimates (Taylor *et al.* 1987). As a consequence of the reduced population abundance, and after an initial harvest moratorium, harvest levels for MC polar bears were drastically reduced to levels that should allow the population to recover and increase. A 3 year genetic mark-recapture study began in 2014.

As with habitat in the GB subpopulation region, Barber and Iacozza (2004) found no trends in ringed seal habitat or sea ice condition from 1980 to 2000 in the MC subpopulation region. A general trend has been detected for earlier break-up and delayed freeze-up (Stern and Laidre 2016, Markus *et al.* 2009), but multiyear ice is predicted to persist into the near future (Sou and Flato 2009, Maslanik *et al.* 2011, Howell *et al.* 2008). Habitat quality could be improved over the short-term and multiyear ice declines.

Northern Beaufort Sea (NB)

Studies of movements and abundance estimates of polar bears in the eastern Beaufort Sea have been conducted using telemetry and mark-recapture at intervals since the early 1970's (Stirling *et al.* 1975, Demaster *et al.* 1980, Stirling *et al.* 1988, Lunn *et al.* 1995). As a result, it was recognized that there were separate populations in the northern and southern Beaufort Sea areas (i.e., the Northern Beaufort Sea [NB] and Southern Beaufort Sea [SB} subpopulations), and not a single population as was suspected initially (Stirling *et al.* 1988, Amstrup *et al.* 1995, Taylor and Lee 1995, Bethke *et al.* 1996). The density of polar bears using the multi-year ice of the northernmost area was lower than it was further south. The subpopulation estimate of 1,200 (Stirling *et al.* 1988) for NB polar bears was believed to be relatively unbiased at the time but the most northerly areas of the northwestern coast of Banks Island and M'Clure Strait were not permitted to be completely surveyed because of concern about disruption to guided polar bear sport hunters at the same time. The most northerly region of the NB subpopulation were later surveyed in 1990–1992; the densities encountered were low, few subadult bears were seen, and the ratio of marked to unmarked polar bears was similar to that in the southern portion of the subpopulation. A mark-recapture survey, completed in 2006 suggested that the size of the NB subpopulation to be 980 (95% CI: 825–1,135), and that it has remained stable over the previous three decades, probably because ice conditions have remained stable and the harvest has been maintained within sustainable limits (Stirling *et al.* 2011). The amount of ice remaining over the continental shelf in the NB subpopulation region in late summer fluctuates. Analyses using data from satellite tracking of female polar bears and spatial modeling techniques suggest that the boundary between NB and SB subpopulations may need to be moved somewhat to the west of its current eastern limit at Pearce Point, in response to changing patterns of breakup and freeze-up resulting from climate warming (Amstrup *et al.* 2004, Amstrup *et al.* 2005). In 2014, the boundary (for management purposes within the Inuvialuit Settlement Area) between NB and SB subpopulations was moved to the vicinity of Tuktoyaktuk on the basis of TEK (Figure 1; Joint Secretariat 2015) and older satellite telemetry data (Amstrup *et al.* 2004). For the purposes of this assessment, we (IUCN/SSC/PBSG) will adopt interim use of the revised boundary between SB and NB subpopulations used by management authorities in the Northwest Territories and Yukon Territory.

Norwegian Bay (NW)

The Norwegian Bay subpopulation (NW) appears to be genetically unique (Malenfant *et al.* 2016). This subpopulation is bounded by heavy multi-year ice to the west, islands to the north, east, and west, and polynyas to the south (Stirling *et al.* 1993, Stirling 1997, Taylor *et al.* 2008). From data collected during mark-recapture studies, and from satellite radiotracking of adult female polar bears, it appears that most of the polar bears in this subpopulation are concentrated along the coastal tide cracks and ridges along the north, east, and southern boundaries (Taylor *et al.* 2001). The most current (1993–1997) estimate is 203 (SE = 44) (Taylor *et al.* 2008). Survival rate estimates for the NW subpopulation were derived from pooled LS and NW data because the subpopulations are adjacent and the number of bears captured in the NW subpopulation region was too small to generate reliable survival estimates. The 5-year mean harvest (2009/10–2013/14) has been well below a sustainable harvest level for that population size. Population data are dated.

Southern Beaufort Sea (SB)

Radio-telemetry and mark-recapture studies through the 1980s indicated that polar bears in the region between Paulatuk and Baillie Island, Northwest Territories (NWT), Canada, and Icy Cape, Alaska, USA, comprised a single Southern Beaufort Sea subpopulation (SB) (Amstrup *et al.* 1986, Amstrup and DeMaster 1988, Stirling *et al.* 1988). Probabilistic models developed from relocations of polar bears carrying satellite radio collars suggested that, rather than exhibiting distinct boundaries, there were areas of overlap between the SB and adjacent subpopulations (Amstrup *et al.* 2004b, Amstrup *et al.* 2005). The results of that study suggested that at Barrow, Alaska, in the west, 50% of polar bears were from the SB subpopulation and 50% were from the Chukchi Sea (CS) subpopulation, and that at Tuktoyaktuk, NWT, to the east, there was a 50% probability of polar bears being either from the SB or the northern Beaufort Sea (NB) subpopulation. To address the issue of overlapping boundaries, resource managers in Canada shifted the eastern boundary westward to 133° W longitude (due north of Tuktoyaktuk) in 2014. A similar boundary shift, or a change in the way harvest is allocated among subpopulations, may be required on the western side of the SB subpopulation where it borders the CS subpopulation (Amstrup *et al.* 2005).

The size of the SB subpopulation was first estimated to be approximately 1,800 animals in 1986 (Amstrup *et al.* 1986). Survival rates of adult females and dependent young were estimated from radio-telemetry data collected from the early 1980s to the mid-1990s (Amstrup and Durner 1995) and observations suggested that abundance was increasing. Results from a mark-recapture study conducted from 2001–2006 in both the USA and Canada indicated that the SB subpopulation included 1,526 (95% CI: 1,211–1,841) polar bears in 2006 (Regehr *et al.* 2006). That study and others found that the survival and breeding of polar bears were negatively affected by changing sea ice conditions, and that population growth rate was strongly negative in years with long ice-free seasons, such as 2005 when Arctic sea ice extent reached a former record low (Hunter *et al*. 2010, Regehr *et al*. 2010). The most recent analysis (covering the years 2001–2010) showed that survival estimates remained low through 2007 and increased through 2009, resulting in an abundance estimate of 907 (95% CI: 548–1,270) polar bears present in 2010 (Bromaghin *et al*. 2015). However, it is important to note that here is the potential for un-modeled spatial heterogeneity in mark-recapture sampling, resulting from field crews being unable to sample the entire geographic reach of the population boundaries, which could bias both survival and abundance estimates. A recent Traditional Knowledge study from Canada concluded that the numbers of polar bears in regularly used hunting areas have remained relatively stable within living memory (Joint Secretariat 2015).

Declines in polar bear body condition, stature, and reproduction have been linked to multi-year trends of declining sea ice (Rode *et al*. 2010), and an assessment of temporal patterns of feeding ecology found that the number of bears in a physiological fasting state increased from the mid-1980s to the mid-2000s (Cherry *et al*. 2009). These data support the hypothesis that energy balance of polar bears has changed in the southern Beaufort Sea, which may explain observed declines in survival. Sea ice habitat for polar bears is declining due to declines in sea ice extent (Stroeve *et al*. 2014), resulting from the continuing effects of climate warming. Atwood *et al*. (2016) and Pongracz and Derocher (2016) found that SB polar bears are spending significantly more time on land, which is correlated with the extent of ice retreat. Further, while on land, many polar bears feed on the subsistence-harvested bowhead whale remains aggregated at Cross Island near the Prudhoe Bay industrial infrastructure and Barter Island near the community of Kaktovik (Herreman and Peacock 2013, Rogers et al. 2015). Increased polar bear activity near human settlements may increase the risk of human-bear interactions.

For the purposes of this assessment, we (IUCN/SSC/PBSG) will adopt interim use of the revised boundary between SB and NB subpopulations used by management authorities in the Northwest Territories and Yukon Territory (Figure 1).

Southern Hudson Bay (SH)

Boundaries of the Southern Hudson Bay polar bear subpopulation (SH) are based on observed movements of marked and collared bears (Jonkel *et al*. 1976, Kolenosky and Prevett 1983, Kolenosky *et al*. 1992, Obbard and Middel 2012, Middel 2013). The range of the SH subpopulation includes much of eastern and southern Hudson Bay and James Bay and large expanses of the coastline of Ontario and Québec as well as areas up to 120 km inland (Kolenosky and Prevett 1983, Obbard and Walton 2004, Obbard and Middel 2012).

An initial estimate of population size of 763 ± 323 animals was derived through a 3-year (1984–1986) capture-recapture study conducted in mainland Ontario (Kolenosky *et al*. 1992). This estimate was subsequently adjusted to 1000 for management purposes by the Canadian Polar Bear Technical Committee (PBTC) because areas away from the coast may have been under-sampled due to the difficulty of locating polar bears in the boreal forest and some areas in James Bay were not sampled (Lunn *et al*. 1998). A re-analysis of the 1984–1986 capture data produced an estimate for the study area of 641 (95% CI: 401–881) for those years (Obbard 2008, Obbard *et al*. 2007). A subsequent 3-year capture-recapture study (2003–2005) produced an estimate of 673 (95% CI: 396–950) (Obbard 2008). An analysis of bears captured on Akimiski Island in James Bay during 1997 and 1998 resulted in the addition of 70–110 bears to the total subpopulation estimate (Obbard 2008). Results of the two capture-recapture studies suggest that abundance was unchanged between 1984–1986 and 2003–2005, though survival rates in all age and sex categories and body condition declined (Obbard *et al*. 2006, Obbard 2008).

Intensive aerial surveys were conducted during the fall ice-free season over mainland Ontario (same geographic area as for the capture–recapture studies) and Akimiski Island in 2011 and over the remaining islands in James Bay, the coastal areas of Québec from Long Island to the SH–FB subpopulation border, and the off-shore islands in eastern Hudson Bay in 2012. Results of this mark-recapture-distance-sampling (MRDS) analysis provided an estimate of 860 bears (95% CI: 580–1,274) in the mainland Ontario, neighboring islands, and Akimiski Island portions of the SH management unit during the 2011 ice-free season. The estimate for the 2012 survey was 83 bears (SE = 4.5) in the 2012 study area. Thus, combining the aerial survey results from 2011 and 2012 yielded an overall estimate of 943 (SE: 174, 95% CI: 658–1350) for SH (Obbard *et al.* 2015). Overall, despite the difference in methodologies, assumptions, and biases between capture–recapture studies and aerial surveys, the evidence suggests it is likely that the subpopulation has not changed in abundance since the mid-1980s. The intensive aerial survey was repeated in September 2016 to assess recent trend in abundance. All areas in Ontario, Nunavut and Québec were sampled within a 3-week period to ensure complete coverage within the same year. Results should be available by March 2017.

The ice-free season within the SH subpopulation boundaries increased by about 30 days from 1980 to 2012 (Obbard *et al.* 2016). Concurrently, body condition declined in all age and sex classes, though the decline was less for cubs than for other social classes. If trends towards a longer ice-free season continue in the future, further declines in body condition and survival rates are likely, and ultimately, declines in abundance.

Viscount Melville Sound (VM)

A five-year study of movements and subpopulation size, using telemetry and mark-recapture, was completed for polar bears inhabiting the Viscount Melville Sound subpopulation (VM) region in 1992 (Messier *et al.* 1992, 1994, Taylor *et al.* 2002). Subpopulation boundaries were based on observed movements of female polar bears with satellite radio-collars and movements of bears tagged in and out of the study area (Bethke *et al.* 1996, Taylor *et al.* 2001). The most recent (i.e., 1992) subpopulation estimate of 161 (SE = 34) (Taylor *et al.* 2002) is 25 years old and the PBSG now regards VM as a data deficient subpopulation. However, in spring 2014, the field component of a mark-recapture study to re-assess abundance and status of the VM subpopulation was completed; the results are not yet available.

Western Hudson Bay (WH)

The current population boundaries of the Western Hudson Bay subpopulation (WH) are based on capture, recapture, and harvest of tagged animals (Stirling *et al.* 1977, Derocher and Stirling 1990, 1995a, Taylor and Lee 1995, Lunn *et al.* 1997). This subpopulation appears to be geographically segregated from the SH subpopulation to the southeast and the FB subpopulation to the north during the open-water season, although all three subpopulations mix on the Hudson Bay sea ice during the winter and spring (Stirling *et al.* 1977, Derocher and Stirling 1990, Stirling and Derocher 1993, Taylor and Lee 1995).

During the 1960s and 70s, abundance likely increased with the closure of the fur trading post at York Factory, withdrawal of military personnel from Churchill, and the closure of hunting in Manitoba (Stirling *et al.* 1977, Derocher and Stirling 1995a). Derocher and Stirling (1995a) estimated the mean population size for 1978–1992 to be 1,000 (SE = 51). This estimate was considered conservative because the study had not covered the southern portion of the range east of the Nelson River; for management purposes, population size was adjusted to 1,200 (Calvert *et al.* 1995, Wiig *et al.* 1995). In 1994 and 1995, Lunn *et al.* (1997) expanded the capture program to sample animals to the boundary between the WH and SH subpopulations. Using these additional data, abundance was estimated to be 1,233 (95% CI: 823–1,643) in autumn 1995. Regehr *et al.* (2007) reported a decline in abundance from 1,194 (95% CI: 1,020–1,368) in 1987 to 935 (95% CI: 794–1,076) in 2004. Further, the survival rates of cubs, sub-adults, and old bears (>20 years) were negatively correlated with the date of sea ice breakup (Regehr *et al.* 2007). A mark-recapture distance sampling study resulted in an abundance estimate of 1,030 (95% CI: 754–1,406) in 2011 (Stapleton *et al.* 2014). During this survey, 711 bears were observed and more bears, particularly adult males, were observed in the coastal areas east of the Nelson River towards the WH-SH subpopulation boundary than were documented during the late 1990s (Stirling *et al.* 2004). Stapleton *et al.* (2014) suggested that a distributional shift may have negatively biased abundance estimates derived from capture samples. The mean litter size (cubs-of-the-year, 1.43 [SE = 0.08]; yearlings, 1.22 [SE = 0.10]) and number of cubs observed as a proportion of total observations (cubs-of-the-year, 0.07; yearlings, 0.03) were lower than those recorded for the neighboring FB and SH subpopulations and consistent with WH bears having low reproductive productivity (Regehr *et al.* 2007, Peacock *et al.* 2010, Stapleton *et al.* 2014). The body mass of solitary adult female polar bears has declined over the past 30 years, which has likely contributed to declining reproductive success (Derocher and Stirling 1995b, Stirling *et al.* 1999, Sciullo *et al.* 2016, Lunn, unpubl. data).

Lunn *et al.* (2016) evaluated the demography and population status of WH polar bears for the period 1984–2011, using a Bayesian implementation of multistate capture-recapture models, coupled with a matrix-based demographic projection model, to integrate several types of data and to incorporate sampling uncertainty, and demographic and environmental stochasticity across the polar bear life cycle. Their analysis resulted in an estimate of 806 (95% CI: 653–984) for polar bears in the core area of study north of the Nelson River in 2011. Although both the aerial survey and capture-recapture estimates are broadly similar with overlapping confidence intervals, it is difficult to make direct comparisons because the geographical area covered differed. The aerial survey likely provides an accurate "snapshot" estimate of the total number and distribution of polar bears in the WH subpopulation region at the time of the survey. The point estimate of abundance from the capture-recapture model, represents the number of bears that move through the smaller, capture-recapture sampling area.

In addition to an estimate of abundance, Lunn *et al.* (2016) documented a significant relationship between sea ice conditions and survival of female polar bears of all age classes. For the recent decade 2001-2011, the growth rate of the female segment of the population was 1.02 (95% CI: 0.98–1.06), which may be due in large part to short-term stability of ice conditions in western Hudson Bay.

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Tables

Table 1. Status table of world polar bear subpopulations.

Subpopulation	Subpopulation size				Subpopulation trend		Sea ice metrics		Human-caused removals: 2011-2015			
									5-year mean		Last year	
	Estimate	95% CI	Year	Method	Relative to historic level (approx. 25-yr past)	Current (approx. 12-yr period centered on present)	Change in spring ice retreat/Change in fall ice advance (days per decade)[1]	Change in summer sea ice area (percent change per decade)	Potential	Actual	Potential	Actual
Arctic Basin	Unknown				Data deficient	Data deficient	-3.2/8.0	-6.7				
Baffin Bay	2826	2059-3593	2012-2013	Genetic capture-recapture	Not reduced	Data deficient	-7.3/5.2	-18.9	140	143	132	133
Barents Sea	2644	1899-3592	2004	Distance sampling	Data deficient	Data deficient	-16.6/24.2	-16.0	N/A	1	N/A	1
Chukchi Sea	Unknown				Data deficient	Data deficient	-3.4/4.2	-18.8	58	29 (U.S.) + approx. 32 (Russia)	58	9 (U.S.) + approx. 32 (Russia)
Davis Strait	2158	1833-2542	2007	Physical capture-recapture	Not reduced	Stable	-7.7/9.7	-19.9	102	109	108	96
East Greenland	Unknown				Data deficient	Data deficient	-6.2/5.5	-6.5	62	63	64	65

Table 1. Continued.

Subpopulation	Comments, vulnerabilities, and concerns	References
Arctic Basin		
Baffin Bay	Due to evidence that the sampling design and environmental conditions likely resulted in an underestimate of abundance in the 1990s, the estimates of abundance for the 1990s and 2010s are not directly comparable and trend cannot be determined. Additionally, satellite telemetry analyses comparing the movements of adult females in the 1990s to the 2000s indicate reduced seasonal ranges, increased isolation, 30+ days more on land on Baffin Island in summer, reduced body condition, reduced cub recruitment with early sea ice break-up, and increased swimming.	SWG 2016
Barents Sea	There has been no hunting since 1973. Recent habitat decline has led to late sea ice formation in autumn around some important denning habitat, in such years few females den in these areas.	Aars et al. 2009
Chukchi Sea	Indices of good body condition and recruitment during springtime research, although autumn observations suggest declining cub survival. Longer ice-free periods are increasing land use. Subsistence harvest is legal and monitored in US. Harvest remains illegal in Russia. Updated estimates of subpopulation size anticipated in 2017.	Belikov 1993; Ovsyanikov 2012; Rode et al. 2014, 2015; Kochnev and Zdor 2016
Davis Strait	Low recruitment rates may reflect negative effects of greater densities or worsening ice conditions	Peacock e al. 2013
East Greenland	Reduction in sea ice habitat quality has led to changes in habitat use based on telemetry analsyes.	Laidre et al. 2015

Table 1. Continued.

Subpopulation	Subpopulation size				Subpopulation trend		Sea ice metrics		Human-caused removals: 2011-2015			
									5-year mean		Last year	
	Estimate	95% CI	Year	Method	Relative to historic level (approx. 25-yr past)	Current (approx. 12-yr period centered on present)	Change in spring ice retreat/Change in fall ice advance (days per decade)[1]	Change in summer sea ice area (percent change per decade)	Potential	Actual	Potential	Actual
Foxe Basin	2585	2096-3189	2009/10	Mark-recapture Distance Sampling	Not reduced	Stable	-5.3/5.8	-14.2	101.4	106.2	130	114
Gulf of Boothia	1592	870-2314	2000	Physical capture-recapture	Data deficient	Data deficient	-6.9/8.3	-12.2	63.4	60	74	67
Kane Basin	357	221-493	2013-2014	Genetic capture-recapture	Not reduced	Increasing	-7.2/5.6	-12.2	11	5	11	5
Kara Sea	Unknown				Data deficient	Data deficient	-9.2/7.6	-18.6	N/A		N/A	
Lancaster Sound	2541	1759-3323	1995-1997	Physical capture-recapture	Data deficient	Data deficient	-5.6/5.1	-7.7	92.8	86.6	89	80
Laptev Sea	Unknown				Data deficient	Data deficient	-8.2/6.5	-14.7	N/A		N/A	

Table 1. Continued.

Subpopulation	Comments, vulnerabilities, and concerns	References
Foxe Basin	There are no estimates of vital rates. Harvest appears to be sustainable.	Stapleton et al. 2012 ; Sahanatien and Derocher 2012; Sahanatien et al. 2015
Gulf of Boothia	Ongoing population assessment	Taylor et al. 2009; Barber and Iacozza 2004
Kane Basin	More bears were documented in the eastern regions of the KB subpopulation area during 2012 – 2014 than during 1990s surveys which may reflect differences in spatial distribution of bears, possibly influenced by reduced hunting pressure by Greenland in eastern KB, but also some differences in sampling protocols between decades. Some caution should be taken in the interpretation of population growth. An additional estimate of abundance based on a springtime 2014 aerial survey in KB was 206 bears (95% lognormal CI: 83 - 510).	Taylor et al. 2008; SWG 2016
Kara Sea	There has been no legal hunting in the Kara Sea area since 1957. Amount of poaching unknown.	
Lancaster Sound	Demographic data are >15 years old. Selective hunting for males in the harvest decreased due to the US import ban and listing under the US ESA. Increase in shipping activities.	Taylor et al. 2008
Laptev Sea	There has been no hunting in the Laptev Sea since 1957. One of the main recent concerns is increasing uncontrolled activity of groups digging for mammoth ivory as well as military activity on the Novosibirsk Islands leading to high potential poaching	

Table 1. Continued.

Subpopulation	Subpopulation size				Subpopulation trend		Sea ice metrics		Human-caused removals: 2011-2015			
									5-year mean		Last year	
	Estimate	95% CI	Year	Method	Relative to historic level (approx. 25-yr past)	Current (approx. 12-yr period centered on present)	Change in spring ice retreat/Change in fall ice advance (days per decade)[1]	Change in summer sea ice area (percent change per decade)	Potential	Actual	Potential	Actual
M'Clintock Channel	284	166-402	2000	Physical capture-recapture	Data deficient	Data deficient	-3.9/5.8	-9.0	3.4	3.4	5	5
Norwegian Bay	203	115-291	1997	Physical capture-recapture	Data deficient	Data deficient	-1.3/4.3	-2.3	4	2.2	4	1
Northern Beaufort Sea	980	825-1135	2006	Physical capture-recapture	Not reduced	Stable	-5.8/3.3	-5.9	142.2	83.0	133.0	57.0

Table 1. Continued.

Subpopulation	Comments, vulnerabilities, and concerns	References
M'Clintock Channel	New reassessment of subpopulation began in 2014; potential for shipping activities. Population is currently managed for recovery with harvest below sustainable rates.	Taylor et al. 2006; Barber and Iacozza 2004
Norwegian Bay	Initial PVA simulations resulted in population decline after 10 years, however vital rates from 2 populations were pooled for the analyses. Projections of decline were also high because of small sample size. Current data are >15 years old; small population.	Taylor et al. 2008; Canadian Wildlife Service Nunavut Consultation Report 2009.
Northern Beaufort Sea	Potential and actual removals merged for NB and SB due to unresolved boundary.	Stirling et al. 2011; Stirling et al. 1988

Table 1. Continued.

Subpopulation	Subpopulation size				Subpopulation trend		Sea ice metrics		Human-caused removals: 2011-2015			
									5-year mean		Last year	
	Estimate	95% CI	Year	Method	Relative to historic level (approx. 25-yr past)	Current (approx. 12-yr period centered on present)	Change in spring ice retreat/Change in fall ice advance (days per decade)[1]	Change in summer sea ice area (percent change per decade)	Potential	Actual	Potential	Actual
Southern Beaufort Sea	907	548-1270	2010	Physical capture-recapture	Reduced	Declining	-8.7/8.7	-20.5				
Southern Hudson Bay	943	658-1350	2012	Mark-recapture Distance Sampling	Not Reduced	Stable	-3.1/4.1	-11.4	60.2	58.8	45	43
Viscount Melville Sound	161	93-229	1992	Physical capture-recapture	Data deficient	Data deficient	-4.7/7.4	-6.1	7.0	5.2	7.0	2.0

Table 1. Continued.

Subpopulation	Comments, vulnerabilities, and concerns	References
Southern Beaufort Sea	Potential and actual removals merged for NB and SB due to unresolved boundary. Concerns include declining body condition, periods of low survival, and growing reliance on land during summer.	Bromaghin et al. 2015; Rode et al. 2014; Atwood et al. 2016; Pongracz and Derocher 2016
Southern Hudson Bay	Declining body condition, declining survival rates	Obbard et al. 2015, 2016
Viscount Melville Sound	Low densities of ringed seals and polar bears were observed during capture-recapture programs (2012-2014). Field program to estimate abundance completed 2014, final report not yet available.	Taylor et al. 2002; Messier et al. 1992; Messier et al. 1994

Table 1. Continued.

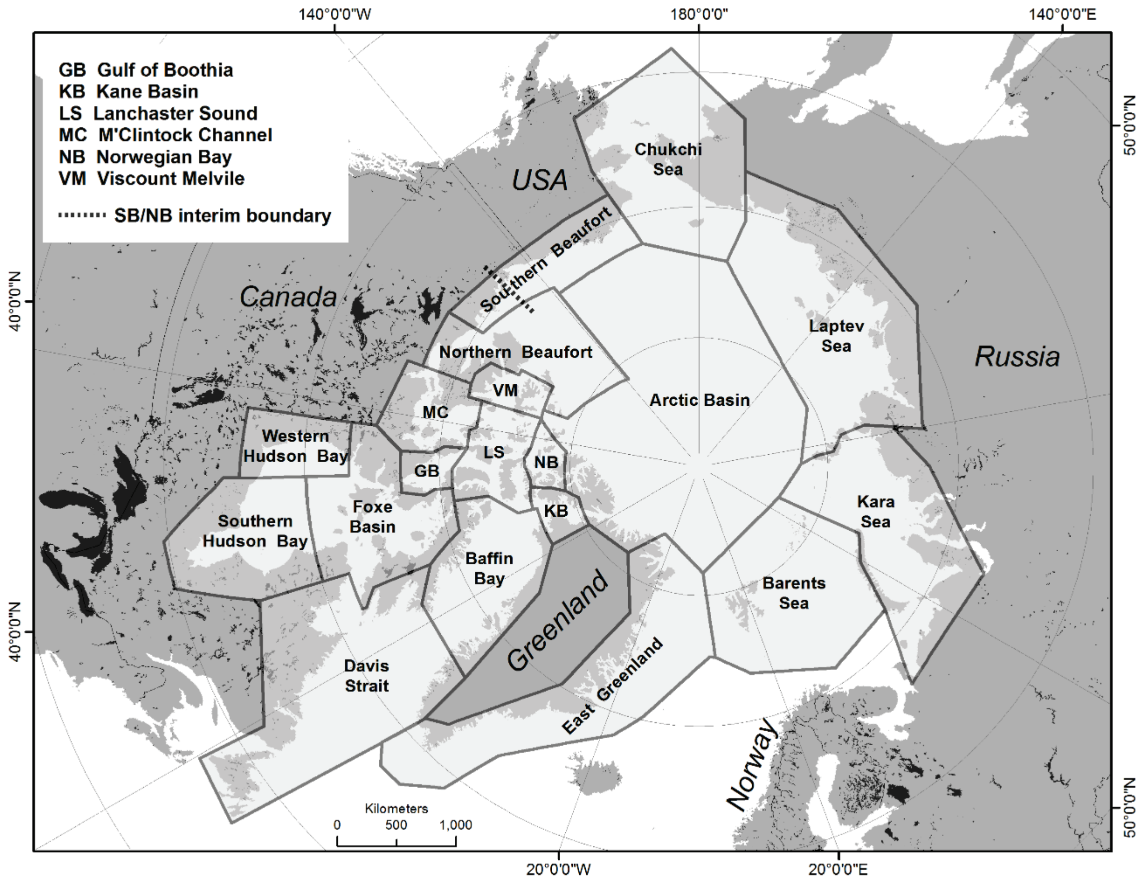
Subpopulation	Subpopulation size				Subpopulation trend		Sea ice metrics		Human-caused removals: 2011-2015			
									5-year mean		Last year	
	Estimate	95% CI	Year	Method	Relative to historic level (approx. 25-yr past)	Current (approx. 12-yr period centered on present)	Change in spring ice retreat/Change in fall ice advance (days per decade)[1]	Change in summer sea ice area (percent change per decade)	Potential	Actual	Potential	Actual
Western Hudson Bay	1030	754-1406	2011	Distance sampling	Reduced	Stable	-5.2/3.6	-16.3	25.0	24.8	28	28

Table 1. Continued.

Subpopulation	Comments, vulnerabilities, and concerns	References
Western Hudson Bay	Concerns include harvest, declines in body condition, and lower productivity compared to adjacent FB and SH subpopulations. Decline in size of subpopulation from late 1980s through late 1990s/early 2000s was linked to reduced survival due to timing of sea ice breakup. Recent analysis indicated stability in subpopulation size from 2001-2010; a period during which there was no significant trend in timing of sea ice breakup or freezeup. This analysis confirmed continued linkage between female survival and sea ice conditions.	Stirling et al. 1999; Derocher et al. 2004; Regehr et al. 2007; Molnár et al. 2010, 2011; Stapleton et al. 2014; Lunn et al. 2016; Sciullo et al. 2016

Figures

Fig. 1. Distribution of 19 polar bear subpopulations within the circumpolar Arctic. Also shown is the interim boundary (133º W) between the Southern Beaufort Sea and Northern Beaufort Sea subpopulations (i.e., SB/NB interim boundary).



Management on Polar Bears in Canada, 2009–2016

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The management on polar bears in Canada, including the setting of hunting quotas, is the responsibility of the provincial and territorial governments and the wildlife management boards, which have been set up under Aboriginal land claim agreements. The federal Government of Canada provides national coordination and is the authority for international agreements (e.g., *Agreement on the Conservation of Polar Bears*, *CITES*), national legislation (e.g., *Species at Risk Act*, *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act*), and the protection of natural heritage (e.g., National Parks, National Park Reserves).

This report, compiled by the Canadian Polar Bear Technical Committee members and reviewed by the Polar Bear Administrative Committee, summarizes the changes in the management of polar bears in Canada that have occurred since the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group (PBSG) in 2009. Changes made prior to 2009 are outlined in the Canadian management reports included in the proceedings of previous working meetings of the PBSG. A summary of the regulations covering polar bear management in Canada, as of 31 December 2015, is presented in Table 1.

National Oversight Committees

Given the shared responsibilities among jurisdictions, wildlife management boards, and Aboriginal groups, it is important that Canada has robust mechanisms to coordinate and ensure complementary actions while respecting each other's areas of responsibility as prescribed by legislation and/or agreements. Three national committees provide oversight of polar bear management in Canada.

Canadian Wildlife Directors' Committee (CWDC)

The CWDC is composed of the wildlife directors representing all 14 jurisdictions with responsibility for wildlife conservation in Canada. The role of the CWDC is to provide leadership in the development and coordination of policies, strategies, programs and activities that address wildlife issues of national concern and contribute to the conservation of biodiversity, and to provide advice and support to appropriate Deputies' and Ministers' Councils on these matters.

Working within the CWDC (1) facilitates a harmonized approach to national programs affecting wildlife; (2) provides a forum for the development of national policy frameworks; (3) facilitates the development of national strategies affecting wildlife; and, (4) promotes co-operative management and information sharing among wildlife agencies in Canada.

Polar Bear Administrative Committee (PBAC)

The PBAC is composed of wildlife managers and directors who represent jurisdictions, management boards, or agencies that have legal responsibility for polar bear management in Canada. The Committee provides a forum for provincial, territorial, and federal management authorities to work together to manage polar bears in Canada and to ensure that Canada fulfills its obligations as a party to the *Agreement on the Conservation of Polar Bears*, as well as any other agreement involving polar bears.

Polar Bear Technical Committee (PBTC)

The PBTC is composed of individuals who have scientific or traditional knowledge of polar bear biology and habitat and are appointed by the jurisdictions, management boards, or agencies that have legal responsibility for polar bear management in Canada. The PBTC meets annually to review scientific and traditional knowledge necessary to meet defined management needs in support of Canada's national and international conservation responsibilities under the 1973 *Agreement on the Conservation of Polar Bears*. The PBTC helps facilitate coordination of research activities among all Canadian jurisdictions that have polar bears, as well as Alaska and Greenland for those subpopulations that are shared with Canada. The PBTC provides technical advice and recommendations to PBAC, as required, on (1) design, collaboration, and conduct of polar bear research in Canada; (2) harvest and population trends; and, (3) the need for management actions.

Status Report On Polar Bear Subpopulations Within and Shared By Canada

The status of the 13 polar bear subpopulations that lie either within Canada's borders or are shared with Greenland and Alaska (Fig. 1, Table 2) is determined by multiple lines of evidence including the number of individuals in the subpopulation, the rates of birth and death (if available), and the rate at which animals are harvested. In addition to science-based research, the assessment and designated status of Canada's polar bear subpopulations is also informed by local and traditional knowledge. Subpopulation boundaries were initially proposed based on barriers to movements, reconnaissance surveys, traditional knowledge, and partly on management considerations (Taylor and Lee 1995). Past revisions to the initial boundaries have occurred following reviews of the movements of individuals determined from mark-recapture studies, mark-kill data, and VHF and satellite telemetry (e.g., Taylor *et al.* 2001, Amstrup *et al.* 2004, 2005). The current status report was developed by the PBTC based on discussions held at the Committee's 2016 meeting in Whitehorse, Yukon.

Polar Bear Kills by Jurisdiction

Table 3 summarizes the annual quotas and total known human-caused mortality from management years 2008/09 through 2014/15 by subpopulation. Table 4 summarizes the total known number of polar bears killed by humans within or shared with Canada by subpopulation and jurisdiction.

Management Changes and Reports

Provincial and Territorial Jurisdictions

Manitoba

Management changes relating to polar bears within Manitoba include increased surveys within the Kaskatamagan Denning Region Wildlife Management Area, east of the Nelson River. A three-year den emergence survey was completed in March of 2016. There have also been changes to Wildlife Management Area (WMA) Use permits both within the Churchill and Kaskatamagan WMAs. Changes have been made to minimize and mitigate human/polar bear encounters to all lodges and operators along the Hudson Bay coastline of Manitoba. Manitoba Sustainable Development continues to work with the Leatherdale International Polar Bear Conservation Center on research projects relating to the conservation and management of polar bears of the western Hudson Bay.

Coastal surveys have been completed each year since 2009. A September survey has been completed every year, with periodical August and November surveys also being done.

The annual Polar Bear Alert Program (PBA) for Churchill and surrounding control zones continues each fall. Polar bear occurrences have increased in the last 5 years during the months of July and August, causing an increase in staffing and patrol coverage. The objectives of the PBA are: 1) to ensure the safety of people and protection of property from damage by polar bears, and (2) to ensure that polar bears are not unnecessary harassed or killed.

Newfoundland and Labrador

In December 2005, the Nunatsiavut Government was established to represent the residents of the Labrador Inuit Settlement Area, which was created by the signing of the *Labrador Inuit Land Claims Agreement* (LILCA) in January 2005. Management authority for polar bears will continue to reside with the Province of Newfoundland and Labrador, but is inclusive of considerable input and solicitation from Nunatsiavut Government (NG), the Torngat Wildlife and Plant Co-Management Board, and Parks Canada. The province issues licences, establishes quotas, seasons and management areas pursuant to Sections 39 and 114 of the Wildlife Regulations and the annual Polar Bear Hunting Order. Pursuant to section 12.3.6 of the Labrador Inuit Land Claims Agreement, Inuit have exclusive right to harvest the total allowable harvest established by the province. The total harvest allocation for polar bears is currently 13 animals from the Davis Strait (DS) subpopulation.

In July 2006, the provincial and Nunatsiavut governments released a 5-year management plan for polar bears, which was a requirement of the species being listed as Vulnerable by the province under its *Endangered Species Act* in 2002. The goal of the management plan is to maintain and enhance the sustainability of the DS polar bear subpopulation through appropriate species and habitat management initiatives within Newfoundland and Labrador. To achieve that goal, a series of objectives have been identified including equitable Labrador Inuit hunting access, continued cooperation, habitat protection, a better understanding of distribution and population numbers of polar bears, threat assessment, and management and development of education and stewardship programs. A new/updated Polar Bear

Management Plan is currently being drafted by the Province and the Nunatsiavut Government and is to be completed in 2016. This plan will provide updated direction and information on polar bear management, science findings and requirements, and Aboriginal traditional knowledge for a five-year period.

Inuvialuit Settlement Region (Northwest Territories [NWT] and Yukon Territory)

Polar bears in the NWT and Yukon are found exclusively in the Inuvialuit Settlement Region (ISR) and are collaboratively managed under the co-management framework set out in the Inuvialuit Final Agreement. The legislative framework for polar bears in the ISR includes the *Western Arctic (Inuvialuit) Settlement Act*, new NWT *Wildlife Act*, the Yukon *Wildlife Act*, the *Canada National Parks Act* and the federal and NWT Species at Risk Acts (SAR). All partners are working together to develop an ISR management plan for polar bears. The objective is to then adopt this ISR wide plan under the federal and NWT SARs as polar bears were listed as Special Concern under the Acts (2011 and 2014 respectively).

Recently NWT and Yukon developed an administrative agreement to recognize an ISR-wide Southern Beaufort Sea (SB) polar bear tag that can be used in both the NWT and Yukon portions of the SB subpopulation range.

The Inuvialuit continue to ensure cooperation and cooperative management of shared subpopulations of polar bears through the two user-to-user agreements in place. The first agreement, between the Inupiat of the Alaskan North Slope and Inuvialuit originally signed in 1988, was updated in 2011. The second user-to-user agreement, signed in 2006 with Inuit of the Kitikmeot West region in Nunavut, continues to ensure communication and coordination for the management of the Northern Beaufort Sea (NB) and Viscount Melville Sound (VM) subpopulations.

Results from mark-recapture estimates completed in 2006 indicate the SB subpopulation is likely declining (Regehr *et al.* 2006) while the NB subpopulation is likely stable (Stirling *et al.* 2011). Information provided by analysis of movements of collared bears (Amstrup *et al.* 2004, 2005) has resulted in a shift of the management boundary between the SB and the NB subpopulations further to the west to 133°W. Further analysis was conducted (Griswold *et al.* 2010) to determine the population shift as a result of the boundary change. The subpopulation estimates were subsequently updated and the Total Allowable Harvests adjusted based on the new estimates through the ISR co-management system.

No other changes have occurred since the last PBSG meeting.

Nunavut

Nunavut together with its management partners completed inventories that have resulted in new abundance estimates for the FB subpopulation in 2010, and the WH subpopulations in 2011. Field programs have been completed for both Baffin Bay (BB) and Kane Basin (KB) subpopulations, which are expected to provide new abundance estimates in summer 2016. In 2014 and 2015, 3-year field programs were initiated to update subpopulation inventories for M'Clintock Channel (MC) and Gulf of Boothia (GB) subpopulations, respectively. Both studies are using genetic mark-recapture techniques.

The Nunavut Land Claim Agreement (NLCA) recognizes that certain populations of wildlife found in the Nunavut Settlement Area (NSA) cross jurisdictional boundaries and are harvested outside the NSA by persons resident elsewhere and therefore requires that the Government of Nunavut (GN) and the Nunavut Wildlife Management Board (NWMB) take into account the harvesting activities outside the NSA and the terms of domestic inter-jurisdictional agreements or international agreements pertaining to wildlife. Nunavut continues to take an active role, via the PBAC, in the development of inter-jurisdictional agreements with territorial and provincial jurisdictions that share polar bear subpopulations with Nunavut (DS, NB, Southern Hudson Bay [SH], VM, WH).

Since the last PBSG report there have been changes to Total Allowable Harvest (TAH) for a number of subpopulations. In 2010/11, the TAH for the BB subpopulation was decreased by 10 animals per year for a four-year period resulting in a reduction from 105 to 95, 85, 75, and 65 for the 2010/11, 2011/12, 2012/13, and 2013/14, respectively. The results of a recent population inventory are expected in summer 2016 and will support a re-assessment of the TAH for 2016/17. In 2012/13, the TAH for the DS subpopulation was increased from 46 to 61 animals per year. In 2014/15, the TAH for the FB subpopulation was increased from 106 to 123 animals per year, which will be re-assessed following completion of a survey that is tentatively planned for 2017/18. At the end of a 5-year moratorium on harvesting from the MC subpopulation, which ended in 2003/04, communities received a TAH of 3 animals per year in order to manage the subpopulation for recovery. In 2015/16, the TAH for the MC subpopulation was increased from 3 to 12 animals per year. In 2011/12, the TAH for the WH subpopulation was increased from 8 to 21 animals and, following completion of the WH aerial survey in early 2012, further increased to 24 animals per year for a 3-year period. The TAH from the WH subpopulation was further increased to 28 animals in 2015/16 and will be revisited after the completion of an aerial survey of WH and SH to be conducted in 2016.

<u>Nunavut Polar Bear Management Plan</u> – In 2013, a working group consisting of representatives from Nunavut Tunngavik's Wildlife and Environmental Advisory Committee (which includes Chairs and Co-chairs of the three Regional Wildlife Organizations) and the Government of Nunavut began drafting an outline of a new co-management plan, and how to engage the public in this process. Community consultations on this initial outline and framework occurred in all 25 Nunavut communities in spring 2014, which resulted in a revised version that was subsequently discussed with Regional Wildlife Organizations in summer 2014. A final version of the plan was submitted to the NWMB in June 2015 and a written public hearing was held that ended in December 2015. The GN is currently reviewing all comments; a revised plan will be re-submitted to the NWMB for consideration.

<u>Polar Bear- Human Conflict Program</u> – Conflict between people and polar bears continues to increase and is a major concern in Nunavut because of damage to property, threats to public safety and the number of defence kills. Improving polar bear deterrent activities, reducing bear attractants, and reducing the potential for conflict have been identified as priorities in GN Department of Environment (DoE) business strategies. The polar bear-human conflict program includes: community-based polar bear-human conflict reduction operational plans, testing the effectiveness of deterrents methods (e.g., electric fences to protect meat caches), a Prevention and Compensation Program that assists individuals and groups to access deterrents and equipment to make their camps and communities more "bear-proof" and provides compensation for property damaged by bears, and public education.

The GN strategy for reducing polar bear-human conflicts in Nunavut is multi-facetted. The program is coordinated by the Wildlife Deterrent Specialist but relies on collaboration and strives for innovation to find practical approaches that can be implemented in communities with limited resources. Conservation Officers are on the frontline and work closely with residents, hunter and trapper organisations/associations (i.e., HTO/HTAs), communities, DoE Research staff, other GN departments, external researchers and non-governmental organisations (i.e., NGOs). Polar bear guards are hired to conduct safety patrols in communities with high levels of polar bear presence. DoE partnered with Parks Canada and WWF to develop a Polar Bear Guard Training Standard (2013) for DoE polar bear guards. New approaches to encourage polar bears to move around and away from communities will continue to be tested, for example, Arviat has been using diversionary lure stations since 2013 that have reduced bear activity. Nunavut has been an active member of the Range States Polar Bear Conflict Working Group (CWG) since its inception in 2009. All Nunavut polar bear conflict occurrences are being entered into the Polar Bear Human Information Management System (PBHIMS) as a CWG project and excellent system for managing Nunavut conflict data. These data will be analysed and reported on in 2017. The Nunavut Polar Bear – Human Conflict Program will begin research activities (2016) to understand the causes of the increasing and higher levels of polar bear conflict occurrences in some parts of the territory.

Ontario

In September 2009, the polar bear was designated as a threatened species under Ontario's *Endangered Species Act, 2007* (*ESA*), following an assessment and designation by the Committee on the Status of Species at Risk in Ontario (COSSARO). This decision was based on trends in the SH subpopulation (Obbard *et al.* 2006, 2007), on trends in the neighbouring WH subpopulation (Regehr *et al.* 2007), and on trends in sea ice (Amstrup *et al.* 2007). Immediately upon being listed as threatened on the Species at Risk in Ontario List in 2009, both the polar bear and its habitat in the province received automatic protection under Ontario's *ESA*.

Protection under the *Endangered Species Act, 2007* – Polar bears in Ontario receive species protection under section 9 of the ESA, which states that no person shall:

(a) kill, harm, capture or take a living member of a species that is listed on the Species at Risk in Ontario List as an extirpated, endangered or threatened species;

(b) possess, transport, collect, buy, sell, lease, trade or offer to buy, sell, lease or trade,

  (i) a living or dead member of a species that is listed on the Species at Risk in Ontario List as an extirpated, endangered or threatened species,

  (ii) any part of a living or dead member of a species referred to in subclause (i),

  (iii) anything derived from a living or dead member of a species referred to in subclause (i); or

(c) sell, lease, trade or offer to sell, lease or trade anything that the person represents to be a thing described in subclause (b) (i), (ii) or (iii).

Clause 9 (1) (b) does not apply to a member of a species that originated outside Ontario if it was lawfully killed, captured or taken in the jurisdiction from which it originated.

Polar bear habitat in Ontario also receives protection under section 10 of the *ESA*, which states that no person shall damage or destroy the habitat of:

(a) a species that is listed on the Species at Risk in Ontario List as an endangered or threatened species.

Section 17 of the *ESA* outlines four types of permits that the Minister of Natural Resources and Forestry may issue to authorize potential contraventions of sections 9 and/or 10 of the Act in specific circumstances.

The *ESA* also acknowledges existing Aboriginal and Treaty rights of Aboriginal peoples of Canada as recognized and affirmed in section 35 of the *Constitution Act, 1982*, and specifies that "nothing in this Act shall be construed so as to abrogate or derogate from the protection provided" for these rights.

Recovery Documents under the *Endangered Species Act, 2007* – For species listed as threatened under the *ESA*, a recovery strategy must be developed within two years of the status designation. A recovery team, led by external consultants, was established that included members of First Nations communities that harvest polar bears, polar bear experts, and Ministry staff. Developing the recovery strategy included consultation with First Nations communities. A recovery strategy (Tonge and Pulfer 2011) was finalized in December 2011 and provides scientific advice to government on the biological needs of the species and the suggested approaches to support recovery.

Following completion of the recovery strategy, Ontario has developed a draft species-specific policy that outlines the protection and recovery actions the government will lead and support for polar bear. The Ministry took additional time to prepare the species-specific policy for polar bear in order to consider all recommendations provided in the recovery strategy, advice provided by stakeholders, complexities associated with the species, and additional jurisdictional, scientific and economic information. In April 2016, Ontario posted the draft government response statement for the polar bear on the province's Environmental Registry (Ontario 2016) and will be considering comments received by June 13, 2016 from the public, stakeholders, and indigenous communities and organizations as the policy is finalized.

Ontario's government response statement on polar bear will contribute to the national management plan for polar bear. The Ontario government is also taking steps to mitigate the impacts of climate change through the development of the Climate Change Strategy released in 2015 and the development of a provincial cap and trade program. Ontario continues to lead and support efforts to increase our knowledge of polar bear through collaborative monitoring and research initiatives, through aerial surveys that monitor trends in abundance, and by supporting the development of community-based monitoring programs.

Québec

Under the James Bay and Northern Québec Agreement (JBNQA) of 1975, the taking of polar bears is restricted to Aboriginal peoples, to protect the traditional subsistence harvesting rights of northern Québec natives. In law, provisions have been made to ensure the Inuit of Nunavik and the Cree of Eeyou Istchee have exclusive access to an agreed level of harvest (Guaranteed Harvest Level - GHL), subject to the principles of conservation, before any sport or commercial activity would be permitted. Set at 62 polar bears per year for the entire region (58 for Inuit, 4 for Cree), this level of harvest is based on the recorded subsistence take during 1976–1980. Under present legislation, sport hunting is not permitted and polar bears may only be harvested for subsistence use. The hide may be sold if a provincial tag is obtained and attached.

Several changes occurred in Québec since the previous report in 2009, including the official designation of the polar bear as a "vulnerable" species, in October 2009, under the "Loi sur les espèces menacéess ou vulnérables du Québec" (i.e., "Laws on the threatened or vulnerable species of Québec"). Two new wildlife management boards have also been created – the Nunavik Marine Region Wildlife Board (NMRWB) and the Eeyou Marine Region Wildlife Board (EMRWB). These boards are responsible for wildlife management in the offshore area adjacent to Québec, and make decisions regarding polar bear management in the Nunavik Marine Region and the Eeyou Marine Region, respectively. It is the responsibility of the Government of Canada and the Government of Nunavut to implement the management decisions of the two boards.

While there is still no mandatory reporting of polar bear harvested by Nunavik Inuit and Cree of the Eeyou Istchee, several inter-jurisdictional initiatives have been implemented during the 2009–2016 period with the objective to better coordinate management and conservation efforts of the various authorities. In September 2011, Inuit and Cree organizations and wildlife management boards, as well as governments involved in the management of the SH polar bear subpopulation met in Inukjuak, QC; this led to a consensus on establishing a temporary voluntary limit to the SH polar bear take (60 bears, including subsistence hunting and defense kills) shared between the Nunavik Inuit (26), the Crees of Eeyou Istchee (4), the Inuit of Nunavut (25) and the coastal Cree Nations of Ontario (5). Following a new population estimate of 951 bears, derived from data from an aerial survey conducted in 2011 and 2012, a new meeting was held in September 2014 and consensus was again reached to reduce the voluntary limit to the annual take of the SH to 45 bears (22 for Nunavik Inuit; 20 for Nunavut Inuit; 3 in total for Ontario and Quebec Cree - with alternating division per harvest season starting with 1 for the Quebec Cree and 2 for the Ontario Cree). Recently, the NMRWB and the EMRWB have submitted final decisions for the establishment of a Total Allowable Take (TAT) and Non-quota Limitations, pursuant to the terms of their respective Land Claims Agreements, to the ministers (federal and Nunavut) for approval; a response to these decisions is expected shortly. A new aerial survey will be conducted in September 2016 to estimate the size of the SH subpopulation.

In May 2015, Inuit representatives from Nunavut, Nunatsiavut, and Nunavik met in Montreal to discuss the management of polar bears for the DS subpopulation. This meeting took place as a response to a proposed joint public hearing process between the wildlife co-management boards for each region (yet to be realized), whereby the outcomes of the meeting would be used as a joint submission by the three Inuit regions to the public hearing process. The NMRWB has been discussing a coordinated public hearing process with the Torngat Wildlife, Plants and Fisheries Secretariat to consider establishing a TAT for the DS subpopulation. The hearing is anticipated to take place in early 2017.

Lastly, in response to multiple concerns raised by the international community related to the sustainability of the Canadian polar bear harvest and the lack of a regulated harvest management regime in Québec, the federal Minister of the Environment requested the NMRWB, in 2012, to establish a management regime, including a TAT for the three sub-populations of polar bear that occur in the Nunavik Marine Region. Given the distribution of polar bears and the jurisdictional complexities of Northern Quebec, it was desirable and practical to have a single management plan that applies to both the onshore portion of Quebec and its adjacent marine regions (the Nunavik Marine Region and the Eeyou Marine Region); such a plan is currently being developed.

Management Boards and Aboriginal Groups

Makivik Hunting, Fishing and Trapping Coordinating Committee

Makivik Corporation was created in 1978 pursuant to the signing of the James Bay and Northern Québec Agreement (JBNQA); it is a non-profit organization owned by the Inuit of Nunavik. While the Hunting, Fishing and Trapping Coordinating Committee is, in the words of the JBNQA, "the preferential and exclusive forum for Native people and governments jointly to formulate regulations and supervise the administration and management of the Hunting, Fishing and Trapping Regime", Makivik is the recognized Inuit Party to the Agreement. Makivik's central mandate is the protection of the integrity of the JBNQA, and focuses on the political, social, and economic development of the Nunavik region.

Nunavik Marine Region Wildlife Board (NMRWB)

With the Nunavik Inuit Land Claim Agreement (NILCA) coming into force in 2008, the NMRWB has been established as the main instrument of wildlife management within the Nunavik Marine Region (NMR). The Nunavik Marine Region is defined within the NILCA and encompasses all the marine areas, islands, lands and waters from the Nunavut Territory that are within a defined boundary from Quebec's coastline. Considering that most of the polar bear harvest by Nunavik Inuit occurs on the sea ice within the NMR, the NMRWB is highly involved in the management of polar bear harvest in Québec. Established pursuant to Section 5 of the NILCA, the responsibilities of the NMRWB include, among others, establishing, modifying or removing levels of total allowable take and non-quota limitations, ascertaining and adjusting the total allowable take to the basic needs level of Nunavik Inuit, as well as cooperating with, and providing advice to, any other management institutions on all matters relating to the management, conservation, protection and regulation of wildlife habitat and wildlife species that are harvested in the NMR. The relevant Federal or Territorial (Nunavut) Ministers, however, maintain ultimate authority.

Eeyou Marine Region Wildlife Board (EMRWB)

The EMRWB was established in 2010 following the signing of the Eeyou Marine Region Land Claims Agreement (EMRLCA) and becomes the main instrument of wildlife management within the Eeyou Marine Region (EMR), which mainly includes the islands and waters of eastern James Bay and a portion of eastern Hudson Bay. Responsibilities of the EMRWB are similar to those described for the NMRWB and the relevant Federal or Territorial (Nunavut) Ministers also maintain ultimate authority.

Nunavut Wildlife Management Board (NWMB)

Through a delegation of authority from the federal government, ultimate responsibility for the management of polar bears in Nunavut lies with the Government of Nunavut, as represented by the Minister of Environment. However, this responsibility is subject to the terms of the Nunavut Land Claims Agreement (NLCA) which established a system of 'co-management' for wildlife. Under the NLCA, the Minister's decision-making authority for wildlife management is shared with the NWMB and is subject to strict requirements for consultation with Regional Wildlife Organizations and community-based Hunters and Trappers Organizations. The NWMB is an institution of public government whose board members are appointed in equal numbers by government and Inuit organizations. The NWMB is the main instrument of wildlife management and the main regulator of access to wildlife – including polar bears – in the Nunavut Settlement Area.

Wildlife Management Advisory Council (North Slope)

The Wildlife Management Advisory Council (North Slope) [WMAC (NS)] was created in 1988 under the Western Arctic (Inuvialuit) Settlement Act, ultimately the result of the 1984 Inuvialuit Final Agreement (IFA). The Council is comprised of five members: two members appointed by the Inuvialuit Game Council, one appointed by the federal Minister of Environment, one appointed by the Yukon Territorial Government, and an independent chairperson appointed by the Yukon Government with the consent of the Inuvialuit and Canada.

WMAC (NS)'s mandate is to conserve and protect wildlife, habitat, and traditional Inuvialuit use within the Yukon North Slope portion of the ISR – an area in the Yukon north of the height of land that lies between the Alaska and NWT borders and inclusive of the adjacent nearshore and offshore waters. The Council provides advice to the appropriate ministers on all matters relating to wildlife policy and the management, regulation, and administration of wildlife, habitat and harvesting for the Yukon North Slope. The Council also provides guidance to a number of boards and councils in the region; recommends quotas for Inuvialuit game harvesting on the Yukon North Slope; and recommends measures to protect critical habitat for wildlife or harvesting purposes.

Wildlife Management Advisory Council (NWT)

The Wildlife Management Advisory Council (NWT) [WMAC (NWT)] was also created in 1988 under the Western Arctic (Inuvialuit) Settlement Act, ultimately the result of the 1984 Inuvialuit Final Agreement. The WMAC (NWT) consists of three members appointed by the Inuvialuit, two members appointed by the Government of the Northwest Territories, one member appointed by the Government of Canada, and a Chair. The Chair is appointed by the Government of the Northwest Territories with the consent of the Inuvialuit and the Government of Canada.

The Council's jurisdiction is that part of the Inuvialuit Settlement Region (ISR) within the Northwest Territories, including the adjacent near shore and offshore waters. The Council's mandate is to advise appropriate ministers on all matters relating to wildlife policy and the management, regulation, research, enforcement, and administration of wildlife, habitat, and harvesting for the Western

Arctic Region, within the NWT. It is the responsibility of the Council to prepare conservation and management plans, and to determine and recommend harvestable quotas. The Council also reviews and advises the appropriate governments on existing or proposed wildlife legislation and on any proposed Canadian position for international purposes that would affect wildlife in the Western Arctic Region.

All harvest of polar bears in the NWT occurs within the ISR. Within the NWT portion of the ISR, the Council is the primary vehicle for wildlife management. The Council makes recommendations for any management changes within the ISR, including quotas, to the NWT Minister of Environment and Natural Resources.

Inuvialuit Game Council

The Inuvialuit Game Council (IGC) represents the collective Inuvialuit interest in wildlife. The IGC is made up of representatives appointed from each of the six community Hunters and Trappers Committees. Among its responsibilities are: appointing Inuvialuit representatives to the IFA co-management boards and other boards as appropriate; advising the Wildlife Management Advisory Councils (NWT and North Slope) on policy, legislation, regulation and administration respecting wildlife, conservation, research, management and enforcement; advising the appropriate governments on existing or proposed wildlife legislation; advising the government on any proposed Canadian position for international purposes that affects wildlife in the ISR; and allocating harvest quotas among the six ISR communities.

Federal Government

Within Environment and Climate Change Canada, polar bear management is conducted primarily by the Canadian Wildlife Service (CWS). Canada is signatory to memoranda of understanding with the Governments of the United States (2008), and Nunavut and Greenland (2009) with respect to the conservation and management of internationally-shared polar bear subpopulations. Moreover, effective management of all Canadian polar bear subpopulations is a responsibility under the 1973 *Agreement on the Conservation of Polar Bears*.

CITES

During the 27th meeting of the CITES Animals Committee (2014), the Committee decided to review the sustainability of trade in polar bears under its Significant Trade Review process. Canada, as the only polar bear range State that allows commercial trade, provided detailed information to the Animals Committee on its sustainable management of harvest and trade to support removal from the Significant Trade Review. The Animals Committee concluded its review at the 28th CITES Animals Committee meeting in September 2015 with the removal of polar bear from the Review.

Following consultations with responsible jurisdictions, wildlife management boards, Inuit wildlife organizations, and other stakeholders, Environment Canada's CITES Scientific Authority completed the Polar Bear Non-Detriment Finding (NDF) Report in December 2009 and updated the information in the report in 2015. The export of legally-harvested polar bears from Canada is considered non-detrimental with no export of bears from the Baffin Bay management unit.

Management of Shared Subpopulations

Polar bear management in Canada is a collaborative effort among the federal, provincial and territorial governments and the Wildlife Management Boards, which were established under the various Land Claims Agreements. Although there are few formal mechanisms for the joint management of polar bear subpopulations in Canada, there is a history of collaboration between jurisdictions and Indigenous groups on cooperative approaches to management of shared polar bear subpopulations. Interjurisdictional cooperation is particularly important for shared subpopulations in the eastern Arctic – DS, FB, and SH due to the number of jurisdictions, management boards, and wildlife organizations involved. Where hunting is permitted and a quota system is in place, the decision-making process is open and considers advice provided by a multitude of stakeholders and interested parties, including governments, technical experts (scientists and indigenous peoples) and non-government organizations. Regardless of the process, these groups recognize that advice regarding harvest levels should be based on the best information, including both science and traditional knowledge, and should include direct input from users that harvest polar bears.

National Conservation Strategy

The National Conservation Strategy is a high-level document that illustrates, strengthens and formalizes the existing polar bear management system in Canada. It seeks to identify current and emerging challenges to polar bear conservation and facilitate future conservation initiatives. The Strategy is intended to be an umbrella document under which the detailed provincial/territorial management plans and inter-jurisdictional agreements will be included. It was finalized and approved by provincial/territorial jurisdictions and wildlife management boards in 2011.

Species at Risk Act/COSEWIC

In November 2011, after extended consultations with provincial/territorial jurisdictions, wildlife management boards, and the public, Canada listed the polar bear as a species of Special Concern under the federal *Species at Risk Act* (*SARA*). Under this listing, ECCC is required to prepare a management plan for the species. Due to the complexities of polar bear management in Canada, there have been some delays in the completion of the plan. ECCC has been working with members of the Polar Bear Administrative Committee and other representatives of the relevant jurisdictions to prepare a *SARA*-compliant management plan that incorporates provincial/territorial management plans currently under development. The National Conservation Strategy will act as the federal contribution and umbrella document that will link the provincial and territorial plans together. The *SARA* management plan is expected to be posted in December 2018, at which time the majority of provincial/territorial plans are expected to have been completed.

Under *SARA*, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) must review the classification of each species at risk at least once every 10 years, or at any time if it has reason to believe that the status of the species has changed significantly. The last status update and assessment of polar bears occurred in 2008 (COSEWIC 2008). In 2015, COSEWIC began the process of re-assessing the status of polar bears in Canada by commissioning the preparation of a status report that contains the best available information on the biology of the species including scientific knowledge, community knowledge, and indigenous knowledge. This status report forms the basis for a species assessment and status designation by COSEWIC – the final report is expected February 2018.

Wildlife Enforcement

ECCC officials from the Enforcement Branch's Wildlife Enforcement Directorate, the Canadian Wildlife Service, and the Science & Technology Branch are collaborating with the provinces, territories, and Indigenous governments and organizations to implement a new approach to tracking polar bear hides in trade. The new "3-Pronged Approach" capitalizes on existing and emerging technologies to enhance the traceability of polar bear hides. Consisting of DNA and Stable Isotope analyses of samples combined with inserting PIT tags (encrypted microchips) into the hides, the approach will strengthen identification and verification capabilities, in support of species conservation and legal trade. Implementation of the "3-Pronged Approach" started in 2015, with progressive expansion to additional Canadian polar bear jurisdictions planned over the coming years.

Parks Canada Agency

The Parks Canada Agency is responsible for the management of Canada's system of protected heritage areas, including national parks and national historic sites. Parks Canada's primary and legislated mandate is to maintain or restore ecological integrity of the national parks (Parks Canada Guiding Principles and Operational Procedures (Parks Canada 1994), *Canada National Parks Act* (S.C. 2000, as amended)). There are currently nine national parks that regularly contain polar bears: Ivvavik in the Yukon; Aulavik in the NWT; Auyuittuq, Qausuittuq, Quttinirpaaq, Sirmilik and Ukkusiksalik in Nunavut; Wapusk in Manitoba; and, Torngat Mountains in Labrador.

Parks Canada's interest in conservation of polar bears and their habitat comes from its ecological integrity mandate and policies of ecosystem-based management and inter-jurisdictional cooperation. Parks Canada contributes to sustaining polar bear populations by protecting important habitats such as maternal denning and coastal summer retreat areas. Parks Canada has and will continue to support polar bear research and monitoring efforts in areas within and adjacent to the national parks.

Parks Canada also has a public safety duty to minimize human–bear encounters and conflict within national parks. Park visitors, researchers, military personnel, local residents, park staff, Inuit and other Indigenous park users all have the potential to come into contact with polar bears. Human and polar bear activities overlap in space and time, particularly during April–November. To date, the number of park visitors and park users in most northern national parks is low and the number of encounters has been correspondingly low. Measures in place to reduce the risk of encounters include mandatory park visitor registration and an orientation that includes polar bear safety messages. Other park users receive safety information, including safety pamphlets, and discuss location-specific risks and mitigation measures with knowledgeable park staff and community members. In all northern national parks, indigenous users have the right to carry firearms for harvesting under land claims or other agreements or legislation. Parks Canada can issue firearms permits to polar bear guards, researchers, guides, military personnel, and traditional local users (Wapusk National Park only) for personal protection and protection of clients in a commercial setting. Parks Canada is collaborating with other government and non-government partners to increase the availability of polar bear guard services in communities adjacent to national parks and across Canada's north. Polar bear safety plans and operational procedures are in place or being developed for the aforementioned national parks. Parks Canada is participating in development of jurisdictional management plans.

International

Polar Bear Range States

The representatives to the Parties that are signatory to the 1973 *Agreement on the Conservation of Polar Bears* (the Range States: Norway, Canada, Greenland, the Russian Federation, and the United States) meet every two years. The general objectives of the meetings were to provide an international forum to discuss the conservation and management of polar bears. Canada hosted the 2011 (Iqaluit) meeting and participated in the 2013 (Moscow, Russia) and 2015 (Ilulissat, Greenland) meetings. Key outcomes from the 2013 Moscow meeting included the 2013 Ministerial Declaration and the commitment to the completion of a Range-wide Conservation Strategy for Polar Bear, otherwise known as the Circumpolar Action Plan (CAP). In 2015, the Range States Heads of Delegation approved the document and implementation is currently underway.

The CAP includes a monitoring schedule for all 19 subpopulations, including 13 in Canada, or shared with neighbouring countries. The frequency of surveys varies among subpopulations, and is subject to change, depending on available resources and conservation concerns. A static frequency is not suitable for all subpopulations as they face a suite of changing pressures (e.g., climate change, harvest). The schedule can be used as a planning tool by Canadian jurisdictions to ensure that abundance estimates for subpopulations do not become out-of-date.

Canada actively participates as a member of several working groups charged with implementation of the CAP, including:

(a) CAP Implementation Team
(b) Polar Bear–Human Conflict Working Group (CWG)
(c) Traditional Ecological Knowledge Working Group (co-led by Canada and Greenland)
(d) Communications Working Group
(e) Operations, Protocols, and Procedures (OPP) Working Group
(f) Trade Working Group

The Trade Working Group has submitted its final report and among its adopted recommendations to the heads of delegation, was the advice to form a Wildlife Enforcement Network. This project will be fleshed out and an update will be provided at the biennial meeting of the parties in 2017.

Convention on Migratory Species (CMS)

The CMS is a United Nations convention ratified by 119 countries; of the five polar bear range states, only Norway is a signatory. Given a mandate to focus on species impacted by climate change, Norway sponsored a proposal to list polar bear on Appendix II of the CMS in 2014. CWS worked with Norwegian counterparts to ensure the proposal was appropriate and accurately reflected the status of polar bears in Canada, the Canadian management system, and the importance of polar bear to Indigenous Peoples in Canada. The Norwegian proposal was successful and the polar bear is now listed on Appendix II of the CMS. An Appendix II listing is appropriate for species of conservation concern, and calls for collaborative action by the Range States, which already occurs under the 1973 *Agreement on the Conservation of Polar Bears*. Non-Range State parties to CMS are encouraged to assist in conservation actions.

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Tables

Table 1. Summary of regulations covering polar bear management in Canada as of 31 December 2015.

	Jurisdiction						
Category	Manitoba	Newfoundland and Labrador	Northwest Territories	Nunavut	Ontario	Québec	Yukon
Hunting	Closed	Reviewed annually: hunting permitted Feb–Jun in portion of Labrador north of Cape Harrison	Season varies between Polar Bear Management Areas: longest 1 Oct–31 May; shortest 1 Jan–31 May	No closed season	Closed, except for polar bears harvested based on Aboriginal and Treaty rights	Closed season between 1 Jun–31 Aug[1]; no sport hunting	1 Oct–31 May as currently identified in regulations
Who can hunt	A person who possesses a Ministerial permit	Nunatsiavut beneficiaries only. Licences issued by Provincial Government and distributed by Nunatsiavut Government	A person who possesses a tag. Tags are distributed by the HTCs	A person who possesses a tag. Tags are allocated by the HTOs	Members of Treaty #9 residing along the coast	Inuit and Cree	Inuit only who are issued polar bear tags
Quota	None[b]	13 (increased from 12 as of Feb 2016)	ISR quota by settlement: 2015/16 quota is 96	By settlement: 2015/16 quota is 433	2014/15 quota of 2; 2015/2016 quota of 1 for the Ontario Cree	No quota; voluntary agreements on harvest within some subpopulations	6, all of which are administered by the NWT under ISR quota
Females and cubs protected by law	Yes	Yes: females accompanied by cubs-of-the-year	Yes: cub defined by hide length; bears accompanied by cubs	Yes: exempt for defence or humane kill	Yes	No[a]	Yes: a cub or a female accompanied by a cub
Bears in dens protected by law	Yes	Yes	Yes: includes bears constructing dens	Yes: includes bears constructing dens	Yes: dens and other habitat depended on for life processes protected	No[a]	Yes

Table 1. Continued.

Category	Jurisdiction						
	Manitoba	Newfoundland and Labrador	Northwest Territories	Nunavut	Ontario	Québec	Yukon
Proof of origin of untanned bear	Required: documented proof	Required: documented proof (no seal on hide implemented to date)	Required: tag on hide and export permit	Required: tag affixed hide and export permit (which needs to indicate harvester and population)	Required: seal on hide, proof of origin required on imported hides	Required: seal on hide	Required: seal on hide
Export permit and cost (out of province or territory of origin)	Required: $20.00	Required: no cost	Recommended: no cost residents; Required: $1500.00 Harvest Fee for non-residents and non-resident aliens collected regardless of export	Required: no fee for export permits, fees are collected on harvesting licence	Required: no cost	Required: no cost	Required: no cost
Export permit out of Canada	All jurisdictions are required by CITES to have an export permit for all polar bears or parts thereof exported out of Canada						
Scientific licences	Discretion of Minister	Discretion of Director	Discretion of Director - Wildlife or Regional Superintendent	Discretion of Superintendent of Wildlife	Discretion of District Supervisor	Discretion of Minister	Discretion of Director, Conservation Officers Services Branch
Selling of hide by hunter	Permitted: subject to conditions of Ministerial permit	Permitted: must be taken legally, tag/seal attached	Permitted: must have tag attached	Permitted: must be taken legally and have tag affixed	Permitted: must be sealed by Ministry staff	Permitted: must be sealed	Permitted: permit required from Conservation Officer
Basis of Regulation	The Wildlife Act; The Endangered Species Act; The Polar Bear Protection Act	Wildlife Act, Chapter W-8 of The Revised Statutes of Newfoundland, 1990; classified as big game	Wildlife Act and Regulations	Wildlife Act and Regulations	Endangered Species Act, 2007; Fish and Wildlife Conservation Act, 1997 (Statutes of Ontario, 1997 Chapter 41)	Wildlife Conservation and Development Act; Laws respecting hunting and fishing rights in the James Bay and New Québec	Wildlife Act 2001; Wildlife Regulations 2012

Table 1. Continued.

	Jurisdiction						
Category	Manitoba	Newfoundland and Labrador	Northwest Territories	Nunavut	Ontario	Québec	Yukon
Fur Dealer Authority licence	Required: $25.00 general, $25.00 travelling	Required: no cost	Required: $400.00 first year, $200.00 each year after	Required: $75.00 residents, $100.00 non-residents and non-resident foreigners	Required: $40.00	Required: $445.47 resident, $905.09 non-resident, Auction dealer's licence: $1,127.49	Required: $25.00 resident, $300.00 non-resident, $5.00 agent, $25.00 non-resident restricted
Taxidermy licence	Required: $30.00	Required: must be taken legally; legislation under review	Required: $200.00 first year, $100.00 for each year after	Required: $75.00 for Nunavut residents, $100.00 for non-residents and non-resident foreigners	see Tanner's Authority	Required: $39.12	Required: $25.00 resident, $30.00 non-resident
Tanner's Authority licence	Required: $30.00	no legislation at present	Required: $200.00 first year, $100.00 each year after	Required: $75.00 resident, $100.00 non-residents and non-resident foreigners	Required: $40.00	Required: $341.03	Required: $2.00 resident, $10.00 non-resident
Live Animal Capture permit	Required: Ministerial permit	Required: Director of Wildlife	Required: $10.00 to capture live wildlife, free for NWT Wildlife Research	Required: $3,015.00 residents, $3,030.00 non-residents and $3,060.00, non-resident foreigners	Required: District Manager	Required: Ministerial permit	Required: Wildlife Research Permit, extremely difficult to obtain
Live Animal Export permit	Required: Ministerial permit	Required: Director of Wildlife	Required: $6,000.00 polar bear (live export not supported by Inuvialuit)	Required on case by case basis	Required: District Manager	Required: Ministerial permit	Required: special permit: extremely difficult

Table 2. Summary of the status of polar bear subpopulations in Canada based on review and discussion by the Canadian Polar Bear Technical Committee, February 2016.

Subpopulation	Jurisdiction[1]	Estimate	±2 SE or 95% CI	Year of Estimate	Method[2]	Historic Trend	Local or TEK assessment
Baffin Bay	GL, NU	2074	1542–2606	1997[3]	MR	Likely reduced	Stable[4]
Davis Strait	GL, NL, NU, QC	2158	1833–2542	2007[7]	MR	Likely increased	Increased[8]
Foxe Basin	NU, QC	2580	2093–3180	2009-10[11]	A	Stable	Increased[12]
Gulf of Boothia	NU	1592	870–2314	2000[15]	MR	Likely stable	Increasing[16]
Kane Basin	GL, NU	164	94–234	1997[19]	MR	Likely reduced	Increasing[20]
Lancaster Sound	NU	2541	1759–3323	1995-97[23]	MR	Likely stable	Increasing[24]
M'Clintock Channel	NU	284	166–402	2000[27]	MR	Likely reduced	Stable[28]

Table 2. Continued.

Subpopulation	Recent Trend	Future Trend	Historical annual removals: 5-year mean 2010/11–2014/15	Historical annual removals: 3-year mean 2012/13–2014/15	Historical annual removals: Last year 2014/15	Potential Removals Last year 2014/15
Baffin Bay	Likely decline[5]	Uncertain[6]	143.2	133.7	133	132 (67 GL, 65 NU)
Davis Strait	Likely increase[9]	Likely decline[10]	109.2	114.7	96	75 + QC (2 GL, 12 NL, 61 NU)
Foxe Basin	Stable[13]	Likely stable[14]	106.2	104.0	114	123 + QC (123 NU)
Gulf of Boothia	Likely stable[17]	Likely stable[18]	60.0	62.0	67	74 (74 NU)
Kane Basin	Uncertain[21]	Uncertain[22]	5.0	5.7	5	11 (6 GL, 5 NU)
Lancaster Sound	Uncertain[25]	Uncertain[26]	86.6	85.3	80	89 (89 NU)
M'Clintock Channel	Likely increase[29]	Uncertain[30]	3.4	3.7	5	5 (5 NU)

Table 2. Continued.

Subpopulation	Comments/Vulnerabilities/Habitat
Baffin Bay	currently being reassessed, high harvest, decline in sea ice, increased shipping
Davis Strait	based upon 2007 survey information, high harvest; decline in sea ice
Foxe Basin	long term decline in sea ice; potential for increased shipping for mineral extraction
Gulf of Boothia	current and projected habitat change may affect productivity of ecosystem; subpopulation has high vital rates and low harvest
Kane Basin	currently being reassessed, likely a sink population connected with Baffin Bay, small subpopulation, decline in sea ice
Lancaster Sound	historic sex-skewed harvest, habitat decline, potential for increased shipping for mineral extraction
M'Clintock Channel	increasing oil/gas development; loss of multi-year ice; currently being reassessed

Table 2. Continued.

Subpopulation	Jurisdiction[1]	Estimate	±2 SE or 95% CI	Year of Estimate	Method[2]	Historic Trend	Local or TEK assessment
Northern Beaufort Sea	NT, NU	1291[31]	n/a	2006[32]	MR	Likely stable	Stable[33]
Norwegian Bay	NU	203	115–291	1997[36]	MR	Uncertain	Stable[37]
Southern Beaufort Sea	NT, US, YT	1215[31]	n/a	2006[40]	MR	Uncertain	Stable[41]
Southern Hudson Bay	NU, ON, QC	943	658–1350	2012[44]	A	Stable	Stable, Increased[45]
Viscount Melville Sound	NT, NU	161	93–229	1992[49]	MR	Likely reduced	Increased[50]
Western Hudson Bay	MB, NU	1030	754–1406	2011[53]	A	Likely reduced	Increased[54]

Table 2. Continued.

Subpopulation	Recent Trend	Future Trend	Historical annual removals: 5-year mean 2010/11–2014/15	Historical annual removals: 3-year mean 2012/13–2014/15	Historical annual removals: Last year 2014/15	Potential Removals Last year 2014/15
Northern Beaufort Sea	Likely stable[34]	Likely stable[35]	43.0	39.3	35	77 (71 NT, 6 NU)
Norwegian Bay	Uncertain[38]	Uncertain[39]	2.2	2.3	1	4 (4 NU)
Southern Beaufort Sea	Likely decline[42]	Likely decline[43]	40.0	32.3	22	56 (15 NT, 35 US, 6 YT)
Southern Hudson Bay	Stable[46]	Uncertain[47]	58.8	46.7	43	45[48] (20 NU, 2 ON, 23 QC)
Viscount Melville Sound	Likely stable[51]	Uncertain[52]	5.2	5.0	2	7 (4 NT, 3 NU)
Western Hudson Bay	Likely stable[55]	Likely decline[56]	24.8	26.7	28	28 (4 MB[57], 24 NU)

Table 2. Continued.

Subpopulation	Comments/Vulnerabilities/Habitat
Northern Beaufort Sea	TEK study completed; increasing oil/gas development; decline in sea ice
Norwegian Bay	small, isolated subpopulation
Southern Beaufort Sea	Bromaghin *et al.* 2015 under review by PBTC – more in depth discussion to occur 2017 meeting; annual variability in ice conditions results in changes in density; bears shifting to NB because of ice conditions; TK study completed; potential for oil/gas development
Southern Hudson Bay	contradictory lines of evidence: declines in body condition & survival rates yet no change in abundance; TEK indicates winter body condition has not changed and reproductive rates have improved; TEK and science indicate changes in sea ice, ice free season increased by 30 days between 1980-2012; recent high harvest, habitat decline; decline of permafrost-based denning habitat; revised voluntary harvest agreement of 45 currently in effect
Viscount Melville Sound	currently being reassessed
Western Hudson Bay	sea ice decline; harvest; declines in body condition; lower productivity compared to adjacent Foxe Basin and South Hudson Bay subpopulations; historic decline in abundance from late 1980s through late 1990s linked to reduced survival due to timing of sea ice breakup; recent analysis indicated relative stability in subpopulation 2001-2010, a period during which there was no significant trend in freeze up or breakup; continued linkage between female survival and sea-ice conditions

a. Not according to law but hunting season and protection of mothers and cubs and bears in dens according to an agreement between Québec government and Inuit (Anguvigak Nunavik Hunters Fishers and Trappers Association, 1984)

b. Polar bears are not hunted in Manitoba; for management purposes, 4 animals are assumed for defense/accidental human-caused mortalities

1. GL, Greenland; MB, Manitoba; NL, Newfoundland and Labrador; NT, Northwest Territories; NU, Nunavut; ON, Ontario; QC, Quebec; US, United States; YT, Yukon Territory
2. A, aerial survey; MR, physical capture-recapture
3. Taylor *et al.* 2005
4. Dowsley 2005, Dowsley and Taylor 2006, Dowsley 2007, Nunavut Wildlife Management Board (NWMB) Public Hearing minutes and submissions for April 2008, September 2009

5. Combined harvested considered unsustainable: Taylor *et al.* 2005 plus simulations in PBSG 14 and 15 proceedings suggest abundance of 1,546 in 2004
6. Vital rates for Riskman PVA are 18 years old; TEK indicates population is stable; there is current research and ongoing assessment
7. Peacock *et al.* 2013
8. Kotierk 2010*a*, *b*
9. Stirling *et al.* 1980, Peacock *et al.* 2013
10. The impact of a TAH increase on the population has not been modeled; predicted trend after survey was completed at harvest levels in 2007 was considered stable (Peacock *et al.* 2013); NWMB Davis Strait public hearing submissions May 16-17, 2011
11. Stapleton *et al.* 2016
12. Sahanatien pers. comm. 7 Feb 2013, Dyck pers. comm. 7 Feb 2013, Canadian Wildlife Service 2009
13. Taylor *et al.* 2006*b*, Stapleton *et al.* 2016
14. No signs of deteriorating body condition or litter size (Stapleton *et al.* 2016)
15. Taylor *et al.* 2009
16. Keith *et al.* 2005, Canadian Wildlife Service 2009
17. For the period 2000–2015, assuming all sources of removals in the population sum to 74 bears/yr, the population can be expected to persist at a stable population size (Taylor *et al.* 2009)
18. Hunters in area reporting ice conditions have improved productivity, harvest levels remain stable (Dyck pers. comm. 2013)
19. Taylor *et al.* 2008*a*
20. Canadian Wildlife Service 2009
21. Population simulations of existing data suggest that only a very small quota (<2) may be sustained for this subpopulation (Taylor *et al.* 2008*a*)
22. Vital rates for PVA are 17 years old, current research and ongoing assessment
23. Taylor *et al.* 2008*b*
24. Canadian Wildlife Service 2009
25. For the period 1997–2012, the population would be expected to be stable under the historical harvest regimen (1993–1997). At the 2002–2006 mean harvest rate of 78 bears/yr, we estimate that the population is more likely to decline than to increase (Taylor *et al.* 2008*b*)
26. Vital rates for Riskman PVA are 16 years old
27. Taylor *et al.* 2006*a*
28. Inuit report that bears are moving to neighbouring areas throughout the region (Keith *et al.* 2005, Canadian Wildlife Service 2009)
29. Likely an increase based on quantitative assessment of growth rate (Taylor *et al.* 2006*a*)
30. Vital rates for PVA are 14 years old; several research planning consultations has been completed; further consultations ongoing
31. Revised estimates resulting from management boundary change
32. Griswold *et al.* 2010, Stirling *et al.* 2011
33. Pokiak pers. comm. 7 Feb 2013, Carpenter pers. comm. 7 Feb 2013
34. Population size used for management was historically adjusted to 1,200 due to bias in in population estimate (Amstrup *et al.* 2005, Stirling *et al.* 2011)
35. Durner *et al.* 2009, Stirling *et al.* 2011, and TEK (Joint Secretariat, unpublished) indicate stable population and habitat conditions may improve in short-term
36. Taylor *et al.* 2008*b*
37. Canadian Wildlife Service 2009
38. Vital rates for Riskman PVA are 17 years old and vital rates were substituted from other populations (Taylor *et al.* 2008*b*); no recent work in the area
39. Vital rates for Riskman PVA are 17 years old and vital rates were substituted from other populations (Taylor *et al.* 2008*b*)
40. Regehr *et al.* 2006, Griswold *et al.* 2010
41. Pokiak pers. comm. 7 Feb 2013, Carpenter pers. comm. 7 Feb 2013

42. Population estimate is lower but not statistically different from previous population estimates (Amstrup *et al.* 1986, Regehr *et al.* 2006). Quotas were based on the understanding that the total harvest of independent females would not exceed the modelled sustainable maximum of 1.5% of the population (Taylor *et al.* 1987) and that a 2:1 ratio of males to females would be maintained in the total quota harvested (Stirling 2002)
43. Based on sea ice declines (Durner *et al.* 2009), changes in body conditions measured in Alaska (Rode *et al.* 2010) and modelling (Regehr *et al.* 2010). Estimated risk of future decline is based on vital rates estimated from 2001-2006 data used in demographic models that incorporate sea ice forecasts
44. Obbard *et al.* 2015
45. Stable in James Bay, increased in eastern Hudson Bay (NMRWB Public Hearing Inukjuak February 2014)
46. Based on comparison with previous subpopulation estimates (Kolenosky *et al.* 1992, Obbard 2008, Obbard *et al.* 2015)
47. Body condition decline, vital rate declines and changes in ice conditions; Inuit observations show no decline in body condition or abundance (Obbard *et al.* 2016, NMRWB, unpublished)
48. Voluntary harvest agreement
49. Taylor *et al.* 2002
50. Canadian Wildlife Service 2009, community consultations in 2012 and 2013
51. Harvest managed for population growth since last survey including a 5 year moratorium; comparable litter size in 2012 (GNWT unpublished)
52. Vital rates for Riskman PVA are 22 years old; population reassessment currently in process
53. Stapleton *et al.* 2014
54. NWMB Public Hearing minutes 2005, Tyrrell 2006, Canadian Wildlife Service 2009, Kotierk 2012
55. Lunn *et al.* 2016
56. Based on body condition, abundance estimates, reduced reproductive productivity, and changes in ice conditions (Stirling and Parkinson 2006, Stapleton *et al.* 2014, Lunn pers. comm.)
57. There is no harvest of polar bears in Manitoba; for management purposes, 4 animals are assumed for defense/accidental human-caused mortalities

Table 3. Harvest quotas and numbers of polar bears killed[1] in Canada, 2008/09 through 2014/15.

	Jurisdiction[2]						
Management Year[3]	ISR[4] (NT, YT)	MB[5]	NL	NU	ON	QC[6]	Total
2008/09							
Quota	103	8	6	458	30	62	667
Killed	41	6	8	463	3	32	553
Sent to zoos	0	0	0	0	0	0	0
2009/10							
Quota	103	8	6	434	30	62	643
Killed	20	0	2	418	1	60	501
Sent to zoos	0	0	0	0	0	0	0
2010/11							
Quota	103	8	6	442	30	62	651
Killed	75	0	13	440	0	101	629
Sent to zoos	0	0	0	0	0	0	0
2011/12							
Quota	103	4	12	449	5	62	635
Killed	81	5	14	460	4	79	643
Sent to zoos	0	0	0	0	0	0	0
2012/13							
Quota	103	4	12	453	5	62	639
Killed	63	0	9	458	2	84	616
Sent to zoos	0	0	0	0	0	0	0
2013/14							
Quota	96	4	12	425	5	62	604
Killed	53	2	12	398	0	81	540
Sent to zoos	0	3	0	0	0	0	3
2014/15							
Quota	96	4	12	474	2	62	650
Killed	42	0	11	422	1	60	536
Sent to zoos	0	2	0	0	0	0	2

1. All known human caused mortalities, including subsistence kills, sport-hunt kills, problem kills, illegal kills, and bears that die while being handled during research
2. ISR, Inuvialuit Settlement Region; MB, Manitoba; NL, Newfoundland and Labrador; NU, Nunavut; ON, Ontario; QC, Québec
3. Management year extends from 1 July to 30 June the following year
4. ISR includes Yukon and NWT harvests under ISR tags
5. There is no quota in Manitoba because polar bears are not hunted. For management purposes, a small number of animals are assumed for defense/accidental human-caused mortalities
6. There is no mandatory reporting of polar bear harvest in Québec. Killed numbers only represent the voluntary reported harvest. The quota represents the Guaranteed Harvest Level established through Agreements with Aboriginal peoples

Table 4. Total known number of polar bears killed by humans[1,2] from subpopulations within or shared with Canada, 2008/09 through 2014/15.

	2008/09				2009/10				2010/11				2011/12				2012/13			
Subpopulation	Total	F	M	U	Total	F	M	U	Total	F	M	U	Total	F	M	U	Total	F	M	U
Baffin Bay																				
Greenland	82	29	46	7	68	12	56	0	63				66				66			
Nunavut	103	40	63	0	86	35	51	0	93	31	62	0	93	36	57	0	74	35	39	0
Sub-total	185	69	109	7	154	47	107	0	156	31	62	0	159	36	57	0	140	35	39	0
Davis Strait																				
Greenland	1	0	1	0	2	1	1	0	1				2				3			
Nfld/Labrador	8	4	4	0	2	1	1	0	13	4	8	1	14	2	9	3	9	2	7	0
Nunavut	44	18	26	0	42	18	24	0	57	16	41	0	37	18	19	0	60	20	40	0
Québec	23	6	17	0	24	6	18	0	24	13	11	0	54	21	32	1	51	13	37	1
Sub-total	76	28	48	0	70	26	44	0	95	33	60	1	107	41	60	4	123	35	84	1
Foxe Basin																				
Nunavut	109	31	78	0	109	40	69	0	104	38	66	0	108	38	70	0	105	51	54	0
Québec	0	0	0	0	0	0	0	0	3	2	1	0	4	3	1	0	2	1	1	0
Sub-total	109	31	78	0	109	40	69	0	107	40	67	0	112	41	71	0	107	52	55	0
Gulf of Boothia																				
Nunavut	72	29	43	0	57	25	32	0	45	18	27	0	69	21	48	0	67	25	42	0
Sub-total	72	29	43	0	57	25	32	0	45	18	27	0	69	21	48	0	67	25	42	0
Kane Basin																				
Greenland	7	1	4	2	3	2	1	0	2				6				6			
Nunavut	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	7	1	4	2	4	2	2	0	2	0	0	0	6	0	0	0	6	0	0	0

Table 4. Continued.

Subpopulation	2013/14 Total	F	M	U	2014/15 Total	F	M	U	5-years (2010/11–2014/15) Mean	Prop'n F	3-years (2012/13–2014/15) Mean	Prop'n F	Current year (2014/15) Total	Prop'n F
Baffin Bay														
Greenland	61				70									
Nunavut	67	20	47	0	63	22	41	0						
Sub-total	128	20	47	0	133	22	41	0	143.2	0.37	133.7	0.38	133	0.35
Davis Strait														
Greenland	1				3									
Nfld/Labrador	12	8	4	0	11	1	10	0						
Nunavut	52	18	34	0	50	21	29	0						
Québec	60	21	39	0	32	12	19	1						
Sub-total	125	47	77	0	96	34	58	1	109.2	0.36	114.7	0.35	96	0.37
Foxe Basin														
Nunavut	81	30	51	0	108	44	64	0						
Québec	10	5	5	0	6	2	3	1						
Sub-total	91	35	56	0	114	46	67	1	106.2	0.40	104.0	0.43	114	0.41
Gulf of Boothia														
Nunavut	52	19	33	0	67	20	47	0						
Sub-total	52	19	33	0	67	20	47	0	60.0	0.34	62.0	0.34	67	0.30
Kane Basin														
Greenland	6				5									
Nunavut	0	0	0	0	0	0	0	0						
Sub-total	6	0	0	0	5	0	0	0	5.0	–	5.7	–	5	–

Table 4. Continued.

Subpopulation	2008/09 Total	F	M	U	2009/10 Total	F	M	U	2010/11 Total	F	M	U	2011/12 Total	F	M	U	2012/13 Total	F	M	U
Lancaster Sound																				
Nunavut	94	36	58	0	73	27	46	0	84	20	64	0	93	27	66	0	91	30	61	0
Sub-total	94	36	58	0	73	27	46	0	84	20	64	0	93	27	66	0	91	30	61	0
M'Clintock Channel																				
Nunavut	2	0	2	0	3	0	3	0	3	1	2	0	3	1	2	0	3	1	2	0
Sub-total	2	0	2	0	3	0	3	0	3	1	2	0	3	1	2	0	3	1	2	0
Northern Beaufort Sea																				
NWT	25	7	14	4	11	7	4	0	42	13	28	1	48	16	32	0	39	8	30	1
Nunavut	4	2	2	0	0	0	0	0	3	1	2	0	4	2	2	0	4	2	2	0
Sub-total	29	9	16	4	11	7	4	0	45	14	30	1	52	18	34	0	43	10	32	1
Norwegian Bay																				
Nunavut	0	0	0	0	1	0	1	0	3	0	3	0	1	0	1	0	3	1	2	0
Sub-total	0	0	0	0	1	0	1	0	3	0	3	0	1	0	1	0	3	1	2	0
Southern Beaufort Sea																				
ISR (NWT+Yukon)	6	0	6	0	7	2	5	0	29	17	11	1	32	12	20	0	20	11	9	0
USA	24	1	16	7	17	10	3	4	23	4	13	6	19	3	12	4	30	4	20	6
Sub-total	30	1	22	7	24	12	8	4	52	21	24	7	51	15	32	4	50	15	29	6
Southern Hudson Bay																				
Nunavut	26	8	18	0	25	8	17	0	30	9	21	0	25	6	19	0	26	4	22	0
Ontario	3	1	1	1	1	0	1	0	0	0	0	0	4	0	2	2	2	0	2	0
Québec	9	4	5	0	36	16	20	0	74	27	46	1	21	7	14	0	31	11	19	1
Sub-total	38	13	24	1	62	24	38	0	104	36	67	1	50	13	35	2	59	15	43	1

Table 4. Continued.

	2013/14				2014/15				5-years (2010/11–2014/15)		3-years (2012/13–2014/15)		Current year (2014/15)	
Subpopulation	Total	F	M	U	Total	F	M	U	Mean	Prop'n F	Mean	Prop'n F	Total	Prop'n F
Lancaster Sound														
Nunavut	85	28	57	0	80	20	60	0						
Sub-total	85	28	57	0	80	20	60	0	86.6	0.29	85.3	0.30	80	0.25
M'Clintock Channel														
Nunavut	3	2	1	0	5	0	5	0						
Sub-total	3	2	1	0	5	0	5	0	3.4	0.29	3.7	0.27	5	0.00
Northern Beaufort Sea														
NWT	40	15	25	0	35	13	22	0						
Nunavut	0	0	0	0	0	0	0	0						
Sub-total	40	15	25	0	35	13	22	0	43.0	0.33	39.3	0.32	35	0.37
Norwegian Bay														
Nunavut	3	0	3	0	1	0	1	0						
Sub-total	3	0	3	0	1	0	1	0	2.2	0.09	2.3	0.14	1	0.00
Southern Beaufort Sea														
ISR (NWT+Yukon)	4	1	3	0	3	1	2	0						
USA	21	7	7	7	19	2	15	2						
Sub-total	25	8	10	7	22	3	17	2	40.0	0.36	32.3	0.32	22	0.15
Southern Hudson Bay														
Nunavut	27	10	17	0	20	6	14	0						
Ontario	0	0	0	0	1	0	1	0						
Québec	11	6	5	0	22	6	16	0						
Sub-total	38	16	22	0	43	12	31	0	58.8	0.32	46.7	0.31	43	0.28

Table 4. Continued.

Subpopulation	2008/09 Total	F	M	U	2009/10 Total	F	M	U	2010/11 Total	F	M	U	2011/12 Total	F	M	U	2012/13 Total	F	M	U
Viscount Melville Sound																				
NWT	4	2	0	2	0	0	0	0	4	3	1	0	1	1	0	0	4	2	2	0
Nunavut	1	0	1	0	3	2	1	0	3	0	3	0	3	1	2	0	3	1	2	0
Sub-total	5	2	1	2	3	2	1	0	7	3	4	0	4	2	2	0	7	3	4	0
Western Hudson Bay																				
Manitoba	6	1	5	0	0	0	0	0	0	0	0	0	5	1	4	0	0	0	0	0
Nunavut	8	4	4	0	18	3	15	0	15	6	9	0	24	8	16	0	22	5	17	0
Sub-total	14	5	9	0	18	3	15	0	15	6	9	0	29	9	20	0	22	5	17	0
Total	661				589				718				736				721			

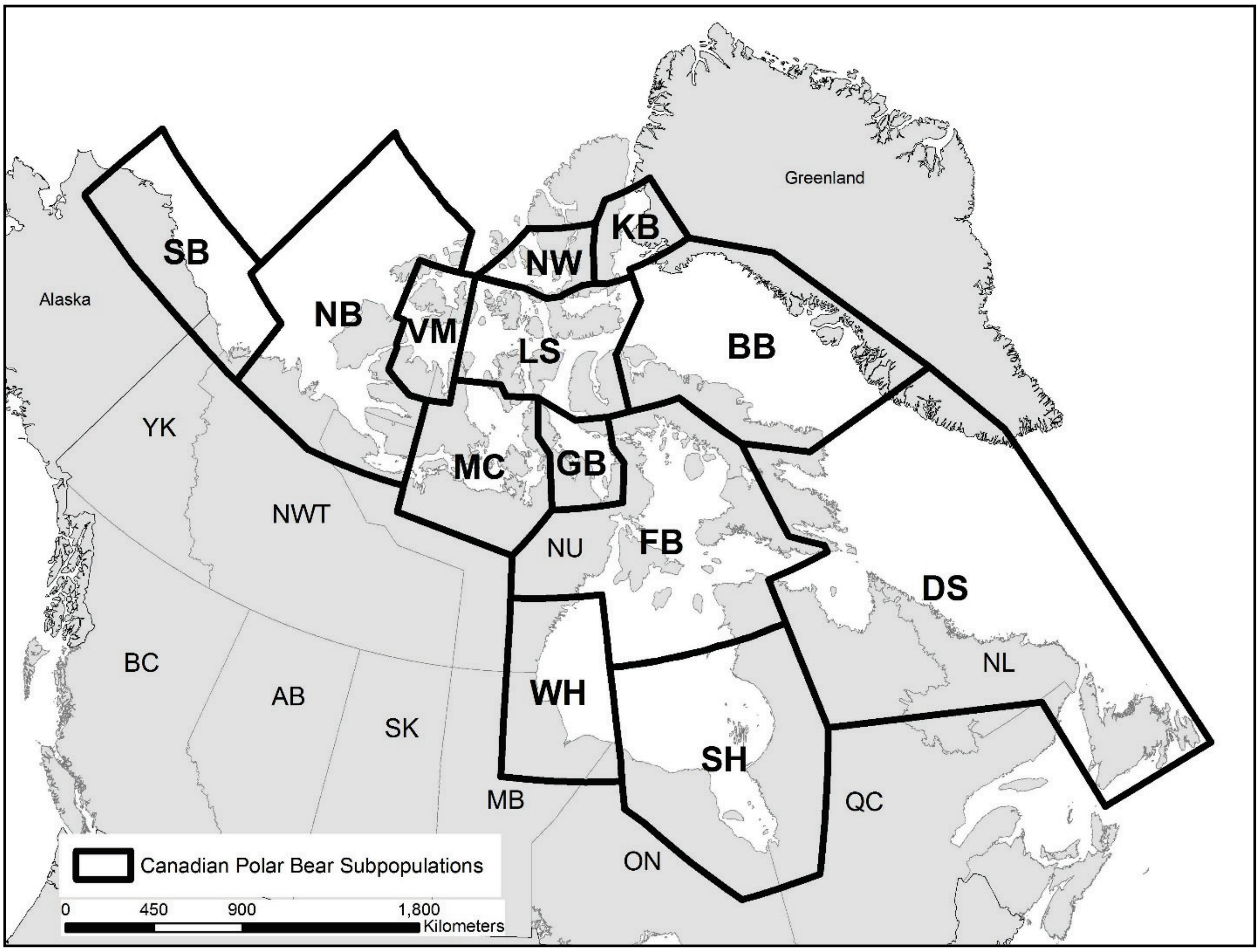
Table 4. Continued.

Subpopulation	2013/14 Total	F	M	U	2014/15 Total	F	M	U	5-years (2010/11–2014/15) Mean	Prop'n F	3-years (2012/13–2014/15) Mean	Prop'n F	Current year (2014/15) Total	Prop'n F
Viscount Melville Sound														
NWT	3	0	3	0	0	0	0	0						
Nunavut	3	1	2	0	2	1	1	0						
Sub-total	6	1	5	0	2	1	1	0	5.2	0.38	5.0	0.33	2	0.50
Western Hudson Bay														
Manitoba	5				2	1	1	0						
Nunavut	25	6	19	0	26	8	18	0						
Sub-total	30	6	19	0	28	9	19	0	24.8	0.29	26.7	0.27	28	0.32
Total	632				631				687.6	0.35	661.3	0.35	631	0.33

1. All known human-caused mortalities, including subsistence kills, sport-hunt kills, problem kills, illegal kills, bears that die while being handled during research, and any mortalities linked to humans (e.g., ingestion of poison)
2. Unverified males or bears of unknown sex are included in annual totals but not in M or F columns

Figures

Fig. 1. Canadian polar bear subpopulations as of 31 December 2015 (BB – Baffin Bay; DS – Davis Strait; FB – Foxe Basin; GB – Gulf of Boothia; KB – Kane Basin; LS – Lancaster Sound; MC – M'Clintock Channel; NB – Northern Beaufort Sea; NW – Norwegian Bay; SB – Southern Beaufort Sea; SH – Southern Hudson Bay; VM – Viscount Melville Sound; WH – Western Hudson Bay).



Research on Polar Bears in Canada, 2009–2015

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Research on polar bears (*Ursus maritimus*) in Canada is conducted by staff of Federal, Provincial, or Territorial governments and by university faculty. This research is often collaborative between university researchers and government scientists and is coordinated through partnership agreements. International cooperative projects are conducted with research partners in Alaska, Denmark, Greenland, and Norway. Funding is provided by government agencies, universities, wildlife management boards, non-governmental organizations, independent foundations, and competitive grants to graduate students. This report summarises research involving Canadian members of the IUCN/SSC Polar Bear Specialist Group from 2009–2015.

Subpopulation Delineation, Abundance Estimation, and Modelling

Subpopulation Delineation

Southern Hudson Bay

Using data from Argos telemetry collars deployed on adult female polar bears in the Southern Hudson Bay (SH) subpopulation from 1997–2003, Obbard and Middel (2012) derived on-ice and off-ice 95% population utilization distributions (UD) to describe the areas occupied by SH bears. There was general agreement between the on-ice UD and the current subpopulation boundary, at least as depicted by space use of adult females. There was slight overlap with the southern portion of the Foxe Basin (FB) subpopulation and with the southeastern portion of the western Hudson Bay (WH) subpopulation. However, the conclusion was that the currently depicted boundaries for the SH subpopulation adopted by the Canadian Polar Bear Technical Committee (Lunn *et al.* 1998) fairly represent the recent population UD and so could be used confidently to manage harvest (Obbard and Middel 2012).

Abundance Estimation

Aerial Surveys

Traditional capture-recapture methods have drawn criticism from various aboriginal groups, including Inuit co-management boards due to concerns about wildlife drugging and handling. In response to these concerns, the Government of Nunavut investigated alternative approaches that might better reflect Inuit societal values as well as enable more rapid and frequent assessment of subpopulations. Numerous researchers have conducted aerial surveys to monitor polar bear populations using a variety of methods (e.g., Belikov *et al.* 1988, Crete *et al.* 1991, McDonald *et al.* 1999, Wiig and Derocher 1999, Evans *et al.* 2003, Aars *et al.* 2009); however, there remained a need for a robust aerial survey technique to estimate abundance of subpopulations where bears are on land during the ice-free months of summer and fall. Therefore, Nunavut Department of Environment (NU DOE), in collaboration with the University of Minnesota (UM) conducted pilot studies over Southampton Island in late-summer 2008 and over the sea ice of Foxe Basin during the spring season of 2009 (Stapleton *et al.* 2012) to assess the feasibility of a comprehensive line transect design to estimate abundance of polar bears. Results of the pilot studies indicated that detectability was poor during spring surveys, but that surveys during the ice-free period held promise. Results of the pilot study over Southampton Island were used to design subsequent surveys conducted during the late summer and fall ice-free season by NU DOE and UM for the FB (2009, 2010) and WH subpopulations (2011), and by the Ontario Ministry of Natural Resources (OMNR), Québec Ministère des Forêts, de la Faune et des Parcs (MFFP), and NU DOE for the SH subpopulation (2011, 2012).

Foxe Basin

Stapleton *et al.* (2016) conducted comprehensive aerial surveys of the FB subpopulation using a combination of distance sampling protocols on inland transects and double-observer protocol on coastal transects during 2009 and 2010. Averaging abundance estimates yielded 2,585 (95% CI: 2,096–3,189) bears. This estimate is similar to an estimate of 2,200 (SE = 260) derived from a capture-recovery tetracycline marking study conducted during the late 1980s and early 1990s (Taylor *et al.* 2006). This result, along with evidence of robust reproductive output, suggests that FB is a stable and healthy subpopulation. Abundance appears to have remained stable since about 1990.

Southern Hudson Bay

Obbard *et al.* (2015) conducted a comprehensive line transect aerial survey of the SH subpopulation using a combination of distance sampling and double observer protocol during early fall in 2011 (mainland Ontario and Akimiski Island, James Bay) and 2012 (remaining islands in James Bay, nearshore islands of the Québec coast, and islands in eastern Hudson Bay). The survey could not be completed in one year due to logistical and financial constraints. The abundance estimate from the survey was 943 (95% CI: 658–1,350) for the entire subpopulation (Obbard *et al.* 2015). Comparing this estimate to previously generated estimates from capture-recapture studies suggest that abundance in the SH subpopulation has been stable since the mid-1980s.

Western Hudson Bay

Stapleton *et al.* (2014) conducted a comprehensive aerial survey of the WH subpopulation during August 2011 using a combination of overland transects perpendicular to the coast (distance sampling), coastal contour transects (double observer protocol), and small island sampling (double observer). Stapleton *et al.* (2014) derived an abundance estimate of 1,030 bears (95% CI: 754–1,406). This estimate was consistent with a 2004 estimate of abundance based on capture-recapture (935; 95% CI: 794–1,076; Regehr *et al.* 2007), though the vital rates estimated from the capture-recapture studies suggested that abundance could decline beyond 2004.

Capture-Recapture Studies

Davis Strait

Peacock *et al.* (2013) analyzed 35 years of capture and harvest data from the Davis Strait (DS) subpopulation, including data from a new study (2005–2007). They estimated the population size in 2007 to be 2,158 (95% CI: 1,833–2,542), a likely increase from the 1970s. They detected variation in survival, reproductive rates, and age-structure of polar bears from geographic sub-regions. Survival and reproduction of bears in southern Davis Strait was greater than in the north and tied to a concurrent dramatic increase in breeding harp seals (*Pagophilus groenlandicus*) in Labrador. The most supported survival models contained geographic and temporal variables. Estimates of declining harvest recovery rate and increasing total survival suggest that the rate of harvest declined over time. Low recruitment rates, average adult survival rates, and high population density, in an environment of high prey density, but deteriorating and variable ice conditions, currently characterize the DS subpopulation. Low reproductive rates may reflect negative effects of greater densities or worsening ice conditions.

Northern Beaufort Sea

Polar bears of the Northern Beaufort Sea (NB) subpopulation occur on the perimeter of the polar basin adjacent to the northwestern islands of the Canadian Arctic Archipelago. Sea ice converges on the islands through most of the year. Stirling *et al.* (2011) used open population capture-recapture models to estimate population size and vital rates of polar bears between 1971 and 2006 to: (1) assess relationships between survival, sex and age, and time period; (2) evaluate the long-term importance of sea ice quality and availability in relation to climate warming; and (3) note future management and conservation concerns. The highest ranking models suggested that survival of polar bears varied by age class and with changes in the sea ice habitat. Model-averaged estimates of survival (which includes harvest mortality) for senescent adults ranged from 0.37 to 0.62, from 0.22 to 0.68 for cubs of the year (COY) and yearlings, and from 0.77 to 0.92 for 2–4 year-olds and adults. Horvtiz-Thompson (HT) estimates of population size were not significantly different among the decades of the study. The mean NB population size estimated for the 2000s was 980 (95% CI: 825–1,135). These estimates apply primarily to that segment of the NB subpopulation residing west and south of Banks Island. This subpopulation appears to have been stable or possibly increasing slightly during the period the study. This suggests that ice conditions have remained suitable and similar for feeding in summer and fall during most years and that the traditional and legal Inuvialuit harvest has not exceeded sustainable levels. However, the amount of ice remaining in the study area at the end of summer, and the proportion that lies over the biologically productive continental shelf (<300 m water depth) declined over the 35-year period of the study. Continued climate warming and habitat loss will eventually cause the NB subpopulation to decline. Management and conservation practices for polar bears in relation to both aboriginal harvesting and offshore industrial activity will need to adapt.

Western Hudson Bay

The last re-assessment of the size of the WH polar bear subpopulation using physical capture-recapture was undertaken in the early 2000s because of the concern of climate change impacts. The analysis showed that the population had declined by 22% from approximately 1,200 in 1987 to 935 in 2004 (Regehr *et al.* 2007). Furthermore, the natural survival rates of dependent young, juvenile bears, and old bears was declining and was related to progressively earlier breakup of sea ice. Evidence for declines in the WH subpopulation led to reductions in harvest levels for aboriginal peoples. These reductions were controversial due to their social and economic effects, and the perception among some that the WH polar bear subpopulation remains abundant and healthy (Lunn *et al.* 2010).

Lunn *et al.* (2016) used live-recapture and dead-recovery data in a Bayesian implementation of multistate capture-recapture models to evaluate the impacts of environmental variation on demographic rates and trends for the WH polar bear subpopulation from 1984–2011. Survival of female bears of all age classes, but not males, was sensitive to sea ice conditions. The relatively high number of male bears killed by humans may be sufficiently large that compensatory effects dampen fluctuations in natural survival, making a potential underlying relationship between male survival and sea ice difficult to detect. The analysis indicated a long-term decline in abundance from 1,185 (95% Bayesian credible interval [BCI]: 993–1,411) in 1987 to 806 (95% BCI: 653–984) in 2011. Over the past 10 years of the study, there was no apparent trend in numbers due to a short-term amelioration in sea ice conditions (mean population growth rate for the period 2001–2010: 1.02, 95% BCI: 0.98–1.06). Looking forward, long-term growth rate for the WH subpopulation of approximately 1.02 (95% BCI: 1.00–1.05) and 0.97 (95% BCI: 0.92–1.01) was estimated under hypothetical 'high' and 'low' sea-ice conditions, respectively.

The findings support previous evidence for a demographic linkage between sea-ice conditions and polar bear population dynamics. Although the subpopulation is capable of responding positively to shorter-term positive trends in sea ice conditions, longer-term forecasts of decreasing duration and extent of sea-ice cover in southern and western Hudson Bay suggest that the long-term trend is likely to be negative. The study emphasized the importance of considering the relationships between vital rates and environmental conditions in demographic assessments for management and conservation planning (Lunn *et al.* 2016).

Movement and Habitat Studies

Polar bear habitat, space use, and movements in Foxe Basin

The annual phenological cycle of sea ice growth and decay has a strong influence on polar bear distribution and ecology. In collaboration with the Government of Nunavut, a study examined habitat selection, movements and spatial ecology of polar bears in Foxe Basin, Nunavut. Sahanatien and Derocher (2012) used satellite telemetry (2007–2011) to collect location data of female polar bears and ice-free season location data of male polar bears, and used satellite imagery to analyse sea ice habitat in Foxe Basin, Hudson Strait, and northern Hudson Bay. Using microwave satellite imagery (25 × 25 km² resolution) sea ice concentration maps were classified into four habitat quality categories to examine trends in fragmentation patch metrics, 1979–2008. Sahanatien and Derocher (2012) found that the amount of preferred sea ice habitat declined in autumn and spring, sea ice season length decreased, and habitat fragmentation increased. The observed trends may affect polar bear movement patterns, energetics, and ultimately population trends in the future.

When on the sea ice, female polar bears were distributed in three spatial clusters that broadly coincided with the three marine water bodies, Foxe Basin, Hudson Strait, and Hudson Bay. Differences in movement metrics (i.e., home range, movement rates, time on ice) were observed between clusters that may reflect sea ice habitat conditions and ocean productivity (Sahanatien *et al.* 2015). Bears showed annual and seasonal home range fidelity with two movement patterns: on-ice range residency and annual migration. High-resolution (150 × 150 m) synthetic aperture radar (SAR) was tested as an information source to examine sea ice habitat structure, as described by floes and leads that were available to female polar bears during their daily movements. The fine scale ice floe and lead patch density were the most important sea ice characteristics for bears when foraging on sea ice. Standard important broad scale variables, ice concentration, bathymetry and distance to land were not in the top resource selection models. Sahanatien *et al.* (2015) examined terrestrial movement patterns and behaviour of female and male polar bears during the annual period of minimum ice cover. Bears remained near the coast but were segregated by sex and reproductive status. All bears moved extensively and swimming was a regular behaviour.

Polar bear distribution in the Southern Beaufort Sea subpopulation

Arctic sea ice extent and thickness have declined in the Beaufort Sea, and have been particularly low since the first record minimum extent in 2007. Pongracz and Derocher (2016) examined polar bear distribution in SB via satellite telemetry from 2007–2011, including years of record low sea ice extent, using kernel density methods to evaluate how recent changes to sea ice conditions may affect the distribution of bears. Pongracz and Derocher (2016) related polar bear distributions to bathymetry and also examined the use of land and sea ice as a summer refuge. Polar bear movement patterns and distribution changed in response to sea ice conditions. Bears were forced to travel greater distances and remain over deeper water longer as they maintained a presence at the edge of the pack that varies annually. Bears also used land areas in Alaska greater than previously documented (Pongracz and Derocher 2016).

Modeling sea ice in Hudson Bay from a polar bear perspective

Castro de la Guardia *et al.* (2013) used a high-resolution sea ice-ocean model to examine break-up and freeze-up dates in western Hudson Bay. The model was validated and calibrated with GPS-data from polar bears. Predictions were based on the IPCC greenhouse gas-emission scenarios: B1, A1B and A2. The model predicted significant changes in western Hudson Bay spring sea ice concentration in A1B and A2, and in the seasonal ice cycle in B1, A1B and A2. From 2061–2100, the mean break-up date advances 15.7 days (B1), 31.5 days (A1B), and 46 days (A2), and the mean ice-free period lengthens by 4.5 weeks (B1), 8.4 weeks (A1B), and 12.5 weeks (A2). Should the model projections be realized, a viable population of polar bears will not likely persist for the WH subpopulation beyond the end of this century.

Projected polar bear sea ice habitat in the Canadian Arctic Archipelago

Hamilton *et al.* (2014) used sea ice projections for the Canadian Arctic Archipelago from 2006–2100 to gain insight into the conservation challenges for polar bears with respect to habitat loss using metrics developed from polar bear energetics modelling. With projected warming by the end of the 21st century, shifts away from multiyear ice to annual ice cover throughout the region, as well as lengthening ice-free periods, may become critical for polar bears. All Archipelago subpopulations may undergo 2–5 months of ice-free conditions, where no such conditions currently exist. Under business-as-usual climate projections, polar bears may face starvation and reproductive failure across the entire Archipelago by the year 2100.

Swimming behaviour

Comparison of satellite tracking data of bears in the Beaufort Sea and in Hudson Bay revealed regional differences with many more long distance (>50 km) swimming events by bears in the Beaufort Sea (Pilfold *et al.* 2016) . Increased swimming was related to changes in the amount and location of summer sea ice. In 2012, 69% of the tracked adult females in the Beaufort Sea swam more than 50 km at least once, the same year in which Arctic sea ice hit a record low. Swimming frequency and other movement factors varied among individuals and showed differences dependent on age, sex, body size, and geographic features of the region. Swims occurred more frequently in the Beaufort Sea than in the Hudson Bay. Females with young cubs tended to swim less, whereas lone subadults swam as frequently as lone adults. The longest recorded swim in the study was by a subadult female that travelled over 400 km in 9 days.

Stirling and van Meurs (2015) documented a long dive by an adult male polar bear during an aquatic stalk of three bearded seals (*Erignathus barbatus*) in the drifting pack ice north of Spitsbergen. The bear dove for a total duration of 3 min 10 s and swam 45–50 m without surfacing to breathe or reorient itself to the seal's location.

Approaches to identifying behavioural processes and define home ranges using animal movement data

Auger-Méthé *et al.* (2015*a*) explored new methods of examining polar bear movement and space-use patterns to study individual strategies and developed new methods to incorporate sea ice drift in home range analyses. Two search strategies have become prominent: the Lévy walk and area-restricted search (ARS) (Auger-Méthé *et al.* 2015*a*). Although the processes underlying these strategies differ, they can produce similar movement patterns and current methods cannot reliably differentiate between them. A method was developed to simultaneously assess the strength of evidence for these two strategies using polar bear telemetry data.

A home range represents the area an animal uses to perform the majority of the activities required for survival and reproduction. As such, measuring home range size has been an important tool to quantity the amount of habitat an animal requires. However, in moving habitats, traditional home range estimates may be ill-suited to this task. Auger-Méthé *et al.* (2015*b*) developed a new approach to estimate the amount of ice habitat encountered by polar bears. These estimates showed that the traditional geographic home range underestimates both the movement of bears and the amount of ice habitat that they encounter. The results also indicated that bears living on highly mobile ice might be exposed to higher energetic costs (compensating for a moving platform), and potentially larger energetic gains (greater availability of prey), than bears inhabiting more stable ice.

Feeding and Dietary Studies

Polar bear feeding ecology in relation to sea ice dynamics

Polar bears rely upon the sea ice as the platform to access their main prey: pagophilic seals. Determining specific effects of climate-induced environmental change on polar bears will require monitoring at numerous spatiotemporal scales and across various levels of biological organization. Cherry *et al.* (2009, 2011) used and refined a variety of ecological monitoring tools that evaluated the effects of seasonal and longer-term unidirectional sea ice changes to various aspects of polar bear ecology. At a molecular level, urea to creatinine ratios in polar bear blood were used to show that an increased number of polar bears were in a physiological fasting state during spring captures in 2005–2006 compared to the mid-1980s (Cherry *et al.* 2009). These changes corresponded to broad-scale changes in Arctic sea ice composition, which may have altered prey availability. Cherry *et al.* (2011) used measurements of naturally occurring stable isotopes (δ^{13C}, δ^{15N}) in polar bear tissues to examine diet, which included both lipid-rich blubber and the proteinaceous tissues of their prey. Because the proportion of proteins and lipids consumed were likely dependent on prey type and size, it was necessary to consider metabolic routing of these macromolecules separately when using isotope mixing models to determine and monitor polar bear diet.

Use of fatty acid signature analysis to study polar bear diets

Polar bears across their circumpolar range are largely dependent on the availability of ringed seals (*Pusa hispida*) as their primary prey. However, at local and regional scales polar bear diets can be diverse and the ecological factors affecting prey selection are poorly understood. An improved understanding of the spatial and temporal dynamics of polar bear foraging, and the constraints and flexibility around prey selection, may provide insights into how polar bears respond to future climate-driven changes in food availability. A series of recent and ongoing studies have used fatty acid signature analysis to examine the feeding behaviour of polar bears across their Canadian range. For the WH and SH subpopulations, longitudinal analysis of individual polar bear diets revealed substantial individual dietary specialization, whereby an individual exploits a subset of resources available to the rest of the population. Specifically, some adult male polar bears act as specialized predators of bearded seals (Thiemann *et al.* 2011). In the central Arctic subpopulations of Baffin Bay (BB), Lancaster Sound (LS), and Gulf of Boothia (GB) polar bears diets were regionally variable with ringed, bearded, and harp seals , as well as beluga whales (*Delphinapterus leucas*), all serving as important food sources (Galicia *et al.* 2015). Polar bears show ontogenetic and sex-specific patterns in prey selection and their diets are strongly influenced by local prey availability. Ongoing projects will further examine the intrinsic (e.g., reproductive status) and extrinsic (e.g., sea ice conditions) factors that influence polar bear predatory behaviour in the subpopulations within the western Canadian Arctic (i.e., SB, NB, Viscount Melville Sound [VM], FB, WH, and SH).

Polar bear foraging ecology in the Beaufort Sea

Polar bears enter a period of intensified feeding in the spring, which allows for the accumulation of energy stores critical to surviving the open water season. Studies on polar bear predation have been limited by sample size and spatial extent, and hypotheses on the demographic composition of seal kills and the spatial distribution of polar bears and seals were incongruent. Pilfold *et al.* (2012) used a long-term dataset (1985–2011) of seals killed by polar bears (n = 650) and predation attempts at ringed seal subnivean lairs (n = 1396) in the Canadian Beaufort Sea to link the habitats polar bears use and the seals that polar bears kill during hyperphagia. Using DNA and field observations, it was determined that polar bears primarily killed ringed seals, but that bearded seals contributed a significant portion of kill biomass (Pilfold *et al.* 2012). An increase in seal kill frequency was observed as spring progressed, associated with the onset of ringed seal whelping. The influence of ringed seal whelping was also observable at inter-annual scales, with total kill frequency positively correlated to years of high ringed seal natality, whereas adults were killed in higher proportion in years when natality was low. Employing locations of seal kills and attempted hunts at ringed seal subnivean lairs, Pilfold *et al.* (2013) showed that polar bears selected for active areas of sea ice near the floe edge when hunting. Ringed seal whelping areas were located over a range of habitats, and the distribution was correlated with their natality rates. In years of low natality, pup kills were observed primarily in shorefast ice close to land, but during years of high natality the distribution widened, and pup kills were observed farther from land and more frequently near active ice areas (Pilfold *et al.* 2013). Results suggest that during periods of high natality, the habitats in which ringed seals whelp overlaps with areas preferred by polar bears for hunting. The spatial overlap between polar bears and whelping ringed seals likely influences a change in the age-class proportions of kills, as polar bears respond to the availability of vulnerable pups. Exploring the assumptions of common analytical modelling approaches in ecology, Pilfold *et al.* (2015) showed that including biologically relevant measures, such as the size of kills, provided significant improvement to the models in both fit and interpretation. Measuring only the occurrence of an ecological event, whether temporally or spatially was insufficient when validated against independent data.

Other Ecological Studies

Monitoring long-term trends in sea ice and body condition in the Southern Hudson Bay subpopulation

In Hudson Bay the ice melts completely each summer, and advances in break-up have resulted in longer ice-free seasons. Consequently, earlier break-up is implicated in declines in body condition, survival, and abundance of polar bears in the WH subpopulation (Stirling *et al.* 1999, Regehr *et al.* 2007). Obbard *et al.* (2016) hypothesised that similar patterns would be evident in the neighbouring SH subpopulation. First, Obbard *et al.* (2016) examined trends 1980–2012 in break-up and freeze-up dates within the entire SH management unit and within smaller coastal break-up and freeze-up zones. Next, they examined trends in body condition for 900 bears captured during 1984–1986, 2000–2005, and 2007–2009 and hypothesised that body condition would be correlated with duration of sea ice. The ice-free season in SH increased by about 30 days 1980–2012. Body condition declined in all age and sex classes, but the decline was less for cubs than for other social classes. If trends towards a longer ice-free season continue in the future, further declines in body condition and survival rates are likely, and ultimately declines in abundance will occur in the SH subpopulation.

Monitoring long-term trends in condition and reproduction of polar bears in relation to climatic warming in the Western Hudson Bay subpopulation

The overall objective of Environment and Climate Change Canada's ongoing research in western Hudson Bay is to quantitatively evaluate the effects of global climate change on the ecology, population dynamics, status, and health of polar bears. The changing climate in the region has a direct impact on the long-term viability of the WH subpopulation. The impacts of earlier sea ice breakup on polar bears of the WH subpopulation have been previously documented and include reductions in body condition, natality, survival of cubs, juveniles, and older bears, and in overall abundance (e.g., Stirling *et al.* 1999, Regehr *et al.* 2007). More recently, Lunn *et al.* (2016) documented relative stability in abundance that may be related to a period of temporary stability in sea ice conditions. Nevertheless, reduction of sea ice habitat remains the most significant threat to polar bears (Stirling and Derocher 1993, Derocher *et al.* 2004, Peacock *et al.* 2010).

A recent analysis of long-term trends in the body condition of polar bears of the WH subpopulation (Sciullo *et al.* 2016) detected significant declines in condition from 2004 to 2014 for adult and subadult male and female polar bears. Body condition was significantly related to timing of sea ice break-up and freeze-up. Sciullo *et al.* (2016) also performed a comparative assessment of multiple condition metrics and found strong correlations among most metrics, but concluded that mathematical models of energy stores (i.e., energy density, *sensu* Molnár *et al.* [2009]) may be the most useful means of tracking changes in physiological condition.

Genetics Studies

Canadian polar bear population structure using Single Nucleotide Polymorphisms (SNPs)

Several previous studies have investigated the genetic structure of polar bear subpopulations in the Canadian Arctic using microsatellite markers (e.g., Paetkau *et al.* 1995, Crompton *et al.* 2008, Campagna *et al.* 2013). Malenfant *et al.* (2015) focused on assessing Canadian polar bear subpopulation structure and potential adaptive variation using a 9K Illumina BeadChip that contained both restriction-site associated DNA (RAD) SNPs (non-coding DNA) and potentially adaptive transcriptomic SNPs developed from fat and blood. Analysis of 30 individuals from each of Canada's 13 polar bear subpopulations revealed 4 moderately differentiated groups corresponding to the Beaufort Sea, the Arctic Archipelago, Norwegian Bay, and the Hudson Complex (Malenfant 2016). Rarefaction analyses show that the Norwegian Bay cluster has reduced genetic variation compared to other genetic clusters, which is likely the result of its small effective population size. There are also two outlier loci (SNPs in PDLIM5 associated with dilated cardiomyopathy and SLC15A5 associated with visceral adipose tissue deposition), that may be related to previously observed unique physical characteristics of Norwegian Bay bears (Malenfant 2016).

Multi-generational pedigree and quantitative genetics in the Western Hudson Bay polar bear subpopulation

In an effort to better understand the mating system, sexual selection and heritability of traits in polar bears, Environment and Climate Change Canada has invested significant resources into the development of a multi-generational pedigree for the WH subpopulation. Malenfant *et al.* (2016) published this pedigree which contains 4,449 individuals inferred from both field and genetic data collected over six generations of bears sampled between 1966 and 2011. The pedigree identified the first case of monozygotic twinning in polar bears, 6 new cases of cub adoption and revealed that there was little to no inbreeding in the WH subpopulation (Malenfant *et al.* 2016). The pedigree is currently being applied to further refine estimates of age-specific reproductive success and sexual selection in polar bears documented by Richardson (2014). Further quantitative analysis by Malenfant (2016) has shown that polar bears exhibit moderate heritabilities for skeletal size traits (e.g., body length) with relatively low levels of evolvability.

Population structure and space-use of polar bears in Hudson Bay

Telemetric and genetic population structure data have rarely been examined concurrently to explore differences and similarities. Viengkone (2015) investigated the utility of both population genetics and breeding season telemetry data to examine polar bear subpopulation structure in Hudson Bay. Genetic population structure was examined in 414 polar bears caught throughout Hudson Bay using two genetic marker systems: microsatellites and single nucleotide polymorphisms (SNPs; Viengkone 2015). SNPs detected a larger number of biologically meaningful subpopulations, with higher proportions of strongly assigned individuals and more precise estimates of ancestry. SNPs identified four genetic clusters that differ from the subpopulation designations currently used for the region. Spatial structure was assessed by comparing utilization distributions (UDs) during the breeding season from two perspectives: 1) by grouping individuals by the management subpopulation where individuals were caught and 2) by grouping individuals by the genetic cluster they strongly assign to. A combination of high-resolution SNP information and geographic positioning system-satellite telemetry data from 62 female polar bears from three subpopulations of Hudson Bay displayed reduced shared space-use between grouped UDs based on genetic assignment compared to those formed by capture location. Combining genetic and telemetric data provides an alternative method for understanding subpopulation delineation.

Re-assessment of genetic structure of Canadian polar bear subpopulations

Peacock *et al.* (2015) conducted an expansive analysis of polar bear circumpolar genetic variation during the last two decades of decline in their sea-ice habitat. They evaluated whether genetic diversity and structure have changed over this period, how their current genetic patterns compare with past patterns, and how genetic demography changed with ancient fluctuations in climate. Characterizing their circumpolar genetic structure using microsatellite data, Peacock *et al.* (2015) defined four clusters that largely correspond to current ecological and oceanographic factors: Eastern Polar Basin, Western Polar Basin, Canadian Archipelago, and Southern Canada. They provided evidence for recent (ca. last 1–3 generations) directional gene flow from Southern Canada and the Eastern Polar Basin towards the Canadian Archipelago, an area hypothesized to be a future refugium for polar bears as climate-induced habitat decline continues. From analyses of mitochondrial DNA, the Canadian Archipelago cluster and the Barents Sea (BS) subpopulation within the Eastern Polar Basin cluster did not show signals of population expansion, suggesting these areas may have served also as past interglacial refugia. Peacock *et al.* (2015) found no genetic signatures of recent hybridization between the polar bears and brown bears (*U. arctos*) in their large, circumpolar sample, suggesting that recently observed hybrids represent localized events.

M'Clintock Channel–Gulf of Boothia subpopulation differentiation

Local ecological and traditional knowledge suggests that polar bears of the neighbouring M'Clintock Channel (MC) and Gulf of Boothia (GB) subpopulations represent one rather than two management units. Movement data of bears from these two areas are sparse; however, tissue samples collected during the last population inventories (1998–2000) were used in a genetic study to examine population differentiation. Campagna *et al.* (2013) used DNA microsatellites and mitochondrial control region sequences from 361 polar bears to quantify genetic differentiation, estimate gene flow, and infer population history of polar bears of the MC and GB subpopulations. Two populations, roughly coincident with GB and MC subpopulations, were significantly differentiated at both nuclear (F_{ST} = 0.01) and mitochondrial (Φ_{ST} = 0.47; F_{ST} = 0.29) loci, allowing Bayesian clustering analyses to assign individuals to either group. Results imply that the causes of the mitochondrial and nuclear genetic patterns differ. Analysis of mtDNA revealed the matrilineal structure dates at least to the Holocene, and is common to individuals throughout the species' range. These mtDNA differences probably reflect both genetic drift and historical colonization dynamics. In contrast, the differentiation inferred from microsatellites is only on the scale of hundreds of years, possibly reflecting contemporary impediments to gene flow. Taken together, the data suggest that gene flow is insufficient to homogenize the GB and MC subpopulations and support their designation as separate polar bear conservation units. The study also provides a striking example of how nuclear DNA and mtDNA capture different aspects of a species' demographic history.

Health and Environment

Evaluating hair cortisol concentration as an indicator of stress in the Southern Hudson Bay subpopulation

The effectiveness of hair cortisol concentration (HCC) as an indicator of environmental stress in polar bears was evaluated using samples from 185 bears from the SH subpopulation, 2007–2009 (Macbeth *et al.* 2012). HCC was influenced by sex, family group status, and capture period but not by body region or hair type. HCC was negatively associated with growth indices (length, mass, and body condition index) linked to fitness in polar bears. Additional research will be required across several polar bear populations to establish the utility of HCC as a tool for polar bear conservation.

Assessing stress in the Western Hudson Bay subpopulation using hair cortisol concentration as a biomarker

Cortisol is the principal effector hormone of the stress response and has been linked to aspects of polar bear biology (e.g., reproduction, growth) that may be negatively influenced by environmental change. Mislan *et al.* (2016) examined the influence of age, reproductive status, and body condition (fatness) on hair cortisol concentration (HCC) in 729 polar bears from the WH subpopulation sampled from 2004–2013. There was a negative relationship between fatness and HCC, suggesting that bears in poorer body condition experienced higher levels of stress. However, when reproductive status was included in the analysis, this relationship only held for male and lone female bears. Females with dependent offspring had consistently low fatness and elevated HCC, likely because of the high cost of maternal care. A positive correlation was found between HCC and age for bears in: 1) poorer body condition, possibly due to nutritional stress compounding effects of senescence; and 2) male bears, potentially due to stress and injury associated with intrasexual mate competition. These findings support the use of HCC as a biomarker for polar bear health and have established a HCC benchmark for the WH subpopulation.

Serum proteins as indicators of stress and health

Polar bears from several subpopulations undergo extended fasting during the ice-free season. However, the animals appear to conserve protein despite the prolonged fasting, though the mechanisms involved are poorly understood. Chow *et al.* (2011) hypothesized that elevated concentrations of corticosteroid binding globulin (CBG), the primary cortisol binding protein in circulation, lead to cortisol resistance and provide a mechanism for protein conservation during extended fasting. The metabolic state (feeding vs. fasting) of 16 field sampled male polar bears was determined based on their serum urea to creatinine ratio (>25 for feeding vs. <5 for fasting). There were no significant differences in serum cortisol levels between all male and female polar bears sampled. Serum CBG expression was greater in lactating females relative to non-lactating females and males. CBG expression was significantly higher in fasting males when compared to non-fasting males. This suggested that CBG expression may serve as a mechanism to conserve protein during extended fasting in polar bears by reducing systemic free cortisol concentrations. This was further supported by a lower serum glucose concentration in the fasting bears. As well, a lack of an enhanced adrenocortical response to acute capture stress supported the hypothesis that chronic hunger is not a stressor in this species. Chow *et al.* (2011) concluded that elevated serum CBG expression may be an important adaptation to spare proteins by limiting cortisol bioavailability during extended fasting in polar bears.

Contaminants Studies

Mercury in polar bear hair

Bechshoft *et al.* (2015) studied the relationship between concentrations of cortisol and total mercury (THg) in guard hair from 378 polar bears sampled from the WH subpopulation, 2004–2012. Mercury has been deemed an endocrine disruptor in other species, but this was the first study investigating this property in polar bears. The sexes did not differ in cortisol concentrations, but females had significantly higher THg concentrations than males (Bechshoft *et al.* 2015). Hair cortisol in males was significantly influenced by THg concentration, age, and body condition. In females, cortisol was related to body condition only. In conclusion, a significant, but complex, relationship was found between THg and cortisol concentrations in hair from male, but not female, polar bears.

Another study of THg involved 24 polar bear family groups from the WH subpopulation. THg concentrations increased with age, with cubs-of-the-year (COY) having significantly lower concentrations than other groups (mother, yearling, 2-year-old; Bechshoft *et al.* 2016). Maternal THg was positively related to body condition and litter size, while overall offspring THg was positively related to maternal body condition in addition to being dependent on the sex and age of the offspring. COY THg concentrations were positively related to maternal THg while also depending on the sex of the offspring. Although dependent young may be particularly sensitive to the effects of environmental pollutants, few studies of polar bears report on contaminants in this group. Considering our results, future studies in polar bear ecotoxicology are encouraged to group and investigate dependent offspring by age and sex.

Penile density and contaminants

As a top predator, polar bears accumulate various contaminants in their tissues, which has led to ongoing circumpolar contaminants monitoring programmes. In order to understand how these contaminants could affect reproduction in the long-term, a study was undertaken to examine bone mineral density (BMD) of polar bear bacula, and whether spatial trends and relationships to contaminants existed. Sonne *et al.* (2015) analysed 279 bacula of polar bears born between 1990 and 2000 representing eight polar bear subpopulations. Because endocrine disrupting chemical (EDC) concentrations were not available from the same specimens, the authors compared BMD with published literature information on EDC concentrations. Latitudinal and longitudinal BMD and EDC gradients were clearly observed, with WH bears having the highest BMD and lowest EDC, and polar bears of the East Greenland (EG) subpopulation carrying the lowest BMD and highest EDC. A BMD vs. polychlorinated biphenyls (PCB) regression analysis showed that BMD tended to decrease as a function of PCB concentration though the relationship was not statistically significant ($P = 0.10$). Risk quotient (RQ) estimation demonstrated that PCBs could be in a range that may lead to disruption of normal reproduction and development. Therefore, it is likely that EDC directly affects development and bone density in polar bears. WH bears had in general the best health and EG bears were at the highest risk of having negative health effects. Though having low levels of BMD is a general health risk, reductions in penile BMD could lead to mating and subsequent fertilization failure as a result of weak penile bones and risk of fractures. Based on this, future studies should assess how polar bear subpopulations respond upon EDC exposure.

Research Techniques

Estimating body mass of polar bears of the Western Hudson Bay subpopulation

The mass of Western Hudson Bay polar bears captured each year had been estimated from an equation developed by Kolenosky *et al.* (1989) that was based on measurements of chest girth and weight from polar bears handled along the Ontario coast over 20 years ago. Declining sea ice conditions associated with Arctic warming have significantly affected body condition, reproduction, survival, and abundance of polar bears in this region (Stirling *et al.* 1999, Regehr *et al.* 2007) and, although it is among the best-studied groups of polar bears in the world, the relationship between morphometry and body mass had not been examined in more than 20 years. From 2007 through 2009, bears captured each fall in western Hudson Bay were weighed on a digital scale suspended from a tripod to investigate the possibility that the morphometry-mass relationship had changed over time.

New predictive equations were developed to estimate the body mass of free-ranging polar bears in WH (Thiemann *et al.* 2011). Using multiple linear and non-linear regressions, a strong relationship between polar bear body weight and linear measures of straight line length and axillary girth was identified. The mass-morphometry relationship appeared to change over time and, therefore, separate equations were developed for polar bears physically weighed during two time periods, 1980-1996 and 2007-2009. Bears were not weighed between 1996 and 2007. Non-linear models were more accurate and provided body mass estimates within 5.8% ($R^2 = 0.98$) and 6.1% ($R^2 = 0.98$) of scale weight in the earlier and later time periods, respectively. These equations were:

<u>1980-1996</u>

$$M = 0.00008989 \times AXG^{1.919} \times SLEN^{1.026}$$

<u>2007-2009</u>

$$M = 0.00006039 \times AXG^{1.762} \times SLEN^{1.249}$$

where M = mass (kg), AXG = axillary girth (cm), and SLEN = straight-line length (cm).

Testing high-resolution satellite images to monitor polar bears

In recent years, the Government of Nunavut has explored research and monitoring techniques that involve less or no handling of wildlife due to the concerns expressed by community members. High-resolution satellite imagery is a promising tool for providing coarse information about polar species abundance and distribution, but current applications are limited. For polar bears, the technique has only proven effective on landscapes with little topographic relief that are devoid of snow and ice, and time-consuming manual review of imagery is required to identify bears. Therefore, LaRue *et al.* (2015) evaluated mechanisms to further develop methods for satellite imagery by examining data from Rowley Island in Foxe Basin. They attempted to automate and expedite detection via a supervised spectral classification and image differencing to expedite image review. LaRue *et al.* (2015) also assessed what proportion of a region should be sampled to obtain reliable estimates of density and abundance. Although the spectral signature of polar bears differed from nontarget objects, these differences were insufficient to yield useful results via a supervised classification process. Conversely, automated image differencing – or subtracting one image from another – correctly identified nearly 90% of polar bear locations. However, this technique also yielded false positives, suggesting that manual review will still be required to confirm polar bear locations. On Rowley Island, bear distribution approximated a Poisson distribution across a range of plot sizes, and resampling suggests that sampling >50% of the site facilitates reliable estimation of density (CV <15%). Satellite imagery may be an effective monitoring tool in certain areas, but large-scale applications remain limited because of the challenges in automation and the limited environments in which the method can be effectively applied. Nevertheless, improvements in resolution may expand opportunities for its future uses.

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Management on Polar Bears in Greenland, 2009–2016

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The socioeconomic and cultural importance of polar bears in Greenland

For millennia, since our ancestors came to Greenland, bringing along with them a tradition of hunting land and marine mammals, polar bears have played a central role for our hunters and their families. Besides providing meat and clothing for the subsistence of the small communities, polar bears have a strong social, economic and cultural role in our society and have always been a mythical figure in our culture. Thus, polar bears are a very important species in Greenland. That implores the Greenlandic people and decision makers, to ensure the long-term survival of the species, through regional and international co-operation.

Management

The Government of Greenland is the responsible authority of the management of polar bears in Greenland, including the national legislation, national coordination and setting of hunting quotas. The Ministry of Fisheries and Hunting (APN) provides national coordination and is the authority for international agreements (e.g. Memorandum of Understanding between Greenland and Canada/Nunavut on the Kane Basin (KB) and Baffin Bay (BB) polar bear subpopulations, Range States meetings, Agreement on the Conservation of Polar Bears, IUCN Polar Bear Specialist Group, and coordinates the polar bear issues subject in the CITES Animals Committee and COP).

The jurisdiction of the KB and BB subpopulations of polar bears are shared between Canada/Nunavut and Greenland. Greenland has also the jurisdiction of the East Greenland (EG) polar bear subpopulation along the eastern Greenlandic coast and the Davis Strait (DS) subpopulation in southwest Greenland.

Legislation

The Greenland Home Rule Act no. 12 of 29 October 1999 on Hunting & Game is the legislative basis of wildlife management in Greenland. It sets the legal boundaries for the protection of wildlife in Greenland, including polar bears. The Executive Order on the protection and hunting of polar bears (2006) regulates the access to the harvest of polar bears and restricts the harvest to single adult polar bear. It also sets the boundaries of polar bear research. The most recent update of the executive order on management of and protection of polar bears was in 2005, when the current system of harvest quotas was introduced. A new executive order is expected to be introduced in 2018. The draft has been under a public hearing since spring 2017. The Greenland Home Rule Act no. 29 of 12 December 2003 on Nature Protection, and the Greenland Home Rule Act no. 25 of 18 December 2003 on Animal Welfare, are also some of the legislative actions that set the basis for the management of polar bears in Greenland.

The Greenland Home Rule Executive Order from 2005 on the Protection and Hunting of polar bears covers the land and the economic zones of Greenland. There are special provisions for access to the National Park in northern and eastern Greenland, and the Melville Bay Nature Reserve. The Executive order has initiated the use of the Government of Greenland's annual polar bear quota system and monitoring, taking into account the following aspects:

- international agreements;

- biological advice provided by Greenland Institute of Natural Resources (GINR);
- harvest statistics; and
- Traditional Ecological Knowledge (TEK), through consultations with the Hunting Council and The association of Fishermen and Hunters in Greenland, (and other relevant partners).

The protective elements in the executive order are as follows:

- a quota-system to dictate permitted harvest level and permitted hunting period;
- only occupational (full time) hunters can hunt polar bears;
- year round protection of all cubs and females accompanied by cubs;
- prohibition on the export of live polar bear cubs;
- protection of polar bears in the EG subpopulation from 1 August – 30 September, and in other subpopulations from 1 July – 31 August;
- prohibition on the export of gall bladders or parts thereof;
- prohibition on disturbing or digging out polar bears in dens;
- mandatory reporting of all catches including struck and lost (i.e., shot and wounded) polar bears to the municipal office, which will send the report to the APN;
- prohibition on the use of air craft, or motorized vehicles, including snow mobiles and boats larger than 20 GRT/15 GT in the hunt or for transportation to and from the hunting grounds;
- prohibition on trophy hunting unless the Cabinet has allocated a specific quota and other conditions have been fulfilled. For example, if the Cabinet introduces a specific ruling in handling trophy hunting and a specific executive order on trophy hunting of polar bears (excluding 2016);
- prohibition on receiving payment or money in relation to transportation of personnel in a boat in connection with polar bear hunting;
- prohibition on the use of poison, traps, foot snares or self-shooting guns for polar bear hunting;
- prohibition on the use of rim-fire rifles, shot guns or semi- or fully automatic weapons. Only rifles with a minimum caliber of 30.06 (7.62 mm) are allowed to be used in polar bear hunting.

Management system

The Minister of Fisheries and Hunting sets an annual quota of polar bear for subsistence harvest. Based on the latest scientific advice and figures of harvest for the preceding harvest season, the Ministry drafts a preliminary allocation of the quota.

The management of polar bear resides at the Wildlife Division, which is located at the APN. The Wildlife Division is the management body of both marine and terrestrial mammals and bird species hunted in Greenlandic economic zones/territory. Forms and licenses from APN to harvest polar bears are issued by the municipalities according to the allocated local quotas, within the annual quotas set by APN or the Cabinet.

The Greenland Fisheries License Control Authority is tasked to enforce the regulations set by the government and the municipalities.

A proposal of a block quotas or annual quota has a minimum of 5 weeks consultation period by the Hunters' National Association (KNAPK), the municipalities, the Ministry of Nature and Environment and the Greenland Institute of Natural Resources and the Council of Hunting. A dialog between stakeholders takes place between the Ministry and stakeholders until a set date, decided at the beginning of the consultation.

Based on the consultation, the Ministry drafts a final proposal to be presented to the Minister if the quota is part of a block quota for 3 to 5 years. If a new block quota is based on a new biological advice, then the Cabinet will decide the new block quota giving a mandate to the Minister to make the final share to the 4 municipalities.

Since Greenland took over the responsibility for wildlife management in 1985 from Denmark, the legislation-executive order on polar bear management has been updated and improved several times.

Each update of the regulations has offered increased protection of polar bears in Greenland while respecting the traditional rights of hunters. This is because the Government of Greenland has strived to adapt to the challenges facing the Arctic and polar bears in particular.

The introduction of quotas and the subsequent quota allocations from 2006 are based on the historical distribution of the harvest, local hearing and recommendations from the scientific advisors.

Polar bear subpopulations

Greenland has 5 subpopulations of polar bears (Fig. 1). Four of these are on the west coast and are shared with Canada/Nunavut/Nunavik, and one on the East coast is Greenland's sole responsibility. The towns and communities are sparsely scattered and there are hundreds of kilometers of remote coastline.

The Greenland quota of polar bears 2010–2016

After the introduction of the quota system in Greenland in 2006, the annual quota for 2009 and 2010 was set to 130, each year. The annual quota from 2011–2016 was set on 140 each year. An additional 10 polar bears were allocated politically to eastern Greenland in 2011–2016. There is no carry-over system.

The fixed annual quota could vary in numbers in reference to incidents with over-harvesting, which are deducted in the following quota year.

There are no quotas for the Arctic Basin (AB) subpopulation, and hunting is not allowed. There is a Qaanaaq local ongoing request to reopen the polar bear hunting in the area, which was closed when the quota system was introduced in 2006 for the KB and BB subpopulations. The hunters in eastern Greenland have also an ongoing request of increased quota; even with a political set quota of 10 extra polar bears for the EG subpopulation has been allocated annually since 2011.

A license is valid for hunting one polar bear. It is illegal to sell polar bear meat to processing plants in Greenland. Before parts can be sold to the local market, which could be everything from the meat, the skull, claws and skin, the license needs to be stamped by the local authority. This is done when the local authority receives the standard form (Fig. 2) with details of the catch from the hunter. The municipal authority forwards the filled standard forms to the APN.

Catch reporting

Greenland is operating with two catch reporting systems. The first of which is a License system where local authorities issue licenses for polar bear hunting to full time occupational hunters. Immediately after a hunt, the hunter reports the catch to the local authority by filling in a standardized form for all polar bear kills (including shot and lost animals; Fig. 2). This form includes data about the date and the position of the catch, as well as size, age and gender of the killed animal, and whether it had tags or tattoos. Similar forms are filled by the authorities for polar bears have been shot either in self-defence or illegally. Data from legal catches, killings of problem bears and illegal catches are input into a national database.

The executive order regulating harvest of polar bears in Greenland contains a paragraph that permits the Minister of Fisheries and Hunting to enable a mandatory delivery of harvest samples as a requisite for obtaining a polar bear hunting licence (Anon 2005). This paragraph was enforced in 2012 and polar bear hunters are expected to deliver a genetic sample to the Greenland Institute of Natural Resources (GINR) for each polar bear harvested. The sample includes a small piece of tissue from the tip of tongue suspended in a saturated salt water solution for DNA analyses and a premolar tooth for age determination. Rates of tissue sampling vary from region to region and there is not full compliance; samples of 310 (44%) of the 704 polar bears killed in Greenland between 2012 and 2016 were sent to GINR by hunters. It must be noted that genetic analysis of harvest samples from the KB and BB subpopulations showed that Greenlandic hunters were prone to misclassify the gender of the harvested polar bears, with 39% of genetic females reported as males and 12% of genetic males reported as females (SWG 2016). The genetic composition of the reported harvest was 54% females for the KB and BB subpopulations in Greenland and SWG (2016) concluded that harvest in Greenland appears to be non-selective for sex.

Local authorities may hand out more licenses than the quota dictates and stop the hunt once the quota is reached. However, this requires a very strict control by the municipality. The Ministry monitors the hunt and will intervene if a municipality fails to do so. Overharvest will be deducted from the following year's quota.

The formed-based scheme is put into a database in the APN, which monitor the hunt in all unit areas. At least once a month, the APN sends a list of catches to each management unit and asks each municipality to check whether the received forms are correct. If not, the municipal office will send revised information.

The second reporting system is the annual catch report from all hunters we call "Piniarneq". This requires that all hunters report their annual catches (including number of polar bears) to the APN every year. The form includes name of hunter/hunters and number of bears killed (struck and lost) in each month.

At the moment, a double reporting system is used due to suspicion that the catches were over-reported in the annual catch reports. Over-reporting is suspected due to either several hunters reporting the same catch, or simple mistakes while filling in the form when reporting annual catches for all species. The catch is compiled on an annual basis (January to January) by APN.

This double reporting system is used to validate catches. In case where there are inconsistencies between the systems (e.g., a hunter has reported through only one system), hunters are contacted directly to verify the information. The Ministry is working on plan to get a better digital reporting system. There is very close cooperation between APN and municipality offices and staff in obtaining the correct catch reporting and verifying the data. As the digital world increases it eases the work and shorten the work time collecting the data.

All licenses are also made in an interactive program, so the workload is also simpler for both the Ministry, the municipal offices and for the hunter.

Problem bears

The number of human-polar bear interactions varies in Greenland (Table 2), and shows no consistent pattern, especially in eastern and northern Greenland. With this in mind, there is a high level of success in deterrence measures. Though, there are still challenges.

There are few encounters which we do not receive reports on. This is an area of focus for the APN, where we focus on capacity building as well as information strategies, to inform the communities and hunters on the importance of reporting these encounters. The APN also receives reports of encounters from research and military groups. The APN has formed written guidelines on handling of problem bears, which are available in three languages; Greenlandic, Danish and English.

Greenland is also part of the Polar Bear Range States Polar Bear HIMS-project to collect data on incidents of problem bears.

Greenland planned to initiate a process of testing the efficiency of bear spray and rubber bullets as physical deterrent measures, which has been proven to be very successful in other range state Countries. However, the Government of Denmark refused the application from APN to get a dispensation to import the bear spray. The Government of

Greenland has, on that basis, decided to wait for further research results on the effects of bear spray on polar bears in other countries.

The APN is working on a simpler reporting schedule for registering polar bear-human interactions in order to improve the information we are collecting.

Habitat protection

Among the protected areas in Greenland of which two sites are within common polar bear habitat. These are Melville Bay (10,500 km^2) in northwest Greenland, and The Greenland National Park (972,000 km^2) in Northeast Greenland. The protection of these areas safeguards the preservation of the biodiversity in the wild, whilst ensuring the access to recreational use of designated areas. The attached map of Greenland marks the protected areas (Fig. 3). The executive order covers the land and the economic zones of Greenland. Special provisions apply for access to the National Park in northeastern Greenland, and the Melville Bay Nature Reserve (Fig. 3).

CITES elements

Greenland is member of the Washington Convention (i.e., *Convention* on International Trade in Endangered Species of Wild Fauna and Flora, or CITES) through Denmark since 1983. In 1985 Greenland CITES Management Authority (CITES M.A.) obtained authority to issue CITES permits and has since then been issuing permits in line with CITES regulations. An executive order on CITES from 2004 is administered by the Ministry of Environment and Nature in Greenland. The Greenland Institute of Natural Resources is the CITES Scientific Authority in Greenland. As such Greenland Institute of Natural Resources is responsible for making Non-Detriment Findings (NDFs) in accordance with the CITES regulations.

Early 2007, the CITES M.A. in Greenland started a process for making a NDF for the polar bear. This resulted in a negative non-detrimental finding. In April 2008, the CITES M.A. introduced a voluntary temporary ban on export of polar bear products after a negative NDF.

Greenland/Canada/Nunavut Polar Bear Joint Commission

Greenland finds it important that co-management agreements are developed between nations sharing polar bear population to ensure that combined harvests does not exceed sustainable levels. Greenland is therefore very proud of the co-management agreement with Canada/Nunavut, which was signed in October 2009 for the KB and BB subpopulations by the Polar Bear Joint Commission (Fig. 4). A final scientific report was delivered to the JCPB by its scientific working group (SWG) in July 2016 (SWG 2016) and a final harvest report was delivered in July 2017 (Regehr et al. 2017).

The Scientific Working Group has been established by the Polar Bear Joint Commission to:

- provide scientific advice and recommendations with respect to the conservation and management of the KB and BB polar bear subpopulations;
- provide recommendations for proposed Total Available Harvest for both KB and BB polar bear subpopulations using best available scientific information;
- recommend new estimates of abundance KB and BB polar bear subpopulations.

Traditional Ecological Knowledge

Greenland has a history of good cooperation between hunters and scientists. They work together in the field collecting scientific data and traditional ecological knowledge. The biologists have experience in collecting and making use of the traditional ecological knowledge that hunters and locals give. This traditional ecological knowledge is vital in understanding a species that has been in the consciousness and life of Greenlander's ancestors for centuries. Traditional ecological knowledge is not only important as an input to management. The hunters and their communities that rely on polar bear need to be invited in the collection of knowledge and the decision-making process.

IUCN Polar Bear Special Group

Greenland is represented with three members in the IUCN Polar Bear Specialist Group by 2 biologists and 1 manager. These individuals provide advice on all 5 subpopulations along the coasts of Greenland both with biological research and management issues.

Greenland and Polar Bear Range States

Greenland is member of the Oslo Convention Agreement on Polar Bears from 1973. Greenland is engaged in the Polar Bear Range States dialogue that has been re-activated since 2007 and participated in its all meetings. Greenland hosted the last Range States meeting in Ilulissat 2015, where Range States members decided to launch a Circumpolar Action Plan on polar bears, following national action plans.

National Action Plan

The Greenlandic National Action Plan for the management of polar bear is due to public hearing along with the Circumpolar Action Plan for polar bear. The objective of the action plans is aiding the management authority for polar bears in Greenland, in ensuring the long-term conservation for polar bears.

Climate change

There have been dramatic changes in weather and the sea-ice in Greenland in the last 20 years in Greenland. The hunters can no longer depend on sea-ice for transportation as they have for many centuries (Born et al. 2011). The sea-ice is unpredictable and hunters cannot always drive on the ice with sledge dogs. Also due to climate change, the ability to harvest natural resources has been changed. Many small communities depend on these resources. These changes alone force the Greenlandic people to re-think the means to their own existence. That is no small challenge.

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Tables

Table 1. The catch quota for polar bears by each Greenland (GRL) polar bear subpopulation and for South Greenland[3], 2010–2016. Kane Basin (KB), Baffin Bay (BB), Davis Strait (DS), and East Greenland (EG). Source: APN.

Subpopulation	2010	2011	2012	2013	2014	2015	2016
KB	6	6	6	6	6	6	6
BB	61	70 [2]	67	67	67	67	67
DS	5		3	3	3	3	3
South GRL[3]	4	4	4	4	4	4	4
EG	50	50+10	50+10	50+10	50+10	50+10	50+10
Total	126 [1]	140	140	140	140	140	140

[1] The total quota for 2010 was originally 130 polar bears. Due to overharvesting in 2009, there was a deduction of 4 polar bears, so the 2010 quota was reduced to 126.

[2] The quota for BB and DS subpopulations in 2011 were counted together, and included the region from Sisimiut to Nuuk (9 bears).

[3] South Greenland includes the region from Paamiut to Nanortalik (4 bears) and includes bears of the EG subpopulation.

Table 2. Actual catch of polar bears by each Greenland (GRL) polar bear subpopulation and for South Greenland[2], 2010–2016, including bears killed in self-defense (in parentheses). Polar bears killed in self-defense are not deducted from the quota. Kane Basin (KB), Baffin Bay (BB), Davis Strait (DS), and East Greenland (EG). Source: APN.

Subpopulation	2010	2011	2012	2013	2014	2015	2016 [1]
KB	2 (0)	6 (0)	6 (0)	6 (0)	5 (0)	6 (5)	4 (2)
BB	63 (0)	66 (0)	71(5)	61 (0)	70 (1)	72 (1)	49 (0)
DS	2 (0)	3 (2)	3 (1)	1 (0)	3 (0)	0 (0)	3 (0)
South GRL [2]	1 (1)	3 (0)	3 (1)	4 (3)	4 (0)	4 (0)	4 (2)
EG	32	53 (1)	60 (3)	55 (0)	61 (1)	60 (7)	60 (2)
Total	100 (1)	131 (3)	138(10)	127(3)	143 (2)	142(13)	120 (6)

[1] Catch numbers in 2016 are preliminary data

[2] South Greenland includes the region from Paamiut to Nanortalik and includes bears from the EG subpopulation.

Figures

Fig. 1. Subpopulations of polar bears within Greenland: Arctic Basin (AB), Kane Basin (KB), Baffin Bay (BB), Davis Strait (DS), and East Greenland (EG). AB, KB, BB and DS subpopulations are shared with Nunavut.

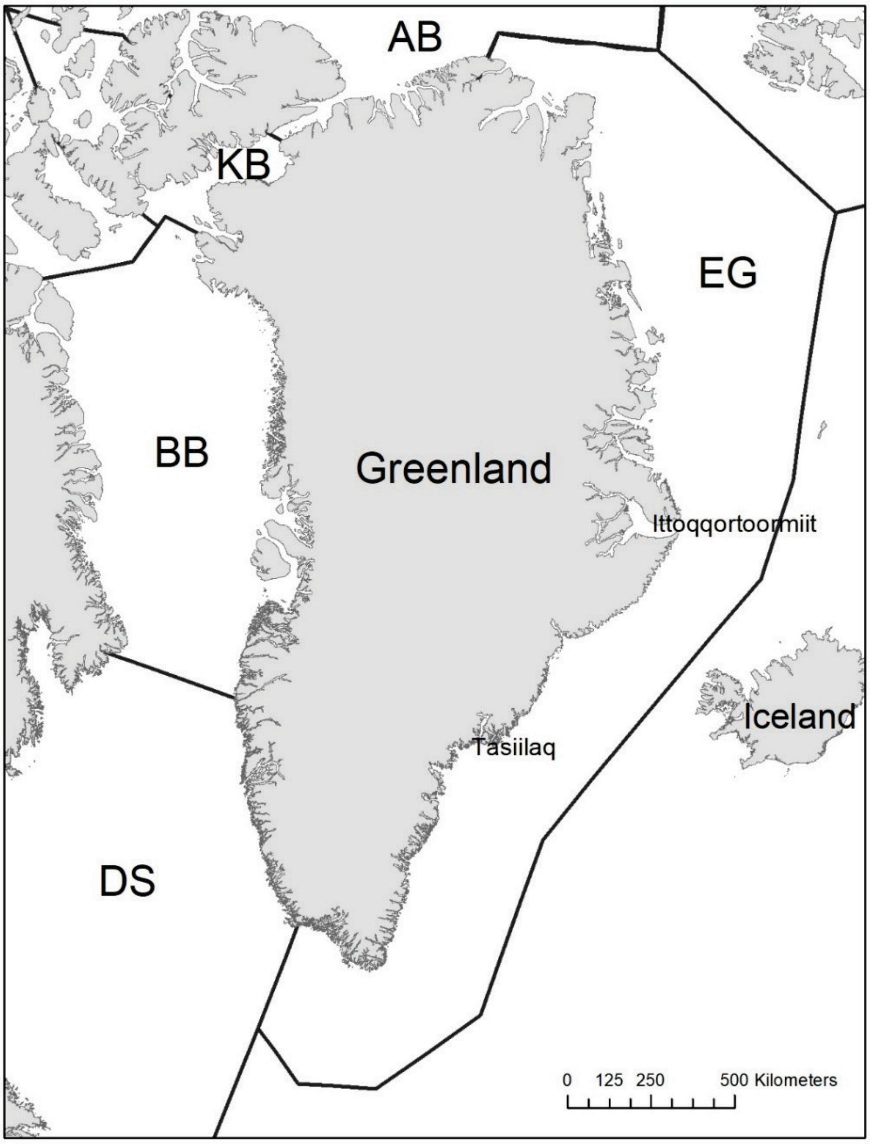

Fig. 2. License form issued by local authorities in Greenland to full time occupational hunters and required to be carried by the hunter during the hunt. Immediately after a hunt, the hunter records the catch of all polar bears (including struck and lost animals) on this standardized form and provides this to the local authority.

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Fig. 3. Protected areas in Greenland which include polar bear habitat, including the National Park in northeastern Greenland (red), Melville Bay Nature Reserve (blue), and the RAMSAR areas (green).

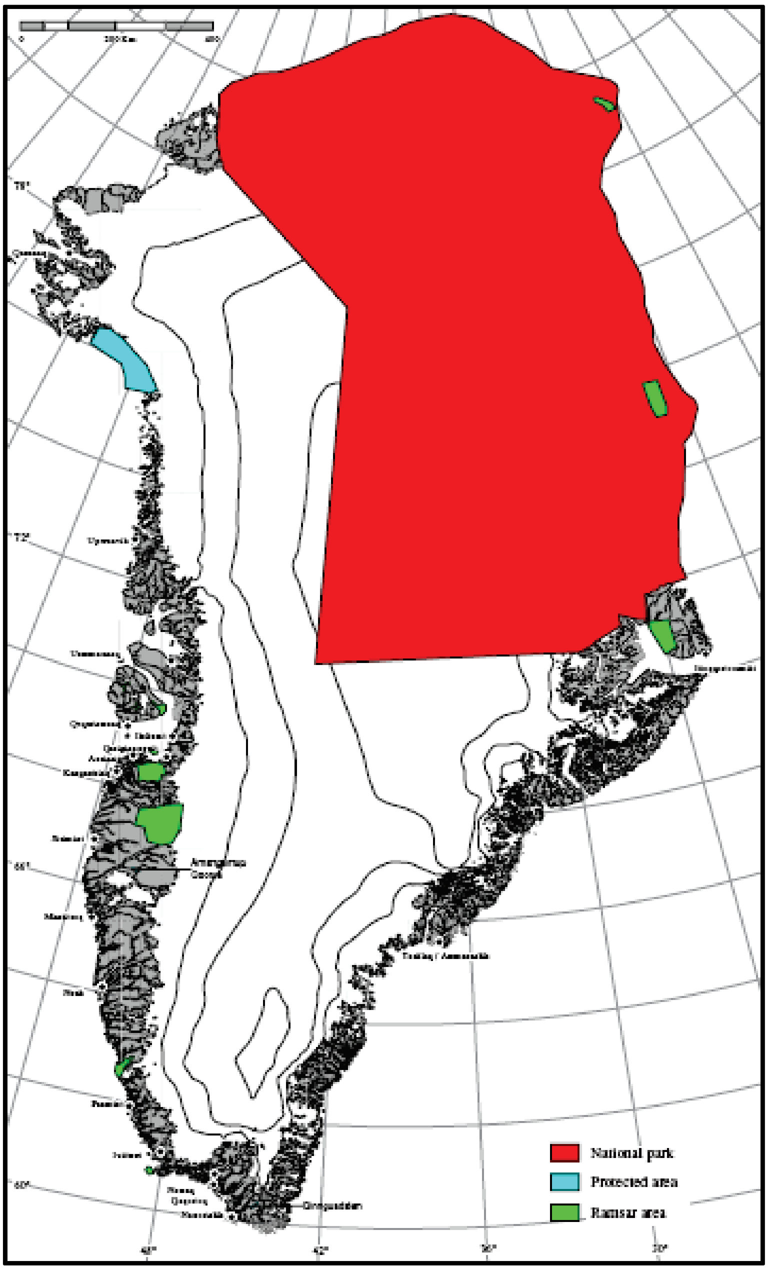
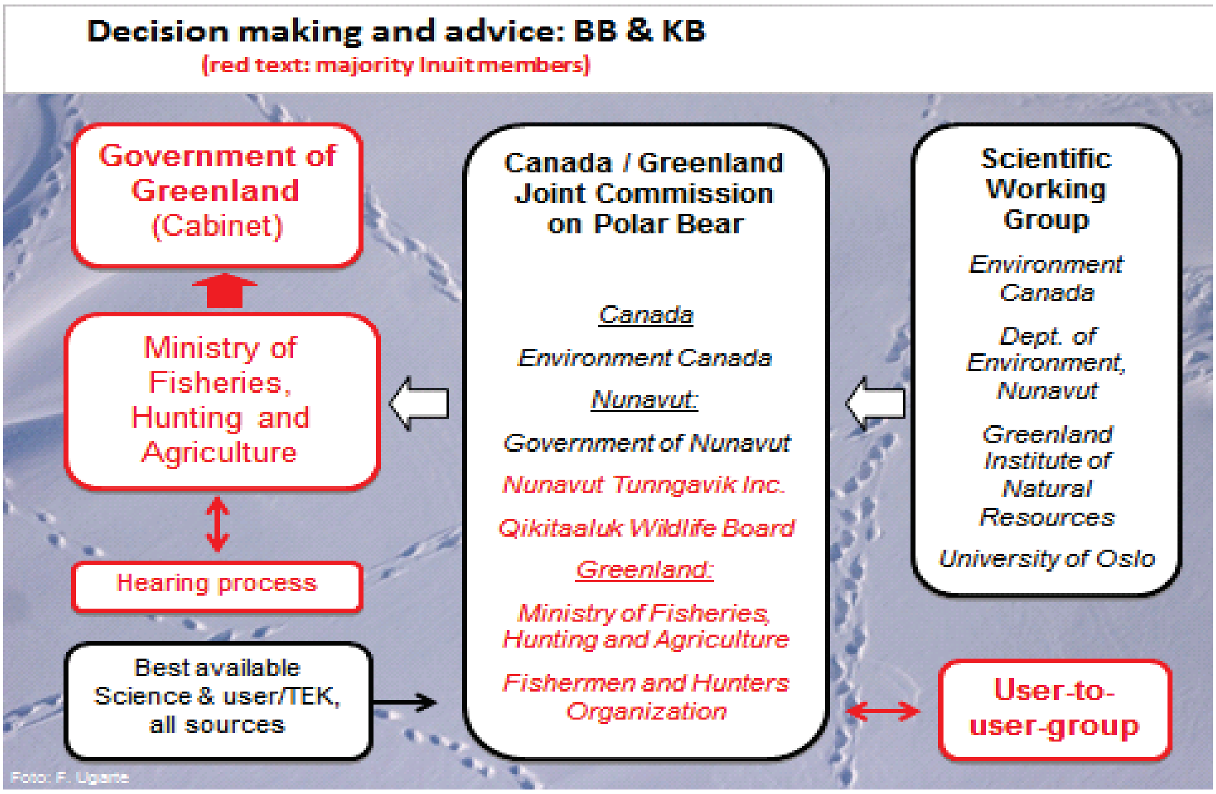


Fig. 4. Flow chart showing the general working strategy of the Greenland/Canada/Nunavut Polar Bear Joint Commission. Source: APN and the Greenland Institute of Natural Resources.



Research on Polar Bears in Greenland, 2009–2016

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This report summarizes the research on polar bears in Greenland since the 15th working meeting of the IUCN/SCC International Polar Bear Specialist Group in Copenhagen Denmark in June 2009 (Obbard *et al.* 2010). The research has focused on new subpopulation assessments of the Baffin Bay (BB) and Kane Basin (KB) polar bear subpopulations, and research of the East Greenland (EG) subpopulation on movements and stock identity, interviews of polar bears subsistence hunters, and continued analyses of concentrations of pollutants and their effects on polar bears. For names of places mentioned in the text see Figure 1.

Studies of the Baffin Bay (BB) and Kane Basin (KB) subpopulations

A multi-year collaborative research project involving the Greenland Institute of Natural Resources (GINR) and the Government of Nunavut (GN) was endorsed by the Canada-Greenland Joint Commission (CGJC) on the Management of Polar Bears. This 4-year research project (2011–2014) was initiated in 2011 to provide updated information on the status of the BB and KB subpopulations of polar bears. The research design included two components: assessment of (1) the size and status of the BB and KB subpopulations by means of genetic mark-recapture (M-R), and (2) demographic closure, in particular whether the KB subpopulation can be considered a separate management unit from the neighboring BB subpopulation. This component is studied by use of satellite telemetry and genetics. Results of the study were presented in a report to the CGJC in July 2016 (SWG 2016). The summary below is based on the SWG (2016).

This work had four basic field components: (1) biopsying polar bears along eastern Baffin Island, northwest Greenland and in Kane Basin, (2) a systematic aerial survey using sight-resight distance sampling in Kane Basin, (3) deployment of satellite transmitters on male and female polar bears in northwest Greenland and Kane Basin, and (4) hunter collection of tissue samples from the catch of polar bears (harvest recoveries) in BB, KB, and adjacent subpopulations. This work was conducted on the schedule as follows: fall biopsying along eastern Baffin Island occurred in fall 2011, 2012 and 2013, fall biopsying in northwest Greenland occurred in fall 2012 and 2013, spring biopsying occurred in northwest Greenland 2011, 2012 and 2013, spring biopsying occurred in Kane Basin 2012–2014 with an aerial survey in 2013, and deployment of satellite radios (collars and ear tags) occurred in spring on the pack ice and fast ice in northwest Greenland from 2009 to 2013.

From 2011 to 2013, 1,111 bears were biopsy darted (and genotyped) along eastern Baffin Island. From 2009 to 2013, 143 bears were physically marked or biopsy darted (and genotyped) in western and northwest Greenland. The spring biopsying program in Kane Basin from 2012 to 2014 resulted in 129 bears physically marked and genotyped or biopsy darted and genotyped.

Furthermore during 2009–2013 a total of 101 satellite radios (55 females, 46 males) were deployed in western and northwest Greenland (Figure 2). During 2012 and 2013 a total of 36 satellite radios (21 females, 15 males) were deployed in Kane Basin. Some individuals were recaptured during the study and furnished with new satellite radios. Hence, a total of 91 individual bears were tagged with satellite transmitters within the bounds of the BB subpopulation and 34 within the bounds of the KB subpopulation (SWG 2016). The satellite radios included small ear satellite tags developed by GINR for tracking adult male polar bears and sub-adults of both sexes (Born *et al.* 2010, Laidre *et al.* 2012).

A total of 234 hunter recoveries (tissue samples) were obtained from the catch of polar bears in Nunavut and Greenland (1993–2013). The hunter recovery program was instituted in Greenland for the first time in 2012. In addition, 635 biopsies from physical M-R operations to assess BB and KB subpopulations in the 1990s (cf. Taylor *et al.* 2005, 2008) were included in the recent M-R assessment analyses (SWG 2016).

These data were collectively analyzed to estimate the abundance and sex (and approximate age) composition of polar bears in the BB and KB subpopulations; compare a new estimate of abundance with those derived from previous studies (1991–1997) in-order to gain insight into subpopulations trend; delineate the boundaries of the BB and KB subpopulations and reassess the validity of these areas as a demographic unit; estimate survival and reproductive parameters (to the extent possible) in-order to facilitate population viability analyses; and evaluate polar bear distribution with respect to environmental variables, particularly ice conditions, topography and food availability/distribution.

Recapture and harvest recovery data examined during the 3-year genetic M-R studies in Baffin Bay and Kane Basin had very low levels of recapture or recovery of bears outside their subpopulation of origin. The total number of bears marked in years 1 and 2 of these studies (2011–2012 in Baffin Bay and 2012–2013 in Kane Basin) was equivalent to ~34% and ~25% of the estimated population size for the BB and KB subpopulations, respectively. Despite this, instances of emigration were ≤ 1% of the recaptures and recoveries of marks for the BB subpopulation. Similarly, for the KB subpopulation, documented cases of emigration comprised < 4% of recaptures and recoveries.

For the BB subpopulation, findings based on analyses of satellite telemetry from adult females during the 2000s show there has been a significant reduction in the size of the subpopulation range in all months and seasons when compared to the range in the 1990s. The most marked reduction was a 60% decline in subpopulation range size in summer. The overlap of the 1990s and 2000s BB subpopulation range was < 50% in all months, reflecting both a contraction and shift northward of this subpopulation in the 2000s. These shifts are related to the loss of annual sea ice and changes in breakup timing. With respect to movements across subpopulation boundaries, BB bears in the 2000s were significantly less likely to leave BB than in the 1990s. In particular, there was a reduction in the number of collared bears moving into Davis Strait (DS) and Lancaster Sound (LS) subpopulations from the BB subpopulation, apparently due to reduced winter sea-ice coverage. This suggests the BB subpopulation has become more discrete, with less exchange between it and other subpopulations. This is supported by genetics and harvest recoveries (SWG 2016).

Furthermore, using telemetry data, SWG (2016) reports that movement rates of adult female polar bears of the BB subpopulation have significantly declined during the open water period (August–October) in the 2000s due to disappearance of offshore and archipelago summertime sea ice. BB bears used significantly lower sea-ice concentrations in winter and spring in the 2000s than the 1990s. In the 2000s, bears spent significantly more time on land on Baffin Island, and arrival dates on Baffin Island in summer were one month earlier in the 2000s than in the 1990s. The amount of time bears spent on land has increased by 20–30 days since the 1990s. Entry dates into maternity dens were >1 month later for polar bears of the BB subpopulation in the 2000s than in the 1990s. Thus, there has been a significantly shorter maternity den duration in the 2000s for BB polar bears (Escajeda et al. 2017). The first date of arrival on land by pregnant females was significantly earlier in the 2000s than the 1990s. Maternity dens in the 2000s also occurred at higher elevations and steeper slopes than maternity dens in the 1990s, likely due to reduced snow cover. From 1993 to 2013, COY recruitment for the BB subpopulation declined concurrent with a trend towards earlier spring sea-ice break-up. Finally, there was evidence of declines in body condition amongst bears of the BB subpopulation between 1993 and 2013. Body condition of BB polar bears declined in close association with the duration of the ice-free period and spring sea ice transition dates.

The mean estimate of total abundance of the BB subpopulation in 2012–2013 using genetic M-R was 2,826 (95% CI: 2,059–3,593) polar bears. Relative to the 2010s data, the 1990s data were characterized by smaller sample sizes, incomplete geographic sampling, a likely higher degree of temporary emigration for bears that remained on sea ice during the summer, and potential non-random temporary emigration for adult females that moved farther inland to den. These issues led to an increased potential for bias in estimates of survival and abundance from the 1990s data. As a result, demographic parameters estimated for the BB subpopulation for the 1990s and 2010s are not directly comparable

For the KB subpopulation, the mean 95% kernel range has expanded since the 1990s. The increase in range use in the 2000s occurred in all seasons, however is statistically significant only in summer (June–September), where ranges doubled between the 1990s and the 2000s (SWG 2016). This range expansion is likely related to changes in sea ice, as the KB subpopulation region is trending towards the characteristics of an annual ice ecoregion where ice melts out almost completely each summer. There is still considerable seasonal overlap in KB subpopulation ranges for bears in the 1990s and 2000s (50–98% overlap over decades), suggesting that bears generally continue to use the same areas within the KB subpopulation bounds. Bears of the KB subpopulation use lower sea ice concentrations in summer months but there are largely no changes in winter and early spring. There were no significant differences in movement rates of KB polar bears between the 1990s and 2000s. Land use within the KB subpopulation region during summer remains intermittent because some sea ice remains inside fjords and coastal areas.

The estimated abundance of the KB subpopulation was 357 polar bears (95% CI: 221–493) for 2013–2014 (SWG 2016). A re-calculation of the 1990s data provided an estimate of 224 bears (95% CI: 145–303) for the period 1995–1997. More bears were documented in the eastern regions of the KB subpopulation area during 2012–2014 than during 1994–1997. Eastern Kane Basin was searched during the 1990s although with less effort than in the 2010s due to the low density of bears observed there. The presence of ringed seals in eastern Kane Basin during spring in the 1990s indicated that this area was good polar bear habitat (Taylor *et al.* 2001). The difference in distribution between the 1990s and 2010s may reflect differences in spatial distribution of bears, possibly influenced by reduced hunting pressure by Greenland in eastern Kane Basin and thus an increased density of bears in that region, but also some differences in sampling protocols.

Studies of the East Greenland (EG) subpopulation

Polar bears in east Greenland are thought to constitute a single subpopulation with limited exchange with other subpopulations. Thus, the East Greenland polar bear subpopulation (EG) is not shared with other countries and the full responsibility for assessment lies on Greenland. Assessing this subpopulation, ranging along one of the longest contiguous stretches of coastline of polar bear habitat in the world, in an uninhabited area is a large undertaking and requires planning and studies conducted across a period of several years.

The assessment of the EG subpopulation was initiated in 2014. The first step was a traditional ecological knowledge (TEK) survey of hunters in Ittoqqortoormiit (Scoresbysund) and Tasiilaq in 2014–2015 (see below), combined with field activities focused in SE Greenland in 2015 and 2016 (continuing in 2017). The purpose of the field work is to quantify connectivity of bears between southeast and northeast Greenland and provide a better understanding of the ecology of polar bears in southeast Greenland and use of sea ice habitat. These are the first springtime studies of polar bears in this part of Greenland.

In 2015 approximately 43 flight hours were used on direct searches and captures. A total of 30 polar bears were immobilized and tagged in southeast Greenland. "Independent" (i.e., only adult and solitary subadult bears; dependent 0, 1 and 2-year-old cubs accompanying their mother not included) constituted 24 individuals. The remainder were cub-of-the-year (COYs): n=2; yearlings: n=2; and 2-year-olds: n=2. Ten satellite radio collars were deployed on adult female bears, and 12 ear satellite radios were deployed on adult male and subadult individuals of both sexes. No bears had been previously captured or marked. A total of 42 h 30 min air time was used for active searching for bears during captures, with an encounter rate of approximately 1.5 bears/hour. Pilot aerial surveys were also flown on two days to assess feasibility of aerial surveys for an assessment of the subpopulation.

In 2016, ~75 hours were flown in southeast Greenland and 58 polar bears were immobilized tagged. Of these, 44 were independent (i.e., only adult and solitary subadult bears; dependent 0, 1 and 2-year old cubs accompanying their mother not included). The remainder were COYs: n=4; yearlings: n=8; and 2-year-olds: n=2. Nineteen satellite radio collars were deployed on adult female bears. One adult male bear had been previously captured in 2015 and the satellite radio tag was still attached to the ear pinna (with destroyed antenna). In addition to satellite radio collars, 10 adult females also received Time Depth Recorders (TDRs) glued to the battery pack of the collar and GeoLocation ear tags in the right ear. These TDRs and Geolocation tags will be retrieved if possible from recaptured bears. The TDR data will be used to develop estimates of the amount of time bears spend in the water which can be used to correct the aerial survey. To date, polar bears tagged in southeast Greenland in spring 2015 and 2016 have largely remained in the vicinity of where they were tagged, however longer-tracking periods and larger sample sizes are needed before conclusions can be drawn about bears in the area.

An interview survey in eastern Greenland

Between December 2015 and January 2016, 25 polar bear hunters were interviewed in the municipalities of Tasiilaq (n=16) and Ittoqqortoormiit (n=9) in eastern Greenland. The purpose was to collect information about hunter's perspectives on the impact of quotas in eastern Greenland, change in the catch due to climate and any observed changes in the polar bears. It also provided information for the future assessment of eastern Greenland as hunters were asked their perspectives on important areas to capture and count polar bears. Data analyses are in progress and a report will be finished by spring 2017.

Population status

Polar bears from four subpopulations are harvested in Greenland: KB, BB, DS, and EG. In addition, the northernmost part of Greenland faces the Arctic Basin (AB), where polar bears have not been studied and are not harvested because there are no Inuit settlements. The KB, BB and DS subpopulations are shared between and Canada and Greenland and are exploited in both countries. The EG subpopulation ranges in eastern and southwest Greenland and is only hunted in Greenland. For the KB and BB subpopulations new estimates of abundance were produced after studies between 2009–2013 and are reported in detail in SWG (2016). For the EG subpopulation, estimates of abundance are not available. For the DS subpopulation, there is an estimate of abundance based on studies during 2005–2007 (Anon. 2009, Peacock 2009).

Prior to 2016, the size of the BB polar bear subpopulation was last estimated by use of mark-recapture during the 1990s (Aars *et al.* 2006, Taylor *et al.* 2005, 2008). At that time, the estimate of the mean abundance for the BB subpopulation during the years 1994–1997 was 2,074 (SE=266) bears (Taylor *et al.* 2005; Anon. 2009). The SWG determined these data to be old and out of date, and thus the new mark-recapture surveys were initiated in 2011. The most recent estimate of mean total abundance in BB in 2012–2013 was 2,826 (95% CI: 2,059–3,593) polar bears. An evaluation of the spatial distribution of onshore captures, together with data on habitat use from satellite telemetry, suggested that more systematic and geographically broader live-recapture sampling, including inland areas and the backs of fjords, occurred during 2011–2013 compared to the previous work in the 1990s. Furthermore, offshore sea ice was available to polar bears during the annual sampling periods in the 1990s, but largely unavailable in the 2010s. Considering statistical uncertainty in estimated parameters and evidence that the sampling design and environmental conditions likely resulted in an underestimate of abundance in the 1990s, it is not possible to conclude that the estimate of total abundance in the 2010s represents an increase in the size of the BB subpopulation. Although the 2010s abundance estimate represents the best-available information and is suitable for informing management, it is not possible to reliably determine the trend in BB subpopulation size over the 1993–2013 study period (SWG 2016).

The size of the KB subpopulation was last assessed using mark-recapture data in 1998 and resulted in an estimate of 164 polar bears (SE=35) (Taylor *et al.* 2008, SWG 2016). This was also determined to be out of date information by the SWG (SWG 2016). The most recent estimated abundance of the KB subpopulation was 357 polar bears (95% CI: 221–493) for 2013–2014. An estimate of abundance was also calculated from a springtime 2014 aerial survey within the KB subpopulation region and was 206 bears (95% lognormal CI: 83–510). The M-R point estimate is higher than the historical M-R estimate for the KB subpopulation. More bears were documented in the eastern areas of the KB subpopulation region during 2012–2014 than during 1994–1997, possibly due to reduced hunting pressure. This suggests relatively strong evidence for a stable to increasing KB subpopulation, and is consistent with data on movements, condition and reproduction (SWG 2016).

In Davis Strait, a comprehensive population inventory using mark-recapture methods (2005–2007) resulted in an estimate of 2,158 bears (SE=180) for the DS subpopulation. This subpopulation is believed at present to be stable (Peacock *et al.* 2013).

The size of the EG subpopulation is unknown. However, studies were initiated in 2015 to examine stock ID and movements as the first step towards an assessment of the subpopulation size. A rough estimate of ca. 2000 polar bears for the EG subpopulation has been proposed as the size required to sustain the catches (cf. Lunn *et al.* 2002). Due to the lack of an abundance estimate for the EG subpopulation the effect of the subsistence hunt cannot be determined (Aars *et al.* 2006, Anon. 2007). This subpopulation has been proposed to be negatively influenced by high levels of pollution (Obbard *et al.* 2011 and next section) and an overall decrease in sea ice (Stern and Laidre 2016).

Pollution studies

Studies of contaminants in Greenland polar bears have been expanded since the last IUCN/SCC PBSG Proceedings (Obbard *et al.* 2010). During 2009–2014 scientists attempted to sample bears in Qaanaaq, North West Greenland however it was not possible to get samples through collaboration with local subsistence hunters. Therefore, full emphasis has been placed on the East Greenland subpopulation via multiple research projects, as well as the AMAP CORE that maintains a collection of samples of 15 individuals annually. Most of the on-going work is summarized by Letcher *et al.* (2010) and Dietz *et al.* (2013a, 2015) and AMAP POPs and Hg Effect Assessment Report AAR4 (In prep.).

Persistent Organic Pollutants (POPs)

Temporal trends - The temporal studies of contaminants in polar bears of the EG subpopulation have been updated and reported by Dietz *et al.* (2013b, c) and Riget *et al.* (2013, 2015) reflecting the longest time series of biota in the Arctic. The study revealed that while most contaminants are declining over recent years, they have stabilized at relatively high concentrations that maintain the concern for the health of EG bears such as prenatal exposure and development and cell differentiation. The brominated flame retardants increased in in bears of the EG subpopulation until year 2014 after which a decline was observed Dietz *et al.* (2013c). A trans-Arctic survey of physiologically-based pharmacokinetic modelling of immune, reproductive and carcinogenic effects from contaminant exposure in polar bears was conducted (Dietz *et al.* 2015). Some brominated flame retardants and PCBs increased post-2000 probably due to changes in the food web structure and access to seals at higher trophic levels (McKinney *et al.* 2013). Further details are available in Dietz *et al.* (2016) of work conducted under the BearHealth programme.

Geographical trends - Clear regional trends in various contaminants in polar bears can be detected within the Arctic region. The EG, Svalbard (i.e., Barents Sea, or BS) and Kara Sea (KS) subpopulations still have the highest levels of most lipophilic POPs (Letcher *et al.* 2010). This information can be used to identify maximum human exposure, where possible biological effects due to high levels of contaminants are most likely to occur, and where the lowest exposed animals can be sampled to serve as reference groups (Dietz *et al.* 2015). The geographic variation in loads of pollutants is related to differences in global atmospheric and sea current transportation and deposition pattern.

Studies of mercury (Hg)

Temporal and geographic trends - The temporal trends of mercury in polar bears is summarized by Dietz *et al.* (2009, 2011, 2013a). Samples taken from polar bears of the EG subpopulation over the period 1892–2009 show a yearly increase of 1.6–1.7% and that current levels are now exceed health effects based on blood and hair concentrations. Continued studies of Hg in polar bear hair document that polar bears from northwest Greenland and the central Canadian Arctic have the highest concentrations of Hg, and polar bears at Svalbard the lowest (Dietz *et al.* 2011, 2013a)

Contaminants and climate change parameters - Trends in contaminants in polar bears of the EG subpopulation have been linked to possible changes in food preferences leading to increasing contaminant levels (McKinney *et al.* 2013). The explanation is based on fatty acid analyses showing that bears have increased feeding on hooded and harp seals due to declining sea ice concentrations which have shifted seal breeding patches closer to the coast and enable bears to reach their breeding patches on the drift and solid ice.

Health effects (POPs and Hg)

Multiple papers (~65) have been published in the scientific literature since the last IUCN PBSG Proceedings (Lunn *et al.* 2010) dealing with bioaccumulation, toxicodynamics and toxicokinetics. Given their nature and the multidisciplinary extent an exhaustive overview is not given and we refer to the reference list of the Proceedings and the international scientific literature. Briefly, studies can be categorized into organ pathology (Sonne *et al.* 2011, 2012b), hormone concentrations (e.g., Bechshøft *et al.* 2011, Erdmann *et al.* 2013, Gabrielsen *et al.* 2015a, 2015b, Styrishave *et al.* In press), skull and baculum measures (Sonne *et al.* 2013, 2015), brain hormones and neurochemicals (Pedersen *et al.* 2015, 2016), vitamins (Bechshøft *et al.* 2016) and PBPK and IBM modelling (Dietz *et al.* 2015, Pavlova *et al.*, in press). Altogether these studies show that multiple organ-systems are affected by contaminants that affect the bears physiology possibly making them sensitive to stress from climate change and new diseases brought into the Arctic (Desforges *et al.* 2016, Jenssen *et al.* 2015).

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Figures

Fig. 1. Map of Greenland including the polar bear subpopulations and localities mentioned in the text.

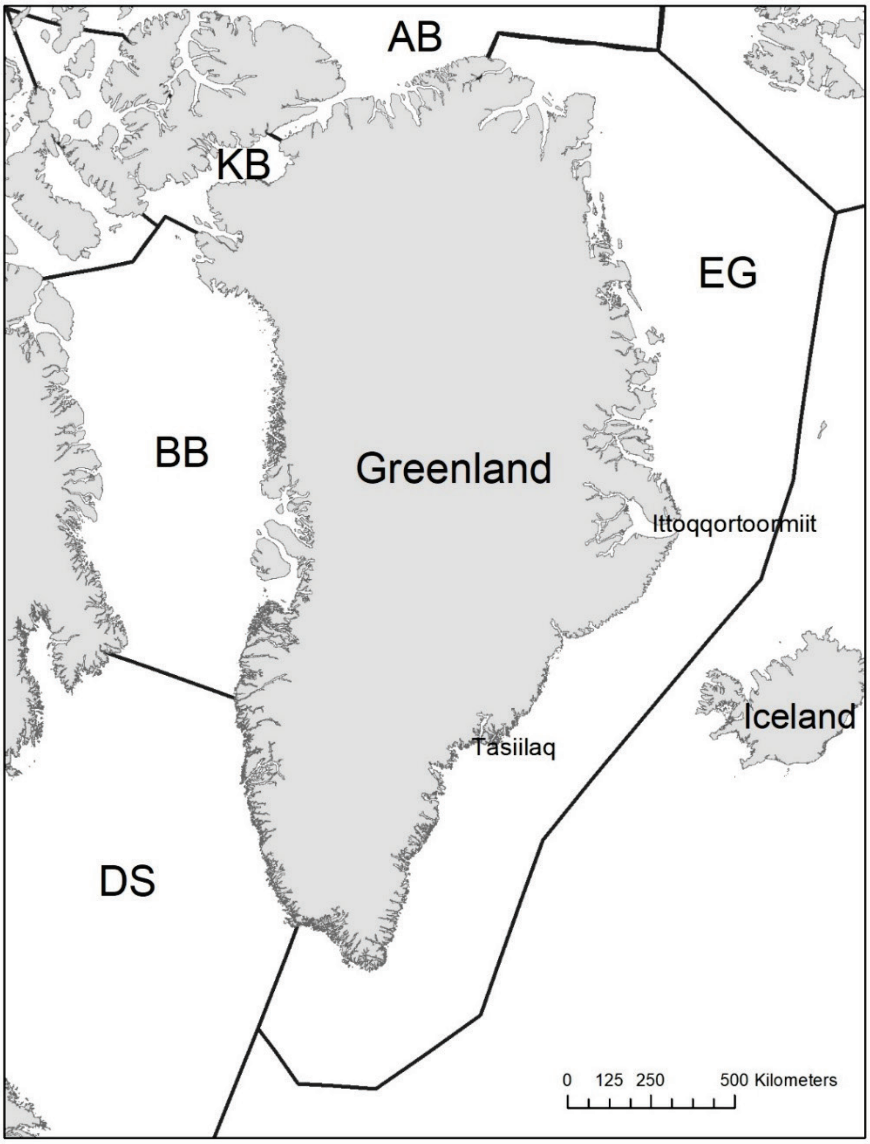


Fig. 2. Distribution of ages and family groups of a total of 139 individual polar bears captured in spring in northwest Greenland, 2009–2013.

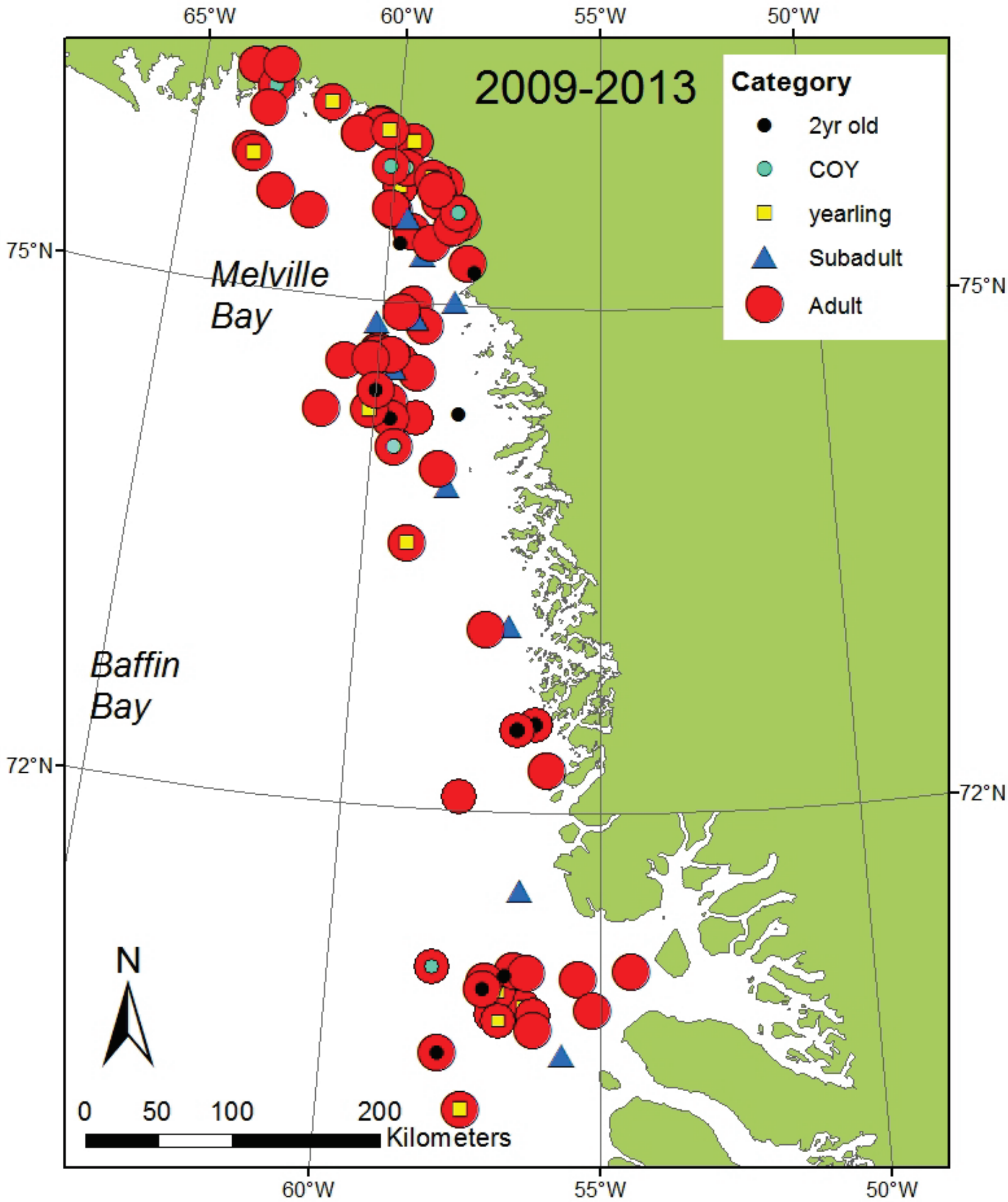
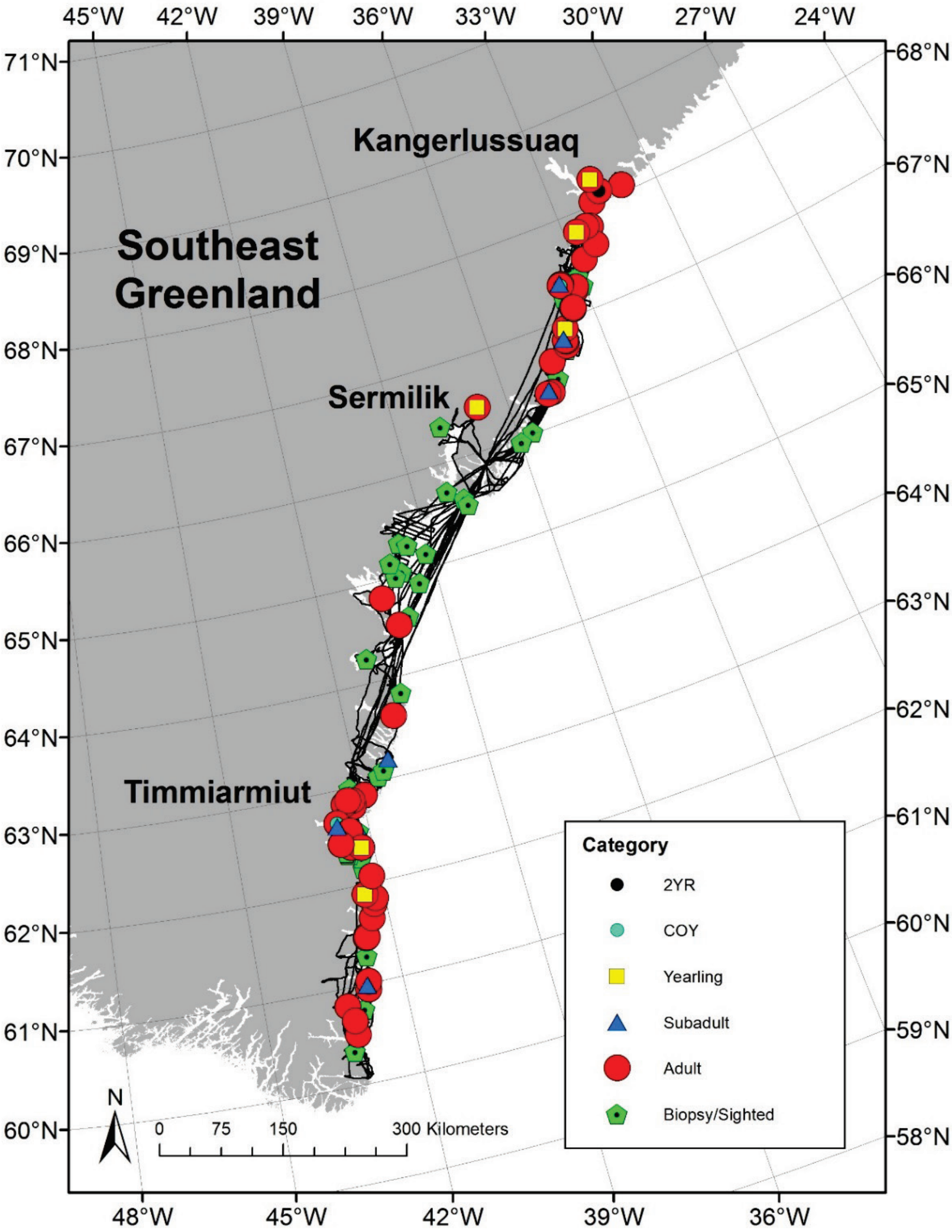


Fig. 3. Search effort (black lines) and map of captures, biopsies and sightings of polar bears in in Southeast Greenland, March–April 2015 and 2016 (Laidre, unpublished data).



Management on Polar Bears in Norway, 2009–2016

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In the period 2009–2016, several important tasks have been completed with respect to the management of polar bears in Norway and the Barents Sea. The release of the Norwegian polar bear action plan in 2013, the repetition of the abundance estimate in 2015, and the improved and formalized cooperation between Norway and Russia on polar bear issues have all been events that have put polar bear management on the agenda in Norway. There is still focus on sustainable management of the ecosystems of Svalbard and the Barents Sea, both through the implementation of management plans for the Barents Sea and the Norwegian Sea and the new management plans for different parts of Svalbard. As the Range State cooperation has been revitalized with regular biannual meetings and reporting as well as the release of the Circumpolar Action Plan with associated activities, these processes have also significantly contributed to an upgrading of the activity level in Norway.

Norwegian Polar Bear Action Plan

The development of a national action plan was based on agreement made at the Range State Meeting in 2009 held in Tromsø, Norway. The plan was commissioned by the Ministry of Climate and Environment and the process involved relevant national stakeholders. The plan document was published in 2013 as a report from the Norwegian Environment Agency (Norwegian Environment Agency 2013). Climate change and unpredictable ecological responses and consequences is the main challenge for the Barents Sea polar bear population (Aars *et al.* 2017, Andersen and Aars 2016) and the plan adds up to a knowledge-based and adaptive management system, where systematic and comprehensive monitoring and research represent the hub. The plan also focuses on the need to contribute to bilateral and circumpolar management in line with the same principles.

The plan has the overall goal: "*the Barents Sea polar bear population shall be conserved as a sustainable subpopulation in the longer term, by targeted and knowledge-based management. In Svalbard the polar bear population should develop with minimal impact from local activities*". The plan outlines separate objectives that underpin the main goal, according to priority fields:

1) Habitat change: Habitat changes resulting from large scale as well as local factors shall be countered by international solutions, local/regional measures and regulations based upon updated knowledge and a precautionary approach.
2) Pollution: Direct and indirect sources of pollution shall be reduced as far as possible by mutual solutions both nationally and internationally and counteractive measures to reduce any effects shall be evaluated and implemented.
3) Acute pollution/emergency response: Oil pollution shall be prevented and shall be counteracted by strict regulations and requirements for risky activities in polar bear habitat, as well as a well-developed emergency plan/management.
4) Disturbance/stress due to human activities: Disturbance from human

activities is complex and is a potentially important stress factor for polar bears, which largely can be prevented by good planning, regulation by the authorities and emergency solutions.

5) Human-bear conflicts: Conflicts between polar bears and humans shall be prevented and minimalized.
6) Neighboring populations: Norway shall, in addition to developing cooperation with Russia on the Barents Sea population, also contribute actively to a proper and knowledge-based management of neighboring populations.
7) International cooperation: Norway shall continue its international engagement and actively support international cooperative initiatives for the circumpolar conservation of polar bears.
8) Communication/outreach: Knowledge-based management depends upon good preparation and communication of scientific results. Intensive gathering of knowledge shall be used informatively and strategically in order to improve the conservation status of the polar bear.
9) Monitoring and research: Targeted monitoring and research should be basic elements in the polar bear management (conservation) and contribute to continuous evaluation and improvement of conservation actions both nationally and internationally. Conservation-oriented research shall be prioritized and will supplement monitoring, e.g., as a quality control and to explain time series data to meet the need for early warning related to undesired developments at individual and population level.

The plan has a 5-year perspective and the implementation of the plan is ongoing while several tasks or actions are completed. New basic structures are also established; a national polar bear advisory board to oversee the implementation of the plan and a joint Norwegian-Russian polar bear working group under the Norwegian-Russian Environmental cooperation to facilitate and underpin the shared responsibility for the Barents Sea population.

Management plans for the Barents Sea and the Norwegian Sea

The integrated management plan for the Barents Sea was finalised and presented to the Norwegian Parliament in March 2006, and passed as a legally binding White Paper shortly after (Norwegian Ministry of Climate and Environment 2006). The management plan was updated in 2011 (Norwegian Ministry of Climate and Environment 2011), and will be revised in 2020.

Svalbard and the northern part of the Barents Sea (north of latitude 74°30'N) are areas where the industrial activity is low, e.g., petroleum activities are still not allowed in this area. However, a dispute over the borderline between Norway and Russia in the Barents was settled in 2010, an agreement which has opened areas for national industrial priorities (e.g., petroleum resources). On the Norwegian side of the new border line, a 45,000 km^2 area east of longitude 32°E was officially opened by the Parliament in 2013, as a direct extension of the already opened areas in the Barents Sea. The present main threatening human activity with relevance to polar bear habitats is still tourism, e.g., cruise ship traffic and snow mobiles in feeding areas. As the sea ice conditions have changed, more open water increases the access to areas (north/east) that were previously less accessible.

The hope is that the cross-sectoral and integrated management plans eventually will be able to secure polar bear critical habitat components as mentioned in Article II in the 1973 Agreement. For instance, the marginal ice zone (MIZ) is classified as a "Particularly valuable and vulnerable area" in the management plan, and in these areas "*special caution will be required and special considerations will apply to the assessments of standards for and restrictions on activities*". These are important political signals as to how the management of some of the most critical polar bear habitats will be managed in the future.

The management plan for the Norwegian Sea was presented in May 2009 as a White Paper from the Ministry of Environment (Norwegian Ministry of Climate and Environment 2009), and was revised in 2017 (Norwegian Ministry of Climate and Environment 2017). This plan is based on the same approach, principles and methods as the Barents Sea management plan, and the geographical scope includes polar bear habitats west of Spitsbergen (Fram Strait). Although not directly focused on polar bear conservation, the plan includes tools and principles relevant for habitat protection and may therefore contribute to the conservation of the polar bears in the area.

New Government White Paper on Svalbard

At regular intervals, the Norwegian Government releases a White Paper where status and intentions for management of environment and human activities in Svalbard are discussed. The last one was released in May 2016 (Norwegian Ministry of Justice and Public Security 2016). The White Paper reconfirms the high environmental objectives on Svalbard and highlights the climate change challenges.

Protected areas in Svalbard

At present, there are a total of 29 protected areas in Svalbard. There are seven national parks, six nature reserves, 15 bird sanctuaries and one geological reserve. The total area of all protected areas is 115,600 km^2. This comprises approx. 77 % of the total area within the territorial borders in Svalbard.

The eastern parts of Svalbard traditionally represent important habitats for polar bears, both for feeding and breeding. These areas, which are protected as nature reserves, are also expected to experience the most significant impact of climate change by changing sea ice breakup and freeze-up (Førland *et al.* 2009,Stern and Laidre 2016). Subsequent increased traffic from cruise ships and research activity in these areas have called for an increased management effort in these important areas for polar bears in times of rapid environmental change. In 2015 a management plan for the eastern parts of Svalbard (Northeast Svalbard and Southeast Svalbard nature reserves) was approved by the Norwegian Environment Agency. The plan includes guidelines for local management and regulations by the Governor of Svalbard on, e.g., motor traffic related to polar bear filming, research, etc. Similar management plans for the western and central parts of Spitsbergen are under preparation by the Governor of Svalbard.

Management plans for Bear Island and Hopen nature reserves were endorsed by the Norwegian Environment Agency in 2005 and 2007. Especially for Hopen, which still might be an important denning site for polar bears (Derocher *et al.* 2011), the plan is an important means by which to promote the conservation goals. Still, denning in Hopen has been marginal in the entire period after 2009 due to lack of sea ice around the island in winter.

New regulations

In 2008 the regulations for the two large nature reserves in the eastern parts of Svalbard, Northeast Svalbard and Southeast Svalbard nature reserves, were adjusted to prohibit tourist ships with more than 200 passengers to go there. However, the most important new adjustment was the prohibition of all heavy ship fuels. No ship can use or bring other fuel than light diesel fuel, class DMA (ISO 8217 Fuel Standard). This will eliminate the risk for oil fouling from accidental spills of heavy bunker fuel oils in these core polar bear areas in the future. Although field data is missing that document effects on oiling on polar bears, experimental studies have shown that oiling can be fatal, both due to toxic effects when bears groom oiled pelts (Øritsland *et al.* 1981), and from significant loss of insulation (Hurst and Øritsland 1982).

In 2011 the Svalbard Environmental Protection Act was changed with respect to reduce the risk of fatal human bear interactions in the field. As an extension of the statutory provisions regarding protection and disturbance of wildlife, an injunction on prevention of polar bear attacks was adopted in order to avoid unnecessary scaring, chasing and killings (harassment) of polar bears, as well as securing of humans. The Governor of Svalbard is authorized to give specified regulations.

New adjustments of regulations for protected areas (core polar bear habitats) include general traffic bans, duty of notification and reporting for all activities in certain areas in the northeast parts of the archipelago, site specific guidelines for commercial tourism and a ban on aviation below 300 m in national parks and 500 m in nature reserves.

Polar bears killed in Svalbard 2009–2016

From 2009 through 2016 a total of 14 polar bears have been killed in Svalbard (Table 1). The data on polar bears killed in self-defence since the ban of all hunting in 1973 does not appear to support a theory that there has been an increase in human-bear confrontations in the last years (Figure 1). However, this observation of lack of trend is only valid if there is a direct link between the real number of confrontations and bears being killed.

Human casualties and human-bear conflicts

In the period 2009–2016 there has been one fatal human casualty and several severe injuries from polar bear attacks. In 2010 two tourists (kayakers) were attacked in their tent, and one was dragged out by the bear, which was later shot by the other kayaker. In 2011 a group of British students were attacked in their tent camp, and one person was killed and four others were injured. The bear was shot by one of the expedition participants. In 2015 a man was dragged out of his tent by a young bear, and the bear was injured by a shot from a revolver, and later killed.

As mentioned above, there appears to be no support in the data on killed bears for a theory that there has been an increase in the number of conflicts between humans and bears on Svalbard. This could indicate that people are better prepared and do more to avoid confrontations, since tourism and other human activity in more distant parts from the settlements in Svalbard have increased significantly. It might also be that there is less polar bear activity around settlements due to a change in the distribution and condition of sea ice around Svalbard, winter and summer. There is, however, still a need to focus on correct human behaviour and methods to minimize risk for both humans and polar bears, especially while camping in remote areas in Svalbard.

On a few occasions, "problem bears" have been immobilised and moved by helicopter to adjacent areas. In 2009 a bear was moved from the Hopen Meteorological Station, in 2010, 2014 and 2016 single bears were moved away from Longyearbyen, and in 2016 a bear was moved from the trapper station on Austfjordnes.

Use and trade of polar bear products

Norway reports all licenses according to the CITES regulations and standard routines. Permits are administrated by the Norwegian Environment Agency. In general, the level of trade/licenses is low and the main volume relates to import and re-export.

Population status

After the protection in 1973 in Svalbard and 1956 in Russia, the Barents Sea population has partly recovered in absence of hunting. The population was estimated to be 2650 (95% CI = approx. 1900–3600) bears in August 2004 (Aars *et al.* 2009). In August 2016, the Norwegian part of the population was estimated as 973 (95% CI = 665-1884), compared to 685 (CI = 501–869) in 2004. The estimated increase in numbers was not statistically significant (Aars *et al.* 2017). On mainland Svalbard, the numbers of bears estimated were similar in the two study years, close to 250, thus the increased number was due to more bears estimated in the pack ice. The increase needs to be interpreted with care, not only because it is not statistically significant, but also because the distribution of bears along the ice edge could be different between the two surveys. However, comparisons between the two estimates indicate that bears in the Svalbard area do quite well despite the change to less available sea ice. The monitoring program on reproduction and condition (www.mosj.no) is designed to follow the population and reveal any severe changes in the biology as soon as possible if they do occur, in a population experiencing a rapid reduction in sea ice availability. One logical reason why the Barents Sea population may increase despite rapid loss of sea ice is that it likely was depleted to well below its carrying capacity before the protection in 1973. Due to the documented, severe reductions of the sea ice habitat (Stern and Laidre 2016) and prognoses for a further decline (Durner *et al.* 2009), a future new population estimate for the Barents Sea subpopulation, also including the Russian part of the area, is considered important.

Threats from climate change

Northern ice covered areas are sensitive to effects of climate change (global warming) and NorACIA[1] models that the most significant change in Svalbard will occur in the north eastern part of the archipelago (Førland *et al.* 2009). Climate change will both reduce polar bear critical habitat and at the same time improve the access for human activities (tourism, research, resident traffic etc.). Derocher *et al.* (2011) studied the denning ecology of female polar bears at Hopen Island. It was concluded that climate change may be negatively affecting the denning ecology of polar bears at the southern extent of their range in the study population. Fall ice cover around important denning areas in Svalbard is monitored, based on the findings that timing of fall sea ice is dictating whether bears can get access to the area or not for denning the coming winter. There is currently a trend towards later sea ice formation and earlier breakup around several important denning areas in Svalbard, and even the important area of Kong Karls Land has experienced so little sea ice in fall that no dens were found during surveys the following spring (www.mosj.no). Both body condition and reproduction are currently monitored in Svalbard polar bears. No trend over time has so far been seen, but for both data series a significant relationship with the AO-index is seen, indicating an effect of climate on the parameters.

The new PBSG sea ice metric, published by Stern and Laidre (2016) shows that the ice free period between spring thaw and fall freeze has increased by 40 days per decade since 1979, i.e., more than 140 days, within the subpopulation area, which is by far the most dramatic change when compared with any other subpopulation area.

It is likely that polar bears will be lost from many areas where they are common today and also that the total population will change into a few more distinctly isolated populations (Wiig *et al.* 2008). It is expected that polar bear habitat in the Barents Sea will be substantially decreased during this century (Durner *et al.* 2009).

Threats from industrial developments

The southern part of the Barents Sea was legally opened for oil and gas developments in 1989 (south of 74° 30' N). Petroleum exploration is still prohibited in the northern part of the Barents Sea, north of latitude 74°30'N, but has, as mentioned above, recently been opened in a new 45,000 km^2 area east of longitude 32°E, due to agreement between Norway and Russia about the border delineation.

The present main threatening human activity with relevance to polar bear habitats is still tourism, e.g., cruise ship traffic and snow mobiles in feeding areas. As the sea ice conditions have changed, more open water increases the access to areas (north/east) that were previously "protected" by ice coverage.

[1] Norwegian domestic follow-up of the circumpolar ACIA (Arctic Climate Impact Assessment) program. See http://noracia.npolar.no.

In the south, the large gas field of Snøhvit has produced Liquified Natural Gas (LNG) since 2007. This is the first developed gas field in the Barents Sea. Gas has been the main discovered hydrocarbon reserve in the region until there was an oil discovery in the Goliat block in 2000, 30 nautical miles southeast of Snøhvit. This was the first oil field to be put in production in the Barents Sea (April 2016). The field is located 30 nautical miles off the Norwegian coast.

The most immediate risk for acute oil spills in polar bear habitats are thus still only from acute oil spills from ship traffic (tourist ships, fishing vessels, research vessels or ice breakers with conventional fuel). However, as oil developments seem to move north and ice cover continues to recede as climate warms, there is an increased concern about oil drilling in ice-infested waters as polar bear critical habitat decreases.

Threats from tourism and disturbance

Tourism has been, and will continue to be, one of the main commercial activities in Svalbard. Tourism is described as one of the main pillars of the societal development as the coal mining industry is terminated (Norwegian Ministry of Justice and Public Security 2016). Tourism activities are increasing at and around Svalbard, both in winter and summer. Both expedition cruises and daytrips have more than doubled since 2001. In addition, the winter tourism (snowmobile traffic) is increasing and expanding. The Governor of Svalbard has put effort into monitoring and patrolling the areas most commonly used during winter-/springtime, with special attention to polar bears.

As the traditional polar bear habitats are shrinking throughout the archipelago, particularly in the warmer parts of the year, due to reduced sea ice, there is an increased concern that polar bears are disturbed in sensitive areas and periods. Although the protection regime in Svalbard is strict, and in large is a success, there are times of the year when snow mobile tourism is intense in areas were females with COYs have emerged from their dens and start to hunt on the ice. Pilot studies of disturbance from snowmobiles have not surprisingly shown that females with small cubs seem to be easier disturbed than males and single females (Andersen and Aars 2008). Other studies, from various regions, have shown both behavioural and physiological impacts on wildlife from motorised traffic (Creel *et al.* 2002, Dyck and Baydack 2004, Overrein 2002). The real negative impact from disturbance from tourism and other activities are unknown. Should future studies indicate that such impacts are significant, the existing legislation allows necessary steps to regulate tourism activities stronger to reduce the total pressure on polar bears.

Harvest

The polar bear has been protected in Norway since 1973, and there has consequently been no harvest of the Barents Sea subpopulation in Norwegian territories. The previous concerns related to possible high levels of illegal harvest in northwest Russia are reduced, partly due to the establishment of the new national park "Russian Arctic" covering Franz Josef Land and north part of Novaya Zemlya. In eastern Greenland, harvest is still set without a population estimate, so whether this harvest is sustainable is still unknown. Studies have shown that there are some overlap of home ranges in the Fram Strait area, and thus that some interaction between East Greenland and Svalbard/Barents Sea bears is likely (Born *et al.* 2012). Population genetics indicate that gene flow is very high between the populations (Paetkau *et al.* 1999).

Threats from pollution

Circumpolar studies indicate that polar bears from the Barents Sea are among the most contaminated of all subpopulations for levels of the most important lipophilic compounds (PCBs and PBDEs) and perfluoroalkyl substances (McKinney *et al.* 2011, Smithwick *et al.* 2005). Concentrations of most lipophilic pollutants and perfluoroctane sulfonate (PFOS) have decreased over time, whereas perfluoroalkyl carboxylates (PFCAs) are increasing (www.mosj.no; Routti et al., under review; Bytingsvik *et al.* 2012). Concentrations of mercury and hexachlorobenzene do not show any trend over time (Riget *et al.* 2011). The high levels of pollutants in polar bears from the Barents Sea area have been related to physiological effects such as disruption of hormone and immune system at individual level (reviewed by Jenssen *et al.* 2015). Also, comparison of pollutants in polar bears to threshold levels in experimental animals suggest that polar bear health is affected by pollutants (Dietz *et al.* 2015, Pavlova *et al.* 2016). However, impact of pollutants on population growth is challenging to quantify (Derocher 2005). Declining sea ice leads to increased tissue concentrations of lipophilic pollutants, as in the absence of sea ice polar bears have reduced feeding opportunities, they become thinner and pollutants get more concentrated (Tartu *et al.* 2017). Furthermore, pollutants may affect the processes how polar bears store fat, but the consequences at individual/population level are unknown (Routti *et al.* 2016). Given the high pollutant concentrations of Barents Sea polar bears and associated health effects, ecotox studies in the area have high priority due to the possible importance in future management. Documenting presence and effects of pollutants in the Arctic ecosystems gives input to international conventions, such as the Stockholm Convention, that regulates the use and production of persistent organic pollutants.

National Red Listing

In 2006, a Norwegian Red List of threatened species was prepared in accordance with the IUCN criteria by the Norwegian Biodiversity Information Centre (http://www.biodiversity.no). Svalbard was for the first time included and the polar bear was listed as vulnerable (VU) according to criteria A3c: a suspected population reduction during the coming three generations (45 years) based on a decline in the area of occupancy, extent and habitat quality. This was in line with the global assessment (Schliebe *et al.* 2006). The last update of the Red List assessment confirmed the initial assessment, this time founded on new estimates of generation length and modelled linkages between reductions in habitat and population size (Wiig *et al.* 2015). Any change of status on the Norwegian Red List will not have any immediate practical consequence for the management of polar bears in Norwegian territory since they have been totally protected since 1973 and the Red List status has no automatic legal implications.

Bilateral and international cooperation

As the Barents Sea polar bear population is shared between Norway and Russia, a targeted cooperation is important in order to exchange data and information, coordinate activity, improve and calibrate methods, etc. Two bilateral expert meetings were arranged in 2011 and 2012, before a Memorandum of Understanding (MoU) was signed in February 2015. The intention behind this MoU was to contribute to formalize the bilateral cooperation with an aim to strengthen the cooperation on polar bear management, monitoring and research. A working group was established to implement the cooperation in the framework of the MoU and the first meeting was arranged in 2016.

In March 2009 Norway invited the Contracting Parties to the 1973 polar bear Agreement to a meeting of the parties in Tromsø, after the five Contracting Parties (the Range States) had not met since 1981 in Oslo to decide that the 1973 agreement should be valid indefinitely. At the Tromsø meeting, it was decided to create a joint circumpolar action plan for the polar bear. Since this meeting, the Range States have met on a biannual basis and developed the plan. At their meeting in Ilulissat in 2015, the Circumpolar Action Plan (Polar Bear Range States 2015) was approved by the Range States. The plan is a result of targeted effort from the Range States. Work is still on-going in relevant thematic subgroups of the Range States collaboration (Heads of delegation, Conflict Working Group, Communication Working Group, and the CAP implementation team), and these international efforts have increased the national focus on the polar bear species in decision-making processes.

International cooperation is one specific objective under the national action plan (Norwegian Environment Agency 2013). Also, Norway supported a listing of polar bears under Convention of Migratory Species - CMS), and polar bears were added on its Appendix II in November 2014 at their COP11[2]. According to CMS, the listing "introduces the global perspective of existing threats to Arctic species stemming from shipping and oil exploration, making it a case for all CMS Parties". CMS has 124 Parties worldwide and given their responsibility to halt global warming in order to conserve polar bears, this CMS listing is a valuable contribution.

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[2] Cf.http://www.cms.int/en/news/governments-commit-step-action-migratory-animals-un-wildlife-conference

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Tables

Table 1. Polar bears killed in Svalbard 2009–2016 (SD=self defence, AM=act of mercy, PM=precautionary measure, GO=Governor's Office, C=station crew, S=scientist, T=tourist). *Source*: Governor of Svalbard, 2016.

Date	Location	Cause	Sex	Recapture?	Age (years)
10.05.2009	Kinnvika, Nordaustlandet	SD	M	Yes	3-4
18.07.2009	Hopen	SD	M	No	Adult
08.07.2010	Hyttevika	SD	M	Yes	10
29.07.2010	Ekstremhuken	SD	M	Yes	11
05.08.2011	Von Post breen	SD	M	No	24
24.03.2013	Hyttevika	SD	M	Yes	6
18.04.2013	Isbukta	SD	M	No	Subadult
04.09.2013	Freeman Sound	S	M	Yes	2
11.04.2014	Petuniabukta	S?	F	Yes	1
19.03.2015	Fredheim	GO	?	?	?
16.04.2016	Verlegenhuken	GO	F	No	2
13.06.2016	Austfjordneset	SD	M	Yes	21
13.06.2016	Austfjordneset	GO	M	Yes	0,5
10.08.2016	Selvågen, Forlandet	S	M	Yes	2,5

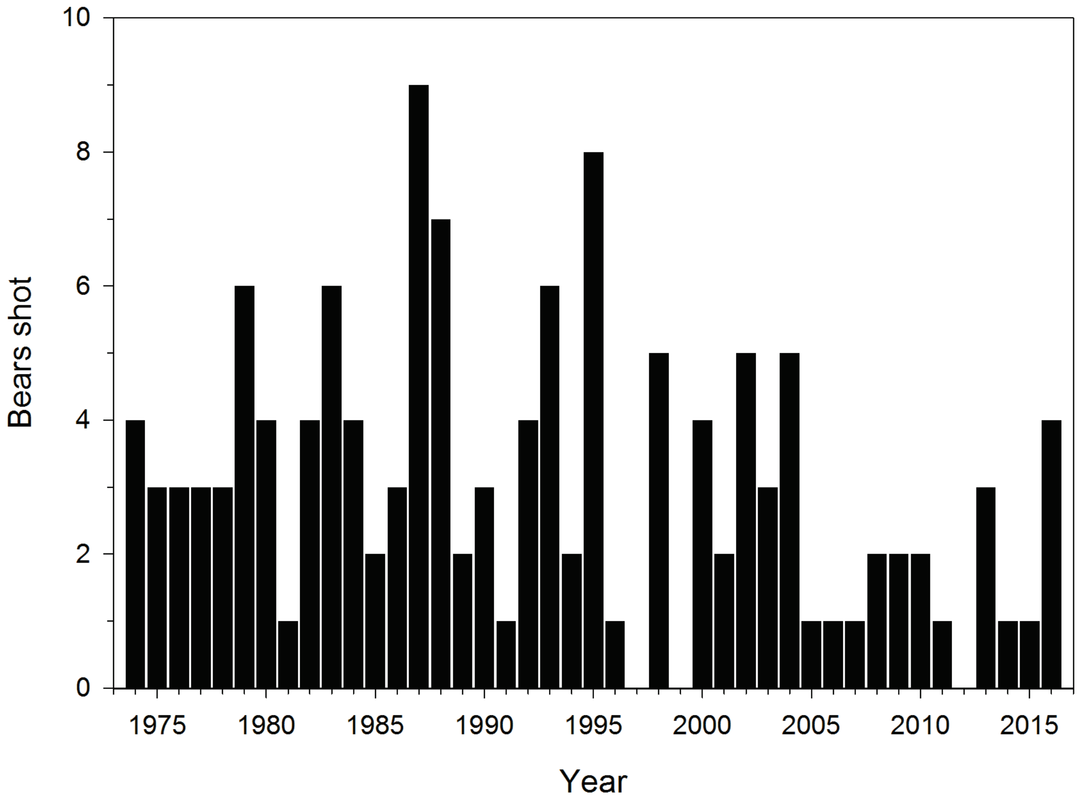
Table 2. CITES permits for import, export and re-export of polar bear skins and parts of polar bears in Norway, 2009–2015.

Year	Import	Export	Re-export
2009	19 SKI (CA), 1 BOD (CA), 2 SKU (CA)	-	10 SKI to JO, SE, RU, CY and CN (all origin CA).
2010	9 SKI (CA)	-	11 SKI to NL, RU, CN and GL, (3 origin CA and 8 origin GL) and 2 claws to GL (origin GL)
2011	10 SKI (CA), 1 SKI (IS), 1 SKI & 1 SKU (GL), 2 SKU (DK-origin GL), 2 SKI (DK- origin GL)	1 SPE (DK) 1 SPE (GB)	1 SKI & 1 BOD (SE), 1 BOD (DK) - all origin CA
2012	7 (4 SKI, 2TRO, 1 BOD CA), 3 SPE (DK, GL)	5 SPE (DK)	1 SKI (CA), 4 SKP & 4 LPS (GL)
2013	9 SKI (CA)	1 SKI (2), 3 SPE	1 SKI (CA), 10 SKP (GL)
2014	2 TRO (CA)	2 SPE (NL, FR), BOD (ES)	1 BOD (China- origin CA), SKI (UK- origin CA)
2015	1 SKU (DK), 30 SKI (CA)	30 SKP (DK), 70 HAI (DK), 3 SKI (SE), 2 SKI (FR)	-

Material abbreviations: SPE=Specimen, SKI=Skin, TRO=Trophy, SKP=Skin pieces, TEE=Teeth, BOD=Body, SKU=Skull, HAI=hair, LPS=Leather product small. Country abbreviations: Canada=CA, CN=China, CY=Cyprus, DK=Denmark, FR=France, DE=Germany, GL=Greenland, IT=Italy, IS=Iceland, JO=Jordan, NL=Netherlands, RU=Russia, ES=Spain, SE=Sweden, UK=United Kingdom

Figures

Fig. 1. Annual number of polar bears shot in defence of humans or property, 1974–2016.



Research on Polar Bears in Norway, 2009–2016

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The Norwegian Polar Institute (NPI) leads polar bear research in Norway. The programme aims to produce knowledge needed by management authorities through population monitoring (for an overview see MOSJ, http://www.mosj.no/en/; Sander *et al.* 2005). While maintaining its long-term perspective, the programme has adapted to answer new questions as they have arisen. The NPI programme initially focused on studying the effect of the century-long period of hunting on the population, but pollution, anthropogenic activity and climate change currently are prioritized issues (for an overview see Andersen and Aars 2016). Long-term research and monitoring of key population biology issues is a major part of the program, and current activities line up well up with circumpolar recommendations (Vongraven *et al.* 2012).

Movements and habitat use

Satellite telemetry collars have been employed on a number of adult females in the Barents Sea subpopulation since 1988. In recent years, NPI has deployed between 10 and 20 annually. Data from later years confirms earlier findings of two ecotypes of female polar bears in the Barents Sea with very different strategies. One ecotype is local and stays close to the Svalbard archipelago year-round. Another ecotype is pelagic and follows the pack ice in the Barents Sea during most of the year and have much larger home ranges. Pelagic bears from SE Svalbard migrate northeast, to the pack ice and over to Franz Josef Land. Pelagic bears from northern and north-western parts of Svalbard may migrate north and in some cases northwest. Within Svalbard, capture-recapture data show very limited movement between the area in north-west and areas in south-east for animals captured in spring in different years (Lone *et al.* 2013).

There is limited information about movements of polar bears between eastern Greenland and the Barents Sea. Results from one study on bears tagged with satellite transmitters in the East Greenland pack ice and in the northern part of the Svalbard archipelago did show some overlap of home ranges in the Fram Strait area (Born *et al.* 2012) but none of the East Greenland bears moved into the Barents Sea (Laidre *et al.* 2015).

During the last couple of decades, as the Barents Sea area has experienced a shortening of the sea ice season of several months (Stern and Laidre 2016), data on collared females show that the pelagic bears have had a dramatic shift in distribution range. They are now using areas several degrees further north much of the year, and frequently even north of the continental shelf. It is therefore assumed that they spend more time in areas with lower productivity (Lone *et al.* 2017), although the effects are not yet analysed. Ongoing work on resource selection function modelling (RSF) along the ice edge so far also confirm general findings from other studies regarding preference for ice coverage of less than 100%, varying with time of year, and preference for shallower waters (Lone *et al.* 2017).

In Svalbard, satellite telemetry data showed that polar bears use glacier fronts frequently in spring, and in particular females with cubs that just had emerged from den (Freitas *et al.* 2012). These glacier fronts are prime ringed seal habitat, and have a high density of lairs with pups. Females with cubs likely prefer near shore areas with less risk for cubs being exposed to cold water (Aars and Plumb 2010), and seal pups are easier to catch than adult seals that may be a preferred prey for bears hunting out in the pack ice. Hunting adult seals may also be difficult for females with small cubs present.

Population ecology

Demographic parameters are part of a monitor program (Monitoring of Svalbard and Jan Mayen, MOSJ, www.mosj.no). While there has been a tendency for a decrease in reproduction over time based on capture data from spring (from 1992 to present), it is a question whether this is a local effect of surveyed areas, or if a geographic shift in denning areas (e.g., to the Russian western Arctic) could be influencing this pattern. Female reproduction and condition of adult males are negatively impacted by warmer years (www.mosj.no). From 2015, NPI has cooperated with Centre d'Ecologie Fonctionnelle et Evolutive, France (CEFE) for modelling of survival and reproduction based on capture-recapture data. A recent review paper (Descamps *et al.* 2016) discusses climatic impacts on both polar bears and other wildlife in the Svalbard area.

Reliable age determination is important for demographic studies. Christensen-Dalsgaard *et al.* (2010) evaluated accuracy in age determination by reading of age layers in rudimentary teeth from the Barents Sea area. It was found that the method is not very accurate for this area. The age of older animals tends to be underestimated, and different labs and different persons may bias estimates differently.

Mating in polar bears has been studied in Svalbard using both capture data (Derocher *et al.* 2010) and genetic data to construct family trees (Zeyl *et al.* 2009). The first study show that older males are fighting most and more frequently found with females in spring. However, the latter study shows that younger males are more successful siring cubs than what should be expected. Smith and Aars (2015) reported a case on mating in late June, much later than the normal mating season, and discuss how such flexibility in a species with delayed implantation makes sense.

Denning ecology

NPI has a GIS database of more than 500 maternity den positions that have been recorded from 1972 until present in the Svalbard area. A study (Andersen *et al.* 2012) investigated the distribution of the dens and how this may have changed over time since 1972, with indications that more bears now den in the western areas of Svalbard than earlier during this period. This may be caused by local bears starting to return to these areas after over-harvestinging before their protection in 1973. Derocher *et al.* (2011) demonstrated that on Hopen, an island in Svalbard, many bears used to den here in years when the drifting sea ice arrived at the island within early November but very few pregnant females were able to reach the island for denning if sea ice arrived in late December or later. Further north, the traditionally very important denning area Kongsøya experienced the same pattern, and very few denning bears have been located here during surveys in recent years (Aars 2013, www.mosj.no). A project that combined snow drift models with terrain models succeeded to map polar bear denning habitat with very high accuracy (evaluated using known denning positions in different years). A paper on this work is currently in revision (Merkel *et al.*, *in prep*). In cooperation with Polar Bear International (PBI), two camera systems were in spring 2016 placed out at known denning sites (located from satellite collar data). One of the cameras successfully filmed the emergence of a female and a cub, and the behaviour at the den the following days. The project is planned to continue in 2017. The system was developed by PBI.

One key question is whether females that do not reach important denning areas in East Svalbard in years with late formation of sea ice, skip reproduction or den somewhere else. Current research aims to address this question by a) collaring more bears in east Svalbard, and b) using light loggers (i.e., geolocators) implemented in the ear tags of females. The loggers provide unique profiles for bears in den (little light and high temperature) as well as a rough position (based on time for sunrise and sunset) in spring. Light loggers have been used on female bears in Svalbard since 2011, and are currently produced by Migratetech (www.migratetech.co.uk/*)*.

A study using genetic markers showed that over generations, female relatives tend to use the same local denning areas within islands, but low genetic variation between islands may indicate that they use alternative denning areas in years when they fail to reach the preferred areas where they were born (Zeyl *et al.* 2010).

Diet

Samples of polar bear scats collected mainly from early spring were analysed for food species contents, both visually and using DNA analyses (Iversen et al. 2013). It was found that ringed seal was the by far most common prey in areas close to shore in Svalbard in spring. Reindeer was also frequently found in the scats, while bearded seals (which are an important prey in summer; Derocher et al. 2002) was present with very low frequency in spring. Both plant material and kelp was also very frequent in scats. Likely predation and later scavenging of carcasses of white beaked dolphins was documented in northern Svalbard (Aars et al. 2015). More frequent utilization of eggs and chicks in bird colonies in western Svalbard has been documented, and explained by more bears spending increasing amounts of time on land due to less sea ice being available during the hatching season, and possibly also more bears returning to these areas after decades of protection from hunting and trapping (Prop et al. 2015). These results are supported by Tartu et al. (2016), who described the diet of Svalbard female polar bears based on stable isotope and fatty acid analyses. The results suggest that polar bears feed more on seabirds in areas with less sea ice whereas polar bears inhabiting areas with more stable sea ice conditions are more selective towards seals. Waterfowl and reindeer also make a part of autumn diet in areas where the sea ice retreats. Furthermore, solitary females were more selective and prey on higher trophic level species compared to females with cubs.

Aerial surveys and population size

The Barents Sea polar bear population was estimated as 2650 (95% CI approximately 1900–3600) for August 2004 (Aars *et al.* 2009). A repeated survey in 2015 partly failed as no permission was granted to work in the Russian part of the area. A partial survey covered the Norwegian part in August 2015, with helicopter surveys using distance sampling methods and also biopsy darting of bears for identification of recaptures. It was found that an estimate of less than 300 bears stayed in Svalbard, similar to what was found in 2004. The biopsy data indicated that these bears were to a large degree local bears that had earlier been captured in spring during the annual monitoring program. In the pack ice, that was separated from Svalbard as the ice edge was located far north, the estimate was considerably higher than in 2004, but the statistical uncertainty was too large to conclude about trend. Also, most bears were located close to the Russian border, and thus net movement east or west along the ice edge could easily have influenced the change in estimate. It was estimated that a total of about 1000 bears were located in the Norwegian Arctic in August 2015 (Aars *et al.*, 2017). A very low recapture rate based on biopsy DNA-profiles in the pack ice area indicate that this part of the population is more isolated from Svalbard than what may have been appreciated earlier, and that the current capture program in Svalbard is well suited for our understanding on the ecology of local bears, but less so for the larger pelagic part of the population.

Morphometric studies of polar bear skulls collected at Svalbard and in East Greenland (Pertoldi *et al.* 2012) indicated that many Barents Sea polar bears are morphometrically similar to the East Greenland ones, suggesting an exchange of individuals between the two subpopulations. Furthermore, a structure within the Barents Sea subpopulation was also indicated.

Genetics

In recent years, samples from Svalbard have contributed to several genetic studies on evolution and large-scale structure, studies that are more pan Arctic and thus will not be discussed further here (Lindqvist *et al.* 2010, Miller *et al.* 2012, Peacock *et al.* 2015). Biopsy samples from the 2015 survey (see above) and updated lab analyses from later years now have provided a library of about 1000 individuals with known profile based on microsatellites for the Barents Sea area, with Svalbard as the core sampling area.

Ecotoxicology

Temporal trends of PCBs, organochlorine pesticides, BDE47, PFOS and mercury are part of an ongoing program on environmental monitoring of Svalbard and Jan Mayen (MOSJ). Screening of new contaminants is conducted by the Norwegian Environment Agency and under specific research projects. During recent years three major research projects have investigated more specific questions related to pollutant levels and effects in polar bears from the Svalbard area. Two projects focusing on interactions between pollutants, energy metabolism and sea ice conditions are led by the Norwegian Polar Institute. "BearEnergy - Synergistic effects of sea ice free periods and contaminant exposure on energy metabolism in polar bears" (2012–2016), funded by the Norwegian Research Council, uses correlative approaches on field samples whereas "Contaminant effects on energy metabolism" (2011–2015), funded by Fram Centre Hazardous Substances Flagship, focuses on *in vitro* and *in silico* methods. IPY-project BearHealth, led by the Norwegian University of Science and Technology has focused on mother-cub pairs sampled in two time periods which are contrasted by pollutant exposure (1997–1998 and 2008) using both field and *in vitro* approaches. The project has also investigated relationships between pollutants and physiological parameters in male vs. female polar bears. All the research projects also involve other institutes from Norway and other countries.

Contaminant levels and trends

Monitoring data on adult female polar bears show that concentrations of PCBs, organochlorine pesticides and BDE47 have decreased over time (www.mosj.no), whereas Hg concentrations do not show any trend over time (Riget *et al.* 2011). Circumpolar studies indicate that polar bears from the Barents Sea are among the most contaminated subpopulations for levels of PCBs and PBDEs, whereas HCH concentrations are higher in the North-American subpopulations (McKinney *et al.* 2011a, b). Also, mercury concentrations are generally low in polar bears from Svalbard (Braune *et al.* 2011). Specific studies (BearHealth) comparing mother-cub pairs during two time periods, 1997–1998 and 2008, show that plasma PCB concentrations were approximately twice as high in the first time period compared to the second (Bytingsvik et al. 2012a). In the same dataset, plasma PFOS concentrations decreased during the study period whereas most perfluoroalkyl carboxylates showed an opposite trend (Bytingsvik et al. 2012b). These studies also show that cubs of the year are exposed to high concentrations of lipophilic POPs due to maternal transfer. Plasma PCB levels were over two and a half times higher in cubs compared to their mothers, whereas opposite pattern was observed for less lipophilic OH-PCBs and perfluoalkyl substances.

Screening studies on new pollutants show that "new" brominated flame retardants decabromodiphenyl ethane and 2,4,6-tribromophenol were found at higher concentrations in polar bear plasma than the major PBDE, BDE47 (Harju *et al.* 2013). Also chlorinated paraffins were present in polar bear plasma samples whereas only few organophosporous flame retardants were detected in some of the samples (Hallanger *et al.* 2015, Harju *et al.* 2013). In addition, nonylphenol has been reported in plasma sample of polar bear cubs (Simon *et al.* 2013). Ongoing activities using non-target screening will give more information about chemical exposure in polar bears from Svalbard. Aubail *et al.* (2012) observed a decreasing time trend in Hg concentrations in teeth of polar bears from Svalbard over the recent four decades while no temporal changes were found in the stable isotope ratios of nitrogen (d15N) and carbon (d13C). This suggests that the decrease of Hg concentrations over time was more likely due to a lower environmental Hg exposure in this region rather than a shift in the feeding habits of Svalbard polar bears. Samples from Svalbard have also been included in large scale studies looking at geographical structure in pollutant levels (McKinney *et al.* 2011a, 2011b; Rigét *et al.* 2011, Dietz *et al.* 2012, Harju *et al.* 2013). Also chlorinated paraffins were present in polar bear plasma samples whereas only few organophosporous flame retardants were detected in some of the samples (Hallanger *et al.* 2015, Harju *et al.* 2013). In addition, nonylphenol has been reported in plasma sample of polar bear cubs (Simon *et al.* 2013). Nonylphenol, phthalates and tonalide were also identified in fat and/or liver extracts from one polar bear using non-target screening (Routti *et al.* 2016); however these findings should be confirmed using more specific analytical techniques on a bigger number of samples. Ongoing activities using non-target screening will give more information about chemical exposure in polar bears from Svalbard.

Pollutants, health and energy metabolism in relation to sea ice conditions

Recent knowledge suggests that contaminants may interfere with energy metabolism, it can thus be hypothesized that exposure to contaminants may lead to suboptimal energy metabolism during ice free periods in polar bears. As a part of the BearEnergy project, blood and fat samples were collected from 112 adult female polar bears sampled during two seasons (April and September) in 2012 and 2013. The bears were caught at three locations of Svalbard with contrasting sea ice conditions and information on body condition, reproductive status and age were collected. Multiple analyses have been performed including concentrations of pollutants (PCBs, chlorinated pesticides, PBDEs and perfluoroalkyl substances), dietary tracers, and physiological and molecular parameters related to energy metabolism and general health.

So far, the data has been presented in two peer-reviewed publications and 3 MSc-thesis. Two more manuscripts are submitted and three under preparation. As described earlier, we investigated diet in these polar bears (Tartu *et al.* 2016). Next, we tested whether environmental factors (year, season and sampling area), and reproductive status influenced concentrations of POPs in plasma and fat, and, POP biotransformation through changes in body condition and diet (Tartu *et al.* 2017). The results indicate that concentrations of the highly lipophilic POPs such as PCBs, chlordanes and HCB in polar bear females are driven by body condition followed by diet. As retreat of sea ice was related to lower body condition and higher POP concentrations, we suggest that loss of sea ice (particularly in winter) leads to increased concentrations of lipophilic pollutants in Svalbard polar bears. The study also indicates that less lipophilic POPs such as *β*-HCH is excreted via milk. Surprisingly, biotransformation of PCBs to OH-PCBs was more efficient in fatter bears, probably due to the influence of nutritional status on activities of xenobiotic enzymes. This paper gives a background for further studies on pollutant levels, which indicate that plasma and fat levels of lipophilic POPs are higher in spring compared to autumn, whereas contrasting pattern is seen for perfluoroalkyl substances (Tartu *et al.*, *submitted*; Bourgeon *et al.*, *in prep*).

Seasonal variations in thyroid disrupting effects of persistent organic pollutants were examined in a MSc-thesis (Riemer 2016). Thyroid hormone levels are generally higher in spring compared to autumn although this seasonal effect was mainly observed in solitary females. Plasma concentrations of free triiodothyronine were negatively related to contaminant concentrations, which is in accordance with previous polar bear studies. Furthermore, linear relationships between contaminants and thyroid hormone ratios differed between bears sampled in spring and autumn.

Plasma clinical-chemical parameters were investigated in a MSc-thesis in relation to season, reproductive status and pollutants (Torget 2015). The ratio of urea to creatinine as well as triglyceride levels indicates that the bears were fasting in the autumn and feeding in spring, whereas body condition was higher in spring compared to autumn (Bourgeon et al., *submitted*). Lipid related physiological parameters were positively related to perfluoroalkyl substances. A manuscript is under revision.

Health status of the polar bears in relation to sampling season and reproductive status was assessed by measures of oxidative stress and antioxidative defence in whole blood (Bingham 2015). In total nine enzymatic and non-enzymatic parameters analysed showed little differences between seasons and status. Two of the parameters were higher in autumn than spring, which could be related to increased oxidative stress due to fasting.

Parallel to the BearEnergy project, effects of pollutants on polar bear energy metabolism have been investigated *in vitro* and *in silico*. An MSc-student (Berg 2013) developed assays which allow study effects of pollutants and their mixtures on polar bear nuclear receptors that are major regulators of energy consumption and storage (peroxisome proliferator-activated receptor; PPAR). Furthermore, Øygarden (2015) established a method using polar bear adipose tissue-derived stem cells (pbASCs) to study fat accumulation by contaminants. A study using the above-mentioned methods and *in silico* modeling (Routti *et al.* 2016) indicates that the main lipophilic POPs in polar bear fat inhibit the activity of polar bear PPAR-gamma, which is the major regulator of fat accumulation in fat cells. However, the same study showed that fat accumulation increased in polar bear and mouse cells when the cells were given polar bear tissue extracts that also contained emerging compounds. As polar bears' energy balance is already challenged by climate change, additional pressure by contaminants affecting energy metabolism induces a multi-stress situation that might be hard to withstand.

Mechanistic studies on thyroid-disruptive effects of pollutants

A series of *in vitro* studies has focused on interactions between pollutants and polar bears and plasma proteins that transport thyroid hormone. Gutleb *et al.* (2010) extracted thyroid transporting proteins from polar bear plasma and found that one of the major OH-PCBs in polar bear plasma has much higher affinity towards transthyretin (TTR) than its natural ligand thyroxine. The study suggested that TTR in free-ranging polar bears are completely saturated by contaminants. As a part of the BearHealth project, Simon *et al.* (2011) developed a sample preparation method to extract a broad range of thyroid hormone disrupting compounds in plasma and test the binding potency towards human TTR. The method was further used by Bytingsvik *et al.* (2013), who showed that contaminant related TTR-binding activity in was twice as high in polar bear cubs sampled in 1997–1998 compared to those sampled in 2008. Furthermore, OH-PCBs explained ~60% of the TTR-binding activity. The binding activity was also positively correlated with plasma levels of OH-PCBs. A followed-up study using effect-directed analyses revealed that the remaining TTR-binding activity of plasma from polar bear cubs was explained by nonylphenol and higher chlorinated OH-PCBs not analysed in the previous study (Simon et al., 2013). In conclusion, the studies suggest that several compounds present in plasma of polar bear cubs have very high affinity to TTR. As these compounds are found at high concentrations, they can occupy all circulating TTRs leaving no place to the natural hormone thyroxine. Exact consequences of fully saturated TTR are not known. However, as thyroid hormones are essential for growth and development, thyroid disrupting properties of pollutants in small polar bear cubs raises concern for effects on neurological development (Jenssen *et al.* 2015).

Physiological parameters and pollutants in male vs. female polar bears

Relationships between physiological parameters and pollutants in male vs. female polar bears have been compared by several studies. A steroid hormone profile in 15 Svalbard female polar bears was characterized by Gustavson *et al.* (2015a). A further study (Gustavson *et al.* 2015b) on correlations between steroid hormones and contaminants showed inverse relationships between plasma levels of pregnenolone (PRE) and androstenedione (AN), and OH-PCBs. This suggests that the enzyme CYP17 may be a potential target for OH-PCBs. A MSc-thesis on steroid hormones on male polar bears (n = 23) suggests that concentrations of pollutants were negatively related on dihydrotestosterone concentrations (Hansen 2012).

Relationships between individual pollutant concentrations and plasma clinical-chemical parameters (Ormbostad 2012) were compared between male and female polar bears. A similar study was done on vitamin D in relation to pollutants and thyroid hormones (Grønning 2013). Both MScs theses, based on multivariate analyses on approximately 20 males and 20 females, suggest that relationships between pollutants and physiological parameters are different between males and females.

MSc-thesis of Gilmore (2015) investigated relationships between contaminants and genotoxicity and mRNA expression of genes related to oxidative stress and biotransformation in 13 male and 34 female polar bears. No differences in contaminant levels or effect parameters were found between males and females. Of the ten mRNA expressions measured in skin one gene related to biotransformation (CYP1B1) and another related to oxidative stress were positively related to contaminant exposure. In contrast, DNA strand breaks in lymphocytes decreased with contaminant exposure.

Health, disease and parasites

Jensen *et al.* (2010) studied prevalence of *Toxoplasma gondii* among polar bears sampled from 2007-2008 in Svalbard, and among some marine mammal prey species. The prevalence among bears had increased very significantly the last decade (compared to results from Oksanen *et al.* 2009), nearly doubled, and was as high as 52% among males and 39% among females. Furthermore, it was found that the prevalence among ringed seals (19%, no age effect) and adult bearded seals (67% among adults) was high, despite *T. gondii* being absent among 48 ringed seals in an earlier Svalbard study (Oksanen *et al.* 1998). *T. gondii* is prevalent in the terrestrial ecosystem in Svalbard (Prestrud *et al.* 2007), but it seems like a marine transmission with recent increase in waterborn oocysts could possibly explain the recent increase in polar bear prevalence. Oocysts may be transferred by seawater from Norway and filtered by mollusks later eaten by seals.

Analyses of blood samples from Svalbard and offshore Barents Sea areas revealed that exposure to *Trichinella* was very high among adults, and considerably higher in Svalbard than off-shore (Åsbakk *et al.* 2010). No recent temporal trend was found (from 1991–2000 to 2006–2008).

Scanning of presence of different viruses in serum samples is ongoing. The last years, a closer follow up of immobilized bears has started, with the aim of better analyses to reveal absence or presence of short term effects from handling.

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Management and Research on Polar Bears in Russia, 2009–2016

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Management

Legal framework for the polar bear subpopulations protection and management

In Russia, conservation and management of rare and endangered species (including polar bears) is regulated by federal laws "On Protection of the Environment" (2002) and "On Wildlife" (1995). The law "On Protection of the Environment" has established the Red Data Book of the Russian Federation (RF) and constituents for the purpose of protecting and monitoring rare and endangered species. Animals included on the Red Data Book of the RF can be removed from the wild in the following cases:

- wildlife conservation
- monitoring of their populations status
- regulating their abundance
- protection of public health
- elimination of threats to human life
- prevention of epidemics among farm livestock and other domestic animals
- supplying traditional needs of indigenous people

The law "On Wildlife" prohibits any actions that may lead to death of Red Data Book animals, decrease of their populations, or damage to their habitats. Companies or individuals conducting business in the areas of Red Data Book species' habitats are responsible for their conservation consistent with Russian federal and regional laws.

The Ministry of Natural Resources and Environment of the RF oversees governmental policy for conservation and restoration of Red Data Book species. Russian regional governments are responsible for monitoring and supervision, and in the case of specially protected natural areas at the federal level (such as state strict nature reserves or national parks), this responsibility is placed on the Federal Supervisory Natural Resources Management Service and its territorial bodies.

A note to the reader

Within this section on activities in Russia related to polar bear conservation, the reader is made aware that subpopulation designations used in Russia for research and management objectives differs from that used by the IUCN Polar Bear Specialist Group (PBSG). In the Red Data Book of the RF (2001) subspecies and populations are specified. Under the Red Data Book, polar bears in Russia are segregated into three different populations: Kara-Barents Sea, Laptev Sea, and Alaska-Chukotka populations. This designation differs from the convention used by the IUCN PBSG in that, first, the single Kara-Barents Sea population is considered two subpopulations (i.e., Barents and the Kara Sea) by the IUCN PBSG, and second, the Alaska-Chukotka population is referred to as the Chukchi Sea subpopulation by the IUCN PBSG. Currently a new edition of the Red Data Book is under preparation where the polar bear will be included again for consideration of its current relevant status.

Management plan for polar bear conservation

The Strategy for Polar Bear Conservation in the RF was approved by the Ministry of Natural Resources and Environment of the RF directive on 5 July 2010. The national Strategy aims to determine mechanisms that will preserve species inhabiting the Russian Arctic under conditions of intensifying anthropogenic impact on marine and coastal ecosystems as well as Arctic climate change.

The Action Plan on polar bear conservation for the period through 2020 was developed based on the Strategy. This plan aims to either eliminate or minimize negative impact from anthropogenic activities on the polar bear and thereby to contribute to the polar bear conservation efforts in the Arctic.

The Action Plan includes the following 8 key components:

1) development of international cooperation;
2) improvement of the legal framework;
3) improvement of the network of specially protected natural areas (SPNA);
4) improvement of the effectiveness of polar bear conservation outside SPNA;
5) scientific research;
6) monitoring of polar bear populations;
7) prevention and resolution of human-bear conflicts; and
8) raising awareness and education.

Each component outlines priority conservation measures for the polar bear establishes timelines for their implementation and designates executing and supervising governmental agencies.

Although the Action Plan is non-binding, certain conservation measures have already been implemented on the federal and regional levels. To provide for more efficient conservation of the Alaska-Chukotka polar bear population, the Governor of Chukotka Autonomous Okrug in October 2011 approved a Plan of Priority Conservation Measures in the region. The signed document envisages a comprehensive set of conservation activities aimed at protecting polar bears and their habitats.

New regulations

Measures aimed at prevention and termination of poaching are particularly important. Accomplishment of this task will be facilitated by amendments introduced in 2013 to the Russian Criminal Code. These amendments increase penalties, up to a criminal penalty, for persons involved in "illegal harvesting, possession, acquiring, storing, transporting, sending, and selling wild animals and aquatic biological resources red-listed in the RF and/or protected under the RF international treaties". The polar bear is one of the red-listed species.

Wildlife listed in the Data Book of the RF are covered by provisions of the *Strategy* for the Conservation of Rare and E*ndangered Species* of Animals, Plants and F*ungi* in the *RF* (Strategy) for the period up to 2030 (was endorsed by the decree of the Government of the *RF* on 17 February 2014, N 212-p.). The Strategy determines goals, tasks and primary areas of state policy in the area of conservation of rare and endangered species of animals, plants and fungi required to streamline management. The Strategy aims at ensuring a long-term conservation and restoration of rare and endangered species of animals, plants and fungi for the benefits of sustainable development of the RF.

According to the results of the meeting on efficient and safe exploration of the Arctic that was held on 5 June 2014, the President of the RF on 29 June 2014 issued a number of assignments to the Government of the RF. Namely, the Government of the RF, jointly with the scientific and environmental institutions, was commissioned to develop a set of measures meant for biodiversity conservation, including measures to prevent loss of wildlife in the event of an of oil spill and for the prevention as well as reduction of negative environmental impact of economic and other activities on the environment in the Arctic area of the RF. These new measures were gradually introduced by the companies that have acquired licenses for exploration of hydrocarbon reserves in the Russian Arctic such as Rosneft and Gazprom. To monitor the Arctic marine ecosystem, the RF Ministry of Natural Resources and Environment approved a check-list of the flora and fauna species acting as indicators of a sustainable marine ecosystem in the Arctic area of the RF. Among marine mammals, the ringed seal, walrus, white whale, bowhead whale, and polar bear fall into the indicator species category.

Other actions

A. N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences (IEE RAS) developed an educational program for specialists from Arctic regions, enabling them to resolve issues related to problem animals locally. The training course organized by IEE RAS and the Permanent Expedition of Russian Academy of Sciences for study of the Russian Red Data Book animals and other key animals of the Russian fauna incorporates both theoretical as well as hands-on exercises at the Chernogolovka Biological Station of IEE RAS, and includes training on animal immobilization methods. Two training workshops were held (May 2015 and March 2016) with participation of Yamalo-Nenets and Nenets Autonomous Okrugs representatives.

IEE RAS developed and proposed a system of parameters to assess the polar bear and white whale populations for the purpose of using them as indicator species on the state of Arctic ecosystems (Rozhnov, 2015). This work was presented at the scientific session in December 2014 of the Russian Academy of Sciences dedicated to the problems related to exploration of the Arctic.

Within 2014–2015 the experts from the Arctic national refuges, Russian national parks (Russian Arctic, Beringia), the strict nature reserve Wrangel Island, and the Unified Directorate of Taimyr strict nature reserves, with participation of the experts from various scientific and research institutes, developed the polar bear population monitoring program in the federal Special Protected Natural Areas (SPNA) of Russia. The resulting document represents a coordinated polar bear monitoring program along with the specific techniques and data collection protocols. Currently this document is undergoing approval process in the Ministry of Natural Resources and Environment of the RF.

Specially protected natural areas

Many of the key polar bear habitats are kept under protection in SPNAs both at the federal and regional level (Figure 1).

With regards to problem resolution related to polar bear conservation, a significant focus is on the further development of the SPNA system along with restricting human activities at places where the animals aggregate during migration, focal feeding areas, and reproduction periods. To further this effort, in 2014, under support of WWF Russia, a project on expanding SPNAs in the Russian Arctic was launched (Solovyev *et al.* 2015). Specialists from several scientific institutions are involved in the project implementation activities. Also, leading experts from field-specific institutes are engaged in the program. The polar bear was chosen as one species for which the target indicators on reaching a sufficient coverage of key habitats by protected areas are developed. This project is scheduled to be completed by the end of 2016. Conservation of wildlife species, as well as their habitats in the territory of all SPNAs is performed in line with the regulation on each specific area.

Russian Arctic National Park

In 2009, by a decree issued by the Government of the RF, the Russian Arctic National Park (RANP) was established which occupies the northern top-end of the Severny Islands in the Novaya Zemlya archipelago. Its total area amounts to 1,426,000 hectares, including 793,910 hectares of marine area. Important polar bear habitats, including denning areas, are in this protected natural area. In summer months, under the current conditions characterized by ice cover shrinkage, the northern end of Novaya Zemlya is becoming a resting area for polar bears who failed to leave the island along with the retreating ice.

The Franz Josef Land wildlife sanctuary is also managed by the park administration. Therefore, key denning areas for the Barents Sea polar bear subpopulation in the Russian Arctic are managed. Further expansion of SPNA areas in the northeast Barents Sea is also planned. Currently, the RANP includes the Franz Josef Land nature reserve along with Victoria Island. The establishment of a park buffer zone at Novaya Zemlya, including a sizable marine area, is also under consideration. An argument to grant the status of a Natural Protected Area to Victoria Island is based on information regarding the importance of this region for sustaining the Barents Sea polar bear subpopulation.

The RANP performs regular monitoring of polar bears in its territory as well as adjacent areas of the seas and islands according to the protocols of the polar bear population monitoring program in federal SPNA's. All polar bear encounters along with signs of bear activities, including denning, are registered. Data is also obtained from tour ships in the region. Concurrently, via non-invasive techniques, samples hair and scat are collected for further molecular and genetic analysis (the samples are split between the A. N. Severtsov Institute of Ecology and Evolution, and the Institute of General Genetics, RAS). All polar bear encounters are recorded into a georeferenced database. Currently, data from 450 encounters including over 600 individual animals for the period from 2010 to 2015 is stored in the database. Recording of conflict encounters is kept in a separate database. The RANP has developed draft guidelines to minimize the number of conflict situations between humans and polar bears.

Beringia National Park

In 2013, by the Decree of the Government of the RF, Beringia National Park (BNP), which includes vast coastal areas of Chukotka Peninsula, was established. A priority task for the park is to execute monitoring and conservation of the Alaska-Chukotka polar bear subpopulation (i.e., referred to as the Chukchi Sea polar bear subpopulation in all other sections of these proceedings). Kolyuchin Island and areas of Chukchi seacoast including Inkigur Cape, the estuary of Chegitun River with adjacent areas, and Dezhnev Cape were included in BNP boundaries. These areas are known to be important polar bear habitats along the coast of Chukotka during the winter when polar bears scavenge marine animal carcasses (for the most part walrus that failed to survive at the coastal rookeries), as well as use by females for maternal denning.

During 2014–2015, the employees of BNP, with participation of specialists from the Institute of Biological Problems of the North, Far East Branch, Russian Academy of Sciences (IBPN FEB RAS) developed principles for polar bear monitoring in BNP. This new protocol will collect year-round observations and documentation of polar bear encounters and signs of activity, including denning locations. The observations tracked in a BNP database.

In 2015, with support from WWF Russia, BNP started to prepare for establishment of marine protected area to include polar bear and other marine mammals coastal habitats in the Chukchi and Bering seas. In support of this project, BNP, jointly with IBPN FEB RAS, performed stationary surveys and observations at several coastal areas of the park during summer and winter. A Rationale and Draft Regulation on the proposed marine protected zone in BNP will be completed in 2016.

U.S.-Russia polar bear cooperation

In the framework of the International Polar Bear Forum that took place in Moscow on 2 December 2014, a declaration of responsible ministers representing the Polar Bear Range Countries was signed. The declaration says that it is necessary to use the Circumpolar Action Plan (CAP) on the polar bear conservation as indispensable tool for international cooperation in the area of management and reduction of the impact factors on polar bears and their ecosystems in the perspective of implementing the 1973 Agreement. It was emphasized that reductions of the summer time ice extent, reduction of the ice thickness, and fragmentation of the ice-cover in the Arctic under the impact of global warming represents a major threat for polar bears.

The CAP for polar bear conservation was adopted by the Polar Bear Range States on 3 September 2015 in Ilulissat, Greenland. Namely, it envisages further development of cooperation between the Polar Bear Range States on study and preservation of shared populations of the species. Such cooperation between Russia and U.S. is implemented in a framework between the Government of the RF and the Government of the United States of America on the Conservation and Management of the Alaska-Chukotka polar bear population, signed October 2000 in Washington, DC, and entered into force September 2007. According to Article 2 of this agreement, the parties shall cooperate with the goal of ensuring the conservation of the Alaska-Chukotka polar bear population, conservation of its habitat, and regulation of its use for subsistence purposes by native peoples. In doing so, the parties should pay particular attention to denning areas and areas of high polar bear concentration during feeding and migration. Thus, the parties emphasize consistency of the Government of the RF and the Government of the United States of America agreement with the principles of the 1973 agreement between the five Arctic states on the conservation of polar bears.

In 2009 a U.S.-Russia Polar Bear Commission was established that is responsible for coordinating conservation and research activities concerning the Alaska-Chukotka polar bear population. The Commission is composed of native and federal representatives from Alaska and Chukotka. The Commission established a Scientific Working Group to assist the Commission on accomplishment of tasks related to the Alaska-Chukotka polar bear population conservation and management.

The U.S.-Russia Polar Bear Commission authorizes only the indigenous people of Alaska and Chukotka, in accordance with each party's domestic laws, to harvest polar bears to satisfy their traditional subsistence needs and to manufacture and sell handicrafts and clothing. That is why one of the primary goals for the Scientific Working Group, as well as the commission, is to determine a sustainable harvest level and set quotas. The U.S. plans to introduce a quota (or a long-term system of quotas) on polar bears harvesting in Alaska-Chukotka polar bear subpopulation for the coming years. In Russia (Chukotka), the moratorium on harvest from this subpopulation is still in effect.

Another important component of U.S.-Russia cooperation is the development of comprehensive studies and monitoring of Alaska-Chukotka polar bear subpopulation's status. The Scientific Working Group developed a draft Plan for joint research on the Alaska-Chukotka polar bear population that was approved by the U.S.-Russia Polar Bear Commission. Research on polar bears at Wrangel Island represents one of the priority areas in this plan.

Both Russia and the U.S. are actively pursuing efforts to nominate a Bering Strait Protected Area, including the southern part of the Chukchi Sea to be included in the list of UNESCO World heritage sites.

Norway-Russia polar bear cooperation

In 2015 Norway and Russia signed a Memorandum of Understanding for cooperation on monitoring of polar bears in the Barents Sea region. The parties agreed to establish a Norway- Russia working group which is commissioned to develop a joint plan on research related to the Kara-Barents Sea polar bear subpopulation.

Upon the initiative of A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, and Barents Sea branch of WWF, an expert-advisory group was created with a mandate to coordinate efforts of various RF institutions and organizations in the area of research and conservation of the Kara-Barents Sea subpopulation of polar bears.

Polar bear harvest

During the 2010–2015 period, 1–3 polar bears were legally removed in response to conflict incidents. Illegal shootings were recorded at several locations. It is especially sizable in Chukotka, where, according to regional expert opinion (Kochnev and Zdor 2014) in the above period 18–56 (in average 32) polar bears are harvested annually.

Research

Following the meeting of PBSG in Fort Collins, Colorado, scientific research projects on polar bears were conducted by individual scientific institutions and non-governmental organizations. These research efforts touched upon different subpopulations of polar bears.

Kara-Barents Sea subpopulation

The Permanent Expedition of RAS for study of the Russian Red Data Book fauna along with specialists from A.N. Severtsov Institute of Ecology and Evolution (IEE RAS), with financial support provided by the Russian Geographical Society, conducted a set of research projects on polar bears over six years. Between 2010–2015, 42 polar bears were captured. Among them: in the area in the Franz Josef Land federal nature reserve–35 animals, in the territory of the Russian Arctic national park at the northern top-end of Novaya Zemlya–2 animals, near Kamenny Islands in the vicinity of the northwest coast of Taimyr peninsula–6 animals. Ten polar bear females were fitted with satellite radio transmitters at Franz Josef Land, and 1–at on the Taimyr. Information obtained from the collars enabled researchers to keep track of the detailed movements (Platonov *et al.* 2011, Rozhnov *et al.* 2014a, Rozhnov *et al.* 2017). The movements of one polar bear female along the Barents Sea ice was estimated both considering the ice-drift and without such consideration (Platonov *et al.* 2014). By means of satellite telemetry, the relationship between polar bear movements and spring phenology of the sea ice was also estimated. The influence of the summer ice melting on directionality of polar bears movements in Kara Sea was also investigated (Rozhnov *et al.* 2017). Biological samples were obtained from all animals and later processed by the respective institutes.

During the ice-free period in 2010–2014, field-work was conducted at Franz Josef Land Nature Reserve and the Russian Arctic National Park (Zhelaniya Cape, Severny Island, and Novaya Zemlya) with park employees to observe polar bears behavior (Rozhnov *et al.* 2014b). Based on observations and findings during 2010–2012, cannibalism cases among polar bears on Franz Josef Land were documented.

In 2012, a number of islands in Franz Josef Land Nature Reserve as well as Victoria Island were surveyed. Twenty-one individual polar bears were observed – one was a female bear with two cubs of the year and three female bears with single two-year old cubs.

Seropositivity towards various pathogens among 26 individual polar bears caught within 2010–2011 period at Franz Josef Land federal nature reserve was determined via an enzyme-immunoassay method. The samples were tested in labs against presence of anti-bodies to canine distemper virus, Aujeszky's desease, influenza A, toxoplasma, dirofilarias, and *Trichinellaspiralis* (Naydenko *et al.* 2013). One of the conclusions from this work was that all adult and sub adult polar bears captured at Franz-Jozef Land had all six pathogens. However, cubs-of-the-year were seronegative for all pathogens. Seropositivity for *Dirofilaria sp.*, influenza A, and Aujeszky's disease among polar bears in the wild was registered for the first time.

Genetic analysis of tissue samples was completed for more than 40 polar bears, the majority of which were from the Franz Josef Land. Similarity of polar bears' haplotypes for from the archipelago with those from other regions was demonstrated. Research on mercury content in the polar bear hair has also shown that the animals from Franz Josef Land have lower mercury levels compared to polar bears from the western part of the Arctic.

In September 2014, during a survey of the Kara Sea coast, specialists from the Russian Arctic National Park performed additional polar bear counts along 5,000 km of coastline from Vaigach Island and the eastern coast of Novaya Zemlya to the northwestern Taimyr Peninsula. A total of 25 polar bears were observed during this survey.

Following a request from the Russian Arctic National Park, the Arctic and Antarctic Research Institute performs weekly monitoring with satellite remote sensing data of the ice-cover development at the north and east regions of the Kara and Barents seas in the areas within the park. They observed that, from 2011–2015 at the end of summer, abnormally light ice-conditions dominated the region. During the 2011, 2012, 2013, and 2015 seasons, overall ice-coverage in the area of Franz Josef Land was below the average values both for the entire satellite remote sensing period (1979–2015), as well as for the last 15 years. However, the 2014 season, was abnormally difficult in terms of overall ice-coverage being above the average.

Alaska-Chukotka subpopulation

The Wrangel Island Nature Reserve has continued its long-term polar bear monitoring program, including observations of polar bears on Wrangel Island in spring, summer, and autumn. Observations are made during hikes across the island, from cruise ships, and in the course of stationary observations at fixed sites of the island. All sightings were recorded in compliance with standard protocols. The bears' gender, age category, body condition, and the age of dependents in family groups, were estimated when the survey conditions allowed.

The collected data was used to examine the possible effects of climate change on the Alaska- Chukotka polar bear subpopulation (Ovsyanikov 2012, 2014). Observations indicated a sustained decrease of polar bear observations on Wrangel Island, a declining number of families with dependents, a low average size of litters, and suggested a high mortality rate of cubs in the first 18 months of life. These observations may reflect the progressive decrease in reproductive potential of the Alaska-Chukotka polar bear subpopulation due to significant loss of sea ice in this region.

We should say that there are neither reliable estimates of Alaska-Chukotka polar bear subpopulation size, nor its survival rates. The size of Alaska-Chukotka polar bear subpopulation in the early 1990s was estimated as 2,000–5,000 animals (Belikov 1992, 1993). The estimate was based on the number of maternal dens found on the Wrangel Island and along the northern coast of the Chukotka peninsula during aerial surveys in the 1970s–1980s. Considering that the survey methodology for dens count along the continental coastline has been imperfect, and the surveys were conducted at different times, the total estimate should rather be considered an expert judgment even for that period. In 2005, the IUCN Polar Bear Specialist Group estimated the Alaska-Chukotka polar bear subpopulation size at approximately 2,000 animals based on historic data and expert opinions. In 2014, the PBSG revised this estimate and replaced it with "unknown" due to lack of any recent data. Polar bears are widely scattered on sea ice across a huge territory with no observation support infrastructure in place and that makes it very difficult to get a reliable estimate of the Alaska-Chukotka polar bear subpopulation size or survival.

However, despite different conclusions about the Chukotka-Alaska polar bear subpopulation status today, most researchers agree that the biggest long-term danger to this population is the loss of sea ice. This loss will change the time-space distribution of polar bears and some other characteristics of the population status, which most likely will have a negative impact according to the long-term forecasts. However, if the global warming trend is reversed, other anthropogenic impacts will constitute the greatest threat for the polar bear (Belikov 2011).

Within 2010–2015 at Chukotka the monitoring of the polar bear autumn concentrations near the coastal walrus rookery areas on the Chukotka shore which was initiated back in 1999 by Chukotka branch of TINRO-Center (Chukot-TINRO) was continued. In 2014 Beringia National Park as well as Biological Problems of the North Institute joined this work. The research activity incorporated a field-gathering of data on abundance, demography, diet, nutritional status and behavior of the polar bears who after the break-up of the ice during the summer-autumn period stay at Chukotka shore and regularly visit the surroundings of the walrus rookeries (Kryukova *et al.* 2010, Pereverzev and Kochnev 2012, Kryukova and Kochnev 2014). Key observation points were situated at Kolyutchin Island as well as in the vicinity of Serdtse-Kamen, Vankarem and Shmidt Cape along the Chukchi Sea coast. We obtained additional information from various sites in the Bering Sea and Bering Strait where observations were performed by indigenous people in a framework of the "Rookery keepers" project run by the Association of Traditional Marine Hunters of Chukotka (ATMMHC). Over the course of six years the polar bears did not form any considerable gatherings (no more than ten animals at the same place) before freeze-up of the sea apart from the year of 2012 when only at Kolyutchin Island 42 animals were aggregated concurrently.

Observations over relationships between polar bears and walruses constituted an important aspect of the research that enabled to estimate a degree of this predators' impact as a disturbance and mortality factor for walruses at coastal rookeries. Materials pertaining to the initial step of such observations gathered within the 1989–1998 period at Wrangel Island were presented in A.A. Kochnev theses (Kochnev 2015).

Within 2011–2012 period, the Chukot-TINRO in cooperation with the ATMMHC and WWF Russia surveyed 24 residential communities at Chukotka. The questionnaires contained a number of questions related to harvesting and use of polar bears, conflict situations and humans' attitude towards polar bears as well as polar bear harvesting. For further analysis, we engaged data obtained in the course of interviewing indigenous people within the 1999–2006 period. Following that, we obtained information on a multi-year polar bear visits to residential communities, local population protection techniques, scale of illegal hunting and its methods, and use of harvested products. Additionally, we estimated a size of illegal harvesting at Chukotka within the 2010–2012 period (Kochnev and Zdor 2016).

In 2013, the Chukot-TINRO jointly with the ATMMHC, Alaska Nanuuk Commission (ANC), and the Alaska office of the USFWS conducted a specialized survey in thirteen villages along the coast of the East Siberian Sea, the Chukchi Sea, and the Bering Strait. They interviewed 72 local residents to provide detailed accounts of conflicts during human-polar bear encounters. Information on 184 conflicts that occurred from 1944 to 2013 was obtained during through the project. In addition, information on 34 conflicts within 1958–2013 period was also added from published stories of the incidents. IBPN FEB RAS will undertake data analysis and structuring for integration into the international database on human polar bear conflicts. Material from this project was also used for preparation of a circumpolar review on polar bear attacks on humans (Wilder *et al.* 2017).

During 2010–2015, the sociological and ethnographic studies the polar bears role in the material and spiritual culture of indigenous peoples of Chukotka were conducted (Kochnev 2016). In 2012 the ChukotTINRO in cooperation with IBPN FEB RAS, Chukotka union of mammal hunters, and ANC initiated a project to gather the traditional knowledge on polar bears and its habitats. This project was a continuation of similar work performed from 1999–2002 (Kochnev *et al.* 2003). Both projects are an effort to identify changes in polar bear distribution, abundance, and behavior at Chukotka over the decade that passed since the first project was completed.

In 2010–2011 the employees of A.N. Severtsov Institute of Ecology and Evolution and RAS performed both vessel and aerial observations of marine mammals and polar bears in the waters of Arctic Russia from the scientific and research vessel "Michail Somov". In 2010 they also incorporated polar bear observations from the coast of Wrangel Island (Solovyev *et al.* 2012). Based on these surveys an attempt was undertaken to evaluate a number of polar bears at the island using simplified modeling as well as polar bear density values depending on distance from the shore. The team also assessed a pilot effort analyzing the potential to observe marine mammals and polar bears via high resolution satellite imagery near Herald Island in Chukchi Sea (Platonov *et al.* 2013). This technique enabled the detection of animals and traces of recent activity, suggesting a promising future for further applications.

Other polar bear research projects

Under the framework of the Working Group on Area 5 U.S.-Russia cooperation on the environment, the employees of A.N. Severtsov Institute of Ecology and Evolution and RAS continue to study the ice distribution and ice volume in the areas of polar bear habitat. The last assessment was done during the time of summer minimum extent along the length of sea ice habitat for polar bears in 2011–2013 using satellite passive microwave sensing of the Russian Arctic seas and adjacent Arctic basin areas (Mordvintsev *et al.* 2011; Platonov *et al.* 2012). Comparing the ice-conditions over a period of satellite-based observations (from 1979 to 2013), it was identified that the sea ice extent was close to the record low value recorded in 2007. However, the spatial distribution of the ice at the end of summer in 2007 and 2011 was not the same due to impacts of atmospheric circulation on the ice-edge location. It was also demonstrated that, starting from 2003, the speed of ice cover reduction increased by a factor of 4. Additional analysis allowed the creation of a linear model that enables short-term forecasts of ice-conditions in the Arctic, as well as reconstruction of summer ice concentration values down to the middle of this century using air temperature data.

In addition, IEE RAS examined the impacts of different polar bear immobilization techniques using cortisol measures in the blood as a proxy. The lowest levels of blood cortisol correlated to immobilization done from a helicopter and through use of a honey-trap (i.e., baited trap). These techniques appeared comparable with controlled immobilization trials using captive bears.

In 2006, WWF initiated the Polar Bear Patrol project in collaboration with the All-Russian Research Institute for Environmental Protection and the Marine Mammal Council, along with representatives of local and indigenous people from a number of coastal communities located along the Russian Arctic coast. Initially, the network of Polar Bear Patrols included 14 communities, one protected area, and 5 polar weather stations. The initiative received support from the administration of Chukotka Autonomous Okrug along with public associations of indigenous people. In the community of Vankarem, the Polar Bear Patrol also incorporates data on maternal dens, including the number of cubs, into their observation notes.

The initial task for the Polar Bear Patrol was guarding the outskirts of communities during times of polar bear activity. Work included the prevention of conflicts between humans and polar bears and remains one of their key tasks today. Today, these patrols collect basic information on polar bears, taking notes of time and place of the encounters, number of animals, gender, as well as age composition when possible. Lastly, some patrol participants are also involved in the non-invasive collection of biological samples from polar bears for genetic analysis.

The Marine Mammal Council, a regional non-governmental organization, conducted a research project in 2013 that received support from the Russian Geographical Society. Experts from All-Russian Research Institute for Environmental Protection also participated in the project. The following activities were executed (Boltunov *et al.* 2014b): a) aerial survey of the spring coastal habitats of polar bears along the Arctic shore of Chukotka during the maximum ice-cover period, and collection of biological samples; b) aerial survey of the Arctic shore of Chukotka, approximately 800 km, and polar bear count at the coast during the ice-free season, along with the collection of biological samples; c) genetic analysis of the polar bear samples collected.

During the spring 2013 survey, the project participants registered all observations of polar bears along the coast. Special attention was given to searching for females with cubs-of-the-year or traces of them. This data enables us to identify probable maternal denning areas. All polar bears encountered during the aerial survey in summer 2013 (15 animals, including one female with a cub) were observed either on shore or in water nearshore. Survey flights over the tundra that were approximately 10–20 kilometers from shore, with a total transect length of around 150 km, failed to locate any polar bears. Apparently, polar bear distribution is determined by two major factors:

- availability of abundant and accessible food resources on shore (the field-project participants have discovered 7 grey whale and walrus carcasses that washed ashore (Belikov *et al.* 2014);
- weather conditions during the project execution period were calm and sunny, so the animals tend to stay by a cooler marine shore where the wind blows. Also, whenever danger occurs polar bears always try to walk away to the sea.

Genetic analysis of the samples obtained from the survey work shows relations between polar bears from 2013 sampling to the animals whose samples were taken via non-invasive techniques during several previous years in Chukotka. Polar bears whose samples were taken in 2013 were related to at least 6 other animals represented by the previous years' samples.

From 24–27 April 2014 an aerial survey of the sea ice was performed from Russky Zavorot Cape in the northeast part of the Barents Sea to the Kara Sea areas that are adjacent to Vaigach Island and the northwestern part of the Baidaratskaya Bay (Boltunov *et al.* 2014a). The survey flights were performed by MI-8MT helicopter. The work was organized by the Marine Mammals Council in cooperation with WWF Russia. The study area was approximately 30,000 $км^2$; total distance was 3600 km, of which the length of "effective" transects accounted for 2,700 km. Altogether, 18 observations of polar bears (27 bears in total) were registered, and traces of polar bear presence were encountered 42 times. In the territory of a polar station at Bolvansky Nos Cape, at Vaigach Island, the carcass of polar bear was found. Another recently killed polar bear was discovered near the northwestern top end of Vaigach Island.

In April 2015, in collaboration with WWF Russia, staff from the Russian Arctic National Park and the Marine Heritage Association explored the seas at the northeastern part of the Kara Sea as well as a piece of area at the northeast part of Laptev Sea and down east from Severnaya Zemlya archipelago, including a polynya in order to assess a status of spring habitats of polar bears, marine mammals and birds. In the course of helicopter surveys along the route, around 2500 km, 11 polar bears were observed, including two family groups. Locations of bear and track observations were mapped along with marine mammal prey sighted.

From 2014–2015 the Marine Mammals Council performed a number of studies (field, laboratory and office studies) with funding from OJSC Arctic Scientific Center, a subsidiary company for OJSC Rosneft Oil Company. All-Russia Research Institute for Environmental Protection employees also took part in this work. The following activities were performed:

- collection of polar bear encounter data and evidence of polar bear presence (tracks, kills, etc);
- collection of biological samples from polar bears and remains of their prey;
- capture and satellite collaring of polar bears;
- deployment of autonomous photo-recorders at Wrangel Island

Field research activities were performed as three complex expeditions organized by Rosneft Oil Company in 2014 and 2015 on a route from the Barents Sea to the Chukchi Sea:

- 13 August–29 September 2014 helicopter operations based on "Academic Treshnikov" scientific research vessel; and ground based work on Wrangel Island;
- 8 April–15 June 2015 helicopter operations based on "Yamal" atomic ice-breaker;
- 14 September–14 October 2015 helicopter and ground based work

on the coast of the East Siberian and Chukchi Seas as well as on Wrangel Island.

As a result of field activities, the following was accomplished:

- approximately 400 biological samples were taken from polar bears and prey species;
- more than 300 encounters with polar bears were registered;
- the condition of over 20 polar bears was comprehensively studied through capture;
- satellite collars were deployed to monitor movements;
- more than 50 trail cameras were mounted at Wrangel and Herald islands;
- obtained biological samples were submitted for further lab processing to perform genetics, hematological tests, and identify composition and content values of some pollutants.

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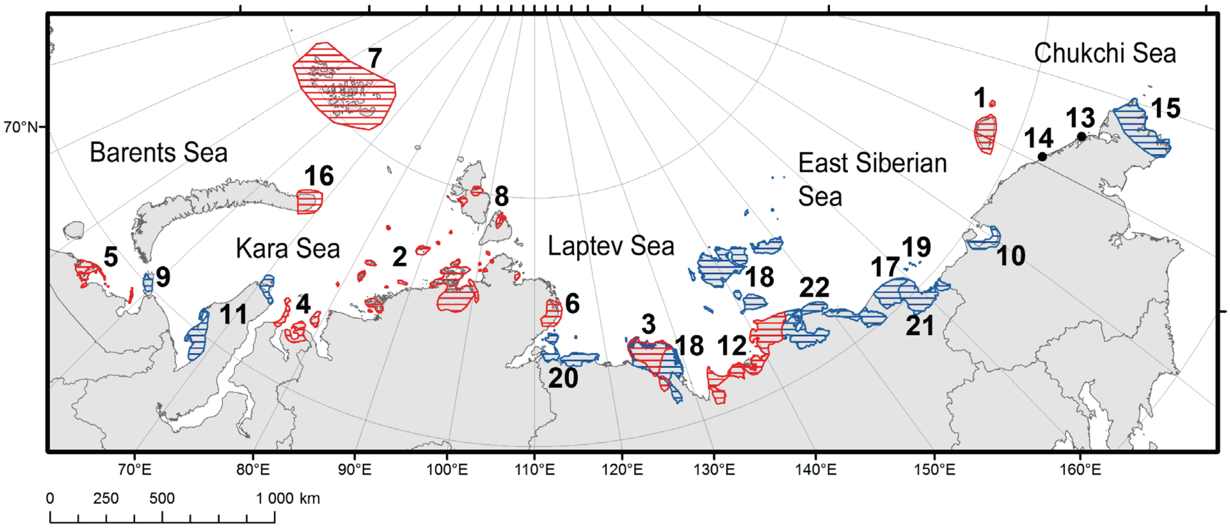
Figures

Fig. 1. Specially Protected Natural Areas in the Russian Arctic where regular appearance of polar bears is observed.
State strict nature reserves (zapovedniks): 1. Wrangel Island; 2. Great Arctic; 3. Ust-Lensky; 4. Gydansky; 5. Nenets; 6. Taimyr (part of Great Arctic).
State federal nature reserves (zakazniks): 7. Franz Josef Land; 8. Severozemelsky. State regional nature reserves: 9. Vaigach; 10. Chaunskaya Guba; 11. Yamalsky; 12. Yanskiye Mammoths.
Regional natural monuments: 13. Cape Vankarem; 14. Cape Kozhevnikov. National parks: 15. Beringia; 16. Russian Arctic.
Resource reserves: 17. Kurdigino-Krestovaya; 18. Lena Delta; 19. Medvezh'yi islands; 20. Terpey-Tumus; 21. Chaigurgino; 22. Katalyk.



U.S. Fish and Wildlife Service Management and Conservation on Polar Bears, 2010–2016

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The U.S. Fish and Wildlife Service (USFWS) has primary management responsibility for polar bears in Alaska. The objective of the USFWS Polar Bear Program is to ensure that polar bear populations in Alaska continue to be healthy, functioning components of the Bering, Chukchi, and Beaufort Sea ecosystems. The USFWS's conservation activity is largely mandated by the Marine Mammal Protection Act (MMPA) and by the Endangered Species Act (ESA). The U.S. is also a member of international treaties and agreements calling for coordinated polar bear conservation.

The U.S. is in the range of two polar bear subpopulations: the Chukchi Sea[6] (CS) and the Southern Beaufort Sea (SB). Polar bear subsistence harvest from the CS subpopulation is managed jointly by the U.S. and Russia under the U.S.-Russia Bilateral Agreement on the Conservation of the Alaska-Chukotka Polar Bear Population (U.S.-Russia Bilateral Agreement). The subsistence harvest of polar bears from the SB subpopulation is managed voluntarily by Alaska Natives in the U.S. under a user-to-user agreement, the Inuvialuit-Inupiat Polar Bear Management Agreement in the Southern Beaufort Sea (I-I Agreement), which was signed in 1988 and reaffirmed in 2000 by the Inuvialuit Game Council and the North Slope Borough (NSB) Fish and Game Management Committee.

To inform management and conservation actions required under the ESA and MMPA, USFWS conducts a range of management, monitoring, and research activities on both the CS and SB subpopulations. These activities involve collaboration with the U.S. Geological Survey,

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[5] Present address: Polar Science Center - Applied Physics Laboratory, Box 355640, University of Washington, 1013 NE 40th Street, Seattle, Washington, 98105, USA
[6] Also referred to as the "Alaska-Chukotka" subpopulation, noting differences in management boundaries as recognized by the PBSG and under the U.S.-Russia Bilateral Agreement on the Conservation of the Alaska-Chukotka Polar Bear Population (US-Russia Bilateral Agreement).

NSB, Alaska Department of Fish and Game, Alaskan Native organizations and communities, industry, non-governmental organizations, and other organizations in the U.S. and internationally.

Endangered Species Act (ESA)

On May 15, 2008, the USFWS published a Final Rule in the Federal Register listing the polar bear as a threatened species under the ESA (73 FR 28212).[7] The listing was based on the best available science, which shows that loss of sea ice threatens and will likely continue to threaten polar bear habitat. Any significant changes in the abundance, distribution, or existence of sea ice will have effects on the number and behavior of these animals and their prey. This loss of habitat puts polar bears at risk of becoming endangered in the foreseeable future, the standard established by the ESA for designating a threatened species.

The USFWS published a Special Rule (78 FR 11766)[8] on February 20, 2013, establishing how activities that may harm the threatened polar bear will be managed under the ESA. The Special Rule effectively maintains the management and conservation framework that has been in effect for the polar bear since it was first protected under the ESA in 2008. The Special Rule, issued under Section 4(d) of the ESA, avoids redundant regulation under the ESA by adopting the longstanding and more stringent protections of the MMPA and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as the primary regulatory provisions for this threatened species.

Conservation Management Plan

On January 7, 2017, the USFWS released a final Conservation Management Plan (CMP) for the polar bear (USFWS 2016), which fulfills obligations under the ESA and MMPA. The CMP outlines actions that will help polar bears persist in the wild in the near-term, while also acknowledging that addressing the primary threat of climate change will require longer-term global actions. The CMP was developed by a diverse team of experts and partners and reflects input on the draft plan submitted during the 2015 public comment period. It calls for reducing human-bear conflicts, collaboratively managing subsistence harvest, protecting denning habitat, and minimizing the risk of contamination from oil spills. Most of these actions are already underway, in partnership with Alaska Native communities, nonprofit groups, and industry representatives who participated in the CMP's creation. The CMP also calls for increased monitoring and research to determine the health of Alaska's two subpopulations and whether the plan's actions are being effective or need to be modified. Further, the CMP calls for a science-based communication effort to highlight the urgent need for significant reductions in emissions to help achieve a global atmospheric level of greenhouse gases that will support conditions for recovery of polar bears from projected declines. The USFWS will continue to work with diverse partners to implement the CMP. The team will share information, identify priorities, leverage resources and adapt the plan according to new and emerging science and information. While the CMP focuses on management actions for the two U.S. subpopulations of polar bears that live off the coast of Alaska, it also contributes to efforts to conserve polar bears in the other four range states of Norway, Greenland, Canada, and Russia.

Critical Habitat

The USFWS designated critical habitat for the polar bear on January 6, 2011 (75 FR 76086).[9]

[7] Available at https://www.federalregister.gov/documents/2008/05/15/E8-11105/endangered-and-threatened-wildlife-and-plants-determination-of-threatened-status-for-the-polar-bear.

[8] Available at https://www.federalregister.gov/documents/2013/02/20/2013-03136/endangered-and-threatened-wildlife-and-plants-special-rule-for-the-polar-bear-under-section-4d-of.

[9] Available at https://www.federalregister.gov/documents/2010/12/07/2010-29925/endangered-and-threatened-wildlife-

The critical habitat designation identified geographic areas that contained features essential for the conservation of the polar bear within Alaska. Polar bear critical habitat included the following habitat types: barrier island habitat, sea ice habitat (both habitats are described in geographic terms), and terrestrial denning habitat (described as a functional determination). Barrier island habitat includes coastal barrier islands and spits along Alaska's coast, which is used for denning, refuge from human disturbance, access to maternal dens, feeding habitat, and travel along the coast. Sea ice habitat is located over the continental shelf, and includes water 300 m (~984 ft) or less in depth. Terrestrial denning habitat includes lands within 32 km (~20 mi) of the northern coast of Alaska between the Canadian border and the Kavik River and within 8 km (~5 mi) of the northern coast of Alaska between the Kavik River and Barrow. The total area designated covers approximately 484,734 km^2 (~187,157 mi^2), and is entirely within the lands and waters of the U.S.

5-year Review

As required by the ESA, on February 22, 2017, the UFSWS completed a status review of the polar bear (USFWS 2017). After a thorough review of new and updated scientific information on polar bear biology and threats, the USFWS concluded that the species continues to meet the definition of a threatened species under the ESA.

Marine Mammal Protection Act (MMPA)

The MMPA was enacted in 1972 for the protection and conservation of marine mammals and their habitats. The MMPA includes provisions for a variety of activities; details of specific provisions are provided in the sections below.

Incidental Take and Intentional Take Programs

Under the Incidental and Intentional Take Program, citizens or groups covered by incidental take regulations, such as oil and gas operators, may apply for a Letter of Authorization (LOA), which, if granted, allows for incidental "take" (as defined under the MMPA)[10] of polar bears during authorized activities. Prior to issuance of an LOA, the USFWS requests companies submit, with the USFWS's assistance if necessary, a plan of cooperation. Most "take" resulting from industry interactions with polar bears is limited to short-term changes in bear behavior (e.g., a bear may avoid or investigate an area of industry activity). The LOAs include measures to minimize such impacts; examples include proper management of "attractants" (such as food and garbage) or placement of a "no activity" one-mile buffer around known dens. At present, regulations for incidental take related to oil and gas activities are in effect in the Chukchi Sea region until 2018. New regulations for the Beaufort Sea region were promulgated in August 2016 for a five-year period.

Directed take (also referred to as intentional harassment or deterrence) authorization is requested when bears may need to be deterred from human-use areas. An example of this type of take is the NSB's Polar Bear Patrol Program, funded by the USFWS. The NSB's program works with coastal communities to deter bears. A similar program exists in oil field areas.

For both incidental and intentional take activities, LOAs include monitoring and reporting requirements. Monitoring and reporting results provide a basis for evaluating

and-plants-designation-of-critical-habitat-for-the-polar-bear.

[10] "Take", as defined under the MMPA, is "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal, including, without limitation, any of the following: the collection of dead animals or parts thereof; the restraint or detention of a marine mammal, no matter how temporary; tagging a marine mammal; or the negligent or intentional operation of an aircraft or vessel, or the doing of any other negligent or intentional act which results in the disturbing or molesting of a marine mammal."

current and future impacts of activities on bears. During the most recent five-year period for which data are complete (2010 to 2014), the oil and gas industry reported a total of 1,234 observations of 1,911 polar bears. Of the 1,911 bears observed, no incidental (i.e., disturbance) take of bears were reported for 81 percent of the bears (1,549 bears). Of the remaining 362 bears observed, incidental takes were reported for 78 bears. The oil and gas industry reported intentional takes by deterrence activities for 260 bears. Effects were unknown for 23 bears, and one lethal take of a bear occurred as a result of industrial activity.

Co-management with Alaska Natives

On November 8, 2016, the USFWS published an Advanced Notice of Proposed Rulemaking (81 FR 78560) that has two purposes: 1) to solicit public comments on developing and administering a co-management partnership with Alaska Natives for their subsistence use of polar bears in Alaska; and 2) to solicit preliminary ideas about the best way to ensure polar bear take limits established by the U.S.-Russia Bilateral Agreement are not exceeded. Because Alaska Native harvest of polar bears has never been federally regulated, the USFWS believes it is important to hear from the public, and especially Alaska Natives, on potential management options for this subsistence harvest. The public comment period closed January 9, 2017. The USFWS hopes to have a new Alaska Native co-management partner formed and functioning in 2017.

Research Activities

Chukchi Sea Capture-recapture Popuation Studies

Accurate scientific information is needed for management and conservation of the Chukchi Sea subpopulation of polar bears. The Chukchi Sea subpopulation inhabits the Bering, Chukchi, and eastern Siberian seas, located west of Alaska. The USFWS and collaborators reinitiated research on the Chukchi Sea subpopulation in 2008. Focal areas of study include nutritional condition, health, and feeding ecology; distribution and habitat use; and population dynamics (e.g., reproductive and survival rates). In 2016, the USFWS and partners analyzed data collected during live-recapture research on the Chukchi Sea subpopulation conducted during the periods 2008–2011, 2013, and 2015–2016. The core data consist of 421 physical captures collected during springtime sampling in the U.S. portion of the Chukchi Sea region between the Seward and Lisburne peninsulas; and movement data from 107 radiocollars and 77 ear-mounted or glue-on satellite tags.

Auxiliary data that were analyzed include search effort from helicopter tracklogs, information on whether bears denned successfully (obtained from radiotelemetry data), spring-time weaning status of two-year-olds, and litter size distribution of yearlings. The goals of the analysis were to estimate abundance and vital rates (e.g., recruitment, survival) and/or related indices for this subpopulation. Analyses were conducted using a multi-event, integrated capture-recapture model that was based on the polar bear life cycle and included "un-observable states", which allowed modeling the movement of bears with respect to the sampling area and thus reduce potential bias in estimated parameters.

Density estimates (bears/km^2) were derived for the sampling area and then extrapolated to larger geographic areas of interest (e.g., the management boundaries of the Chukchi Sea subpopulation) based on indices of habitat use derived from resource selection functions. Findings from this analysis will be submitted for publication in 2017.

Southern Beaufort Sea Coastal Surveys

Fall coastal surveys for polar bears along the northern Alaskan coastline, between Barrow, Alaska, and the Canadian border, were conducted by the USFWS between 2000 and 2014. The USFWS has analyzed those data (USFWS unpublished data) to estimate the weekly number of polar bears on shore in fall; identify annual trends, if any, in the number of bears on shore; and determine which factors influence the number and distribution of bears along the coast. Preliminary results suggest:

(a) The mean annual number of polar bears onshore during the study was 140 (95% CI: 127–157).

(b) The number of polar bears on shore each week was strongly related to sea ice conditions; with more bears on shore when ice return dates were later.

(c) Distribution of polar bears on shore was affected by sea ice conditions, presence of barrier islands, and presence of subsistence-harvested whale carcasses. Polar bears tended to occur in greater numbers in areas with whale remains, more barrier island habitat, and earlier dates of sea ice return in fall.

Instrument-based Aerial Surveys for Polar Bears and Ice Seals in the Chukchi Sea

The National Marine Fisheries Service, in collaboration with USFWS and other partners, conducted instrument-based aerial surveys for ice seals and polar bears in U.S. portions of the Chukchi Sea region in spring 2016. Surveys consisted of 25 flights totaling 15,720 km (9,768 mi) of search effort in Alaska. Concurrent surveys were flown by a Russian research team in Russian portions of the Chukchi Sea region. Data were collected remotely via an array of thermal cameras on which marine mammals show up as "hot spots", and high-resolution digital cameras that can subsequently determine the species of animal. Preliminary results suggest that images from the thermal-digital camera combination, when processed using automated software, successfully detected approximately 75% of the polar bears on the surface of the sea ice. Therefore, based on a study design analysis that was completed prior to the surveys (Conn *et al.* 2016), indications are that the instrument-based approach will provide a useful estimate of abundance for the Chukchi Sea polar bear subpopulation. Results from this effort are expected to be published in 2018 or 2019.

Performance and retention of lightweight satellite radio tags applied to the ears of polar bears — Satellite telemetry studies provide information that is critical to the conservation and management of species affected by ecological change. Here we report on the performance and retention of two types (SPOT-227 and SPOT-305A) of ear-mounted Argos-linked satellite transmitters (i.e., Platform Transmitter Terminal, or PTT) deployed on free-ranging polar bears in Eastern Greenland, Baffin Bay, Kane Basin, the southern Beaufort Sea, and the Chukchi Sea during 2007–2013. Transmissions from 142 out of 145 PTTs deployed on polar bears were received for an average of 69.3 days. The average functional longevity, defined as the number of days they transmitted while still attached to polar bears, for SPOT-227 was 56.8 days and for SPOT-305A was 48.6 days. Thirty-four of the 142 (24%) PTTs showed signs of being detached before they stopped transmitting, indicating that tag loss was an important aspect of tag failure. Furthemore, 10 of 26 (38%) bears that were re-observed following application of a PTT had a split ear pinna, suggesting that some transmitters were detached by force. All six PTTs that were still on bears upon recapture had lost the antenna, which indicates that antenna breakage was a significant contributor to PTT failure. Finally, only nine of the 142 (6%) PTTs - three of which were still attached to bears - had a final voltage reading close to the value indicating battery exhaustion. This suggests that battery exhaustion was not a major factor in tag performance. The average functional longevity of approximately two months for ear-mounted PTTs (this study) is poor compared to PTT collars fitted to adult female polar bears, which can last for several years. Early failure of the ear-mounted PTTs appeared to be caused primarily by detachment from the ear or antenna breakage. We suggest that much smaller and lighter ear- mounted transmitters are necessary to reduce the risk of tissue irritation, tissue damage, and tag detachment, and with a more robust antenna design. Our results are applicable to other tag types (e.g., Iridium and VHF systems) and to research on other large mammals that cannot wear radio collars.

Wiig, Ø., Born, E.W., Laidre, K.L., Deitz, R., Jensen, M.V., Durner, G.M., Pagano, A.M., Regehr, E.V., St. Martin, M., Atkinson, S., and Dyck, M. 2017. Performance and retention of lightweight satellite radio tags applied to the ears of polar bears (*Ursus maritimus*). *Animal Biotelemetry* 5:9.

Identifying polar bear resource selection patterns to inform offshore development in a dynamic and changing Arctic — Although sea ice loss is the primary threat to polar bears, little can be done to mitigate its effects without global efforts to reduce greenhouse gas emissions. Other factors, however, could exacerbate the impacts of sea ice loss on polar bears, such as exposure to increased industrial activity. The Arctic Ocean has enormous oil and gas potential, and its development is expected to increase in the coming decades. Estimates of polar bear resource selection will inform managers how bears use areas slated for oil development and to help guide conservation planning. We estimated temporally-varying resource selection patterns for non-denning adult female polar bears in the Chukchi Sea population (2008–2012) at two scales (i.e., home range and weekly steps) to identify factors predictive of polar bear use throughout the year, before any offshore development. From the best models at each scale, we estimated scale-integrated resource selection functions to predict polar bear space use across the population's range and determined when bears were most likely to use the region where offshore oil and gas development in the United States is slated to occur. Polar bears exhibited significant intra-annual variation in selection patterns at both scales but the strength and annual patterns of selection differed between scales for most variables. Bears were most likely to use the offshore oil and gas planning area during ice retreat and growth with the highest predicted use occurring in the southern portion of the planning area. The average proportion of predicted high-value habitat in the planning area was .15% of the total high-value habitat for the population during sea ice retreat and growth and reached a high of 50% during November 2010. Our results provide a baseline on which to judge future changes to non-denning adult female polar bear resource selection in the Chukchi Sea and help guide offshore development in the region. Lastly, our study provides a framework for assessing potential impacts of offshore oil and gas development to other polar bear populations around the Arctic.

Wilson, R.R., Horne, J.S., Rode, K.D., Regehr, E.V., and Durner, G.M. 2014. Identifying polar bear resource selection patterns to inform offshore development in a dynamic and changing Arctic. *Ecosphere* 5:136.

Invariant polar bear habitat selection during a period of sea ice loss — Climate change is expected to alter many species' habitat. A species' ability to adjust to these changes is partially determined by their ability to adjust habitat selection preferences to new environmental conditions. Sea ice loss has forced polar bears to spend longer periods annually over less productive waters, which may be a primary driver of population declines. A negative population response to greater time spent over less productive water implies, however, that prey are not also shifting their space use in response to sea ice loss. We show that polar bear habitat selection in the Chukchi Sea has not changed between periods before and after significant sea ice loss, leading to a 75% reduction of highly selected habitat in summer. Summer was the only period with loss of highly selected habitat, supporting the contention that summer will be a critical period for polar bears as sea ice loss continues. Our results indicate that bears are either unable to shift selection patterns to reflect new prey use patterns or that there has not been a shift towards polar basin waters becoming more productive for prey. Continued sea ice loss is likely to further reduce habitat with population-level consequences for polar bears.

Wilson, R.R., Regehr, E.V., Rode, K.D., and St. Martin, M. 2016. Invariant polar bear habitat selection during a period of sea ice loss. *Proceedings of the Royal Society B* 283:20160380.

Harvesting wildlife affected by climate change: a modelling and management approach for polar bears —

(a) The conservation of many wildlife species requires understanding the demographic effects of climate change, including interactions between climate change and harvest, which can provide cultural, nutritional or economic value to humans.
(b) We present a demographic model that is based on the polar bear life cycle and includes density-dependent relationships linking vital rates to environmental carrying capacity (*K*). Using this model, we develop a state-dependent management framework to calculate a harvest level that (i) maintains a population above its maximum net productivity level (MNPL; the population size that produces the greatest net increment in abundance) relative to a changing *K*, and (ii) has a limited negative effect on population persistence.
(c) Our density-dependent relationships suggest that MNPL for polar bears occurs at approximately 0.69 (95% CI = 0.63–0.74) of *K*. Population growth rate at MNPL was approximately 0.82 (95% CI = 0.79–0.84) of the maximum intrinsic growth rate, suggesting relatively strong compensation for human-caused mortality.
(d) Our findings indicate that it is possible to minimize the demographic risks of harvest under climate change, including the risk that harvest will accelerate population declines driven by loss of the polar bear's sea-ice habitat. This requires that (i) the harvest rate – which could be 0 in some situations – accounts for a population's intrinsic growth rate, (ii) the harvest rate accounts for the quality of population data (e.g. lower harvest when uncertainty is large), and (iii) the harvest level is obtained by multiplying the harvest rate by an updated estimate of population size. Environmental variability, the sex and age of removed animals and risk tolerance can also affect the harvest rate.
(e) *Synthesis and applications*. We present a coupled modelling and management approach for wildlife that accounts for climate change and can be used to balance trade-offs among multiple conservation goals. In our example application to polar bears experiencing sea-ice loss, the goals are to maintain population viability while providing continued opportunities for subsistence harvest. Our approach may be relevant to other species for which near-term management is focused on human factors that directly influence population dynamics within the broader context of climate-induced habitat degradation.

Regehr, E., Wilson, R., Rode, K., Runge, M., and Stern, H. 2017. Harvesting wildlife affected by climate change: a modeling and management approach for polar bears. *Journal of Applied Ecology*. doi: 10.1111/1365-2664.12864.

Conservation status of polar bears in relation to projected sea-ice declines — Loss of Arctic sea ice owing to climate change is the primary threat to polar bears throughout their range. We evaluated the potential response of polar bears to sea-ice declines by (i) calculating generation length (GL) for the species, which determines the timeframe for conservation assessments; (ii) developing a standardized sea-ice metric representing important habitat; and (iii) using statistical models and computer simulation to project changes in the global population under three approaches relating polar bear abundance to sea ice. Mean GL was 11.5 years. Ice-covered days declined in all subpopulation areas during 1979–2014 (median -1.26 days year^{-1}). The estimated probabilities that reductions in the mean global population size of polar bears will be greater than 30%, 50% and 80% over three generations (35–41 years) were 0.71 (range 0.20–0.95), 0.07 (range 0–0.35) and less than 0.01 (range 0–0.02), respectively.

According to IUCN Red List reduction thresholds, which provide a common measure of extinction risk across taxa, these results are consistent with listing the species as vulnerable. Our findings support the potential for large declines in polar bear numbers owing to sea-ice loss, and highlight near-term uncertainty in statistical projections as well as the sensitivity of projections to different plausible assumptions.

Regehr, E., Laidre, K., Akçakaya, H.R., Amstrup, S., Atwood, T., Lunn, N., Obbard, M., Stern, H., Thiemann, G., and Wiig, Ø. 2016. Conservation status of polar bears (*Ursus maritimus*) in relation to projected sea-ice declines. *Biology Letters* 12:20160556.

Polar bear-grizzly bear interactions during the autumn open-water period in Alaska — Reduction of summer sea ice extent has led some polar bear populations to increase their use of land during the summer/autumn open-water period. While terrestrial food resources are generally not sufficient to compensate for lost hunting opportunities on the sea ice, marine mammal carcasses, where available, could help reduce the energetic cost of longer periods of land use. Subsistence-harvested bowhead whale (*Balaena mysticetus*) remains are available annually near local communities along the Alaskan portion of the Beaufort Sea coast to bears that come to shore. Relatively large numbers of polar bears and some grizzly bears (*U. arctos*) use these resources, creating a competitive environment among species and social classes. We documented competitive interactions among polar bears and between polar and grizzly bears for bowhead whale remains adjacent to a small community in northeastern Alaska in September 2005–2007. We observed temporal partitioning of the resource by bears, with lone adult polar bears and grizzly bears primarily feeding at night, and higher use by polar bear family groups and subadults during dawn and dusk. Interspecific interactions were less frequently aggressive than intraspecific interactions, but polar bears were more likely to be displaced from the feeding site by grizzly bears than by conspecifics. Female polar bears with cubs were more likely to display aggressive behavior than other social classes during intra- and interspecific aggressive interactions. Our results indicate that grizzly bears are socially dominant during interspecific competition with polar bears for marine mammal carcasses during autumn.

Miller, S., Wilder, J., and Wilson, R.R. 2015. Polar bear-grizzly bear interactions during the autumn open-water period in Alaska. *Journal of Mammalogy* 96:1317–1325.

Polar Bear Harvest and Human-Caused Removals

With the assistance of local taggers in Alaska's communities, the USFWS's Marking, Tagging, and Reporting Program (MTRP) collects and analyzes data and samples on polar bears harvested by Alaska Natives during subsistence activities. Receiving accurate and timely harvest data helps the USFWS to sustainably manage Alaska's polar bear populations, allows for documentation of traditional subsistence use, and provides information for monitoring the health and status of polar bears in Alaska. This information is critical to enabling the USFWS and partners to manage polar bears and human activities for continued subsistence opportunities.

Co-management of the Alaskan Harvest of the Alaska–Chukotka Polar Bear Subpopulation: How to Implement a Harvest Quota — The Alaska Department of Fish and Game, the Alaska Nanuuq Commission, and the USFWS conducted a review of the USFWS's Alaska-Chukotka (i.e., Chukchi Sea) polar bear subpopulation harvest database compiled by the MTRP. The review identified needed polar bear harvest reporting improvements and provided recommendations to enhance effective implementation of the US-Russia Bilateral Agreement and co-management between the USFWS and Alaska Native co-management partners.

Schliebe, S.L., Benter, B., Regehr, E.V., Quakenbush, L., Omelak, J., Nelson, M., and Nesvacil, K. 2016. Co-management of the Alaskan harvest of the Alaska-Chukotka polar bear subpopulation: how to implement a harvest quota. Wildlife

Technical Bulletin ADF&G/DWC/WTB-2016-15. Alaska Department of Fish and Game, Juneau, Alaska, U.S.A., 65 pp.

Reported Polar Bear Mortality in Alaska, 2007–2016

Statewide Removal of Polar Bears

For the period 2007–2016, 462 polar bear mortalities due to human causes were reported in Alaska (Table 1). Of the 462 bear mortalities reported, 277 bears (61%) were reported as male, 98 (21%) as female, and the sex was unknown or was not reported for 8 bears (18%). If the assumption is made that bears of unknown or unreported sex are female, the revised female removal is 179 bears (39%). Removals were reported in all months of the year, but the majority of mortalities occurred in spring (March, April, and May) (Figure 2). Mortalities include those from subsistence activities, defense of life, industry- and research-related mortalities, and other causes (Table 2).

In addition to the 462 reported bear mortalities from human causes, six bears were reported with unknown causes of death; three were reported in 2012, two in 2013, and one in 2014. Nine bears were reported as having died from natural causes from 2007 to 2016.

Statewide Harvest of Polar Bears by Alaska Natives for Subsistence Purposes

Reported polar bear harvest for subsistence purposes by Alaska Natives statewide totaled 425 bears for the period from 2007 to 2016 (Table 3). Sex composition of the 425 bears reported as harvested for subsistence purposes was similar to the total removals described above: 259 bears (61%) were reported as male, 89 (21%) as female, and the sex was unknown or was not reported for 77 bears (18%). If the assumption is made that bears of unknown or unreported sex are female, the revised female harvest 166 bears (39%).

The statewide average annual harvest for subsistence purposes was 43 bears, and ranged from a low of 14 bears (in 2015) to a high of 84 bears (in 2012). Statewide subsistence harvest was also reported in all months of the year, but the majority of harvest occurred in spring (March, April, and May) (Figure 1).

Removal of Polar Bears in Villages Party to the I-I Agreement

In Alaska villages party to the I-I Agreement,[11] 195 polar bear mortalities due to human causes were reported for the period 2007 to 2016. Of the 195 bears reported as removed, 115 (59%) were reported as male, 37 (19%) were reported as female, and the sex was unknown or was not reported for 43 bears (22%). If the assumption is made that bears of unknown or unreported sex are female bears, the revised female removal is 80 bears (41%). Removals were reported in all months of the year, with slightly higher monthly averages in May and September (Figure 1).

Harvest of Polar Bears by Alaska Natives for Subsistence Purposes in Villages Party to the I-I Agreement

Reported polar bear harvest for subsistence purposes by Alaska Natives in villages party to the I-I Agreement totaled 174 bears for the period from 2007 to 2016 (Table 3). Of the 174 bears reported as harvested for subsistence purposes in villages party to the I-I Agreement, 101 bears (58%) were reported as male, 32 (18%) as female, and the sex was unknown or was not reported for 41 bears (24%). If the assumption is made that bears of unknown or unreported sex are female bears, the revised female harvest totals 73 bears (42%). This sex composition was similar to that reported for statewide harvest, though the sex was unknown

[11] Alaska villages party to the I-I Agreement are: Atqasuk, Barrow, Kakatovik, Nuiqsut, and Wainwright.

or unreported for a higher percentage of bears in villages party to the I-I Agreement.

The average annual harvest of polar bears in villages party to the I-I Agreement was 17 bears, and ranged from a low of nine bears (in 2015) to a high of 31 bears (in 2013). Polar bears were harvested more consistently year-round in villages party to the I-I Agreement than when compared to statewide harvest (Figure 2). The lowest levels of harvest in villages party to the I-I Agreement generally occurred in summer and fall months (i.e., the open water season), with the exception of September, the month in which fall subsistence whaling activities generally occur.

Management and Monitoring Activities

Community-based Conservation Activities at Barter Island

The USFWS has been conducting community-based conservation activities at Kaktovik, Alaska (on Barter Island), annually during the fall open water period since 2002. The overall goals are to monitor the number, age/sex class, body condition, and habitat use patterns of bears that come to shore and aggregate near the community, and to minimize human-bear conflicts. Monitoring results indicate that, on average, there were 30 polar bears per year from 2002 to 2016 at Barter Island during the core monitoring period (September 7–26); no definitive upward or downward trend in abundance is apparent (Figure 2). However, an increasing trend in the number of bears present at the onset of our core monitoring period seems to be occurring. For example, during the first five years of the study (2002–2006), no more than 30 bears were counted during the first week of September. In 2012–2016, we observed a minimum of 30 and up to 69 bears during the first week of September in all years except 2015. Additionally, in 2016, 51 bears were present as early as August 17, 2016, and 38 bears were still present during our final count on October 13, 2016. Local residents also reported that about ten bears remained in the area until mid-November, most of which were family groups and sub-adult bears. These observations are similar to other scientific findings that polar bears in the Beaufort Sea are arriving earlier on shore, increasing their length of stay, and departing later back to sea ice (Atwood et al. 2016).

To reduce human-bear conflicts, the USFWS has been funding locally-hired Polar Bear Patrols since 2010 through a deterrence program implemented locally by the NSB. Patrollers are trained to use non-lethal methods to keep bears out of town, which has been effective in providing community protection for local residents, as well as reducing the number of bears killed in conflict situations in Kaktovik during the fall open water season. Another effort to reduce human-bear conflicts in town involves managing food attractants by working with the non-profit organization Defenders of Wildlife to provide household food storage lockers that are designed to store subsistence foods in a manner that prevents access by bears. As of 2016, four families have been provided with new, improved models that have been effective in preventing bears from receiving food rewards in town. The USFWS continues to work with Defenders of Wildlife to seek additional funding for the construction of additional lockers, with the hopes that they can be provided to all families in the community over the next few years.

Tourism and Recreational Viewing

The National Wildlife Refuge System Improvement Act of 1997 identifies wildlife observation as one of the six priority public uses of Refuges. In Alaska, the majority of polar bear tourism and viewing occurs on Barter Island, in and near the village of Kaktovik. The reliable annual presence of polar bears on land near Kaktovik has become increasingly known to the public, resulting in an increasing number of visitors who wish to view polar bears.

Growing tourism has resulted in an increasing need for the USFWS Arctic National Wildlife Refuge to manage boat-based polar bear viewing on Refuge waters surrounding Barter Island. Commercial uses of Arctic National Wildlife Refuge lands are monitored to ensure activities are compatible with the purposes of the Refuge. This oversight, formalized through Special Use Permits (SUPs), seeks to meet the mission of the USFWS and the Refuge System, and comply with other applicable laws (e.g., ESA and MMPA), while allowing for responsible commercial uses. To avoid potential negative impacts to polar bears from recreational viewing, and to address visitor concerns about potential crowding while viewing polar bears, in 2016 Arctic Refuge implemented a voluntary 27 m (90 ft) distance buffer for boats viewing polar bears. Further, USFWS staff "meet and greet" visitors, work with the Kaktovik Youth Ambassadors to deliver polar bear safety and awareness information, and provide input on the Refuge's efforts to develop a comprehensive polar bear viewing management strategy that will address the significant increase in polar bear viewing around Kaktovik.

Guided recreational polar bear viewing 2015–2016 summary report — Visitor use data from Arctic Refuge come from SUP reports submitted by commercial guides operating boats on the waters surrounding Barter Island for the purposes of polar bear viewing.[12] From 2011 to 2016, the viewing season (i.e., the period from the first to last date that commercial guides operate during a year) averaged 87 days, from a minimum of 61 days (in 2016) to a maximum of 108 days (in 2015) due to variations in environmental conditions (i.e., availability of open water) and guide schedules. However, the number of viewing days (i.e., the number of days commercial guides operated during the viewing season) averaged 56 days, from a minimum of 36 days (in 2011; a 94-day viewing season) to 80 days (in 2015; a 108-day viewing season). The number of views[13] of polar bears increased sharply from 260 views in 2011 to an estimated 2500 views in 2016; daily average views increased from 7 in 2011 to 43 in 2016. Lastly, the average daily viewing hours for all operators combined increased from 7 hours (in 2011) to 30 hours (in 2016).

Polar bear viewing increased sharply between 2011 and 2015; however, between 2015 and 2016, visitor use numbers were fairly static, indicating that the maximum number of visitors that can be accommodated may have been met due to limits on available commercial flights, visitor housing, and number of authorized boat guides.

USFWS. 2017. Guided recreational polar bear viewing 2015-2016 summary report. Arctic National Wildlife Refuge. Available at: https://www.fws.gov/uploadedFiles/Region_7/NWRS/Zone_1/Arctic/PDF/2015-16%20PBV%20Summary%20Report.pdf.

Non-lethal Deterrence of Polar Bears

The USFWS works with partners to conduct polar bear training programs, such as polar bear awareness and safety, polar bear deterrence, and train-the-trainer programs. In 2016, the USFWS conducted eight training courses with a total of 73 participants. Fifty-two students attended six polar bear deterrence training courses and 21 students completed two separate train-the-trainer courses. The USFWS published a polar bear deterrence train-the-trainer manual in 2015 (USFWS 2015b).

Since 2010, the USFWS has been providing funding, training assistance, and on-the-ground support to the NSB Polar Bear Patrol program in Kaktovik. This program involves specially trained local residents who provide a critical safety function for their community and contribute to polar bear conservation by deterring bears from the village using non-lethal methods.

Oil Spill Preparedness

The USFWS has identified minimizing risk of contamination from oil spills as a high priority conservation and recovery action in the Polar

[12] Due to missing information from some client use report, and inconsistent client use reporting, the data are considered to reflect minimum numbers, be preliminary, and are subject to change.

[13] "Views" defined here as the count of all individuals, guides as well as clients, for each trip they take, even if individuals take multiple trips per day.

Bear Conservation Management Plan (USFWS 2016). We have been working with various partners to increase response capabilities for polar bears if an oil spill were to occur. While the USFWS's response strategy emphasizes preventative measures, significant steps have been taken in the last five years to improve response capabilities for treating a small number of oiled polar bears. For example, the USFWS has joined other response partners to form a marine mammal working group to improve communication and planning among response partners for marine mammals and conduct field drills.

The USFWS updated the *Oil Spill Response Plan for Polar Bears in Alaska* (USFWS 2015a). The Plan classifies response activities for polar bear protection into primary, secondary and tertiary strategies. Primary response involves keeping spilled oil away from polar bears and physical protection of areas most important to polar bears. Primary response strategies also include guidance on the removal of oiled carcasses from the environment to prevent scavenging/ingestion by polar bears. Secondary response is designed to prevent polar bears from entering oiled areas. Tertiary response involves the capture, handling, transport, and treatment of oiled bears, and either their return to the wild or placement in a designated facility.

Progress has been made toward increasing capacity to treat a small number of oiled polar bears in Alaska, including the design and construction of specialized equipment such as washing tables, transport cages, and a collapsible polar bear holding pen (Miller 2016). In addition, two experiments were conducted in 2012 to determine how best remove oil from polar bear fur, with promising results (S. Jensen, unpublished data).

In 2016, USFWS initiated a study to determine the potential effects of oil spills in the Chukchi and Beaufort Seas during autumn by running spill simulations for four sites in the Beaufort Sea where oil production occurs, and four sites in the Chukchi Sea where production may occur in the future. Simulations at Beaufort Sea wells were for a discharge of 4,800 barrels/day from an underwater pipeline for a six day period, with released oil being tracked in the environment for a period of 50 days following the spill. Simulations in the Chukchi Sea also allowed for an underwater 'blowout' with a discharge of 25,000 barrels/day for 30 days, with released oil being tracked in the environment for a period of 75 days following the spill. The model predicted the probability that different areas of the ocean and coastline were oiled for all scenarios and the location and density of oil during each day of the simulation. Data derived from this study are currently being used to determine how much polar bear habitat would likely be affected by an oil spill in each region, and how many bears might be exposed to oil if a spill were to occur. This information will be useful for planning purposes on how to respond to an oil spill, how large of a response might be needed, and where resources might be best deployed. The simulation component of the study was completed in June 2016 and the USFWS expects to complete an assessment of the potential impact to polar bears in 2017.

International Treaties and Conventions

U.S.-Russian Bilateral Agreement

The U.S.-Russia Bilateral Agreement was signed in 2000 to address the need for coordinated management of the shared Chukchi Sea (i.e., Alaska-Chukotka) polar bear subpopulation that inhabits the Chukchi and northern Bering seas. This treaty identified goals to improve polar bear conservation and safeguard the cultural and traditional use of polar bears by Native peoples. For Native peoples of Chukotka, this treaty is intended to re-establish their ability to hunt polar bears for subsistence purposes. The Treaty established a joint U.S.-Russia Commission responsible for making management decisions concerning polar bears in this region. The Commission is composed of a Native and federal representative from each country.

At a meeting in June 2010, the Commission decided to place an upper limit on harvest from the Chukchi Sea subpopulation of 19 female and 39 male (for a total of 58) polar bears per year based on the recommendation of the Scientific Working Group (SWG; the body formed to advise the Commission) and identified subsistence needs. This harvest limit has been re-affirmed by the Commission each year through 2016, and is split evenly between Native peoples of Alaska and Chukotka. Therefore, the Alaskan share of the harvest is 29 polar bears (20 males and 9 females). The scientific basis for this decision was documented in a 2010 report of the SWG[14]. A notice of the sustainable harvest limit was most recently published in the Federal Register on January 20, 2016 (81 FR 3153).

Scientific Working Group of the U.S.-Russia Bilateral Agreement

The U.S.-Russia Bilateral Agreement established SWG, the body responsible for providing expert advice to the Commission on the basis of science and Traditional Knowledge. The SWG helps the Commission meet the dual goals of conserving and protecting the Chukchi Sea polar bear subpopulation, and of providing opportunities for sustainable subsistence use by Native people in a manner consistent with national laws, as specified by the U.S.-Russia Bilateral Agreement. The SWG consists of American and Russian co-chairs, plus up to seven members from each country. Members are selected and confirmed by the Commission on the basis of having scientific or traditional knowledge of polar bear biology, habitat, or wildlife management; and of having a direct and active role in research, management, or conservation of the Chukchi Sea polar bear subpopulation.

Since its formation in 2009, the SWG has met annually to review new information on the status of the Chukchi Sea subpopulation and to provide recommendations to the Commission. The SWG has developed planning documents including joint study plans applicable to the entire subpopulation, and specific to polar bears on Wrangel Island. Documents related to the work of the SWG are available at https://www.fws.gov/alaska/fisheries/mmm/polarbear/swg.htm.

Inuvialuit-Inupiat Agreement (I-I Agreement)

The I-I Agreement, signed in 1988 and reaffirmed in 2000 by the Inuvialuit Game Council, and the NSB Fish and Game Management Committee, is a voluntary user-to-user agreement between Inuvialuit (in Canada) and Inupiat (in Alaska) hunters. The I-I Agreement provides for annual quotas, hunting seasons, protection of bears in or during construction of dens, females accompanied by cubs-of-the-year and yearlings, collection of information and specimens to monitor harvest composition, and annual meetings to exchange information on the harvest, research, and management (Brower *et al.* 2002). The I-I also establishes a Joint Commission to implement the I-I Agreement, and a Technical Advisory Committee, consisting of biologists from agencies in the U.S. and Canada involved in research and management, to collect and evaluate scientific data and make recommendations to the Joint Commission.

1973 Agreement on the Conservation of Polar Bears and Their Habitat (The Range States Agreement)

In 1973, Canada, Denmark (Greenland), Norway, the Soviet Union, and the U.S. (collectively referred to as "the Range States") met and signed the Agreement on the Conservation of Polar Bears (the 1973 Agreement). The 1973 Agreement was created due to concern over polar bear harvest levels, largely as a result of sport hunting, and calls for cooperative international management and protection of polar bears. Each country agreed to take appropriate action to protect the ecosystems of which polar bears are a part, and to manage polar bear populations in accordance with sound conservation practices based on the best available scientific data. In addition, the 1973 Agreement allows for traditional harvest of polar bears by local people using traditional

[14] Report available online at https://www.fws.gov/alaska/fisheries/mmm/polarbear/swg.htm.

methods, but requests additional protections for polar bear family groups and denning bears.

The Range States adopted a 10-year Circumpolar Action Plan (CAP) in 2015 (Polar Bear Range States 2015). The CAP emphasizes international cooperation to conserve polar bears across their range. The vision of the CAP is to secure the long-term persistence of polar bears in the wild that represent the genetic, behavioral, and ecological diversity of the species. This vision cannot be achieved without adequate mitigation of greenhouse gas emissions by the global community. The objectives of the CAP are to:

(a) Minimize threats to polar bears and their habitat;
(b) Communicate to the public, policy makers, and legislators around the world the importance of mitigating greenhouse gas emissions to polar bear conservation;
(c) Ensure the preservation and protection of essential habitat for polar bears;
(d) Ensure responsible harvest management systems today that will sustain polar bear subpopulation for future generation;
(e) Manage human-bear interactions to ensure human safety and to minimize polar bear injury or mortality; and,
(f) Ensure that international legal trade of polar bears is carried out according to conservation principles and that poaching and illegal trade is curtailed.

In 2015, the Trade Working Group of the Range States produced six recommendations to counter the threat of poaching and illegal trade in polar bear parts, enhance cooperation among law enforcement agencies, improve the clarity of legal trade data, and improve identification of legally traded specimens.

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Tables

Table 1. Reported human-caused polar bear mortalities in Alaska, by sex and village, 2007–2016.

	2007			2008			2009			2010			2011			2012			2013			2014			2015			2016			Total
Village	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	
Atqasuk*	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Barrow*	5	7	3	1	11	3	3	5	2	4	3	3	1	7	5	2	3	2	1	7	9	2	4	1	0	3	0	2	9	0	108
Brevig Mission	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cape Lisburne	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Fort Yukon	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gambell	4	7	0	0	0	0	0	0	0	2	0	0	0	0	0	4	10	3	0	0	1	0	1	2	0	0	0	0	2	0	36
Kaktovik*	1	0	0	0	2	0	4	1	1	0	0	0	0	0	0	0	2	0	2	2	2	0	1	0	0	0	0	1	0	0	19
Kivalina	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	5
Kotzebue	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Little Diomede	2	3	0	3	1	0	3	3	0	0	0	0	1	0	0	0	4	0	0	1	1	0	1	0	0	0	0	0	2	0	25
Noatak	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nome	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Noorvik	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nuiqsut*	0	0	0	0	0	0	1	0	1	0	0	2	0	0	0	2	2	0	1	1	0	0	0	0	0	0	1	0	0	2	13
Point Hope	2	7	1	5	5	5	1	3	1	0	2	1	4	28	2	7	16	8	1	12	2	0	6	0	0	3	1	1	6	0	130
Point Lay	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	5
Prudhoe Bay	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
Savoonga	5	5	2	1	0	0	0	1	0	1	4	1	0	0	0	1	1	0	0	2	0	0	1	0	0	0	0	0	0	0	25
Shishmaref	0	3	1	0	0	0	0	0	0	0	0	0	1	3	0	0	1	1	0	2	1	0	1	0	0	0	0	0	1	0	15
Wainwright*	0	0	1	0	1	0	0	0	0	0	3	0	0	5	0	0	11	2	1	8	1	2	3	0	0	7	0	1	6	1	53
Wales	1	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	8
Total	23	36	9	11	21	9	12	14	5	7	14	7	12	44	7	16	53	17	8	37	18	4	18	4	0	14	2	5	26	3	456

* Villages party to the I-I Agreement.

Table 2. Reported types of human-caused polar bear mortalities in Alaska, 2007–2016.

Mortality Type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Subsistence	68	39	26	24	59	81	55	22	14	30	418
Defense of life	0	1	4	3	2	2	6	0	2	4	24
Research mortality	0	0	1	0	0	0	0	0	0	0	1
Industry	0	0	0	0	1	0	0	0	0	0	1
Struck and lost	0	0	0	1	0	3	1	2	0	0	7
Zoo collection	0	0	0	0	1	0	1	0	0	0	2
Euthanized	0	1	0	0	0	0	0	0	0	0	1
Defense of life (by a non-Native person)	0	0	0	0	0	0	0	2	0	0	2
Total	68	41	31	28	63	86	63	26	16	34	456

Table 3. Reported harvest of polar bears by Alaska Natives in Alaska, by sex and village, 2007–2016.

	2007			2008			2009			2010			2011			2012			2013			2014			2015			2016			Total
Village	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	
Atqasuk	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Barrow	5	7	3	1	10	3	3	5	2	4	3	2	1	6	5	1	3	2	1	7	9	2	4	1	0	3	0	2	7	0	102
Brevig Mission	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gambell	4	7	0	0	0	0	0	0	0	2	0	0	0	0	0	4	10	3	0	0	1	0	1	2	0	0	0	0	2	0	36
Kaktovik	1	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	2	0	2	2	2	0	0	0	0	0	0	1	0	0	13
Kivalina	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	5
Kotzebue	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Little Diomede	2	3	0	3	1	0	3	3	0	0	0	0	1	0	0	0	4	0	0	1	1	0	1	0	0	0	0	0	2	0	25
Noatak	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nome	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Noorvik	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nuiqsut	0	0	0	0	0	0	1	0	1	0	0	2	0	0	0	2	2	0	1	1	0	0	0	0	0	0	0	0	0	2	12
Point Hope	2	7	1	5	5	5	1	3	1	0	1	1	4	28	2	7	16	7	1	11	2	0	6	0	0	3	1	1	6	0	127
Point Lay	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	4
Savoonga	5	5	2	1	0	0	0	1	0	1	4	1	0	0	0	1	1	0	0	2	0	0	1	0	0	0	0	0	0	0	25
Shishmaref	0	3	1	0	0	0	0	0	0	0	0	0	1	2	0	0	1	1	0	2	1	0	1	0	0	0	0	0	1	0	14
Wainwright	0	0	1	0	1	0	0	0	0	0	2	0	0	5	0	0	11	2	1	4	1	2	3	0	0	6	0	1	4	1	45
Wales	1	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	8
Total	23	36	9	10	20	9	8	13	5	7	12	6	10	42	7	15	53	16	7	31	18	4	17	3	0	13	1	5	22	3	425

Figures

Fig. 1. Average reported mortality and subsistence removals of polar bears in Alaska, and in Alaska villages party to the I-I Agreement, 2007–2016.

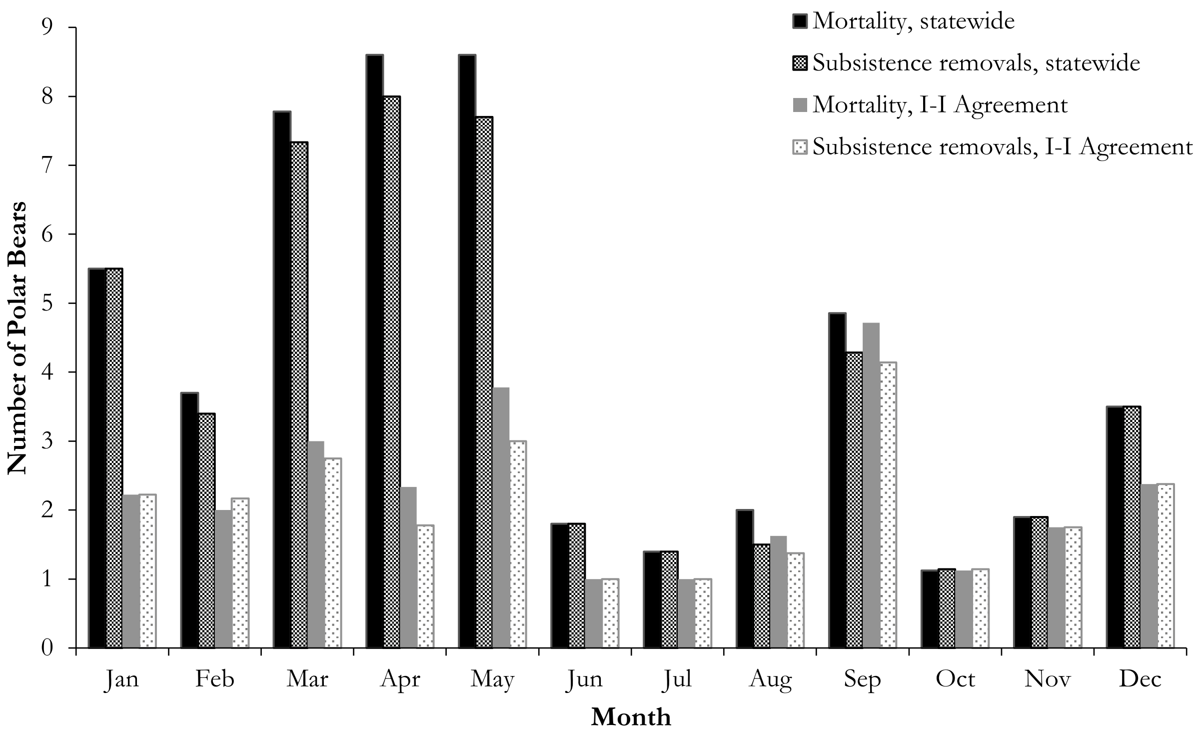
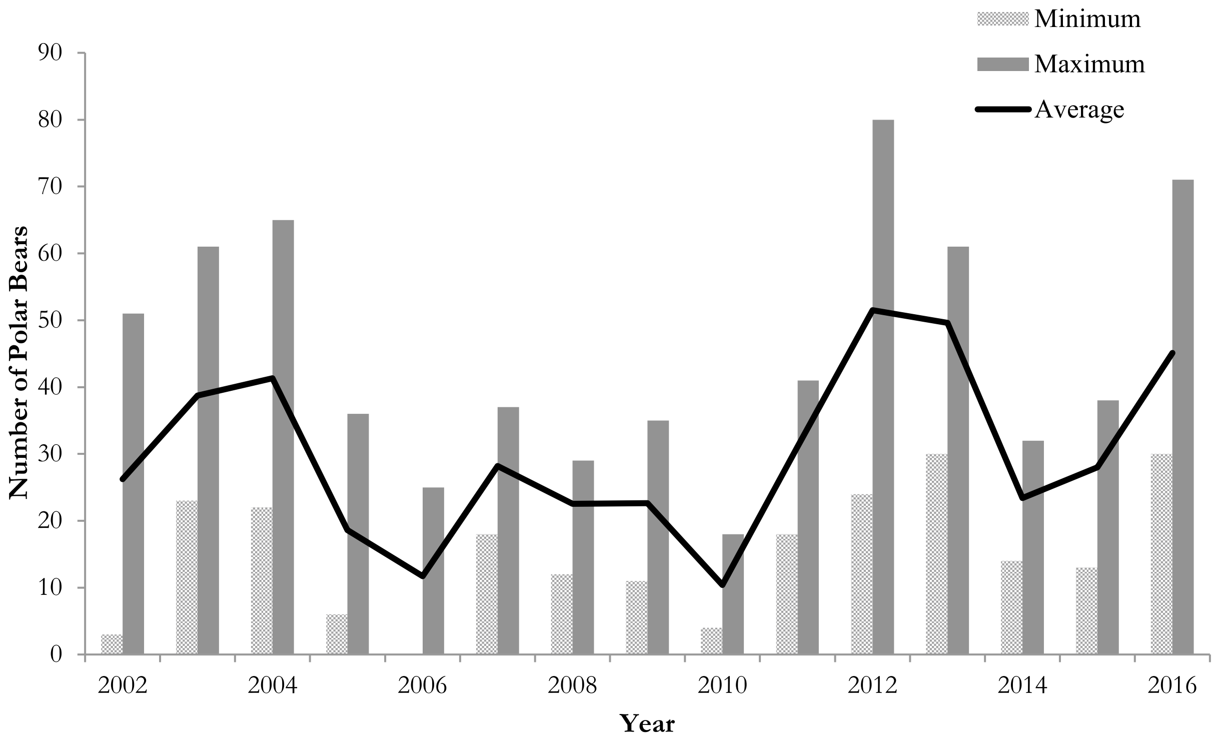


Fig. 2. Polar bears observed at Barter Island, Alaska, September 7–26, 2002–2016.



U.S. Geological Survey Research on Polar Bears, 2010–2016

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Since the 15th Working Meeting of the Polar Bear Specialist Group in 2009, the U.S. Geological Survey (USGS) continued its studies directed towards understanding the status of the subpopulation of polar bears in the southern Beaufort Sea. Research objectives were targeted at quantifying polar bear population dynamics, movements and distribution, foraging behavior, habitat use, health, and the impacts of climate change. USGS continues this research in order to address the information needs of management agencies within the Department of the Interior (DOI), including the U.S. Fish and Wildlife Service (USFWS), Bureau of Land Management (BLM), and Bureau of Ocean Energy Management (BOEM). This research also serves to inform the co-management agreement between the Inuvialuit Game Council in Canada and the North Slope Borough in the United States.

Since 2007, the USGS has continued research on the relationship between polar bears and their changing environment. Much of our previous and continuing long-term research has employed standard mark-recapture methods, though significant effort and resources are being devoted to adapting and developing less- and non-invasive methods for studying polar bears. Research efforts are largely focused on improving our capacity to model population responses to changing environmental conditions and reducing the uncertainty of population forecasts.

Southern Beaufort Sea Subpopulation

USGS polar bear research is focused on developing indices of population vital rates in the Southern Beaufort Sea (SB) subpopulation, and improving our understanding of how polar bears are responding to environmental change. The USGS is committed to describing and explaining the environmental mechanisms that determine the status and trend of polar bear populations. The USGS continues to welcome international collaborations that help reduce the uncertainty of forecasts for those polar bear subpopulations in Alaska and elsewhere, particularly regions with limited data.

The USGS has conducted annual mark-recapture field work in the SB during late-March through mid-May (spring). The primary focus is to maintain a consistent data record for continued future assessments of age and sex composition, survival, and recruitment. The spring capture work also provides valuable body condition and physiological data representative of the SB subpopulation. Additionally, a small subset of bears is radio-tagged to assess movements and habitat use, and distribution and timing of maternal denning. This long-term program has been the foundation of the information provided to managers and stakeholders in Alaska and neighboring areas for more than 30 years.

Characteristics of the SB spring sampling

During spring field work in 2010-2016, we captured an average of 59 ± 17 (SD) polar bears per year. This is less than the 88 ± 14 SD individuals captured each year during 2005-2009. We assessed body condition of captured animals using a subjective fatness index in which condition category 1 represents a bear in very poor condition and condition category 5 represents an obese bear. From 2010-2016, the annual proportion of independent sub-adult (<5 years old) and adult bears (without dependent young) in condition category 3 (i.e., "average") was 0.48, 0.83, 0.79, 0.85, 0.80, 0.65, and 0.89, respectively. Although there was considerable fluctuation of proportions within each condition category, no category 1 and category 5 bears were reported during the duration and no category 4 bears were observed during spring 2015 (Fig. 1).

The proportion of bears in the spring sample by major age class for each year is presented in Figure 2. Since 2010, a large proportion of the captures have been adult bears. The proportion of cubs-of-the-year (COY) has remained relatively unchanged, while the proportions of yearlings and 2-yr-old animals have declined. No 2-yr old bears were observed in 2014 or 2015.

The annual proportion of recaptures by total captures for adult (≥5 years) polar bears encountered by standard search (i.e., opportunistic) in the SB during spring is shown in Table 1. The proportion of recaptures has averaged 58% since 2010. The percentage of recaptured bears in 2016 was 47%, the lowest recorded during spring field work since 2011.

Recent Research

Population ecology studies

Forecasting the relative influence of environmental and anthropogenic stressors on polar bears — Effective conservation planning requires understanding and ranking threats to wildlife populations. We developed a Bayesian network model to evaluate the relative influence of environmental and anthropogenic stressors, and their mitigation, on the persistence of polar bears. Overall sea ice conditions, affected by rising global temperatures, were the most influential determinant of population outcomes. Accordingly, unabated rise in atmospheric greenhouse gas (GHG) concentrations was the dominant influence leading to worsened population outcomes, with polar bears in 3 of 4 ecoregions reaching a dominant probability of decreased or greatly decreased by the latter part of this century. Stabilization of atmospheric GHG concentrations by mid-century delayed the greatly reduced state by ≈25 yr in two ecoregions. Prompt and aggressive mitigation of emissions reduced the probability of any regional population becoming greatly reduced by up to 25%. Marine prey availability, linked closely to sea ice trend, had slightly less influence on outcome state than sea ice availability itself. Reduced mortality from hunting and defense of life and property interactions resulted in modest declines in the probability of a decreased or greatly decreased population outcome. Minimizing other stressors such as trans-Arctic shipping, oil and gas exploration, and contaminants had a negligible effect on polar bear outcomes, although the model was not well-informed with respect to the potential influence of these stressors. Adverse consequences of loss of sea ice habitat became more pronounced as the summer ice-free period lengthened beyond 4 months, which could occur in most of the Arctic basin after mid-century if GHG emissions are not promptly reduced. Long-term conservation of polar bears would be best supported by holding global mean temperature to ≤ 2°C above pre-industrial levels. Until further sea ice loss is stopped, management of other stressors may serve to slow the transition of populations to progressively worsened outcomes, and improve the prospects for their long-term persistence.

Atwood, T.C., Marcot, B., Douglas, D., Amstrup, S., Rode, K., Durner, G., and Bromaghin, J. 2016. Forecasting the relative influence of environmental and anthropogenic stressors on polar bears. *Ecosphere* 7(6):e01370.10.1002/ecs2.1370.

Evaluating and ranking threats to the long-term persistence of polar bears — The polar bear was listed as a globally threatened species under the U.S. Endangered Species Act (ESA) in 2008, mostly due to the significant threat to their future population viability from rapidly declining Arctic sea ice. A core mandate of the ESA is the development of a recovery plan that identifies steps to maintain viable populations of a listed species. A substantive evaluation of the relative influence of putative threats to population persistence is helpful to recovery planning. Because management actions must often be taken in the face of substantial information gaps, a formalized evaluation hypothesizing potential stressors and their relationships with population persistence can improve identification of relevant conservation actions. To this end, we updated a Bayesian network model previously used to forecast the future status of polar bears worldwide. We used new information on actual and predicted sea ice loss and polar bear responses to evaluate the relative influence of plausible threats and their mitigation through management actions on the persistence of polar bears in four ecoregions. We found that polar bear outcomes worsened over time through the end of the century under both stabilized and unabated greenhouse gas (GHG) emission pathways. Under the unabated pathway (i.e., RCP 8.5), the time it took for polar bear populations in two of four ecoregions to reach a dominant probability of greatly decreased was hastened by about 25 years. Under the stabilized GHG emission pathway (i.e., RCP 4.5), where GHG emissions peak around the year 2040, the polar bear population in the Archipelago Ecoregion of High Arctic Canada never reached a dominant probability of greatly decreased, reinforcing earlier suggestions of this ecoregion's potential to serve as a long-term refugium. The most influential drivers of adverse polar bear outcomes were declines to overall sea ice conditions and to the marine prey base. Improved sea ice conditions substantively lowered the probability of a decreased or greatly decreased outcome, while an elevated marine prey base was slightly less influential in lowering the probability of a decreased or greatly decreased outcome. Stressors associated with *in situ* human activities exerted considerably less influence on population outcomes. Reduced mortality from hunting and defense of life and property interactions resulted in modest declines in the probability of a decreased or greatly decreased population outcome. Minimizing other stressors such as trans-Arctic shipping, oil and gas exploration, and point-source pollution had negligible effects on polar bear outcomes, but that could be attributed to uncertainties in the ecological relevance of those specific stressors. Our findings suggest adverse consequences of loss of sea ice habitat become more pronounced as the summer ice-free period lengthens beyond 4 months, which could occur in portions of the Arctic by the middle of this century under the unabated pathway. The long-term persistence of polar bears may be achieved through ameliorating the loss of sea ice habitat, which will likely require stabilizing CO_2 emissions at or below the ceiling represented by RCP 4.5. Management of other stressors may serve to slow the transition of polar bear populations to progressively worsened outcomes, and improve the prospects of persistence, pending GHG mitigation.

Atwood, T.C., Marcot, B., Douglas, D., Amstrup, S., Rode. K., Durner, G., and Bromaghin, J. 2015. Evaluating and ranking threats to the long-term persistence of polar bears. U.S. Geological Survey, Open-File Report, 2014–1254, 114 p., http://dx.doi.org/10.3133/ofr20141254.

Summer declines in activity and body temperature offer polar bears limited energy savings — Polar bears summer on the sea ice or, where it melts, on shore. Although the physiology of "ice" bears in summer is unknown, "shore" bears purportedly minimize energy losses by entering a hibernation-like state when deprived of food. Such a strategy could partially compensate for the loss of on-ice foraging opportunities caused by climate change. However, here we report gradual, moderate declines in activity and body temperature of both shore and ice bears in summer, resembling energy expenditures typical of fasting, nonhibernating mammals. Also, we found that to avoid unsustainable heat loss while swimming, bears employed unusual heterothermy of the body core. Thus, although well adapted to seasonal ice melt, polar bears appear susceptible to deleterious declines in body condition during the lengthening period of summer food deprivation.

Whiteman, J.P., Harlow, H.J., Durner, G. M., Anderson-Sprecher, R., Albeke, S.E., Regehr, E.V., Amstrup, S.C., and Ben-David, M. 2015. Summer declines in activity and body temperature offer polar bears limited energy savings. *Science* 349(6245):295–298. doi:10.1126/science.aaa8623.

Polar bears in the Beaufort Sea: population decline and stabilization in the 2000's — In the southern Beaufort Sea of the United States and Canada, prior investigations have linked declines in summer sea ice to reduced physical condition, growth, and survival of polar bears. Combined with projections of population decline due to continued climate warming and the ensuing loss of sea ice habitat, those findings contributed to the 2008 decision to list the species as threatened under the U.S. Endangered Species Act. Here, we used mark–recapture models to investigate the population dynamics of polar bears in the southern Beaufort Sea from 2001 to 2010, years during which the spatial and temporal extent of summer sea ice generally declined. Low survival from 2004 through 2006 led to a 25–50% decline in abundance. We hypothesize that low survival during this period resulted from (1) unfavorable ice conditions that limited access to prey during multiple seasons; and possibly, (2) low prey abundance. For reasons that are not clear, survival of adults and cubs began to improve in 2007 and abundance was comparatively stable from 2008 to 2010, with ~900 bears in 2010 (90% CI = 606–1212). However, survival of subadult bears declined throughout the entire period. Reduced spatial and temporal availability of sea ice is expected to increasingly force population dynamics of polar bears as the climate continues to warm. However, in the short term, our findings suggest that factors other than sea ice can influence survival. A refined understanding of the ecological mechanisms underlying polar bear population dynamics is necessary to improve projections of their future status and facilitate development of management strategies.

Bromaghin, J.F., McDonald, T.L., Stirling, I., Derocher, A.E., Richardson, E.S., Regehr, E.V., Douglas, D.C., Durner, G.M., Atwood, T., and Amstrup, S.C. 2015. Polar bear population dynamics in the southern Beaufort Sea during a period of sea ice decline. *Ecological Applications* 25:634–651.

Demographic composition and behavior of polar bears summering on shore in Alaska — Historically, polar bears of the southern Beaufort Sea (SB) have remained on the sea ice year-round (except during denning), but recent changes in the extent and phenology of sea ice habitat have coincided with increased use of terrestrial habitat. We characterized the demographic composition, spatial behavior, and nutritional condition of polar bears spending summer on shore along Alaska's northern coast to better understand the nexus between rapid environmental change and increased use of terrestrial habitat. We found that the proportion of the SB subpopulation coming ashore in summer and fall doubled from 2000 to 2014, and the sex and age class composition of polar bears on shore was similar to the composition of bears encountered in our study area on the sea ice in spring. Moreover, we detected trends of earlier arrival on shore, increased length of stay, and later departure back to sea ice, all of which were related to declines in the availability of sea ice habitat over the continental shelf and changes to sea ice phenology. Since the late 1990s, the duration of the open-water season in the SB increased by 36 days, and the length of stay on shore increased by 25 days. While on shore, the distribution of polar bears was influenced by the availability of scavenge subsidies in the form of subsistence-harvested bowhead whale (*Balaena mysticetus*) remains aggregated at sites along the coast. Analyses of nutritional condition suggest bears may derive a benefit from scavenging. The declining availability of sea ice habitat, the lengthening melt season, and increased availability of human-provisioned resources are likely to result in continued growing use of land. Increased residency on land is cause for concern given that, while there, bears may be exposed to a greater array of risk factors including those associated with increased human activities.

Atwood, T.C., Peacock, E., McKinney, M.A., Lillie, K., Wilson, R., and Miller, S. 2015. Demographic composition and behavior of polar bears summering on shore in Alaska. U.S. Geological Survey, Administrative Report, 27 p.

Variation in the response of an Arctic top predator experiencing habitat loss: feeding and reproductive ecology of two polar bear populations — In this study, we compared the body size, condition, and recruitment of polar bears captured in the Chukchi-Bering Seas (CS) between two periods (1986-1994 and 2008-2011) when declines in sea ice habitat occurred. Additionally, we compared metrics for the CS population 2008-2011 with those of the adjacent Southern Beaufort Sea (SB) population where loss in sea ice habitat has been associated with declines in body condition, size, recruitment, and survival. We evaluated how variation in body condition and recruitment were related to feeding ecology. Comparing habitat conditions between populations, there were twice as many reduced-ice days over continental shelf waters per year in 2008-2011 in the SB than the CS. CS polar bears were larger and in better condition, and appeared to have higher reproduction than SB bears. Although SB and CS bears had similar diets, twice as many bears were fasting in spring in the SB than the CS. Between 1986-1994 and 2008-2011, body size, condition, and recruitment indices in the CS were not reduced despite a 44-day increase in the number of reduced-ice days. Bears in the CS exhibited large body size, good body condition, and high indices of recruitment compared to most other populations measured to date. Higher biological productivity and prey availability in the CS relative to the SB, and a shorter recent history of reduced sea ice habitat, may explain the maintenance of condition and recruitment of CS bears. These geographic differences in the response of polar bears to climate change are relevant to range-wide forecasts for this and other ice-dependent species.

Rode, K.D., Regehr, E.V., Douglas, D.C., Durner, G., Derocher, A.E., Thiemann, G.W., and Budge, S.M. 2014. Variation in the response of an Arctic top predator experiencing habitat loss: feeding and reproductive ecology of two polar bear populations. *Global Change Biology* 20:76–88.

Effects of capturing and collaring on bears: findings from long-term research on the southern Beaufort population — The potential for research methods to affect wildlife is an increasing concern among both scientists and the public. This topic has a particular urgency for polar bears because additional research is needed to monitor and understand population responses to rapid loss of sea ice habitat. This study used data collected from polar bears sampled in the Alaska portion of the southern Beaufort Sea to investigate the potential for capture to adversely affect behavior and vital rates. We evaluated the extent to which capture, collaring, and handling may influence activity and movement days to weeks post-capture, and body mass, body condition, reproduction, and survival over 6 months or more. We compared post-capture activity and movement rates, and relationships between prior capture history and body mass, body condition and reproductive success. We also summarized data on capture-related mortality. Individual-based estimates of activity and movement rates reached near-normal levels within 2-3 days and fully normal levels within 5 days post-capture. Models of activity and movement rates among all bears had poor fit, but suggested potential for prolonged, lower-level rate reductions. Repeated captures were not related to negative effects on body condition, reproduction, or cub growth or survival. Capture related mortality was substantially reduced after 1986, when immobilization drugs were changed, with only 3 mortalities in 2,517 captures from 1987-2013. Polar bears in the southern Beaufort Sea exhibited the greatest reductions in activity and movement rates 3.5 days post-capture. These shorter-term, post-capture effects do not appear to have translated into any long-term effects on body condition, reproduction, or cub survival. Additionally, collaring had no effect on polar bear recovery rates, body condition, reproduction, or cub survival. This study provides empirical evidence that current capture-based research methods do not have long term implications, and are not contributing to observed changes in body condition, reproduction, or survival in the southern Beaufort Sea. Continued refinement of capture protocols, such as the use of low-impact dart rifles and reversible drug combinations, might improve polar bear response to capture and abate short-term reductions in activity and movement post-capture.

Rode, K.D., Pagano, A., Bromaghin, J.F., Atwood, T.C., Durner, G.M., Simac, K.S., and Amstrup, S.C. 2014. Effects of capturing and collaring on bears: findings from long-term research on the southern Beaufort population. *Wildlife Research* 41:311–322.

The utility of harvest recoveries of marked individuals to assess polar bear survival — Management of polar bear populations requires the periodic assessment of life history metrics such as survival rate. This information is frequently obtained during short-term capture and marking efforts (e.g., over the course of three years) that result in hundreds of marked bears remaining in the population after active marking is finished. Using 10 additional years of harvest recovery subsequent to a period of active marking, we provide updated estimates of annual survival for polar bears in the Baffin Bay population of Greenland and Canada. Our analysis suggests a decline in survival of polar bears since the period of active marking that ended in 1997; some of the decline in survival can likely be attributed to a decline in springtime ice concentration over the continental shelf of Baffin Island. The variance around the survival estimates is comparatively high because of the declining number of marks available; therefore, results must be interpreted with caution. The variance of the estimates of survival increased most substantially in the sixth-year post-marking. When survival estimates calculated with recovery-only and recapture-recovery data sets from the period of active marking were compared, survival rates were indistinguishable. However, for the period when fewer marks were available, survival estimates were lower using the recovery-only data set, which indicates that part of the decline we detected for 2003–2009 may be due to using only harvest recovery data. Nevertheless, the decline in the estimates of survival is consistent with population projections derived from harvest numbers and earlier vital rates, as well as with an observed decline in the extent of sea ice habitat.

Peacock, E., Laake, J.L., Laidre, K.L., Born, E.W., and Atkinson, S.N. 2012. The utility of harvest recoveries of marked individuals to assess polar bear (*Ursus maritimus*) survival. *Arctic* 65(4):391–400.

A tale of two polar bear populations: climate change, harvest, and body condition — At the time of this publication, negative effects of sea ice loss had been documented for two of 19 recognized populations. Effects of sea ice loss on other polar bear populations that differ in harvest rate, population density, and/or feeding ecology have been assumed, but empirical support, especially quantitative data on population size, demography, and/or body condition spanning two or more decades, have been lacking. We examined trends in body condition metrics of captured bears and relationships with summertime ice concentration between 1977 and 2010 for the Baffin Bay (BB) and Davis Strait (DS) polar bear populations. Polar bears in these regions occupy areas with annual sea ice that has decreased markedly starting in the 1990s. Despite differences in harvest rate, population density, sea ice concentration, and prey base, polar bears in both populations exhibited positive relationships between body condition and summertime sea ice cover during the recent period of sea ice decline. Furthermore, females and cubs exhibited relationships with sea ice that were not apparent during the earlier period (1977-1990s) when sea ice loss did not occur. We suggested that declining body condition in BB may be a result of recent declines in sea ice habitat. In DS, high population density and/or sea ice loss may be responsible for the declines in body condition.

Rode, K.D., Peacock, E., Taylor, M., Stirling, I., Born, E.W., Laidre, K.L., and Wiig, Ø. 2012. A tale of two polar bear populations: climate change, harvest, and body condition. *Population Ecology* 54:3–18.

Polar bear population status in the Northern Beaufort Sea, Canada, 1971-2006 — Polar bears of the northern Beaufort Sea (NB) population occur on the perimeter of the polar basin adjacent to the northwestern islands of the Canadian Arctic Archipelago. Sea ice converges on the islands through most of the year. We used open-population capture–recapture models to estimate population size and vital rates of polar bears between 1971 and 2006 to: (1) assess relationships between survival, sex and age, and time period; (2) evaluate the long-term importance of sea ice quality and availability in relation to climate warming; and (3) note future management and conservation concerns. The highest-ranking models suggested that survival of polar bears varied by age class and with changes in the sea ice habitat. Model-averaged estimates of survival (which includes harvest mortality) for senescent adults ranged from 0.37 to 0.62, from 0.22 to 0.68 for cubs of the year (COY) and yearlings, and from 0.77 to 0.92 for 2–4 year-olds and adults. Horvtiz-Thompson (HT) estimates of population size were not significantly different among the decades of our study. The population size estimated for the 2000s was 980 ± 155 (mean and 95% CI). These estimates apply primarily to that segment of the NB population residing west and south of Banks Island. The NB polar bear population appears to have been stable or possibly increasing slightly during the period of our study. This suggests that ice conditions have remained suitable and similar for feeding in summer and fall during most years and that the traditional and legal Inuvialuit harvest has not exceeded sustainable levels. However, the amount of ice remaining in the study area at the end of summer, and the proportion that continues to lie over the biologically productive continental shelf (<300 m water depth) has declined over the 35-year period of this study. If the climate continues to warm as predicted, we predict that the polar bear population in the northern Beaufort Sea will eventually decline. Management and conservation practices for polar bears in relation to both aboriginal harvesting and offshore industrial activity will need to adapt.

Stirling, I., McDonald, T.L., Richardson, E.S., Regehr, E.V., and Amstrup, S.C. 2011. Polar bear population status in the Northern Beaufort Sea, Canada, 1971-2006. *Ecological Applications* 21(3):859–876. doi:10.1890/10-0849.1.

Reduced body size and cub recruitment in polar bears associated with sea ice decline — This study is the published version of a previous USGS report. We tested whether patterns in body size, condition, and cub recruitment of polar bears in the southern Beaufort Sea (SB) of Alaska were related to the availability of preferred sea ice habitats and whether these measures and habitat availability exhibited trends over time, between 1982 and 2006. The mean skull size and body length of all polar bears over 3 years of age declined over time corresponding with long term declines in the spatial and temporal availability of sea ice habitat. Body size of young, growing bears declined over time and was smaller after years when sea ice availability was reduced. Reduced litter mass and numbers of yearlings per female following years with lower availability of optimal sea ice habitat, suggest reduced reproductive output and juvenile survival. These results, based on analysis of a long-term data set, suggest that declining sea ice is associated with nutritional limitations that reduced body size and reproduction in this population.

Rode, K.D., Amstrup, S.C., and Regehr, E.V. 2010. Reduced body size and cub recruitment in polar bears associated with sea ice decline. *Ecological Applications* 20:768–782.

Climate change threatens polar bear populations: A stochastic demographic analysis — The polar bear depends on sea ice for feeding, breeding, and movement. Significant reductions in Arctic sea ice are forecast to continue because of climate warming. We evaluated the impacts of climate change on polar bears in the southern Beaufort Sea by means of a demographic analysis, combining deterministic, stochastic, environment-dependent matrix population models with forecasts of future sea ice conditions from IPCC general circulation models (GCMs). The matrix population models classified individuals by age and breeding status; mothers and dependent cubs were treated as units. Parameter estimates were obtained from a capture–recapture study conducted from 2001 to 2006. Candidate statistical models allowed vital rates to vary with time and as functions of a sea ice covariate. Model averaging was used to produce the vital rate estimates, and a parametric bootstrap procedure was used to quantify model selection and parameter estimation uncertainty. Deterministic models projected population growth in years with more extensive ice coverage (2001–2003) and population decline in years with less ice coverage (2004–2005). LTRE (life table response experiment) analysis showed that the reduction in λ in years with low sea ice was due primarily to reduced adult female survival, and secondarily to reduced breeding. A stochastic model with two environmental states, good and poor sea ice conditions, projected a declining stochastic growth rate, log λ_s, as the frequency of poor ice years increased. The observed frequency of poor ice years since 1979 would imply log $\lambda_s \approx -0.01$, which agrees with available (albeit crude) observations of population size. The stochastic model was linked to a set of 10 GCMs compiled by the IPCC; the models were chosen for their ability to reproduce historical observations of sea ice and were forced with "business as usual" (A1B) greenhouse gas emissions. The resulting stochastic population projections showed drastic declines in the polar bear population by the end of the 21st century. These projections were instrumental in the decision to list the polar bear as a threatened species under the U.S. Endangered Species Act.

Hunter, C.M., Caswell, H., Runge, M.C., Regehr, E.V., Amstrup, S.C., and Stirling, I. 2010. Climate change threatens polar bear populations: A stochastic demographic analysis. *Ecology* 91:2883–2897.

Greenhouse gas mitigation can reduce sea-ice loss and increase polar bear persistence — On the basis of projected losses of their essential sea-ice habitats, a United States Geological Survey research team concluded in 2007 that two-thirds of the world's polar bears could disappear by mid-century if business-as-usual greenhouse gas emissions continue. That projection, however, did not consider the possible benefits of greenhouse gas mitigation. A key question is whether temperature increases lead to proportional losses of sea-ice habitat, or whether sea-ice cover crosses a tipping point and irreversibly collapses when temperature reaches a critical threshold. Such a tipping point would mean future greenhouse gas mitigation would confer no conservation benefits to polar bears. Here we show, using a general circulation model, that substantially more sea-ice habitat would be retained if greenhouse gas rise is mitigated. We also show, with Bayesian network model outcomes, that increased habitat retention under greenhouse gas mitigation means that polar bears could persist throughout the century in greater numbers and more areas than in the business-as-usual case. Our general circulation model outcomes did not reveal thresholds leading to irreversible loss of ice; instead, a linear relationship between global mean surface air temperature and sea-ice habitat substantiated the hypothesis that sea-ice thermodynamics can overcome albedo feedbacks proposed to cause sea-ice tipping points. Our outcomes indicate that rapid summer ice losses in models and observations represent increased volatility of a thinning sea-ice cover, rather than tipping-point behaviour. Mitigation-driven Bayesian network outcomes show that previously predicted declines in polar bear distribution and numbers are not unavoidable. Because polar bears are sentinels of the Arctic marine ecosystem and trends in their sea-ice habitats foreshadow future global changes, mitigating greenhouse gas emissions to improve polar bear status would have conservation benefits throughout and beyond the Arctic.

Amstrup, S.C., DeWeaver, E.T., Douglas, D.C., Marcot, B.G., Durner, G.M., Bitz, C.M., and Bailey, D.A. 2010. Greenhouse gas mitigation can reduce sea-ice loss and increase polar bear persistence. Nature 468:955–958. doi:10.1038/nature09653.

Foraging ecology studies

Onshore food subsidies add complexity to the response of Alaska polar bears to climate change — From 2000-2013, use of land as a seasonal habitat by polar bears of the Southern Beaufort Sea (SB) subpopulation substantially increased. This onshore use has been linked to reduced spatial and temporal availability of sea ice, as well as to the availability of subsistence-harvested bowhead whale (*Balaena mysticetus*) bone piles. Here, we evaluated the role of climate conditions on consumption of traditional ice-associated prey relative to onshore bowhead whale bone piles. We determined seasonal and interannual trends in the diets of SB polar bears using fatty acid-based analysis during this period of increasing land use. Diet estimates of 569 SB polar bears from 2004-2012 showed high seasonal fluctuations in the proportions of prey consumed. Higher proportions of bowhead whale, as well as ringed seal (*Pusa hispida*) and beluga whale (*Delphinapterus leucas*), were estimated to occur in the winter-spring diet, while higher proportions of bearded seal (*Erignathus barbatus*) were estimated for summer-fall diets. Trends in the annual mean proportions of individual prey items were not found in either period, except for declines in the proportion of beluga in spring-sampled bears. Nonetheless, in years following a high winter Arctic oscillation index, proportions of ice-associated ringed seal were lower in the winter-spring diets of adult females and juveniles. Proportions of bowhead increased in the winter-spring diets of adult males with the number of ice-free days over the continental shelf. In one or both seasons, polar bears that were in better condition were estimated to have consumed less ringed seal and/or more bowhead whale than those in worse condition. Therefore, climate variation over this recent period appeared to influence the extent of onshore versus on-ice food use, which in turn, appeared to be linked to fluctuating condition of SB polar bears.

McKinney, M., Atwood, T.C., Iverson, S.J., and Peacock, L. 2017. Temporal complexity of southern Beaufort Sea polar bear diets during a period of increasing land use. *Ecosphere* 8(1):e01633. 10.1002/ecs2.1633.

Isotopic turnover and effects of fasting and dietary lipids on isotopic discrimination in a large, carnivorous mammal — Two primary chemical tracers are used to estimate polar bear diets: fatty acids and stable isotopes. Fatty acids rely on having a small fat tissue sample from the bear, whereas stable isotopes can be used to estimate diet from blood and hair. Both methods require understanding the role that metabolism plays in altering the chemical composition of the prey relative to the tissue of the predator sampled. In this study, we examined the potential implications of several factors when using stable isotopes to estimate the diets of bears, which can consume lipid-rich diets and, alternatively, fast for weeks to months. We conducted feeding trials with captive brown bears and polar bears. As dietary lipid content increased to ~90%, we observed increasing differences between blood plasma and diets that had not been lipid extracted ($\Delta^{13}C_{\text{tissue-bulk diet}}$) and slightly decreasing differences between plasma $\delta^{13}C$ and lipid-extracted diet. Plasma $\Delta^{15}N_{\text{tissue-bulk diet}}$ increased with increasing protein content for the four polar bears in this study and data for other mammals from previous studies that were fed purely carnivorous diets. Four adult and four yearling brown bears that fasted 120 days had plasma $\delta^{15}N$ values that changed by $< \pm 2‰$. Fasting bears exhibited no trend in plasma $\delta^{13}C$. Isotopic incorporation in red blood cells and whole blood was $\geq$ 6 months in subadult and adult bears, which is considerably longer than previously measured in younger and smaller black bears (*U. americanus*). Our results suggest that short-term fasting in carnivores has minimal effects on

$\delta^{13}C$ and $\delta^{15}N$ discrimination between predators and their prey but that dietary lipid content is an important factor directly affecting $\delta^{13}C$ discrimination and indirectly affecting $\delta^{15}N$ discrimination via the inverse relationship with dietary protein content.

Rode, K.D., Stricker, C., Erlenbach, J., Robbins, C.T., Jensen, S., Cutting, A., Newsome, S., and Cherry, S. 2016. Isotopic turnover and effects of fasting and dietary lipids on isotopic discrimination in a large, carnivorous mammal. *Physiological and Biochemical Zoology*. doi:10.1086/686490.

Distance measures and optimization spaces in quantitative fatty acid signature analysis — Quantitative fatty acid signature analysis has become an important method of diet estimation in ecology, especially marine ecology. Controlled feeding trials to validate the method and estimate the calibration coefficients necessary to account for differential metabolism of individual fatty acids have been conducted with several species from diverse taxa. However, research into potential refinements of the estimation method has been limited. We compared the performance of the original method of estimating diet composition with that of five variants based on different combinations of distance measures and calibration-coefficient transformations between prey and predator fatty acid signature spaces. Fatty acid signatures of pseudopredators were constructed using known diet mixtures of two prey data sets previously used to estimate the diets of polar bears and gray seals *Halichoerus grypus*, and their diets were then estimated using all six variants. In addition, previously published diets of Chukchi Sea polar bears were re-estimated using all six methods. Our findings reveal that the selection of an estimation method can meaningfully influence estimates of diet composition. Among the pseudopredator results, which allowed evaluation of bias and precision, differences in estimator performance were rarely large, and no one estimator was universally preferred, although estimators based on the Aitchison distance measure tended to have modestly superior properties compared to estimators based on the Kullback–Leibler distance measure. However, greater differences were observed among estimated polar bear diets, most likely due to differential estimator sensitivity to assumption violations. Our results, particularly the polar bear example, suggest that additional research into estimator performance and model diagnostics is warranted.

Bromaghin, J.F., Rode, K.D., Budge, S.M., and Thiemann, G.W. 2015. Distance measures and optimization spaces in quantitative fatty acid signature analysis. *Ecology and Evolution* 5:1249–1262.

Can polar bears use terrestrial foods to offset lost ice-based hunting opportunities, assumptions versus reality? — In this review article, we evaluated the nutritional needs and physiological and environmental constraints shaping the polar bear's use of terrestrial ecosystems. Only small numbers of polar bears have been documented consuming terrestrial foods even in modest quantities. Over much of the polar bear's range, limited terrestrial food availability supports only low densities of much smaller, resident brown bears which more efficiently use low quality resources and may compete with polar bears in terrestrial habitats. Where consumption of terrestrial foods has been documented, polar bear body condition and vital rates have declined even as land use has increased. Terrestrial food consumption observed thus far is insufficient to offset lost ice-based hunting opportunities but can have ecological consequences for other species. Warming-induced loss of sea ice remains the most significant threat facing polar bears.

Rode, K.D., Robbins, C.T., Amstrup, S.C., and Nelson, L. 2015. Can polar bears use terrestrial foods to offset lost ice-based hunting opportunities, assumptions versus reality? *Frontiers in Ecology and the Environment* 13:138–145.

Diet of female polar bears in the southern Beaufort Sea of Alaska: evidence for an emerging alternative foraging strategy in response to environmental change — Polar bear diet may become more variable in some Arctic regions due to climate warming and altered sea ice habitat. We surveyed carbon and nitrogen stable isotope profiles of five polar bear tissues sampled from adult females in the Southern Beaufort Sea of Alaska in order to assess inter-tissue isotopic variability and to determine whether any dietary shifts are occurring in this population. We did not detect any significant shifts from historical means in population-level tissue stable isotope values. A number of sectioned hair samples, however, were significantly depleted in ^{15}N relative to the mean. We hypothesized that lower hair $\delta^{15}N$ values were due to the consumption of bowhead whale (*Balaena mysticetus*) tissue. Telemetry data showed that polar bears with ^{15}N-depleted hair sections were located on multiple dates near known subsistence-harvested bowhead whale bone piles and had spent 90 % of the prior year within 50 km of the shore. Bears with hair section $\delta^{15}N$ values at or above the mean spent no time near bowhead whale bone piles and less than half of the year nearshore. An isotopic mixing model estimation of diet proportions determined that bowhead whale comprised approximately 50–70 % of fall diet for bears with lower hair $\delta^{15}N$ values. We conclude that these results offer emergent evidence of an alternative foraging strategy within this population: 'coastal' bears, which remain near to shore for much of the year and use bowhead whale bone piles when they are present. In contrast, 'pelagic' bears follow a more typical strategy and forage widely on sea ice for seals.

Rogers, M.C., Peacock, E., Simac, K.S., O'Dell, M.B., and Welker, J.M. 2015. Diet of female polar bears in the southern Beaufort Sea of Alaska: evidence for an emerging alternative foraging strategy in response to environmental change. *Polar Biology*. doi:10.1007/s00300-015-1665-4.

Polar bear use of a persistent food subsidy: Insights from non-invasive genetic sampling in Alaska — Remains of bowhead whales (*Balaena mysticetus*) harvested by Iñupiat whalers are deposited in bone piles along the coast of Alaska and have become persistent and reliable food sources for polar bears. The importance of bone piles to individuals and the population, the patterns of use, and the number, sex, and age of bears using these resources are poorly understood. We implemented barbed-wire hair snaring to obtain genetic identities from bears using the Point Barrow bone pile in winter 2010–11. Eighty-three percent of genotyped samples produced individual and sex identification. We identified 97 bears from 200 samples. Using genetic mark–recapture techniques, we estimated that 228 bears used the bone pile during November to February, which would represent approximately 15% of the Southern Beaufort Sea polar bear subpopulation, if all bears were from this subpopulation. We found that polar bears of all age and sex classes simultaneously used the bone pile. More males than females used the bone pile, and males predominated in February, likely because 1/3 of adult females would be denning during this period. On average, bears spent 10 days at the bone pile (median = 5 days); the probability that an individual bear remained at the bone pile from week to week was 63% for females and 45% for males. Most bears in the sample were detected visiting the bone pile once or twice. We found some evidence of matrilineal fidelity to the bone pile, but the group of animals visiting the bone pile did not differ genetically from the Southern Beaufort Sea subpopulation, nor did patterns of relatedness. We demonstrate that bowhead whale bone piles may be an influential food subsidy for polar bears in the Barrow region in autumn and winter for all sex and age classes.

Herreman, J., and E. Peacock, E. 2013. Polar bear use of a persistent food subsidy: Insights from non-invasive genetic sampling in Alaska. *Ursus* 24(2):148–163. doi:10.2192/URSUS-D-12-00030.1.

Methods development studies

Use of collar temperature sensor data to identify long-term patterns in southern Beaufort Sea polar bear den distribution on pack ice and land — Polar bears in the southern Beaufort Sea have increasingly been observed using land for maternal denning. To aid in detecting denning behavior, we developed an objective method to identify polar bear denning events using temperature sensor data collected in polar bear collars deployed on adult females 1985-2013. We then applied this method to determine if southern Beaufort polar bears have continued to increase land denning with recent sea-ice loss and examined whether sea-ice conditions affect the distribution of dens between pack-ice and coastal substrates. Because summering on land has also increased, we examined potential associations between summering substrate and denning substrate.

Statistical process control methods applied to temperature-sensor data identified denning events with 94.5% accuracy in comparison to direct observations and 96.3% accuracy relative to subjective classifications based on temperature, location, and activity sensor data. We found an increase in land-based denning during the study period. The frequency of land denning was directly related to the distance that sea ice retreated from the coast. Among females that denned, 100% of those that summered on land subsequently denned there whereas 29% of those summering on ice denned on land. These results suggest that denning on land may continue to increase with further loss of sea ice. While the effects that den substrate have on nutrition, energetics, and reproduction are unclear, more polar bears denning onshore will likely increase human-bear interactions.

Olson, J.W., Rode, K.D., Eggett, D., Smith, T.S., Wilson, R.R., Durner, G.M., Fischbach, A., Atwood, T.C., and Douglas, D.C. 2017. Collar temperature sensor data reveal long-term patterns in southern Beaufort Sea polar bear den distribution on pack ice and land. *Marine Ecology Progress Series* 564:211–224. doi:10.3354/meps12000.

Using tri-axial accelerometers to identify wild polar bear behaviors — Tri-axial accelerometers have been used to remotely identify the behaviors of a wide range of taxa. Assigning behaviors to accelerometer data often involves the use of captive animals or surrogate species, as accelerometer signatures are generally assumed to be similar to those of their wild counterparts. However, this has rarely been tested. Validated accelerometer data are needed for polar bears to understand how habitat conditions may influence behavior and energy demands. We used accelerometer and water conductivity data to remotely distinguish 10 polar bear behaviors. We calibrated accelerometer and conductivity data collected from collars with behaviors from video-recorded captive polar bears and brown bears *U. arctos*, and with video from camera collars deployed on free-ranging polar bears on the sea ice and on land. We used random forest models to predict behaviors and found strong ability to discriminate the most common wild polar bear behaviors using a combination of accelerometer and conductivity sensor data from captive or wild polar bears. In contrast, models using data from captive brown bears failed to reliably distinguish most active behaviors in wild polar bears. Our ability to discriminate behavior was greatest when species- and habitat-specific data from wild individuals were used to train models. Data from captive individuals may be suitable for calibrating accelerometers, but may provide reduced ability to discriminate some behaviors. The accelerometer calibrations developed here provide a method to quantify polar bear behaviors to evaluate the impacts of declines in Arctic sea ice.

Pagano, A.M., Rode, K.D., Cutting, A., Owen, M.A., Jensen, S., Ware, J.V., Robbins, C.T., Durner, G.M., Atwood, T.C., Obbard, M.E., Middel, K.R., Thiemann, G.W., and Williams, T.M. 2017. Using tri-axial accelerometers to identify wild polar bear behaviors. *Endangered Species Research* 32: 19–33. doi:10.3354/esr00779.

Assessing the robustness of quantitative fatty acid signature analysis to assumption violations — Knowledge of animal diets can provide important insights into life history and ecology, relationships among species in a community and potential response to ecosystem change or perturbation. Quantitative fatty acid signature analysis (QFASA) is a method of estimating diets from data on the composition, or signature, of fatty acids stored in adipose tissue. Given data on signatures of potential prey, a predator diet is estimated by minimizing the distance between its signature and a mixture of prey signatures. Calibration coefficients, constants derived from feeding trials, are used to account for differential metabolism of individual fatty acids. QFASA has been widely applied since its introduction and several variants of the original estimator have appeared in the literature. However, work to compare the statistical properties of QFASA estimators has been limited. One important characteristic of an estimator is its robustness to violations of model assumptions. The primary assumptions of QFASA are that prey signature data contain representatives of all prey types consumed and the calibration coefficients are known without error. We investigated the robustness of two QFASA estimators to a range of violations of these assumptions using computer simulation and recorded the resulting bias in diet estimates. We found that the Aitchison distance measure was most robust to errors in the calibration coefficients. Conversely, the Kullback–Leibler distance measure was most robust to the consumption of prey without representation in the prey signature data. In most QFASA applications, investigators will generally have some knowledge of the prey available to predators and be able to assess the completeness of prey signature data and sample additional prey as necessary. Conversely, because calibration coefficients are derived from feeding trials with captive animals and their values may be sensitive to consumer physiology and nutritional status, their applicability to free-ranging animals is difficult to establish. We therefore recommend that investigators first make any improvements to the prey signature data that seem warranted and then base estimation on the Aitchison distance measure, as it appears to minimize risk from violations of the assumption that is most difficult to verify.

Bromaghin, J.F., Budge, S.M., Thiemann, G.W., and Rode, K.D. 2016. Assessing the robustness of quantitative fatty acid signature analysis to assumption violations. *Methods in Ecology and Evolution* 7(1):51–59. doi:10.1111/2041-210X.12456.

Validation of mercury tip-switch and accelerometer-based activity sensors for identifying resting versus active behavior in bears — In this study, we examined the performance of a mercury tip-switch and a tri-axial accelerometer housed in collars to determine whether sensor data can be accurately classified as resting and active behaviors and whether data are comparable for the 2 sensor types. Five captive bears (3 polar and 2 brown were fitted with a collar specially designed to internally house the sensors. The bears' behaviors were recorded, classified, and then compared with sensor readings. A separate tri-axial accelerometer that sampled continuously at a higher frequency and provided raw acceleration values from 3 axes was also mounted on the collar to compare with the lower resolution sensors. Both accelerometers more accurately identified resting and active behaviors at time intervals ranging from 1 minute to 1 hour (≥91.1% accuracy) compared with the mercury tip-switch (range = 75.5–86.3%). However, mercury tip-switch accuracy improved when sampled at longer intervals (30 vs. 60 min). Data from the lower resolution accelerometer, but not the mercury tip-switch, accurately predicted the percentage of time spent resting during an hour. Although the number of bears available for this study was small, our results suggest that these activity sensors can remotely identify resting versus active behaviors across most time intervals. We recommend that investigators consider both study objectives and the variation in accuracy of classifying resting and active behaviors reported here when determining sampling interval.

Ware, J., Rode, K.D., Pagano, A.M., Bromaghin, J., Robbins, C.T., Erlenbach, J., Jensen, S., Cutting, A., Nicassio-Hiskey, N., Hash, A., Owen, M., and Jansen, H.T. 2015. Validation of mercury tip-switch and accelerometer-based activity sensors for identifying resting versus active behavior in bears. *Ursus* 26: 86–96.

Expanding applications for using high-resolution satellite imagery to monitor polar bear abundance and distribution — High-resolution satellite imagery is a promising tool for providing coarse information about polar species abundance and distribution, but current applications are limited. With polar bears, the technique has only proven effective on landscapes with little topographic relief that are devoid of snow and ice, and time-consuming manual review of imagery is required to identify bears. Here, we evaluated mechanisms to further develop methods for satellite imagery by examining data from Rowley Island, Canada. We attempted to automate and expedite detection via a supervised spectral classification and image differencing to expedite image review. We also assessed what proportion of a region should be sampled to obtain reliable estimates of density and abundance. Although the spectral signature of polar bears differed from non-target objects, these differences were insufficient to yield useful results via a supervised classification process. Conversely, automated image differencing—or subtracting one image from another—correctly identified nearly 90% of polar bear locations. This technique, however, also yielded false positives, suggesting that manual review will still be required to confirm polar bear locations. On Rowley Island, bear distribution approximated a Poisson distribution across a range of plot sizes, and resampling suggests that sampling >50% of the site facilitates reliable estimation of density (CV <15%). Satellite imagery may be an effective monitoring tool in certain areas, but large-scale applications remain limited because of the challenges in automation and the limited environments in which the method can be effectively applied. Improvements in resolution may expand opportunities for its future uses.

LaRue, M.A., Stapleton, S., Porter, C., Atkinson, S., Atwood, T., Dyck, M., and Lecomte, N. 2015. Testing methods for using high-resolution satellite imagery to monitor polar bear abundance and distribution. *Wildlife Society Bulletin* 39:772–779.

Polar bears from space: assessing satellite imagery as a tool to monitor Arctic wildlife — Development of efficient techniques for monitoring wildlife is a priority in the Arctic, where the impacts of climate change are acute and remoteness and logistical constraints hinder access. We evaluated high resolution satellite imagery as a tool to track the distribution and abundance of polar bears. We examined satellite images of a small island in Foxe Basin, Canada, occupied by a high density of bears during the summer ice-free season. Bears were distinguished from other light-colored spots by comparing images collected on different dates. A sample of ground-truthed points demonstrated that we accurately classified bears. Independent observers reviewed images and a population estimate was obtained using mark–recapture models. This estimate was remarkably similar to an abundance estimate derived from a line transect aerial survey conducted a few days earlier. Our findings suggest that satellite imagery is a promising tool for monitoring polar bears on land, with implications for use with other Arctic wildlife. Large scale applications may require development of automated detection processes to expedite review and analysis. Future research should assess the utility of multi-spectral imagery and examine sites with different environmental characteristics.

Stapleton, S., LaRue, M., Lecomte, N., Atkinson, S., Garshelis, D., Porter, C., and Atwood, T.C. 2014. Polar bears from space: assessing satellite imagery as a tool to monitor Arctic wildlife. *PLoS One*. doi:10.1371/journal.pone.0101513.

Validation of adipose lipid content from biopsies as a body condition index using polar bears — Body condition is a key indicator of individual and population health. Yet, there is little consensus as to the most appropriate condition index (CI), and most of the currently used CIs have not been thoroughly validated and are logistically challenging. Adipose samples from large datasets of capture biopsied, remote biopsied, and harvested polar bears were used to validate adipose lipid content as a CI via tests of accuracy, precision, sensitivity, biopsy depth, and storage conditions and comparisons to established CIs, to measures of health and to demographic and ecological parameters. The lipid content analyses of even very small biopsy samples were highly accurate and precise, but results were influenced by tissue depth at which the sample was taken. Lipid content of capture biopsies and samples from harvested adult females was correlated with established CIs and/or conformed to expected biological variation and ecological changes. However, lipid content of remote biopsies was lower than capture biopsies and harvested samples, possibly due to lipid loss during dart retrieval. Lipid content CI is a biologically relevant, relatively inexpensive and rapidly assessed CI and can be determined routinely for individuals and populations in order to infer large-scale spatial and long-term temporal trends. As it is possible to collect samples during routine harvesting or remotely using biopsy darts, monitoring and assessment of body condition can be accomplished without capture and handling procedures or noninvasively, which are methods that are preferred by local communities. However, further work is needed to apply the method to remote biopsies.

McKinney, M.A., Atwood, T., Dietz, R., Sonne, C., Iverson, S.J., and Peacock, E. 2014. Validation of adipose lipid content from biopsies as a body condition index using polar bears. *Ecology and Evolution* 4:516–527.

Remote biopsy darting and marking of polar bears — Remote biopsy darting of polar bears is less invasive and time intensive than physical capture and is therefore useful when capture is challenging or unsafe. We worked with two manufacturers to develop a combination biopsy and marking dart for use on polar bears. We had an 80% success rate of collecting a tissue sample with a single biopsy dart and collected tissue samples from 143 polar bears on land, in water, and on sea ice. Dye marks ensured that 96% of the bears were not resampled during the same sampling period, and we recovered 96% of the darts fired. Biopsy heads with 5 mm diameters collected an average of 0.12 g of fur, tissue, and subcutaneous adipose tissue, while biopsy heads with 7 mm diameters collected an average of 0.32 g. Tissue samples were 99.3% successful (142 of 143 samples) in providing a genetic and sex identification of individuals. We had a 64% success rate collecting adipose tissue and we successfully examined fatty acid signatures in all adipose samples. Adipose lipid content values were lower compared to values from immobilized or harvested polar bears, indicating that our method was not suitable for quantifying adipose lipid content.

Pagano, A.M., Peacock, E., and McKinney, M.A. 2013. Remote biopsy darting and marking of polar bears. *Marine Mammal Science*. doi:10.1111/mms.12029.

Habitat ecology studies

Summer activity of polar bears in response to habitat degradation in the Chukchi and Beaufort Seas — Polar bear subpopulations have demonstrated variation in their near-term responses to sea ice decline. We sought to identify behavioral responses of two adjacent subpopulations to changes in habitat availability during the annual sea ice minimum using activity data. Satellite collar location and activity sensor data collected from 1989-2014 for 202 adult female polar bears in the Southern Beaufort Sea (SB) and Chukchi Sea (CS) subpopulations were used to compare activity in three habitat types varying in prey availability: 1) land; 2) ice over shallow, biologically-productive waters; and 3) ice over deeper, less productive Arctic basin waters. Bears varied activity across and within habitats. They were most active in their preferred habitat of 50-75% sea ice concentration over shallow water and less active on ice over deeper water and on land. While on land, SB bears exhibited variable but relatively high activity associated with use of subsistence-harvested bowhead whale carcasses, whereas CS bears exhibited low activity consistent with minimal feeding. Both subpopulations exhibited fewer observations in their preferred sea ice habitats in recent years, corresponding with declines in availability of this substrate. The substantially higher use of marginal habitats by SB bears is an additional mechanism that may explain why this subpopulation has experienced negative effects of sea ice loss while the CS subpopulation appears to have remained productive. Variability in activity among and within habitats suggests bears alter their behavior in response to habitat conditions presumably in an attempt to balance prey availability with energy costs. The potential nutritional implications of changes in behavior in response to habitat use and distribution warrant further investigation.

Ware, J.V., Rode, K.D., Bromaghin, J.F., Douglas, D.C., Wilson, R.R., Regehr, E.V., Amstrup, S.C., Durner, G., Pagano, A.M., Olson, J., Robbins, C.T., and Jansen, H.T. 2017. Habitat degradation affects the summer activity of polar bears. *Oecologia*. doi:10.1007/s00442-017-3839-y.

Effects of a changing climate on polar bears — Several sources of uncertainty affect how precisely the future status of polar bears can be forecasted. Foremost are unknowns about the future levels of global greenhouse gas emissions, which could range from an unabated increase to an aggressively mitigated reduction. Uncertainties also arise because different climate models project different amounts and rates of future warming (and sea ice loss) – even for the same emissions scenario. There are also uncertainties about how global warming could affect the Arctic Ocean's food web, so even if climate models project the presence of sea ice in the future, the availability of polar bear prey is not guaranteed. Under a worst-case emissions scenario in which rates of greenhouse gas emissions continue to rise unabated to century's end, the uncertainties about polar bear status center on a potential for extinction. If the species were to persist, it would likely be restricted to a high-latitude refugium in northern Canada and Greenland—assuming a food web also existed with enough accessible prey to fuel weight gains for surviving onshore during the most extreme years of summer ice melt. On the other hand, if emissions were to be aggressively mitigated at the levels proposed in the Paris Climate Change Agreement, healthy polar bear populations would probably continue to occupy all but the most southern areas of their contemporary summer range. While polar bears have survived previous warming phases — which indicate some resiliency to the loss of sea ice habitat — what is certain is that the present pace of warming is unprecedented and will increasingly expose polar bears to historically novel stressors.

Douglas, D.C., and Atwood, T.C. 2017. Effects of a changing climate on polar bears. Pages 463–474 in Marine Mammal Welfare, A. Butterworth (ed.). Springer, New York, New York, USA.

Polar bears and habitat change — The polar bear is an obligate apex predator of Arctic sea ice and as such can be affected by climate warming-induced changes in the extent and composition of pack ice, and its impacts on their seal prey. Sea ice declines have negatively impacted some polar bear subpopulations through reduced energy input because of loss of hunting habitats, higher energy costs due to greater ice drift, ice fracturing and open water, and ultimately greater challenges to recruit young. Projections made from the output of global climate models suggest that polar bears in peripheral Arctic and sub-Arctic seas will be reduced in numbers or become extirpated by the end of the 21st century if the rate of climate warming continues on its present trajectory. The same projections also suggest that polar bears may persist in the high latitude Arctic where heavy multi-year sea ice that has been typical in that region is being replaced by thinner annual ice. Underlying physical and biological oceanography provides clues as to why polar bear in some regions are negatively impacted while bears in other regions have shown no apparent changes. However, continued declines in sea ice will eventually challenge the survival of polar bears and efforts to conserve them in all regions of the Arctic.

Durner, G.M., and Atwood, T.C. 2017. Polar bears and habitat change. Pages 419–444 in Marine Mammal Welfare, A. Butterworth (ed.). Springer, New York, New York, USA.

Implications of rapid environmental change for polar bear behavior and social structure — The behavior and sociality of polar bears have been shaped by evolved preferences for sea ice habitat and preying on marine mammals. However, human behavior is causing changes to the Arctic marine ecosystem through the influence of greenhouse gas emissions that drive long-term change in ecosystem processes, and via the presence of *in situ* stressors associated with increasing human activities. These changes are making it more difficult for polar bears to reliably use their traditional habitats and maintain fitness. Here, I provide an overview of how human activities in the Arctic are likely to change behavioral traits that may influence polar bear sensitivity and resilience to environmental change. Developing a more thorough understanding of polar bear behavior and their capacity for flexibility in response to anthropogenic disturbances and subsequent mitigations may lead to successful near-term management interventions.

Atwood, T.C. 2017. Implications of rapid environmental change for polar bear

behavior and social structure. Pages 445-462 in Marine Mammal Welfare, A. Butterworth (ed.). Springer, New York, New York, USA.

Historical hunting of polar bears — Harvest of polar bears by aboriginal peoples has occurred for millennia across the circumpolar Arctic. While harvest for sport and the commercial fur trade increased dramatically as southerners expanded into the Arctic, the 1973 international Agreement for the Conservation of Polar Bears curtailed harvest again largely to aboriginal peoples. This Agreement, spurned by global concern for declining polar bear populations, is a hallmark for international cooperation in conservation. In Russia, polar bear harvest has in fact been illegal since 1957, although there are concerns of poaching by local people for food security and also for the black market fur trade. Norway banned all harvest with their ratification of the Agreement. The United States allows for polar bear harvest by the Inupiat of Alaska. Quotas for the two populations shared with the United States are determined by an international user-to-user agreement between aboriginal people of Alaska and Canada, and an international agreement between USA and Russia, respectively. In Greenland, polar bears are harvested by a quota system, currently based on historic numbers by only professional Inuit hunters. In most of Canada, where two-thirds of the world's polar bears are harvested, anyone can harvest a polar bear, but only within a quota system assigned to and managed by Inuit communities. In Canada, harvest is largely managed formalized quota systems based on scientific information, but also by historic levels by treaty and local traditional ecological knowledge. Globally, polar bear harvest averages 798 (44 SD) per year. The vast majority is for subsistence, with 6% for sport (Canada), and a lesser proportion for defense of life and property. The legal international market for polar bear hides is fed only by exports from Canada. Climate change poses a greater threat to polar bears than do the current levels of harvest. However, habitat change and harvest interact because of increasing use by land by polar bears. Further, there are scientific and conservation questions about the appropriateness of harvesting polar bears, even for subsistence, from populations that are declining due to climate change.

Peacock, E. 2017. Historical hunting of polar bears. Pages 475-488 in Marine Mammal Welfare, A. Butterworth (ed.). Springer, New York, New York, USA.

Rapid environmental change drives increased land use by an Arctic marine predator — In the Arctic Ocean's southern Beaufort Sea (SB), the length of the sea ice melt season (i.e., period between the onset of sea ice break-up in summer and freeze-up in fall) has increased substantially since the late 1990s. Historically, polar bears of the SB have mostly remained on the sea ice year-round (except for those that came ashore to den), but recent changes in the extent and phenology of sea ice habitat have coincided with evidence that use of terrestrial habitat is increasing. We characterized the spatial behavior of polar bears spending summer and fall on land along Alaska's north coast to better understand the nexus between rapid environmental change and increased use of terrestrial habitat. We found that the percentage of radiocollared adult females from the SB subpopulation coming ashore has tripled over 15 years. Moreover, we detected trends of earlier arrival on shore, increased length of stay, and later departure back to sea ice, all of which were related to declines in the availability of sea ice habitat over the continental shelf and changes to sea ice phenology. Since the late 1990s, the mean duration of the open-water season in the SB increased by 36 days, and the mean length of stay on shore increased by 31 days. While on shore, the distribution of polar bears was influenced by the availability of scavenge subsidies in the form of subsistence-harvested bowhead whale (*Balaena mysticetus*) remains aggregated at sites along the coast. The declining spatiotemporal availability of sea ice habitat and increased availability of human-provisioned resources are likely to result in increased use of land. Increased residency on land is cause for concern given that, while there, bears may be exposed to a greater array of risk factors including those associated with increased human activities.

Atwood, T.C., Peacock, E., McKinney, M.,

Douglas, D., Lillie, K., Wilson, R., Terletzky,P., and Miller, S. 2016. Rapid environmental change drives increased land use by an Arctic marine predator. *PLoS One* 11(6). doi:10.1371/journal.pone.0155932.

Mapping polar bear maternal denning habitat in the National Petroleum Reserve - Alaska with an IfSAR digital terrain model — The National Petroleum Reserve–Alaska (NPR-A) in northeastern Alaska provides winter maternal denning habitat for polar bears and also has high potential for recoverable hydrocarbons. Denning polar bears exposed to human activities may abandon their dens before their young are able to survive the severity of Arctic winter weather. To ensure that wintertime petroleum activities do not threaten polar bears, managers need to know the distribution of landscape features in which maternal dens are likely to occur. Here, we present a map of potential denning habitat within the NPR-A. We used a fine-grain digital elevation model derived from Interferometric Synthetic Aperture Radar (IfSAR) to generate a map of putative denning habitat. We then tested the map's ability to identify polar bear denning habitat on the landscape. Our final map correctly identified 82% of denning habitat estimated to be within the NPR-A. Mapped denning habitat comprised 19.7 km2 (0.1% of the study area) and was widely dispersed. Though mapping denning habitat with IfSAR data was as effective as mapping with the photogrammetric methods used for other regions of the Alaskan Arctic coastal plain, the use of GIS to analyze IfSAR data allowed greater objectivity and flexibility with less manual labor. Analytical advantages and performance equivalent to that of manual cartographic methods suggest that the use of IfSAR data to identify polar bear maternal denning habitat is a better management tool in the NPR-A and wherever such data may be available.

Durner, G.M., Simac, K.S., and Amstrup, S.C. 2013. Mapping polar bear maternal denning habitat in the National Petroleum Reserve - Alaska with an IfSAR digital terrain model. *Arctic* 66(2):197–206.

Long-distance swimming by polar bears of the southern Beaufort Sea during years of extensive open water — Polar bears depend on sea ice for catching marine mammal prey. Recent sea-ice declines have been linked to reductions in body condition, survival, and population size. Reduced foraging opportunity is hypothesized to be the primary cause of sea-ice-linked declines, but the costs of travel through a deteriorated sea-ice environment also may be a factor. We used movement data from 52 adult female polar bears wearing Global Positioning System (GPS) collars, including some with dependent young, to document long-distance swimming (>50 km) by polar bears in the southern Beaufort and Chukchi seas. Over a 6 year period (2004–2009), we identified 50 long-distance swims by 20 bears. Swim duration and distance ranged from 0.7 to 9.7 days (mean = 3.4 days) and 53.7 to 687.1 km (mean = 154.2 km), respectively. Frequency of swimming appeared to increase over the course of the study. We show that adult female polar bears and their cubs are capable of swimming long distances during periods when extensive areas of open water are present. However, long-distance swimming appears to have higher energetic demands than moving over sea ice. Our observations suggest long-distance swimming is a behavioral response to declining summer sea-ice conditions.

Pagano, A.M., Durner, G.M., Amstrup, S.C., Simac, K.S., and York, G.S. 2012. Long-distance swimming by polar bears (*Ursus maritimus*) of the southern Beaufort Sea during years of extensive open water. *Canadian Journal of Zoology* 90:663–676. doi:10.1139/z2012-033.

Consequences of long-distance swimming and travel over deep-water ice for a female polar bear during a year of extreme sea ice retreat — Polar bears prefer to live on Arctic sea ice but may swim between ice floes or between sea ice and land. Although anecdotal observations suggest that polar bears are capable of swimming long distances, no data have been available to describe in detail long distance swimming events or the physiological and reproductive consequences of such behavior. Between an initial capture in late August and a recapture in late October 2008, a radio-collared adult female polar bear in the Beaufort Sea made a continuous swim of 687 km over 9 days and then intermittently swam and walked on the sea ice surface an additional 1,800 km. Measures of movement rate, hourly activity, and subcutaneous and external temperature revealed distinct profiles of swimming and walking. Between captures, this polar bear lost 22% of her body mass and her yearling cub. The extraordinary long-distance swimming ability of polar bears, which we confirm here, may help them cope with reduced Arctic sea ice. Our observation, however, indicates that long distance swimming in Arctic waters, and travel over deep water pack ice, may result in high energetic costs and compromise reproductive fitness.

Durner, G.M., Whiteman, J.P., Harlow, H.J., Amstrup, S.C., Regehr, E.V., and Ben-David, M. 2011. Consequences of long-distance swimming and travel over deep-water ice for a female polar bear during a year of extreme sea ice retreat. *Polar Biology* 34:975–984. doi:10.1007/s00300-010-0953-2.

Catalogue of Polar Bear Maternal Den Locations in the Beaufort Sea and Neighboring Regions, Alaska, 1910-2010 — This report presents data on the approximate locations and methods of discovery of 392 polar bear maternal dens found in the Beaufort Sea and neighboring regions between 1910 and 2010 that are archived by the U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska. A description of data collection methods, biases associated with collection method, primary time periods, and spatial resolution are provided. Polar bears in the Beaufort Sea and nearby regions den on both the sea ice and on land. Standardized VHF surveys and satellite radio telemetry data provide a general understanding of where polar bears have denned in this region over the past 3 decades. Den observations made during other research activities and anecdotal reports from other government agencies, coastal residents, and industry personnel also are reported. Data on past polar bear maternal den locations are provided to inform the public and to provide information for natural resource agencies in planning activities to avoid or minimize interference with polar bear maternity dens.

Durner, G.M., Fischbach, A.S., Amstrup, S.C., and Douglas, D.C. 2010. Catalogue of polar bear (*Ursus maritimus*) maternal den locations in the Beaufort Sea and neighboring regions, Alaska, 1910-2010. U.S. Geological Survey Data Series 568, 14p. https://pubs.usgs.gov/ds/568/.

Arctic sea ice decline: Projected changes in timing and extent of sea ice in the Bering and Chukchi Seas — The Arctic region is warming faster than most regions of the world due in part to increasing greenhouse gases and positive feedbacks associated with the loss of snow and ice cover. One consequence has been a rapid decline in Arctic sea ice over the past 3 decades—a decline that is projected to continue by state-of-the-art models. Many stakeholders are therefore interested in how global warming may change the timing and extent of sea ice Arctic-wide, and for specific regions. To inform the public and decision makers of anticipated environmental changes, scientists are striving to better understand how sea ice influences ecosystem structure, local weather, and global climate. Here, projected changes in the Bering and Chukchi Seas are examined because sea ice influences the presence of, or accessibility to, a variety of local resources of commercial and cultural value. In this study, 21st century sea ice conditions in the Bering and Chukchi Seas are based on projections by 18 general circulation models (GCMs) prepared for the fourth reporting period by the Intergovernmental Panel on Climate Change (IPCC) in 2007. Sea ice projections are analyzed for each of two IPCC greenhouse gas forcing scenarios: the A1B 'business as usual' scenario and the A2 scenario that is somewhat more aggressive in its CO2 emissions during the second half of the century. A large spread of uncertainty among projections by all 18 models was constrained by creating model subsets that excluded GCMs that poorly simulated the 1979–2008 satellite record of ice extent and seasonality. At the end of the 21st century (2090–2099), median sea ice projections among all combinations of model ensemble and forcing scenario were qualitatively similar. June is projected to experience the least amount of sea ice loss among all months. For the Chukchi Sea, projections show extensive ice melt during July and ice-free conditions during August, September, and October by the end of the century, with high agreement among models. High agreement also accompanies projections that the Chukchi Sea will be completely ice covered during February, March, and April at the end of the century. Large uncertainties, however, are associated with the timing and amount of partial ice cover during the intervening periods of melt and freeze. For the Bering Sea, median March ice extent is projected to be about 25 percent less than the 1979–1988 average by mid-century and 60 percent less by the end of the century. The ice-free season in the Bering Sea is projected to increase from its contemporary average of 5.5 months to a median of about 8.5 months by the end of the century. A 3-month longer ice- free season in the Bering Sea is attained by a 1-month advance in melt and a 2-month delay in freeze, meaning the ice edge typically will pass through the Bering Strait in May and January at the end of the century rather than June and November as presently observed.

Douglas, D.C. 2010. Arctic sea ice decline: Projected changes in timing and extent of sea ice in the Bering and Chukchi Seas. U.S. Geological Survey Open-File Report 2010-1176, 32p. https://pubs.usgs.gov/of/2010/1176/.

Health studies

Enhanced biological processes associated with alopecia in polar bears — Populations of wildlife species worldwide experience incidents of mass morbidity and mortality. Primary or secondary drivers of these events may escape classical detection methods for identifying microbial insults, toxin exposure, or additional stressors. In 2012, 28% of polar bears sampled in a study in the southern Beaufort Sea region of Alaska had varying degrees of alopecia that was concomitant with reduced body condition. Concurrently, elevated numbers of sick or dead ringed seals were detected in the southern Beaufort, Chukchi, and Bering seas in 2012, resulting in the declaration of an unusual mortality event (UME) by the National Oceanic and Atmospheric Administration (NOAA). The primary and possible ancillary causative stressors of these events are unknown, and related physiological changes within individual animals have been undetectable using classical diagnostic methods. Here we present an emerging technology as a potentially guiding investigative approach aimed at elucidating the circumstances responsible for the susceptibility of certain polar bears to observed conditions. Using transcriptomic analysis, we identified enhanced biological processes including immune response, viral defense, and response to stress in polar bears with alopecia. Our results support an alternative mechanism of investigation into the causative agents that, when used proactively, could serve as an early indicator for populations and species at risk. We suggest that current or classical methods for investigation into events of unusual morbidity and mortality can be costly, sometimes unfocused, and often inconclusive. Advances in technology allow for implementation of a holistic system of surveillance and investigation that could provide early warning of health concerns in wildlife species important to humans.

Bowen, L., Miles, A.K., Stott, J., Waters, S., and Atwood, T.C. 2015. Enhanced biological processes associated with alopecia in polar bears (*Ursus maritimus*). *Science of the Total Environment* 529:114–120.

Development of a baseline for diagnostic gene transcription in polar bears — Polar bears in the Beaufort (SB) and Chukchi (CS) Seas experience different environments due primarily to a longer history of sea ice loss in the Beaufort Sea. Ecological differences have been identified as a possible reason for the generally poorer body condition and reproduction of Beaufort polar bears compared to those from the Chukchi, but the influence of exposure to other stressors remains unknown. We use molecular technology, quantitative PCR, to identify gene transcription differences among polar bears from the Beaufort and Chukchi Seas as well as captive healthy polar bears. We identified significant transcriptional differences among a priori groups (i.e., captive bears, SB 2012, SB 2013, CS 2013) for ten of the 14 genes of interest (i.e., CaM, HSP70, CCR3, TGFb, COX2, THRa, T-bet, Gata3, CD69, and IL17); transcription levels of DRb, IL1b, AHR, and Mx1 did not differ among groups. Multivariate analysis also demonstrated separation among the groups of polar bears. Specifically, we detected transcript profiles consistent with immune function impairment in polar bears from the Beaufort Sea, when compared with Chukchi and captive polar bears. Although there is no strong indication of differential exposure to contaminants or pathogens between CS and SB bears, there are clearly differences in important transcriptional responses between populations. Further investigation is warranted to refine interpretation of potential effects of described stress-related conditions for the SB population.

Bowen, L., Miles, A.K., Waters, S., Meyerson, R., and Atwood, T.C. 2015. Development of a baseline for diagnostic gene transcription in polar bears *(Ursus maritimus)*. *Polar Biology* 38:1413–1427.

A review of infectious agents in polar bears and their long-term ecological Relevance — Disease was a listing criterion for the polar bear as threatened under the Endangered Species Act in 2008; it is therefore important to evaluate the current state of knowledge and identify any information gaps pertaining to diseases in polar bears. We conducted a systematic literature review focused on infectious agents and associated health impacts identified in polar bears. Overall, the majority of reports in free-ranging bears concerned serosurveys or fecal examinations with little to no information on associated health effects. In contrast, most reports documenting illness or pathology referenced captive animals and diseases caused by etiologic agents not representative of exposure opportunities in wild bears. As such, most of the available infectious disease literature has limited utility as a basis for development of future health assessment and management plans. Given that ecological change is a considerable risk facing polar bear populations, future work should focus on cumulative effects of multiple stressors that could impact polar bear population dynamics.

Fagre, A., Nol, P., Atwood, T.C., Patyk, K., Hueffer, K., and Duncan, C. 2015. A review of infectious agents in polar bears *(Ursus maritimus)* and their long-term ecological relevance. *EcoHealth*. doi:10.1007/s10393-015-1023-6.

Establishing a definition of polar bear health to guide research and management activities — The meaning of health for wildlife and perspectives on how to assess and measure health, are not well characterized. For wildlife at risk, such as some polar bear subpopulations, establishing comprehensive monitoring programs that include health status is an emerging need. Environmental changes, especially loss of sea ice habitat, have raised concern about polar bear health. Effective and consistent monitoring of polar bear health requires an unambiguous definition of health. We used the Delphi method of soliciting and interpreting expert knowledge to propose a working definition of polar bear health and to identify current concerns regarding health, challenges in measuring health, and important metrics for monitoring health. The expert opinion elicited through the exercise agreed that polar bear health is defined by characteristics and knowledge at the individual, population, and ecosystem level. The most important threats identified were in decreasing order: climate change, increased nutritional stress, chronic physiological stress, harvest management, increased exposure to contaminants, increased frequency of human interaction, diseases and parasites, and increased exposure to competitors. Fifteen metrics were identified to monitor polar bear health. Of these, indicators of body condition, disease and parasite exposure, contaminant exposure, and reproductive success were ranked as most important. We suggest that a cumulative effects approach to research and monitoring will improve the ability to assess the biological, ecological, and social determinants of polar bear health and provide measurable objectives for conservation goals and priorities and to evaluate progress.

Patyk, K., Duncan, C., Nol, P., Sonne, C., Laidre, K., Obbard, M, Wiig, Ø., Aars, J., Regehr, E., Gustafson, L., and Atwood, T.C. 2015. Establishing a definition of polar bear (*Ursus maritimus*) health to guide research and management activities. *Science for the Total Environment* 514:371–378.

Prevalence and spatio-temporal variation of an alopecia syndrome detected in polar bears in the southern Beaufort Sea — Alopecia (hair loss) has been observed in several marine mammal species and has potential energetic consequences for sustaining a normal core body temperature, especially for Arctic marine mammals routinely exposed to harsh environmental conditions. Polar bears rely on a thick layer of adipose tissue and a dense pelage to ameliorate convective heat loss while moving between sea ice and open water. From 1998 to 2012, we observed an alopecia syndrome in polar bears from the southern Beaufort Sea of Alaska that presented as bilaterally asymmetrical loss of guard hairs and thinning of the undercoat around the head, neck, and shoulders, which, in severe cases, was accompanied by exudation and crusted skin lesions. Alopecia was observed in 49 (3.45%) of the bears sampled during 1,421 captures, and the apparent prevalence varied by years with peaks occurring in 1999 (16%) and 2012 (28%). The probability that a bear had alopecia was greatest for subadults and for bears captured in the Prudhoe Bay region, and alopecic individuals had a lower body condition score than unaffected individuals. The cause of the syndrome remains unknown and future work should focus on identifying the causative agent and potential effects on population vital rates.

Atwood, T.C., Peacock, E., Burek-Huntington, K., Shearn-Bochsler, V., Bodenstein, B., Durner, G., and Beckmann, K. 2015. Prevalence and spatio-temporal variation of an alopecia syndrome detected in polar bears in the southern Beaufort Sea. *Journal of Wildlife Diseases* 51:48–59.

Hematology of Southern Beaufort Sea polar bears (2005–2007): biomarker for an Arctic ecosystem health sentinel — Declines in sea-ice habitats have resulted in declining stature, productivity, and survival of polar bears in some regions. With continuing sea-ice declines, negative population effects are projected to expand throughout the polar bear's range. Precise causes of diminished polar bear life history performance are unknown; however, climate and sea-ice condition change are expected to adversely impact polar bear health and population dynamics. As apex predators in the Arctic, polar bears integrate the status of lower trophic levels and are therefore sentinels of ecosystem health. Arctic residents feed at the apex of the ecosystem, thus polar bears can serve as indicators of human health in the Arctic. Despite their value as indicators of ecosystem welfare, population-level health data for U.S. polar bears are lacking. We present hematological reference ranges for southern Beaufort Sea polar bears. Hematological parameters in southern Beaufort Sea polar bears varied by age, geographic location, and reproductive status. Total leukocytes, lymphocytes, monocytes, eosinophils, and serum immunoglobulin G were significantly greater in males than females. These measures were greater in non-lactating females ages ≥5, than lactating adult females ages ≥5, suggesting that females encumbered by young may be less resilient to new immune system challenges that may accompany ongoing climate change. Hematological values established here provide a necessary baseline for anticipated changes in health as arctic temperatures warm and sea-ice declines accelerate. Data suggest that females with dependent young may be most vulnerable to these changes and should therefore be a targeted cohort for monitoring in this sentinel.

Kirk, C.M., Amstrup, S., Swor, R., Holcomb, D., and O'Hara, T.M. 2010. Hematology of Southern Beaufort Sea polar bears (2005-2007): biomarker for an Arctic ecosystem health sentinel. *EcoHealth*. doi:10.1007/s10393-010-0322-1.

Morbillivirus and Toxoplasma exposure and association with hematological parameters for southern Beaufort Sea polar bears: Potential response to infectious agents in a sentinel species — Arctic temperatures are increasing in response to greenhouse gas forcing and polar bears have already responded to changing conditions. Declines in body stature and vital rates have been linked to warming-induced loss of sea-ice. As food webs change and human activities respond to a milder Arctic, exposure of polar bears and other arctic marine organisms to infectious agents may increase. Because of the polar bear's status as arctic ecosystem sentinel, polar bear health could provide an index of changing pathogen occurrence throughout the Arctic, however, exposure and monitoring protocols have yet to be established. We examine prevalence of antibodies to *Toxoplasma gondii,* and four morbilliviruses (canine distemper [CDV], phocine distemper [PDV], dolphin morbillivirus [DMV], porpoise morbillivirus [PMV]) including risk factors for exposure. We also examine the relationships between antibody levels and hematologic values established in the previous companion article. Antibodies to *Toxoplasma gondii* and morbilliviruses were found in both sample years. We found a significant inverse relationship between CDV titer and total leukocytes, neutrophils, monocytes, and eosinophils, and a significant positive relationship between eosinophils and *Toxoplasma gondii* antibodies. Morbilliviral prevalence varied significantly among age cohorts, with 1–2 year olds least likely to be seropositive and bears aged 5–7 most likely. Data suggest that the presence of CDV and *Toxoplasma gondii* antibodies is associated with polar bear hematologic values. We conclude that exposure to CDV-like antigen is not randomly distributed among age classes and suggest that differing behaviors among life history stages may drive probability of specific antibody presence.

Kirk, C.M., Amstrup, S., Swor, R., Holcomb, D., and O'Hara, T.M. 2010. Morbillivirus and Toxoplasma exposure and association with hematological parameters for southern Beaufort Sea polar bears: Potential response to infectious agents in a sentinel species. *Ecohealth*. doi:10.1007/s10393-010-0323-0.

Other Research

Monitoring polar bear populations — Most programs for monitoring the welfare of wildlife populations support efforts aimed at reaching discrete management objectives, like mitigating conflict with humans. While such programs can be effective, their limited scope may preclude systemic evaluations needed for large-scale conservation initiatives like the recovery of at-risk species. We discuss select categories of metrics that can be used to monitor how polar bears are responding to the primary threat to their long-term persistence - loss of sea ice habitat due to the unabated rise in atmospheric greenhouse gas (GHG; e.g., CO_2) concentrations - that can also provide information on ecosystem function and health. Monitoring key aspects of polar bear population dynamics, spatial behavior, and health and resiliency can provide valuable insight into ecosystem state and function, and could be a powerful tool for achieving Arctic conservation objectives, particularly those that have trans-national policy implications.

Atwood, T.C., Duncan, C., Patyk, K., Peacock, E., and Sonthsagen, S. 2017. Monitoring the welfare of polar bear populations in a rapidly changing Arctic. Pages 503-527 in Marine Mammal Welfare, A. Butterworth (ed.). Springer, New York, New York, USA.

Effects of human activities on polar bears — Historically, the Arctic sea ice has functioned as a structural barrier that has limited the nature and extent of interactions between humans and polar bears. However, declining sea ice extent, brought about by global climate change, is increasing the potential for human-polar bear interactions. Loss of sea ice habitat is driving changes to both human and polar bear behavior – it is spurring increases in human activities (e.g., offshore oil and gas exploration and extraction, trans-Arctic shipping, recreation), while also causing the displacement of bears from preferred foraging habitat (i.e., sea ice over biologically productive shallow) to land. The end result of these changes is that polar bears are spending greater amounts of time in close proximity to people and industrial infrastructure. Co-existence between humans and polar bears will require imposing mechanisms to manage further development, as well as mitigation strategies that reduce the burden to local communities.

Atwood, T.C., Breck, S.W., York, G., and Simac, K. 2017. Human-polar bear interactions in a changing Arctic: existing and emerging concerns. Pages 397-418 in Marine Mammal Welfare, A. Butterworth (ed.). Springer, New York, New York, USA.

An experimental investigation of chemical communication in the polar bear — The polar bear, with its wide-ranging movements, solitary existence and seasonal reproduction, is expected to favor chemosignaling over other communication modalities. However, the topography of its Arctic sea ice habitat is generally lacking in stationary vertical substrates routinely used for targeted scent marking in other bears. These environmental constraints may have shaped a marking strategy, unique to polar bears, for widely dispersed continuous dissemination of scent via foot pads. To investigate the role of chemical communication, pedal scents were collected from free-ranging polar bears of different sex and reproductive classes captured on spring sea ice in the Beaufort and Chukchi seas, and presented in a controlled fashion to 26 bears in zoos. Results from behavioral bioassays indicated that bears, especially females, were more likely to approach conspecific scent during the spring than the fall. Male flehmen behavior, indicative of chemosignal delivery to the vomeronasal organ, differentiated scent donor by sex and reproductive condition. Histologic examination of pedal skin collected from two females indicated prominent and profuse apocrine glands in association with large compound hair follicles, suggesting that they may produce scents that function as chemosignals. These results suggest that pedal scent, regardless of origin, conveys information to conspecifics that may facilitate social and reproductive behavior, and that chemical communication in this species has been adaptively shaped by environmental constraints of its habitat. However, continuously distributed scent signals necessary for breeding behavior may prove less effective if current and future environmental conditions cause disruption of scent trails due to increased fracturing of sea ice.

Owen, M.A., Swaisgood, R.R., Slocomb, C., Amstrup, S.C., Durner, G.M., Simac, K.S., and Pessier, A.P. 2015. An experimental investigation of chemical communication in the polar bear. *Journal of Zoology* 295(1):36–43. doi:10.1111/jzo.12181.

Forecasting wildlife response to rapid warming in the Alaskan Arctic — Arctic wildlife species face a dynamic and increasingly novel environment because of climate warming and the associated increase in human activity. Both marine and terrestrial environments are undergoing rapid environmental shifts, including loss of sea ice, permafrost degradation, and altered biogeochemical fluxes. Forecasting wildlife responses to climate change can facilitate proactive decisions that balance stewardship with resource development. In this article, we discuss the primary and secondary responses to physical climate-related drivers in the Arctic, associated wildlife responses, and additional sources of complexity in forecasting wildlife population outcomes. Although the effects of warming on wildlife populations are becoming increasingly well documented in the scientific literature, clear mechanistic links are often difficult to establish. An integrated science approach and robust modeling tools are necessary to make predictions and determine resiliency to change. We provide a conceptual framework and introduce examples relevant for developing wildlife forecasts useful to management decisions.

Van Hemert, C., Flint, P., Udevitz, M.S., Koch, J.C., Atwood, T.C., Oakley, K.L., and Pearce, J. 2015. Forecasting wildlife response to rapid warming in the Alaskan Arctic. *Bioscience* 65:718–728.

Implications of the circumpolar genetic structure of polar bears for their conservation in a rapidly warming Arctic — We provide an expansive analysis of polar bear circumpolar genetic variation during the last two decades of decline in their sea-ice habitat. We sought to evaluate whether their genetic diversity and structure have changed over this period of habitat decline, how their current genetic patterns compare with past patterns, and how genetic demography changed with ancient fluctuations in climate. Characterizing their circumpolar genetic structure using microsatellite data, we defined four clusters that largely correspond to current ecological and oceanographic factors: Eastern Polar Basin, Western Polar Basin, Canadian Archipelago and Southern Canada. We document evidence for recent (ca. last 1–3 generations) directional gene flow from Southern Canada and the Eastern Polar Basin towards the Canadian Archipelago, an area hypothesized to be a future refugium for polar bears as climate-induced habitat decline continues. Our data provide empirical evidence in support of this hypothesis. The direction of current gene flow differs from earlier patterns of gene flow in the Holocene. From analyses of mitochondrial DNA, the Canadian Archipelago cluster and the Barents Sea subpopulation within the Eastern Polar Basin cluster did not show signals of population expansion, suggesting these areas may have served also as past interglacial refugia. Mismatch analyses of mitochondrial DNA data from polar and the paraphyletic brown bear (*U. arctos*) uncovered offset signals in timing of population expansion between the two species, that are attributed to differential demographic responses to past climate cycling. Mitogenomic structure of polar bears was shallow and developed recently, in contrast to the multiple clades of brown bears. We found no genetic signatures of recent hybridization between the species in our large, circumpolar sample, suggesting that recently observed hybrids represent localized events. Documenting changes in subpopulation connectivity will allow polar nations to proactively adjust conservation actions to continuing decline in sea-ice habitat.

Peacock, E., Sonsthagen, S.A., Obbard, M.E., Boltunov, A., Regehr, E.V., Ovsyanikov, N., Aars, J., Atkinson, S.N., Sage, G.K., Hope, A.G., Zeyl, E., Bachmann, L., Ehrich, D., Scribner, K.T., Amstrup, S.C., Belikov, S.E., Born, E.W., Derocher, A.E., Stirling, I, Taylor, M.K., Wiig, Ø., Paetkau, D., and Talbot, S.L. 2015. Implications of the circumpolar genetic structure of polar bears for their conservation in a rapidly warming Arctic. *PLoS One* 10(1). doi:10.1371/journal.pone.0112021.

Polar bears exhibit genome-wide signatures of bioenergetic adaptation to life in the Arctic environment — Polar bears face extremely cold temperatures and periods of fasting, which might result in more severe energetic challenges than those experienced by their sister species, the brown bear (*U. arctos*). We have examined the mitochondrial and nuclear genomes of polar and brown bears to investigate whether polar bears demonstrate lineage-specific signals of molecular adaptation in genes associated with cellular respiration/energy production. We observed increased evolutionary rates in the mitochondrial cytochrome *c* oxidase I gene in polar but not brown bears. An amino acid substitution occurred near the interaction site with a nuclear-encoded subunit of the cytochrome *c* oxidase complex and was predicted to lead to a functional change, although the significance of this remains unclear. The nuclear genomes of brown and polar bears demonstrate different adaptations related to cellular respiration. Analyses of the genomes of brown bears exhibited substitutions that may alter the function of proteins that regulate glucose uptake, which could be beneficial when feeding on carbohydrate-dominated diets during hyperphagia, followed by fasting during hibernation. In polar bears, genes demonstrating signatures of functional divergence and those potentially under positive selection were enriched in functions related to production of nitric oxide (NO), which can regulate energy production in several different ways. This suggests that polar bears may be able to fine-tune intracellular levels of NO as an adaptive response to control trade-offs between energy production in the form of adenosine triphosphate versus generation of heat (thermogenesis).

Welch, A.J., Bedoya-Reina, O.C., Carretro-Paulet, L., Miller, W., Rode, K.D., and

Lindqvist, C. 2014. Polar bears exhibit genome-wide signatures of bioenergetic adaptation to life in the Arctic environment. *Genome Biology and Evolution* 6(2):433–450.

A circumpolar monitoring framework for polar bears — Polar bears occupy remote regions that are characterized by harsh weather and limited access. Polar bear populations can only persist where temporal and spatial availability of sea ice provides adequate access to their marine mammal prey. Observed declines in sea ice availability will continue as long as greenhouse gas concentrations rise. At the same time, human intrusion and pollution levels in the Arctic are expected to increase. A circumpolar understanding of the cumulative impacts of current and future stressors is lacking, long-term trends are known from only a few subpopulations, and there is no globally coordinated effort to monitor effects of stressors. Here, we describe a framework for an integrated circumpolar monitoring plan to detect ongoing patterns, predict future trends, and identify the most vulnerable polar bear subpopulations. We recommend strategies for monitoring subpopulation abundance and trends, reproduction, survival, ecosystem change, human-caused mortality, human–bear conflict, prey availability, health, stature, distribution, behavioral change, and the effects that monitoring itself may have on polar bears. We assign monitoring intensity for each subpopulation through adaptive assessment of the quality of existing baseline data and research accessibility. A global perspective is achieved by recommending high intensity monitoring for at least one subpopulation in each of four major polar bear ecoregions. Collection of data on harvest, where it occurs, and remote sensing of habitat, should occur with the same intensity for all subpopulations. We outline how local traditional knowledge may most effectively be combined with the best scientific methods to provide comparable and complementary lines of evidence. We also outline how previously collected intensive monitoring data may be sub-sampled to guide future sampling frequencies and develop indirect estimates or indices of subpopulation status. Adoption of this framework will inform management and policy responses to changing worldwide polar bear status and trends.

Vongraven, D., Aars, J., Amstrup, S., Atkinson, S.N., Belikov, S., Born, E.W., DeBruyn, T.D., Deroche, A.E., Durner, G., Gill, M., Lunn, N., Obbard, M.E., Omelak, J., Ovsyanikov, N., Peacock, E., Richardson, E., Sahanatien, V., Stirling, I., and Wiig, Ø. 2012. A circumpolar monitoring framework for polar bears. Ursus 23(sp2):1–66. doi:10.2192/URSUS-D-11-00026.1.

Polar and brown bear genomes reveal ancient admixture and demographic footprints of past climate change — Polar bears (PBs) are superbly adapted to the extreme Arctic environment and have become emblematic of the threat to biodiversity from global climate change. Their divergence from the lower-latitude brown bear provides a textbook example of rapid evolution of distinct phenotypes. However, limited mitochondrial and nuclear DNA evidence conflicts in the timing of PB origin as well as placement of the species within versus sister to the brown bear lineage. We gathered extensive genomic sequence data from contemporary polar, brown, and American black bear samples, in addition to a 130,000- to 110,000-y old PB, to examine this problem from a genome-wide perspective. Nuclear DNA markers reflect a species tree consistent with expectation, showing polar and brown bears to be sister species. However, for the enigmatic brown bears native to Alaska's Alexander Archipelago, we estimate that not only their mitochondrial genome, but also 5–10% of their nuclear genome, is most closely related to PBs, indicating ancient admixture between the two species. Explicit admixture analyses are consistent with ancient splits among PBs, brown bears and black bears that were later followed by occasional admixture. We also provide paleodemographic estimates that suggest bear evolution has tracked key climate events, and that PB in particular experienced a prolonged and dramatic decline in its effective population size during the last ca. 500,000 years. We demonstrate that brown bears and PBs have had sufficiently independent evolutionary histories over the last 4–5 million years to leave imprints in the PB nuclear genome that likely are associated with ecological adaptation to the Arctic environment.

Miller, W., Schuster, S.C., Welch, A.J., Ratan, A., Bedoya-Reina, O.C., Zhao, F., Kim, H.L., Burhans, R.C., Drautz, D.I., Wittenkindt, N.E., Tomsho, L.P., Ibarra-Laclette, E., Herrera-Estrella, L., Peacock, E., Farley, S.D., Sage, G.K., Rode, K.D., Obbard, M.E., Montiel, R., Bachmann, L., Ingólfsson, Ó., Aars, J., Mailund, T., Wiig, Ø., Talbot, S.L., and Lindqvist, C. 2012. Polar and brown bear genomes reveal ancient admixture and demographic footprints of past climate change. *Proceedings of the National Academy of Sciences of the United States of America* 109:14295-14296. doi:10.1073/pnas.1210506109.

Development of a pan-Arctic monitoring plan for polar bears: Background paper — We provide background science to support the development of: a circumpolar polar bear monitoring plan, to be adopted across the Arctic that: (i) identifies the monitoring techniques and optimal sampling regimes that are likely to succeed in the 19 different subpopulations, given specific characteristics and logistics of the subpopulations themselves; (ii) identifies suites of metrics that can provide parallel lines of evidence of the status of polar bear populations, where intensive research is not possible; (iii) identifies standardized parameters for intensively researched subpopulations, with a specific focus on identifying factors responsible for determining mechanistic relationships and trends in population; (iv) identifies new methods, including less-invasive approaches, for conducting directed research and monitoring, recognizing the need for more effective monitoring; and, (v) develops population projection models that incorporate response to environmental change. Additionally, we provide a set of circumpolar indices and indicators to provide regular, consistent and credible reports on the status and trends of individual polar bear subpopulations.

Vongraven, D., and Peacock, E. 2011. Development of a pan-Arctic monitoring plan for polar bears: Background paper. Circumpolar Biodiversity Monitoring Programme, CAFF Monitoring Series Report No.1, January 2011, CAFF International Secretariat, Akureyri, Iceland. ISBN 978-9935-431-01-1.

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Tables

Table 1. Annual proportion of recaptures of adult (≥ 5 years old) polar bears captured in the spring of 2010–2016 by standard search in the southern Beaufort Sea by the USGS.

Year	Total Captures	Recaptures	Proportion recaptured
2010	38	30	0.79
2011	26	12	0.46
2012	43	25	0.58
2013	36	21	0.58
2014	24	15	0.62
2015	20	11	0.55
2016	15	7	0.47

Figures

Fig. 1. Annual composition of adult and sub-adult polar bears by subjective body condition index in the USGS spring (March–May) Southern Beaufort Sea capture, 2010–2016. Data do not include adult females with dependent young.

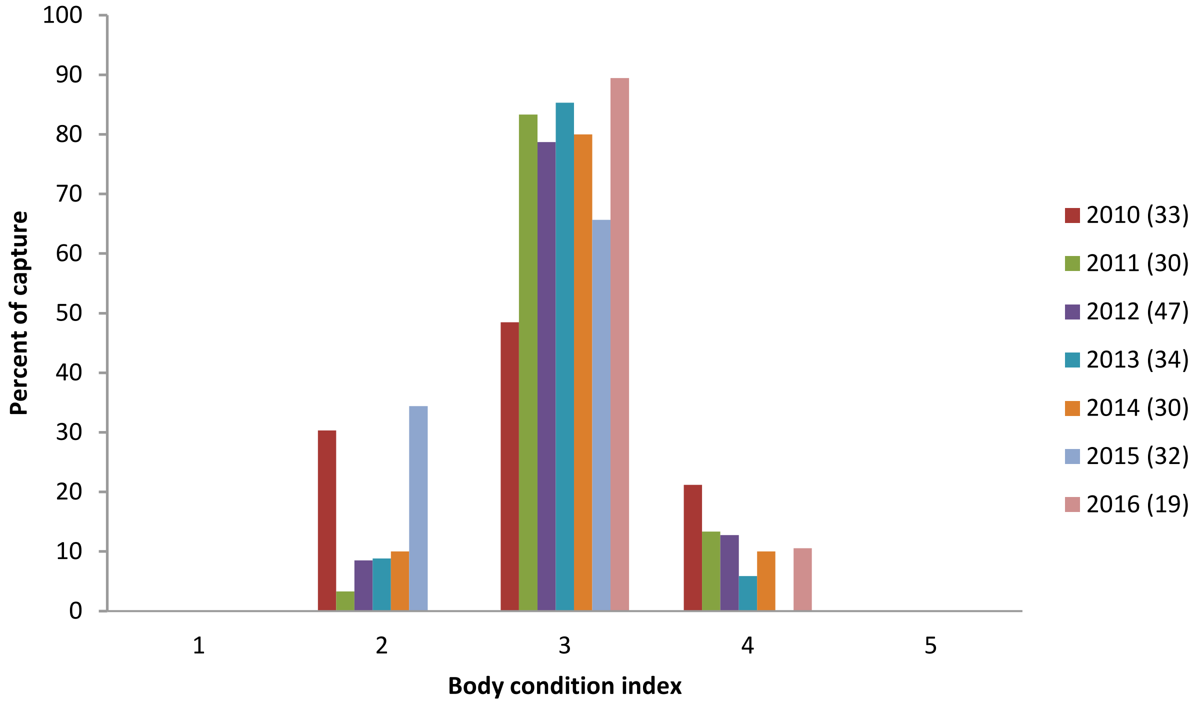
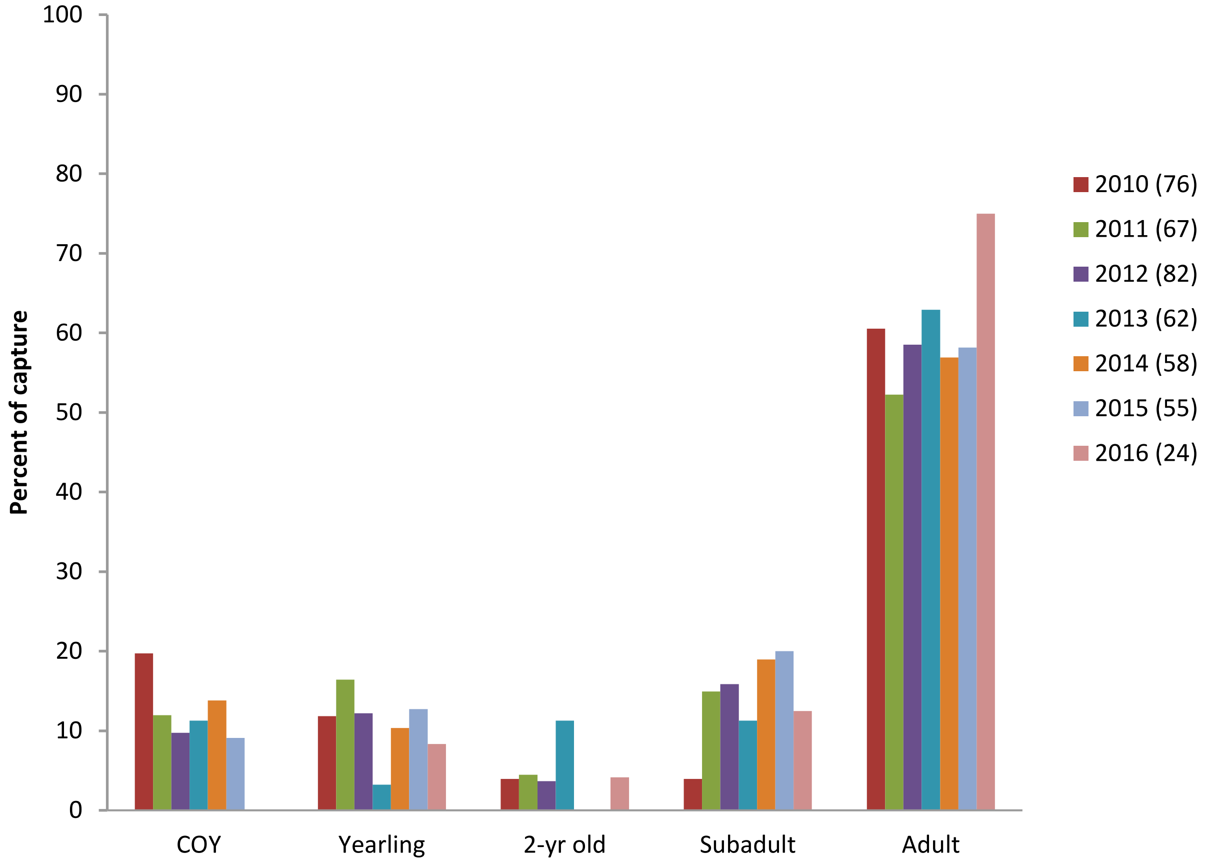


Fig. 2. Annual composition of polar bears by major age category in the USGS spring (March–May) southern Beaufort Sea capture, 2010–2016. We did not capture any 2-yr olds in 2014 or 2015. No COYS were captured in 2016. Data include all captures.



Acknowledgements

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Appendix 1

Agreement on the Conservation of Polar Bears

Oslo, 15 November 1973

The Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics and the United States of America,

Recognizing the special responsibilities and special interests of the States of the Arctic Region in relation to the protection of the fauna and flora of the Arctic Region;

Recognizing that the polar bear is a significant resource of the Arctic Region which requires additional protection;

Having decided that such protection should be achieved through co-ordinated national measures taken by the States of the Arctic Region;

Desiring to take immediate action to bring further conservation and management measures into effect;

Having agreed as follows:

Article I

1. The taking of polar bears shall be prohibited except as provided in Article III.
2. For the purposes of this Agreement, the term "taking" includes hunting, killing and capturing.

Article II

Each Contracting Party shall take appropriate action to protect the ecosystems of which polar bears are a part, with special attention to habitat components such as denning and feeding sites and migration patterns, and shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data.

Article III

1. Subject to the provisions of Articles II and IV any Contracting Party may allow the taking of polar bears when such taking is carried out:
    a. for bona fide scientific purposes; or
    by that Party for conservation purposes; or
    to prevent serious disturbance of the management of other living resources, subject to forfeiture to that Party of the skins and other items of value resulting from such taking; or
    by local people using traditional methods in the exercise of their traditional rights and in accordance with the laws of that Party; or
    b. wherever polar bears have or might have been subject to taking by traditional means by its nationals.
2. The skins and other items of value resulting from taking under sub-paragraph (b) and (c) of paragraph 1 of this Article shall not be available for commercial purposes.

Article IV

The use of aircraft and large motorized vessels for the purpose of taking polar bears shall be prohibited, except where the application of such prohibition would be inconsistent with domestic laws.

Article V

A Contracting Party shall prohibit the exportation from, the importation and delivery into, and traffic within, its territory of polar bears or any part or product thereof taken in violation of this Agreement.

Article VI

1. Each Contracting Party shall enact and enforce such legislation and other measures as may be necessary for the purpose of giving effect to this Agreement.
2. Nothing in this Agreement shall prevent a Contracting Party from maintaining or amending existing legislation or other measures or establishing new measures on the taking of polar bears so as to provide more stringent controls than those required under the provisions of this Agreement.

Article VII

The Contracting Parties shall conduct national research programmes on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate co-ordinate such research with research carried out by other Parties, consult with other Parties on the management of migrating polar bear populations, and exchange information on research and management programmes, research results and data on bears taken.

Article VIII

Each Contracting Party shall take action as appropriate to promote compliance with the provisions of this Agreement by nationals of States not party to this Agreement.

Article IX

The Contracting Parties shall continue to consult with one another with the object of giving further protection to polar bears.

Article X

1. This Agreement shall be open for signature at Oslo by the Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics and the United States of America until 31st March 1974.
2. This Agreement shall be subject to ratification or approval by the signatory Governments. Instruments of ratification or approval shall be deposited with the Government of Norway as soon as possible.
3. This Agreement shall be open for accession by the Governments referred to in paragraph I of this Article. Instruments of accession shall be deposited with the Depositary Government.
4. This Agreement shall enter into force ninety days after the deposit of the third instrument of ratification, approval or accession. Thereafter, it shall enter into force for a signatory or acceding Government on the date of deposit of its instrument of ratification. approval or accession.
5. This Agreement shall remain in force initially for a period of five years from its date of entry into force, and unless any Contracting Party during that period requests the termination of the Agreement at the end of that period. it shall continue in force thereafter.
6. On the request addressed to the Depositary Government by any of the Governments referred to in paragraph I of this Article. consultations shall be conducted with a view to convening a meeting of representatives of the five Governments to consider the revision or amendment of this Agreement.
7. Any Party may denounce this Agreement by written notification to the Depositary Government at any time after five years from the date of entry into force of this Agreement. The denunciation shall take effect twelve months after the Depositary Government has received the notification.
8. The Depositary Government shall notify the Governments referred to in paragraph 1 of this Article of the deposit of instruments of ratification, approval or accession, of the entry into force of this Agreement and of the receipt of notifications of denunciation and any other communications from a Contracting Part specifically provided for in this Agreement.
9. The original of this Agreement shall be deposited with the Government of Norway which shall deliver certified copies thereof to each of the Governments referred to in paragraph I of this Article.
10. The Depositary Government shall transmit certified copies of this Agreement to the Secretary-General of the United Nations for registration and publication in accordance with Article 102 of the Charter of the United Nations.

In Witness Whereof the undersigned, being duly authorized by their Governments, have signed this Agreement.

Done at Oslo, in the English and Russian languages, each text being equally authentic, this fifteenth day of November, 1973.

[The Agreement came into effect in May 1976, three months after the third nation required to ratify did so in February 1976. All five nations ratified by 1978. After the initial period of five years, all five Contracting Parties met in Oslo, Norway, in January 1981, and unanimously reaffirmed the continuation of the agreement.]

Appendix 2

Numbers allocated to each country for eartags and tattoos used in polar bear management and research

Number series	Letter[1]	Country	Year assigned
1–249	A	USA	1968
250–499	N	Norway	1968
500–749	X	Canada	1968
750–999	C	USSR	1968
1000–1999	A	USA	1969
2000–5999	X	Canada	1971–1976
6000–6999	A	USA	1976
7000–7499	D	Denmark	1976
7500–7999	N	Norway	1976
8000–8499	C	USSR	1976
8500–9999	X	Canada	1980
10000–19999	X	Canada	1984
20000–22999	A	USA	1984
23000–23999	N	Norway	1984
24000–24999	D	Denmark	1984
25000–25999	C	USSR/Russia	1984
26000–29999	N	Norway	1997
30000–39999	X	Canada	1997

[1]A unique letter has been assigned to each country for use on eartags and in tattoos in combination with the above series.

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Greenland Institute of Natural Resources

University of Washington

Aarhus University

Norwegian Environment Agency

Norsk Polarinstitutt

Universitas Osloensis MDCCCXI

All-Russian Research Institute for Environment Protection

Совет по морским млекопитающим

ИБПС

ИПЭЭ РАН

U.S. Fish & Wildlife Service

USGS science for a changing world

Polar Bears International

University of Toronto Scarborough