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Community clusters in wildlife and environmental management: using TEK and community involvement to improve co-management in an era of rapid environmental change

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Keywords

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Abstract

Environmental change has stressed wildlife co-management systems in the Arctic because parameters are changing more rapidly than traditional scientific monitoring can accommodate. Co-management systems have also been criticized for not fully integrating harvesters into the local management of resources. These two problems can be approached through the use of spatially-defined human social units termed community clusters, which are based on the demographic or ecological units being managed. An examination of polar bear management in Nunavut Territory, Canada, shows that community clusters provide a forum to collect and analyse traditional ecological knowledge (TEK) over a geographic area that mirrors the management unit, providing detailed information of local conditions. This case study also provides examples of how instituting community clusters at a governance level provides harvesters with social space in which to develop their roles as managers, along the continuum from being powerless spectators to active, adaptive co-managers. Five steps for enhancing co-management systems through the inclusion of community clusters and their knowledge are: (1) the acceptance of TEK, science, the precautionary principle and the right of harvesters not to be constrained by overly-conservative management decisions; (2) data collection involving TEK and science, and a collaboration between the two; (3) institutionalization of community clusters for data collection; (4) institutionalization of community clusters in the management process; and (5) grass-roots initiatives to take advantage of the social space provided by the community cluster approach, in order to adapt the management to local conditions, and to effect policy changes at higher levels, so as to better meet local objectives.

Arctic marine wildlife populations are vulnerable to changes in the sea-ice environment (Tynan & DeMaster 1997; Ferguson et al. 2005; Grebmeier et al. 2006; Learmonth et al. 2006). Currently, the Arctic is losing sea-ice cover and thickness on a global scale (Serreze et al. 2007), but the variability in the interannual data and the variability in the rate of change are both high. For example, some areas are experiencing, or are expected to experience, increased ice cover (Laidre & Heide-Jørgensen 2005; Dumas et al. 2006; Moore & Laidre 2006). Thus, changes in the distribution and abundance of both harvested and unharvested populations of multiple species will be manifested differently over temporal and spatial scales, which can be anticipated as being species specific.

The changes are difficult to predict because of the interrelationships and complexities of the sea-ice environment and other climatic variables, as well as the adaptability of each species and the effects of climate change on other trophic-linked species (Tynan & DeMaster 1997; Derocher et al. 2004; Laidre & Heide-Jørgensen 2005; Simmonds & Isaac 2007).

Human relationships with the environment and wildlife are also changing (Krupnik & Jolly 2002; Gearheard et al. 2006; Ford et al. 2007). Arctic communities rely on their environment and on wildlife for food and monetary income as well as other cultural purposes (Smith & Wright 1989; Langdon 1991; Reeves 1993; Pars et al. 2001; Sejerssen 2001; Duhaime et al. 2002; Wenzel 2005;

Chan et al. 2006). Accessing wildlife is expected to become more difficult as a result of climate change (Berkes & Jolly 2002; Berman & Kofinas 2004), and has already reduced the access to marine mammals in some areas, such as Baffin Bay (Born 2005; Dowsley & Taylor 2006a, b; Stirling & Parkinson 2006).

In the past few decades, scientists have become more attuned to the dynamic complexity of natural systems and the inadequacy of wildlife and environmental management models that assume static or only slowly changing parameters (Wilson 2002; Folke & Gunderson 2006). There has also been a paradigm shift in ecology towards understanding humans as being embedded in ecosystems and forming a complex social-ecological system (Holling 2001; Berkes 2004). The integration of different academic disciplines and traditional ecological knowledge (TEK, defined as both concrete information and abstract/cultural perceptions) is increasingly viewed as essential in order to deal with complex environmental problems, which require both technical data and the juggling of multiple viewpoints on management (Clark 2000; Berkes et al. 2007).

An examination of how improvements might be made to an Arctic adaptive co-management system is particularly salient to this broader discussion, given the heightened rate of change in Arctic environments, the regional history of resource use by indigenous people and the strong commitment to co-management in the North, which is legislated in North American land claims and other agreements (White 2006; Nunavut Tunngavik Incorporated [NTI] 2000).

Research into co-management or adaptive co-management systems typically focuses on two topics: the value of using TEK (Huntington 2000; Johannes et al. 2000; Usher 2000; Kendrick et al. 2005; Berkes et al. 2007), and/or the involvement of resource harvesters in management decision making (Armitage 2005; Fabricius et al. 2007). Researchers have demonstrated the usefulness of combining TEK and ecological studies to examine Arctic climate-change issues (Hinzman et al. 2005; Laidler, 2006; Berkes et al. 2007), as well as the benefits of combining TEK from many communities to develop an understanding of larger geographic areas or shared resources (Huntington et al. 1999; Mallory et al. 2003; Gilchrist et al. 2005; Fraser et al. 2006; Berkes et al. 2007). However, these approaches to data collection have not yet become widely institutionalized in Northern co-management systems. With regards to the second research focus, i.e., the role of harvesters in decision making, management systems have been modified to incorporate harvesters (and to some extent their TEK), particularly at the regional level, through the development of co-management boards as the main tool of

wildlife and environmental management in the North American Arctic (White 2006; NTI 2000). Although this is an important step towards equity, several researchers have commented on the lack of effective integration of the perspectives and ecological data of resource harvesters (Nadasdy 2003; Peters 2003; Fernandez-Gimenez et al. 2006; White 2006; Woo et al. 2007). In fact, the effective integration of resource harvesters into decision-making structures is presented as a key challenge to the development of adaptive co-management worldwide (Plummer & Armitage 2007). This paper proposes a spatially organized, or "community cluster", approach to improve co-management and adaptive co-management institutions, through targeted incorporation of TEK as a data source, and through strengthening the role of harvesters as decision makers at the subregional level.

Community cluster refers to a social unit made up of neighbouring communities that share a spatially-defined resource (e.g., a wildlife population). These spatial units have the potential to improve wildlife and environmental management in two ways. First, they can increase the information available to the co-management decision-making process. The specific ways in which they can do this are through collaborative scientific research, which is more cost and time efficient, and through providing monitoring that can lead to the faster recognition of changes in the resource under examination. Both of these can improve system response times, an important consideration in an era of rapid environmental change. The second area where community clusters can improve management is through increasing the involvement of harvesters in decision making in a coordinated fashion, using units that are defined by natural management units. Development of community clusters, either informally as a new social arena or formally as a new level of governance, can assist communities by improving their communication with each other, with researchers and with other parties in the co-management system. This would strengthen their involvement in, and understanding of, conservation issues and processes. The increased participation of resource users can highlight and reduce any policy barriers that have been preventing the efficient use of a resource, such as constructing obstacles to sustainable cultural practices or preventing communities from adapting to local environmental conditions. This paper argues that community clusters should be formally institutionalized as components of wildlife and environmental management systems, introducing a new level on the governance scale above the community level, but below regional institutions or wildlife co-management boards.

Nunavut's polar bear management system, like other adaptive co-management systems in the Arctic, is dealing

with rapidly changing environmental conditions that cause difficulties with information input, namely in research and monitoring. Moreover, it has suffered complaints that the views of harvesters are not effectively integrated into management decisions (Keith 2005; Dowsley & Wenzel 2008). Nonetheless, Nunavut's polar bear management system is at the forefront in terms of developing mechanisms for incorporating TEK as an information source, and has been developing the governance role of communities, at least in part because of the importance of this species at all levels of the social scale (from local to international), incorporating economic, cultural, existence and symbolic values. Nunavut's polar bear management system will be used here in a retrospective analysis of some of its features that fit into the idea of a community-cluster approach to natural resource management in a rapidly changing environment, and will provide examples of how such a system could work to improve adaptive co-management.

First, sections on background and case-study selection orient the reader both theoretically and geographically. These are followed by a brief overview of Nunavut polar bear management history. Next, a historic analysis of the case study gives insight into the two main uses of community clusters: as a conduit for TEK data, and as a forum for harvesters to participate in management. The paper concludes with future possibilities for the case study and broader lessons on how to use community clusters to improve co-management.

Background

Typically, the legislative mandate for conservation lies with governmental agencies. With respect to wildlife and ecosystem management, the local governance level functions very differently than the higher levels. This is because lower levels of governance involve complex individual relationships among people, while higher levels involve more official, less personal relationships (MEA 2003, 2005; Berkes 2004; Folke et al. 2005). However, initiatives for implementing adaptation to environmental change are often aimed at the local level. The impacts of these initiatives are important, not only for those people directly involved during the tenure of the programmes, but also for future generations, and range over wider geographic and social scopes than the programme boundaries (Berkes 2004). Fabricius and colleagues (2007) place communities into three groups based on their adaptive capacity: powerless spectators, coping actors and adaptive co-managers. Powerless spectators lack the capacity to respond to perturbations in the social-ecological system. Coping actors are reactive to change through the employment of short-term strategies:

they have options, but lack capacity, leadership and vision to behave proactively. Adaptive co-managers are those communities that have the capacity for social learning. They deal with change and possess a long-term vision. Understanding and promoting the movement of communities along this scale from spectators to active managers within a larger governance structure is the impetus for this paper, and is considered both from the perspective of utilizing TEK as a knowledge source, and of increasing the involvement of resource users in management.

TEK is used here to refer to the current ecological knowledge gained through an individual's lifetime, and also to the knowledge that is passed on from previous generations. The totality of the traditional knowledge of the Inuit (including the social and cultural context, and the process by which knowledge is evaluated as it is being passed along) is called *Inuit Qaujimajatuqangit* (IQ) in Nunavut. TEK is used here in statements relating to the general concept, whereas IQ is used to denote TEK held by Inuit in Nunavut. In this paper, TEK and IQ refer mainly to ecological/environmental observations and interpretations, and to how these are directly used in hunting and other land-use activities. The more abstract, holistic and ideological aspects of aboriginal knowledge are also recognized; however, these have proven difficult for agencies and co-management boards to incorporate into management systems (Usher 2000; Wenzel 2004; White 2006; Dowsley and Wenzel 2008). It is hoped that the role of these more abstract aspects of TEK can be enhanced over time, as familiarity and acceptance for aboriginal knowledge is gained by non-aboriginal co-management partners. This paper thus recognizes that co-management is an iterative and changing process, and it encourages the use of experimentation discussed in the adaptive management literature in order to develop an adaptive co-management approach to natural resources (Holling 2001; Carlsson & Berkes 2005; Cash et al. 2006; Plummer & Armitage 2007).

The recognition of the differences between TEK and scientific knowledge is an important first step in promoting local involvement in ecosystem and wildlife management. Scientific investigations in the Arctic, often aircraft-assisted, operate on the geographic scales that can range from hundreds to hundreds of thousands of square kilometres (Stirling et al. 1999; Laidre & Heide-Jørgensen 2005). Researchers cover geographic areas that are inaccessible to local people, such as areas that are remote from communities, including impassable or difficult terrain, steep mountains, non-navigable sea ice and open ocean. A third feature is that most scientific research dates back only a few decades. TEK from most contemporary individual knowledge holders generally focuses on the smaller end of the geographic scale, from less than one square kilometre

to hundreds of square kilometres, is constrained to navigable land, sea ice and open water, and has a timescale from the present to over a century ago, through oral transmission (e.g., Ferguson et al. 1998; Krupnik & Jolly 2002). TEK about wildlife populations or large-scale environmental features can be imprecise, and is usually qualitative, but it is relatively inexpensive to collect and document, and covers a broad range of possible environmental indicators. Scientific studies are typically much more expensive, but can only provide reliable knowledge when the results are accurate and sufficiently precise to discriminate between competing hypotheses (Moller et al. 2004; Berkes et al. 2007). For example, TEK is often able to report on wildlife population trends, but not on population size (Fernandez-Gimenez et al. 2006; NTI 2007), whereas scientific population surveys are able to estimate population size, and also the uncertainty associated with that estimate. However, scientific surveys are constrained in their frequency by human and financial resource limitations, thereby reducing their usefulness for identifying short-term changes such as population trends. Scientific sampling can also fail to meet the assumptions of the analysis model, and the results can be biased. When the assumptions of the analysis model have not been met by the sampling protocol, science can provide precise estimates that are nonetheless ambiguous and unreliable. The differences in geographic scales, geographic areas, frequency of observations/data collection, and the dependence of scientific research on the appropriate sampling of wildlife populations or environmental parameters must be considered when comparing TEK with scientific information. An objective comparison of the two types of information encourages the use of complementary approaches to obtain the most reliable information.

Case-study selection

Polar bear management in Nunavut is used in this paper as a case study of a system that is struggling to deal with rapid environmental change, but has an existing community-cluster approach that could be more fully developed. It was therefore selected for both ecological and social organization/governance reasons.

Partly because of an international agreement, most polar bear subpopulations have been managed to conform to both national and international conservation standards for approximately 40 years (Fikkan et al. 1993). Nunavut, which has or shares over half of the world's polar bears (Aars et al. 2006) sustains most of the costs (biological, social, financial, etc.) of polar bear conservation. This Canadian territory also has an 85% Inuit majority population, and uses co-management arrangements to manage natural resources under the Nunavut Land Claims Agree-

ment (NTI 2000). Nunavut communities have a long and intimate relationship with polar bears, involving many aspects of culture, subsistence and, more recently, monetary income, and thus polar bear conservation is not an insignificant issue (Smith & Jonkel 1976; Wenzel 1983; Freeman & Wenzel 2006). In Nunavut, the role of IQ and of Inuit communities in polar bear management has been developing for at least two decades.

Recent scientific research has shown that changes in sea ice related to climatic warming have had a negative impact on the population parameters of two polar bear subpopulations, and may be affecting other polar bear subpopulations (Derocher et al. 2004; Stirling et al. 1999; Stirling & Parkinson 2006). According to the most current estimates of birth and death rates for the western Hudson Bay population and the southern Beaufort Sea population (see Fig. 1), neither population is viable in the long term, even if there are no anthropogenic removals (Stirling et al. 1999; Regehr et al. 2006; Regehr et al. 2007). The polar bear was recently uplisted on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species from Least Concern to Vulnerable "due to the likelihood of an overall decline in the size of the total population of more than 30% within the next 35 to 50 years" as a result of predicted climate change effects (Aars et al. 2006: 61; Schliebe et al. 2006).

Monitoring this species, which is protected under an international agreement (Lentfer 1974a), is clearly a conservation priority. However, climatic warming may occur more rapidly than scientific monitoring and current management processes can accommodate. Climate change may also make it difficult to implement the established scientific methodologies used to estimate population parameters, making the studies more expensive, and increasing the confidence intervals of the statistical information (Derocher et al. 2004). The annual cost of maintaining a 15-year rotational population inventory for all 13 Canadian polar bear subpopulations is about 1 million CAD per year, for the research programs, plus about 500 000 CAD per year for salaries and benefits for indeterminate technical (i.e., scientific) staff. Continuing scientific studies at historical levels may not be sufficient to meet the enhanced monitoring, required by rapidly changing environmental conditions, needed to keep the polar bear harvest within conservation parameters that are not so precautionary that aboriginal hunters can no longer support them.

Polar bear subpopulations and management units

Polar bears are not subject to absolute barriers to their movements, and have been recorded to travel extraordi-

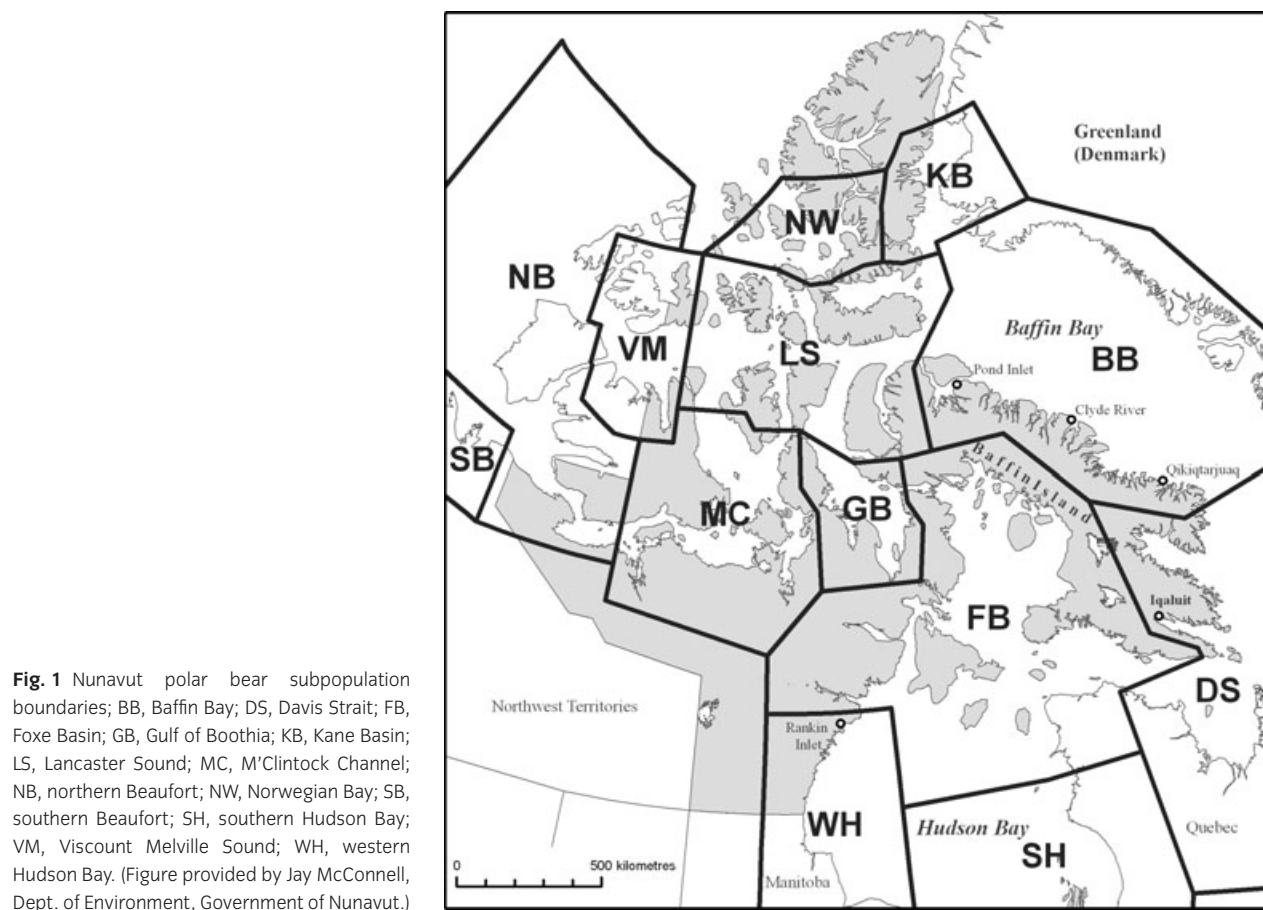


Fig. 1 Nunavut polar bear subpopulation boundaries; BB, Baffin Bay; DS, Davis Strait; FB, Foxe Basin; GB, Gulf of Boothia; KB, Kane Basin; LS, Lancaster Sound; MC, M'Clintock Channel; NB, northern Beaufort; NW, Norwegian Bay; SB, southern Beaufort; SH, southern Hudson Bay; VM, Viscount Melville Sound; WH, western Hudson Bay. (Figure provided by Jay McConnell, Dept. of Environment, Government of Nunavut.)

nary distances (Durner & Amstrup 1995; Messier et al. 2001). However, they are not nomadic, and most remain entirely within relatively well-defined subpopulation boundaries throughout their lives (Taylor & Lee 1995; Bethke et al. 1996; Taylor et al. 2001). These boundaries are partly derived from physical features of the landscape that cause discontinuities in their movements, and partly derived from deliberate movements to critical hyperphagic feeding areas in the late spring and early summer (Taylor et al. 2001). Nineteen subpopulations have been identified for this species, 12 of which are partially or wholly within Nunavut (see Fig. 1). Subpopulations are defined as “spatial units where population dynamics are mainly influenced by intrinsic vital rates and anthropogenic removals” (Taylor et al. 2001: 691).

The number of recognized subpopulations and their boundaries has evolved since overt, large-scale scientific research and management began in the late 1960s (Stirling 1988; Taylor & Lee 1995). Early boundaries were based on qualitative features such as topography, sea-ice conditions, TEK, reconnaissance-level aerial surveys and mark-recapture sampling (Taylor et al. 2001). Mark-recapture and mark-kill data have been used to delineate

boundaries since the 1970s, and this method is continuing today in many jurisdictions for boundary demarcation as well as in other studies (Lentfer 1974b, 1983; Kiliaan et al. 1978; Stirling & Kiliaan 1980; Schweinsburg et al. 1981; Schweinsburg et al. 1982; Furnell & Schweinsburg 1984; Larsen 1985; Derocher 1995; Taylor et al. 2005; Taylor et al. 2006). Telemetry data gathered using VHF (Taylor unpubl. data) and satellite radio collars have also been used in boundary demarcation (Schweinsburg & Lee 1982; Schweinsburg et al. 1982; Amstrup 1995; Lunn et al. 1995; Wiig 1995; Bethke et al. 1996; Born et al. 1997; Amstrup et al. 2004). Genetic evaluation (Paetkau et al. 1999) and cluster analysis of data (Bethke et al. 1996; Taylor et al. 2001) continue to improve boundary delineation, but have not yet been applied to all areas (Aars et al. 2006). In Nunavut and the Northwest Territories, research and management of polar bears occurs at the subpopulation level, which fits well with the human geographic scale. The area encompassed by these subpopulations can be entirely surveyed within seasonal “weather-windows” that allow safe access to the whole of the population. The subpopulations are also small enough that they only overlap the hunting territories of a few

human communities, and each community hunts only one or two bear subpopulations.

Nunavut's polar bear management history

The Canadian jurisdiction of the Northwest Territories (NWT) instituted a quota system to control the harvest of polar bears in the late 1960s (Table 1). This initiative was triggered by concerns about growing harvest levels associated with the increased use of snowmobiles in Arctic communities in the 1960s (Schweinsburg 1981). A lack of biological data on polar bears prompted the setting of community and provincial/territorial quotas based on the fur-trade records of each community for the 15 years prior to the first quota. Over the next few decades, quotas were revised in the NWT, based on new biological information, and sometimes on political pressure (Prestrud & Stirling 1994).

The government of the NWT has a history of consulting communities regarding polar bear quotas (Stirling et al. 1984; Davis 1999). This process was formally institutionalized through Polar Bear Management Agreements in the NWT, followed by Polar Bear Memoranda of Understanding (MOUs) in Nunavut, when it assumed responsibility for wildlife as part of territorial division. These agreements are formed between groups of communities hunting the same subpopulation of bears (defined here as a community cluster), the regional wildlife organization and the responsible government minister.

The first agreement was signed in 1985, and involved two communities that hunt the Baffin Bay polar bear

subpopulation (Davis 1999). The next agreements were NWT-wide, and most were completed by 1993. At that time, the quota system was modified from assignment of an independent quota to each community, to assignment of a quota for the polar bear subpopulation area, which is then divided amongst the involved communities. Each community negotiates its share with the others through the agreement/MOU process, and this is sanctioned by the regional wildlife management organizations as co-signatories of the agreements/MOUs. This system is in keeping with the community cluster approach, as it created groupings of communities that parallel the ecological boundaries of the resource to be managed (polar bear subpopulations), and gave the communities the power to negotiate their share of that resource amongst themselves.

The 1993 agreements were replaced in Nunavut (NU) by MOUs in 1996, and renewed in 2004. These were formally accepted in Nunavut by the Nunavut Wildlife Management Board and the Nunavut Minister of Environment as part of the co-management process identified in the Nunavut Land Claim Agreement. The root purpose of these Agreements and MOUs was consultation for developing regulations as a consensus process. A secondary motivation that emerged in 1996 was to qualify subpopulations for the US sport hunt, under the terms identified in the US Amendment to the Marine Mammal Protection Act (Taylor, pers. comm.). This motivation provided additional economic incentive for communities to work together and ensure sound management of their subpopulation.

Table 1 Time-line of the development of polar bear management in the Northwest Territories, from which Nunavut Territory was created in 1999.

Year	Event	Significance
1968	First polar bear quotas introduced in Northwest Territories (NWT), assigned to individual communities.	Top-down management begins.
1960s–80s	Communities consulted independently, and quotas modified for various reasons.	Consultation with individual communities begins.
1985	First polar bear agreement signed between government and community hunters and trappers organizations for the Baffin Bay polar bear management unit.	Communities sharing a management unit first consulted as a group (de facto start of community cluster approach to management).
1993	Quota system modified to assign a quota to a de facto community cluster sharing a polar bear subpopulation, with the quota divided amongst cluster communities by lower levels of governance.	Use of de facto community cluster approach institutionalized across NWT.
1993	Nunavut (NU) assumes responsibility for wildlife management from NWT as part of territorial division.	Co-management institutionalized in NU at territorial level though creation of Nunavut Wildlife Management Board.
1996	NU replaces management agreements with memoranda of understanding (MOUs).	
1999	NU separates from NWT becomes a new territory, Nunavut Land Claim Agreement signed.	
2004	NU and community clusters sign new MOUs, and agree to use <i>Inuit Qaujimajatuqangit</i> (IQ) for setting quotas in second half of management cycle (years 8–15 of 15-year cycle).	IQ formally acknowledged and incorporated in quota decision making. Methods of collection, responsibility for collection and archiving not developed.

Table 2 Organizations involved in polar bear management relevant to the case study, arranged from international to local.

Organization	Composition	Relevant role
Polar Bear Specialist Group of the International Union for the Conservation of Nature (PBSG/IUCN)	Representative scientists from polar bear range countries.	Share data and collaborate on research and management, apply pressure to member countries to abide by the International Agreement on the Conservation of Polar Bears.
Canadian Federal/ Provincial/ Territorial Polar Bear Technical Committee (PBTC)	Professional polar bear scientists and managers from across Canada.	Share data on polar bear management.
Government of Nunavut	Territorial managers and scientists, Minister of Environment.	Conduct research on wildlife species, consult with communities and co-management partner (NWMB) on appropriate management decisions. Minister has final authority.
Nunavut Wildlife Management Board (NWMB)	Representatives from Territorial and Federal Ministries, Nunavut Land Claim Organization.	Co-management partner with territorial government. Makes decisions on management of wildlife.
Regional Wildlife Organization Hunters and Trappers Organization (HTO)	Representatives from HTOs. All harvesters in community, board elected by members.	Divides subpopulation quota among communities. Decides community regulations, represents community to higher levels of governance.

Features of the community cluster approach in the history of Nunavut's polar bear management

Historically in NWT, and later in Nunavut, consultation by what are effectively community clusters proved to be useful for disseminating scientific information and developing regulations for polar bear subpopulations. Consultation also provided a vehicle for IQ input into the management system, although the responsibility and method for the collection, analysis and archiving of IQ has not yet been formally developed. The consultations have also reduced policy barriers to management by presenting co-management authorities with a consensus on polar bear management options. In this section, examples are given of how community clusters have increased the use of IQ and the involvement of resource users in polar bear management decision-making. First are examples of how IQ and science have proven to be complimentary in terms of research and monitoring. This is followed by examples of how basing the co-management process on polar bear subpopulation community clusters has increased community adaptive capacity, and improved the management system. Table 2 provides a summary of the current government structures for polar bear conservation that are relevant to the case-study examples.

Community clusters as sources of TEK data for management

Currently, IQ on polar bears in Nunavut is communicated to higher levels of governance during consultations (generally for MOUs) between de facto community clusters,

the Government of Nunavut and other co-management partners. Two examples illustrate how community cluster IQ has provided useful information, and has reduced the time between the onset of a change in the resource and the subsequent management response. A third example describes one community cluster research methodology that proved useful for management, and could be considered for adoption in adaptive co-management systems.

In 1985 the first polar bear agreement was developed between the NWT government and the communities of Clyde River and Broughton Island (now located in Nunavut), regarding the management of the Baffin Bay (BB) polar bear subpopulation (Fig. 1). During the consultation process, Inuit argued that the science-based mark-recapture subpopulation estimate (400–600 animals; Taylor et al. 2005) was too low, as the surveys has been conducted in the spring, when bears spread over the pack ice from Baffin Island to Greenland (Davis 1999). The BB scientific survey teams working in spring were restricted to the shore-fast ice, and assumed that the bears on the shore-fast ice were randomly mixed with the other bears in the subpopulation. The IQ was not seriously considered at the time, and quotas were drastically reduced based on the mark-recapture data (Taylor et al. 2005).

By agreement, the subpopulation was resurveyed from 1993 to 1998. This initiative made use of new satellite telemetry technology to track polar bear movements, and researchers expanded the study area through a partnership with Greenland (Prestrud & Stirling 1994). Prior to initiating the mark-recapture sampling, the communities were consulted and encouraged to contribute their IQ. Based on community recommendations, the capture

work was carried out during the open-water season, when Inuit knowledge and satellite telemetry indicated most individuals from this subpopulation were onshore in the Canadian sector. Local hunters participated in the capture work, and provided other support through contribution of their knowledge of polar bear distribution (which varied from year to year), and their hunting and land skills. The revised subpopulation estimate was 2074 (± 266), which was in agreement with the impressions of local hunters regarding sustainable harvest levels. This estimate was the basis of the 1996 MOU for BB (Taylor et al. 2005). This example illustrates that IQ, and TEK more generally, can assist in developing and implementing research methodologies.

Another example of the value of TEK for research comes from the M'Clintock Channel (MC) polar bear subpopulation area (see Fig. 1). During the early 1980s a somewhat subjective scientific subpopulation estimate of 900 bears was identified for MC (Taylor et al. 2006). During the consultations for the 1996 MOUs, Inuit hunters from two communities reported that the bear subpopulation appeared to be declining. A new subpopulation estimate of 700 was agreed, and harvest quotas were adjusted accordingly. A valid scientific estimate of the MC subpopulation was not available until 2001, and this estimate indicated the subpopulation had been reduced by over-harvesting. Analysis of harvest data and the new survey data gathered from 1999 to 2000 indicated the subpopulation had fallen to 284 animals (± 59.3 ; Taylor et al. 2006). The Government of Nunavut and the Nunavut Wildlife Management Board (NWMB) imposed a significant quota reduction in 2001, followed by a harvesting moratorium in 2001/02, which remained in place until a new MOU was completed in 2004.

The MC example illustrates how community cluster information reduced the management response times to a resource problem. During the time of the subpopulation decline, MC hunters were able to fill their quotas by relying on their hunting skills; however, they were very much aware that either numbers were declining or the distribution was changing. This example illustrates that population trends can be detected by TEK and that communities can work together by sharing information, and can also work with higher levels of governance in management. It also indicates a potential problem with TEK, which is the difficulty in quantifying an appropriate management response to qualitative information, even when that qualitative information is fully correct. An unfortunate postscript to this example is that although MC communities were promised that they would be included in the research, and that IQ would be collected and archived simultaneously with the scientific research, this did not occur. The NWMB and Government of Nunavut

issued a press release on their co-management decision to reduce, and then cease, polar bear harvesting in MC before they notified the community hunters and trappers organizations (HTOs), and regional wildlife organizations. These events polarized the relationship between community HTOs and the co-management authorities, and have continued to influence the management landscape even after IQ was collected and archived, and the 2004 MC MOU was signed (Keith 2005).

These two examples indicate that polar bear subpopulation monitoring by community clusters can provide useful information for management that can reduce management response times. In the first case, Inuit correctly identified an error in the scientific estimate of subpopulation numbers, and also provided a methodological solution to the sampling problem of the scientific research. In the second case, Inuit reported a decline in the bear subpopulation in 1996 that would not have been observed by the scientific research programme until 2001, when the damage from over-hunting would have been even greater. Clearly the harvest statistics alone were insufficient to detect the problem, because quotas were being filled with the agreed-upon sex-ratio of approximately two males per female, right up to the harvest moratorium. Changes in sex and age composition of the subpopulation were evident to the government biologists after their survey study was completed (Taylor et al. 2006), and were actually used in dealing with the problem. However, the initial observation of a subpopulation change came from community cluster IQ. It should also be mentioned that no community exceeded the government-approved quotas in MC at any time. The decline in the MC subpopulation was caused by an overestimation of subpopulation numbers, and the consequent overestimation of sustainable harvest rates by government scientists. The MC example also serves to illustrate the importance of good faith and respectful practices from co-management authorities to retain community support for essential management initiatives.

In order to improve the use of TEK in management, collection methods for this form of data need to be developed. Several researchers have collected TEK data from multiple communities, in order to parallel the geographic and biological scale upon which ecological data are often collected (McDonald et al. 1997; Ferguson et al. 1998; Mallory et al. 2003; Gilchrist et al. 2005; Parlee et al. 2005; Dowsley 2007). The data collected in these studies has the potential to assist in management decisions, and some of these studies have contributed to management already (e.g., Ferguson et al. 1998). However, few jurisdictions have formally institutionalized the use of community cluster TEK data in management, nor have they made a commitment to TEK collection and use. The

Government of Nunavut formalized a commitment to do this, with respect to polar bears, through the polar bear MOU process, and within the MOUs themselves.

The recognition of the need to integrate IQ into polar bear management was a fundamental part of the 2004 MOU initiative that began with community consultations in 2002. Almost immediately after the MOUs came into effect in December 2004, community perspectives came into conflict with scientific perspectives. The quotas for both BB and western Hudson Bay (WH) subpopulations had been increased in 2004 partly based on IQ presented during the consultation meetings that suggested these subpopulations had increased under historical harvest rates (Government of Nunavut 2005a, b). In February of 2005, new information on the Greenland harvest from the BB subpopulation, and new scientific information on the status of the WH subpopulation, was provided at the Canadian Federal/Provincial/Territorial Polar Bear Technical Committee Meeting (PBTC). The new information suggested polar bear numbers were declining in these subpopulations. Climate change was considered by several scientists as the ultimate cause of the declines (Stirling & Parkinson 2006). Nunavut was criticized internationally for the quota increases because they used non-scientific information, and did not provide written documentation of the IQ data (Aars et al. 2006).

In response to the need to document IQ, Dowsley (2007) used a community cluster approach in 2005 to collect and analyse IQ data on BB polar bears. Unfortunately, the funding did not allow Greenlandic hunting communities on the east side of the bay to be surveyed. However, IQ and science from the earlier research indicated that during the open-water season the polar bears of this subpopulation are found mainly on the Nunavut side (Taylor et al. 2001). Forty-eight semi-directed interviews were conducted in the three Nunavut communities that hunt the BB polar bear subpopulation: Pond Inlet (located on the north-eastern coast of Baffin Island), Clyde River (located on the central coast) and Qikiqtarjuaq (located along the south-eastern part of the coast). The purpose was to investigate observations of, and possible links between, climate change and changes in the BB polar bear subpopulation. The majority of respondents in all three communities agreed that: the sea ice is breaking up earlier than in the past, the ice is now thinner, the floe edge is located closer to the land and icebergs are not grounding as often as in the past. The three communities did not differ significantly in their reports of environmental changes occurring in their respective harvesting and travelling areas (which, when combined, cover most of the western shore of Baffin Bay). This suggests similar environmental changes were being experienced throughout the study area.

In this same study, the discussions relating to the BB polar bear subpopulation revealed that most of the interview participants in each community had observed an increase in polar bear numbers, and in polar bears approaching people and damaging property. Had the study been performed in any one of the communities, this would have been the main conclusion. However, comparisons of the three communities in the same polar bear subpopulation area revealed statistically significant differences along a north–south gradient. The responses from the most southern community of Qikiqtarjuaq were more mixed than the northern communities when asked about any change in the size of the polar bear subpopulation ($P = 0.01$), and about any changes in the number of bears coming to town ($P = 0.021$) (for each community $n = 15$, on average). Qikiqtarjuaq residents did not have a high level of agreement amongst themselves on these topics, whereas the two more northern communities strongly agreed that the subpopulation size was increasing, and that more polar bears were coming to town. Other non-significant results and qualitative comments also showed a north–south gradient for this topic.

The IQ collected in this study suggests that changes in the land-fast ice were similar throughout the study area, but changes in the frequency of sighting polar bears and in polar bear behaviour were not the same throughout the area. More bears were seen in general, and in the towns of the north-western part of Baffin Bay. This information documents a more complex situation than a simple correlation between the ice conditions and the polar bear subpopulation and behaviour. The research adds to previous scientific information that revealed a weak differentiation between northern and southern groups of bears in the BB subpopulation, as a result of currents and movement of pack ice (Dunlap & Tang 2006; Taylor et al. 2001). This method of collecting TEK from a community cluster revealed very detailed information and allowed for geographic variation to be uncovered. This example illustrates a methodology for the collection of community cluster TEK that can provide information for management discussions, provide research questions for scientists, and identify discrepancies between scientific perspectives and TEK.

Community clusters as a level of governance

The second way in which community clusters can improve wildlife and management systems is through their use as social arenas, where communities can work together to deal with local management issues. One potential use of this forum is to reduce policy barriers that constrain or limit community-level influence on decision-making, and thus reduce/impair the adaptive

capacity of the community to deal with environmental change. Examples are given of how, over time, Nunavut has created space within the management system for communities to work together. The creation of community clusters as a level of governance is then discussed in terms of its potential for moving communities from powerless spectators in natural resource management to active managers.

Polar bear quotas were first used in 1968 (Schweinsburg 1981), but their provisional nature was recognized by the government of the NWT, and community requests to modify quotas or regulations for economic reasons were sometimes granted until scientific information could provide recommendations to better ensure conservation (MacPherson & Jonkel 1970; Stirling & Macpherson 1972). This early willingness on the part of the NWT government to discuss and modify the quotas has provided a forum for communities to discuss hunting regulations.

Since the 1970s, NWT, and later the Government of Nunavut, developed rules that assign responsibilities for polar bear management to different levels, rather than maintain all of the control at the highest territorial level. This gives power to lower levels, in particular the regional and individual community levels, and to some extent also to de facto community clusters, while providing management and research coordination at the level of the polar bear subpopulation. For example, in Nunavut, the community-level HTOs can regulate a polar bear season as they wish in order to accommodate local environmental conditions, and to maximize the economic benefits to their community as a result of seasonal changes in hide quality. This multi-level governance approach has allowed individual communities to adjust regulations to meet local needs. The opportunity exists for the communities to work together to develop subpopulation-wide regulations, but this has not yet become common practice.

One example of communities working together as a cluster comes from the introduction of the flexible quota system in 2004. Under the flexible quota system, the Government of Nunavut maintains an account of the quota credits or debits of each community HTO. In the case of over-harvesting males or females, the debits are paid back the following year. Un-harvested bears in any given year can be harvested in subsequent years as credits, which may also be shared with other communities within the same bear subpopulation area (i.e., the community cluster), if the donating community so chooses. This flexible quota system provides for the conservation of polar bears, but also for the correction of mistakes at the community level, such as misjudging the sex of a bear before harvesting, and the accommodation of unexpected defensive, accidental or illegal kills. The

system also allows space for communities within a cluster to coordinate their harvests by giving or loaning tags if they so choose.

These structural features of the co-management system allow for communities to form clusters and initiate regulatory changes. The ability to make changes is important for communities who may experience environmental changes that must be dealt with on a shorter timescale than is possible as a response time at higher levels of government. Nunavut's system further allows for communities to work together as clusters to effect change at higher levels of governance through the modification of management policy and goals.

Nunavut has focused its polar bear management on maximizing the sustainable yield of bears in order to satisfy a high demand for hunting, and also to keep subpopulations high to show good management to the people of Nunavut, the Canadian Government and the international community through the Polar Bear Specialist Group of the IUCN. This has had two results: first, subpopulations have been managed using sex-selective harvesting biased towards the harvest of males; second, subpopulations have been managed to obtain target numbers that are based on mark-recapture subpopulation estimates from the past 20 years. There is space within the management system for community clusters to take a more active role in management decision making relating to both of these policies, and thus to move the role of harvesters towards that of active managers.

The male-selective harvest system was developed to maximize the sustainable harvest of polar bears. New modelling information suggests that female mating success may suffer a rapid collapse if the proportion of males in the subpopulation crosses a certain threshold (Molnár et al. 2008). However, the Nunavut harvest system would not reduce males to this threshold level (Taylor et al. 2006). Although concerns about the sex-selective harvesting system have been raised by Nunavummiut harvesters in management discussions between de facto community clusters and government managers (Dowsley & Taylor 2006a, b), Nunavut harvesters have not been willing to accept the lower quotas that non-selective harvesting would require.

Fewer males would be harvested if the proportion of males in the harvest were reduced. However, a corresponding increase in the harvest of females would jeopardize the subpopulations by pushing the harvest of females beyond sustainable limits, as the harvest of females is already at the estimated maximum for sustainable levels. Therefore, the overall quota for each subpopulation would have to be reduced to accommodate an unselective harvest. Each community cluster must balance their concerns for the subpopulation with

their wish to hunt it at current levels. They must also decide on the timing of their modifications of the current harvesting system. They could be proactive and decide on an acceptable sex-ratio, and then reduce their quota in order to reduce their concern that the current male-selective harvest practices will be detrimental to the population's productivity. If the community cluster set goals and managed to meet those goals, this arrangement would fall into the category of adaptive management as defined by Fabricius et al. (2007). If the community cluster did not take on such a leadership role, i.e., it waited and let others initiate changes, it would fall into the coping actors category. Either way, the communities must work as a community cluster in order to modify the management of their polar bear subpopulation. Unilateral decisions by a single community would be more likely to affect the resource negatively than positively. If one community decreased hunting, all communities in the cluster would benefit in the long term, but if a single community increased hunting, a "tragedy of the commons" could result.

The second area where community clusters could increase their management decision making involvement is the setting of target numbers for subpopulations. The target number for a subpopulation is the number of polar bears that the subpopulation is being managed to maintain as its population. It generally closely reflects the subpopulation level from the last scientific survey. The polar bear MOUs commit to maintaining those numbers in perpetuity, or until the MOUs are revised. Environmental changes that may affect polar bear subpopulation productivity and carrying capacity were not considered in setting these targets. In any case, the carrying capacity is difficult to estimate for harvested subpopulations because as such they are at levels considered to be less than the ecological carrying capacity. However, environmentally-induced reductions to population productivity have been identified for some populations (Stirling et al. 1999; Regehr et al. 2006; Stirling & Parkinson 2006; Regehr et al. 2007), and have been suggested for others (Stirling & Parkinson 2006). This information has called into question the practice of setting target numbers for subpopulations. Additionally, Inuit have indicated that human-bear encounters have increased, and they have expressed concerns about human safety during traditional land-use activities in recent years (Dowsley & Taylor 2006a, b; NTI 2007). The history of subpopulation numerical trends in some subpopulations has also been contested, and some authors have hypothesized long-term declines in polar bear habitat quality, with consequent reductions in polar bear numbers (Stirling & Parkinson 2006).

Community HTOs have the opportunity to work with each other as a community cluster to develop strategies

for dealing with these issues. One option is the identification of lower subpopulation targets, and an agreement to hunt to reduce the subpopulations to the reduced levels. The initial benefit of higher quotas to reduce the subpopulation size would have the undesirable result of reduced harvests for future generations of Inuit. The medium- to long-term safety outcome would be reduced encounters with bears. Another option would be reducing harvest rates right away in the hopes of retaining the current number of polar bears by compensating for reduced productivity with reduced harvest mortality. A third option is to continue historical harvest practices and assume that environmental conditions will improve, or that the scientific information is flawed, or that the decline in polar bear habitat and productivity that has been documented in some areas is specific to those areas only. Again, these various options would place a given community cluster in either of the coping actor or active manager categories.

Goals for management are changing because of new conservation concerns and changing environmental conditions. Nunavut has a management structure through the MOU process that allows community HTOs to assume more responsibility for management if they choose to become more proactive, and take advantage of the opportunity provided by de facto community clusters to effect change.

The road ahead

Co-management scenarios that result in successful adaptive management of wildlife resources by harvester communities exhibit six key characteristics: enabling policies, knowledge networks, nested institutions, links between culture and management, leadership and vision, and motivation (Fabricius et al. 2007). The development of community clusters provides an opportunity to improve policies and knowledge networks. Nunavut's co-management system has created nested institutions, and Nunavut has made some progress in linking culture and management, although this area is still developing (White 2006; Dowsley & Wenzel 2008). Leadership, vision and motivation can best be developed as grassroots initiatives, and are therefore essential goals for Nunavut communities and Inuit organizations if they want to develop the capacity to manage their environmental resources sustainably in an era of increased environmental change.

The case study of Nunavut's polar bear management relates to the larger issue of conservation in Canada. Canada's Species at Risk Act mandates federal intervention at various levels for species designated as "at risk". Environment Canada's (2008) website states:

The precautionary approach/precautionary principle is distinctive within science-based risk management. It recognizes that the absence of full scientific certainty shall not be used as a reason to postpone decisions when faced with the threat of serious or irreversible harm.

The Nunavut Land Claim Agreement (NLCA) fits within this view, by identifying a top-down based co-management system as constitutional law, but does not clearly state how TEK or IQ should be used.

However, the NLCA also requires the Nunavut Wildlife Management Boards, or the responsible minister, to demonstrate that a restriction or limitation on Inuit harvesting is necessary because of one of three reasons: to effect a valid conservation purpose, to give effect to the allocation system outlined in the land claim, or to provide for public health or safety (NTI 2000). The NWMB have indicated that they feel compelled to include and incorporate TEK/IQ in their management decisions because of NLCA sections 5.1.2. and 5.1.3. The first section states there is a need for an effective system of wildlife management that complements Inuit harvesting rights and priorities and recognizes Inuit systems of wildlife management that contribute to the conservation of wildlife and protection of wildlife habitat.

Section 5.1.3. states that a management system must be developed that "reflects the traditional and current levels, patterns and character of Inuit harvesting". A precautionary response in the absence of scientific information is obviously problematic to the Nunavut co-management process, because of the constitutional rights of the harvesters. Equally problematic is an NWMB management response (or lack of response) that does not consider the inherent risk of uncertainty, or is unresponsive to Canada's Species at Risk Act. In order to maximize conservation effectiveness, the precautionary principle is obviously useful. However, the degree of precaution that may be used must also consider the rights of the harvesters.

Two recent events illustrate that the management system in Nunavut is moving towards adaptive co-management. First, during the meeting of the IUCN Polar Bear Specialist Group in 2005, Nunavut cast the only vote against a resolution that stated polar bear harvest management decisions should be based on science only. Second, the Government of Nunavut has shown increased support for greater community involvement in management by identifying a full-time IQ social scientist as part of their conservation staff in 2006.

A lack of community involvement in scientific research and in management can lead to problems such as time lags in implementing action plans, and the erosion of harvester trust in science and management.

One recent example of this comes from the WH sub-population, which is shared between Nunavut and the Canadian province of Manitoba. The total allowable harvest for this population was increased to 56 animals per year in December 2004, based partly on Inuit observations of increased numbers and an extension of the historical summer retreat range (NTI 2007). However, scientific information from the Canadian Wildlife Service (CWS), based on a long-term study of this sub-population in its summer retreat area around Churchill, Manitoba, indicates that polar bear numbers are declining as a result of changes in the sea ice and legal harvest levels (Regehr et al. 2007). The CWS does not have any agreement to consult with Nunavut communities on research performed outside of Nunavut, even though Nunavummiut are the main harvesters of the WH sub-population. The CWS results indicating a decline in the population were initially presented to the WH community cluster in 2005. IQ indicated an increase in polar bears based on observations of a wider distribution on land and increased encounters between bears and humans. The lack of use of IQ in CWS's research was considered unacceptable by the community cluster. As a result, the community cluster did not support management action, and instead asked for more scientific research and more involvement of harvesters.

In 2007, the CWS presented data directly to the NWMB indicating a sustainable combined removal rate of 16 animals per year for Nunavut and Manitoba. Historically, eight of these removals have been required by Manitoba for control activities around the community of Churchill. The NWMB decided in 2007 to reduce the WH polar bear quota for 2007/08 from 56 to 38, and then to 8 animals per year in 2008/09. This decision was accepted by the Government of Nunavut Minister of Environment. However, the community cluster was not satisfied with the outcome. The Minister of Environment was heavily criticized in Nunavut's legislative assembly for supporting scientific information over community cluster IQ. Also, scientific questions remain. The CWS research group recently published revised survival estimates that suggest that no sustainable harvest may be possible (Regehr et al. 2007). If this is the case, the effect of the NWMB decision may only be to slow the decline of the WH subpopulation. The changes in the science-based estimates were not explained to the WH community cluster, or to the NWMB.

This example illustrates that scientists and agencies need to improve communication with communities and co-management bodies. Also, the role of harvesters and of TEK must be clearly defined and agreed upon by both scientists and community clusters before ecological research is conducted. Without community cluster

support, management decisions will be delayed, and also risk being disregarded by harvesters.

This example of a management issue in WH polar bears is important because it hints at things to come in other polar bear subpopulations. The WH subpopulation is the most studied polar bear subpopulation in the world (Aars et al. 2006). Data are collected annually both through research conducted by the CWS and through the collection of harvest statistics and 15-year-cycle subpopulation surveys by the Government of Nunavut. Other Nunavut subpopulations are only studied through harvest statistics and the 15-year surveys, whereas other jurisdictions worldwide have less intensive research programmes. If climate change continues and affects polar bears as predicted by some scientists (Stirling & Derocher 1993; Derocher et al. 2004; Stirling & Parkinson 2006), the time lag between the onset of climate change effects and the implementation of management action for any affected subpopulations are likely to be longer than that experienced in western Hudson Bay (two years from scientific reporting of problem to management decision). Discovering the types and magnitude of changes in other subpopulations is expected to take longer under current monitoring systems and research programs, and thus managing the effects on these other less well-studied subpopulations will take longer from the initial onset of the problem. In an era of rapid environmental change this is an important concern. Unfortunately, financial and political constraints are major barriers to increasing scientific research on other polar bear subpopulations. The creation of community clusters as units for TEK data collection and management discussions is a low financial cost method of increasing the monitoring of subpopulations. It also improves management through improving communications and harvester involvement in decision-making, which increases community support for decisions.

The situation in western Hudson Bay might be interpreted by some as reason to reduce community-level involvement in management, because of the time lag between the reporting of scientific data that indicated a problem and the management action. However, in the long run this view will not produce better conservation results, nor is it equitable to harvesters.

Several things are essential to bring together the top-down and bottom-up perspectives in Nunavut and in wildlife and environmental resource management, more generally. First, there must be an institutional commitment of the human and financial resources necessary to collect and archive TEK so it can be brought forward and properly considered. The commitment of resources assumes a system-wide (including government scientists) agreement to use TEK in the co-management process.

The second essential component is a mutual understanding of the limitations of TEK and a grass-roots commitment to the precautionary principle when there is uncertainty and cause for concern. Third, there must be a commitment from both top-down and bottom-up perspectives that conservation is a shared goal, whereas other goals may shift. TEK and science and their various knowledge holders (community clusters and scientists) can only work effectively together when both forms of knowledge are reported honestly, and when both sides trust each other. Moving forward on this agenda will require leadership and motivation from both sides, but will also benefit both sides and help meet the shared goal of sustainable resource management.

Five steps for enhancing co-management systems through the inclusion of community clusters and their knowledge are as follows.

- (1) Recognition/acceptance of TEK and science, the precautionary principle, and the right of harvesters not to be constrained by overly conservative management decisions.
- (2) Data collection using both TEK and science, and a collaboration between the two.
- (3) Institutionalization of community clusters for data collection.
- (4) Institutionalization, either formally or informally, of community clusters in the management process.
- (5) Grassroots initiatives to take advantage of the social space provided by the community cluster approach in order to adapt management to local conditions, and to effect policy changes at higher levels, to better meet local objectives.

The institutionalization of community clusters in wildlife and environmental management not only increases the amount of information available to management systems, it also provides a space within the management system to improve communications between managers and communities, and between communities within the cluster. This space has been used in Nunavut to improve system efficiency, and it has reduced policy barriers that constrain community-level decision-making. Reducing such barriers is important for increasing community options, and thus the adaptive capacity that can help to cope with environmental change. The community cluster approach can be developed from both top-down and bottom-up directions to improve management through increased data input for decision-making and increased involvement of harvesters in decision-making.

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