6. KNOWLEDGE GAPS
Basic knowledge on the vast majority of Arctic biodiversity is limited. Often, only the distribution of mammals, birds and vascular plants is sufficiently documented. Comprehensive data for abundance, population densities and trends are generally available only for vertebrates considered to be of direct significance to people, for example for commercial or other harvest, and for many taxa even the taxonomic status is incomplete. Thus, substantial gaps in biodiversity knowledge are apparent, and a more synoptic approach is necessary to:

- Address critical gaps contributing to a fundamental and functional understanding of diversity as a basis for recognizing and predicting the effects of accelerating change driven by climate and other disturbances.
- Improve understanding of diversity (from species to populations) and interactions of vertebrates, invertebrates and microorganisms that collectively form the web of relationships within northern marine, freshwater and terrestrial systems.
- Improve understanding of the functioning of Arctic ecosystems as to provide a scientifically sound basis for ecosystem-based management.
- Build requisite knowledge that supports ecosystem sustainability and paths for mitigation and adaptation within Arctic societies responding to rapid change and increasing threats to food security.

There is an enormous deficit in our knowledge of species richness in many groups of organisms in the Arctic, and monitoring here is lagging far behind that in other regions of the world. Even for the better-studied Arctic species and ecosystems we have insufficient data on trends in distribution, abundance and phenology.

Photo: Orsolya Haarberg/naturepl.com
The causes of some data gaps are found worldwide, whereas others emerge from factors more special for the Arctic, such as remote and harsh environments, challenging logistics and the dearth of permanent infrastructure for science. Extreme and difficult conditions increasingly converge with the continuing global decline in scientists with appropriate expertise to provide authoritative identifications as a basis for biodiversity survey, inventory and monitoring activities.

Specimen archives, both spatially broad and temporally deep extending into the Quaternary, must be developed in conjunction with permanent museum repositories holding geo-referenced samples backed by web-available databases for large-scale informatics analyses across the Arctic (e.g. Christiansen & Reist, Chapter 6, Hodkinson, Chapter 7, Daniëls et al., Chapter 9, Dahlberg & Bültmann, Chaper 10, Hoberg & Kutz, Chapter 15, Cook, Chapter 17). International cooperative agreements and participation by local communities are essential to efficiently build this high-latitude resource. In the absence of such resources as the functional basis for information systems, rapid and real-time progress
in developing a broad view of Arctic biodiversity is not possible. Specimen archives assembled over years and decades constitute essential baselines for documenting and assessing the causes of spatial and temporal change in northern systems, and they provide pathways to employ new and expanding analytical approaches to assess diversity.

A profound challenge to our understanding of Arctic ecosystem functioning and our capacity to perform ecosystem-based management, is the very few dedicated programs and research stations that maintain fully integrated ecosystem-based approaches to research and monitoring in the Arctic. Regularly repeated measurements according to sampling design that both targets specific hypothesis and allows for detection of surprises (Lindenmayer et al. 2010) are essential to monitor changes in community composition and structure, diversity, productivity, phenology and other critical aspects of biodiversity and ecosystem integrity. Further, knowledge about the effects of the range of drivers and stressors on Arctic biodiversity is basic to its management. In support of biodiversity assessment on the ground, remote sensing from satellites and aircraft can provide temporally and spatially replicated data essential for monitoring, with remarkable speed and cost-effectiveness.
Integrated data resources for archives (collections of specimens, survey, inventory and monitoring) along with field observations and census across circumpolar regions must be developed and coordinated. A potential model is seen in the Circumpolar Biodiversity Monitoring Program (CBMP), although this and similar resources must be explicitly tied to specimens, hard data and authoritative identifications to document current and changing ecological conditions (see Box 5).

In synergy, these form the foundations for comprehensive ecosystem-based approaches to research and monitoring that can reveal how biodiversity may be affected by stressors and disturbances that cascade through food webs. However, this requires more emphasis than present on ecosystem level integration through all stages of science-based inferences from sampling, through data management, statistical modeling and interpretation of empirical results.

Similarly, the International Study of Arctic Change (ISAC) formed by the International Arctic Science Committee (IASC) and the Arctic Ocean Science Board (AOSB) recommends increased efforts to understand and model the physical and biological interactions governing Arctic ecosystems and their relation to Arctic peoples and the rest of the globe (Murray et al. 2010).

The traditional knowledge of indigenous Arctic peoples contains a wealth of information on the uses of Arctic organisms including present and historic locations of fish spawning grounds, phenological events, etc., often indicated by place names. Several initiatives have been undertaken to better engage traditional knowledge and to reduce conflicts between local hunters and fishermen and government authorities devising regulations (Freese 2000, Klein 2005). One example is the co-management program Opening Doors to Native Knowledge in Greenland (Huntington et al., Chapter 19). Improved knowledge of the conditions and actions that foster such collaboration and mutual understanding will help in the design and implementation of local conservation programs.

Commercial bioprospecting of organisms is already underway in Arctic ecosystems, particularly the marine environment, and coordinated careful consideration is needed to balance community and commercial interests (Leary 2008). The potential of the genetic resources present in the Arctic remains poorly understood, however, making it difficult to assess their value in this regard.

From the perspective of scientists, lack of information for particular areas can hamper acquisition of open and unbiased analysis and make accurate conclusions and predictions very difficult. Therefore, possibilities for acquisition, cooperation and sharing of data from all parts of the Arctic are important for scientific analysis as well as for resource management.

**Possible actions**

Detailed suggestions for filling specific knowledge gaps are provided in the various chapters of this assessment. Here, we describe why major categories of knowledge gaps must be filled, urgently and to the best of our collective ability. A great deal is known about Arctic biodiversity, as demonstrated by the depth and detail of the chapters of this assessment, and the need for vigorous and prompt conservation action is strongly supported by current knowledge. At the same time, much remains to be learned, which will help design and carry out more specific and effective conservation measures in the context of rapid change and increasing industrial development in the Arctic.
The lack of basic knowledge about many aspects of Arctic biodiversity hampers our ability to evaluate the effectiveness of conservation actions. The threat of overharvest has been greatly reduced in the Arctic in part because sufficient knowledge exists to develop effective conservation measures and to build support for those actions. This success applies, however, only to a relatively few harvested species. Other conservation measures make up for a lack of specific knowledge with a broad approach, as is the case with protection of large areas of habitat. A comprehensive approach to gathering data about species and ecosystems is needed to better understand how environmental change and changes in human activity will affect Arctic biodiversity and the conservation thereof.

The lack of monitoring and modeling capability for many aspects of Arctic biodiversity and their drivers of change makes it difficult to assess change, its cause and its implications, and what could be rational conservation actions. Change cannot be measured without a baseline. For many species and ecosystem processes, that baseline of knowledge does not exist. Similarly, modeling efforts have focused on the physical environment and a few key species or ecosystem parameters. A coordinated ecosystem-level oriented monitoring and modeling effort is needed to support biodiversity conservation efforts in a time of rapid change.

The lack of specimens and museum collections means that a firm foundation for assessing biodiversity and changes thereto is missing. A solid baseline requires hard data and definitive specimens. This area has received insufficient attention to date. A collaborative approach to collection and archiving of specimens could help ensure that further change can be assessed and quantified.

A great deal of research has been done on various aspects of Arctic biodiversity, but overall databases and knowledge bases do not exist for most topics. The circumpolar study of Arctic biodiversity is further hindered by barriers to the access of field sites. Broad support for open science, from field work to analysis to archives, would help address this issue and provide a means to pool collective knowledge and expertise.

The shortage of trained professionals in appropriate fields related to biodiversity means that filling knowledge gaps will remain a challenge. Too few scientists are available to work on many aspects of biodiversity, from taxonomy and systematics to integrative problem solving at the ecosystem level. Greater efforts could be made to recruit and support specialists in these fields, so that needed knowledge can be generated in a timely fashion to support conservation of Arctic biodiversity.

The lack of awareness of most aspects of Arctic biodiversity, combined with the limited degree to which Arctic residents are involved in biodiversity research and conservation, reduces public and political support for important conservation actions. Charismatic species get a great deal of attention, which can help support species-oriented conservation measures. A commitment to conserving overall biodiversity as a vital legacy for all of humankind, however, will require broader public understanding of what is at stake, and broader participation in generating information and solutions.