ABSTRACT. Local and traditional ecological knowledge (LTK) is increasingly recognized as an important component of scientific research, conservation, and resource management. Especially where there are gaps in the scientific literature, LTK can be a critical source of basic environmental data; this situation is particularly apparent in the case of marine ecosystems, about which comparatively less is known than terrestrial ones. We surveyed the global literature relating to the LTK of marine environments and analyzed what knowledge has been collected and with what aims and results. A large proportion of LTK which has been documented by researchers consists of species-specific information that is important for traditional resource use. However, knowledge relating to marine ecology, environmental change, and contemporary resource management practices is increasingly emphasized in the literature. Today, marine LTK is being used to provide historical and contemporary baseline information, suggest stewardship techniques, improve conservation planning and practice, and to resolve management disputes. Still, comparatively few studies are geared toward the practicalities of developing a truly collaborative, adaptive, and resilient management infrastructure that is embracive of modern science and LTK and practices in marine environments. Based on the literature, we thus suggest how such an infrastructure might be advanced through collaborative projects and “bridging” institutions that highlight the importance of trust-building and the involvement of communities in all stages of research, and the importance of shared interest in project objectives, settings (seascapes), and outcomes.

Key Words: adaptive comanagement; collaborative research; collaborative resource management; ecological monitoring; environmental change; historical ecology; local and traditional knowledge (LTK); marine conservation; marine ecology; marine ecosystems

INTRODUCTION
Over the past several decades, as concerns about declines in local habitats, species, and livelihoods have increased, the potential contributions of local and traditional knowledge (LTK) to ecosystem research and management have been increasingly recognized. To date, LTK studies have been diverse and often interdisciplinary. However, there are few examples of works that bring together the literature across these fields in the marine context (see Johannes and Neis 2007 for one broad review). Given the increasing concern about marine ecosystems in relation to climate change, overfishing, pollution, and other anthropogenic impacts, coupled with humanity’s comparative ignorance of the sea in relation to terrestrial environments, interest in marine LTK can be expected to increase. Furthermore, conceptualizations of marine ecosystems inherent in LTK may have increasing relevance to critical adaptation and conservation tasks, such as identifying historical baselines and environmental change, establishing restoration and sustainability targets for species, increasing the resilience of marine social-ecological systems, and improving coastal zone and marine spatial planning and fisheries management.

As a contribution to this effort, we review both the aims and substantive content of work to date on marine LTK, in order to highlight key themes and critical gaps, and to address the role of marine LTK in marine social-ecological systems. We conclude that while empirical studies of LTK are numerous, few engage local knowledge systems and indigenous epistemologies enough to achieve a respectful synthesis or integration (Agrawal 1995, Hamilton and Walter 1999, Nadasdy 1999, Cruikshank 2001, Agrawal 2002, Simpson 2004, Cruikshank 2005, Nadasdy 2005, Wilson et al. 2006, Berkes 2009b). Genuine collaborative projects are rare and often insufficient in scope and depth to address critical, multiscale conservation, adaptation, and management issues facing coastal seascapes today. We explore how this situation might be remedied through collaborative research and management projects that enhance genuine coproduction of knowledge and collaborative implementation of that knowledge in policy. Finally we suggest how diverse, time-tested, traditional knowledge; stewardship principles; and technologies embedded in LTK systems may be applicable to the human adaptation and resilience needs of a complex, changing environment (Berkes et al. 1995). Before turning to the review of the aims and substantive content of LTK studies, we first briefly set out key definitions and how marine LTK may be best understood.

Marine LTK as a body of knowledge
To understand its cultural context and interrelationships, LTK is best conceptualized as a body or system of knowledge rather than a mere assemblage of facts. Foremost, this involves understanding how LTK, including related skills, is
communicated and transmitted in situ and in vivo as part of the exigencies of maritime life (Aporta and Higgs 2005, Berkes and Turner 2006, Crona and Bodin 2006, Foa 2006b, Murray et al. 2006, Akyeampong 2007, Palmer and Wadley 2007, Poepoe et al. 2007, Reyes-Garcia et al. 2007, Alessa et al. 2008, Bonny and Berkes 2008, Pearce et al. 2011). Secondly, it involves examining the structure and distribution of knowledge within communities (Felt 1994, Ruddle 1994, Olsson and Folke 2001, Crona 2006, Knudsen 2008) and how it corresponds to broader differentiations and power relations (Crona and Bodin 2010). For example, Chapman (1987) focuses particularly on the different fishing practices and ecological knowledge held by men and women in Oceania, which are distinct but complementary. At a broader scale, the question of how ecological knowledge systems interact at different decision-making scales has also been examined (Evans 2010), as have the impacts of the broader social and political context on the ability of marine tenure systems to adapt and support well-being (Coulthard 2011). Local tenure systems—such as those in the Fiji Local Marine Management Areas network, which are based on traditional i poli (fishing territories) (Fiji Locally Managed Marine Areas Network 2011)—have also been successfully aggregated, in order to appropriately scale LTK and participation to marine ecosystem governance needs.

Valdés-Pizzini and García-Quijano (2009:163) collected LTK at the level of the individual fisher, on habitats, species, and the relationships between these two variables, while also exploring fishers’ mental schemata of habitats and the habitat–species coupling using the specific example of mutton snapper as a prototype. The relationship between fishers’ ecological knowledge and their fishing success has been probed, finding that human factors such as knowledge and skill may play as much of a role in fishing success as material or technological factors (Bjarnason and Thorlindsson 1993), and that LTK may correlate positively with success, where success is understood as a fisher’s ability to manage unpredictability in a complex, changing environment (García-Quijano 2009).

A second, growing body of literature discusses the role of LTK in national and international policy (Agrawal 1995, Mauro and Hardison 2000, Berkes et al. 2001b, Agrawal 2002, Memon et al. 2003, Ellis 2005). For example, Satria (2007) analyses why traditional fishing practices ceased and then were re-instituted in Indonesia. Power and Mercer (2003) describe the role of fishers’ knowledge in the implementation of the Oceans Act in Canada, while Shepert (2008) describes the relationship between LTK and the legal framework for fishfin aquaculture in British Columbia. More broadly, Zurba (2009) examines how local knowledge may be excluded from governance systems due to existing policies, drawing on data from Great Barrier Reef Marine Park. Finally, Jones et al. (2010) note the important role of LTK in marine spatial planning, which from the Haida First Nation’s perspective, is foundational to successful comanagement with Canada’s Department of Fisheries and Oceans.

A third body of literature critically reflects on methods (Neis et al. 1999, Neis and Felt 2000, Berkes et al. 2001a, Vayda et al. 2006, Watson and Huntington 2008) and ethics in LTK research (Wenzel 1999, Maurstad 2002, Silver and Campbell 2005). These studies caution against simple, extractive approaches and show how deeper-level ethnographic, participatory, and iterative methods can lead to more ethical, respectful, and constructive engagements with LTK bearers and indigenous communities. The benefits of a deep ethnographic approach, often involving years of research, are evident in a handful of classic marine LTK monographs (e.g., Malinowski 1922, Nelson 1969, Johannes 1981).

Fourth, some work has sought to compare LTK and data gathered by Western scientific methods. For example, Silvano and Valbo-Jorgensen (2008) compare Brazilian fishermen’s knowledge with published studies, finding cases of both agreement and disagreement, as do Batista and Lima (2010) in a similar examination of knowledge of jaraquís. Silvano and Valbo-Jorgensen argue that divergent results should prompt new studies rather than lead to the assumption that one knowledge system has the right answer. Dow et al. (2011) compares fishers’ reports of catch rates with official landings data and underwater visual census (UVC) in the Seychelles, finding that each data source gave different perceptions of trends in the biomass of fish and catches over the study period. Other such studies have compared seasonal abundance patterns (Manajarréz-Martínez et al. 2010) and seabird chick emergence and size (Moller at al. 2009a). Aporta and Macdonald (2011) contrast scientific and Inuit approaches to sea ice, focusing on the difficulty of documenting the complex interplay of Inuit knowledge and practices outside the context of sea ice travel.

In other cases, rather than comparing knowledge from both LTK and science, work on climate change in the Arctic in particular has sought to improve our understanding of climate change by examining both scientific and Inuit perspectives (for example, Laidler 2006). Finally, a few studies have probed the relationship between scientific and indigenous epistemologies in the context of collaborative management projects (Fienup-Riordan 1999, Zavaleta 1999, Norton 2002, Gearheard et al. 2006, Leduc 2007, Murray et al. 2008). Dale and Armitage (2011) posit a set of five interrelated dimensions—knowledge gathering, sharing, integration, interpretation, and application—requisite for successful knowledge coproduction and adaptive capacity building in Arctic marine mammal comanagement (see also Armitage 2005, Armitage et al. 2007). On a similar theme, Pulssifer et al. (2011) discuss how a sea ice data management system could be structured so as to create a process that includes data based on indigenous knowledge systems linked to data collected in the Western scientific tradition.
This summary of work examining marine LTK as a knowledge system illustrates how the literature focuses not only on knowledge and on the practices themselves, but may also consider processes by which LTK is transmitted within a community or into broader society, and in light of changes, such as technological innovation, that communities face. One potential gap in this literature is an exploration of what conditions are necessary for the continued creation and maintenance of LTK. If LTK is a living, dynamic body of knowledge then, like science, it requires application and refinement in practice in order to persist. Dale and Armitage (2011:446) emphasize that “application is not an end-point in a knowledge co-production process, but rather involves the translation of evolving knowledge into specific management decisions and the development, modification and evaluation of the plans and programs it shapes.” Evolving knowledge is also a theme for Aporta and Higgs (2005:738), who analyze how GPS technology affects traditional way-finding, and note that “despite the well-known Inuit ability to adapt to new technologies and new circumstances, GPS technology has the potential to deeply modify and cause disengagement from a well-established approach to the geographic surroundings and to the environment in general.” Other work, such as that of Reyes-Garcia et al. (2007), which considers how market integration of Amazonian societies affects botanical LTK, may be useful in revealing what critical constraints shape the contemporary development and maintenance of marine LTK. These studies suggest that while LTK does not simply erode or ossify in the wake of social, technical, and environmental change, its content, resilience, and adaptive development are not guaranteed and depend on a range of interrelated factors.

MARINE LTK RESEARCH TO DATE: AIMS, SUBJECT MATTER, AND POTENTIAL

This part reviews the aims and focus of marine LTK research to date, highlighting the roles that LTK plays, and could potentially play, in the governance of marine social-ecological systems. We proceed first by defining key terms and the review’s scope.

Definitions and scope of review

A broad range of concepts, topics, and terms can be related to LTK, including indigenous knowledge (IK), indigenous skill, folk knowledge, informal knowledge, ethnobiology, ethnoscience, and ethnoichthyology. As noted above, LTK is best understood as integrated and situated knowledge rather than as merely an assemblage of facts; an oft-cited definition of traditional ecological knowledge (TEK) is that it is “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment” (Berkes et al. 2000:1252). LTK and TEK are used synonymously here, though LTK is perhaps a broader term because it may include knowledge that is, strictly speaking, not ecological (Berkes 2008). Marine LTK may thus embrace subjects ranging from indigenous knowledge of salmon spawning grounds to the multiple Inuit terms for sea ice, commercial fishermen’s knowledge of bait-to-catch ratios, and navigators’ knowledge of currents and tides. The term “marine” is similarly broad, and for our purposes includes LTK relating to the zone between the deep sea and coastal habitats.

Our study was carried out by surveying the scholarly literature via electronic databases and library catalogue searches for relevant sources. The review effort attempted to be as comprehensive as possible, but some subject areas were excluded. Inland waters are generally excluded except where they relate to animals that travel inland from the ocean to spawn or to seabirds that inhabit delta regions. Wetlands are also excluded. Moreover, while there is also a burgeoning field of literature dedicated to indigenous knowledge and climate change, this review is limited to studies that are directly concerned with the components of the marine environment, such as sea ice. In addition, the review excludes most work related to prehistory, as well as the medicinal uses of marine resources (cf. Demunshi and Chugh 2010). The review includes studies that describe LTK and those that analyze specific practices, as long as the latter draw links between the practices and ecological knowledge.

The study reviewed over 240 scholarly articles and books. Geographically, of the articles and books that focus on a particular location, 42% of the research is centered in North America (with studies in Arctic Canada and Alaska accounting for 54% of those North American articles), 22% in Oceania, and 12% in Asia, with each of Africa, Europe, South America, and Central America and the Caribbean) accounting for 2 to 8% of the articles. The predominance of articles from North America reflects a similar finding by Brook and McLachlan (2008) in a broad review of the use of LEK in scholarly research. This dominance can be attributed to the rapid development of these studies among northern indigenous peoples in conjunction with management, conservation, and development initiatives in North America (cf. Cruikshank 2001, Hunn et al. 2003, Turner and Berkes 2006).

Aims of marine LTK research

Given the calls for greater collaboration between scientists and local knowledge holders, we first examine the aims of academic research relating to marine LTK. Broadly put, marine LTK studies can be divided into “documentation” type studies that add to existing knowledge for various uses, and more instrumental studies that explicitly seek to improve marine resource management.

Documentation and research design

Documentation studies are those that describe and interpret LTK within a cultural or cross-cultural context (see, Table 1). For example, within anthropology there is a long history of
<table>
<thead>
<tr>
<th>LTK collected</th>
<th>Species</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current abundance and spatial distribution of species</td>
<td>Beluga whales</td>
<td>Carter and Nielsen 2011</td>
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<tr>
<td></td>
<td>Bumphead parrotfish</td>
<td>Aswani and Hamilton 2004, Dulvy and Polunin 2004</td>
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<td></td>
<td>Bowhead whales</td>
<td>Noongwook et al. 2007</td>
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<td></td>
<td>Goliath grouper</td>
<td>Cavaleri Gerhardinger et al. 2009b</td>
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<td></td>
<td>Ivory gull</td>
<td>Mallory et al. 2003</td>
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<td></td>
<td>Oysters</td>
<td>Hill et al. 2010</td>
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<td></td>
<td>Polar bears</td>
<td>Dowsley and Wenzel 2008</td>
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<tr>
<td></td>
<td>Spatial variation in emergence of sooty shearwater chick</td>
<td>Moller et al. 2009a</td>
</tr>
<tr>
<td>Migratory or seasonal movements</td>
<td>Beluga whale</td>
<td>Huntingdon et al. 1999, Mymrin et al. 1999</td>
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<tr>
<td></td>
<td>Bowhead whale</td>
<td>Noongwook et al. 2007</td>
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<td></td>
<td>Brazilian coastal fish</td>
<td>Silvano et al. 2006</td>
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<td></td>
<td>Cod</td>
<td>Murray et al. 2008</td>
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<td></td>
<td>Jaraquis</td>
<td>Batista and Lima 2010</td>
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<td></td>
<td>Pomatomus saltatrix</td>
<td>Silvano and Begossi 2005</td>
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<tr>
<td>Sightings of species</td>
<td>Dugongs</td>
<td>Rajamani and Marsh 2010</td>
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<td></td>
<td>Sharks</td>
<td>Rasalato et al. 2010</td>
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<tr>
<td>Stranding incidents</td>
<td>Dugongs</td>
<td>Rajamani and Marsh 2010</td>
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<tr>
<td>Health of species</td>
<td>Condition of polar bears</td>
<td>Dowsley and Wenzel 2008</td>
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<tr>
<td>Size of species</td>
<td>Patterns in size of Puffinus griseus chicks</td>
<td>Moller et al. 2009a</td>
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<tr>
<td>Life history</td>
<td>Goliath grouper</td>
<td>Cavaleri Gerhardinger et al. 2006</td>
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<td></td>
<td>Jaraquis (size of sexual maturity, growth, mortality)</td>
<td>Batista and Lima 2010</td>
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<tr>
<td>Stock structure</td>
<td>Cod</td>
<td>Goss et al. 2003, Murray et al. 2008</td>
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<tr>
<td>Key habitats</td>
<td>Gadoid fishes</td>
<td>Bergmann et al. 2004</td>
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<tr>
<td>Spawning and nursery areas</td>
<td>Cod</td>
<td>Ames 2007</td>
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<tr>
<td></td>
<td>Goliath grouper</td>
<td>Aguilar-Perera et al. 2009</td>
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<td></td>
<td>Multiple fish species</td>
<td>Knutsen et al. 2010</td>
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<tr>
<td>Past abundance</td>
<td>Beluga whales</td>
<td>Carter and Nielsen 2011</td>
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<td></td>
<td>Chinese bahaba</td>
<td>Sadovy and Cheung 2003</td>
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<td></td>
<td>Cod stocks</td>
<td>Rosenberg et al. 2005</td>
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<td></td>
<td>Frigate tuna</td>
<td>Venkatachalam et al. 2010</td>
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<td></td>
<td>Goliath grouper</td>
<td>Aguilar-Perera et al. 2009</td>
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<td></td>
<td>Herring</td>
<td>Jones 2007, Thornton et al. 2010</td>
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<td></td>
<td>Lobster (Jasus frontalis)</td>
<td>Eddy et al. 2010</td>
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<td></td>
<td>Multiple finfish species (local extinction)</td>
<td>Lavides et al. 2009</td>
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<tr>
<td>Behavior</td>
<td>Carangidae fish aggregation</td>
<td>Hamilton and Walter 1999</td>
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<td></td>
<td>Polar bears</td>
<td>Keith et al. 2005, Lemelin et al. 2010</td>
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<tr>
<td></td>
<td>Dugongs</td>
<td>Johannes and MacFarlane 1991</td>
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<tr>
<td>Reproduction-related behavior</td>
<td>Breeding of geese in relation to storm surges</td>
<td>Fienup-Riordan 1999</td>
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<td></td>
<td>Calving in beluga whales</td>
<td>Huntingdon et al. 1999, Mymrin et al. 1999</td>
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<td></td>
<td>Nesting-site fidelity in sea turtles</td>
<td>Johannes and Nels 2007</td>
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<td></td>
<td>Parental care in jaraquis</td>
<td>Batista and Lima 2010</td>
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<tr>
<td></td>
<td>Reproduction in various coastal fish</td>
<td>Silvano et al. 2006</td>
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<td></td>
<td>Reproduction in Pomatomus saltatrix</td>
<td>Silvano and Begossi 2005</td>
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<td></td>
<td>Spawning of longfin emperor</td>
<td>Hamilton 2005</td>
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<td></td>
<td>Spawning behavior of various reef fishes</td>
<td>Boomhower et al. 2007</td>
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<td></td>
<td>Lunar cycles and fish reproduction</td>
<td>Johannes et al. 1981</td>
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<tr>
<td>Feeding behavior</td>
<td>Beluga whales</td>
<td>Huntingdon et al. 1999, Mymrin et al. 1999</td>
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<td></td>
<td>Jaraquis</td>
<td>Batista and Lima 2010</td>
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<tr>
<td></td>
<td>Polar bears</td>
<td>Lemelin et al. 2010</td>
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<td></td>
<td>Pomatomus saltatrix</td>
<td>Silvano and Begossi 2005</td>
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<tr>
<td>Effect of physical environment</td>
<td>Effects of lunar periodicity on fish</td>
<td>Aswani and Hamilton 2004</td>
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<td></td>
<td>Reactions of eider to shifting ice pack</td>
<td>Gilchrist and Robertson 2000</td>
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<td></td>
<td>Effects of climate variability on Arctic char</td>
<td>Knopp 2010</td>
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<tr>
<td>Human-animal interactions and effects</td>
<td>Polar bears</td>
<td>Keith et al. 2005, Lemelin et al. 2010</td>
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<td></td>
<td>Reactions of seals to fishing nets</td>
<td>Moore 2003</td>
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<td></td>
<td>Reactions of tuna to fishing devices</td>
<td>Moreno et al. 2007b</td>
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</table>
Improving resource management

The bulk of recent LTK research has been conducted with resource management in mind. Table 2 highlights three broad categories of studies. These categories include improving management through increased knowledge, improving or assessing management techniques, and informing conservation strategies.

The studies set out in Table 2 give some sense of the breadth of ways in which LTK can contribute to marine resource management. Moreover, specific studies within each of these categories illustrate the unique role that LTK can play in management and conservation. First, in relation to improving management simply through increasing the knowledge base about a given species or habitat, such an observation is most apparent in relation to studies that examine LTK of environmental change. In many cases, scientific measures are either too narrow, shallow, or broad to be meaningful in the context of community adaptation at the landscape scale. LTK anchored in particular locales over generations, in contrast, systematically records and contextualizes observations, which can help ground truth environmental events, impacts, and projections that may be captured only by scientific instruments or models at a very broad scale, if at all. Ames (2007:154) argues that the preoccupation of contemporary fisheries science with simplified models “has left it without the historical parameters needed to interpret fine-scale changes in stock distribution, behavior, or migration patterns over time. Consequently, management has lacked the ability to detect or interpret these changes . . .” Using LTK can thus be especially meaningful in recognizing and interpreting changes in habitat, species abundance and distribution, sea-ice qualities, and the like (Knopp 2010, Krupnik et al. 2010, Lauer and Aswani 2010).

Second, LTK has brought to light potentially useful traditional practices or institutions that could be incorporated into “contemporary” resource management. For example, it has been argued that the values, knowledge, and stewardship practices of First Nations peoples could be fruitfully integrated into the management and restoration of watersheds and coastal habitats (e.g., Berkes 1977, Jones and Williams-Davidson 2000, Thornton et al. 2009, Thornton and Kitka 2010, Thornton et al. 2010, Thornton 2012). At the same time, some works caution against a hasty borrowing of traditional practices for management (e.g., Palmer 1994:238), especially where population, habitat, or use conditions have changed appreciably. LTK’s very inclusion in management processes may change the broader social context to foster community empowerment in participatory management, such as in sea-urchin harvesting in St. Lucia (Warner 1997). This valorization, reflecting LTK’s continuing legitimacy and development, may in turn improve the resilience of the local knowledge and practices by encouraging young people to retain it “as a matter of personal experience” (Johannes 1981:149).

Studies highlighting LTK’s role in management conflicts shows that collaboration between LTK holders and scientists holds potential for improving stewardship. For example, Dowsley and Wenzel (2008:184) explore varying perceptions of polar bear abundance in Nunavut in the context of a comanagement arrangement, finding that disagreements over polar bear population numbers may be the result of either or both “incomplete data collection and synthesis among Inuit observers, or of scientific data collection that is too narrowly confined in geographic area.” They also note the possibility that LTK bearers have not yet perceived declines in bear conditions or population size, and suggest that improved collaboration between locals and scientists in interpreting large-scale scientific studies in relation to local observations might lead to broader consensus about the status and management of polar bears (Dowsley and Wenzel 2008:186). Huntington et al. (2004) emphasize similar spatial complementarity in studying the migration of beluga whales.

Third, in relation to conservation and marine spatial planning, numerous studies underscore the useful role of LTK. Drew (2005) argues that TEK can strengthen conservation programs through improved knowledge of the specific location and relevant environmental linkages, and through the improved local capacity and power sharing that comes with including knowledge holders as equal partners in research programs. LTK can be especially valuable in planning and assessing Marine Protected Areas (MPAs). For example, Ban et al. (2009) developed a framework for integrating the preferences and concerns of First Nations peoples into the site selection of potential MPAs. A recent review of MPAs suggests there is a long way to go, however, because “potentially existing
Table 2. Management-focused marine LTK studies: examples from the literature.

<table>
<thead>
<tr>
<th>Broad aim</th>
<th>LTK–management focus</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase knowledge base to improve management</td>
<td>Species or habitat</td>
<td>Silvano et al. 2006, Hill et al. 2010, Lemelin et al. 2010, Rasalato et al. 2010</td>
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<td></td>
<td>Sightings</td>
<td>Rajamani and Marsh 2010</td>
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<td></td>
<td>Seasonal patterns</td>
<td>Manajarrez-Martinez et al. 2010</td>
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<td></td>
<td>Stock structure</td>
<td>Gosse et al. 2003, Nielsen 2009</td>
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<td></td>
<td>Hunting incidence/incidental catch</td>
<td>Rajamani and Marsh 2010</td>
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<td></td>
<td>Environmental change</td>
<td>Lauer and Aswani 2010, Knopp 2010</td>
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<tr>
<td></td>
<td>Identify commonalities between LTK and commercial fishers knowledge</td>
<td>Batista and Lima 2010</td>
</tr>
<tr>
<td>Assess, improve, and/or develop management techniques</td>
<td>Examine seabird egg harvesting strategies in relation to population ecology</td>
<td>Hunn et al. 2003</td>
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<td></td>
<td>Resolve management disputes</td>
<td>Davis et al. 2004, Dowsey and Wenzel 2008</td>
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<td></td>
<td>Assess parametric fisheries management</td>
<td>Acheson and Wilson 1996</td>
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<td></td>
<td>GIS mapping of mapping local fishing areas</td>
<td>Anuchiracheeva et al. 2003</td>
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<td></td>
<td>GIS mapping of spawning and nursery areas</td>
<td>Knutsen et al. 2010, Thornton et al. 2010</td>
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<td></td>
<td>Classification of remote sensing imagery</td>
<td>Lauer and Aswani 2008</td>
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<tr>
<td></td>
<td>Develop expert system models</td>
<td>Mackinson 2001, Grant and Berkes 2007</td>
</tr>
<tr>
<td></td>
<td>Develop parametric indicators</td>
<td>Wilson et al. 2006</td>
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<tr>
<td></td>
<td>Inform marine spatial planning</td>
<td>Cinner et al. 2010</td>
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<tr>
<td></td>
<td>Identify essential habitats</td>
<td>Bergmann et al. 2004</td>
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<tr>
<td>Develop and inform conservation strategies</td>
<td>Bringing together fisher and scientist knowledge</td>
<td>Akimichi 2001</td>
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<td></td>
<td>Construction of artificial reefs</td>
<td>Kurien 2001</td>
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<td></td>
<td>Assess effectiveness of conservation zone</td>
<td>Baird and Flaherty 2005</td>
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<td></td>
<td>Assess conservation status of species in IUCN hotspots</td>
<td>Dulvy and Polunin 2004</td>
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<td></td>
<td>Determine local extinction vulnerability of species</td>
<td>Castellanos-Galindo et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Identify potential environmental and human-related factors impacting beluga whales</td>
<td>Carter and Nielsen 2011</td>
</tr>
<tr>
<td></td>
<td>Inventory the disappearance of certain fish</td>
<td>Lavides et al. 2010</td>
</tr>
<tr>
<td></td>
<td>Improve conservation through targeted data collection</td>
<td>Cavaleri Gerhardinger et al. 2006, Richmond et al. 2007, Cavaleri Gerhardinger et al. 2009b</td>
</tr>
<tr>
<td></td>
<td>Study fisher perception of conservation efforts</td>
<td>Rosa et al. 2005</td>
</tr>
<tr>
<td></td>
<td>Inform mangrove restoration</td>
<td>Biswas et al. 2009</td>
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</table>

ecological knowledge of local communities is seldom acknowledged when designing MPAs” (Ferse et al. 2010:26). Indeed, in the context of a national park in southern Brazil, Almudi and Coswig Kalikoski (2010:225) found that a top-down MPA model “disregarded the fisherfolk’s cultural practices and particular knowledge, thereby violating their rights as traditional people.” Such violations tend to further undermine the integrity and resilience of LTK and livelihood systems.

**Substantive focus of LTK research**

A broad review of the literature reveals that LTK has been collected about many facets of marine environments, though species-specific studies are particularly prominent. Table 1 details these findings.
Table 3. How the substantive focus of marine LTK studies has broadened: examples from the literature.

<table>
<thead>
<tr>
<th>Category</th>
<th>Study focus</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecology</td>
<td>Marine habitats, spawning and nursery areas</td>
<td>Knutsen et al. 2010, Thornton et al. 2010</td>
</tr>
<tr>
<td></td>
<td>Historical ecology of coral reef guilds</td>
<td>Shackeroff et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Marine/coastal habitats and tsunami impacts</td>
<td>Venkatachalam et al. 2010</td>
</tr>
<tr>
<td>Physical environment and cultural adaptation</td>
<td>Tidal cycles and wind patterns</td>
<td>Tobisson et al. 1998, Nirmale et al. 2004a</td>
</tr>
<tr>
<td></td>
<td>Lunar cycles</td>
<td>Cordell 1974, Nirmale et al. 2004a</td>
</tr>
<tr>
<td></td>
<td>Effect of water color on catch</td>
<td>Nirmale et al. 2004a</td>
</tr>
<tr>
<td></td>
<td>Weather and climate</td>
<td>Lefale 2010</td>
</tr>
<tr>
<td></td>
<td>Indicators of cyclone intensity</td>
<td>Nirmale et al. 2004a, 2007</td>
</tr>
<tr>
<td></td>
<td>Seabed morphology</td>
<td>Tobisson et al. 1998</td>
</tr>
<tr>
<td></td>
<td>Finding fishing spots based on physical environment</td>
<td>Forman 1967, Schafer and Reis 2008</td>
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<tr>
<td></td>
<td>Response to potentially tsunami-forming earthquakes</td>
<td>McAdoo et al. 2009</td>
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<tr>
<td></td>
<td>Interpreting satellite images and aerial photos using LTK</td>
<td>Aswani and Lauer 2006</td>
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<tr>
<td></td>
<td>Tropical coastal habitat connectivity</td>
<td>Garcia-Quijano 2007</td>
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<tr>
<td></td>
<td>Currents and island waters</td>
<td>Johannes 1981</td>
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<tr>
<td></td>
<td>Adaptation to sea ice environment</td>
<td>Riewe 1991, George et al. 2004</td>
</tr>
<tr>
<td></td>
<td>Incorporation of sea ice LTK and satellite imagery</td>
<td>Laidler et al. 2011</td>
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<tr>
<td></td>
<td>Navigation (general)</td>
<td>Cruikshank 2001, 2005</td>
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<tr>
<td></td>
<td>Collaborative mapping</td>
<td>Aporta 2003</td>
</tr>
<tr>
<td></td>
<td>Weather/ocean/climate conditions</td>
<td>Gearheard et al. 2011</td>
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<tr>
<td></td>
<td>Mangrove forests (e.g., disturbance, extent)</td>
<td>Alvarez and Vodden 2009</td>
</tr>
<tr>
<td></td>
<td>Assessing environmental change</td>
<td>Kovacs 2000, Hernandez Cornejo et al. 2005</td>
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<tr>
<td></td>
<td>Geographic distribution, seasonality and severity of algal blooms</td>
<td>Schlacher et al. 2010</td>
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<td></td>
<td>Long-term ecological change in seagrass meadows and causal factors</td>
<td>Lauer and Aswani 2010</td>
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<td></td>
<td>Nearshore macrobenthos affected by local sewage disposal</td>
<td>Jewett et al. 2009</td>
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<td></td>
<td>Climate variability and Arctic</td>
<td>Knopp 2010, Barber et al. 2010</td>
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<td></td>
<td>Changes in sea ice</td>
<td>Gearheard et al. 2006</td>
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<td></td>
<td>Relationship between sea ice and climate change</td>
<td>Laudier 2006</td>
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<td></td>
<td>Names for fish</td>
<td>Krupnik and Carleton Ray 2007, Metcalf and Robards 2008</td>
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<tr>
<td></td>
<td>Marine invertebrates</td>
<td>Sloan and Barthier 2009</td>
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<td></td>
<td>Names for hydrological features</td>
<td>Burenhult 2008</td>
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<td></td>
<td>Coastal proverbs</td>
<td>Kurien 1998</td>
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<td></td>
<td>Ancestral sayings and a coastal wetland plant</td>
<td>Wehi 2009</td>
</tr>
<tr>
<td></td>
<td>Management practices in small-scale subsistence or commercial fisheries</td>
<td>(con’d)</td>
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</table>
Not surprisingly, LTK collected in these studies is focused at
the human scale of experience. For example, animal-related
LTK focuses especially on species that are hunted, while that
which deals with physical geography generally relates to
navigation and safety. This emphasis supports the view that
fishers’ ecological knowledge is primarily, though not
exclusively, utilitarian (McGoodwin 2001). Indeed, Foale
(1998:200) remarks that most LTK “possessed by subsistence,
artisanal and commercial fishers is focused on how to locate
individuals of a target species in space and time, and, once
located, how to capture them.” Baines (1992:100) adds that
on a Pacific island, fishers’ knowledge is instrumental, or
“primarily behavior oriented, focusing on the information
required to find and capture.” Correlatively, “empirical gaps”
(Foale 2006a) in LTK concern parts of the life cycle that are
comparatively unknown to fishers because they are beyond
the scope of their experience or perception. Thus local
observations and traditional knowledge are generally not very
useful at chemical, biochemical, or cellular levels (Berkes et
al. 2007). On the other hand, the phenotypic manifestations of
chemical changes within an animal may be readily perceived
by LTK holders.

Table 3 summarizes marine LTK studies relating to ecology,
the physical environment, assessments of environmental
change, language, and resource management. The table
illustrates how the substantive focus of modern LTK studies
has broadened beyond knowledge of species to include marine
ecological and physical processes. Knowledge of marine
ecology is often built up and maintained in the context of
specific subsistence practices, such as hunting and fishing,
which are conditioned by broader ecosystem dynamics
(Johannes and MacFarlane 1991). For example, following a
2007 tsunami in the Solomon Islands, McAdoo et al. (2009:81)
found that indigenous knowledge can be “an effective tsunami
mitigation tool when the right combination of education and
physiography come together”. Many authors (Wohlfithor
2009, Gearheard et al. 2011, Pearce et al. 2011, ) suggest that
LTK can be used not only to understand the physical and socio-
cultural risks, vulnerabilities, and other impacts of climate
change in the Arctic but also as a source of resilience and
adaptive capacity in response to these changes.

Moreover, classical ethnoscience studies carried out by
linguists and ecological anthropologists (cf. Conklin 1957)
have recognized the importance of language and nomenclature
in reflecting the LTK of environments. Indeed, names for
marine species, habitats, and the like can be an important first
step in integrating LTK with scientific knowledge (Sloan and
Barthier 2009). The potential link between the richness of
terminology and knowledge of geological features and
processes has also been highlighted in recent studies (Terry
and Etienne 2011). There is scope to further explore such
relationships between language, culture, and marine ecology
and biocultural diversity.

In parallel with the studies described above, which aim to
improve management techniques, another body of research
embraces the diversity of community resource management
practices. For example, Klee (1980; see also Johannes 1981)
describes taboos and bans in lagoon tenure systems in the
South Pacific Islands, as well as the figure of the “Master
Fishermen” who acted as an island’s authority on fishing lore
and practice. Thornton (2008, 2012) describes a similar
“Master of the Stream” figure for important Tlingit salmon
link the “first salmon” ritual of multiple aboriginal
communities in California to conservation practice.
Knowledge of this diversity can improve regulatory regimes
when these rules do not conflict with sustainable local
practices; McClanahan and Cinner 2008), for example,
examined the fishing gear used by a community in Papua New
Guinea, and suggest that LTK in tandem with scientific
monitoring could be used to establish an adaptive management
framework for gear restrictions.

AN EMERGING FOCUS ON COLLABORATIVE
RESEARCH AND MANAGEMENT
As noted above, collaboration and the coproduction of
knowledge between LTK communities, scientists, and
resource managers on research and management projects is a potentially constructive pathway to bridge science and LTK. The growing literature on collaborative projects is instructive in providing guidelines for how to approach this bridging in ways that maintain the integrity of knowledge systems and enhance exchange between them, while at the same time improving adaptive management. This section examines eleven examples of collaborative projects. Table 4 lists the main studies examined, and their focus and methods. The table makes it clear that the majority of these examples come from the North American Arctic, where it would appear there is the most collaborative research activity. The following analysis therefore bears in mind this context, although it is arguable that a number of the considerations discussed will be applicable elsewhere.

How have collaborative projects managed the relationship between LTK and modern science? The differences between LTK and modern science are often significant (Cruikshank 2005) and underpinned by foundational differences in cosmology and worldview, but at the same time can be overdrawn (Agrawal 1995). As Krupnik (2002:185) suggests, “it is not a different nature but rather a different focus of scientific and ‘local’ knowledge, that commonly keeps these two types of expertise looking in different directions.” An appreciation of where LTK and science have their relative expertise is thus important, as is the relative status of that expertise (Laidler 2006) and mutual respect (Moller et al. 2009b). In cases where the focus or scale of inquiry may be the same, collaborative research may take science and LTK as equals. Carmack and Macdonald (2008:25) term this approach “coscience” where “natural phenomena are examined through both indigenous and Western methods; each approach is assumed valid within its own set of rules and neither replaces the other.” They argue further that “the practical and emergent outcome of this approach is that joint enquiry will focus on phenomena that are important to native peoples for their way of life and will bring Western scientists closer to a ‘system science’ level of understanding.” Similarly, in a participatory mapping exercise, Hall et al. (2009:2059) aimed to create a “virtual space” in which LTK and science “can play equal roles relative to rekindling the broader goal of collaborative participation in management and planning.” However, appreciative inquiry and participatory methods in themselves may not lead to the development of co-equal knowledge and management systems (Nadasdy 2003).

Fernandez-Giminez et al. (2006) delineate signs of successful integration of LTK and science. In examining the Alaska Beluga Whale Committee, they found that hunters began to communicate scientific knowledge, and even quite specific scientific studies, amongst each other, while scientists began to understand the broader cultural context and implications of their work. Moller et al. (2009b:234) report that Maori interest in research led to the formation of Maori research methodologies “where Maori remain in charge of research initiation, benefits, representation, legitimation and accountability.” The process of getting to such an understanding may be a necessary first step toward developing co-equal knowledge and management systems, and can be fostered by setting collaboration milestones to achieve successful integration. Yet cases of native-led research and equitable partnerships between science and LTK, despite the promise of coscience, are still quite rare.

In terms of practical engagement, the importance of relationships and trust is emphasized in successful collaborative projects. Many scientists have noted the important role that ongoing relationships in a given community play in their work (Norton 2002, Fernandez-Giminez et al. 2006, Gearheard et al. 2006, Tremblay et al. 2008). Indeed, Moller et al. (2009b:219) note that of the attributes identified for successful comanagement by scientists and local resource managers, “trust and respect for each other were the most fundamental and time consuming to establish and demonstrate.” Where such relationships did not initially exist, it was important for scientists to build trust and respect for themselves (Fienup-Riordan 1999). Norton

Table 4. Collaborative projects that bridge LTK and science: examples from the literature.

<table>
<thead>
<tr>
<th>Examples</th>
<th>Focus</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baines 1992</td>
<td>Various subjects, focusing on fish and fishing</td>
<td>Researchers resident in community, reciprocal training</td>
</tr>
<tr>
<td>Carmack and Macdonald 2008</td>
<td>Water and ice-related phenomena (Arctic Canada)</td>
<td>Dialogue with elder</td>
</tr>
<tr>
<td>Fernandez-Giminez et al. 2006</td>
<td>Beluga whales (Alaska)</td>
<td>Comanagement committee</td>
</tr>
<tr>
<td>Fienup-Riordan 1999</td>
<td>Geese (Alaska)</td>
<td>Interviews</td>
</tr>
<tr>
<td>Gearheard et al. 2006</td>
<td>Sea ice (Alaska/Canada)</td>
<td>Knowledge exchange with field trips</td>
</tr>
<tr>
<td>Hall et al. 2009</td>
<td>Oyster fishery (New Zealand)</td>
<td>Participatory monitoring</td>
</tr>
<tr>
<td>Krupnik 2002</td>
<td>Ice and weather (Alaska)</td>
<td>Workshop and locally led documentation project</td>
</tr>
<tr>
<td>Moller et al. 2009b</td>
<td>Seabird harvest (New Zealand)</td>
<td>Long-term research partnership</td>
</tr>
<tr>
<td>Norton 2002</td>
<td>Sea ice (Alaska)</td>
<td>Symposium</td>
</tr>
<tr>
<td>Obura et al. 2002</td>
<td>Local fish monitoring (Tanzania)</td>
<td>Community engagement in research</td>
</tr>
<tr>
<td>Tremblay et al. 2008</td>
<td>Local climate (Arctic Canada)</td>
<td>Community-based monitoring</td>
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http://www.ecologyandsociety.org/vol17/iss3/art8/
(2002:131) describes how these relationships grew by "scientists learning to live and conduct fieldwork safely on the ice alongside whalers for two months each spring." In building these relationships, the creation of different opportunities in which communication can be fostered is important, through both formal and informal interactions (Baines 1992, Fernandez-Giminez et al. 2006, Gearheard et al. 2006). In particular, Gearheard et al. (2006:203) note that "opportunities for cultural exchange were an important aspect of the project that helped create trust and comfort in the research team."

Obura et al. (2002) also argue that, particularly in the case of long-term monitoring, relationships are crucial, and that commitment from all actors involved is necessary. Even before any knowledge sharing can begin, and questions of how to bring together science and LTK can be raised, relationships based on trust and shared experience must be developed. Moller et al. (2004) note that studies which aim to combine scientific and traditional methods may be a fruitful context in which to build such relationships. Indeed, Turnbull (1997:551) affirms that there is a need to "enable disparate knowledge traditions to work together through the creation of a third space in which the social organization of trust can be negotiated."

In project design, this "third space" often springs from a shared interest in a vital subject. For example, both Norton (2002) and Tremblay et al. (2008) note that their focus on nearshore sea ice and its link to safety meant that their research was useful to the community, which is a compelling environmental change and management problem for study. Moller et al. (2009b) explain that concern for seabirds and their well-being meant that many birders saw long-term value in the research. In other cases, the desire to collaborate on formal documentation of LTK was motivated by the community’s aim to safeguard the knowledge for future generations (Baines 1992, Krupnik 2002, Fernandez-Giminez et al. 2006, Hall et al. 2009).

The collaboration of LTK bearers in codirecting all phases of the research is consistently highlighted as an important element of successful projects. Research questions and protocol are best developed in collaboration with village elders (Fienup-Riordan 1999). In cases in which collaboration focuses on a group setting, it is crucial that the group be made up of locals and scientists (Fernandez-Giminez et al. 2006, Gearheard et al. 2006) and that the organizational structure be conducive to power sharing (Fernandez-Giminez et al. 2006). In cases in which collaboration emphasizes monitoring, an appropriate level of training is requisite (Obura et al. 2002). Ultimately, these factors contribute enormously to a constructive sense of cooperative ownership of the project (Fernandez-Giminez et al. 2006). These considerations are reflected in Pearce et al.’s (2009) review of collaborative climate change research in Arctic Canada, which also emphasizes the importance of having early and ongoing communication, involving communities in research design and development, and facilitating opportunities for employment and disseminating results. Correlatively, Gearheard and Shirley (2007) make a number of recommendations stemming from their analysis of natural sciences research in Nunavut, among them that trust-building can be fostered through early community consultation, regular research reports, and the use of local experience and resources.

However, as Obura et al. (2002:219) stress, project design must also help local communities build capacity for the collection, analysis, and dissemination of technical information so that their ability to participate in resource management is strengthened. Thus, funding for community participation and “the equitable sharing of resources to facilitate active participation is essential” (Moller et al. 2009b:229). Projects with such community benefits are more likely to garner community involvement and support that will enhance long-term relationships necessary for trust and capacity-building and adaptive learning about the benefits of LTK in relation to science.

Yet, collaborative research poses a number of challenges. The cases examined emphasize that perceptions of the role of science and the aims of the scientists may have an influence on how projects proceed, particularly at their inception. For example, Fienup-Riordan (1999) found that elders expressed deep resentment toward the nonlocal control that researchers and wildlife managers represented, while Fernandez-Giminez et al. (2006) note that hunters often perceived knowledge to be a tool of state control. Moller et al. (2009b) maintain that in order to succeed, research partnership projects require both a strong mandate from the community at large and active leadership from within the participating community. Project design therefore not only has to be cognizant of these attitudes but has to take positive steps to engage them by creating a new space for knowledge coproduction, colearning, and comanagement.

Logistically, the costs and complexity of creating such spaces can be high. Even setting up a simple knowledge exchange with field visits is expensive (Gearheard et al. 2006). Obura et al. (2002) discovered the difficulty of securing sufficient long-term funding for such things as monitoring. The pace of research is also likely to be slower than that done in the absence of a community of interest (Moller et al. 2009b). Other challenges to successful collaboration include: local employment trends and attitudes, revolving membership and leadership of community organizations, competing or concurrent local activities at the time of research, cultural barriers, poor historical research, community–researcher relations, the economic subtext of many community–research relationships, financial limitations, time constraints, and communicating results to stakeholders (Pearce 2009). These practical challenges can undermine the viability, equality,
integrity, and resilience of coscience systems emerging in the third space.

Stable bridging institutions such as the Alaska Eskimo Whaling Commission remain the exception rather than the rule, and they require significant funding, logistical support, and community backing to carry out their mandates. Significantly, this institution was born in the early 1980s out of conflict surrounding a proposed international moratorium on whaling that could have ended Eskimo subsistence on foundational species like the bowhead. Instead, however, the Commission was created to improve the science at the local scale by incorporating LTK (which showed significantly more whales present than scientists had been able to count) and management (distribution of hunting quotas) in meaningful and substantive ways. This has been highly effective, as Huntington (1992:115) relates, because: (1) the whalers administer the allocation and scientific review regime; (2) the quotas reflect the real needs of communities for whales; (3) whaling is a major economic and communal activity with strong traditional protocols and support for sharing and cooperation; and (4) “the goals of the AEWC have always been clear, and the battle with an outside authority has helped the whalers form a cohesive group. By averting the threat to Eskimo culture, the AEWC proved its usefulness, earning the pride and respect of the whalers.” In addition to this strong foundation and track record, the Commission is also comparatively well funded and high profile in its activities, reflecting its status and legitimacy across cultures.

CONCLUSION: A COLLABORATIVE AGENDA FOR MARINE SCIENCE AND LTK

Despite comprising more than 70% of the Earth’s surface, marine environments remain among the least understood of ecosystems. Yet they are increasingly under threat from development, degradation, climate change, and other forces. A lack of historical–ecological depth in marine studies means that in many cases we do not realize what we have lost (Anderson 2007, Roberts 2007). Despite some classic studies, marine LTK research overall is relatively young and is evolving rapidly, and there is a critical need for more substantive, deep ethnographic and multiscale research on marine ecosystems, as our ocean-dominated planet continues to evolve and change.

The successes and challenges discussed provide some guidelines for how successful collaborative work may proceed to improve our understanding of marine systems and foster adaptive management as they change. A diversity of approaches is evident in the literature, including multilocal bridging organizations, such as the Alaska Beluga Whale Committee (Fernandez-Giminez et al. 2006). These comanagement organizations are made up of local and state actors that can “provide an arena for knowledge co-production, trust building, sense making, learning, vertical and horizontal collaboration and conflict resolution” (Berkes 2009a:1695). Such institutions can create a forum in which local and scientific knowledge can be shared, produced, maintained, and used collaboratively. Dowsley (2009) advocates for a “community cluster approach” consisting of neighboring communities that share a spatially defined resource. She suggests that collaborative research would benefit from such a networked approach through increased information and monitoring that can lead to faster recognition of changes in the resource.

To keep the collaborative projects “moving forward” (Neis 2011), novel and hybrid approaches may be necessary to successfully represent LTK in the academy and beyond. Watson and Huntington (2008), for example, show how a traditional academic paper can be restructured to better represent different accounts of reality. Felt (2008) proposes that fisheries scientists in training should take part in a residency of a few months with local fishers, as such immersion through participant observation can help build trust and mutual appreciation and understanding. Workshops cosponsored with LTK holders may also provide “a practical and concrete basis upon which to build a shared understanding, or at least greater insight into the reasons behind divergent views” (Huntington et al. 2002:788). The Sitka Tribe of Alaska (a collaborator in numerous LTK studies) has, in the case of one key cultural species, gone beyond workshops to found the broad-based Sitka Sound Herring Research Planning Group to carry the collaborative agenda forward through regular communications, thereby building towards new research and management priorities that link local fishers’ knowledge and practices to appropriate methods and scales of marine ecosystem governance. Like their Haida neighbors, the Sitka Tribe seeks to collaborate with scientists to improve understandings of critical, complex, and changing marine environments with the help of LTK. Unfortunately, the embrace of LTK by state management is still too limited, though recent actions to create subsistence-only zones in key herring-spawning habitats in Sitka Sound (as requested by the Sitka Tribe) are an encouraging sign of respect for LTK and its herring-management principles.

These examples demonstrate that there is considerable room for constructive engagement of LTK as part of marine research, monitoring, spatial planning, and conservation. Further steps to enhance its role in improving adaptation and resilience should include: (1) stronger recognition of the relationship between marine biodiversity and the cultural diversity among maritime peoples; (2) acknowledgement of threats and stresses to marine LTK and sustainable livelihoods by historical and contemporary commercial harvesting, development, and environmental change in coastal zones and seascapes; and (3) the nurturing of traditional and collaborative stewardship systems to protect, restore, and enhance the productivity, diversity, and resilience of critical marine ecosystems that support sustainable maritime cultures.
By reviewing some of the successes and failures in marine LTK—science production, dissemination, policy implementation, and collaborative infrastructure development, we hope that more successful bridging projects and institutions that link local knowledge and science will be conceived, funded, and implemented in order to better inform critical environmental change and adaptive comanagement issues facing marine social-ecological systems today. This is a matter of some urgency, for as Alaskan Yup’ik Eskimo elder John Eric states, drawing on his own people’s reservoir of marine LTK: "We cannot live without the ocean. Our ancestors sustained themselves mainly from the ocean . . . . It’s no wonder that the ocean has the name imarpik [from imaq, "contents."], because it holds everything" (Fienup-Riordan and Reardon 2012:215).

Responses to this article can be read online at: http://www.ecologyandsociety.org/vol17/iss3/art8/responses/

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LITERATURE CITED


Ames, T. 2007. Putting fishers’ knowledge to work: reconstructing the Gulf of Maine cod spawning ground on the


Aporta, C. 2002. Life on the ice: understanding the codes of a changing environment. *Polar Record* 38:341-354. [http://dx.doi.org/10.1017/S002672720200018039](http://dx.doi.org/10.1017/S002672720200018039)


Cablitz, G. 2008. What “what” is “where”: a linguistic analysis of landscape terms, place names and body part terms, place


Demunshi, Y., and A. Chugh. 2010. Role of traditional knowledge in marine bioprospecting. *Biodiversity and


Fiji Locally Managed Marine Areas Network (FLMMA). 2011. The way we work together: guidelines for members of the FLMMA network, final 1.7 March 2011. FLMMA Operations Guide. Institute of Applied Sciences, Faculty of Science Technology and Environment, University of the South Pacific, Suva, Fiji.


Hall, B. G., A. Moore, P. Knight, and N. Hankey. 2009. The extraction and utilization of local and scientific geospatial knowledge within the Bluff oyster fishery, New Zealand. *Journal of Environmental Management* 90:2055-2070. [http://dx.doi.org/10.1016/j.jenenvman.2007.08.022](http://dx.doi.org/10.1016/j.jenenvman.2007.08.022)


Henshaw, A. 2009. Sea ice: the sociocultural dimensions of a melting environment in the Arctic. In S. Crate and M. Nuttall, editors. *Anthropology and climate change: from encounters to action*. Left Coast Press, Walnut Creek, California, USA.


Huntington, H., R. Suydam, and D. Rosenberg. 2004. Traditional knowledge and satellite tracking as complementary approaches to ecological understanding. *Environmental Conservation* 31:177-180. [http://dx.doi.org/10.1017/S0376892904001559](http://dx.doi.org/10.1017/S0376892904001559)


Krupnik, I. 2002. Watching ice and weather our way: some lessons from Yupik observations of sea ice and weather on St. Lawrence Island. Pages 156-197 in I. Krupnik and D. Jolly, editors. The Earth is faster now: indigenous observations of Arctic environmental change. ARCUS, Fairbanks, Alaska, USA.


Linkous Brown, K. 2006. As it was in the past: a return to the use of live-capture technology in the aboriginal riverine fishery. Pages 47-63 in C. Menzies, editor. Traditional ecological knowledge and natural resource management. University of Nebraska Press, Lincoln, Nebraska, USA.


Moreno, G., I. Dagorn, G. Sancho, D. Garcia, and D. Itano. 2007a. Using local ecological knowledge (LEK) to provide insight on the tuna purse seine fleets of the Indian Ocean useful


Mymrin, N.; the Communities of Novoe Chaplino, Sireniki, Uelen, and Yanrakinnot; and H. Huntington. 1999. Traditional knowledge of the ecology of beluga whales (Delphinapterus leucas) in the northern Bering Sea, Chukotka, Russia. Arctic 52:62-70.


Noongwook G., the native village of Savoonga, the native village of Gambell, H. Huntington, and J. George. 2007. Use of indigenous knowledge by coastal fisher folk of Mumbai district in Maharashtra. Indian Journal of Traditional Knowledge 6:378-382.


URL: http://www.ecologyandsociety.org/vol17/iss3/art8/


