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Community-Based Conservation and Traditional Ecological Knowledge: Implications for Social-Ecological Resilience

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ABSTRACT. Our review highlights how traditional ecological knowledge influences people's adaptive capacity to social-ecological change and identifies a set of mechanisms that contribute to such capacity in the context of community-based biodiversity conservation initiatives. Twenty-three publications, including twenty-nine case studies, were reviewed with the aim of investigating how local knowledge, community-based conservation, and resilience interrelate in social-ecological systems. We highlight that such relationships have not been systematically addressed in regions where a great number of community conservation initiatives are found; and we identify a set of factors that foster people's adaptive capacity to social-ecological change and a number of social processes that, in contrast, undermine such capacity and the overall resilience of the social-ecological system. We suggest that there is a need to further investigate how climate variability and other events affect the joint evolution of conservation outcomes and traditional ecological knowledge, and there is a need to expand the current focus on social factors to explain changes in traditional ecological knowledge and adaptive capacity towards a broader approach that pays attention to ecosystem dynamics and environmental change.

Key Words: *adaptive capacity; biodiversity conservation; community-based conservation; ecosystem services; local ecological knowledge; natural resource management; social-ecological change; social-ecological resilience; traditional ecological knowledge*

INTRODUCTION

Researchers argue that the resilience of social-ecological systems is desirable for facilitating the sustainability of natural resources and ecosystem services and to ensure a stable environment for human life and well-being (Adger 2006, 2007). Ecological resilience is associated with ecosystem diversity and the stability of the ecosystems' functions and survival of keystone species. But the resilience of social-ecological systems is also influenced by social factors, such as people's ability to anticipate changes and plan for the future (i.e., adaptive capacity), which is in turn shaped by human agency, institutional rules, and the level of exposure to and the impacts of global change on people's lives (Adger 2007, Nelson et al. 2007). Ecological and social resilience are thus dynamically interconnected through evolving forms of natural resource management and the subsequent response of biophysical systems.

In rural contexts, communities have often defined the spaces and the uses of natural resources according to their historical experience with disturbance and ecological surprise (Gadgil et al. 1993, Berkes et al. 2000, Colding et al. 2003, Folke et al. 2003, Toledo et al. 2003, Tompkins and Adger 2004, Berkes 2007). Local responses to socioeconomic and environmental change are mediated by formal and informal institutions, access to power and/or decision making over land and natural resources, as well as by existing ecological knowledge (Holt-Gimenez 2002, Adger et al. 2005, Eakin 2005, Lebel et al.

2006, Janssen et al. 2007, Naess 2012). In particular, traditional ecological knowledge lies behind the adaptive capacity of many rural and indigenous communities that have historically been able to conserve biodiversity while enhancing livelihoods and adapting to perturbations. Although some researchers use local ecological knowledge instead of traditional ecological knowledge because the term "traditional" is often associated with the concept of "indigenous", Olsson and Folke (2001) argue that local ecological knowledge differs from traditional ecological knowledge because the first might be a mix of scientific and practical knowledge whereas the second is not scientific. To avoid misunderstandings, in this review we adopt the widespread used term traditional ecological knowledge to refer to people's cumulative body of nonscientific knowledge, beliefs, and practice about local ecosystems and their management that evolves through social learning and adaptive processes, and which is supported by customary institutions and handed down through generations by cultural transmission (Ostrom 1990, Berkes 1993, Berkes et al. 2000).

In fact, several studies illustrate how this knowledge can contribute to deal with global change and to guide decision making regarding natural resource management and biodiversity conservation practices (Agarwal 2001, Colding et al. 2003, Mishra et al. 2003, Berkes 2007, Grant and Berkes 2007, Rai 2007). Such practices can include monitoring, temporal or total protection of species or habitats, multiple

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species management, resource rotation, succession management, and the social mechanisms behind them such as cross-scale institutions, taboos and regulations, rituals or ceremonies, and social and religious sanctions, among others (Berkes et al. 2000). In south and southeast Asia, for example, Colding et al. (2003) found that coastal communities holding inherited local knowledge of tsunamis were better in responding to such events and recovered quicker than other communities. In some instances, however, traditional ecological knowledge can undermine social-ecological systems resilience when, for instance, local people use their knowledge about wildlife to hunt or harvest indiscriminately for satisfying commercial demand (Gadgil et al. 2000, Fabricius et al. 2007).

At present, global environmental change is unfolding at an unprecedented speed, with current patterns of production and consumption, and the ensuing climate change, being the key causes and drivers (Wilk 2002, Pachauri and Reisinger 2007, Perry et al. 2010). Sociopolitical and economic processes operating at different spatial scales, such as increased logging pressure, agribusiness expansion, and land grabs, impact upon the ability of rural communities to access and sustainably manage formally owned and informally used resources (Dauvergne and Neville 2010, Yurdi and Heiner 2010, Cotula 2012, Scheidel and Sorman 2012). In many regions of the world, climate change is also contributing to transform ecosystems and species niches through altered rainfall and temperature patterns, thus having effects on the conditions for community-based conservation (McClanahan et al. 2008, Groves et al. 2012).

We understand community-based conservation to be any voluntary initiative of “natural resources or biodiversity protection conducted by, for, and with the local community” (Western and Wright 1994, p. 7). Community-based conservation aims “to enhance wildlife/biodiversity conservation and to provide incentives, normally economic, for local people” (Campbell and Vainio-Mattila 2003, p. 421). Community-based conservation can thus encompass a myriad of initiatives with different aims, governance systems, and levels of local decision-making power, ranging from *self-regulated* to *comanaged* conservation strategies (Dudley 2008). In self-regulated initiatives (i.e., community-managed forests, sacred forests, agropastoral systems, and small-scale fisheries), management authority and responsibility rest with rural communities and/or indigenous peoples (Dudley 2008) whose informal rules and social bonds can facilitate institutional flexibility to deal with rapid change (Folke et al. 2005). In comanaged initiatives (i.e., comanagement of protected areas), international and national agencies with the support of nongovernmental organizations (NGOs) promote community-based conservation by involving local people in decision making around natural resource management. These initiatives are sometimes developed to respond to the failure of top-down conservation models (Berkes 2004, 2007) or as

a strategy to reinforce conservation initiatives led by self-governing communities (Armitage 2005). In both contexts, complex institutional mechanisms are designed to allocate management authority and responsibility among a plurality of actors (Dudley 2008), which can in turn draw upon both traditional ecological knowledge and scientific knowledge to define specific conservation strategies (Aswani et al. 2007, Mehring et al. 2011).

The interconnectedness between traditional ecological knowledge, adaptive capacity, and resilience in community-based conservation initiatives is not yet well understood and it has not been systematically analyzed to date. Examining how traditional ecological knowledge shapes people's adaptive capacity patterns in community-based conservation initiatives regulated by different types of governance systems (i.e., self-regulated and comanaged) is critical to provide a nuanced understanding of the potential of and the limitations of traditional ecological knowledge in enhancing or limiting the ability of communities to deal with multiple stressors and sources of change. Through a review of scholarly literature that has simultaneously treated traditional ecological knowledge, adaptive capacity, and/or resilience in community-based conservation contexts, we discuss the interconnectedness between these three elements. We hypothesize that traditional ecological knowledge is conducive to favorable conservation outcomes and that it plays a more fundamental role in shaping people's adaptive capacity in the face of disturbance and crisis in self-regulated than in comanaged community-based conservation initiatives where other factors external to communities, such as formal institutional rules and scientific knowledge, may be more relevant in explaining positive adaptation.

Our review includes community-based conservation initiatives that involve rural and indigenous communities subject to varying degrees of ecological and socioeconomic perturbations, such as droughts, regulatory policies, market integration, religion, and migration. Scholars mostly rely on qualitative methods, and they less often combine the latter with on-site or secondary quantitative assessments of social-ecological dynamics to discuss whether social-ecological systems are resilient. Traditional ecological knowledge appears as a crucial factor in both types of community-based conservation initiatives and can create synergies with other factors to enhance resilience in social-ecological systems. However, the latter can be undermined when the system is exposed to substantial perturbations, traditional institutions lose legitimacy, and natural resource management involves strict regulations.

The paper is organized as follows. The next section introduces the methodology for the review, whilst the third explains the results structured around two guiding questions: (1) What is the role of traditional ecological knowledge in successful

conservation in self-regulated and comanaged community-based conservation initiatives? and (2) How do traditional ecological knowledge- and potentially nontraditional ecological knowledge-related factors influence social-ecological resilience in both types of initiatives? The fourth section discusses the findings and the last section concludes the paper.

METHODS

Literature review

To explore the evidence on the role of traditional ecological knowledge in community-based conservation and the latter's effects on adaptive capacity and resilience we conducted a review of academic journal articles published between January 2000 and January 2012. Previous articles were excluded because the resilience perspective influenced sustainability science and resource management studies in the late 1990s and because most empirical research on the issue has been developed in the last decade (Folke 2006). Relevant publications were identified by performing a keyword search in the ISI Web of Knowledge using the following key terms "comm*, conserv*, know*, AND adapt*". We used this database because it is one of the premier platforms covering most of the international and regional journals in every area of both natural and social sciences. Case study research published in nonpeer-reviewed journals, or in reports, books, or articles not indexed in the ISI Web of Knowledge were excluded. Given these limitations and the fact that some of the articles reviewed may have unintentionally omitted information relevant for this review, we suggest treating our results with caution.

From the first tranche of collected material we excluded articles from subject areas not related to natural resource management, such as genetics, biochemistry, and evolutionary biology. As a result we identified 532 articles. We then repeated our search using "resilien*" instead of "adapt*" and found 180 results that had also been picked up by our original search. Subsequently, the abstract of each identified article (N=532) was reviewed and 52 of them were fully considered as they reported case studies and addressed the three main topics of concern in this review, i.e., traditional ecological knowledge, resilience and/or adaptive capacity, and community-based conservation. Out of these 52, only 23 were included in our final analysis because they explicitly examined the role of traditional ecological knowledge in explaining positive or negative conservation outcomes and its contribution to adaptive capacity and social-ecological systems resilience in community-based conservation contexts. Among the discarded papers (N=29, see Appendix 1) fourteen did not analyze factors contributing to local adaptive capacity (including traditional ecological knowledge) when the system was altered by climate variability or other perturbations, six did not describe traditional ecological knowledge's

contribution to adaptive management in community-based conservation initiatives, another six were not based on case study research, and three did not refer to explicit conservation outcomes.

Analysis

Twenty-nine case studies were thus analyzed from 23 selected publications. An identification number was assigned to each selected article. For articles reporting more than one case study, only those case studies addressing the two research questions highlighted in our introduction were included in the review. For instance, Gadgil et al. (2000) analyzed 52 case studies, but only three of them gave enough data for our analytical purposes.

Information on methodology, including study sites and data collection characteristics, was first tabulated with the aim of characterizing each article. To answer our first question we analyzed traditional ecological knowledge mechanisms supporting decision making and effective management of natural resources in conservation initiatives. We drew upon the four main levels of analysis defined by Berkes (1999) to address traditional ecological knowledge (i.e., empirical knowledge, world view, practical applications, and institutions), which we in turn labeled and codified as: (1) local observations, (2) rituals and ceremonies, (3) informal sanctions, and (4) customary institutions. For instance, Brewer's (2011) article on Maine's fisheries was coded as "local observations" because it only highlights the local knowledge on marine species as a component of traditional ecological knowledge contributing to community-based conservation. The study by Clark et al. (2008) focusing on the role of Inuit Qaujimagatuqangit as the totality of the traditional knowledge of the Inuit was coded using the four codes defined above. We also identified nontraditional ecological knowledge mechanisms contributing to effective community-based conservation initiatives through the publications' data and created the following coding categories: (1) scientific information, (2) dominant religion, (3) formal regulations, and (4) official institutions. The study by McLeod et al. (2009), for instance, was coded as "dominant religion" because it describes the role of Christianity in supporting some of the traditional ceremonies and rituals that contribute to maintain customary marine resource management and the conservation system in an Indonesian village.

To answer our second question and discuss which factors including traditional ecological knowledge contribute to adaptive capacity and social-ecological resilience in self-regulated and comanaged community-based conservation initiatives we developed coding categories based on Berkes et al. (2000): (1) decisions based on local experience, (2) respect of local institutions, (3) flexible institutional decision making, (4) trust and social bonds, (5) local leadership, (6) power sharing, and (7) mutual learning. Finally, we had additional

codes to describe nontraditional ecological knowledge factors affecting resilience that are related to the type of perturbation as described by the reviewed papers, including: (8) official regulations, (9) dominant religion, (10) climate change, and (11) market integration. All information was coded by the first author of the paper and was validated by the second author.

RESULTS

Research origins and foci

Table 1 describes study site characteristics and summarizes information on methodological issues of the 29 selected case studies. The table covers 19 community-based conservation initiatives where decision making relies on customary institutions, sometimes supported by NGOs (n=6), and ten initiatives of comanagement involving local managers and governments (five with the support of NGOs).

Twenty case studies were situated in tropical regions, mainly in south, southeast, and east Asia (n=16). Three case studies were located in Oceania and there was only one case study for Latin America, Europe, and Africa. India (n=6) and Canada (n=5) hosted more case studies. Canadian research groups led most publications, followed by U.S. researchers (7 and 6 articles out of 23, respectively) whereas Latin American and African institutions led none.

Research was conducted at local and regional levels (with 13 and 8 articles, respectively) rather than at the national scale (2 articles). Case studies concerned both terrestrial (n=15) and aquatic (n=14) biomes. In terrestrial biomes, articles examined agroforestry and forestry systems, focusing at the ecosystem level rather than the species level (i.e., forest cover change) to understand conservation outcomes and interpret social-ecological resilience. In aquatic environments, studies frequently analyzed coral reefs and lagoon fisheries, as well as marine wildlife management systems, where conservation efforts focused at the species level (i.e., parrotfish, polar bears, marine turtles). Reported conservation outcomes were assessed directly through recall in several case studies (n=16) whereas only five assessed ecological factors of the targeted species. In other cases (n=9) conservation outcomes were referred to data collected by other researchers.

Most case studies analyzed more than one perturbation as drivers of change in social-ecological systems. Research was predominantly concerned with rural communities' ability to adapt to opening markets for agricultural, marine, and forest resources (n=20). Ten case studies also highlighted the consequences of political stressors in community-based conservation initiatives (i.e., land-use policy changes), eight case studies analyzed socio-cultural perturbations (i.e., population growth, religion conversion) and four examined the effects of climate change (e.g., reduction of sea ice) in the system's resilience.

Nine of the 29 case studies reviewed lacked detail on research designs and methods (i.e., sample size, period of data analysis, interview templates, and coding frameworks for content analysis). Many relied on qualitative data (n=22) gathered through ethnographic tools (i.e., interviews, participant observation) and reviews of existing gray literature (i.e., reports, articles, archival data). Quantitative data of social-ecological systems were collected in seven case studies through surveys, satellite imagery analysis, or biological monitoring. The surveys collected information on local people's livelihood options at household level. However, only one study reported quantitative data regarding fishing families' socioeconomic differences in accessing and using natural resources, which were in turn related to various households' adaptive management strategies (ID#10).

Collected data were often used to conduct historical analyses of the links between traditional ecological knowledge and community-based conservation in shaping adaptive capacity at community level. Based on past experience, the robustness of community-based conservation in the future was then tentatively inferred, and policy and management recommendations were provided in order to cope with future perturbations. The reinforcement of sustainable traditional fishing practices and institutions by statutory law (ID#10 and #14-1), the involvement of local people in decision making and forest management in protected areas (ID#11 and #19), or the improvement of cross-scale communication and information exchange between governments, scientists, and communities on polar bears and goose populations in arctic regions (ID#8 and #18) are examples of such recommendations.

Exploring the relationships between traditional ecological knowledge and community-based conservation

Decision making around natural resource management based on traditional ecological knowledge was identified as a key factor contributing to successful conservation in both types of community-based conservation initiatives. Local communities were involved in a process of social learning through the transmission and sharing of such knowledge and ideas. The role of traditional ecological knowledge, however, was more fundamental in self-regulated than in comanaged initiatives in which other social mechanisms supported decision making for effective conservation (Table 2).

In the case of self-regulated community-based conservation initiatives, research highlighted that traditional ecological knowledge has been historically instrumental in ensuring biodiversity conservation and enhancing local livelihoods. Biodiversity monitoring based on local observations, taboos and regulations, informal sanctions, customary institutions defining decision making, and rituals and ceremonies enforcing behavior that supports conservation goals were

Table 1. Methodological characteristics of case studies included in the review, by lead author.

ID	Reference institution	Country	Ethnic group	Latitude	Type of biome	Study site			Conservation effort	Perturbation	Period of analysis ¹	Scale	General tools	Measurement of conservation
						Type of social-ecological systems	Type of agroforestry	Type of community-based conservation governance system						
1	Armitage U of Waterloo, Canada	Indonesia	Kaili	Tropical	Terrestrial	Agroforestry	Comanaged	Agrobiodiversity, forest resources, & water	Land-use policy change (crop agriculture intensification)	Not specified-2000	Regional	Current & historical maps, transects, seasonal calendars, focus groups, interviews	Direct on site through mapping & interviews about land-use change.	
2	Aswani et al. 2007	Solomon Islands	^	Tropical	Aquatic	Lagoon fisheries	Comanaged	Triggerfish, groupers, parrotfish	Population growth, immigration (increased fishing pressure)	2005-2006	Local	Biological monitoring, interviews	Direct on site through ecological assessment of coral reef & fish abundance.	
3	Berkes & Turner 2006	Canada	Chisasibi Cree	Arctic	Terrestrial	Terrestrial wildlife management	Comanaged	Caribou	Market integration (access to repeating rifles)	1910-1990	Regional	Literature review	Indirect through other study reporting data on caribou population (Berkes 1999).	
4	Brewer 2011	USA	Anglo-American	Arctic-Boreal	Aquatic	Marine fisheries	Self-regulated	Groundfish & lobster (mainly)	Management policy changes (catch shares), immigration (new fishermen)	1970-2010	Regional	Literature review, interviews, survey, observation	Indirect through official data on targeted fish stocks (Northeast Fisheries Science Center 2008).	
5-1	Cinner et al. 2006	Indonesia	^	Tropical	Aquatic	Coral reefs fisheries	Self-regulated	Parrotfish, damselfish, others	Market integration (increased fishing pressure)	Not specified-2002	Local	Biological monitoring, interviews, participatory observation	Direct on site through ecological assessment of fish biomass, size, & abundance.	
5-2		Papua New Guinea	^	Tropical	Aquatic	Coral reefs fisheries	Self-regulated	Polar bear	Climate change (reduction of sea ice), market	1973-2007	National	Literature review	Indirect through official data on polar bear	
6	Clark et al. 2008	Canada	Inuit	Arctic	Aquatic	Marine wildlife management	Comanaged	Polar bear						

7	Coulthard U 2011 UK	India	^	Tropical	Aquatic	Lagoon fisheries	Self-regulated	Prawns (mainly)	Population growth, climate change (seasonal fluctuations of prawns), market integration (blue revolution)	1980-2009	Local	Interviews, participant observation	Indirect through other studies reporting fishing pressure (Mathew 1991, Coulthard 2006).
8	Dowsley 2009	Lakehead U, Canada	Inuit	Arctic	Aquatic	Marine wildlife management	Comanaged	Polar bear	Climate change (reduction of sea ice)	1968-2004	Regional	Literature review	Indirect through other study reporting data on polar bear populations (Regehr et al. 2006).
9-1	Gadgil et al. 2000	India	^	Tropical	Terrestrial	Forestry & wildlife management	Self-regulated	Forest resources	Market integration (increased commerce), management & land tenure policy changes	1996-1998	National	Interviews, participant observation, mapping	Indirect through other study reporting the status of the forest (Gokhale et al. 1998).
9-2		India		Tropical	Terrestrial	Forestry & wildlife management	Self-regulated						Direct on site through interviews & mapping.
9-3		India		Tropical	Terrestrial	Forestry & wildlife management	Comanaged						
10	Gelcich et al. 2006	U Wales- Bangor, UK	^	Tropical	Aquatic	Marine fisheries	Self-regulated	Benthic resources (bull-kelp)	Management policy changes (open-access fisheries)	2002-2004	Local	Participant observation, interviews, survey	Direct on site through interviews about bull-kelp populations.
11	Kalibo & Medley 2007	Miami U, USA	Kasigau Taita	Tropical	Terrestrial	Agroforestry	Self-regulated	Agrobiodiversity & water	Droughts	1937-2003	Local	Participatory mapping, transect walks, interviews	Direct on site through qualitative methods about agroforestry resources.

12	Kennett et al. 2004	Charles Darwin U, Australia	Australia	Yolngu	Tropical	Aquatic	Marine wildlife management	Comanaged	Marine turtle	Market integration (increased marine debris & vehicle traffic, hunting)	1992-2003	Regional Literature review	Indirect through other study reporting marine turtle distribution & abundance (Kennett et al. 1998).
13	Lauer & Aswani 2010	San Diego State U, USA	Solomon Islands	^	Tropical	Aquatic	Lagoon fisheries	Comanaged	Seagrass meadows	Population growth, market integration (fishing pressures)	1947-2008	Local Aerial photographs, interviews	Direct on site through ecological assessment of seagrass meadow size.
14-1	McLeod et al. 2009	The Nature Conservancy USA	Indonesia	Matbat (mainly)	Tropical	Aquatic	Coral reefs fisheries	Self-regulated	Shellfish, pearl oyster, green snail (mainly)	Religious conversion, market integration (pearl farm)	1930-2006	Local Literature review, participant observation, interviews, surveys	Direct on site through qualitative methods on targeted fish populations.
14-2			Indonesia	Ma_ya (mainly)	Tropical	Aquatic	Coral reefs fisheries	Self-regulated					
15	Mehring et al. 2011	EMA U Greifswald, Germany	Indonesia	Kulawi	Tropical	Terrestrial	Forestry & wildlife management	Comanaged	Forest resources	Population growth, market integration (road, cocoa market)	1990-2008	Local Literature review, participant observation, interviews, focus group	Direct on site through interviews on land-use change.
16	Olsson & Folke 2001	Stockholm U, Sweden	Sweden	European	Boreal	Aquatic	Lake fisheries	Comanaged	Crayfish	Industrialization (water acidification)	1950-1999	Local Literature review, interviews, survey	Direct on site through surveys on crayfish population.
17	Parlee et al. 2005	U of Manitoba, Canada	Canada	Denésoliné	Boreal	Terrestrial	Terrestrial wildlife management	Self-regulated	Caribou	Market integration (mining, roads), forest fires	1950-2004	Local Satellite images, literature review, interviews	Direct on site through interviews on caribou population.
18	Peloquin & Berkes 2009	U of Manitoba, Canada	Canada	Cree	Arctic	Terrestrial	Terrestrial wildlife management	Self-regulated	Canada goose	Market integration (motorboat, float planes, helicopter travel), climate change	1975-2007	Local Interviews	Direct on site through interviews about goose population.
19	Pickering et al. 2010	Colorado State U, USA	USA	Oglala Lakota	Temperate	Terrestrial	Forestry & wildlife management	Self-regulated	Forest resources	Historical land-use policy (favoring)	2001-2008	Regional Surveys	Direct on site through surveys about ecological

20	Rai 2007	U of Delhi, India	India	Apatani, Lepchas, Limbus	Temperate - Alpine	Terrestrial Agroforestry	Self-regulated	Agrobiodiversity & forest resources	Market integration (increased commerce) & urbanization	Not specified	Regional Literature review, interviews, focus groups, observation	Direct on site through qualitative methods on land-use change.
21-1	Rerkasem et al. 2009	Chiang Mai U, Thailand	China	Hani	Tropical	Terrestrial Agroforestry	Self-regulated	Agrobiodiversity & water	Land-use policy change (opium cultivation prohibition), market integration (road)	1934-1990	Regional Literature review	Indirect through other studies reporting changes in cropping systems (not detailed here).
21-2			Thailand	Hmong	Tropical	Terrestrial Agroforestry	Self-regulated					
22	Shukla & Sinclair 2010	U of Manitoba, Canada	India	Konkani	Tropical	Terrestrial Agroforestry	Comanaged	Forest resources	Market integration (logging), failed conservation regulations (Forest officials' poor enforcement)	1951-2007	Local Interviews, focus groups, workshops	Direct on site through interviews about forest protection.
23-1	Tang & Tang 2010	National ChengChi U, Taiwan	Taiwan	Tao	Tropical	Aquatic	Lagoon fisheries	Flying fish	Religious conversion (Christianity), market integration (motorboat)	1950-2006	Local Literature review, interviews	Direct on site through interviews about fish stock preservation.
23-2			Taiwan	Atayal	Tropical	Terrestrial Forestry & wildlife management	Self-regulated	Forest resources	Religious conversion (Christianity), outmigration			Direct on site through interviews about forest preservation.

¹ Period of data analysis was estimated in several case studies.

identified as key processes sustaining natural resource management. Case studies in Indonesia and Papua New Guinea, for example, documented positive effects on reef resources of periodic closures managed through a body of traditional ecological knowledge that allowed for the rapid assessment of fisheries' conditions (ID#5-1 and #5-2). Village farmers in the Chinese province of Yunnan operated mixed farming systems based on their knowledge about forest regeneration, which was a key component in determining the sustainability of shifting cultivation systems (ID#21-1). Animistic beliefs and ceremonies played an important role in forest protection and sustainable land use in the Indonesian region of Banawa-Marawola. Villagers did not cut large trees because they held the belief that trees were spirits that would punish them by causing sickness and damage to crops (ID#1). In a few cases other factors, such as collaboration with scientists (n=2), the dominant religion principles (n=2) and formal institutions (n=2), also contributed to successful conservation outcomes. For example, Indonesian laws on the management of fisheries provided a legal basis for supporting traditional rights over coastal waters, which contributed to communities' maintenance of sustainable and customary resource management practices (ID#14-1 and #14-2). However, documented trade-offs between traditional ecological knowledge and community-based conservation in self-regulated initiatives were related to the formalization of such initiatives by national agencies. For example, the creation of a management and exploitation area for benthic resources in Chile invalidated prior informal regulations and rules and imposed regulations on access rights, thereby excluding traditional ecological knowledge from formal decision-making procedures over catch arrangements (ID#10).

In comanaged, community-based conservation initiatives, which combine traditional and official regulations as well as informal and formal sanctions established by cross-scale institutions, traditional ecological knowledge was considered the basis for sound decision making around natural resource management, alongside scientific knowledge. For example, in the Swedish Lake Racken, self-organized local institutions recognized the value of traditional knowledge and management rules for crayfish, which were in turn influenced and regularly reshaped by changes in sanctions, local monitoring data, scientific information, and the practices of governmental authorities (ID#16). A seemingly successful example was the comanagement of caribou populations in Hudson Bay and James Bay, Canada, which relied on local elders to regulate young people's overhunting. Elders relied on oral history and Cree ethics to make young hunters aware of the importance of following traditional hunting standards with the aim of sustaining wildlife and resources (ID#3). A shift in the governance of such type of initiatives, however, can undermine the role of customary institutions in decision making and weaken traditional ecological knowledge. The

failure of a comanagement regime for polar bear management due to policy conflicts and detrimental effects on Inuit Qaujimagatuqangit has also been documented (ID#6).

Factors explaining resilience in community-based conservation

All the studies reviewed claimed to address the concept of resilience from a social-ecological perspective, i.e., they referred to both ecosystem capacity and communities' ability to adapt positively to a perturbation whilst maintaining social functions and conservation outcomes. Twenty-two case studies reported resilient systems to perturbations: 14 of them in self-regulated community-based conservation and eight in comanaged initiatives. Seven cases reported social-ecological systems that failed to adapt to a given perturbation (Table 3). Methodologically, however, only 5 among the 29 cases reviewed, which were concerned with fisheries, systematically analyzed ecological attributes and ecosystem dynamics. Among these, only one examined resilience over a period of 60 years (ID#13) whereas three studies limited the analysis to short-term processes of <3 years (ID#2, #5-1, and #5-2) and the other did not specify the period of data analysis (ID#10). The remaining 24 cases relied on interviews, historical maps, and oral histories to discuss only social elements of resilience, such as knowledge systems and governance issues, usually over periods >30 years (n=16). The latter may lead to underestimating the role of ecological dynamics in adaptation and/or to misrepresenting the role of social attributes in explaining social-ecological systems resilience.

Generally speaking, the publications reviewed considered self-regulated initiatives resilient to a given (set of) perturbation(s) when such initiatives held some of the following traits related to traditional ecological knowledge: (1) they maintain a decision-making system, based on local observations, beliefs, and perceptions, that guarantees the conservation status of a resource; (2) in decision making, they respect the role of customary institutions that rely on cultural values (i.e., sharing and reciprocity), taboos, and customary sanctions, which also hold the transmission of the cumulative body of ecological knowledge; (3) they have developed an institutional learning and have integrated formal and informal mechanisms for flexible and rapid decision making; (4) they have reinforced community networks through trust building and social bonds to incentivize regulatory compliance; and (5) they are guided by local leaders who have a commitment to their community traditions and cultural values and who support sustainable management practices to enhance both the well-being of local people and biodiversity conservation. For example, Cree geese hunters in Canada relied on social memory and exchange of ecological observations to track geese population changes and related the latter to ecological disturbances. This knowledge allowed hunters to continuously adapt management strategies and reduce hunting pressure in the light of changing environmental conditions (ID#18). Also

Table 2. Decision-making mechanisms contributing to sustainable natural resource management and conservation, by type of community-based conservation governance system.

ID	Traditional ecological knowledge-related				Nontraditional ecological knowledge			
	Local observations	Rituals and ceremonies	Informal sanctions	Customary institutions	Scientific information	Dominant religion	Formal regulations	Official institutions
Self-regulated community-based conservation								
1	+	+	+	+				
4	+				+			
5-1	+	+	+	+				
5-2	+	+	+	+				
7	+		+	+				
9-1		+	+	+				
9-2			+	+				
10	+				+			
11	+	+	+	+				
14-1	+	+	+	+		+		+
14-2	+	+	+	+				+
17	+	+	+	+				
18	+	+	+	+				
19	+							
20		+	+	+				
21-1	+		+	+				
21-2	+		+	+				
23-1	+	+	+	+				
23-2	+	+	+	+		+		
Comanaged community-based conservation								
2	+	+		+	+		+	+
3	+		+	+	+			+
6	+	+	+	+	+		+	+
8	+		+	+	+		+	+
9-3		+	+	+				
12	+	+	+	+	+		+	+
13	+	+	+	+	+		+	+
15	+		+	+			+	
16	+	+	+	+	+		+	+
22	+		+	+	+		+	+

in Canada, the Denésoliné traditional system for monitoring movements of caribou allowed the Denésoliné to deal with variability in species' migration patterns by organizing to observe, and communicate and learn about, caribou movements through periodic meetings during hunting (ID#17).

In co-managed regimes, reviewed articles pointed out two additional traits that contribute to social-ecological systems resilience: 6) they rely on cross-institutional collaboration between customary and government institutions, often supported by research groups and NGOs, to make deliberative decisions that provide opportunities to deal with change; and 7) they involve a process of mutual learning, reinforced through the creation of knowledge networks between scientists and local managers that are complementary to

existing forms of institutional learning and knowledge sharing of local communities. For example, institutional learning capacity characterized the Baripada Forest Adaptation Initiative, an Indian comanaged community-based conservation effort in northeast India that adapts local rules to changing social-ecological conditions in village forests. In 2002, an increase in family size and forest cover led them to extend the period for removing fuel wood by one month (ID#22).

Diminished resilience in five self-regulated community-based conservation initiatives was explained by the failure of local communities to deal with internal and external processes that were altering local behavior or the conditions of resource management. In Fanfanlap, Indonesia, local leadership undermined the legitimacy of customary institutions, thereby contributing to the erosion of community-based conservation

Table 3. Reported factors enhancing resilience (+) and undermining resilience (-) in the context of community-based conservation (CBC) initiatives, by type of community-based conservation governance system.

CBC ID	Resilient	Factors based on traditional ecological knowledge					Factors including traditional ecological knowledge		Nontraditional ecological knowledge factors			
		Decisions based on local experience	Respect of local institutions	Flexible institutional decision making	Trust and social bonds	Local leadership	Cross-scale institutions	Collaboration with scientists	Government regulations	Religion conversion	Climate change	Market integration
Self-regulated												
1	Yes	+	+			-						
4	No		+			+						
5-1	Yes	+	+	+	+	+						
5-2	Yes	+	+	+	+	+						
7	Yes	+	+	+	+							
9-1	Yes	+	+	+	+							
9-2	Yes	+	+	+	+	+						
10	No			+								
11	Yes	+	+	+								
14-1	Yes	+	+	+	+	+						
14-2	No			+		-						
17	Yes	+	+	+	+							
18	Yes	+	+	+								
19	No	+	+		+							
20	Yes	+	+	+	+							
21-1	Yes	+	+	+	+							
21-2	Yes	+	+	+								
23-1	No				+							
23-2	Yes	+	+		+	-						
Comanaged												
2	Yes	+	+	+	+		+	+				
3	Yes	+	+	+			-	+	+			
6	No	+			+		+	+				
8	Yes		+	+	+		+	+	+			
9-3	No						-					
12	Yes	+	+	+			+	+	+			
13	Yes	+	+	+			+	+	+			
15	Yes	+	+		+	+	+	+				
16	Yes	+	+	+		+	+	+	+			
20	Yes	+	+	+	+	+	+	+	+			

and the weakening of local communities' adaptive capacity to cope with economic and socio-cultural change. The corruption of the local leader was translated in a loss of social trust and, subsequently, the *sasi* (i.e., the local customary marine tenure system) became contested and led to over fishing (ID#14-2). Changes in religious beliefs can also weaken the adaptive capacity of social-ecological systems to external pressures. On a tourist island of Taiwan, for example, Christianity replaced the Tao belief system; consequently, traditional rules, taboos, and ceremonies governing the use of the coastal fishery have progressively lost importance against other values. Young people are now catching flying fish with motorboats and trading with tourists, which is leading to the depletion of fish stocks (ID#23-1). Finally, strong imposition of official management regulations can also jeopardize local adaptive capacity, as shown by the case of catch shares imposed in Maine's fisheries to protect groundfish populations. Catch shares excluded local knowledge, social rules, and informal sanctions from decision-making processes, and failed to sustain fish populations and fishermen's livelihoods (ID#4).

Lack of resilience was also documented in two case studies of comanaged community-based conservation: one in Canada (ID#6) and one in India (ID#9-3). In northern Canada, factors undermining resilience were related to power-sharing conflicts between Inuit people and conservation managers (that is, environmental NGOs and scientists), which were explained by competing perspectives on polar bear management and conservation. Such conflicts were fueled by lack of transparency, communication, and trust between local people and policy makers, and weakened adaptive capacity to cope with change and achieve conservation outcomes. Additionally, the rapid reduction of sea ice—affecting polar bear survival and the increasing market for sport hunted-trophies that translate into income opportunities for local people—have also had a negative impacts on social-ecological systems resilience. Similarly, in a village in Rajasthan in northwest India, community-conserved areas of sacred groves became government property after a land-reform policy was enacted. Formal conservation regulations subsequently undermined the role of traditional leaders in regulating

harvesting in the groves and led to the degradation of existing sites.

DISCUSSION

The results presented above indicate that traditional ecological knowledge plays a more important role in enhancing local people's adaptive capacity to new social-ecological challenges in self-regulated community-based conservation initiatives than in comanaged community-based conservation initiatives where collaboration with government and scientists play a more central role. Furthermore, the review suggests the existence of four critical mechanisms through which traditional ecological knowledge results in positive adaptation in contexts of community-based conservation. First, people have the capacity to elaborate knowledge about ecosystems by testing it iteratively, as well as to learn from crises and management mistakes. Second, they are able to transmit and guard it locally, with the aim of adjusting management practices to new social-ecological states arising after perturbations. These two mechanisms are related to the dynamic nature of local knowledge (Evans et al. 2011, Gómez-Baggethun and Reyes-Garcia 2013) Third, an appropriate interpretation of ecosystem change is related to the traditional ceremonies and rituals that contribute to the cultural internalization of conservation rules. And fourth, such rules are the basis of flexible decision making. This is consistent with previous studies that have identified the linkages between local knowledge and resilience in social-ecological systems (Berkes et al. 2000, Folke et al. 2005). A review conducted by Berkes et al. (2000), for example, also identified the use of rules supported by customary institutions, rituals, and other traditions; flexibility in decision making; accumulation of ecosystem knowledge; and diversification of livelihood strategies as key mechanisms used by local people to cope with dynamic change in traditionally managed systems. In a recent study, Gómez-Baggethun et al. (2012) also identified these coping mechanisms as instrumental elements of traditional resource management in Spain's National Park of Doñana. Particularly in community-based conservation contexts, reported outcomes of the reviewed case studies suggest that, even though current environmental change is faster than the processes of generating and transmitting traditional ecological knowledge, many communities engaged in community-based conservation have been able to learn from experience and errors, engage young people in this learning process, and innovate and generate new knowledge to overcome crisis.

Traditional ecological knowledge mechanisms that enhance resilience are also present in comanaged conservation initiatives. In general, cross-scale institutions and official regulations have had positive effects on both traditional ecological knowledge and local adaptive capacity. However, our review also shows that these mechanisms can be undermined when a community-based conservation initiative

is formally established, particularly if the latter involves strict regulations enacted by external actors. Rigid management and governance structures can sometimes constrain people's ability to respond to changing conditions because such structures are slow in learning from past experience and they innovate through new institutional arrangements (Brewer 2011). Although official regulations are indeed important for addressing international obligations and priorities and for complying with national policies on biodiversity conservation, the practical implementation of these regulations can result in conflicts among stakeholders and have detrimental effects on their well-being and biodiversity conservation. In indigenous territories, this is not new given that comanagement approaches often lie behind the failure of many integrated conservation and development projects (Brown 2002). In response to that, some researchers have argued for flexible, multilevel conservation models involving the devolution of power to local communities (Berkes 2010, Folke et al. 2005). Such approach requires the input and knowledge of local people that should be embraced and considered a key tool for deliberation and not an alternative if science fails (Berkes 2007). To create the conditions for the successful harmonization of traditional ecological knowledge and community-based conservation initiatives, social sources of resilience, such as social memory and social capital, should then be guaranteed and strengthened (Folke et al. 2005). Moreover, the presence of enforcement mechanisms that prevent free-riding behavior and that reinforce trust, sense of community, and social networks among local stakeholders and between local people and governments is another important requirement for effective community-based conservation (Ostrom 1990). This challenge involves neither centralization nor decentralization of power, but the linking traditional ecological knowledge with flexible institutions and multilevel governance systems for building trust through adaptive governance systems (Folke et al. 2005). This also implies a previous understanding of the local interests, institutions, and power relations that make adaptation difficult (Naess 2012).

The results presented also suggest that resilience theory and robust methodological approaches have yet to figure prominently in community-based conservation research. The ecological attributes of a system that are important for understanding resilience were hardly assessed in the studies reviewed and their analyses were limited to short periods of time. Climate variability and shocks figured as less analyzed stressors to traditional ecological knowledge and community-based conservation than socioeconomic and political issues. Only four reviewed case studies, most of which were conducted in the Arctic, paid attention to climate-related events and trends as key factors behind the weakening of traditional ecological knowledge and community-based conservation objectives. Scholars have already paid attention to comparing adaptive management strategies to climate

variability and environmental change in rural Africa (Goulden et al. 2009) but no similar attempt has been undertaken to compare people's strategies for adapting to environmental change across community-based conservation initiatives located in regions vulnerable to climate change different from the Arctic. The latter would be meaningful in determining whether community-based conservation limits or expands the portfolio of people's adaptive strategies and in highlighting whether community-based conservation itself is adapting to the new risks and opportunities posed by climate change (e.g. changes in temperature and rainfall that can translate to changes in population numbers of certain species or changes in distributional patterns). In this regard, we believe that there is a need for further multidisciplinary comparative studies that focus on understanding the role that traditional ecological knowledge and community institutions can play in reducing local vulnerability and enhancing resilience in the context of community-based conservation. These should ideally account for both ecological and social dimensions of resilience to address past, present, and future climate variability and risks, and they could build, for example, on archival data, oral testimonies, and future scenarios, respectively (Walker et al. 2002, Gómez-Baggethun et al. 2012). These scenarios may then be used to describe and better understand the role of traditional ecological knowledge in shaping communities' adaptive capacity to cope with global environmental change, as well as the thresholds concerning adaptive capacity.

CONCLUSION

We set out to gather insights on how traditional ecological knowledge has influenced community-based conservation, and to explain how traditional ecological knowledge and other accompanying factors have influenced people's adaptive capacity and social-ecological systems resilience in such conservation contexts. Reviewed publications indicate the potential of traditional ecological knowledge in enhancing communities' ability to deal with global change. To cope with dynamic change, rural and indigenous communities often relied on their local experience and knowledge of environmental phenomena, cultural values and worldview, community networks, and local institutions while promoting biodiversity conservation and enhancing their livelihoods in self-regulated community-based conservation initiatives. In comanaged initiatives, local people also benefited from cross-institutional arrangements and scientific knowledge that contributed to capacity building, knowledge generation through mutual learning, and trust building. Some of the reviewed cases also suggest, however, that traditional ecological knowledge has limitations in contributing to people's adaptive capacity in both types of community-based conservation initiatives. Traditional ecological knowledge can be undermined by community-based conservation when the latter results in imposed regulations and new management conflicts, whilst both traditional ecological knowledge and

community-based conservation can also be undermined by the loss of institutional legitimacy and the imposition of formal regulations, as well as new market pressures, shifting behavior, and environmental change.

The review has allowed us to identify two major research gaps. On the one hand, there is a need for panel data on case study research documenting the effects of climate variability and shocks in the joint evolution of traditional ecological knowledge and community-based conservation, and their subsequent impacts on social-ecological resilience in temperate and tropical social-ecological systems. On the other, there is a need to expand the current focus on social variables and processes to explain changes in traditional ecological knowledge and adaptive capacity in the context of community-based conservation towards a broader approach that pays attention to endogenous ecological dynamics and current patterns of environmental change. Only by fully comprehending existing synergies, conflicts, and trade-offs between traditional ecological knowledge, community-based conservation, and adaptive capacity in changing environments may we grasp the complexities and guide decision making for conservation across governance scales in meaningful ways.

Responses to this article can be read online at:

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APPENDIX. List of Non-Included -Although Initially Selected- Publications, by Reason of Exclusion (N=29)

Publications not assessing local adaptive capacity or SES resilience

- 1) Ban, N. C., C. Picard, and A. C. J. Vincent. 2008. Moving toward spatial solutions in marine conservation with indigenous communities. *Ecology and Society* 13(1): 32.
- 2) Cinner, J.E., Basurto, X., Fidelman, P., Kuange, J., Lahari, R., and A. Mukminin. 2012. Institutional designs of customary fisheries management arrangements in Indonesia, Papua New Guinea, and Mexico. *Marine Policy* 36:278-285.
- 3) Grant, S., and F. Berkes. 2007. Fisher knowledge as expert system: A case from the longline fishery of Grenada, the Eastern Caribbean. *Fisheries Research* 84:162-170.
- 4) Herrmann, T. M., and M. C. Torri. 2009. Changing forest conservation and management paradigms: traditional ecological knowledge systems and sustainable forestry: Perspectives from Chile and India. *International Journal of Sustainable Development & World Ecology* 16(6):392-403.
- 5) Lawrence, A., K. Paudel, R. Barnes, and Y. Malla. 2006. Adaptive value of participatory biodiversity monitoring in community forestry. *Environmental Conservation* 33(4):325-334.
- 6) Mbile, P., M. Vabi, M. Meboka, D. Okon, J. Arrey-Mbo, F. Nkongho, E. Ebong. 2005. Linking management and livelihood in environmental conservation: case of the Korup National Park Cameroon. *Journal of Environmental Management* 76:1-13.
- 7) Medley, K.E., and H.W. Kalibo. 2007. Global localism: Recentering the research agenda for biodiversity conservation. *Natural Resources Forum* 31:151-161.
- 8) Mishra, C., H.H.T. Prins, and S.E. Van Wieren. 2003. Diversity, Risk Mediation, and Change in a Trans-Himalayan Agropastoral System. *Human Ecology* 31(4):595-609.
- 9) Moller, H., F. Berkes, P.O. Lyver, and M. Kislalioglu. 2004. Combining science and traditional ecological knowledge: Monitoring Populations for co-management. *Ecology and Society* 9(3): 2.
- 10) Moller, H., J.C. Kitson, and T.M. Downs. 2009. Knowing by doing: Learning for sustainable muttonbird harvesting. *New Zealand Journal of Zoology* 36(3):243-258.
- 11) Swemmer, L.K., and S. Taljaard. 2011. SANParks, people and adaptive management: Understanding a diverse field of practice during changing times. *Koedoe* 53(2-1017): 7.
- 12) Terer, T., A.M. Muasya, F. Dahdouh-Guebas, G.G. Ndiritu, and L. Triest. 2012. Integrating local ecological knowledge and management practices of an isolated semi-arid papyrus swamp (Loboi, Kenya) into a wider conservation framework. *Journal of Environmental Management* 93:71-84.
- 13) Willebrand, T., C. Sandström, and T. Lundgren. 2006. Reaching for new perspectives on socio-ecological systems: exploring the possibilities for adaptive co-management in the Swedish mountain region. *International Journal of Biodiversity Science & Management* 2(4):359-369.
- 14) Wollenberg, E., B. Campbell, E. Dounias, P. Gunarso, M. Moeliono, and D. Sheil. 2008. Interactive landuse planning in Indonesian rain-forest landscapes: reconnecting plans to practice. *Ecology and Society* 14(1): 35.

Publications not describing TEK's contribution to adaptive management in CBC contexts

- 15) De Steven, D., and R. Lowrance. 2011. Agricultural conservation practices and wetland ecosystem services in the wetland-rich Piedmont-Coastal Plain region. *Ecological Applications* 21(3):S3-S17.
 - 16) Elbakidze, M., P. K. Angelstam, C. Sandström, and R. Axelsson. 2010. Multi-stakeholder collaboration in Russian and Swedish Model Forest
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- initiatives: adaptive governance toward sustainable forest management? *Ecology and Society* 15(2): 14.
- 17) Enserink, B., M. Patel, N. Kranz, and J. Maestu. 2007. Cultural factors as co-determinants of participation in river basin management. *Ecology and Society* 12(2): 24.
 - 18) McClanahan, T.R., J.E. Cinner, N.A.J. Graham, T.M. Daw, J. Maina, S.M. Stead, A. Wamukota, K. Brown, V. Venus, and N.V.C. Polunin. Identifying Reefs of Hope and Hopeful Actions: Contextualizing Environmental, Ecological, and Social Parameters to Respond Effectively to Climate Change. *Conservation Biology* 23(3):662-671.
 - 19) Ohl-Schacherer, J., E. Mannigel, C. Kirkby, G.H. Shepard Jr, and D.W. Yu. 2008. Indigenous ecotourism in the Amazon: a case study of 'Casa Matsigenka' in Manu National Park, Peru. *Environmental Conservation* 35(1):14-25.
 - 20) Thompson, P., P. Sultana, and R. Arthur. 2010. Integrating biological conservation into management: Community adaptive learning in the wetlands of Bangladesh. *Biodiversity* 11(1-2):31-38.
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Publications not based on case-study research

- 21) Boyd, E. 2008. Navigating Amazonia under uncertainty: past, present and future environmental governance. *Philosophical Transactions of The Royal Society* 363:1911-1916.
 - 22) Cinner, J. E., and S. Aswani. 2007. Integrating customary management into marine conservation. *Biological Conservation* 140:201-206.
 - 23) Fabricius, C., E. Koch, and H. Magome. 2001. Towards strengthening collaborative ecosystem management: Lessons from environmental conflict and political change in southern Africa. *Journal of the Royal Society of New Zealand* 31(4):831-844.
 - 24) Fabricius, C., C. Folke, G. Cundill, and L. Schultz. 2007. Powerless Spectators, Coping Actors, and Adaptive Co-managers: a Synthesis of the Role of Communities in Ecosystem Management. *Ecology and Society* 12(1):29.
 - 25) Ferse, S.C.A., M. Mañez Costa, K. Schwerdtner Mañez, D.S. Adhuri, and M. Glaser. 2010. Allies, not aliens: increasing the role of local communities in marine protected area implementation. *Environmental Conservation* 37(1):23-34.
 - 26) Folke, C., T. Hahn, P. Olsson, and J. Norberg. 2005. Adaptive governance of Social-Ecological Systems. *Annual Review of Environment and Resources* 30:441-473.
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Publication not referred to explicit conservation outcomes

- 27) Armitage, D.R. 2005. Adaptive Capacity and Community-Based Natural Resource Management. *Environmental Management* 35(6):703-715.
 - 28) Crate, S.A. 2006. Investigating Local Definitions of Sustainability in the Arctic: Insights from Post-Soviet Sakha Villages. *Arctic* 59(3):294-310.
 - 29) Sandström, A., and C. Rova. 2010. Adaptive co-management networks: a comparative analysis of two fishery conservation areas in Sweden. *Ecology and Society* 15(3): 14.
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