Species protection has focused on preventing overharvest, which has historically been the largest threat to Arctic biodiversity. Seabirds are an example of biodiversity that is susceptible to such overharvest, and this has caused population declines in some parts of their range. In these areas, careful regulation of harvest is necessary as part of a conservation and restoration strategy. Kippaku, NW Greenland. Photo: Knud Falk.
Chapter 19

Disturbance, Feedbacks and Conservation

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We were told not to hunt animals for the sense of killing. Because you are not able to use that animal for eternity. I believe we were also taught that there is a certain purpose here in this particular time for us to utilize these marine mammals. That was what I heard the elderly people say from the older generation, like Pelaasi and others, used to say. They were saying: the ‘plan’ has been already made. The ‘master plan’ is that our purpose is to hunt marine mammals, but that we should not take that for granted. This is why conservation is so important in our culture.

SUMMARY

Humans disturb the environment in various ways, notably from industrial development and other activities in formerly pristine areas. Components of the earth system affect one another in a web of feedbacks, including between ecosystems and climate. Conservation is the human attempt to avoid or minimize negative impacts of human activity on species and habitats. This chapter examines all three topics.

Disturbance here refers to the disruption of normal ecological functions or distributions at the landscape level. While many types of human activity can affect local environments, industrial development is most likely to affect larger areas, followed by spatially extensive practices such as reindeer herding that can lead to heavy grazing and trampling. Around the Arctic, human activity is increasing, with more roads and other infrastructure, leading to a greater overall impact, especially in areas with oil and gas or other valuable commodities.

Feedbacks occur in many forms at many scales. Here, we look at the primarily positive feedbacks from Arctic warming to global climate, which are likely to lead to still greater warming. For example, the loss of ice and snow leaves a darker surface, so that more sunlight is absorbed, leading to greater warming and so on. Changes in the Arctic’s role in the carbon cycle, through release of carbon dioxide and methane and possible increased uptake of carbon dioxide through increased vegetation growth, will affect global climate. Forcing through positive feedbacks is likely to outweigh the impacts of negative feedbacks within the Arctic.

Three measures of conservation are addressed next. Habitat protection is usually measured in terms of protected areas, which are generally strong on land in the Arctic but nearly absent in the marine environment. Species protection includes those species listed in various categories at risk of extinction, and unfortunately these lists appear to be growing in the Arctic as elsewhere in the world. Effective conservation also requires the participation of the people who are likely to either create threats or be affected by management measures. A growing number of programs seek to include Arctic residents in gathering, analyzing and making use of observational data, which often cannot be obtained in other ways.

For the purposes of this assessment, disturbance refers more narrowly to the disruption of normal ecological functions or distributions at the landscape level, posing a threat to biodiversity. While many types of human activity can affect local environments, industrial development is most likely to affect larger areas, followed by spatially extensive practices such as reindeer *Rangifer tarandus* herding that can lead to heavy grazing and trampling of vegetation.

Feedbacks are in one sense a part of the natural world, constraining the natural cycles of weather, climate and biology. Feedbacks large and small are thus present throughout the world. While negative feedbacks tend to push a system back to its original state, positive feedbacks lead to ever greater or faster change. Melting snow, ice and permafrost in the Arctic are one such positive feedback, and are described herein. This feedback is already important at the global scale, and likely to become even more significant in the near future as sea ice retreats in summer, snow cover becomes less extensive in space and time, and permafrost degrades and thaws, all of which will lead to greater warming and thus further change.

On a more optimistic note, conservation efforts are mankind’s attempt to reduce its negative impacts on the environment. Habitat protection recognizes that biodiversity requires intact ecosystems for natural processes to continue. Species protection focuses directly on populations that are at risk, aiming at its simplest to avoid extinction from human causes. Environmental monitoring is essential to determine what is at risk and whether conservation efforts are succeeding. In the Arctic, sparse populations and remote areas create a special need for the involvement of local residents in community-based initiatives. These three conservation measures are addressed here.

This chapter is neither exhaustive nor definitive on the topics of disturbance, feedbacks and conservation. It aims instead at describing key aspects of human-ecosystem interactions, focusing on matters of special significance in the Arctic, with the expectation that these areas of focus will be relevant markers for future consideration of trends in Arctic ecosystems and their relationship to humans and to the world as a whole.

19.1. INTRODUCTION

Humans interact with Arctic ecosystems in many ways. This chapter examines three types of interactions: disturbance, feedbacks and conservation. Disturbance is the effect that human activity has on the natural environment. Taken broadly, nearly everything humans do creates some form of disturbance, since the natural world is altered by our presence and our activities. Some of this interaction is the normal result of people living as part of the ecosystem, and thus does not constitute a threat.
of contaminants, from mining to tourism. Direct effects on certain Arctic ecosystems with a significant human presence, such as the hydrocarbon fields of northern Russia, are likely to be even more imperative than climate change in the next few decades. These effects include direct and indirect impacts associated with, for example, resource exploitation and altered grazing regimes due to changing patterns of reindeer husbandry. Evidence shows that even small scale, low intensity disturbances can accumulate spatially from local to regional scales.

Besides habitat disturbance, human activities may cause disturbance in the form of displacement (scaring) of wildlife from preferred habitat. This is not dealt with here, but see Meltofte et al. (Chapter 1), Reid et al. (Chapter 3) and Ganter & Gaston (Chapter 4).

### 19.2.2. Direct impacts

In general, the direct mechanical disturbance of Arctic terrain, including vegetation, soil and the underlying permafrost layer, can lead to erosion where slope and/or ice-rich permafrost are present (Forbes et al. 2001). Unchecked, severe erosion can progress to eventually degrade entire landscapes. Among the aforementioned three components, vegetation has special importance, not only as the basic link to the upper trophic levels of an ecosystem, but also in terms of its controls over permafrost and ground-ice maintenance in tundra substrates. In addition, the regeneration of an ecosystem after disturbance is dependent upon revegetation, which is the essential first step of ecosystem recovery. Vegetation cover, therefore, is one of the best criteria to assess overall ecosystem status in the wake of previous environmental degradation. Restoration efforts are generally lacking in tundra ecosystems because of the constraints imposed by climate, although assisted revegetation efforts can succeed under certain circumstances when viable seeds or vegetative cuttings are properly cultivated and subsidies of nutrients and water are sufficient. Such efforts can be expensive, however, and most disturbed terrain is left to revegetate naturally, except where control of aeolian erosion is essential (Forbes & McKendrick 2002). Regeneration is slower in the high Arctic compared with the low Arctic and proceeds more quickly on moist-wet terrain, unless there has been subsidence from thawing permafrost. Some of the scars from oil exploration on Alaska’s North Slope in the 1950s are still visible today (Forbes et al. 2001).

Anthropogenic impacts are complex in that various human activities can influence ecosystems simultaneously and cumulatively, and can have both immediate catastrophic and long-term effects. In practice it can be difficult to distinguish between direct and indirect impacts, and scientists may use different methods for classifying disturbances (Crawford 1997, Gilders & Cronin 2000, Nellemann et al. 2001, National Research Council 2003). For example, Russian scientists distinguish three main classes of disturbed areas: ochagovy (local), lineinyi (linear) and fonovy (spatial) (Khitun & Rebristaya 2002). The most striking example of the first type includes sites surrounding petroleum bore-holes (drill sites). Recent data from Arctic Russia indicate that each drilling denudes vegetation over an area of about 120-200 m in diameter, with moderate impacts beyond that distance (Forbes et al. 2009). Transport corridors appearing in connection with road and pipeline construction constitute linear disturbances. Large territories affected by air pollution are examples of spatial disturbances. Especially in the older gas and oil fields, the amount of terrain disturbed on Russian territories exceeds by an order of magnitude that from North American (Tab. 19.1). The track record in Russia has improved in recent years, particularly in the case of post-Soviet joint ventures, such as the Ardalin Oil Field first developed in 1993-94 by ConocoPhillips’ Polar Lights Co. in the Timan-Pechora basin (Rasmussen & Koroleva 2003, Stammler & Forbes 2006).


<table>
<thead>
<tr>
<th>Northwest Siberia</th>
<th>Area (km²)</th>
<th>Arc. Coastal Plain</th>
<th>Alaska</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamal-Gydan region</td>
<td>235,000</td>
<td>230,000</td>
<td></td>
</tr>
<tr>
<td>Yamal Peninsula</td>
<td>112,000</td>
<td>71,000</td>
<td></td>
</tr>
<tr>
<td>Total area disturbed (Yamal-Gydan)</td>
<td>6,000-7,000</td>
<td>785</td>
<td>Total area disturbed (Trans-Alaska Pipeline System)</td>
</tr>
<tr>
<td>Bovanenkovo Gas Field (BGF)</td>
<td>2,052</td>
<td>991</td>
<td>Prudhoe Bay Oil Field (PBOF)</td>
</tr>
<tr>
<td>Bovanenkovo Gas Field</td>
<td>200</td>
<td>16.9</td>
<td>Prudhoe Bay Oil Field</td>
</tr>
<tr>
<td>Severely disturbed terrain (BGF)</td>
<td>277-287</td>
<td>8.8</td>
<td>Severely disturbed terrain (PBOF)</td>
</tr>
<tr>
<td>Indirect impact zone (BGF)</td>
<td>448</td>
<td>na</td>
<td>Indirect impact zone (PBOF)</td>
</tr>
<tr>
<td>To be disturbed in the near future</td>
<td>500</td>
<td>na</td>
<td>To be disturbed in the near future</td>
</tr>
</tbody>
</table>

The point at which small disturbances create large impacts can be hard to identify, but for indigenous peoples it may begin with a sense of breaking the ‘whole’ that constitutes their environment and the role of humans therein.

One of the most widespread types of direct impact is damage to tundra from off-road vehicle traffic (Forbes et al. 2001, Kumpula et al. 2011). In vehicle tracks, plant and soil nutrient cycling regimes can become significantly different than in undisturbed areas, with increases and decreases variable among species, growth forms and soil types. Although the actual ruts may be small to begin with, the shift from scale-of-impact to scale-of-response can be several orders of magnitude, as in the case of drained wetlands. Even shallow ruts from as little as a single-pass vehicle track are capable of effectively diverting runoff from spring snowmelt away from wet and mesic sedge fens that depend upon this source of moisture. Such desiccation of wet tundra has resulted in the local extinction of aquatic sedges Carex spp., sphagnum mosses Sphagnum spp. and other hydric bryophytes, as well as an increase in surface albedo (Forbes 1997). Similarly, as little as a single passage of a vehicle in summer is sufficient to significantly reduce the abundance of soil arthropods (Kevan et al. 1995). In areas with substantial ground-ice, thermokarst activity can expand appreciably. In northern Alaska, some disturbances on silty sediments covered at least twice the original area of impact after 30 years, but most off-road traffic has been effectively banned since the mid-1970s (Forbes et al. 2001). A similar ban has been in place in the hydrocarbon fields of Arctic Russia since the late 1980s, but has proven far less effective (Khitun & Rebristaya 2002, Kumpula et al. 2011).

We often learn of plans for industrial development only by accident; for example we have learned about the shelf oil-field development project from the American side, and we began to write about it. The authorities often hold back ecological information from us that is important for the society. That’s why we often support something without being aware of the ecological consequences.

(Andrey Novikova 2008).

### 19.2.3. Indirect and cumulative impacts

In addition to direct disturbances of the ground surface, other, less visible impacts can accumulate over time. These may occur independently of each other, or may be exacerbated through synergy among various proximal effects. These indirect or cumulative impacts are well-documented, especially in the hydrocarbon fields of North America and Russia. Whereas in the early years of development they were often unforeseen, scientists are now better able to predict them (e.g. Gilders & Cronin 2000, Forbes et al. 2001, Kumpula et al. 2011).

Given the large amount of hydrocarbon extraction activities that have taken place over several decades on both the North Slope of Alaska and the Yamal-Nenets Autonomous Okrug (YNAO), it is worthwhile to compare the extent of impacts in these two regions (Tab. 19.1). In most cases, the extent of indirect impacts exceeds the physical footprint of an Arctic oil or gas field complex, although efforts at mitigation have continued to improve (Forbes et al. 2009). For example, construction of the entire 1,288 km Trans-Alaska Pipeline directly disturbed 785 km² of land (Walker 1996). It is claimed that if Alaska’s Prudhoe Bay Oil Field were developed today using current technology and consolidation of facilities, gravel would cover at least 80% less area, and the oil field’s direct footprint would be less than half its current size (Gilders & Cronin 2000, National Research Council 2003). In the case of the YNAO and the Nenets Autonomous Okrug (NAO), where migratory Nenets and their large reindeer herds move back and forth across actively exploited fields, it is important to note that it is not only a matter of how much territory is affected, but what kind of territory and which migrations routes are affected by the losses. Furthermore, research based on extensive participant observation and interviews with nomads has revealed that each territory has its own particular meaning and importance for users, so that one territory is not equivalent to another (Forbes et al. 2009, Kumpula et al. 2011).

By 1994, disturbed terrain comprised an estimated 6,000-7,000 km² of the YNAO. Most of the damage to date has been in the southern portion of the region (Khitun & Rebristaya 2002). The impact in the northern tundra zone is still in the early stages, but includes intensive terrestrial and aquatic impacts in and around the Bovanenkovo Gas Field on the territory of the Yarsalinski sovkhoz. At that time, the gas field encompassed more than 200 km², of which half was severely disturbed and which affected narrow migratory corridors. As of 2005, the visibly affected area around Bovanenkovo, including both direct and indirect impacts, had encompassed about 450 km² (Forbes et al. 2009). This has increased in the last several years as the gas field expands to the northeast so the affected area was 836 km² as of summer 2011 (Kumpula et al. 2012). Oil development in the Arctic regions of the NAO is some years behind that of the YNAO but is catching up quickly.

Several other indirect (and direct) impacts in both terrestrial and aquatic habitats stem from roads and railways. One example is the construction of a transport corridor on Yamal Peninsula between Bovanenkovo and the port of Kharasavey to the northwest (Fig. 19.1). According to nomadic Nenets reindeer herders, the building of about 130 bridges initially degraded key rivers and lakes so that the supply of fish for daily subsistence, especially critical for reindeer herders during summer migration, was less reliable for several years (Forbes et al. 2009). However, in 2011 the same herders reported that fish had begun to return in significant numbers (Kumpula et al. 2012). In the absence of strict regulatory oversight, poaching can be a chronic problem whenever access to formerly remote regions becomes possible for the general population. Thus, the ongoing influx of workers in both the NAO and YNAO is certain to increase fishing pressure and accelerate this process since...
enforcement of existing regulations remains lax relative to North America (Forbes et al. 2009). Throughout the Arctic, gravel roads and sand quarries are subject to wind erosion and can spread sand and dust up to one kilometer from the source (Forbes 1995, Myers-Smith et al. 2006). Road dust is alkaline and is capable of rapidly smothering bryophytes, lichens and mushrooms on the surface. Dust significantly increases the pH of soils and surface waters, and alters the nutrient contents of abundant vascular plants and mosses in as few as four years. During the same time period, blowing sand can bury all mosses and lichens, and many vascular plants, up to a distance of 250 m from the source (Forbes 1995).

Additional types of impacts result from oil leaks and spills. Massive oil spills, such as the Exxon Valdez or the Deepwater Horizon, have not yet occurred in truly Arctic waters. However, the multifaceted concerns surrounding offshore development continue to grow quickly as the economic viability of fields in the Beaufort, Barents and Kara Seas increases annually, where difficulties in cleaning up after a spill would likely be exacerbated by cold temperatures and ice in part of the year (Margesin & Schinner 1999). The scope of actual and potential development, and the environmental risks involved,
has been detailed in two landmark reports by AMAP (1998, 2007). Onshore, one of the largest spills in history occurred near Usinsk, Komi Republic, in 1994, resulting in a release of oil into tributaries of the Pechora River estimated to be eight times greater than the Exxon Valdez spill (Crawford 1997). Experts argue that since cleanup of such accidents can be difficult or impossible, as well as astronomically expensive, the best solution is a sustained, all-out effort at prevention (Jernelöv 2010). However, the spotlight on British Petroleum’s (BP) practices in recent years in Alaska and the Gulf of Mexico has detailed the extent to which certain companies clearly prefer to channel resources into production and profits rather than field safety and longevity (Graham & Reilly 2011, Goldenberg 2011, New York Times 2011a, 2011b). Other important issues are airborne pollution from the flaring of excess gas within active fields and, in the Murmansk and Norilsk regions, from smelters. Evidence from both North America and Eurasian high latitudes indicates that pollutants, including heavy metals, accumulate in terrestrial and aquatic systems downwind and can persist for decades (AMAP 1998). As in the case of drained wetlands cited earlier (Forbes et al. 2001), the shift from scale-of-impact to scale-of-response can be several orders of magnitude when pollutants spread outward from point sources and either settle on the surface or are entrained in atmospheric air currents for longer periods and carried out to sea, contributing to Arctic haze (AMAP 1998, 2007).

The economic development of Chukotka has influenced the life of Eskimos because the environment has deteriorated and land rehabilitation is not being realized. Atmospheric pollution leaves its mark. Living in the permafrost zone means that filtration occurs very slowly, all the pollutants remain on top of the ground, the reindeers then eat it, and finally people eat their meat. The same thing happens to the sea. Nobody cleans oil spills, especially in cold waters. The pollutants do not disappear without a trace. Once we brought a whale and the meat was polluted with spilled oil.

(Raisa Mikhaylovna Zotova in Novikova 2008).

19.2.5. Herbivore responses to disturbance

Herbivory is important as a force to contend with, both as a form of disturbance in itself and as a potential limiting factor during succession (Forbes & McKendrick 2002) and under a warming climate (Post & Pedersen 2008, Olófsson et al. 2009). This is particularly the case in the relatively lush lowland and coastal tundra ecosystems with high herbivore densities where extensive hydrocarbon extraction is now active (e.g. Prudhoe Bay, Alaska; NAO, Russia) and expected to spread to (e.g. Naval Petroleum Reserve-Alaska and Arctic National Wildlife Refuge, Alaska; YNAO, Russia). Equally important is the displacement of populations of large herbivores (Cameron et al. 2005). The responses of caribou/reindeer to disturbance can be complex and highly variable depending upon sex, age and season, among other factors (Cameron et al. 2005, Haskell et al. 2006). In the case of new infrastructure, such as roads or power lines, animals (and particularly pregnant females) may initially avoid these. To date, the evidence that animals can adapt to the presence of infrastructure and associated disturbance within or across years is inconsistent (Haskell et al. 2006, Vistnes & Nellemann 2008).

Grazing by vertebrate herbivores can have profound effects on dynamic processes in Arctic ecosystems, particularly in successional communities. In addition to favoring graminoids and weedy mosaics at the expense of lichens and certain selected dwarf shrubs, grazing is an ecologically important limiting factor in the regeneration of many vascular plant species (Forbes & Kumpula 2009). Numerous Arctic researchers have noted that herbivores ranging in size from lemmings to caribou/reindeer are attracted to the plants growing on experimental fertilization plots and that they can affect the structure, cover/abundance and successional trajectory of the affected communities. Caribou, for example, may use sites with high forage nitrogen concentrations more intensely as a strategy of maximizing nutrient intake, leading to a positive feedback loop over the long-term (Forbes & McKendrick 2002). The same pattern has been observed in the boreal zone, where selective grazing of vegetation plots has been reported for periods of up to five years after a one-time addition of NPK fertilizer (John & Turkington 1997). This has serious implications for areas where assisted revegetation is attempted because, although plants are selected primarily to prevent erosion, many of the chosen species also provide important food for wildlife. Since it is standard practice to apply organic matter and/or chemical fertilizers to subsidize the initial stages of growth, managers trying to restore the original vegetation cover need to be wary about the access of herbivores to sites either naturally recovering from disturbance or actively revegetated. On the other hand, if the aim is simply to encourage the growth of forage for herbivores then regardless of the species composition, free access to fertilized sites is encouraged because of the positive feedbacks likely to encourage biomass accumulation (Forbes & McKendrick 2002).

With regard to climate change, the prevailing assumption until recently has been that the dominance of woody shrubs will increase under ongoing and future warming. At least in systems with low erect shrubs (e.g. dwarf birch Betula nana, willow Salix spp.), large herbivores like reindeer and muskoxen may be able to check increases in shrub biomass/height (Post & Pedersen 2008, Olófsson et al. 2009, Ims & Ehrich, Chapter 12). However, in cases where high erect shrubs are already above the browse line (c. 1.3–1.8 m), herbivory does not limit shrub growth (Forbes et al. 2010, Macias-Fauria et al. 2012).

19.2.6. Future prospects

During the next few decades, hotspots to observe for extensive terrestrial ecosystem disturbances include the major oil and gas bearing regions, such as the Alaskan...
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North Slope, the Mackenzie River delta in Canada and the Timan-Pechora and W Siberian basins of NW Russia. Cumulative impacts from piecemeal tourism and residential development are of concern to rural communities in northernmost Fennoscandia, where new cabins, power lines and expanding ski areas and road networks threaten to further fragment territories used for forage and migration by reindeer and other forms of wildlife (Vistnes & Nellemann 2008). Another emerging topic being watched closely in Fennoscandia is that of the rapidly-expanding mining industry. Similarly, the development of wind power in northern and high elevation areas in Fennoscandia is being closely watched. The empirical literature is still quite limited, but a recent national review in Sweden identified groups of terrestrial mammals potentially affected by existing and planned developments (Helldin et al. 2012). Interestingly, the authors conclude that one of the presumed knock-on effects of wind power is very similar to the aforementioned piecemeal developments. Namely, that the expanding road system to access turbines will enhance access for recreation, hunting and leisure traffic, likely resulting in impacts on populations of wild and domestic reindeer, moose and large carnivores (Helldin et al. 2012). For the time being, however, the data remain inconclusive.

19.3. FEEDBACKS TO ECOSYSTEMS AND CLIMATE

Changes in climate affect the structure and function of ecosystems. The biosphere and the atmosphere are a fully coupled system, therefore changes in the structure and function of terrestrial ecosystems may, in turn, feedback to the climate. In order to project Arctic (and global) climate variability into the future with certainty, these feedback loops must be understood. In this section, we focus on: (1) the influence of climate on Arctic ecosystems and (2) the regional and global feedbacks to climate by these ecosystems. We examine a number of these climatically sensitive processes and feedbacks, including carbon and methane cycling, permafrost dynamics, soil conditions, air pollutants, snow and ice cover dynamics, vegetation shifts, fire regimes and lake area. Cryosphere phenomena such as snow cover extend far beyond the Arctic, but we have not attempted to separate the Arctic component of feedbacks such as the snow-albedo effect. It is simpler, and more consistent with current research and modeling, to use the full winter snow cover for the northern hemisphere. Similar considerations have been used for other feedbacks.

19.3.1. Greenhouse gases: carbon dioxide and methane

The Arctic plays an important role in the global carbon budget, making significant contributions to the global fluxes of carbon dioxide and methane between ecosystems and the atmosphere. Increasing concentrations of atmospheric greenhouse gases are key driving factors in warming trends in the Arctic. Both carbon dioxide (CO₂) and methane (CH₄) are increasing in the atmosphere, and are estimated to have caused a c. 1.66 W/m² and c. 0.48 W/m² increase in radiative forcing globally since 1750, respectively (Forster et al. 2007). Methane is present in the atmosphere in much smaller concentrations compared with carbon dioxide, but is relatively more potent with a high potential for global warming. Over a 100-year time scale, methane is 25 times more effective per molecule than CO₂ at absorbing long-wave radiation, despite its shorter lifetime in the atmosphere. Since terrestrial ecosystems fix CO₂ through photosynthesis and release it through respiration, any change that impacts these processes will feedback to climate.

These fluxes of carbon are particularly important since, in their efforts to regulate carbon emissions, governments rely on estimates of carbon losses and gains related to climate change. Notably, the ‘social cost of carbon’, the estimated price of damages caused by each ton of CO₂ released into the atmosphere, varies by country. Consequently, any mechanism that results in increased CO₂ sequestration in Arctic ecosystems, such as increased vegetation growth, would have a positive impact on climate mitigation. Likewise, any mechanism that causes decreases in CO₂ sequestration, including the potential loss of carbon from Arctic ecosystems caused by increased development and human disturbance, would have a negative impact on climate mitigation. While the monetary value of carbon sequestration potential in the tropics is now part of the UN-led climate negotiations (through the instrument Reducing Emissions from Deforestation and Forest Degradation (REDD)), this issue is not recognized in the case of Arctic ecosystems.

While Arctic terrestrial ecosystems are currently estimated to be a sink of atmospheric CO₂, the strength of this sink in a warmer Arctic is forecast to deteriorate and may switch to acting as a source in the future (Canadell & Raupach 2009, McGuire et al. 2009). This is due to a variety of factors, including increases in the decomposition of soil organic matter under a warming climate, permafrost degradation and acclimation of the plants to increased atmospheric CO₂. Consequently, this means that while Arctic terrestrial ecosystems currently exert a decelerating (i.e. negative) feedback to raising atmospheric greenhouse gas concentrations, in the future they are projected to wield a less decelerating, or even accelerating (i.e. positive) feedback to climate warming, although this depends on the effect of increased vegetation growth, as mentioned below. As the amounts of carbon stored in Arctic soils that are vulnerable to the effects of warming are vast, the potential of Arctic terrestrial ecosystems to accelerate climate warming is significant. In terms of methane, the Arctic is currently a source of atmospheric methane, due in large part to methane emissions from lakes and wetlands. It is thought that methane emissions will continue or increase in the warmer Arctic of the future, providing a positive feedback to climate warming (McGuire et al. 2009).
19.3.2. Permafrost degradation and changes to soil conditions

Predicting the response of permafrost thaw to climate warming is complicated by the wide variety of factors that influence soil temperature, including air temperature, snow depth, topographic effects on insolation, soil texture, organic layer depth, surface water and runoff, groundwater movement and soil moisture. Studies have documented increases in permafrost degradation across the Arctic (Jorgenson et al. 2001, Zhang et al. 2005), and with ongoing warming these trends are expected to continue (Lawrence et al. 2008). Permafrost is a strong heat sink that reduces surface temperature and heat flux to the atmosphere, and consequently, the thawing of permafrost releases heat, causing a positive climate feedback. Moreover, recent estimates suggest that the top three meters of permafrost soils contain more than twice the amount of carbon as the atmosphere (Tarnocai et al. 2009). This carbon has been accumulating over long periods of time as a result of cold and waterlogged permafrost soil conditions. Degradation of permafrost – from deepening of the annually developing thawed layer to its complete disappearance near the ground surface – fundamentally enhances the conditions for soil microorganisms to decompose old soil carbon. As a result, greenhouse gas releases from thawing permafrost may act as a more sustained and much larger positive climate feedback than previously thought (Schuur et al. 2008). An important landscape aspect controlling both magnitude and direction of climate feedbacks following permafrost thaw is the resulting soil wetness near the surface. An increase in wetness will promote anaerobic conditions and increased methane emissions while slowing overall decomposition and CO₂ release. In contrast, dryer conditions can promote greater decomposition and release of CO₂, and decrease methane emissions. On an ecosystem scale, climate feedbacks associated with carbon and methane releases related to permafrost degradation are likely substantial during this century – in the range of those projected to be released by global deforestation scenarios (Zhuang et al. 2006).

19.3.3. Air pollutants

While greenhouse gases are the dominant driving factor in warming trends and climate feedbacks in the Arctic and globally, Arctic air pollutants, including aerosols, are also important (Key & Stohl 2007). The aerosols are usually introduced to the Arctic from Eurasia in the form of sulfates and black carbon (soot). Boreal forest fires and tundra fires (Hu et al. 2010) act as significant aerosol pollution sources in the circumpolar Arctic and may become more prevalent in the future. The pollution influences the Arctic climate through changes in surface radiative forcing, i.e. heat being absorbed at, or near, the Earth’s surface. Some of these particles of pollution absorb sunlight, acting as a positive feedback to warming, while others reflect sunlight, acting as a negative feedback to warming. For example, deposition of black carbon on snow reduces surface albedo, and acts as a positive feedback to warming, while sulfates scatter incoming solar radiation, resulting in a cooling effect. Globally, the radiative forcing of aerosols is a negative feedback to warming (Myhre 2009), but the net radiative forcing of these pollutants in the Arctic is still uncertain and a topic of study. However, recent work suggests that decreasing concentrations of sulfate aerosols and increasing concentrations of black carbon have substantially contributed to rapid Arctic warming during the past three decades (Shindell & Faluvegi 2009).

19.3.4. Snow and ice

Snow and ice albedo feedback loops in the Arctic are strong: as snow or ice melts, a dark surface is exposed, less solar energy is reflected back to space, and more energy is absorbed and transferred to the atmosphere, causing a positive feedback loop that reinforces warming. Across the Arctic, and between 1970 and 2000, a decrease in duration of approximately 2.5 days per year of the snow season translate to a 2.5 W/m² decade warming during this same period (Euskirchen et al. 2007). Changes in ice cover also represent a strong positive feedback to warming. The extent of sea ice has declined since the beginning of the record in 1953, with the lowest value recorded in 2012 (Stroeve et al. 2007, Perovich et al. 2012; see Fig. 1.5 in Meltofte et al., Chapter 1), and a strong thinning of multiyear ice and an increase in the area of melt ponds. All of these factors exacerbate the ice-albedo positive feedback loop to warming (Light et al. 2008, Pedersen et al. 2009). The additional or amplified warming caused by the loss of sea ice is not constrained to the Arctic Ocean, but also influences adjacent land areas, especially during autumn and winter, and may lead to hastened degradation of certain types of permafrost (Lawrence et al. 2008; see also Section 19.3.2). There is also a negative feedback following the loss of sea ice due to an increase in evapo-transpiration, causing an increase in summer clouds, which then increases net radiation, and decreases heating to the atmosphere (Chapin et al. 2005). However, this negative feedback is expected to be relatively weak, and will likely not counteract the strong ice-albedo feedback loop (Chapin et al. 2005).

19.3.5. Vegetation shifts

Studies have documented recent changes in the vegetation in the Arctic. This has included treeline advancement in some areas, retreat in other areas, and an encroachment of tall, woody shrubs in the tundra. Treeline advancement and tall, woody shrub encroachment are likely due to a longer growing season with increases in temperature and moisture (Sturm et al. 2001, Lloyd et al. 2003). This replacement of tundra with boreal forest and increases of tall, woody shrubs will result in greater carbon uptake into the vegetation, acting as a negative feedback to climate warming. On an ecosystem scale, it is currently under study whether the vegetation shift will lead to releases of soil carbon that would affect magnitude or direction of this negative feedback. However, any event that causes an advance of treeline and
shrubs will reduce albedo, causing a positive feedback to warming (Sturm et al. 2005, Euskirchen et al. 2009). In fact, research has shown that the net uptake or release of carbon associated with changes in treeline is likely a much smaller feedback to climate than the feedback due to changes in surface energy balance (Betts 2000).

Treeline retreat is likely in some areas due to drought stress under high temperatures, which then interacts with slow recruitment and reduced seed sources to decrease the success of tree regeneration following disturbance (McGuire et al. 2010). As a result, increased proportions of forests may regenerate as open forests or shrubland. In addition, permafrost degradation may also cause a decline of forest extent as forests may be replaced by bogs. Open forest, shrubland, or bogs would store less vegetation carbon but more soil carbon than a forest with the resulting net carbon feedback depending on the relative magnitude of these effects. However, the land surface of these less vegetated ecosystems would have a generally high albedo and act as a negative feedback to warming.

19.3.6. Changes in lake area

Methane emissions from Arctic lakes are substantial, and increases in their emissions act as a positive feedback to global climate warming (Walter et al. 2007). Changes in lake area in the Arctic have been documented due to permafrost thaw. Consequently, in the future, the amount of methane emissions may be highly dependent on changes in lake area. In southern areas of warm permafrost, studies have generally documented a decrease in lake area due to lake drainage following permafrost thaw (Smith et al. 2005, Riordan et al. 2006), whereas lake area tends to increase with permafrost thaw in northern ice-rich zones of cold permafrost (Smith et al. 2005; see also Wrona & Reist, Chapter 13). In addition to changing methane emissions, these increases or decreases in lake area would also impact albedo, with increases in lake area resulting in an increase in albedo and a negative climate feedback. Decreases in lake area will likely not have the opposite positive feedback effect, as the new surface can also have an increased albedo, dependent on the type of vegetation colonizing (Rouse et al. 2005). Overall, while the magnitude of the climate feedback due to changes in lake area has not been quantified, it would depend on the relative changes of methane emissions versus albedo.

19.3.7. Future prospects

In the coming decades, we will continue to observe changes in the sink strength of the Arctic in terms of carbon and methane, the duration of the snow and ice cover, the integrity of the permafrost, and vegetation shifts, all of which will generally promote positive feedbacks to climate. In fact, the number and strength of positive feedbacks to climate will likely continue to be larger than the number and strength of negative feedbacks (McGuire et al. 2006, Euskirchen et al. 2010), and there is indication that some positive feedbacks, such as albedo loss and permafrost thaw, accelerate each other (Canadell & Raupach 2009). Currently, the primary positive climate feedbacks are likely related to changes in surface albedo due to changes in ice and snow cover. While negative feedbacks to climate have been quantified, including increased carbon uptake by vegetation due to a longer growing season, these negative feedbacks are increasingly understood not be large enough – or last long enough – to counterbalance the larger and more sustained positive feedbacks. While models consistently simulate these feedbacks into the future, continuing to measure and monitor key indicators on integrated landscape and regional scales is extremely important. Key indicators to monitor include all those influencing energy fluxes and carbon cycling, for example, permafrost integrity, snow and ice cover duration, extent and thickness, landscape wetness and greenness, vegetation composition, as well as fire regimes and their related successional dynamics.

The impacts of Arctic climate feedbacks will extend well beyond the Arctic, necessitating an integrated understanding of the Arctic ecosystem processes and their representation in global climate models.

19.4. CONSERVATION

19.4.1. Habitat protection

Protected areas have long been the foundation of biodiversity conservation programs. Although many of the first protected areas were established primarily for the purposes of recreation, they have evolved since that time to become important tools for habitat protection and species conservation. This is as true for the Arctic as it is elsewhere.

The first protected areas in the North were established in Sweden and Alaska at the beginning of the 20th century. It was not until the 1980s that there was a significant increase in number of areas under protection. Recent decades have seen an exponential growth in the number of protected areas in the circumpolar north. As of 2010, there are 1,127 protected areas in the region, covering approximately 3.5 million km² or 11% of the CAFF cooperation area (Tab. 19.2). These areas vary considerably in terms of size, type and nature of protection.

The International Union for the Conservation of Nature and Natural Resources (IUCN) has a classification system for protected areas as a means to help collate data from protected areas around the world. Since its inception, this international system has developed “to provide a framework in which various protection strategies can be combined together, along with support-ive management systems outside protected areas, into a coherent approach to conserving nature” (Dudley 2008). The categories, therefore, can help countries and regions assess their progress to meeting defined conservation goals. In the Arctic, the majority of protected areas fall into category II, Ecosystem Conservation and Protection (Tab. 19.2, Fig. 19.2).
Table 19.2. Total Arctic territories in IUCN protection categories (CAFF 2010). N.B.: The definition of Arctic for this table is the CAFF boundary, not the ABA boundary.

<table>
<thead>
<tr>
<th>Category</th>
<th>Title</th>
<th>Managed for</th>
<th>No. of protected areas</th>
<th>Total area (ha)</th>
<th>% of Arctic covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia</td>
<td>Strict protection: strict nature reserve</td>
<td>Science</td>
<td>350</td>
<td>273,000</td>
<td>0.8</td>
</tr>
<tr>
<td>Ib</td>
<td>Strict protection: wilderness area</td>
<td>Wilderness protection</td>
<td>111</td>
<td>795,000</td>
<td>2.5</td>
</tr>
<tr>
<td>II</td>
<td>Ecosystem conservation and protection (e.g. national park)</td>
<td>Ecosystem protection or recreation</td>
<td>102</td>
<td>1,530,000</td>
<td>4.7</td>
</tr>
<tr>
<td>III</td>
<td>Conservation of natural features (e.g. natural monument)</td>
<td>Conservation of specific natural features</td>
<td>103</td>
<td>52,600</td>
<td>0.2</td>
</tr>
<tr>
<td>IV</td>
<td>Conservation through active management (e.g. habitat/species management area)</td>
<td>Conservation through management intervention</td>
<td>125</td>
<td>154,000</td>
<td>0.5</td>
</tr>
<tr>
<td>V</td>
<td>Landscape/seascape conservation and protection (e.g. protected landscape/ seascape)</td>
<td>Landscape/seascape conservation and recreation</td>
<td>60</td>
<td>64,600</td>
<td>0.2</td>
</tr>
<tr>
<td>VI</td>
<td>Sustainable use of natural resources (e.g. managed resource protected area)</td>
<td>Sustainable use of natural ecosystems</td>
<td>120</td>
<td>648,000</td>
<td>2.0</td>
</tr>
<tr>
<td>No category assigned</td>
<td></td>
<td></td>
<td>156</td>
<td>30,800</td>
<td>0.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1,127</td>
<td>3,550,000</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Figure 19.2. Protected areas within the political cooperation area of CAFF.
Box 19.1. Aleut perspectives on national parks on the Kommandorskye Islands, Russia

Tero and Kaisu Mustonen

The methods of habitat protection are not always viewed favorably by Arctic residents. In some cases, this is due to an interest in resource development. In others, it is a result of real or perceived clashes between protection regulations and traditional practices. The Aleut region of the Kommandorskye Islands in the Bering Sea is one such example (Meschtyb 2008).

Dorfei Semionovich Berezin was born on Bering Island. In general, he says, in the past fishing was good in the rivers that the local population has always used for their subsistence. Today, park regulations only allow three fish species to be taken over the whole summer period. This means that local people have started to poach. Berezin notes that the underlying cause for the illegal fishing, an almost universal phenomenon on the island including the fishing inspection personnel, is the deteriorating standard of life of islanders.

Zinaida Ivannovna Kvasiuk lives in the village of Nikolskoe on the Bering Island. She believes that poorly thought out economic and administrative policies have upset the ecological balance on Bering Island and are damaging the traditional Aleut way of life. Zinaida says that the local community used to have a structured economic life based on fishing, hunting of marine mammals and a little bit of farming. So despite the harsh island conditions they were self-sufficient people. She says the park does not do enough for environmental protection but hinders traditional Aleut activities. Zinaida is adamant that the Aleut people cannot live without fish, seal and sea lion meat.

Gennadii Mikhailovich Yakolev was born on Mednyi Island in 1935, and now resides in the village of Nikolskoe. Traditional livelihoods have been the basis of his way of life: “The fat of a seal for Aleut people is like butter for others.”

For him, the traditional use of nature is not only a means of providing food, but is also a specific cultural legacy: “I try to take my grandsons with me so that they can become accustomed to real Aleut food.” He feels that the bureaucracy, which for him represents the majority culture at its most absurd, has done far too much harm with its directives and policies. The overall impact of the national park in the center of Bering Island has placed traditional Aleut activities under a vast array of regulations.

Nikolai Nikolaevich Tiuterev has similar views. He describes how in the past the local community had hunted for seals in the summer and winter but now it is only permitted in the autumn and by specially accredited hunters. Tiuterev recalls earlier years when locals were permitted to hunt sea lions and seals but now this has been banned. He finds the official explanations difficult to understand:

“Our ancestors hunted these animals and their numbers never decreased. Yet, today, the authorities are afraid that we will exterminate them. In the past, when somebody needed a couple of seals for food, they would hunt for them. Why would we want to waste seals by over-hunting? It provides meat for the whole village.

“New regulations state that it is necessary to go to Lake Sarannoe, but this is a considerable distance from the community, and there is no transportation for local fishermen. Many people do not always receive any fish, especially pensioners.”

All these regulations interfere with the practices of the traditional economy and Aleut livelihoods. Moreover, Tiuterev believes that they have a negative impact on the self-worth of the Aleut people as an indigenous culture.

While protected areas are a powerful conservation tool, they can also—depending on the exact rules in place—constrain some traditional activities, which can erode support for such conservation measures (see Box 19.1 for examples of indigenous views on conservation). Such a situation can be seen, for example, in the Malla nature reserve in Finland, where the removal of human activities has led to conflicts over the impacts of reindeer grazing, which can benefit some species as well as have negative impacts on others (Jokinen 2005). As with other forms of conservation measures, the establishment and management of protected areas needs to address traditional practices and potential conflicts to achieve the overall goals of habitat protection and biodiversity conservation.

19.4.1.1. Aichi target 11

Target 11 of the Convention on Biological Diversity’s (CBD) Aichi Targets states that: “By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.”

While terrestrial areas are relatively well represented in Arctic protected areas, the marine environment continues to be under-represented (CAFF 2010). Although
over 40% of the protected areas inside the CAFF cooperation area have a coastal component, the extent to which the neighboring marine environment is incorporated is undetermined for most (Barry & McLennan 2010). The Arctic marine environment is one of the least understood regions of Earth, especially in the high Arctic. Historically, the harsh conditions of this area have made it difficult to study. With some projections indicating that the Arctic Ocean could be ice-free in late summer by mid-century or even before, the development pressure will increase. There is a critical need for identification of ecologically important and vulnerable marine areas in the Arctic and recommendations for their management. A recent effort in this direction has been the identification of ecologically and culturally important marine areas, following one of the recommendations of the Arctic Marine Shipping Assessment (AMSA 2009). This work is being carried out under three Arctic Council working groups: the Arctic Monitoring and Assessment Program (AMAP), CAFF and the Sustainable Development Working Group (SDWG).

### 19.4.1.2. Sacred sites

The IUCN broadly defines sacred sites as follows: “Sacred site – an area of special spiritual significance to peoples and communities; Sacred natural site – areas of land or water having special spiritual significance to peoples and communities” (Wild & McLeod 2008). They have been further described as “reflect[ing] the diversity of spiritual and cultural values that indigenous peoples attribute to their territories, landscapes, biota, and particular sites” (CAFF 2004).

In the Arctic, in particular, most sacred sites are natural areas, often high in biodiversity values, and so may contribute to biodiversity conservation with a strong link to customary livelihoods (CAFF 2004). A study by CAFF (2004) on the conservation values of sacred sites of indigenous peoples in the Arctic noted that “Not only are most sacred sites located on or in the vicinity to migration routes, fishing sites, or pastures; the active use, maintenance and protection of these sites depend largely on healthy livelihood systems.”

Despite their conservation values, the role of sacred sites in habitat protection and biodiversity conservation has not received the same degree of attention as other types of protected areas. Ideally, sacred sites should be supported by national and regional protected area systems, but this is often not the case (Wild & McLeod 2008). While tangible sacred sites (e.g. human-built structures) tend to be afforded a reasonable degree of protection, intangible sites (e.g. holy rivers and lakes) are under-represented (Wild & McLeod 2008). While it may be that not all practices associated with sacred sites are in line with broader conservation objectives (e.g. conflicts between traditional reindeer herding practices and conservation of large predators), sacred sites have the potential to provide an important link in habitat conservation and protected area networks.

One of the challenges to fully incorporating sacred sites into formal protected area networks may be reluctance on the part of indigenous peoples to have their sacred sites formally classified. There are issues with the protection of cultural and intellectual property. The CAFF study also noted that the non-codified status of sacred sites, like traditional knowledge in general, leaves it open to abuse (CAFF 2004). Some of the key recommendations from that study include:

- developing an action plan for the further integration of sacred sites and indigenous territories of traditional nature use into broader protected areas networks;
- encouraging indigenous peoples to seek further reporting on sacred sites and their protection into national reporting on the implementation of the CBD;
- bringing to the attention of the World Intellectual Property Organization (WIPO) the need to accommodate within its work the knowledge about indigenous sacred sites, as this is a significant and important perspective for the intellectual property, traditional knowledge and genetic resources of indigenous peoples (CAFF 2004).

### 19.4.1.3. Potential for habitat shifts

One of the greatest challenges facing Arctic protected areas is climate change. The changes wrought by a warming climate are raising a number of questions regarding the effectiveness of protected areas as a conservation tool in the future. The changes to the physical environment are already well documented and include such effects as reductions in snow and ice and changes in precipitation patterns. The associated impacts as a result of these changes include a northward shift in species, ‘greening’ of the Arctic, changes in timing of key life cycle events and changing migration patterns, to name just a few.

Changes in habitat type, in particular, pose significant threats to protection efforts. Already there is evidence of significant shifts in Arctic vegetation in recent decades, and this is expected to continue with further warming (Henry & Elmendorf 2010). Henry & Elmendorf (2010) noted that treeline encroachment is threatening the southern margins of the tundra. According to some models, treelines may advance by as much as 500 km north over the next century with a resultant loss of 51% of tundra habitat (Callaghan et al. 2005).

A study assessing changes in biome types in Canada’s protected areas networks under climate change found that the representation of northern biomes — tundra, taiga/tundra and boreal conifer forest — in protected areas was projected to decrease (Lemieux & Scott 2005). The study projected that 38–79% fewer protected areas will still have part of tundra biomes, and 81–87% fewer protected areas will contain at least part of the taiga/tundra biome (Lemieux & Scott 2005). These decreases are the result of decreases in these biomes overall, so that a lower proportion of tundra overall translates into a lower proportion of tundra within protected areas.
A similar and perhaps more dramatic change is occurring in the Arctic sea ice habitat. Changes are already being seen in the extent and thickness of the sea ice, with thicker multi-year ice being replaced by thinner first-year ice (NSIDC 2010). Current predictions indicate that the Arctic Ocean could be nearly ice-free in late summer by the middle of this century or even sooner (Wang & Overland 2009). Sea ice represents a unique ecosystem in the Arctic providing habitat for numerous ice-associated species (see Josefson & Mokievsky, Chapter 8 and Michel, Chapter 14). Changes in sea ice can be expected to have impacts throughout the marine food web, from phytoplankton and zooplankton to seabirds and marine mammals. Indigenous peoples of the Arctic will also be affected by these changes as many use sea ice for transportation and hunting. In response to the changes occurring in this important ecosystem, CAFF is conducting an Arctic Sea Ice Associated Biodiversity Assessment which will summarize the current status and trends of sea ice-associated biodiversity and recommendations that might mitigate these changes.

Further complicating these habitat shifts and changes is the associated issue of invasive species. As the climate warms and more human activity takes place across the Arctic, both northward range expansions and biological invasions (i.e. transport by humans, intentionally or otherwise) are likely to increase (Lassuy & Lewis 2010; Lassuy & Lewis, Chapter 16).

There is a further issue of habitat fragmentation outside of formally protected areas that may further reduce the ability of species and ecosystems to adapt to change. Although such patterns are most likely a long way off for the Arctic, protected areas can become isolated islands in a broader sea of development (industrial, agricultural, etc.) inhibiting the movement of species to more suitable habitats. The scale of development in most of the circumpolar Arctic is far below that seen in more southern regions, and some of the largest unaltered habitats are found here. The pressure to develop, however, is strong and will likely continue to grow as the Arctic becomes more accessible as a result of climate change.

19.4.1.4. Future prospects

The scale of environmental change facing the Arctic forces us to ask whether protected areas can continue to be an effective conservation tool in the future. The majority of protected areas are selected on the basis of ecosystem representation, where there is an underlying assumption that they will remain static, unchanged. The rapid changes occurring in the Arctic, however, show that this is not guaranteed. With habitat shifts resulting from climate change, it will be more difficult to define ‘natural’ in the future (Lemieux & Scott 2005).

The question remains how protected areas can be used to help ecosystems and species adapt to stressors, climate change in particular. More systematic research and monitoring are needed to address the large uncertainties facing protected areas in light of climate change. In addition, more efforts are needed to place protected areas in the context of broader habitat conservation measures, i.e. conservation outside of protected areas. New tools will also be needed to help make sound management and policy decisions in a changing Arctic. The WWF project, Rapid Assessment of CircumArctic Ecosystem Resilience (RACER), is an example of a tool that has been developed to help identify and map places of importance in the Arctic, looking for areas of resilience that are likely to persist under the changes the Arctic is experiencing (Christie & Sommerkorn 2012).

While protected areas are facing clear threats as a result of climate change, they can also help mitigate some climate change impacts (e.g. carbon sequestration, flood control). They can also provide areas where natural processes can continue and potentially adapt to the impacts of climate change. For these reasons, protected areas will continue to be vital to habitat and biodiversity conservation efforts in the future (e.g. Livingston 2011).

19.4.2. Species protection

“A recurring theme in wildlife and fisheries management over the centuries is that numerical abundance is not always a hedge against declines... We only have to think of salmon, northern cod, (and) bison... What determines persistence is rate of change not the size of the starting population. But numerical abundance carries the risk of over-confidence – ‘there’s still lots of caribou.’ Another contribution to over confidence among users is that the caribou, being cyclic in their abundance, have been low in number before and have come back. However, given changing environmental conditions, the past may not be a secure guide to the future” (CARMA 2010).

The Arctic embraces a wide variety of species of global importance. Almost a quarter of the world’s shorebird species are endemic to the Arctic, and all but three of the world’s 17 Arctic and sub-Arctic goose species have populations numbering in the hundreds of thousands or millions (Ganter & Gaston, Chapter 4). It is also home to several million reindeer and caribou and many unique marine mammals such as the polar bear Ursus maritimus, walrus Odobenus rosmarus and narwhal Monodon monoceros. Seasonal changes are extreme, with dark winters, snow, ice and temperatures plummeting to −50 °C. Summers bask in 24 hour daylight with temperatures soaring to above 20 °C. During this brief summer, several millions of birds and many thousands of terrestrial and marine mammals migrate into the area to breed and take advantage of the brief rich feeding grounds.

Historically, these dependable – albeit extreme – conditions helped protect Arctic species by limiting physical access. This in turn helped to reduce disturbance, slowed habitat fragmentation and generally limited other human activities. History, however, may no longer be an adequate guide to the future of the Arctic.
19.4.2.1. Challenges

The Arctic is one of the most rapidly changing regions on Earth. Increasing interest in developing natural resources there, coupled with rapid warming, will radically change this area once protected by its inaccessibility and the higher costs associated with extractive industrial development. These cumulative pressures create significant hurdles for conserving biodiversity (Fig. 19.3). The combination of rapid climatic warming and increasing human activities will require the development of new management tools, investment in basic scientific monitoring, and new governance agreements across the Arctic.

An entire marine ecosystem – from phytoplankton to polar bears and bowhead whales *Balaena mysticetus* – depends on the continued existence of Arctic sea ice. As temperatures increase and sea ice continues to decline, ice-associated species such as the ringed seal *Pusa hispida*, walrus and polar bear will find it more and more difficult to survive within historical ranges or current abundance. On land, thawing permafrost and shifting biophysical drivers will fundamentally alter current terrestrial ecosystems. Disturbance and fragmentation of habitats through increased human activities (primarily resource extraction) will further complicate conditions in this once relatively undisturbed region.

The conservation of species in the Arctic has traditionally focused on large mammals which are, or have been, commercially harvested. Examples are bowhead whales, walrus, caribou and polar bears. However, the basis for the rich marine and estuarine food webs has rarely, if ever, been acknowledged and protected. For example, the increasing loss of sea ice due to climate warming will have a dramatic impact on the plankton community living under the ice (see Michel, Chapter 14). That will alter the Arctic ecosystem as we know it today by affecting fish assemblages, ice-associated seals and polar bears (see Reid et al., Chapter 3). The only long-term solutions for protecting this ecosystem and the species that have evolved with it are to decrease global greenhouse gas emissions and to manage human activities inside the Arctic.

In 2006, the polar bear was added to the IUCN’s Red List as a vulnerable species, largely due to predicted impacts from climate change and the expected loss of sea ice habitat. Hudson Bay and southern Beaufort Sea polar bear subpopulations have shown significant declines (Regehr 2007) or metrics of pending decline including decreased adult size and decreased cub survival (Regehr 2010) over the last two decades. These changes in survival and condition have been directly linked to a decrease in summer sea ice habitat as a result of climate warming and are expected to affect polar bears across their range if warming trends continue unabated (Wiig et al. 2008; see also Reid et al., Chapter 3).

While polar bears are often the face of Arctic warming, many species are or will become negatively affected by...
climate change. Hundreds of endemic Arctic species, from small beetles, ice associated algae and plankton, mushrooms, lichens, flowers and lemmings, to large mammals such as caribou, walrus and narwhal face an uncertain future. Barren Ground caribou numbers have dropped across their range in recent years, and experts suspect climate change is a significant contributing factor, though there are signs that the declining trend is reversing (Reid et al., Chapter 3). Impacts include possible changes in the timing and availability of peak forage in the early summer and increased freezing rain events during winter that cover the vegetation in ice and decrease availability (Hummel & Ray 2008).

Many Arctic species are migratory and spend most of the year in much lower latitudes. For conservation, this often means protection of an Arctic species has to take place in areas far from the Arctic (Scott 1998). An example is the spoon-billed sandpiper Calidris pygmeus which breeds in the low hundreds in Chukotka, Russia and passes through coastal wetlands in China while migrating to overwintering grounds in SE Asia. During the last 30 years, the number of spoon-billed sandpipers has decreased dramatically from about 6,000 breeding pairs to just a few hundred pairs. Besides loss of habitat in staging and wintering areas, the most eminent cause of the decline appears to be indiscriminate hunting in Myanmar where the birds are caught in mist nets and sold to local markets as food (Zöckler et al. 2010). The only way to save this migrating Arctic species from extinction is to protect it outside the Arctic while safeguarding critical summer nesting areas within the Arctic (see Ganter & Gaston, Chapter 4).

Diminishing summer sea ice will also lead to an increase of human activities such as shipping, fishing, mining and oil and gas exploration. There is an urgent need for circumarctic management and governance that ensure a stewardship-first approach to these increasing demands for once inaccessible resources (e.g. Chapin et al. 2009a, 2009b). The Arctic remains one of the largest largely intact ecosystems on earth. Careful planning that incorporates future change and cumulative impact assessment prior to activities proceeding could reduce additional stressors to an already strained system (e.g. Meek 2011).

19.4.2.2. Management and regulation

The most effective way to protect the vast majority of species is to safeguard habitat, which often conserves representative ecosystems (see Section 19.4.1). More typically, species protection has focused on preventing overharvest, which has historically been the largest threat to Arctic biodiversity (e.g. Meltzoff et al., Chapter 1, Reid et al., Chapter 3, Ganter & Gaston, Chapter 4, Christiansen & Reid, Chapter 6). Species protection in the Arctic is regulated at different levels. For example, The Agreement on the Conservation of Polar Bears from 1973 sets forth standards for polar bear conservation across its range. This landmark ‘range state’ agreement dramatically improved harvest management of polar bears and set up a framework to better coordinate and communicate scientific research and circumarctic management (Larsen & Stirling 2009).

Most species protection falls under national legislation, or a mix of national legislation, and bilateral and international agreements. In Greenland, for example, the International Whaling Commission (IWC) sets national subsistence quotas for minke whales Balaenoptera acutorostrata. Narwhals and beluga whales Delphinapterus leucas, however, are regulated by the Canada-Greenland Joint Commission on the Conservation and Management of Narwhal and Beluga (DFO 2008).

As noted above, national parks and nature reserves are often created to protect a certain habitat for individual species. However, rapid climate change means the conditions for keeping these specific habitats (and inhabitants) within the reserve boundaries may be altered. In many cases the protected habitat itself will change over time. For example, the tundra in northernmost Scandinavia will shift to forest as the tree line moves north due to increasing temperatures (Heiskanen et al. 2008).

National legislation for typical nature reserves and protected areas is established to preserve what currently exists, but doesn’t address what will happen in the future in the context of a rapidly changing world. Similar challenges exist with conservation constructs at the international level. While the IUCN’s mission, for example, preserves the ‘now’, assuming stable conditions, it does not take into account future changes under unstable systems. Many national parks and nature reserves will not be able to meet the goals they set in terms of protecting viable populations of specific species or unique habitats. New tools and adaptive management strategies will be required as we move into uncharted territory.

19.4.2.3. Future prospects

The changing Arctic environment will put pressure on species as well as entire ecological processes. It is expected that high Arctic species, such as red knots Calidris canutus, will have fewer options in a changing environment, since the high Arctic zone in particular, will be ‘squeezed in’ between the northward expanding low Arctic biome and the Arctic Ocean (Meltzoff et al. 2007; see also Ganter & Gaston, Chapter 4). Southern species, such as the red fox Vulpes vulpes, may see range expansions putting Arctic species under pressure (see Reid et al., Chapter 3 and Ims & Ehrich, Chapter 12). Wildlife can try to adapt (an unlikely option given the current and expected rates of change), migrate or face a very uncertain future. Species that today are considered sentinel may be marginalized as ecosystems cross significant thresholds and shift into new phases. Single species protection will still be important, but it will likely become more important to preserve ecological processes over time.

A variety of regional, national and international legal mechanisms exist to help manage at-risk species such
as the IUCN Red List, the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) and the various national legislation and regulations. Current and predicted impacts from rapidly warming climate scenarios have led to an almost preemptive push to list species as endangered or threatened at the regional, federal and international levels and often across species ranges. Listing of species under various legal articles provides increased public awareness of species status and threats, generally increases legal protections and can boost basic research and monitoring efforts as seen following the 2007 US listing of the polar bear as threatened.

However, initiating increased protections indicates a failure to manage on other fronts and can have unintended consequences. The addition of species to higher categories of risk under constructs like the IUCN Red List is nothing to strive for or to celebrate. It measures the continued loss of biodiversity and societal or society’s lack of understanding, will or ability to successfully manage the challenges facing species today. Range-wide listing decisions, as seen with both the polar bear and ice-associated species of seal listings in the US, may not adequately account for the varying rates of anticipated change across dramatically differing habitats within the Arctic. Existing legal structures, at the international and national levels, were not developed for pervasive, long term threats like climate change and often lack flexibility once enacted.

Polar bears provide one example. There are 19 subpopulations, or management units, of polar bears in the Arctic inhabiting a range of very different habitats. We are likely to see up to 19 different stories unfold as warming affects different areas at different times and in different ways. While scientists are already noting population declines or indices suggesting decline in the most southerly clines or indices suggesting decline in the most southerly regions once enacted.

Successful management of Arctic species will require new management tools and greater flexibility. The overarching threat posed by rapid climate warming will challenge our best efforts and existing legal mechanisms. It must also be recognized that people live in the Arctic and rely on its wildlife. Any plan to protect Arctic species must involve the people who live with them. It must understand the food and economic security challenges that come with increased legal protective status, and potential clashes with established indigenous rights. The situation is complex and demands well thought out and complex responses to the threats of today and the challenges of tomorrow.

19.4.3. Conservation through community involvement

The last several decades have seen continued interest in natural resource monitoring that involves both scientists and local stakeholders (Gofman 2010, Huntington 2011). This partnership, often referred to as community based monitoring (CBM), or community-based observations, continues to evolve and exert increased influence on decision making and resource management (Gofman 2010). The scope of CBM is diverse and complex and continues to develop as experiences of integration are shared. Moreover, the overwhelming connection of Arctic peoples to the land provides opportunities for strong conservation partnerships, for example initiatives related to ecological monitoring, food security or sacred sites.

In essence, CBM seeks to improve the ability to share observations and understanding of local changes that are occurring in a vast and remote region through the eyes of Arctic residents. The idea is that intimate and multi-generational knowledge held by local stakeholders can help governments and local organizations identify and address serious environment and development challenges at early stages (Harremoës et al. 2001).

19.4.3.1. Monitoring approaches

Monitoring approaches in all Arctic countries have some level of local involvement, and examples of CBM exist throughout the Arctic. These monitoring approaches range from programs involving local stakeholders only in data collection (citizen science) with the design, analysis and interpretation undertaken by professional researchers, to entirely autonomous monitoring schemes run by local people (see Gofman 2010 for full discussion).

The level of involvement by local peoples beyond project development and planning to include analysis can contribute to longer-term capacity and implementation benefits beyond just the collected data (Tab. 19.3). Although local residents can unquestionably monitor and report on certain observed changes, their interpretation of the changes and any policy implications they may have are sometimes left aside. However, this is not a problem limited to CBM. From a policy implementation perspective, opportunities to involve Arctic peoples in knowledge production, in an open and transparent manner, is critical when considering managing individual and commercial activities in the North.

19.4.3.2. Validity of CBM data

The struggle to break through the perceived limitations surrounding CBM is often linked to the approaches and skepticism at the heart of western approaches to knowledge production. Scientists have documented Arctic community members’ detailed knowledge of key components of their environment, such as sea-ice (Laid-
Many of the potential limitations of CBM can be overcome by careful planning, by explicit consideration of likely biases, and by thorough training and supervision of the participants (Danielsen et al. 2009, Gofman 2010, Luzar et al. 2011). It is a challenge, however, that community monitoring can superficially appear low-tech and therefore primitive in a high-tech world. There remains a huge unexplored potential for strengthening monitoring efforts across the Arctic by engaging more communities and encouraging linkages with scientific monitoring programs (Huntington 2008). Often, an investment to build capacity to collect, interpret and manage data are central to maximizing such monitoring efforts (Gofman 2010).

### 19.4.3.3. Challenges

As the CBM record evolves and demonstrates continued improvement of accessible information on Arctic biodiversity, it is anticipated that there will be a delay between information production and use, accessibility and integration. In northwestern Canada and northeastern Alaska, for example, the reporting by the Arctic Borderlands Ecological Knowledge Co-op of CBM data on population health and body condition of the Porcupine caribou herd were largely dismissed and undervalued in favor of scientific models projecting substantive

<table>
<thead>
<tr>
<th>Category of monitoring</th>
<th>Arctic examples</th>
<th>Description</th>
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<tbody>
<tr>
<td>Fully autonomous local monitoring</td>
<td>Customary conservation regimes, e.g. in Canada (Ferguson et al. 1998, Moller et al. 2004)</td>
<td>The whole monitoring process – from design, to data collection, to analysis, and finally to use of data for management decisions – is carried out autonomously by local stakeholders</td>
</tr>
<tr>
<td>Collaborative monitoring with local data interpretation</td>
<td>Arctic Borderlands Ecological Knowledge Co-op, Canada (Eamer 2006, Russell et al. 2013); Community-based monitoring by Inuvialuit Settlement region, Canada (Huntington 2011); Opening Doors to the Native Knowledge of the Indigenous Peoples of the Nenets Autonomous Okrug, Russia (The Association of the Nenets People Yasavey and RAIPON); Piniakkanik Sumilliinni Nalunaarsuineq, Greenland (Danielsen et al. in press)</td>
<td>Locally based monitoring involving local stakeholders in data collection, interpretation or analysis, and management decision making, although external scientists may provide advice and training. The original data collected by local people remain in the area being monitored, but copies of the data may be sent to professional researchers for in-depth or larger-scale analysis</td>
</tr>
<tr>
<td>Collaborative monitoring with external data interpretation</td>
<td>Community Moose Monitoring Project, Canada (Gofman 2010); Integrated Ecosystem Management (ECORA), Russia (Larsen et al. 2011)</td>
<td>Local stakeholders involved in data collection and monitoring-based management decision making, but the design of the scheme and the data analysis and interpretation are undertaken by external scientists</td>
</tr>
<tr>
<td>Externally driven monitoring with local data collectors</td>
<td>Bering Sea Sub Network, Alaska and Russia (Gofman &amp; Smith 2009); Environmental Observations of Seal Hunters, Finland (Gofman 2010); Fávllis Network, Norway (Gofman 2010); Monitoring of breeding common eiders, Greenland (Merkel 2010); The Piniarnaq fisheries catch and hunting report database, Greenland</td>
<td>Local stakeholders involved only in data collection stage, with design, analysis and interpretation of monitoring results for decision-making being undertaken by professional researchers, generally far from the site</td>
</tr>
<tr>
<td>Externally driven, researcher executed monitoring</td>
<td>Multiple scientist-executed natural resource monitoring schemes with no involvement of the local stakeholders</td>
<td>Design and implementation conducted entirely by professional scientists who are funded by external agencies and generally reside elsewhere</td>
</tr>
</tbody>
</table>

### Notes

* Where scientists aspire to be impartial (Beardsley 2010), some fishermen, hunters and environmentally interested people may have a conflict of interest in their assessment of the status of those resources on which they depend for their livelihoods or that they are otherwise interested in (Root & Alpert 1994). For instance, a special local interest in certain resources or a preoccupation with certain challenges to resource management may influence which attributes are recorded, when and where. The community perspective is relevant too. Indigenous communities often view scientific initiatives with suspicion, if the scientists do not possess social and cultural skills to appreciate context and locality, creating a need to establish credibility in both directions.

* Many of the potential limitations of CBM can be overcome by careful planning, by explicit consideration of likely biases, and by thorough training and supervision of the participants (Danielsen et al. 2009, Gofman 2010, Luzar et al. 2011). It is a challenge, however, that community monitoring can superficially appear low-tech and therefore primitive in a high-tech world. There remains a huge unexplored potential for strengthening monitoring efforts across the Arctic by engaging more communities and encouraging linkages with scientific monitoring programs (Huntington 2008). Often, an investment to build capacity to collect, interpret and manage data are central to maximizing such monitoring efforts (Gofman 2010).
population declines (Gofman 2010, Russell et al. 2013). Moreover, such projected declines prompted government and decision makers to push for and build harvest regimes that limited northern residents’ ability to harvest. Indeed in 2012, several years after the CBM results were released, scientific population surveys revealed record numbers of caribou actually existed. In this case, CBM would have limited harvest concerns and supported improved access to northern food. However, the combination of the potential for conflict of interest and the lack of demonstrable validation capacity may have contributed to placing limited value on the information from this source.

Such examples suggest that efforts to emphasize analysis and integration between the two knowledge production approaches should continue. Indeed, more recent biodiversity monitoring planning processes are proposing ways of integrating and coordinating the methods for knowledge co-production (Gofman 2010, Yongraven et al. 2012). The Circumpolar Biodiversity Monitoring Program’s (CBMP) strategy for bridging some of the structural challenges over the next few years includes improving the access to CBM data via improved provision of and access to metadata, modeling and demonstrating integration examples of CBM with scientific monitoring processes (Gill et al. 2011, Culp et al. 2012).

19.4.3.4. Contributions to biodiversity monitoring

Full participation in biodiversity monitoring programs continues to be a challenge for many Arctic peoples. Greenland’s effort to increase involvement of CBM with management provides one of the promising stories becoming more common in the Arctic. The Greenland government is piloting a natural resource monitoring system whereby local people and local authority staff are directly involved in data collection, interpretation and resource management. The scheme is called Pini-akkaniq sumijuinni nalumarsuinneq (Opening Doors to Native Knowledge). Four communities in Disko Bay and Umanak/Uummannaq Fjord are involved: Akunnaaq, Kitsiussuruit, Qaarsut and Jakobshavn/Illulissat.

As in other parts of the Arctic, the communities in Greenland are widely distributed over a vast territory, and the opportunities for environmental monitoring and for implementing hunting and fishing regulations on the ground are limited. It has long been a priority of the Greenland government to increase the involvement of local citizens in the decision-making process related to natural resources (Greenland Government 1999, Haaland et al. 2005). However, there is limited funding available for monitoring Greenland’s resources, and many species and populations are thus monitored infrequently or not at all (Nielsen 2009). There is therefore insufficient knowledge available about some wildlife populations to guide government decision making and consequently a need to supplement the existing scientist-led monitoring programs with low-cost monitoring, for example through CBM.

The following are examples of how the influence and impact of the data are increasing when it comes to Arctic resource management. In each of the examples, local community observations were central to effecting changes to management regimes.

Conservation of marine habitat: In Akunnaaq, Greenland, the Natural Resource Committee (NRC) recorded trawlers fishing for shrimp in a shallow sea area adjacent to their village on a daily basis. There were 4-5 vessels almost every day throughout April and May 2010. This number was the same as in 2009 but higher than in previous years. Moreover, the vessels were larger and used heavier fishing gear. The NRC in Akunnaaq was worried that potential degradation of the seafloor might affect the breeding and production of Atlantic wolf-fish Anarhichas lupus. The NRC therefore proposed that the municipality should issue an ordinance to restrict the size of vessels in the area.

Influencing marine harvest techniques: One of the attributes recorded by Qaarsut NRC concerned their catch of Greenland halibut Reinhardtius hippoglossoides in Umanak/Uummannaq Fjord. On the basis of their catch-and-effort data from long-line fishery, they estimated that the local Greenland halibut population was the same in May 2010 but higher in June-September 2010 than in the same months of 2009. Nevertheless, the NRC was concerned that many nets were being set over their longlines and that some nets were left at sea when the sea froze over. This resulted in many rotting fish, which attracted Greenland sharks Somniosus microcephalus. The NRC therefore proposed that the municipality should issue an ordinance to restrict net fishing in Umanak/Uummannaq Fjord. The fisheries legislation in Greenland allows municipalities – subject to ministerial approval – to prohibit the use of certain vessels and equipment in specific areas (Greenland Government 1996).

Influencing goose harvest pressure: Members of the Qaarsut NRC have observed that, over the past decade, the population of Canada goose Branta canadensis has risen sharply. Canada goose may out-compete the threatened Greenland white-fronted goose Anser albifrons flavirostris (Boyd & Fox 2008 versus Raundrup et al. 2012). Hunting seasons in Greenland are decided by the Ministry of Fisheries, Hunting and Agriculture on the basis of advice from scientists and from public input during a hearing process. The current hunting season for Canada goose is 15 August to 15 October (Department of Fisheries, Hunting and Agriculture 2011). The NRC proposed that the municipality should suggest to the Ministry that the hunting season for Canada goose be extended, for example by two weeks, to help keep the population from expanding further. However, a recent study has not found such competition between Canada geese and Greenland white-fronts during molt (Raundrup et al. 2012).

In all three examples, it is noteworthy that the proposals if implemented will benefit the people having put them forward. International experiences however suggest that
CBM also often leads to people suggesting restrictions in their own take of resources (Danielsen et al. 2007). CBM encourages people to take a long term perspective on the use of resources through facilitating agreements at community and municipal level to increase or reduce the use of resources.

19.4.3.5. Future prospects

The Arctic environment is rapidly changing (e.g. Hinzman et al. 2005, CAFF 2010) and there is increasing pressure on its natural resources. There is therefore also an increased need for monitoring. To date, many examples exist of Arctic peoples describing the changes they witness related to climate, sea ice and especially to harvested wildlife species. There is a persistent need for more CBM that can detect change, interpret and integrate results, and lead to prompt decision-making to help tackle environmental challenges at operational levels of resource management (Huntington & Fox 2005, Danielsen et al. 2010).

Representatives of indigenous communities practice wildlife management guided by their indigenous knowledge, realizing that indigenous knowledge and western scientific knowledge are based on different knowledge generation systems or epistemologies (e.g. Agrawal 1995, Huntington et al. 2004). Through CBM, however, it may be possible to find a suitable means of cooperation and collaboration in which monitoring can be based on local observations and knowledge (Pulsifer et al. 2010, van der Velden 2010) and, at the same time, follow principles of data handling and data management in accordance with Western concepts of scientific accuracy (Yoccoz et al. 2001), which is what national government agencies and international conventions require. Several Arctic programs (including the CBMP) and Arctic peoples have already started to implement strategies to bridge this gap by building structures such as inventories and metadatabases to better access, use and integrate CBM knowledge in the arctic (e.g. Pulsifer et al. 2012).

In combination, the increased need for data and the necessity of promoting locally relevant knowledge and management actions suggest that there are substantial prospects in the coming decades for more CBM around the Arctic, and that such an increase will contribute to effective local conservation actions.

19.5. DISCUSSION AND CONCLUSIONS

The sections of this chapter have addressed a wide range of topics, quantitatively where possible and qualitatively otherwise. Evaluating the status and likely trends of disturbances, feedbacks and conservation efforts is not easy (see Tab. 19.4). For example, an increase in the number of species listed as threatened or endangered may indicate greater commitment to species protection, or it may indicate a greater number of species at risk. More extensive habitat protection will benefit biodiversity, but what occurs outside of protected areas may ultimately be more important, since protected areas are unlikely to cover a majority of the Arctic.

Community involvement offers a number of clear benefits, but should not replace national and other monitoring and conservation efforts, since community practices may not always be consistent with the protection of biodiversity (see Huntington, Chapter 18). Disturbance is equally clearly a negative outcome of human-ecosystem interactions, though the causes vary from industrial exploitation of petroleum and minerals, heavy grazing and trampling, and the impacts of climate change. Determining how to address disturbance is thus not always straightforward, especially where large financial interests are at stake. The potential for climate feedbacks to magnify warming trends is worrisome, pointing to the need for global action to address threats with global causes. Action within the Arctic will not always be sufficient to conserve Arctic biodiversity.

To monitor trends in these indicators of human actions that affect biodiversity, a set of quantitative indicators should be developed. Other types of disturbance, feedbacks and conservation measures should also be considered. Noise and chemical pollution, including ocean acidification, may disturb the metabolism or behavior of many animals. The Arctic hydrological cycle, including the potential for sea level rise from melting of ice caps, has feedbacks to the global climate system, and the well-being of migratory species depends on the interrelationship of Arctic conditions with conditions elsewhere in the annual journeys of those species. Conservation outside of protected areas, the regulation of fishing and hunting, human population growth and the rate of consumption of non-renewable resources are all relevant to the success of biodiversity conservation generally.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Trend</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbance</td>
<td>Increasing</td>
<td>Roads and industrial activity are expanding, creating more potential for disturbance</td>
</tr>
<tr>
<td>Feedbacks to ecosystems and climate</td>
<td>?</td>
<td>Positive feedbacks, especially to climate, are exacerbating feedbacks from the Arctic to the globe</td>
</tr>
<tr>
<td>Habitat protection</td>
<td>Increasing</td>
<td>Parks and protected areas are more numerous, but additional designations may become harder; marine protection is nearly absent</td>
</tr>
<tr>
<td>Species protection</td>
<td>Increasing</td>
<td>Protective measures are increasing, but perhaps reflecting more species in need of protection</td>
</tr>
<tr>
<td>Conservation through community involvement</td>
<td>Increasing</td>
<td>Interest in this approach is growing, though the creation of new programs is slow</td>
</tr>
</tbody>
</table>

Table 19.4. Trends in the five indicators considered in this chapter. Note that ‘Increasing’ may be regarded as positive or negative depending on the indicator.
Tracking all potential indicators is not possible, but a robust set of measures against which progress or decline can be monitored would greatly help in providing the public and policy makers with a means of assessing whether Arctic communities, Arctic countries and the world as a whole are contributing to the conservation of Arctic biodiversity or the opposite. Without timely and unambiguous measures of performance, uncertainty will provide an excuse for inaction or for accepting greater levels of risk than are consistent with a commitment to protecting the future of Arctic ecosystems and those who use them.

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