POLAR BEAR
RESEARCH PROSPECTUS

EAZA Polar Bear EEP

EAZA Bear TAG

Version 1.0 • September 2023

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digital prospectus

Participants in the March 2023 polar bear research prospectus workshop held at Tierpark Berlin.

Back row, standing (left to right): Megan Owen, Douglas Richardson, Thea Bechshoft, Gregory W. Thiemann, Florian Sicks. Front row, kneeling (left to right): Marion Schneider, Marissa Krouse, Amy Cutting, José Kok, Lydia Kolter. Missing: Marina Galeshchuk and Varvara Levitskaya. Photo courtesy of Tierpark Berlin.

This publication may be cited as:

Bechshoft, T., Cutting, A., Galeshchuk, M., Krouse, M., Kok, J., Kolter, L., Levitskaya, V., Owen, M., Richardson, D., Schneider, M., Sicks, F., Thiemann, G. W. (2023). Polar bear research prospectus (T. Bechshoft, Ed.). European Association of Zoos and Aquaria (EAZA), Polar Bear Ex-situ Programme (EEP).

Cover: Polar bear family group. Photo courtesy of BJ Kirschhoffer/Polar Bears International.

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Foreword

People and polar bears are connected. Indigenous cultures across the circumpolar Arctic have ancient relationships with polar bears, while people in southern latitudes see polar bears and relate to both their strength and their vulnerability. Perhaps as a consequence of this relationship, polar bears are often at the forefront of humanity's concerns about global warming.

As a wildlife ecologist and member of the IUCN/SSC Polar Bear Specialist Group, I have focused my 22-year career on understanding the ecology and conservation of polar bears. Although global warming is the primary concern for polar bears, there are other threats to their long-term existence. Zoo-based research, including the projects described in this prospectus, can contribute to understanding and mitigating all of them.

Climate change is dramatically and rapidly shrinking the extent and seasonal duration of annual sea ice, the polar bear's primary habitat. This loss of habitat impairs the ability of polar bears to hunt seals, find mates, and reach terrestrial denning areas. Research on polar bears in zoos and aquaria can help us understand and quantify the relationships between climate, sea ice, and polar bear ecology. It can help develop new tools for studying the diets or movements of wild bears, help identify the physiological markers of chronic stress, or quantify the energetic costs of swimming and thermoregulating in an increasingly ice-free Arctic.

Industrial development activities are expanding across the Arctic as declining sea ice opens up new shipping routes. Oil and gas exploration, mining, tourism, and transportation – and their associated environmental risks – are all increasing in polar bear range. Zoo-based research can provide crucial insights into the potential effects of anthropogenic activities in the Arctic. For instance, bears in managed care can help us understand the sensory ecology of the species and the thresholds for disturbance from noise or vibration. Such insights can be directly applied to the management and mitigation of industrial impacts.

Exploitation (i.e., the lethal removal) of polar bears is a threat when it exceeds sustainable limits. The subsistence harvest of polar bears is an important economic and cultural activity of Indigenous peoples in Canada, the United States, and Greenland and is strictly regulated to ensure sustainability. The number of polar bears killed in conflict with humans is more difficult to quantify or predict. However, those numbers are likely to grow as polar bears spend more time on land and nutritional stress motivates them to seek out anthropogenic foods. Zoo-based research can help develop mitigation strategies such as non-lethal deterrents and bear-proof containers that local communities can use to improve public safety and promote human-polar bear coexistence.

Pollution from both local and long-distance sources is a threat to the health of individual polar bears and can have important population-level effects. Although many long-term impacts are still being studied, contaminants can impair immune function and reproductive health and impose synergistic or cumulative effects on animals facing other environmental stressors. Polar bears in the controlled environments of zoos and aquaria can provide important comparisons to their free-ranging counterparts. They can reveal mechanisms of contaminant absorption and biomagnification and the role of diet or environmental conditions.

Polar bears on exhibit are a popular visitor attraction. The immediate vulnerability of polar bears to climate change provides powerful and intuitive opportunities to educate visitors not only on the threats to their conservation, but broader global impacts of greenhouse gas emissions and options for mitigation and transitioning to a more sustainable future.

Photo courtesy of G. Thiemann.

There is mounting recognition of the social and economic costs of climate warming and the vulnerability of human and non-human animals to the ecological changes associated with global warming. At the same time there is a growing appreciation that zoos and aquaria can play a leading role in conservation research and education.

Individual polar bears under human care deserve the best possible welfare and husbandry practices. They also deserve the opportunity to contribute to the long-term wellbeing of their species. The research outlined in this prospectus strives to do both.

Dr. Gregory Thiemann
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Member, IUCN/SSC Polar Bear Specialist Group

Polar bear research prospectus

Photo courtesy of Kt Miller / Polar Bears International.

BACKGROUND

Polar bears, a key species in the Arctic ecosystem, are under significant threat due to climate change. As the loss of sea ice, their main hunting, mating, and traveling habitat, accelerates due to anthropogenic climate warming, their existence hangs in the balance (Molnár et al., 2020). Polar bears are currently listed as Vulnerable on the IUCN Red List as, without swift intervention to drastically reduce our CO_2 emissions, their global population is projected to decline by 30% by 2050, a trend set to continue into the foreseeable future (Wiig et al., 2015).

Robust scientific research forms the bedrock of effective conservation interventions. Over the past four decades, despite considerable logistical hurdles, researchers have successfully conducted in-depth studies on polar bears in their natural habitats. This has yielded crucial information about their ecology, distribution, and population trends, thereby deepening our understanding of the species and their survival needs (IUCN/SSC Polar Bear Specialist Group, 2021).

However, certain vital studies are impossible to conduct in the wild, making zoos and aquaria indispensable partners in polar bear conservation research. Unlike their wild counterparts, bears in managed care can be continuously observed and accessed or sampled repeatedly over extended periods, enabling the acquisition of a more comprehensive dataset. These controlled environments also offer the ideal testing grounds for the calibration and validation of new research methodologies and technologies before their field deployment (e.g., Prop et al. 2020).

A number of organizations are instrumental in advancing this research agenda. The European Association of Zoos and Aquaria's polar bear European Ex-situ Programme (EAZA EEP) and the EAZA Bear Taxon Advisory Group (EAZA Bear TAG) are among those leading the efforts in Europe. Simultaneously, the Association of Zoos and Aquariums' Polar Bear Research Council (AZA PBRC) in North America presents an exciting potential for transatlantic collaboration (Polar Bear Research Council, 2022). Individually as well as through coordinated efforts and information sharing, these entities help increase research sample sizes, reduce redundant efforts, and contribute substantially to our scientific understanding of polar bears and the challenges they face in a warming Arctic. Such comprehensive, combined efforts in research, conducted both in the natural habitat (in situ) and controlled environments (ex situ), are providing the necessary scientific basis for effective and informed conservation strategies, safeguarding the future of polar bears.

The importance of such collaborative work between researchers and zoos was recently underscored by the EAZA polar bear long-term management plan listing participation in ex situ research for in situ conservation as one of its calls to action (EAZA Polar Bear EEP, 2022), and by the IUCN via its approval of motion 094 "Linking in situ and ex situ efforts to save threatened species" (The IUCN World Conservation Congress, 2020).

THE PROSPECTUS PROCESS AND AIM

This research prospectus is tailored for researchers and institutions interested in conservation-oriented studies on polar bears in EAZA facilities (see Table 1 and Figure 1 below), as well as the staff involved in their care. The prospectus will be regularly updated to serve as a guide for collaborative, conservation-relevant polar bear research.

The prospectus outlines five main areas of interest (topics): Behaviour and physiology; Biobanking and research data management; Disease and pathology; Energetics, diet and nutrition; and Field techniques. It is worth noting that these topics are inherently interconnected, an unavoidable reality given the complex nature of ecological research.

The research opportunities outlined in each section were generated through a process beginning with an online survey in which more than 50 specialists with significant in-field polar bear experience were invited to provide suggestions for conservation-focused research. These experts, hailing from all five polar bear nations, represented a variety of institutions, including government agencies, universities, and NGOs. The proposed research projects were then carefully evaluated for urgency, feasibility, and potential conservation impact during an in-person workshop in March 2023. This evaluation was carried out by polar bear specialists from various organizations, including the EAZA polar bear EEP, the EAZA Bear TAG, SDZWA, Polar Bears International, and the IUCN PBSG. The process aimed to incorporate perspectives from both ex situ and in situ professionals, and to balance the conservation impacts with the practical feasibility of the proposed studies.

An old male polar bear from the Churchill, Canada, population. Photo courtesy of BJ Kirschhoffer / Polar Bears International.

Demographics and location of the EAZA polar bear population

INSTITUTION	COUNTRY	MALES	FEMALES	TOTAL
Aalborg Zoo	Denmark	0	3	3
Aqua Zoo Friesland	Netherlands	2	0	2
Berlin Tierpark	Germany	0	2	2
Brno Zoo	Czech Republic	0	1	1
Budapest Zoo	Hungary	1	0	1
Copenhagen Zoo	Denmark	0	3	3
Dierenrijk Europa	Netherlands	1	1	2
Highland Wildlife Park	UK	3	1	4
Kazan Zoological Garden	Russia	1	0	1
Monde Sauvage Safari	Belgium	1	1	2
Moscow Zoo	Russia	1	2	3
Münchner Tierpark Hellabrunn	Germany	0	3	3
Orsa Rovdjurspark	Sweden	0	2	2
Ouwehand Zoo	Netherlands	1	3	4
Pairi Daiza	Belgium	2	2	4
Parc Zoo du Reynou	France	2	0	2
Parc Zoologique d'Amneville	France	2	0	2
Parc Zoologique de La Fleche	France	2	1	3
Parc Zoologique Mulhouse	France	0	3	3
Peak Wildlife Park	UK	2	1	3
Prague Zoo	Czech Republic	1	1	2
Ranua Wildlife Park	Finnland	0	1	1
Rostock Zoo	Germany	0	5	5
Rotterdam Zoo	Netherlands	2	0	2
Sosto Zoo	Hungary	1	1	2
Tallinn Zoo	Estonia	1	1	2
Tiergarten Nürnberg	Germany	1	2	3
Tiergarten Schönbrunn, Vienna	Austria	1	1	2
Tierpark Hagenbeck	Germany	0	2	2
Tierpark Neumünster	Germany	1	1	2
Warsaw Zoo	Poland	2	0	2
Wildlands Adventure Zoo Emmen	Netherlands	0	3	3
Yorkshire Wildlife Park	UK	6	2	8
Zoo am Meer Bremerhaven	Germany	0	3	3
Zoo de Cerza	France	2	2	4
Zoo Hannover	Germany	1	2	3
Zoo Karlsruhe	Germany	1	1	2
ZOOM Erlebniswelt Gelsenkirchen	Germany	1	2	3
TOTAL (EAZA POLAR BEAR EEP)		42	59	101

Table 1: *Location and number of polar bears in EAZA institutions as of July 2023. An updated version of the information contained in this table can be requested via the chair of the EAZA Bear TAG (see "How to use the prospectus").*

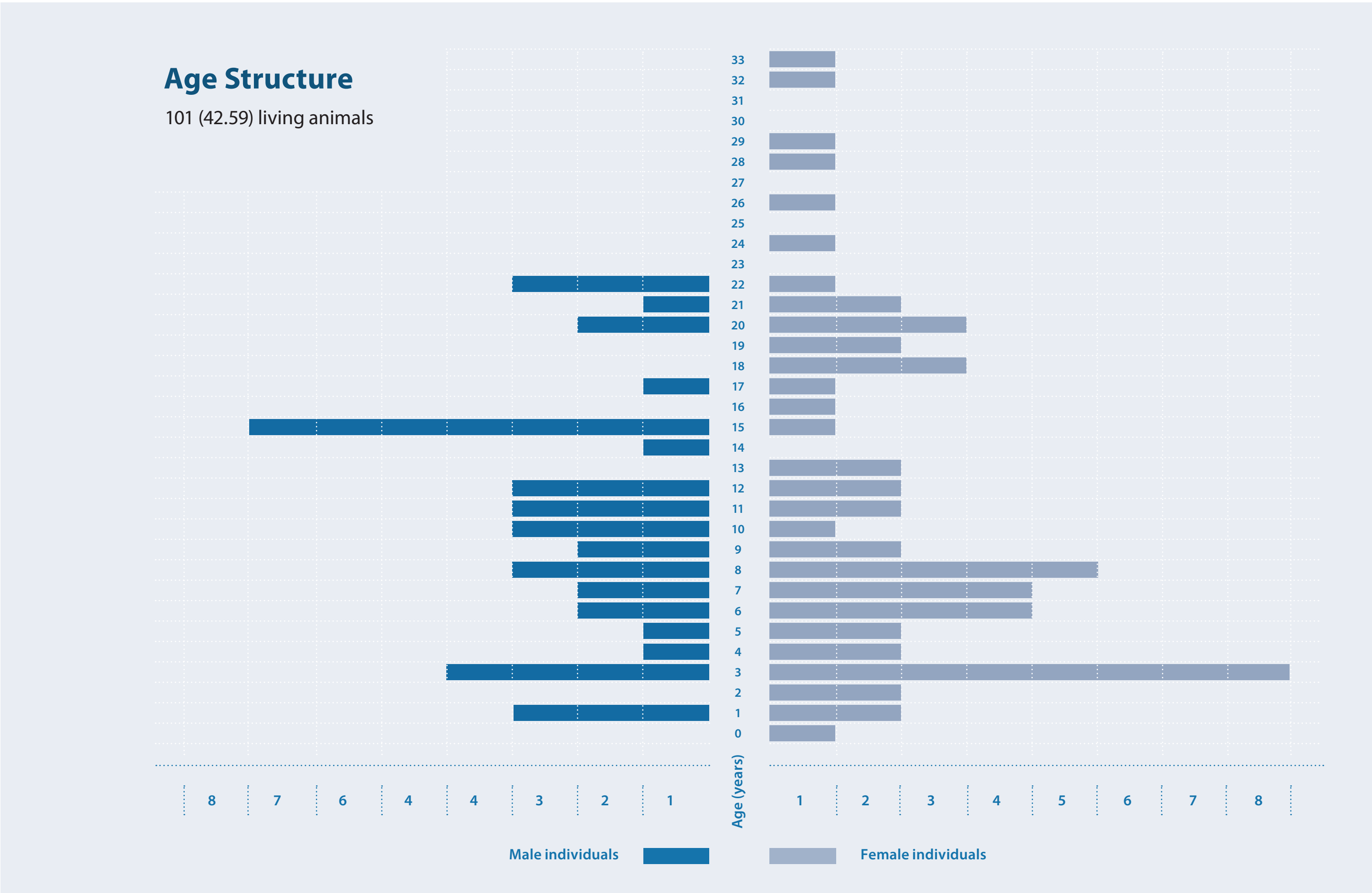


Figure 1: *Age distribution of polar bears in EAZA institutions as of July 2023. An updated version of the information contained in this figure can be requested via the chair of the EAZA Bear TAG (see "How to use the prospectus").*

HOW TO USE THE PROSPECTUS

This research prospectus is a comprehensive guide for conservation-oriented, collaborative polar bear research. It outlines five key topics, with both detailed and broad suggestions that inspire specific research queries. Readers are invited to propose additional research ideas or seek clarification on included projects by contacting the chair of the EAZA Bear TAG (José Kok, jose.kok@ouwehand.nl). The prospectus also includes essential practicalities: Appendix A provides considerations for partners initiating collaborative projects (as well as a note on ethical considerations), while Appendix B describes the process to request project proposal endorsement by the polar bear EEP, and the inherent value of this endorsement.

Polar bear female with her 102 days old cub at Tierpark Berlin. Photo courtesy of Tierpark Berlin.

Photo courtesy of BJ Kirschhoffer / Polar Bears International.

Conservation-relevant topics for future in situ / ex situ polar bear research collaborations

- **Behaviour and physiology**
- **Biobanking and research data management**
- **Disease and pathology**
- **Energetics, diet, and nutrition**
- **Field techniques**

Behaviour and physiology

Understanding the complex behaviour and physiology of polar bears is crucial for their effective conservation and the management of human-polar bear interactions in the wild. Of particular interest is their denning behaviour, including maternal care and in-den cub development, domains that remain largely unexplored but vital to the survival of the species in the wild. As polar bear dens in situ are inaccessible, and observing bears inside the den is (currently) impossible, observing polar bear denning in zoo environments is an invaluable opportunity (e.g., Owen 2021; Gartland et al. 2023). Further, assessing polar bears' cognitive abilities and sensory ecology could prove essential in the efforts to minimize potentially hazardous interactions and to shape successful management strategies, including non-lethal deterrents (e.g., Owen and Bowles, 2011).

The physiological well-being and survival of polar bears is significantly impacted by environmental stressors. These include climate change, pollution, human-polar bear conflict, and notably, increasing resource extraction and industrial activities in the Arctic region (Wiig et al., 2015; IUCN/SSC Polar Bear Specialist Group, 2021). The potential disturbance caused

Photo courtesy of Erinn Hermsen / Polar Bears International.

to denning females due to industrial activities is particularly concerning (e.g., Owen et al. 2021). However, comprehending these and many other physiological aspects requires the contextual information that can only be acquired through ex situ studies (e.g., Curry et al., 2012).

Undertaking extensive research on the interconnected aspects of polar bear behaviour and physiology not only fortifies conservation efforts, but can also reduce human-wildlife conflicts, ultimately supporting the preservation of polar bears in their natural habitats.

EX SITU RESEARCH OPPORTUNITIES

Assessing polar bear capacity for problem solving and tool use

Research confirms that bears, including polar bears, demonstrate problem-solving and tool use capabilities (Waroff et al., 2017; Stirling et al., 2021). Controlled ex situ environments present an opportunity for a more thorough examination of polar bears' capacity to utilize tools in problem-solving tasks. A deeper comprehension of these cognitive abilities can be applied in designing bear-resistant infrastructure and field equipment. This approach can enhance safety in the Arctic region by discouraging undesirable encounters between polar bears and humans, thereby ensuring the protection of both.

CONSERVATION PRIORITY: High.
METHOD: The setup for this project could be very simple or highly complex, depending on the available resources.
FEASIBILITY IN EXISTING ZOOS: High. Requires setup of experimental equipment within the polar bear enclosure (either the public area or behind the scenes).

Predicting reproductive success

Analysing ex situ data on polar bear body weight and reproduction contributes to a more comprehensive understanding of the relationship between these key factors in their natural environment (Derocher and Stirling, 1994; Molnár et al., 2011). This research would help identify seasonal patterns in activity, weight gain associated with successful pregnancies and offer insights into the seasonal energy requirements of polar bears that is part of the requirements for a successful reproductive outcome (Rode et al., 2010).

CONSERVATION PRIORITY: High.
METHOD: Regular weigh-ins of any polar bears of reproductive age as well as meticulous recordkeeping of diet (and potentially consumption) as well as mating data and any potential stressors the bears may have been subjected to during the study period. May also include data mining of previous records.
FEASIBILITY IN EXISTING ZOOS: High. Requires staff participation in addition to installation of scales.

Reference ranges of serum-based indicators of stress

Serum-based markers of (e.g., nutritional or disturbance-related) stress such as corticosteroid hormones are commonly used in wildlife studies. However, these levels can rapidly spike due to the acute stress of capture, making it challenging to measure chronic stress. Corticosteroid-binding globulin (CBG), a glucocorticoid transporter in blood, has been identified as a potentially more accurate chronic stress marker in bears (Chow et al. 2011). Concurrently, serum heat shock proteins (HSPs) show resilience to acute stressors and, like CBG, have been linked to metabolic changes (Hamilton, 2008; Chow et al, 2011). Both CBG and HSPs hold promise for gaining valuable insights into in situ polar bear stress and health, necessitating further ex situ research to define their reference ranges in polar bears with documented life histories.

CONSERVATION PRIORITY: High.
METHOD: Regular blood draws (by voluntary animal participation or opportunistically).
FEASIBILITY IN EXISTING ZOOS: Moderate. Requires staff participation and potentially animal training, as well as capacity for storing blood samples.

Susceptibility of denning bears to disturbance

Examining the behavioural and physiological responses of denning polar bears to noise and other anthropogenic stimuli through zoo studies would provide insights into their susceptibility to disturbance from human activities in situ. As such, findings could meaningfully contribute to the development of optimal management practices to mitigate anthropogenic noise around polar bear dens in the wild; serving as a crucial step towards protecting polar bears during the exceedingly vulnerable denning time, but also in safeguarding the species against the increasing threats posed by human encroachment and activity in the Arctic (IUCN/SSC Polar Bear Specialist Group, 2021). (Also see related research opportunities listed in this prospectus: "Validating collar-mounted accelerometers in a denning context" and "Validating collar-mounted acoustic tags to indicate cub birth").

CONSERVATION PRIORITY: High.
METHOD: Measure the movement and other behavioural and physiological responses to noise disturbances and human activities while denning.
FEASIBILITY IN EXISTING ZOOS: Moderate. Requirements include an instrumented den (camera and sound recorder), and a mated female polar bear equipped with a collar bearing an accelerometer or other biologger, as well as zoo staff note-keeping of any potentially disturbing activities in the area near the den.

How individual and environmental variation affect denning

Studying maternal denning in polar bears, particularly in a zoo setting, can offer valuable insights into the impact of individual variation and environmental factors on the parturition and cub-rearing process (e.g., Owen 2021; Gartland et al. 2023). By closely examining the unique drivers behind each bear's denning habits and their connection to the surrounding environment, researchers can uncover the interplay between individual traits and external influences.

CONSERVATION PRIORITY: Moderate.
METHOD: Behavioural observations gleaned from video recordings, in addition to staff notes on e.g., den construction and disturbances.
FEASIBILITY IN EXISTING ZOOS: High. Requires an instrumented den (camera and sound recorder).

Kin recognition

Investigating whether polar bears possess the ability to recognize their close relatives holds important implications for in situ management. Kin recognition could influence their inbreeding rates as well as willingness to share resources with conspecifics (Hamilton 1964a,b; Malenfant et al., 2016). Furthermore, there is the question of whether adult male polar bears can recognize their own cubs and if being able to do so could influence the likelihood of infanticide (e.g., Ivanov et al., 2020).

CONSERVATION PRIORITY: Moderate.
METHOD: Use EAZA studbook data to determine kinship between zoo- and aquarium-housed polar bears and select the group to be included in behavioural discrimination trials involving scent samples (likely toe swabs, with the option to also include faecal or urine samples).
FEASIBILITY IN EXISTING ZOOS: High. Requires staff participation and potentially animal training for scent collection (depending on the sample chosen).

Numerical ability

The cognitive capabilities of polar bears, encompassing thinking, knowledge, and problem-solving, remain largely unexplored. Determining their ability to count or assess quantity could have crucial evolutionary implications, as it would likely enhance their hunting, foraging, and navigation strategies (Nieder, 2020). A deeper grasp of these abilities would broaden our understanding of polar bear evolution and behaviour.

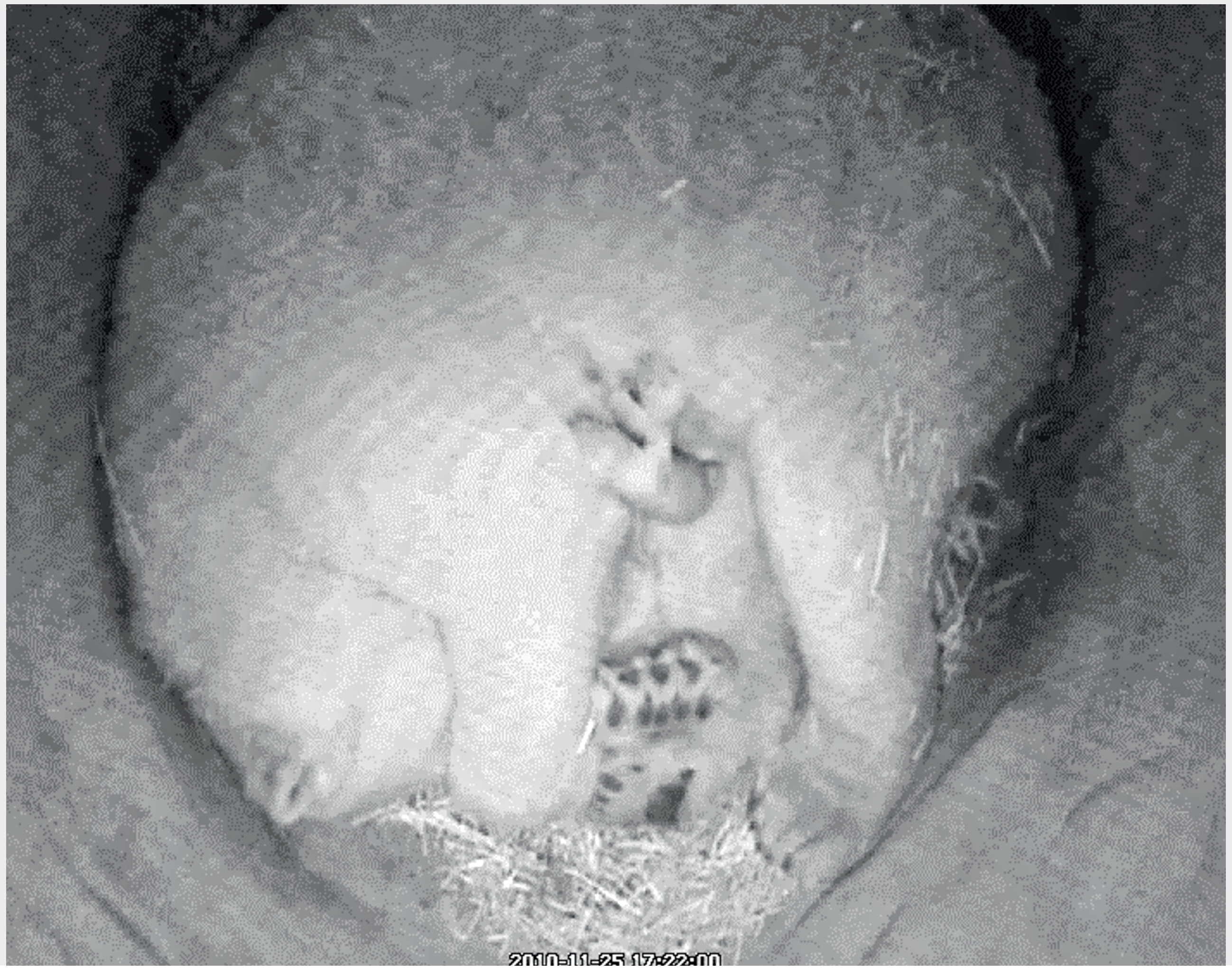
CONSERVATION PRIORITY: Low.
METHOD: Requires a setup for numerical behavioural discrimination training and trials.
FEASIBILITY IN EXISTING ZOOS: Moderate. Requires staff participation.

Sensory modalities

Through zoo-based research, we have gleaned insights into the auditory and olfactory capabilities of polar bears (e.g., Owen and Bowles, 2011; Owen et al., 2014). Yet, a more in-depth understanding of these and other sensory perceptions (e.g., sight, taste, and touch) remains largely anecdotal. Expanding our understanding of the polar bear's "umwelt," or their perceptual world, is paramount. It can provide a more detailed account of how human activities impact their habitat, and aid in management applications, e.g., by devising effective attractant or deterrent strategies in situ. Fundamentally, a more holistic grasp of the polar bear's sensory world would inform a wide range of conservation strategies.

CONSERVATION PRIORITY: Low.
METHOD: The setup for this project could be very simple or highly complex, depending on the available resources.
FEASIBILITY IN EXISTING ZOOS: Moderate. Requires setup of experimental equipment (inside or outside the polar bear enclosure, depending on the specific research question).

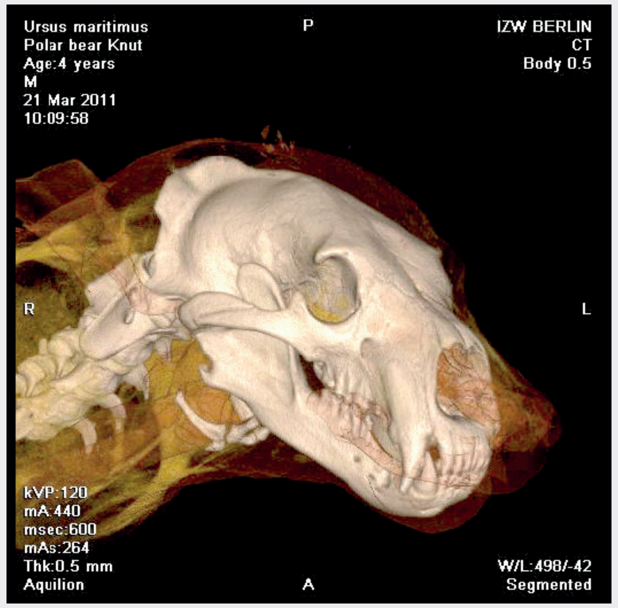
Screenshot of a live feed provided by a video camera in a zoo polar bear maternity den. Photo courtesy of Ouwehands Zoo.



Biobanking and research data management

The systematic archiving of biological samples, coupled with the careful collection of consistent life history data from animals within zoological institutions, plays a pivotal role in polar bear research. The effective management of the vast quantities of data acquired is equally critical (Kanza et al., 2022). Unlike their wild counterparts, polar bears in zoos and aquaria have extensively documented life histories, providing a wealth of contextual data that serve as a benchmark for comparison to wild polar bears.

Such data can cover a wide range of factors, from reproductive behaviour to annual vitamin concentration fluctuations. Consequently, the realm of biobanking and research data management exhibits considerable overlap with most other research topics and ex situ research recommendations outlined in this prospectus. This intersectionality underscores the value of maintaining existing collections of biological samples, and where none currently exist, the establishment of new ones. These repositories are invaluable assets, offering a means to retrospectively investigate physiological and environmental changes over time.



CT scan of a polar bear skull. Photo courtesy of Leibniz Institute for Zoo and Wildlife Research, Berlin.

EX SITU RESEARCH OPPORTUNITIES

Biobanks: supporting their existence and applying their resources to conservation research

Biobanking, the systematic collection, preservation, and storage of skulls/bone, fur, tissue samples and/or cell lines (from both in situ and ex situ individuals), is vital for addressing a wide range of conservation research questions within pathology, genetics, ecology, and environmental impacts. Beyond storage, biobanking includes detailed documentation of each sample, as well as life history data on the source animal. To augment the value of such collections, formally connecting zoos and aquaria with relevant national agencies responsible for in situ polar bear research and management is encouraged, e.g., through data sharing agreements. As the ex situ samples serve to contextualize data from wild polar bears (and potentially vice versa), biobanks support longitudinal studies and retrospective analyses, allowing for monitoring of changes over time and examining historical trends. Biobanks can also preserve genetic diversity that may be lost as populations decline and be a source of material for genetic rescue in the future. In acknowledgement of their importance to polar bear conservation, uniform tissue sampling protocols are currently under development for use across polar bear holding facilities. Meanwhile, the EAZA Biobank is already coordinating, collecting, archiving, and facilitating research on a selection of samples from a range of species for genetics-based population management and conservation research (for more information on this project, including sampling protocols, please visit https://www.eaza.net/conservation/research/eaza-biobank/).

CONSERVATION PRIORITY: High.
METHOD: Biosampling of live, sedated, or deceased polar bears, depending on the type of tissue collected. Data sharing agreements with the relevant biobank and sample donating institutions.
FEASIBILITY IN EXISTING ZOOS: High. Depending on tissue type, samples can be collected opportunistically, or the animals can be trained to participate in the collection of samples on a voluntary basis. Requires staff participation and potentially animal training, as well as capacity for storing tissue samples.

Supporting and utilizing data from animal collection management software
Animal collection management software is a type of software specifically designed for managing animal populations, particularly in zoos, aquariums, wildlife conservation organizations, and research facilities. Popular examples include ZIMS (ZIMS, 2023) and Tracks (Tracks Software, 2023), software solutions that aid in the recordkeeping and management of various aspects of animal care and population management. This can include information about an animal's individual health, genetics, breeding history, diet, and medication. Such data collections can be used for various purposes, including conservation research (Schwartz et al., 2017; ZIMS, 2023), as the extensive ex situ database can provide a comprehensive context to the often comparatively limited data gathered from polar bears in the wild (e.g., on blood test results, age-related health issues or other).

CONSERVATION PRIORITY: High.
METHOD: Data sharing agreements. For e.g., ZIMS such an agreement would be with the organization Species360, which is instrumental to any data mining necessary for a given research project.
FEASIBILITY IN EXISTING ZOOS: High. Zoo participation requires that the institution has access to ZIMS (or similar animal collection management software) and regularly enters data on their polar bears into the system.

Disease and pathology

Climate change is causing wetter and warmer conditions in the Arctic (McCrystall et al., 2021; Druckenmiller et al., 2022). This, in conjunction with other ecosystem changes, may drive changes in pathogen exposure, disease outbreaks, and an expansion in pathogen range into areas previously unaffected (Fagre et al., 2015; Pilfold et al. 2021). In addition, the changing climate leads to changes in the concentrations and composition of the often endocrine-disrupting persistent contaminants found in the Arctic and ingested by polar bears via their prey (Routti et al., 2019). Further, the decline in Arctic sea ice appears to exacerbate these mechanisms in several ways: partly because polar bears are spending more time on land, an environment more abundant in pathogens than is sea ice, and partly because a decline in body condition can lead to reduced immune function and increased susceptibility to disease (Whiteman et al., 2019).

Monitoring the health and disease emergence in zoo- and aquaria-housed polar bears can aid in examining the relationship between a warming climate and changing health for wild bears by establishing clinical pathology reference ranges, validating disease-related biomarkers, and monitoring disease emergence (e.g., Espinosa-Gongora et al. 2021). In addition to identifying variables of key importance in predicting pathology in captive individuals, this approach also helps researchers to better understand and prioritize markers and samples of interest for collection and analyses in wild populations.

Foot crate training, a vital step in preparing the bears for participation in research that for example requires voluntary blood draws. Photo courtesy of Yorkshire Wildlife Park.

EX SITU RESEARCH OPPORTUNITIES

Disease incidence rate and reference ranges

Polar bears in zoos and aquaria can provide essential baseline data on common diseases and general health indicators, including clinical pathology reference ranges and incidence rate of different categories of disease. Such data can then be compared to that of in situ populations of polar bears, helping to identify the primary health markers and samples involved in predicting diseases in polar bears. A deeper understanding of these health indicators can assist researchers in investigating the link between a shifting climate and the changing health conditions of in situ polar bears. At the same time, identifying which particular samples are critical for predicting disease is likely to allow data collection from a larger number of polar bears across various subpopulations.

CONSERVATION PRIORITY: High.
METHOD: Biosampling and data mining of the veterinary records of ex situ polar bears included in the study.
FEASIBILITY IN EXISTING ZOOS: Moderate to high. Samples can be collected opportunistically, or the animals can be trained to participate in the collection of samples on a voluntary basis. Requires staff participation and potentially animal training, as well as capacity for storing tissue samples.

Dose response studies

Dose response studies focus on understanding the relationship between exposure to a pathogen or a contaminant and the health response of living cells (or cell lines) from samples that are often challenging to collect from wild polar bears, such as adrenal glands, liver, brain, and gonads (e.g., Simon et al., 2013). By investigating the direct consequences to the cell of varying dose concentrations, data from such studies can feed into models of population-level effects, thereby aiding in the assessment of the impact of climate warming and the diminishing sea ice on the susceptibility of in situ polar bears to these contaminants and diseases.

CONSERVATION PRIORITY: High.
METHOD: Biosampling and data mining of the veterinary records of ex situ polar bears included in the study.
FEASIBILITY IN EXISTING ZOOS: High. Samples can be collected opportunistically. Requires staff participation as well as capacity for storing tissue samples.

Effects of ambient temperature on physiological processes

Ambient temperatures in the Arctic are increasing due to climate change. This warming could affect the physiological processes of polar bears, including those related to metabolism and immune function (Whiteman et al., 2019; Leishman et al., 2022). Current EAZA polar bear holding facilities span a wide range of latitudes and temperature zones (Table 1). Collecting data on selected physiological processes in these bears would benefit our understanding of how their in situ peers respond physiologically to the observed rise in Arctic temperatures and how this may be affecting their overall health.

CONSERVATION PRIORITY: High.
METHOD: Biosampling and data mining of the veterinary records of ex situ polar bears included in the study.
FEASIBILITY IN EXISTING ZOOS: Moderate to high. Samples can be collected opportunistically, or the animals can be trained to participate in the collection of samples on a voluntary basis. Requires staff participation and potentially animal training, as well as capacity for storing tissue samples.

Svalbard polar bear walking in front of a glacier. Photo courtesy of BJ Kirschhoffer / Polar Bears International.

Energetics, diet, and nutrition

Our understanding of how climate change is affecting the feeding habits of polar bears in situ remains fragmented. Research has shown that as the availability of preferred sea ice foraging habitat declines, polar bears explore alternative prey items, in addition to potentially changing their macronutrient intake (e.g., Rode et al., 2023). This shift in dietary behaviour raises questions about potential health effects on polar bears in their natural habitats. Additional studies are required on the nutritional value of novel food sources, as well as how effectively polar bears can exploit them. To gather this information, a multi-faceted research approach is needed. Regular monitoring of weight and detailed diet record-keeping of polar bears in zoo settings can offer invaluable insights, while simultaneously contributing to improved animal welfare (Rode et al., 2021; Robbins et al., 2021,). Further, controlled feeding trials with polar bears in zoos and aquaria can support the validation of observations from wild populations.

A swim flume chamber, built to measure the bear's oxygen consumption as it swims at different speeds. Photo courtesy of Michael Durham / Oregon Zoo.

This validation allows a broader understanding of wild bears' dietary habits, which is vital for energy modelling and interpreting the ecological consequences of changing prey assemblages. Such research could help anticipate the future survival strategies of polar bears and their overall resilience to the ongoing climate-induced transformation of their habitat.

EX SITU RESEARCH OPPORTUNITIES

Quantifying metabolic cost of thermoregulation in water

To enhance predictive models of the effects of declining sea ice on polar bears, understanding their energy expenditure during swimming is key (Pagano et al., 2019). This requires detailed data on the metabolic costs of thermoregulation while swimming. The most effective and minimally invasive method to obtain this data involves measuring a bear's oxygen consumption as they swim at different speeds. This can be accomplished using a swim flume and chamber - a compact, counter-current pool where the bear must exert effort to maintain position, and the surface is enclosed to facilitate gas exchange monitoring (Pagano et al., 2019).

CONSERVATION PRIORITY: High
METHOD: Metabolic chamber equipped with a setup to measure oxygen consumption.
FEASIBILITY IN EXISTING ZOOS: Low. Participation requires a swim flume and chamber (or similar setup) and animal training.

Turnover rate of dietary tracers

Dietary tracers like fatty acid profiles and stable isotopes are key tools in assessing diet changes in polar bears in the wild (e.g., Rode et al., 2023). By studying the turnover rates of these tracers - the time taken for a new diet to be reflected in biosamples after a known food item being ingested by a bear - researchers can calibrate their models for more accurate predictions about wild polar bear diets. This understanding is crucial for gauging the potential implications of climate change on polar bear diet in situ.

CONSERVATION PRIORITY: High.
METHOD: Diet manipulations followed by biosampling at fixed intervals.
FEASIBILITY IN EXISTING ZOOS: Moderate. Participation requires animal training and a willingness to manipulate polar bear diets.

Nutritional value of alternate food sources

Refining our understanding of polar bear diet changes due to the impact of climate change is vital for assessing the potential consequences on their circumpolar existence (e.g., Rode et al., 2023). Research literature has explored the availability of alternative food sources in the region, but there is a lack of studies evaluating the nutritional value of these resources and the likelihood of polar bears exploiting them as the Arctic ecosystems continue their climate transformation.

CONSERVATION PRIORITY: Moderate.
METHOD: Diet manipulations followed by biosampling.
FEASIBILITY IN EXISTING ZOOS: Moderate. Participation requires animal training, sourcing of the alternate food sources to be investigated, and a willingness to manipulate polar bear diets.

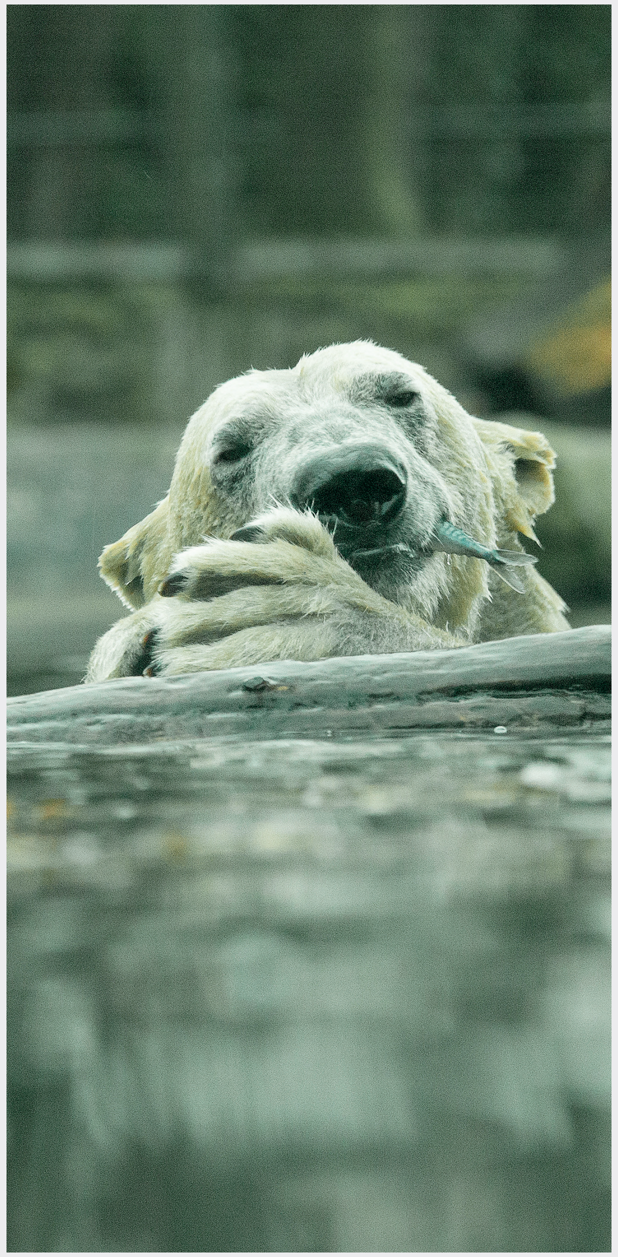


Photo courtesy of Ouwehands Zoo.

Field techniques

Polar bear being fitted with a prototype of a fur-mounted satellite tag. Photo courtesy of Scandinavian Wildlife Park.

Field techniques include activities that enable the monitoring and study of wild polar bears, focusing on innovations and refinements of in-field tools and techniques such as sensor validation/calibration trials, biomarker validation, and tracking tag attachment testing. Given their predominantly solitary existence over expansive, remote home ranges, polar bears present logistical hurdles for researchers. The decrease in sea ice has exacerbated these challenges, impacting safe capture, health assessments, and sample collection (e.g., Atwood, 2023). An innovative and creative approach to in situ polar bear research can significantly contribute to overcoming these challenges, especially if developed in a collaborative in situ/ex situ setting. Controlled environments housing ex situ polar bears provide a platform for in-depth, repeated observations and monitoring, helping to create reliable, field-ready tools. This approach reduces the risk of field deployment failure, thereby enhancing the likelihood of successfully producing high quality data and results. New field techniques could include tagging innovations (e.g., fur-mounted satellite tags [Polar Bears International, 2022] and light-level geolocation tags [Merkel et al., 2023]) or addressing the growing need to develop and validate minimally invasive biomarkers for samples such as tissue dart biopsies, hair strands or faecal matter (e.g., Bechshøft et al., 2011; Pagano et al., 2014; Michaux et al., 2021). These latter methods allow for an extended range of studies including health, population numbers, and movement, without the requirement of chemical immobilization. Further, if focused on expanding the tools available for minimally invasive monitoring, such methods potentially facilitate the expansion of in situ research to the less accessible, lesser-studied polar bear subpopulations.

EX SITU RESEARCH OPPORTUNITIES

Deterrents and attractants

In safely managing human-polar bear interactions, identifying both non-harmful deterrents and attractants is pivotal. Information on the scents that draw bears, the distances at which they can detect food, and how to mitigate these attractants is valuable in reducing encounters. Exploring new deterrents, like specific scents, sounds, or materials, can help discourage bears from approaching human settlements. Conversely, knowing attractants can help in management as well as research contexts (e.g., Berezowska-Cnota et al., 2017; Barrueto et al., 2023). Potential deterrents as well as attractants could be investigated with polar bears in zoos and aquaria.

CONSERVATION PRIORITY: High.
METHOD: The setup for this project could be very simple or highly complex, depending on the available resources.
FEASIBILITY IN EXISTING ZOOS: High. Requires setup of experimental equipment (inside or outside the polar bear enclosure, depending on the specific research question). May require large holding facilities to ensure reliable data.

Validating collar-mounted accelerometers in a denning context

Collar-mounted accelerometers, while proven useful with polar bears in situ (e.g., Pagano et al., 2017), have not yet been validated in a denning context. By instrumenting a soon-to-be denning, pregnant female polar bear in a zoo setting, such devices could be validated for den use and help researchers gain insights into specific den behaviours. The accelerometer data can reveal patterns related to rest, activity, and potential stress indicators if reflected in movement. Such a detailed understanding of denning behaviour, not available in the wild, can provide insights into the bears' coping mechanisms during this crucial period and how environmental stressors may impact them. (Also see related research opportunities listed in this prospectus: "Susceptibility of denning bears to disturbance" and "Validating collar-mounted acoustic tags to indicate cub birth").

CONSERVATION PRIORITY: High.
METHOD: In collaboration with the Chair of the Bear TAG (refer to "How to use the prospectus" for more information), identify female polar bears that are candidates for breeding recommendations and could be equipped with a collar. Compare collar accelerometer data from these bears with data obtained via camera and sound recorder in the maternity den.
FEASIBILITY IN EXISTING ZOOS: Low. Requirements include an instrumented den (camera and sound recorder), and a mated female polar bear equipped with a collar mounted with an accelerometer. This requires either sedation of the bear or collar training for voluntary participation. Additionally, zoo staff must keep note of any potentially disturbing activities in the area near the den.

Validating collar-mounted acoustic tags to indicate cub birth

Validating collar-mounted acoustic tags for polar bears could enable precise identification of cub births through vocalizations. New-born cubs vocalize frequently and loudly and are readily identifiable relative to the pre-partum in-den soundscape (Owen, 2021). Such acoustic data, validated in a zoo environment, could be used to confirm the birth event even in secluded dens in the Arctic. This validation process could enhance our understanding of polar bear reproduction, including timing and influencing conditions. Consequently, it could be instrumental in conservation, providing targeted strategies to protect the bears during this vulnerable period. (Also see related research opportunities listed in this prospectus: "Susceptibility of denning bears to disturbance" and "Validating collar-mounted accelerometers in a denning context").

CONSERVATION PRIORITY: High.
METHOD: In collaboration with the Chair of the Bear TAG (refer to "How to use the prospectus" for more information), identify female polar bears that are candidates for breeding recommendations and could be equipped with a collar. Compare acoustic tag data with data obtained via camera and sound recorder in the den.
FEASIBILITY IN EXISTING ZOOS: Low. Requirements include an instrumented den (camera and sound recorder), and a mated female polar bear equipped with a collar mounted with an acoustic tag. This requires either sedation of the bear or collar training for voluntary participation. Additionally, zoo staff must keep note of any potentially disturbing activities in the area near the den.

Extracting steroid hormones from EAZA polar bear hair samples. Photo courtesy of Anna Hein.

Validating UAV imagery on body mass

Body mass is crucial to polar bear health and reproductive success (e.g., Rode et al., 2010). Currently, acquiring accurate data on body weight in situ is challenging as it requires sedating the animals. Unmanned aerial vehicle (UAV) imagery offers a less invasive method, as proven with other mammals (e.g., Hodgson et al., 2020). However, before this method can be deployed in the Arctic, it must be calibrated to a point where it can accurately correlate drone-obtained body size measurements with known body mass (in zoo and wild bears; see Colby et al. 1993 for a discussion of potential differences in distribution of adipose tissue between the two). Through calibrating this remote sensing technique, a UAV photogrammetry method to assess polar bear body condition from a safe distance can be developed, reducing the need for direct human intervention while boosting data collection precision.

CONSERVATION PRIORITY: High.
METHOD: Compare the body mass of polar bears to their UAV imagery, possibly by use of AI.
FEASIBILITY IN EXISTING ZOOS: High. Requires polar bear weigh-ins and permits to fly a UAV over the polar bears while in their enclosure.

Validating the time period represented by minimally invasive biomarker matrices

The effective use of minimally invasive matrices, such as hair, claws, and faecal samples, in polar bear research requires validation against well-understood measurements in e.g., blood. Biomarker matrices all offer snapshots of a bear's physiological state, yet each is unique as to which period of time in the bear's life it represents (e.g., Hein et al., 2020). Working with ex situ polar bears to validate these timelines and cross-comparing data across different tissues are crucial for accurate representation of the bear's biological state at a given time (e.g., Bechshoft et al., 2019; Hein et al., 2021). This in turn can facilitate understanding of changes in for example hormone levels, diet, or stress responses within highly specific time frames in samples from wild polar bears.

CONSERVATION PRIORITY: High.
METHOD: Biosampling of one or multiple types of matrices throughout the period of interest, along with notes (e.g., behavioural, veterinary) on the sampled polar bears during this period.
FEASIBILITY IN EXISTING ZOOS: Moderate to high. Requires regular biosampling during the period of interest. Depending on the matrix/-eces under investigation, this biosampling could require no interaction with the animal, interaction on a voluntary basis (which requires animal training), or sedation of the animal.

Photo courtesy of BJ Kirschhoffer / Polar Bears International.

Transport best practices

Polar bears in the field occasionally need to be air transported between locations by use of net or sling. To optimize their welfare during and following these translocations, it's imperative to devise a comprehensive protocol, leveraging the knowledge gained from zoos experienced in moving live polar bears (e.g., Cattet et al., 1999). Working with ex situ polar bears, this protocol would meticulously explore (without necessarily moving the bear between facilities) factors like suitable sedation techniques, optimum body postures, and appropriate design of the net or sling transport system for air travel via fixed-wing aircraft or helicopters. The goal is to ensure a humane and minimally stressful relocation process in the field, prioritizing the health and comfort of the wild polar bears being transported throughout their journey.

CONSERVATION PRIORITY: Moderate.
METHOD: Manipulating the position of a polar bear under sedation combined with observation of a range of physiological variables. May require biosampling.
FEASIBILITY IN EXISTING ZOOS: Low to moderate. Requires zoo vet expertise with regards to sedation of polar bears.

Photo courtesy of Kt Miller / Polar Bears International.

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Pointers for those considering a polar bear conservation research partnership

Appendix A

In situ/ex situ research collaborations with a conservation focus hold immense value for our improved understanding of the challenges faced by wild polar bears in a warming Arctic and how to best protect them. However, before diving into such a partnership, it is highly recommended that one, through dialogue, familiarizes oneself with the norms and expectations of one's research partner(s). Proactive thoughtful communication helps prevent avoidable obstacles and miscommunications throughout the research process. The following considerations - listed here for both researchers and zoo professionals - can serve as a useful foundation for initiating these conversations and partnerships.

CONSIDERATIONS FOR RESEARCHERS

Developing a proposal in collaboration with your zoo partner(s)

- Create a detailed proposal delineating critical success factors and negotiable aspects, while respecting keepers' schedules (clearly outline time commitments and distribution of responsibilities during the project).
- Be prepared to adapt your methodology based on staff feedback.
- Consider adding to your project budget expenses for resources such as financial support, labour, or equipment to the zoo.
- Adhere strictly to the standards set by the respective zoo association, ensuring the project and the zoo's integrity.
- Address potential challenges like animal welfare, veterinary concerns, and public perception, while ensuring compliance with all necessary permits and standards.
- Cultural sensitivity: Account for language and cultural differences. Favour phrases like „conservation science“ and „in human care“ over potentially sensitive terms. Translate materials when necessary.
- EAZA Support: Utilize the skills of the EAZA Bear TAG and team (see "How to use the prospectus") for project problem-solving, facility pairing, endorsements, and aid to enhance the project's efficiency and reach.

Clear, proactive communication

- Project onboarding: Transparently discuss the unique goals and potential challenges of the research project with the zoo staff. Ensure consistent updates about the project's progress to reduce apprehensions.
- Staff engagement: Build strong relationships with the zoo staff through regular, personal interactions, and appropriate incentives. Provide regular project updates and express appreciation for contributions. Foster an open, positive, and appreciative working environment and clearly communicate the project's contribution to broader conservation efforts.
- Future project implications: Consider your project's impact on future collaborations. Aim to create a path for successful partnerships in future research endeavours.

Acknowledgement

- Credit and intellectual property rights: Establish a fair credit allocation system, emphasizing co-authorship and contribution acknowledgment. At the project's outset, clarify data and sample ownership, including control and usage of collected information.

Adding value for the institution

- Public engagement: Be prepared for participation in public and popular media events showcasing the project. Contribute to zoo newsletters, social media, and other public-facing materials.

CONSIDERATIONS FOR ZOO PROFESSIONALS AND INSTITUTIONS

Preparing your team for research collaborations

- In preparation for research participation, aim at building capacity in terms of equipment and personnel.
- Set your team up with the necessary tools and knowledge.
- Get your polar bears acquainted with the concept of training, e.g., for a voluntary blood draw.
- Prepare for common inquiries, such as whether your polar bears' diets can be altered for the purpose of a study.
- The EAZA polar bear EEP can offer guidance on such questions and help guide you through this preparatory process.

Communication

- Point of contact (POC): Designate a specific individual as the primary contact for the Principal Investigator (PI) to ensure clear, consistent communication.
- Patience: Understanding that researchers may not be familiar with the complexities of zoo environments is important. Patience and clear communication can help bridge this knowledge gap.
- Changes affecting data collection: Inform researchers promptly about events that could impact data collection, including relocation, medication changes, veterinary procedures, bear behavioural dynamics, changes in husbandry practices, construction activities, and observed medical conditions in the bears.
- Multiple projects: The PI should be informed if the zoo is participating in other projects concurrently, as this could potentially affect the research.
- EAZA support: Utilize the skills of the EAZA Bear TAG and team (see "How to use the prospectus") for project problem-solving as necessary.

Supporting researchers

- Safety procedures: Institutions must provide a thorough safety briefing and essential guidelines for working on-site to ensure the safety of all involved.
- Research questions: The research question may appear overly specific, obvious, or not directly related to conservation. However, it is usually a small part of a larger puzzle or a variable in a complex model that researchers are trying to decipher.
- Rigor in science: Recognize that scientific research generally demands high levels of rigor, which can sometimes be perceived as inflexibility.
- Student involvement: Research might be conducted by a student who is still learning. This can provide opportunities for unpaid assistance but may also require hands-on training and support from the zoo for successful outcomes.

A NOTE ON ETHICAL CONSIDERATIONS

The prospectus contains numerous ex situ research suggestions, some of which may raise ethical or welfare concerns. Any such projects must of course be undertaken only after obtaining all the required permits that explicitly address these issues. Nevertheless, it is important to highlight that all the projects mentioned in the prospectus remain immensely valuable for in situ polar bear conservation. In addition, research studies often bring benefits beyond their primary purpose, such as enhancing animal welfare ex situ (e.g., Puppe et al., 2007; Hopper et al., 2016; Rode et al 2021). The key to success in these studies thus involves a comprehensive education component that explains why the research is being done. This educational focus not only fosters a greater understanding of the research among colleagues, but also bolsters acceptance among visitors who may come into contact with the study. Therefore, this important aspect should not be overlooked when discussing the merits and potential impact of the research being conducted.

Photo courtesy of Simon Gee / Polar Bears International.

Submitting a polar bear research proposal for EAZA polar bear EEP endorsement

Appendix B

THE VALUE OF AN ENDORSEMENT FROM THE EEP

Securing an endorsement from the EEP is invaluable. When you submit your project proposal to the EAZA polar bear EEP, you are inviting expert insights from specialists that can substantially elevate the conservation scope, reach, and overall effectiveness of any in situ/ ex situ collaborative polar bear research. From a practical perspective, the EEP's endorsement will boost your project's acceptance among zoo partners and assist in expanding your sample size through the engagement of multiple zoo partners. Moreover, you can consult the chair of the EAZA Bear TAG and team (see "How to use the prospectus") for advice on project troubleshooting, facility matching, and permit-related queries.

SUBMITTING A PROJECT PROPOSAL

Below, you will find a schematic of the application procedure that a polar bear research proposal must go through to receive an endorsement from the EAZA polar bear EEP (Figure 2). As well, you will find a copy of the document to be used when submitting your project proposal to the EEP. As you begin to fill this document in, please keep in mind the pointers listed in Appendix A. Should you have any questions on the application materials, requirements, or process, please contact the EAZA Bear TAG and team (see "How to use the prospectus").

APPLICATION PROCEDURE FOR EX SITU BEAR RESEARCH IN EAZA ZOOS

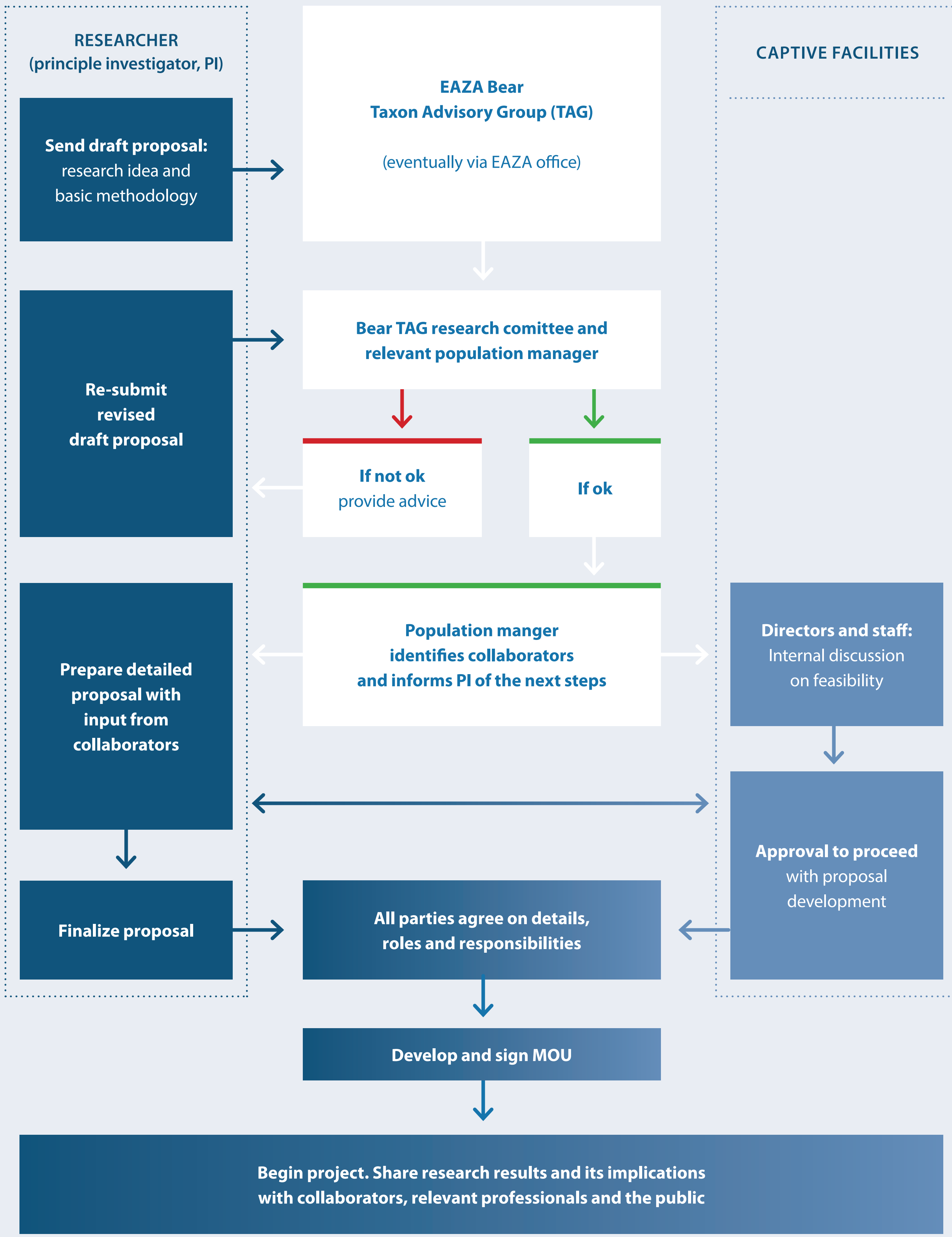

Figure 2: *Schematic of the application procedure that a polar bear research proposal must go through to attain endorsement from the EAZA polar bear EEP.*

EAZA
Application for Research Support

FOR OFFICE USE ONLY
Received:

Section 1 Project Summary

Project Title			
Brief Project Summary *(Max. 200 words; please include justification for study, project aims, methods and expected project outcome)*			
Proposed start date of data collection (dd/mm/yyyy)		**Proposed end date of data collection** (dd/mm/yyyy)	

Section 2 Researchers involved in the study

Please add as many rows as is required.			
Name and Institution Please include all people involved in the project	**Role(s) in the study** e.g. Principal Investigator	**Is this contributing to your academic qualification?** If so, please include qualification level (e.g. M.Sc.) and course subject	**Institutional contact details**
			Address : **Email :** **Tel :**
			Address : **Email :** **Tel :**
			Address : **Email :** **Tel :**
			Address : **Email :** **Tel :**

Section 3 Project Outline

Section 3a Introduction

Background/Introduction:
Research Aims and Objectives:

Section 3b Methods

Methodology:
Research Design:

Section 3c Project Ethics, Benefits and Output

Will the animals or their environment need to be manipulated for research purposes during the course of the study? *For example altering feeding practices, adaptation of enclosure, use of contraception trapping.**	☐ Yes ☐ No ☐ N/A

* ***N.B.*** *Projects which involve manipulation of the animal or its environment must have been reviewed by an Ethical Review Committee*

Will this project be submitted or has it been submitted to an ethical review committee for approval? *If yes, please provide evidence if approval has already been obtained or please give details of the status of the application:*	☐ Yes ☐ No ☐ N/A

Summary of what is needed from EAZA collections:
Project Deliverables and Outputs: *How will this project contribute to science, education, welfare, husbandry and/or conservation?*
What do you aim to give back to the collections who participate once the project is finished? *The support of collaborating zoos will be fully acknowledged in any publications and presentations. If required, the relevant Taxon Advisory Group will be supplied with a copy of any published journal articles that relate to this study, and an electronic copy of the final postgraduate thesis on completion.*
Please indicate whether you would have signed or be willing to sign a Non-Disclosure Agreement in case you will be requesting potentially sensitive data?

Section 4 References

Please ensure all cited references are listed:

Section 5 Signatures

All people named in Section 2 must sign this form		
Name (please print)	**Signature**	**Date**

Section 6 Submission Status- For office use only

Review by TAG members and/or TAG Research Group	
Reviewed by member of TAG Research Group	*Approved (Y/N):* *Enter name and signature below*:
Reviewed by Species Committee Coordinator and/or TAG Chair	*Approved (Y/N):* *Enter name and signature below*:
Reviewer Comments	

Status (approved, conditionally approved or not approved) *Please state reason for decision*

Back cover photo courtesy of Tierpark Berlin.