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Counting what counts: using local knowledge to improve Arctic resource management

Finn Danielsen[a]*, Elmer Topp-Jørgensen[b], Nette Levermann[c], Piitaaraq Løvstrøm[c], Martin Schiøtz[d], Martin Enghoff[e] and Pâviârak Jakobsen[f]

[a]*Nordisk Fond for Miljø og Udvikling, Skindergade 23-III, DK-1159 Copenhagen, Denmark;* [b]*Department of Bioscience, Aarhus University, DK-4000, Roskilde, Denmark;* [c]*Ministry of Fisheries, Hunting and Agriculture, Government of Greenland, P.O. Box 269, DK-3900 Nuuk, Greenland;* [d]*Ministry of Environment and Nature, Government of Greenland, P.O. Box 1614, DK-3900 Nuuk, Greenland;* [e]*NORDECO, Skindergade 23, DK-1159, Copenhagen, Denmark;* [f]*Qaasuitsup Kommunia, Aasiaat Servicecenter, Niels Egedes Plads 1, P.O. Box 220, DK-3950 Aasiaat, Greenland*

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The climate is changing and the people in the Arctic are facing huge challenges. Many rely on natural resources for both subsistence and income. Successful adaptation to climate change and the sustainable use of resources requires observation of the environment. Scientific knowledge of the environment is incomplete and conventional scientific monitoring is logistically difficult. Local fishers and hunters observe the environment all year-round. Their observations and knowledge are, however, not consistently quantified, analyzed, or used for resource management. We present a simple, field-based system for monitoring and managing resources developed specifically to enable Greenlandic fishers and hunters to document trends in living resources and to propose management decisions themselves. This system was designed to build upon existing informal observing methods, and there is interest in the system among rural fishers and hunters. We describe correspondence between community members' perceptions and professional scientists' assessments of the abundance of sea-ice, shipping, fish, mammals, and birds. Community-based documentation can pinpoint particular species and areas that are in need of attention. At the same time, it can help link observed environmental changes to management action. We hope this paper will encourage other stakeholders to develop their own local monitoring systems so as to facilitate adaptive management responses at both local and national levels.

Introduction

The polar regions are experiencing rapid environmental changes (Post *et al.* 2009). Knowledge of these changes is necessary in order to adapt the resource management and livelihood strategies of the Arctic communities (Riedlinger and Berkes 2001).

*Corresponding author. Email: fd@nfmu.org

There is incomplete scientific knowledge of populations and trends in the Arctic's living resources (Meltofte 2013). Local knowledge abounds (Ferguson *et al.* 1998; Krupnik *et al.* 2010; Weatherhead *et al.* 2010) but, with few exceptions (Russell *et al.* 2013), this is not consistently being quantified or used in broader decision-making (Sejersen 2003; Johnson *et al.* 2014). The declarations from the third to the eighth Ministerial Meetings of the Arctic Council (2002–2013) all emphasize the importance of using 'traditional knowledge' (Berkes *et al.* 2000) to address challenges in Arctic communities.

In response to this, several programs for capturing and sharing local observations have been established (Gofman and Smith 2009; Oskal *et al.* 2009; Gofman 2010; Merkel 2010; Huntington 2011; Larsen *et al.* 2011; Mustonen and Mustonen 2011; Knopp *et al.* 2013; see also arcticcbm.org). The Government of Greenland is contributing to such international efforts and has stipulated legal requirements for involving users in the management of natural resources (Greenland Government 1999). Moreover, the government has piloted the development of a community-based monitoring system (Ministry of Fisheries, Hunting and Agriculture 2014).

Each component of community-based monitoring programs presents a set of challenges (Pulsifer *et al.* 2014). For instance, differences in language and worldview can hinder communication and mutual understanding (Berkes 2012). Access to data management systems may be difficult in remote regions or may not be culturally appropriate in some instances. Interpretation of data requires some degree of judgment which, in turn, may distance the initial observation from its local context in the quest to enable comparisons over time and space. This paper outlines how the Government of Greenland has attempted to tackle these and other challenges in developing a systematic system for community-based monitoring in Greenland.

Historically, hunting and fishing in Greenland have undergone major changes. Speed boats have provided access to areas that previously were inaccessible and modern fishing gear and rifles have improved efficiency (Huntington 2013). Combined with historic population growth and a continued cultural importance of fishing and hunting, there is therefore a need for a well-functioning system for regulating resource use.

We describe the Greenland community-based monitoring system from conception to implementation and discuss the findings from the first three years. First, we explain how the system was developed. Then we present the theoretical framework for the system and how it works at the community level. We assess whether community members enroll in the system or not and whether the community members' findings correspond with those of the professional scientists. Finally, we discuss the incentives for the participants, the extent to which the system is culturally sensitive, and we propose some further developments of the system. The article's structure builds on the study of Danielsen *et al.* (2000). Latin names are provided in Annex S1 (supplementary article) (this and other supplementary materials are available on the journal's website). Nomenclature follows Génsbøl 2004.

Methods for developing the documentation and management system

For many Greenlanders, the word 'monitoring' has strong negative connotations. We therefore call this system a 'documentation and management system.' However, the system was not only renamed to appeal to Greenlanders. The system is profoundly different from conventional monitoring systems, as we describe below.

Development and implementation of this system were carried out over a three-year period, from 2009 to 2012, alongside the capacity building of government staff and community members in local documentation and management of living resources in four communities. Our team comprised six professionals in environmental planning, wildlife management and administration from the Government of Greenland, three Greenlandic local authority staff members from Qaasuitsup Kommunia, a Danish ecologist, and a Danish rural sociologist. The Greenland government staff input, in terms of person-months, was approx. five times the external staff input. Every 6–8 months an advisory group met to supervise the work. This group included scientists and government staff and representatives of the Greenland Fishers and Hunters Association (KNAPK), the Greenland Association of Municipalities (KANUKOKA), the Greenland Institute of Natural Resources (GINR), the Inuit Circumpolar Council (ICC) Aarhus University, Norwegian Institute for Nature Research, and Iceland's Environment and Food Agency.

We searched the literature for community-based approaches to environmental monitoring (e.g. Huntington 1998, 2000; Johannes *et al.* 2000; Folke 2004; Huntington *et al.* 2004; Moller *et al.* 2004) and then assessed current natural resource management practices at field level in the communities involved. National and local authority government staff, representatives of KNAPK, and locally resident government game officers participated in the assessments.

The assessments helped us to identify the methodological concepts of the system. With this palette of concepts, we held meetings with local communities to select the system and adapt it to the local context, in terms of human and natural resources and institutional set-up. The tools were tested and adapted over a 24-month period so that we could identify the methodological issues that had to be solved in order to acknowledge the needs of both local communities and authorities. These methodological issues related mainly to: (1) avoiding overburdening the participants by keeping data collection and data management simple and (2) identifying suitable approaches for translating the results into local authority decision-making. This time-consuming process also meant that the conclusions were acceptable to a broader range of people and it encouraged ownership of the system both locally and in the government administrative system.

Based on the literature and the field assessments, we drafted a manual. This was discussed with representatives of the community members, local authority staff, and the advisory group, and the manual was revised accordingly. Five visits were subsequently made by government staff and a Danish ecologist to the communities to assist and supervise them in field implementation (27 April–5 May 2010; 28 September–6 October 2010; 29 January–7 February 2011; 18–23 June 2011; and 22 September–1 October 2012).

The system was initially established in three communities in Disko Bugt and Uummannaq Fiord: Akunnaaq, Qaarsut, and Ilulissat/Jakobshavn (figure 1). As the system was being established, a fourth community asked to be involved, Kitsissuarsuit/Hunde Ejland. Whereas Kitsissuarsuit, Akunnaaq, and Qaarsut are small settlements with 79, 101, and 196 inhabitants, respectively, Ilulissat has a population of 4546 and is the third largest town in Greenland (2010 figures; Statistics Greenland 2013).

Theoretical framework for participatory documentation of resources in Greenland

The Government of Greenland wants to establish 'adaptive management' (Berkes *et al*. 2000) by ensuring that relevant decisions and actions are taken for the management of living resources. Decisions can be taken at different levels: local community, local (municipal) government authority, and central government (figure 1). Repeated data collection or 'monitoring' is important in order to identify and understand status and trends and thus improve decision-making on resource management (Spellerberg 2005).

Examples of biological questions that monitoring can answer:

- Are populations of animals increasing or decreasing?
- Are animals arriving later or earlier than 'normal'?

Examples of resource management questions that monitoring can answer:

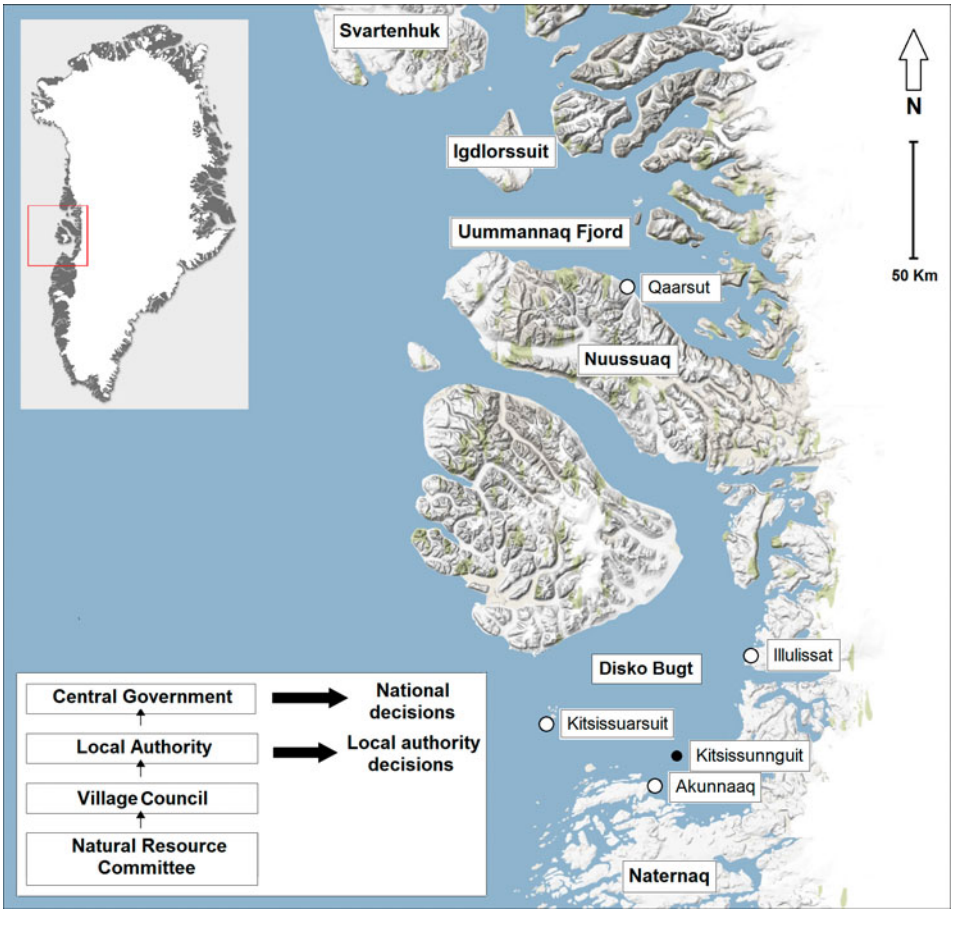

Figure 1. The locations of the areas in Uummannaq Fjord and Disko Bugt, North West Greenland, that are mentioned in the text. Abbreviations: Km, kilometers; N, North. The diagram shows the flow of recommendations (small arrows) between the different institutional levels and the associated decisions on natural resource management (large arrows) that can be taken within the current regulations.

- Is there a need to adjust the management of certain populations or species?
- Are the regulations having the desired effect on stocks?
- Is there a need to investigate some observed changes in more detail?

In other words, monitoring can decide whether management initiatives in the region are effective in addressing human and climate-induced changes in the living resources. When combined with explicit management aims for populations of fish and wildlife, monitoring can help the citizens adapt resource utilization in order to get the most out of the existing resources within sustainable limits.

Existing monitoring activities

In some areas of Greenland, there are local ways in which hunters control access to resources. For example, in accordance with Qaanaaq municipality by-laws, hunting of narwhale is only allowed using traditional hunting methods (Nielsen 2009). Moreover, merely by living in the coastal areas, using the resources and observing their environment, the communities notice changes in the resources. The monitoring system was designed to build upon and strengthen such existing informal community-based observation and management systems.

Aside from this, most monitoring of Greenland's living resources takes place by hunters and fishers reporting their catch to the government and by scientists carrying out monitoring and research-based studies. Since 1993, the government has collected harvest statistics on a national scale (Merkel 2011). These statistics, in principle, include all hunting in Greenland, but also egg collection, gillnet harvest of ringed seals and, since 2002, bycatch of guillemots and eiders.

Available human capacity and financial resources

The availability of human capacity and financial resources has an important bearing on a monitoring system. At the local level, communities in Greenland are usually supported by a service-center that hands out forms and licenses, etc., and one government official for all aspects related to economic development in that community. Typically, this official is responsible for several communities in a wide area. The person frequently has experience of local authority administration or the private sector. Given their workload, they have very little time available to assist in monitoring efforts, and this is not likely to change.

At the central government level, human resources are limited to 10 people responsible for the government's wildlife management, around 10 people for fisheries management, and 9 locally resident government game officers. It is difficult for them to achieve management aims, given the current tasks and priorities. There is, therefore, also limited time for additional tasks related to a community-based monitoring system, e.g. data handling and community feedback.

The GINR has more than 50 employees who conduct research and provide advice to the government on the basis of scientific protocols (GINR 2013). With government and external funding, the institute implements three- or five-year monitoring plans. Local hunters and fishers may assist as paid data collectors following standard scientific protocols.

The financial resources available for monitoring are also limited. GINR monitoring focuses on the stocks of highest socio-economic value and is complemented by

external funding. External funds are particularly needed for those stocks where the harvest is low relative to the cost of surveying, such as polar bear in West and East Greenland and walrus and whales in East Greenland (F. Ugarte *in litt.)*.

Natural resource monitoring has to compete for staff time and funds with other government focus areas such as social welfare, hospitals, and schools. When developing the system, we had to acknowledge these limitations in human capacity and finances.

Approach and methods of the documentation and management system

The objective of the system is to help decision-makers in communities, local authorities, and central government by providing information from the regular collection and interpretation of data on living resources and their utilization. The focus is on *detecting changes* in natural resources and their use as early as possible in order to *guide decision-making* on resource management.

The system's specific objectives are to:

- strengthen documentation of the locals' knowledge of the living resources by utilizing their observational capacity;
- encourage local analysis, interpretation and discussion of changes in the living resources, thereby increasing local capacity and creating an understanding of the need for management interventions;
- make local observations, analysis, and recommendations available to the government;
- enhance the local stakeholders' influence over government decisions on fishing and hunting;
- provide a forum for data-based dialog between local stakeholders and the government.

Who can monitor resources?

Monitoring of the living resources is carried out by natural resource committees (NRCs) in each community. The NRCs consist of 5–12 people who are interested in helping to manage the living resources. They typically come from those families in the community who are significant users of the resources, often including the most experienced fishers and hunters. The participants are often also involved in voluntary work in the local branches of fisher and hunter organizations.

The NRCs are established at village meetings where interested individuals have the opportunity to join the committee. It is the government's intention that the NRC members should represent different age groups and include middle-aged, young, and old. The NRC elects a coordinator who reports to the Village Council. When NRC members are in the field, they gather data on the living resources and their use. These data are summarized, discussed and analyzed at committee meetings, and possible management initiatives are considered (guidelines for facilitating NRC meetings are found in Annex S2).

What are the responsibilities of the NRCs?

At the NRC meetings, the members are responsible for:

- proposing monitoring targets, i.e. selecting living resources and resource uses that the NRC has an interest in and an ability to observe, and proposing to the government that it should keep track of them;
- the NRC members agree on the names and boundaries of each of the sites where they will monitor the selected species and resource uses;
- providing management recommendations and advice to the Village Council and the local authority on the basis of their observations;
- organizing separate census activities for, e.g., caribou, musk ox, fish, and birds, as needed.

How are data collected and used?

The two methods used for data collection are: (1) patrol records kept by community members and (2) community focus group discussions on the status of the natural resources and resource use (Danielsen *et al*. 2014). Patrol records entail filling out sheets on a standard calendar (analog, with one page per day) with the community members' own observations and records of key species and resource uses immediately after hunting, fishing and other trips to the field (Danielsen *et al*. 2005). Survey effort is localized and varies between trips, and different habitats are sampled unrepresentatively. Measures built into the system to reduce potential biases are described in Annex S3.

The data collected by NRC members are interpreted at their meetings. The proposed management decisions, with supporting data, are used by the community, the local government authority, and the central government when taking decisions about the management of living resources (figure 1). Some of the information will make the Village Council, local authorities, and government aware of perceived local management needs and conditions that need further exploration by the government, e.g. significant changes in species distribution and abundance.

What are the steps to establishing and implementing the system?

There are five steps to establishing and implementing the system in each community:

Step 1. Identifying a natural resource committee

The Village Council in each community chooses the members of an NRC on the advice of local fishers' and hunters' organizations, the local authority staff, and local game officers.

Step 2. Making observations

After each trip to the field, the NRC members enter data on observations and catches on a personal calendar, specifying the resource or taxon, the quantity, time, and place. For example, Karl Tobiassen wrote in his calender: *21 February 2011, Narwhale, 45 individuals in Uummannaq Fjord off Igdlorssuit*. These hand-written observations constitute the most disaggregated data in the system.

Step 3. Interpreting the data at the local level

Once every three months, the NRC meets in the community. At this meeting, data and knowledge from the community's monitoring of natural resources are summarized by each member, and then discussed, and interpreted. Suggestions for management initiatives are also considered. The local interpretation is prompted by the filling-in of a summary form which, at the end of the meeting, is signed by the participants. Both data on dead and observations of live animals are accompanied by data on effort. The summary form has the following headings:

- Resource (e.g. Greenland halibut)
- Month and year (e.g. September 2010)
- Area (e.g. sea off Qaarsut, Uummannaq Fjord)
- Number of fishing or hunting days (e.g. six days)
- Fishing or hunting gear (e.g. dinghy, long-line)
- Fishing or hunting effort and catch (e.g. 600 hooks used on six fishing days; 3600 kg)
- Trend in relation to same time last year (e.g. increase)
- Importance of the finding (e.g. very important)
- Possible explanation (e.g. possible population increase) and
- Proposed action (e.g. none for the time being)

The filling-in of this summary form is a fundamental element of the system as it encourages self-evaluation of local observations and knowledge and, at the same time, promotes local discussion of trends, their possible reasons, and relevant actions.

Step 4. Proposing management initiatives

The proposals for management initiatives are presented at meetings of the Village Council and the local government authority. They consider whether there is a need for more knowledge or whether initiatives can be taken locally on the basis of the NRC results. The Village Council and local government authority are encouraged to take decisions about *what* should be done, by *whom* and *when*.

Step 5. Discussing the results at a community meeting

Once in a year, the NRC organizes a meeting with all people in the community with an interest in the environment. At this meeting, the results of the community's monitoring of resources and resource uses are presented. Proposed management actions are discussed and evaluated. During this meeting, others in the community have an opportunity to learn about the NRC's findings in their area. At the same time, the meetings allow for feedback from other community members, which can result in broad support for management actions.

How are the data handled?

In each community, the person responsible for stewardship of the data in the system is the local NRC coordinator. The system generates two kinds of data: (1) observations of resources and resource uses made by community members and (2) summary forms with a description of the proposed management decisions and the supporting data and analysis prepared by the NRC. Both types of data are

Table 1. Decisions that can be taken at the local (municipal) authority level within the current regulations in order to manage fish, seals, cetaceans, ungulates and birds in Greenland (Greenland Government 1996, 1999; Ministry of Fisheries, Hunting and Agriculture 2011).

Potential local authority decision	Fish	Seals*	Cetaceans	Ungulates†	Birds
Local time closure‡	■	■		■	■
Local area closure	■	■			■
Local restriction for specific methods and gear‡	■	■			■
Local adjustment of fishing operation	■				
Propose change to national quotas, seasons and bag limits	■		■	■	■
Make quotas sex- or age-specific				■	
Sub-divide quotas for specific sites				■	
Divide the quotas and bag-limits between part- and fulltime-hunters				■	■

Note: See Annex S4 for examples.
*Ringed seal, harp seal, hooded seal, bearded seal, †Caribou, musk ox, ‡within the government's overall framework in terms of fishing/hunting seasons, and permitted methods, boats and gear.

filed in ring-binders and stored in the municipal office in each community. The ring-binders of data constitute the system's main database. The data belong to the NRCs but the local authority and the central government can obtain copies.

Which decisions can be taken at the local level?

From the government's perspective, the starting point for this system was that it should encourage data-based decision-making on natural resources on the part of the local authority and the communities. However, early on it became clear that there was little knowledge available as to what local decisions could be taken without breaking the law (Haaland *et al.* 2005). We therefore assessed the current regulatory framework in order to identify potential decisions that local authorities could take for natural resource management.

We found that, for fish, seals, cetaceans, musk ox, caribou, and birds, the local government authority could take only a few decisions independently of the central government, namely:

1. Reducing the time or area and adjusting the methods and gear used to fish and hunt and
2. Sub-dividing the nationally set quotas and bag limits into smaller units specific to, e.g., the sex and age of animals, the hunting area, the hunting community, or the individual hunters' registration as either a full- or a part-time hunter (Table 1; examples in Annex S4).

Results from the first three years

What did the community members find?

In the first three years (2009–2011), a total of 33 fishermen, hunters, and environmentally interested people enrolled in the monitoring system. Most participants were men (94%). Eight community members contributed written

Table 2. Comparison of community members' perceptions and professional scientists' assessments of trends in abundance of sea-ice, two human activities and 21 populations of fish, mammals and birds in Disko Bugt, Uummannaq Fjord, and adjacent areas of North West Greenland 2009–2011.

Attributes	Perceptions*	Scientists' assessments	Source of scientists' assessments†	Correspondence
Fish				
Atlantic cod, D	‡	Few data	Siegstad 2011	NA
Wolffish *spp.*, D	↑	↑/⇔	Siegstad 2012	(✓)
Greenland halibut	↑	↓/⇔	Siegstad 2011, 2012	⊘
Marine mammals				
Ringed seal	↓	Few data	Boertmann 2007; Rosing-Asvid 2010	NA
Harp seal, D	↑	↑	Department of Fisheries and Oceans 2010; Rosing-Asvid 2010	✓
Narwhale	‡	Few data	North Atlantic Marine Mammal Commission 2012	NA
Humpback whale	↑	↑	Heide-Jørgensen *et al.* 2011	(✓)
Minke whale, D	↑	↑	Heide-Jørgensen *et al.* 2010	(✓)
Minke whale, U	⇔	Few data	No information	NA
Land mammals				
Arctic fox, D	↑	Few data	Boertmann 2007	NA
Caribou, N	⇔	⇔	Cuyler *et al.* 2005; Cuyler and Nymand 2011	✓
Musk ox, L	‡	Few data	No information	NA
Birds				
Snow goose, D	↑	↑	Boertman 2007	✓
Greenland white-fronted goose, U	↓	↓	Boertmann 2007; Boyd and Fox 2008	✓
Canada goose	↑	↑	Bennike 1990; Fox *et al.* 1996; Boertman 2007	✓
Common eider	↑	↑	Chaulk *et al.* 2005; Merkel 2010	(✓)
White-tailed eagle, D	↑	Few data	No information	NA
Large gulls**, D	↑	Few data	Boertmann 2007	NA
Arctic tern, D	↑	⇔	Boertmann 2007; Egevang and Frederiksen 2011	⊘
Brünnich's guillemot, breeding	↓	↓	Burnham *et al.* 2005; Labansen and Merkel 2012	✓
Little auk, D	↑	Few data	Egevang and Boertmann 2001; Boertmann 2007	NA

Table 2. Continued.

Attributes	Perceptions*	Scientists' assessments	Source of scientists' assessments†	Correspondence
Other				
Winter sea-ice††, U	↓	↓	Danish Meteorological Institute	✓
Offshore ships, U	↑	↑	Arctic Marine Shipping Assessment 2009	(✓)
Trawling, D	↑	Few data	No information	NA

Note: ↑, increased abundance; ↓, declining abundance; ⇔, no major change in the abundance; ‡, increased abundance reported in some areas, decline in other areas; Few data, there are little or no abundance data available; ✓, correspondence between community members' and scientists' assessments; (✓), probable correspondence between community members' and scientists' assessments but the time, area and/or temporal/spatial scale of the assessments do not match; ⊘, no correspondence. D, Disko Bugt; L, Naternaq/Lersletten and Svartenhuk; N, Nassuttooq/Nordre Strømfjord; NA, not applicable; U, Uummannaq Fjord.
*The community members' findings are presented in Annex S5.
†The scientists' assessments are summarized in Annex S7. ** Great black-backed, Iceland, and glaucous gull. †† 2010. See supporting information for literature cited.

observations from their fishing and hunting trips, whereas the other contributed their observations verbally during the NRC meetings. The community members summarized their observations and knowledge of trends in abundance for 24 attributes, including sea-ice, trawling, shipping and three fish, nine mammal, and nine bird populations. The community members' findings are presented in Annex S5 and summarized in Table 2. The filled-in summary forms from the NRC meetings are provided in Annex S6 for the purpose of replicating and building on this work. For most of the attributes, the community members reported positive trends in abundance in Disko Bugt, Uummannaq Fjord, and adjacent areas (63%; $n = 24$).

For three species, the NRCs provided information on body conditions: harp seal, minke whale, and caribou. Harp seals in Disko Bugt were reported to be frequently 'thin' and in 'poor' body condition. Minke whales in the same area were 'generally smaller in size than before,' and caribou in Nassuttooq in 2011 were described as in 'poor' condition (Annex S5).

The NRCs reported the community members' perceptions of ecological dynamics and relationships related to 13 taxa of fish, mammals, and birds. Their reports included five distinct types of dynamics and relationships: (1) threats to wildlife populations; (2) species competing with each other (Greenland white-fronted goose, Canada goose); (3) species of nuisance to dinghy traffic and fishing (multiple); (4) food choice of wildlife species (Greenland shark); and (5) 'natural phenomena' such as terns abandoning their eggs simultaneously across wide areas. The community members described the following threats to wildlife populations: sea-floor degradation from shrimp trawling in shallow areas (wolffish), noise from shipping traffic (narwhale), disturbance from tourists (caribou), and by-catch in gill nets (guillemots) (Table 3).

The ultimate objective of the system is to guide and improve decision-making on natural resource management. In order to assess the performance of the system, we therefore kept track of management proposals resulting from it. A total of 14 distinct recommendations were made for 12 resources (Annex S5). The proposals

Table 3. Comparison of community members' perceptions of ecological dynamics and relationships in North West Greenland 2009–2011, with information from the peer-reviewed literature.

Species	Community members' perceptions	Scientists' information*	Correspondence
Striped/ spotted wolffish	'Wolffish are vulnerable to sea floor degradation'	Freese *et al.* 1999; Lachance *et al.* 2010	✓
Greenland shark	'Greenland shark is attracted to rotten fish'	Leclerc *et al.* 2011	✓
Narwhale	'Narwhale is disturbed by shipping traffic'	Nowacek *et al.* 2007	✓
Humpback whale	'Humpback whales pose a threat to dinghy traffic'	Laist *et al.* 2001; Parsons 2012	✓
Caribou	'Caribous are disturbed by hiking tourists'	Reimers *et al.* 2006	✓
Geese	'Greenland white-fronted and Canada goose are competing with each other'	Boyd and Fox 2008	✓
Arctic tern	'Some years, thousands of terns abandon their eggs'	Monaghan *et al.* 1989; Erikstad *et al.* 1998; Egevang and Frederiksen 2011	✓
Guillemot	'Historically, the decline in breeding Brünnich's guillemot in West Greenland was caused by by-catch in nets'	Tull *et al.* 1972†	(✓)
Multiple	Harp seal, narwhale, humpback whale, and great black-backed, Iceland, and glaucous gull constitute a competition or nuisance to the fishing of Atlantic cod and Greenland halibut (Disko Bugt)	Perkins *et al.* 1982; Finley *et al.* 1990; Lawson *et al.* 1995; Johnson *et al.* 2005; Laidre and Heide-Jørgensen 2005; Witteveen *et al.* 2006; Neilson *et al.* 2009	(✓)

Note: ✓, potential correspondence between community members' perceptions and biologists' assessments; (✓), partial correspondence between community members' perceptions and biologists' assessments.
*See Annex S8 for a summary of the scientific literature; †Other scholars have attributed this decline to (still continuing) summer hunting and disturbance at the breeding colonies (Falk and Kampp 1997; Labansen *et al.* 2013). See supporting information for literature cited.

relate to the setting of quotas for harvesting resources (2 proposals), the changing of hunting seasons (5), the need for research into particular topics (3), the regulation of fisheries through the establishment of municipal bylaws (2), and other types of actions (2). As of June 2013, the local municipal authority had reviewed and made decisions regarding 11 of these 14 proposals.

Correspondence between community members' and professional scientists' assessments

Are the local reports biased by 'conflicts of interest' when harvesters are themselves monitoring the resource? To explore this question, we compared the local reports on abundance, body conditions and ecological dynamics, with data produced by

scientists who do not have a direct harvest interest. We obtained such data from peer-reviewed literature, technical reports, and advisory information prepared by scientists for the Greenland Government. If the local reports are biased by harvest interests, we would expect the locals' findings to differ substantially from scientists' findings.

First, we compared locals' and scientists' reports of trends in the abundance of the 24 attributes that were summarized by the community members in the NRCs from 2009 to 2011 (Table 2; Annex S7). Unfortunately, we could only find scientist-executed studies from the same areas and at the same time for four attributes (17%; $n = 24$). Nevertheless, scientists' data from adjacent areas can provide a preliminary indication of the degree of correspondence between the locals' and professional scientists' reports. We found that, despite considerable differences in the way their knowledge is obtained, the community members and the professional scientists produced similar results for 12 attributes: spotted wolffish, harp seal, humpback whale, minke whale, caribou, snow goose, Greenland white-fronted goose, Canada goose, common eider, breeding Brünnich's guillemot, winter sea-ice, and shipping. We found that, for two populations, nearshore Greenland halibut and breeding Arctic tern, there was disagreement between local and scientists' reports of trends in abundance. For 10 attributes, we were unable to find data from professional scientific surveys to allow for a comparison with the community members' findings.

Second, for body conditions, community members provided information on harp seal, minke whale, and caribou (Annex S5). We were unable to locate reports by professional scientists on harp seal and minke whale but we found information on caribou from the same year and area (Cuyler and Nymand 2011), and these results matched the community members' findings. For ecological dynamics and relationships, we found that none of the 13 relationships reported by the community members were directly dismissed by the peer-reviewed scientific literature (Table 3; Annex S8).

Discussion

We have described the theoretical framework and methods used in the local documentation and management system in North West Greenland, and we have presented the results from the first three years of monitoring. Our analysis shows that the system has engaged community members in discussions of their observations and knowledge of the natural resources. Fishers, hunters, and other environmentally interested people in the rural communities are using their own observations and knowledge to keep track of environmental changes and are participating meaningfully in decision-making processes around natural resource management. Moreover, the local authority is taking actions on the basis of the community members' proposals.

The prescribed methods have not, however, been fully complied with. First, only a minority (24%) of the NRC members wrote down their observations. Most hunters and fishers preferred to present their observations verbally at the meetings of the NRCs. Second, when there were long periods with no fishing and hunting, there were no meetings among the NRC members so the intended schedule of quarterly meetings was not fulfilled. Third, although it was the intention that the NRC members should be chosen by the Village Council in each community, in

practice it was those community members who were interested that were enrolled in the system. Fourth, the local NRC coordinators did not always give a copy of the summary forms with the list of possible management initiatives to the Village Council for endorsement before submitting the forms to the municipality and the central government. A continued dialogue is needed between the central government, the local authority, and the NRCs.

Despite strong efforts to be objective in our comparison of community members' and professional scientists' reports, some areas remained subjective. First, the local reports may be based not only on local observations and local knowledge but may also have been influenced by publicity surrounding scientific findings that have become accepted knowledge in a local community (Huntington *et al.* 2004). Second, our approach was retrospective and opportunistic, and insufficient match between the area, time, and geographical and temporal scale of the local and scientists' reports may have affected the comparisons. Third, our main comparisons were between community members' perceptions and professional scientists' methods, which mainly included fish-biomass assessments, aerial surveys, remote-sensing, and breeding bird censuses (Annex S7). These methods are also recognized to have weaknesses in terms of capturing 'true' trends in the abundance of resources (e.g. Caughley 1974). Nevertheless, our results provide preliminary support for the idea that community-based monitoring in the Arctic can yield locally relevant results that can be as reliable as those derived from professional scientist-executed monitoring.

Many of the NRC recommendations involve increasing the harvest of other species because these are perceived to constitute threatening competition or a nuisance to Atlantic cod and Greenland halibut gillnet and long-line fisheries (harp seal, narwhale, humpback whale, and great black-backed, Iceland, and glaucous gull). The management decisions proposed by the locals for these species were: support marketing opportunities for whole seals, permit catch of solitary narwhales during summer outside of the quota system, increase the quota for humpback whale, and expand the egg collection season for colonies of large white gulls only (Annex S5). Whether these proposed decisions will have the intended effect on the cod and halibut fishery – and whether the severity of the competition justifies the proposed actions – is beyond the scope of this paper.

Our findings on the consistency of local reports relative to biological assessments concur with previous studies of common eider, harlequin duck, and ivory gull in the Arctic (Gilchrist *et al.* 2005). Gilchrist *et al.* (2005) also compared locals' and scientists' reports of the breeding population of Brünnich's guillemot in Greenland. Hunters and scientists agreed that the breeding numbers in Upernavik Region had declined but disagreed over the cause of the decline. Most hunters attributed it to the fact that the colonies had moved, whereas the scientists, based on aerial and boat surveys of the entire West coast of Greenland, concluded that no new colonies had been initiated and that there had been an overall decline in the breeding population (Gilchrist *et al.* 2005). It is therefore important that monitoring at the local scale is backed up by monitoring by scientists or community members at a larger scale so as to be able to determine whether locally detected changes reflect broader changes in abundance or in the range of the resources.

Incentives for the participants

Why is there interest from rural fishers and hunters in participating in the monitoring system? Initially, a workshop was held to discuss the monitoring plans with the local authorities and with representatives of the communities in Disko Bugt and Uummannaq Fjord. It was made clear that the community monitoring was intended to serve as an *opportunity* provided by the government for use only by those communities and fishers and hunters who were interested. Direct payment of participants, which is frequent in other government and externally funded initiatives in the country, would be impossible for the government to sustain.

Most people at the workshop decided that they would still like to enroll in the system. We believe there are several reasons as to why community members would be keen on participating as volunteers in the system. First, they are keen on participating because of their interest. Fishing and hunting are a central part of the life and identity of the communities (Dahl 2000; Nuttall 2005). For some of the participants, fishing and hunting constitute their mainstay. For others, they provide additional incomes, while their principal income comes from a paid job. The status and abundance of the wildlife populations and the use of the living resources are topics of the utmost importance, even to those who are not fishers and hunters. The monitoring system was designed to build on what people are interested in. For instance, the monitoring targets are not selected by scientists or by the government. Each NRC decides among its members – on the basis of their interests and with advice from government facilitators – which species and resource uses they will keep track of. While one might think that this would lead to a wide array of different monitoring targets, which would complicate analysis, the four NRCs all selected the same species and resource uses to record. From other countries, it is also known that the improved status from being part of a community committee can be an important incentive for some community members (Topp-Jørgensen *et al.* 2005).

Second, participating in the community monitoring provides an opportunity for the community members' insights and knowledge to be used and their voices heard (Funder *et al.* 2013). In Greenland, as in other parts of the Arctic, discrepancies between the authorities' perceptions of the status of the environment and the local peoples' knowledge and perceptions have, in some areas, led to frustration among community members and to limited local understanding and acceptance of government decisions (Sejersen 2003). The government would therefore like to increase the involvement of the 'users' in the government's decision-making. Occasional phone calls from fishers and hunters telling government staff about observations of huge numbers of wildlife are impossible to use in government decisions. In contrast, direct-count data, compiled by the same people at the same sites over an extended time frame, especially when written down and supported by local interpretation and analysis, can provide very useful information for the government (e.g. Merkel 2010), especially where conventional scientific monitoring programs are providing infrequent or no information.

Third, it is easy to participate. There is little extra work associated with the community monitoring routines for the participants. The work can easily be integrated into the existing day-to-day activities of most community members. The routines only require that the community members note their observations on a calendar, and that they regularly interpret their observations and discuss possible management decisions with the other participants in the community. The monitoring routines also do not require the use of special equipment. The only equipment

Table 4. Tenets for an indigenist paradigm for research programs, formulated by Pulsifer *et al.* 2011 (adapted from Barnhardt and Kawagley 2001; Wilson 2007, 2008).

1.	Respect, reciprocity and responsibility of the researchers.
2.	Research designed and executed in partnership with, if not led by, indigenous communities.
3.	Research leads to a better understanding of, and provision for, indigenous people.
4.	Ontology and epistemology focus on relationships between things or 'relationality' (e.g. ourselves, others, environment, spirit, ideas) rather than the things themselves.
5.	Researchers remain accountable for the relationships and transformations that they initiate.
6.	Recognition of indigenous languages and cultures as living processes.
7.	Rejection of the notion of the objective observer; knowledge is produced in a cultural and political context.
8.	The emergence of knowledge through a synthesis of experience, observation and experimentation.
9.	Cooperative rather than oppositional knowledge production processes.
10.	Use of metaphors and symbolism.
11.	Articulating what the indigenist research paradigm is rather than comparing with other knowledge production systems; and understanding the context of data production.

needed is pencils, a standard calendar, and, if available, a pair of binoculars and a mobile phone with camera (for documentation purposes).

Is the system culturally appropriate?

To explore whether the system is culturally appropriate, we examined its relationship to an indigenist paradigm for research programs presented in Table 4. The methods of the system form part of a management approach that builds on the existing local and indigenous institutions and participants in North West Greenland. The system is designed precisely to enable natural resource management decisions at appropriate levels of government to respond to community-identified issues. The local authorities' actions, based on the NRCs' proposals, promote respect for the observations and knowledge of the NRCs and reciprocity between different actors (point 1, Table 4) and, at the same time, increase the ability of the community members to propose management decisions that are realistic and well-supported by their field observations and knowledge. Local indigenous community members in the NRCs are taking a lead in the system (point 2). However, both the Village Council and the local and central government have the option of rejecting the NRC proposals. This is, however, no different from other relationships in society; one can propose and argue for a government intervention but whether it will be followed depends on what the democratically elected government decides, on the basis of technical input from its staff. The system leads to better provision for indigenous and other local communities by encouraging a more inclusive management of natural resources (point 3). The local observations provide insights into ecological relationships (point 4). Central government and local authority staff involved in the system provide regular feedback to the communities on their proposed management decisions, and whether they have been acted upon or not, and why (point 5). The system uses indigenous language and emphasizes oral culture (point 6), particularly during the discussions in the NRCs, when data interpretation is undertaken. The system attempts to make it explicit as to who made a specific observation (point 7). The local knowledge is not merely reduced to 'anecdotal information' as has often

been the case in natural science research papers in the past but is given credit as a source of independent environmental information. The system thereby helps to recognize the cultural, economic, and political context of data production. The system builds on knowledge generated both by experience and direct observations but not on experimentation (point 8). The NRC discussions and annual community meetings of the system encourage open dialog. These discussions and meetings are highly cooperative and help enable the incorporation of observation data and different perspectives into the knowledge production processes (point 9). The NRC discussions use the local context, including culturally rooted understanding of species, areas, and practices (point 10). The interpretation of data in the system is undertaken via an inclusive and open process (point 11). Some species are, however, subject to detailed international management regimes that the government has to comply with. The management proposals emanating from the system are therefore subject to scrutiny by either the local government authority or the central government before they can be acted upon. In conclusion, the system includes most of the aspects that are believed to make initiatives culturally appropriate.

Desirable further developments

In the long run, communities are only likely to continue monitoring if their efforts continue to be acknowledged, accepted and included in the decision-making processes at local and central levels. If the government wants to provide greater opportunities for NRCs and the local authorities to take decisions on the management of natural resources, some form of dispensation will be necessary from the government. To help this process, we provide examples of possible dispensations for Greenland halibut, caribou, musk ox, and Arctic tern (Annex S4).

In the pilot communities, the management proposals that follow the monitoring activities have mainly been reactions to immediate threats or locally observed trends in the natural resources rather than to trends revealed by analyses of large data-sets across several areas. At present, the NRCs do make numerical, quantitative analyses, and comparisons across multiple years based on observations and local knowledge from their fishing and hunting areas. However, even with more capacity development and training, it is unlikely that the NRCs will ever undertake comparisons across many geographical areas on a municipal or national scale, using very large data-sets.

At the national level, however, there is considerable scope for collecting the local observations and using them to track wider trends in the abundance of resources while at the same time increasing local people's input into higher-level decision-making (Danielsen *et al.* 2013). Data from local monitoring could potentially be aggregated to generate larger-scale overviews of, for instance, species range and phenology, habitat condition, opportunities and threats, impacts of management interventions, and delivery of benefits such as wildlife resources to the local communities from the natural ecosystems.

For some species and populations (e.g. coastal populations of Atlantic cod, arctic fox, some populations of caribou and musk ox, snow goose, Canada goose, and white-tailed eagle), community-based monitoring is perhaps the only source of information, and hunters cover surprisingly large areas with outboard engines on their dinghies (Due and Ingerslev 2000).

Professional biologists' research will, however, remain very much needed, for instance, in determining safe thresholds for harvesting wildlife populations and

providing other quantitative information on the abundance of resources where management requires 'exact' knowledge of population numbers. This holds true especially for Greenland white-fronted goose and breeding Brünnich's guillemot, which are both rapidly declining in numbers in this part of Greenland (Boertmann 2007; Labansen and Merkel 2012; and local knowledge in this study; Annex S5–S6) as well as for polar bear, walrus, and cetaceans, which are included in international management regimes where the boards rely on scientific methods (Polar Bear Specialist Group, North Atlantic Marine Mammal Commission, International Whaling Commission). Community-based monitoring has the potential to provide a second-informed opinion on some of those species. It likewise has potential to contribute important knowledge about trends in abundance during periods when GINR is not monitoring.

A future national monitoring strategy in Greenland should therefore combine several monitoring methods, including conventional scientific methods and community-based monitoring approaches such as the present system. If the current local system were to be transformed into a national system for using local observations and knowledge to improve resource management in Greenland, it would require the establishment of strong linkages between the local and the national data management systems. It would also require expanding the local monitoring to more communities, geographically spread across Greenland.

Experience from abroad suggests that the scope for linking local and national natural resource monitoring may best be explained by thinking about contributions and relative benefits (Pratihast and Herold 2011). If there are not benefits for both sides, the local–national linkages are unlikely to be sustained. On the other hand, if both sides contribute and benefit, a situation can be created that can help to stimulate and sustain collaboration. In figure 2, we conceptualize how communities can be linked to national monitoring in Greenland in a mutually beneficial way. If

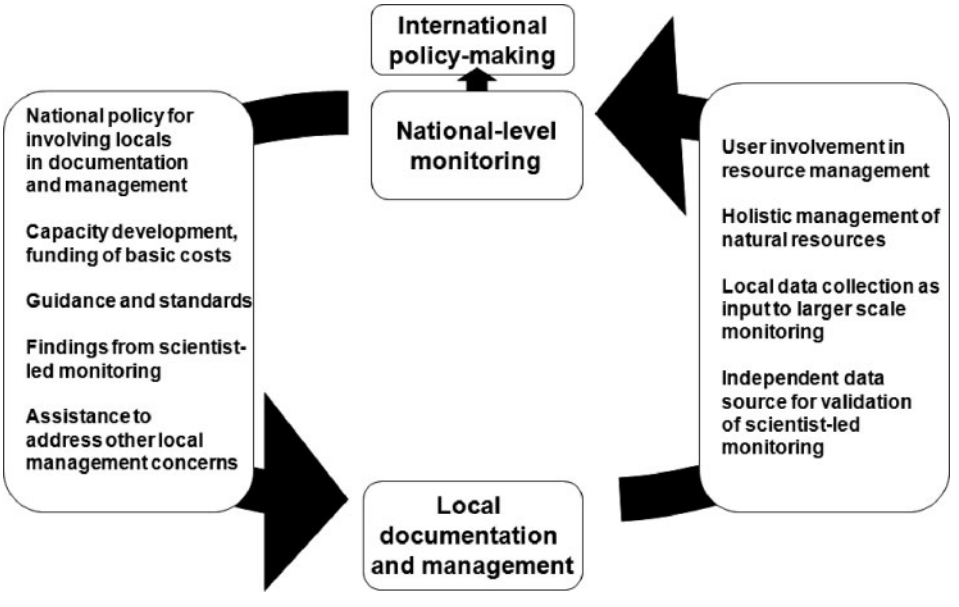

Figure 2. Contributions to and benefits of local documentation and management for national-level monitoring of natural resources in Greenland.

the current local system were to be transformed into a networked, national system, the central government would need to provide a policy that sets aside government staff time and funds, develop minimum requirements for local monitoring, and establish a data infrastructure system so that locally acquired data, similar to professional scientists' data, can be uploaded, and made publicly available subject to the approval of the data-providing community members. In return, local monitoring could encourage community engagement in decision-making and holistic approaches to resource management, and contribute data to national policy-making (Sutherland *et al.* 2013). Such efforts would, however, add costs to a system that is currently paper-based and low-tech, and the only cost of which is the limited time of administrators at municipal and central government level.

Conclusions

In the social science literature, there is growing support for the idea that, when citizens are engaged in collecting, analysing, and sharing data on the environment, they will build their own capacity to adaptively manage local environmental resources (discussion in Tidball and Krasny 2012). Whereas community-based documentation cannot replace scientists' monitoring of Greenland's natural resources, our experience suggests there is great potential for combining the two approaches. Both have roles to play and partnerships could only be beneficial (Huntington *et al.* 2004). If properly coordinated, local monitoring can provide information on those species and populations that matter most to fishermen, hunters, and environmentally interested community members. The resulting dialog between local communities and authorities can facilitate a better differentiation of fishing and hunting periods and quotas geographically and help adjust the resource management to the changing environmental conditions. The dialog can also lead to a common understanding of local natural resource use and an increased ownership and acceptance of regulatory actions, whether implemented by the local or the national level.

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Supplemental data

Supplemental data for this article can be accessed here.

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