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Local Knowledge, Subsistence Harvests, and Social–Ecological Complexity in James Bay

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Abstract Ecosystems are complex and difficult to predict and control. Western science-based societies have tended to simplify ecosystems to manage them. Some indigenous and other rural groups who interact closely with a given resource system seem to have developed practices that are adapted to live with complexity. This paper examines how indigenous Cree hunters in James Bay, subarctic Canada, understand and deal with ecological complexity and dynamics, and how their understanding of uncertainty and variability shape subsistence activities. The focus is the Canada goose (*Branta canadensis*) hunt which is adaptive to shifts and changes in local and regional conditions. Ecological understandings of Cree hunters allow them to account for and deal with a very large number of variables at multiples scales. The Cree deal with these variables qualitatively, an approach consistent with some scientific ways of dealing with complexity, such as adaptive management and fuzzy logic.

Keywords Indigenous knowledge · Traditional ecological knowledge · Cree people · Complexity · Fuzzy logic · Adaptive management Canada goose · James Bay · Subarctic · Hunting

Introduction

Environment and resource systems are complex with a number of characteristics not seen in simple systems, such as scale, non-linear dynamics, and uncertainty (Levin 1999). For example, unstable and unpredictable relationships among variables result in uncertainty in systems scaled in space and time (Gunderson and Holling 2002). Hence multilevel systems are inherently difficult to predict and control and managing ecosystems is problematic.

Western science-based societies have tended to simplify ecosystems in order to manage them, for example, by creating monocultures in place of traditional mixed systems such as agroforestry. Management efforts often dampen the natural variability of ecosystems in an attempt to increase and stabilize resource production—but at the cost of impairing the functioning of renewal cycles and resilience of ecosystems (Holling and Meffe 1996). As observed by Gregory Bateson, “The continuum of nature is constantly broken down into a discontinuum of variables in the act of description” (Bateson and Bateson 1987:165). Such a discontinuum makes reductionism possible, but reductionism has important shortcomings in a context of complexity of environmental systems.

The environmental monitoring practices of some indigenous and rural societies are significant in identifying ways to perceive the continuum of nature holistically, as opposed to trying to reduce complexity to a few measurable and controllable variables. Indigenous knowledge does not have the quantitative tools and approaches used by western science and technology, but some local and indigenous systems seem to have developed ways to deal with complexity.

In this paper, we examine the ways in which indigenous people understand and deal with complexity, using the example of Cree hunters of James Bay in the Canadian eastern subarctic. Our unit of analysis is the integrated social–ecological system (Berkes and Folke 1998) or the coupled human-environment system. We investigate social–

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ecological change in the goose hunt, a resource of prime importance to the Wemindji Cree people of James Bay. First we establish the context of the relationship between complex systems thinking and indigenous knowledge, reviewing how the two have been linked in the literature, especially the case for presenting indigenous knowledge as a holistic approach with parallels to adaptive management and fuzzy logic.

Following a section on the study context and methods, the main part of the paper reveals how Wemindji hunters make sense of the changes affecting the goose hunt. Hunters derive their reading of the situation from a relational, holistic approach that looks at a large number of variables as manifested through specific events, anecdotes, unusual occurrences or patterns. These variables include both ecological and social factors. By sharing their observations with each other, individual hunters contribute to a collective understanding that is flexible and that allows them to grapple with complexity. This collective understanding leads to either confirmation or revision of adaptive strategies, both at the scale of individual hunting territory as well as at the regional scale.

Finally, in "Discussion and Conclusions", we make the case that Wemindji hunters perceive change in the goose hunt as resulting from multiple factors and trends in the broader social–ecological context. This allows an understanding of the consequences of these patterns as they occur at multiple scales. Hunters' assessments rely not so much on precise measurements but on linkages between various processes. These processes are evaluated in a probabilistic manner that seems in agreement with fuzzy logic approaches.

Complex Systems and Indigenous Knowledge

The concept of complexity is used here to broadly refer to an "interconnected network of components that cannot be described by a few rules; generally manifest in structure, order and functioning emerging from the interactions among diverse parts" (Levin 1999:231). Social–ecological systems can be treated as complex adaptive systems as they show many characteristics not found in simple systems. They encompass dynamic structures emerging from numerous interactions between social and ecological processes, as they span across scales, often in non-linear patterns (Liu *et al.* 2007). Such emergent structure is "characterized by lack of dominant periodicity and by great sensitivity to initial conditions" (Levin 1999:238), making simplistic analyses all but useless.

Human groups who interact closely with their environment—indigenous resource users, hunters, fishers, farmers and others—often develop knowledge and practices that are pragmatically adaptive to shifts and changes in the environment (Berkes *et al.* 2000). Indigenous knowledge or traditional ecological knowledge refers to this body of knowledge–practice–institutions–worldview (Berkes 2008). Implicit in this concept are the notions that indigenous knowledge is dynamic, and that the social processes underpinning human–environment relations, such as resource use, are often grounded in epistemological frameworks that differ markedly from one society to another.

Folke *et al.* (2003) have listed the elements of an approach that allows societies to live with complexity and change. These include various sets of practices, rituals and institutional arrangements that provide the capacity to monitor change, and to revise and adjust practices following recognition of their shortcomings and/or failures due to changing conditions. Studies in human ecology from various parts of the world have shown that many indigenous and rural societies entertain relationships with their environment that do meet many of these criteria (Olsson and Folke 2001; Hunn *et al.* 2003; Parlee *et al.* 2006). The reductionist approach has been of limited application in the day-to-day decision-making of resource users; its prevalence is recent and mostly limited to agro-industrial societies (Sardar 1994; Scott 1998). Human–environment relations for many groups have been characterized by knowledge and resource use systems that are holistic, that view human action as tightly bound to its environment and that allow for unpredictability and non-linearity (Sardar 1994).

Some indigenous knowledge systems show a high degree of sophistication related to an apparent understanding of complex environmental processes, such as disturbance regimes and multi-level processes (Berkes 1998; Hunn *et al.* 2003; Moller *et al.* 2004). This knowledge is expressed as individual practices encoded in institutional arrangements that include resource allocation regimes, religious beliefs, and rituals that invite behaviors that adapt to shifts and changes in the environment. For example, Parlee *et al.* (2006) looked at how fluctuations in berry availability relate to changes in the rules-in-practice that govern access to these resources among the Gwich'in people of northwestern Canada, showing that in times of scarcity, information and permission to collect berries in specific sites become more restricted.

Many indigenous practices involve rotation of harvesting effort in space and time, documented in domains as diverse as tropical agroforestry (Dove 1985; Toledo *et al.* 2003) and subsistence hunting and fishing among northern indigenous peoples (Scott 1986; Feit 1987). For example, James Bay Cree fishers rotate their fishing grounds and adjust gillnet mesh size according to what they anticipate to harvest, which results in a diffusion of harvesting pressure over space and time, and by species and size-class (Berkes

1977, 1998). A similar practice has been observed in Cree beaver trapping, in which the trapper uses portions of a territory heavily for a short period of time and then 'rests' it to allow the beaver population to replenish itself (Feit 1987). As we will see in detail in later sections, the Cree goose hunt also involves rotation to spread out the effects of disturbance in space and time.

Some indigenous knowledge systems seem to have developed ways to deal with complexity by finding ways of perceiving the continuum of nature (Bateson and Bateson 1987) and working with it. Gadgil *et al.* (1993) suggested that the key might be the use of 'rules of thumb,' simple prescriptions based on indigenous knowledge and understanding backed up by religious belief, ritual, taboos and social conventions. It is well known in the theory of complex adaptive systems that complexity can emerge from simple rules (Levin 1999). We are suggesting here a corollary: that simple rules can be appropriate for dealing with complexity. There are several examples in the literature of apparently simple management prescriptions that result in outcomes that suggest complex systems thinking and holistic understanding of ecological dynamics.

A classic example is Rappaport's (1984) Papua New Guinea case that analyzes indigenous practice as a self-regulating, feedback-driven cybernetic system in which periodically occurring ritual pig slaughter and tribal warfare regulate resource abundance.[1] Less well known is the system of gift-giving and reciprocity that regulates herd size of llamas in the highlands of Ayachuco of Peru, studied by use of simulation models by Flannery *et al.* (1989). In Lansing's (2006) case from Bali, Hindu priests manage a system of water temples that 'optimizes' the use of irrigation water for rice terraces. When the system was disbanded ('modernized') with the arrival of Green Revolution rice varieties, the new scientific irrigation system worked so poorly compared to the old one that the traditional system had to be restored.

How do indigenous knowledge systems develop holistic approaches to convert day-to-day observations into complex systems thinking? Some authors have focused on fuzzy logic as a way to explain how rules of thumb and other simple prescriptions can be used to deal with complexity. Fuzzy logic, or fuzzy-set theory, is a form of multivalued logic that seeks explanation through approximate rather than numerically precise reasoning. Relations between elements are given an approximate probability, making it useful for management in conditions of uncertainty (Zadeh 1973). This approach, combined with systems thinking on the dynamic *relations* among elements, rather than on elements themselves, has been of great use in computer programming, engineering, and more recently in environmental monitoring and assessment (Silvert 1997; Prato 2005).

Mackinson (2001) used a fuzzy logic approach to model the decision-making of herring fishers of British Columbia, Canada. The model starts by pointing out that local knowledge does not lend itself well to mathematical representation, and develops an alternative way. A fuzzy logic expert system is used to combine scientific information and fisher knowledge to understand the dynamics of herring shoals. Similarly, Grant and Berkes (2007) analyzed the pelagic longline fishery in the Caribbean island state of Grenada as a fuzzy logic expert system. They identified ten categories of local knowledge important for finding and catching tuna and other large pelagic fish, conceptualized as a decision-making rule structure.

Using examples from the Hudson Bay Inuit and other indigenous knowledge systems from northern Canada, Berkes and Kislalioglu Berkes (2009) argued that fuzzy logic appears to be a good fit with indigenous knowledge, and an approach that may provide insights on the question of how local and indigenous knowledge systems may be dealing with complexity. Indigenous knowledge seems to build holistic pictures of the environment by considering a large number of variables qualitatively, whereas science tends to concentrate on a small number of variables quantitatively. There are certain advantages to using the latter approach because of what Zadeh (1973:28) calls the principle of incompatibility: "as the complexity of a system increases, our ability to make precise and yet significant statements about its behaviour diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics."

The holistic, qualitative approach to complexity through indigenous knowledge does not replace science, but it does provide a different way to think about ecosystems and other kinds of complexity. It also provides a new window on the study of processes of change, such as climate change, by drawing attention to ways of knowing—ways of perceiving, understanding and interpreting the environment (Ingold 2000). There is a distinction to be made between knowledge as content versus ways of knowing. The former is static and assumes that knowledge can be treated as something that can be transferred from one container to another. The latter is dynamic and focuses on the way knowledge is acquired through practical experience. Indigenous ways of knowing are different from scientific ways of acquiring knowledge.

In the sections that follow, we examine James Bay Cree hunters' evaluation of the shifts and changes affecting the

[1] While Rappaport's study remains a hallmark as one of the earliest applications of cybernetics and systems thinking in human ecology, it has been criticized for relying too heavily on ecological energetics, and focusing on homeostasis to the exclusion of dynamics (e.g., Vayda and McCay 1975).

goose hunt. By 'scanning' and evaluating a large number of variables, hunters grasp the implications of complex interactions of social and ecological processes occurring at multiple levels, and respond to them in various ways. Studying the processes of change is an excellent way to explore the distinction between knowledge as process and knowledge as content. There can be no pre-knowledge ('traditional' knowledge) for example of climate change. Indigenous experts do not know what to expect as the outcome of change. What they do know is what to look for and how to look for what is important.

Such knowledge production is in effect a learning process in the adaptive management sense (Gunderson and Holling 2002). The experience with various variables, and the evaluation of their impacts over time, iteratively add to knowledge holders' experience. This continuous learning process and the ability to deal flexibly with new observations make the knowledge holder a practitioner of adaptive management. Knowledge is shared and is communal, rather than individual. Knowledge building relies on monitoring and evaluating a large numbers of variables, consistent with fuzzy logic. Observing and learning follow culturally constructed rules; they are framed by 'knowledge institutions' (Davidson-Hunt and Berkes 2003; Davidson-Hunt 2006). Communal understandings or communal mental models are built to describe the world and to provide rules of thumb that simplify complexity.

Study Context and Methods

This study takes place in the Boreal region of James Bay, in mid-Northern Quebec (lat. 52° N). The environment consists of a patchwork of shallow coastal bays and salt marshes, lichen-spruce heaths and open-crown spruce-lichen woodlands, along with numerous lakes and rivers. The Cree have historically been a seminomadic, kinship-based society pursuing subsistence hunting, fishing and trapping over vast territories. During the last three centuries, they have been key actors in the fur trade, and more recently they have become involved in wage labor, while also remaining primarily a subsistence hunting society. A substantial proportion remain full-time occupational hunters and fishers, and an even larger proportion continues to engage in these subsistence activities on a part-time basis. They live in ten permanent settlements that dot the territory from the coast to the longitudinal center of Quebec. The Cree Nation of Wemindji is a coastal community situated on the eastern seaboard of James Bay with a population of about 1,500.

This paper is based on collaborative research carried out as part of a team project on aboriginal cultural continuity, economic development, and environmental stewardship.[2] We sought an understanding of Cree ecological knowledge and environmental stewardship practices by looking at how these practices fared in the context of rapid social and ecological change. We focused on the goose hunt because (1) this harvest is among the most important ones for the coastal Cree (Preston 1978; Scott 1996), (2) it is characterized by sets of customs and practices that are of interest from a human ecology point-of-view (Scott 1996), and (3) it has been undergoing dramatic changes over the last decade or so (CRA 2005; Peloquin unpub. field notes). This study combines years of research experience in James Bay with a focused study effort in Wemindji from 2006 to 2007. Favoring an ethnographic approach, we carried out 60 semidirected interviews with hunters, *uuchimaau* (customary 'stewards' of a given family hunting territory) and elders.[3]

Given our interest in how hunters make sense of complex phenomena, we favored in-depth, prolonged and repeated conversations with a select number of participants, often in the field, instead of a 'survey' type of research carried out 'ex-situ.' Participants were involved on the basis of (1) self-selection based on personal interest and willingness to teach on these matters, (2) the nature of personal relations with the researchers, and (3) recommendations from authoritative sources (*uuchimaau*). The pool of active participants primarily included 15 persons, whose views were often supplemented by inputs from relatives and friends on the topics at hand. They are identified in the quotations in this paper by their initials or by full name if that was their preference.

Another element of our analytical treatment pertains to the notion of 'consensus' and collective knowledge. We sought to accommodate the Algonquian view that 'truth' is not something that is 'out there,' but that it is revealed through teachings, and the notion that knowledge and meaning is personal (Preston 2002; Davidson-Hunt 2006). Cree hunters, including participants in this research, usually avoid judging someone else's perception and knowledge, and favor speaking from direct experience. When participants speak of a phenomenon, they usually refer to a specific event that they have themselves observed. In the less common case of reliance on secondary sources, this secondary source's view is usually reported with specifications on the source and the time of the exchange. This has implications for the treatment of 'what is known' at the collective level, the notion of consensus, and on the diversity of explanations. Results and conclusions were

[2] The Wemindji-Paakumshumwaau Project: Environment, Development and Sustainability in a James Bay Cree Community www.wemindjiprotectedarea.org.

[3] For more details on the methodological approach, see Peloquin (2007:44–58).

verified with individual participants during follow-up field work in 2007. We presented our interpretations, the resulting synthetic diagrams, and the field notes and interview excerpts on which these interpretations were based. This exercise provided opportunities for verification, confirmation or correction of our findings, and a starting point for additional analysis.

The Goose Hunt, Variability, Unpredictability and Change

The hunt takes place in the spring and in the fall, as migratory Canada geese (*Branta canadensis*) travel to and from their nesting and breeding grounds to the north. As they do, they usually move in stages, landing in the bays and on the points and islands that dot the coastline, and making use of these various habitats for feeding and resting (Reed *et al.* 1996). During these periods, hunters seek to intercept small flocks of geese, all the while remaining careful to avoid scaring the main flocks of geese and disrupting the migration. Hunters coordinate their efforts around goose hunting territories, each of which has a number of sites suitable for the hunt.

Hunters stay at a camp on the territory, and each morning select the site where they will go for the day. In most cases, a 'shooting boss' (*paaschichaau uuchimau*) chooses the site, taking into account the direction and strength of the winds, temperature, previous hunting pressure, goose behavior and so on. Normally a new site is chosen each day, and there are days when the goose-boss decides that no hunting should take place. On these days, either the conditions are not right (e.g., not windy enough), or it is simply decided that the territory should be ‘rested’ for a time. These practices have the effect of diffusing hunting pressure in space and time, with the goal of not disturbing migratory geese past a threshold beyond which they would avoid the territory altogether.

In addition to this system of rotation, there are number of other 'rules-in-practice' that contribute to that goal: hunters should not shoot into the main flocks, not shoot after dusk, and avoid creating visible disturbances on the ground (no red or other brightly colored gear, no garbage left visible, etc.). The details of management practices surrounding the coastal Cree goose hunt, along with their significance in cultural anthropology and resource management have been discussed elsewhere (Preston 1978; Scott 1986, 1996). For the purposes of this paper, we are concerned with the fact that harvesting efforts and approaches are informed by a constant monitoring of shifts and changes – many of them rather subtle – that amount to a resource use and management system allowing hunters to live with variability to maintain the resource. Table 1 provides a list of some of the variables that are taken into account in this decision-making process, and provides a good example of a local resource use and management system that is responsive to the shifts and changes in ecological dynamics.

The practices are derived from direct engagement with the elements, with great attention to the nature of the relationship between processes. Over time, perception, creativity and agency combine with traditional teachings and form sets of practices. This amounts to an approach that is flexible, attentive to initial conditions, and to the effects of various disturbances, including anthropogenic ones. Such an account helps in understanding the ways in which hunters usually make their decisions as to where, when and

Table 1 Key variables observed in decisions about site selection and hunting technique

Variable	Explanation
Wind	Wind ‘muffles’ the sound of shooting and other human activities, and also influences geese flight patterns. Hunters then seek to attune their efforts both to the strength and the direction of the wind
Tide level	Geese visit inter-tidal feeding sites at low-tides, and go elsewhere during high tides
	Hunters take account of tide levels when choosing a given site
Flock size and behavior	Some hunting techniques are only suitable when a large, well established flock is present, whereas other techniques are preferred at the onset of the migratory season, when the first arriving geese are in small numbers
	Some hunters may guess when geese will be departing the area, as they 'prepare' for their travel
	Flight patterns from feeding to resting sites are important
Landing patterns	Geese may not be shot at when they land in a given direction
Flight altitude	Are geese flying low enough to be hunted without unnecessarily scaring them?
Sea-ice	Does sea-ice allow or hinder safe and sensible access to and use of given sites?
Snow melt	Thick snow can prevent geese from accessing certain food sources, may push geese to favor other sites
Food availability	Where and when are marshy plants, berries, eelgrass, and other food sources available to geese?
Recent hunting pressure	Preference is given to sites that have not been recently used, combined with other factors
Number of hunters	The size of a group may influence the selection/choice of sites

how to go about hunting geese. Table 1 lists some of the variables hunters usually look for during their assessment of the situation. It is important to note, however, that these just happen to be some of the factors that often are of higher direct relevance in decision-making pertaining to harvesting strategies. One should not interpret Table 1 as a comprehensive checklist that automatically takes precedence over other observations. As one hunter has put it during an interview, “in the bush, everything changes all the time.” In such a complex and dynamic context, undue reliance on specific, preidentified variables does not work well.

Decline of Goose Harvesting Success

How is ecological knowledge produced and transmitted in a context where everything changes? How does hunters' knowledge cut across the complexity that results from myriad dynamic interactions between countless processes and patterns? In-depth inquiries on contemporary waterfowl hunting in James Bay provide a good view of how hunters make sense of social–ecological complexity and change, showing how Cree hunters' ecological knowledge entails direct immersion in and constant observation of countless elements.

According to hunters, shifts in ecological processes are part of the ‘normal’ course of things in boreal environments. That being said, the last three decades have been characterized by significantly accelerated and aggravated changes in James Bay, namely very rapid socioeconomic and biophysical transformations associated with industrial developments and related aboriginal land claim settlements (discussed below).

For Wemindji hunters, one of the important aspects of these changes has been the dramatic decline in the numbers of geese harvested during both the spring and fall hunts. This problem has been mentioned by Cree hunters since the late 1970s (Scott 1996). Coastal Cree participants in the *Voices from the Bay* project reported that the situation has been particularly problematic since the mid 1980s (McDonald *et al.* 1997). More recent accounts suggest that the situation has further worsened since the early 2000s. Here are some of the ways in which hunters describe this trend:

> It's been getting worse every year, bad goose hunt last two years; I did not catch any goose this spring (2006). Many others also did not catch any. It used to be 100 in a season (F. Stewart).

> Hardly any geese anymore. In 1984, got 50 geese a day, now you get ten and return home because you know you won't get any more (J. Blackned).

Interviews with hunters and elders provide us with a view of how they understand this decline in hunting success. The most directly relevant clusters of factors in relation to changes in the goose hunt pertain to changes in waterfowl behavior. This explains how the decline in catches has taken place during the same period that government-mandated wildlife scientists observed unprecedented growth in meta-population numbers of Canada goose (flyway), with estimates suggesting a five-fold increase in breeding pairs from 1996, when the population was at an all-time low, to 2006, when the present study began (Harvey and Rodrigue 2006). Thus, declines in goose availability in Wemindji territory are not directly linked to meta-population trends. According to hunters, it is a number of behavioral changes among both geese and hunters that has made the encounters between the two – the hunt – less successful in recent years.

Changes in Goose Behavior

Table 2 enumerates some of the key behavioral changes observed among geese that are seen as related to the decline in catches, along with the temporal and spatial levels at which these factors take place. While hunters do not make reference to levels or scale *per* se, we have added this dimension to our explanation to better illustrate the flexibility of Cree ways of knowing in a manner that is compelling to those trained in western science and management. For example, the first question, “where geese fly,” is simultaneously applied at multiple spatial and temporal levels: whether or not geese will fly above a given pond on a given morning, whether or not they will visit a given territory over the course of a week, all of which are also linked to the multiyear shifts in the regional flyway, and other trends that play out at subcontinental scales. We have organized these factors as ‘first order’ factors because they are usually linked more directly with the declines over hunting success.

Hunters indicate that goose migratory patterns now occur in ways that tend to contradict the expectations on which hunting practices are based. Migration across the territory takes place over a shorter period, as geese leave the territory early. Geese increasingly fly at night when they cannot be hunted, or they fly too high and simply avoid landing in the territory. Moreover, they are seen as increasingly favoring migration routes that are further inland (100+ km from the coast) as opposed to the coastal route (McDonald *et al.* 1997). Lastly, some hunting techniques now have a diminished success: for instance, geese often do not return to a site after being chased, whereas key techniques directly rely on the historically correct view that geese are better hunted upon their return to a site from which they were chased.

According to some research participants, the newly observed goose behavior could be partly attributed to

Table 2 First-order variables, factors, events linked to on-going changes surrounding the goose hunt

Category	Factor	Question	Time	Space
Goose behavior	Flight patterns	Where do geese fly?	a b c d e	v w x y z
	Landing patterns	Where do geese land?	a b c d e	v w x y z
	Feeding habits	Are they eating? Resting?	a b	v w
	Congregation size	How many geese at a given spot?	a b c	w
	Response to hunting efforts	Do they return after chased?	a b	v w
	Geese long-term collective memory	What events in the past may trigger current situation? Have geese previously been scared from a site following hunter recklessness?	c d e	v w x y
Hunter behavior	Site rotation	Are hunting sites adequately selected in function of wind, goose flight patterns, and prior hunting pressure? Are sites sufficiently 'rested'?	a b c	v w
	Noise 'disturbance'	Do hunters shoot on calm days? Do helicopters fly in the vicinity?	b c d	v w x
	Visual 'disturbance'	Do hunters shoot after dark? Are there open fires?	a b c d e	v w
		Are sites clean from garbage? Is colorful gear camouflaged?		
	Coordination of hunting efforts	Are hunters following the directions of the hunting boss?	a b c	v w
	Ability to travel	Can hunters access their territory and various hunting sites reliably and safely?	b c	v w

Temporal scales: *a* hour, *b* day, *c*, week, *d* month, *e* year(s); spatial scales: *v* hunting, site/pond, *w* goose hunting territory, *x* community level territory, *y* region, *z* continent

changes in the ways some hunters go about hunting. It is reported that hunters do not always rotate hunting sites as they should. Moreover, there are reports of instances of shooting after dusk, hunting even on calm days (when the sound carries), and hunting everyday, not letting territories 'rest' – all transgressions of the customary practice, and adding to the disturbance effect of an increased reliance on motorboats, float planes and helicopter travel.

Other participants, however, favor the view that "we do the same things; it is the geese that have changed." Numerous aspects of the social–ecological system of the Cree have been undergoing many dramatic transformations over the last decades. This includes massive environmental modifications in the aftermath of hydroelectric developments that started in the late 1970s, with impacts on the salinity and thermal regime of James Bay. To this are added concerns over climate change, contaminants in the Bay, and the changes in the way Cree perceive their environment (McDonald *et al.* 1997; Rosenberg *et al.* 1997).

"In the Bush, Everything Changes, Not Just the Geese"

Additional discussions on the circumstances in which the aforementioned events occur helped identify some of the underlying factors that are put forward by hunters as they seek to understand and explain what these changes mean, and to find out how they must respond to them. We have grouped these items as second-order factors (Table 3). Again, almost all of these factors operate at more than one spatial and temporal level, and the perceived directedness of their influence on the goose hunt is subject to variation.

One frequently recurring cluster of factors pertains to weather patterns. Due to their impact on both animal availability and safety, hunters are highly attentive and responsive to the various shifts and change in temperature, winds, and freezing and thawing patterns. According to hunters, recent trends in weather patterns suggest a departure from the expected. There are numerous signs and signals on which hunters rely in assessing weather. These include the speed and severity of storms, ice freeze-up and break-up dates, ice thickness, temperatures at given dates, and dates at which certain migrations occur.

> The weather has been changing a lot since the late 1970s. It's not as cold in the wintertime, and after freeze-up you have to wait a long time before you can travel on the ice. And people say the ice is not as thick as it used to be, even out in the Bay. In late February I put out my fish nets, five kilometers from here, I was surprised that the ice was very thin, it was about this thin (~30 cm), it used to be about 1 meter thick. It makes it easier for digging a hole in the ice (JM).

> Freeze-up takes longer, we must wait a long time before going on ice (in the fall), and then in the spring ice goes out really fast, too fast (LU).

Again, these signs and signals are observed at multiple scales: how long does it take for a storm to form? At what date must one stop to travel over sea-ice by snowmobile? Are

Table 3 Second order variables, factors, events linked to on-going changes surrounding the goose hunt

Category	Factor	Question	Time	Space
Bio-physical	Temperature, weather	Is spring long and gradual so that geese 'stick around'? Do sea-ice conditions ensure safe travel? Is weather predictable? Is it cool and wet enough that berries can grow?	b c d e	v w x y z
	Goose habitat	Do ponds and bays flood or dry out? Are small-dikes sufficient to retain water? Is 'goose-food' still available or replaced by woody vegetation?	c d e	v
	Regional physical geography	What are the potential impacts of large-scale modifications following hydroelectric development? Do these influence goose behavior?	d e	y
	Isostatic uplift	Are new sites created/formed to offset the losses due to glacial rebound?	e	y
Social-cultural	Values and lifestyle	Are hunters respectful of the geese? Do they 'monitor' the territory just to observe what is happening?	e	x y z
	Economic organization	When must hunters return to the village for work, school? How long can they 'wait around' to hunt, to travel back to town?	e	x y z
	Technologies	Where, how, why, and when is one to travel by snowmobile? Helicopter? Trucks? What impacts on the geese?	a b c	w x y
Related eco-logical dynamics	Cycles, fluctuations in time	Has this happened before? What is the time frame of these events?	e	w x y z
	Abundance of other animals	Are certain predators scaring the geese? Are there other unusual patterns that may be related?	d e	x y z

Temporal scales: *a* hour, *b* day, *c* week, *d* month, *e* year(s); spatial scales: *v* hunting site/pond, *w* goose hunting territory, *x* community level territory, *y* region, *z* continent

berries available on islands when geese return in the fall? It is reported that recent patterns of these weather-related signs and signals diminish the reliability of the ecological indicators on which the Cree normally base their decisions. This makes subsistence activities on the land more hazardous. At the same time, hunters' behavior is also influenced by these manifestations of climate change. For example, the ability to move from one site to another is controlled by the thickness and reliability of ice on the Bay. Thinner ice prevents access to many of the sites. As one site is 'rested', hunters must go to another, but going further out on the ice may not be possible when the ice is too thin. Often hunters choose to stay closer to the camp to avoid undue risk, resulting in a concentration of hunting pressure.[4] Moreover, these factors directly impact goose availability. For example, early and fast spring break-up, as well as warm weather, are all seen as key factors influencing geese: "It's too warm, it's not good for the geese, they fly right through, it's probably why the geese change their patterns" (AV).[5]

> This year and last year, we had an early spring, early open water. The ice went really fast, so there is less geese. Because the snow is really going fast, and there is hardly any water in the swampy areas, the geese don't land and (they) don't stick around. This spring and last spring, I noticed it's early spring, and there is hardly any geese. (S. Mistacheesick).

These factors are interpreted in combination with other processes. The implications of changing weather patterns for subsistence hunting are indissociable from myriad other trends and events. For example, warmer weather combines with the effects of background isostatic rebound.[6] This process takes place at the regional scale, but it has implications at the level of specific hunting sites, as ponds dry out and marshy vegetation is replaced with woody species not palatable to the geese. Furthermore, these processes take place in the context of series of large scale disturbances—anthropogenic this time—associated with the massive hydroelectric developments in the area, and their potential impacts on the regional hydrology as well as on Bay-wide oceanography (Rosenberg *et al.* 1997):

> I think since Hydro-Quebec made the reservoirs, the geese changed their patterns. If you look at the maps all the way to Eastmain River, there is a lot of water, just like James Bay. That's why I think that's one thing that they follow. And along the Bay, there used to be grass. How do you call that? We call it in the Cree *sishkabash* [eelgrass, *Zostera marina*]. Over 10 years now, there used to be lot of *sishkabash*, so I noticed when I set the nets in the water there is just a little bit of that now…They say it came from La

[4] See Peloquin and Berkes (*forthcoming*) for more details on how this plays out at the level of one hunting territory.

[5] For more details on the climate-related aspects of this study, see Peloquin (2007:99–103), Berkes (2008:172–174).

[6] Post-glacial isostatic uplift is the slow rebounding of the land after the release pressure of glacial ice. Near Wemindji, the land is currently 'growing back' (as the Cree put it) at a rate of approximately 1 m per century.

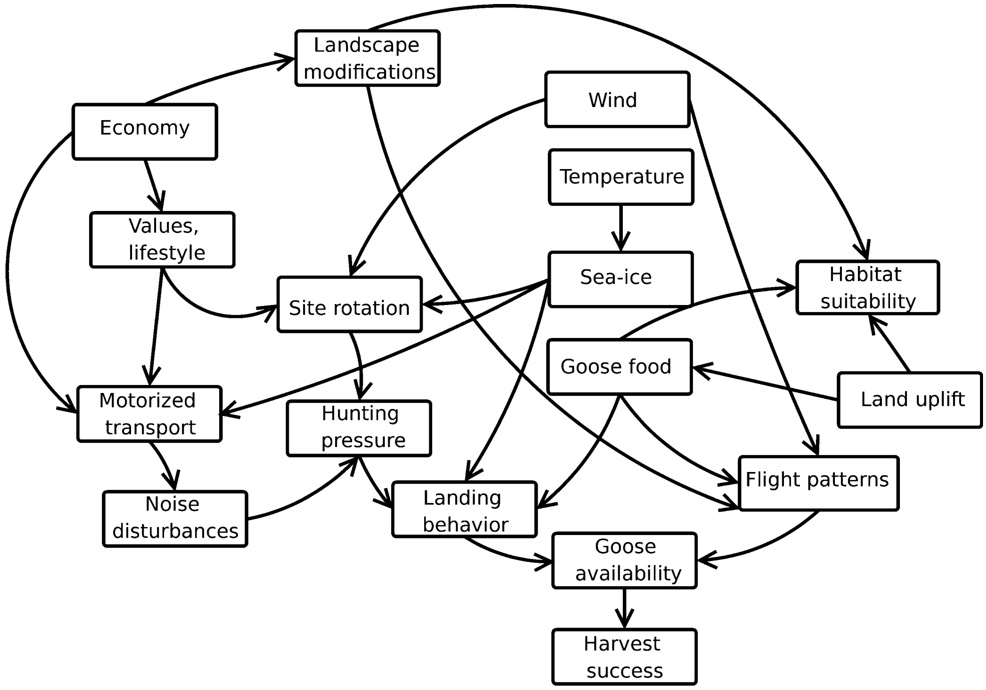

Fig. 1 Categories of factors affecting the goose hunt and how they interact according to Cree hunters

Grande, I think it changed the water. I don't know. (F. Atsynia).[7]

These various biophysical factors are seen as having a direct influence on the goose hunt, but they are also taking place in a context of rapid social–cultural change, which further influences how hunters engage in this harvest. Hydroelectric developments have opened the territory to further transformations, including roads and other transport infrastructure. Gradual changes in the economic and social organization of Cree societies, new institutional arrangements, and changes in cultural identity and aspirations can all be linked to these hydroelectric developments, and they are central to the Cree perception of a changing world (Hornig 1999; Carlson 2008). Economic changes have meant that many Cree have more rigid schedules due to various commitments in town, which reduces their flexibility; hunters cannot all just wait for a week or two for the best conditions to hunt and travel. Some respond to this by hunting even when conditions are not as good as they should be, and some rely on helicopters to travel between their camp and town:

> People are flown back because they have to come back right away. They can't wait because they are workers, or students, so they need the air-lift, using helicopters down the coast. All the coastal communities do it, so it must scare them [the geese]. It is since they have been using that, in 1985, that there is less geese. There used to be more, now they are scared (S. Georgekish).

Figure 1 provides a representation of factors affecting the goose hunt, and some of the linkages between these factors. All of these dimensions have been mentioned by Cree hunters as factors of relevance in understanding the goose hunt, and the larger context in which this, as well as other subsistence activities take place. No specific cause is singled out as being solely responsible for all these changes in goose behavior.[8] Rather, each factor is linked with many other kinds of social–ecological change. The factors identified by the Cree are extremely diverse, and include what natural and social scientists may call biophysical factors and socio-cultural factors, except that the Cree do not make that distinction. Figure 2 is an attempt to simplify the variables identified by the Cree by clustering them in a way that western scientists might. The figure makes the point that Cree hunters' holistic view of their social–ecological system brings together variables (e.g., goose habitat conditions, human disturbance, changes in hunter behavior) that are normally segregated out and studied by different 'tribes' of social and natural scientists.

[7] The reasons for the decline of eelgrass in Hudson and James Bay have not been resolved but are thought to be associated with changes in water temperature, salinity, and turbidity, with impacts on the ecology of waterfowl, especially brant geese but also Canada geese and ducks (Short 2007).

[8] In fact each box in the figure represents one category of factor that was mentioned by at least one participant in the study (but usually by more). Arrows linking the boxes are relationships, observed or hypothesized, between the different categories of factors that have been mentioned by participants. This diagram is conservative in that many other links are plausible between these factors but they were not explicitly mentioned during our conversations with hunters.

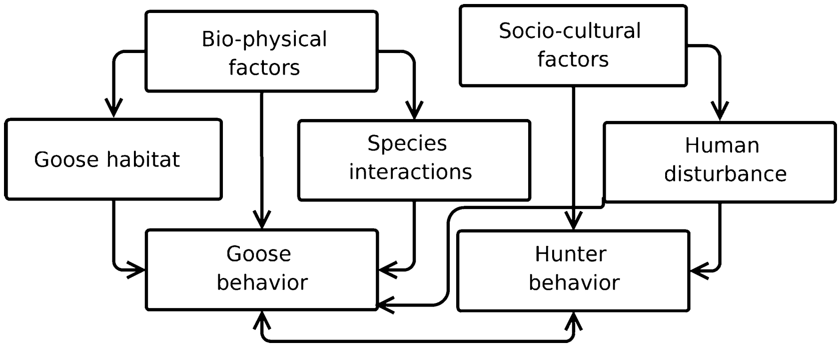

Fig. 2 Clusters of factors that affect the goose hunt

During our conversations about changes on the land, Cree experts often referred to specific events and observations, which were then juxtaposed. To the researcher, these associations between events first appear to serve as mere temporal reference points, but they also are mentioned in a way that suggests linkages between them, links that may or may not be causal. The processes surrounding the decline in goose hunt are comprehended by the Wemindji Cree as an integral part of a broad network of social and ecological processes. The ways in which hunters collectively understand the myriad interactions between social–ecological processes shaping their environment informs the ways in which they respond to change. Some individuals continue to hunt the same way as before. Others use the newly built roads to hunt geese at inland sites.

In recent years, hunters are increasingly favoring road-based travel for the goose hunt, both in the spring and in the fall. Reliance on roads to access camps is less vulnerable to changing weather patterns and ice conditions than are boat or air travel. As well, one does not have to rush to leave before ice break up, or to wait for the ice to have cleared up before returning to the community. It is safer, less costly and less complicated than flying by helicopter. Road travel does not scare geese; thus, moving inland diminishes the disturbance and diffuses hunting pressure over a broader area.

As suggested by an experienced Wemindji hunter: “Helicopters are expensive and noisy, let’s hunt geese along the road, leave the coast a chance to rest” (OV). The reference to 'resting' is significant: the use of inland hunting sites may thus allow the coast to become attractive to the geese once again, extending the Cree notion of site rotation to the regional scale.

The gradual move of the goose hunt inland involves a number of interesting strategies. For example some hunters create pond-like features in the snow-covered gravel pits along the roads in which they place decoys. During the time of the fall goose hunt, by opting to go inland instead of on the coast, hunters can combine their investments and efforts with the ones for the moose hunt, which also takes place inland shortly after (in fact, the respective harvest periods are not fixed, and some temporal overlap is not uncommon). This appears to be a risk-hedging strategy in which hunters minimize how much there is at stake in the pursuit of the goose hunt that is becoming less reliable. Figure 3 provides a representation of the role of road travel in the context of adapting to changing conditions.

Discussion and Conclusions

These results show that hunters rely on constant monitoring of numerous patterns and processes in their day-to-day activities. The practice of the goose hunt allows hunters to adjust to shifts and changes in biophysical and socioeconomic processes taking place at multiple scales. Since the

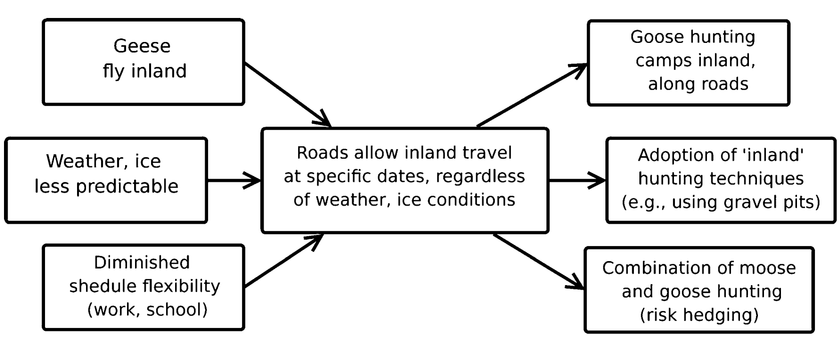

Fig. 3 The role of roads in response to change

boreal environment is characterized by large year-to-year natural variability, the notion of 'departure from normality' is difficult to describe. Hunters rely on social memory to construct an understanding of the expected range of observations (e.g., goose hunt success, timing of spring ice break-up). They exchange observations of specific events, with a focus on unusual occurrences and anomalies (e.g., unexpectedly thin and dangerous sea-ice) at a particular time and place, rather than on central measures or averages such as those relied upon by climate change models.

Changes are evaluated with a wide range of factors in mind. Consistent with other northern indigenous peoples (Berkes *et al.* 2007), the Cree restrain themselves from reaching simplistic cause-effect conclusions (e.g., the decline of the goose hunt is simply due to the impacts of hydroelectric development). Rather, in the mind of the Cree hunter, the possibility of causal links between various factors is neither 'denied' nor 'confirmed'. They observe and monitor change in great detail, and suggest possible links among different factors. For example, the goose hunt can be represented as sets of relations linking hunters and geese, and the variables in the complexity of the goose hunt can be assigned diverse degrees of causality. Uncertainty and unpredictability are acknowledged and natural cycles are recognized. Cyclicity is a common theme in Cree ideology, especially in relation to the return of animals (Berkes 2008). In the present case it comes up in relation to resting the coastal habitat to restore the coastal goose hunt.

Coming back to the theme of complexity and indigenous knowledge, it may be argued that people who directly derive their livelihood from resource use must develop a hands-on approach to knowing how their ecosystem works, and their role in it. We suggest that the Cree hunters' understanding of environmental processes is not affected by the western legacy of the assumption of separateness of nature and culture (Bateson and Bateson 1987). Further, it functions without undue fixation on the measurable (Sardar 1994). As Preston suggests, "precise answers are not easily given by (…) the Cree, for the contingencies of the Cree world are not predictably patterned and directly apprehended in all their complexity" (Preston 2002:152). The Cree do not seek to diminish complexity or uncertainty but embrace it. They act upon a relational model of their environment in which events and patterns are understood in probabilistic terms, an approach that allows for the treatment of large number of variables, especially at the collective level when hunters and elders deliberate over the meanings of their observations.

Ethnographic work on cultural models suggests that the central processes of making a livelihood are culturally constructed (Ingold 2000). "Gaining a livelihood might be modelled as a causal and instrumental act, as a natural and inevitable sequence, as a result of supernatural dispositions or as a combination of all these" (Gudeman 1986:47). This emphasizes the importance of cultural processes not only as a tool but also as motivational force in decision-making (Quinn and Holland 1987). However, there has been debate as to whether hunter–gatherers rely at all on a 'model' of their environment, as a representation outside of itself *per se* (Ridington 1982; Bird-David 1990). For example, according to Ingold:

> For the Ojibway (…) knowledge does not lie in the accumulation of mental content. It is not by representing it in the mind that they get to know the world, but rather by moving around in their environment, whether in dreams or waking life, by watching, listening and feeling, actively seeking out the signs by which it is revealed (Ingold 2000:99, after Hallowell 1960).

Hunters communicate, exchange observations, and as appropriate, attempt to change their practices and behavior according to their interpretations of ongoing changes and develop adaptation strategies (Peloquin and Berkes, in press). This amounts to a flexible monitoring of change that relies on opportunistic observations of unusual events and occurrences. The Cree ways of knowing, in this context, appear to be largely (but not exclusively) qualitative and probabilistic. They note unusual events but do not seek to measure trends or observations of change as scientists might. Their understanding does not require proving causal links or cause-effect relationships. Instead, the Cree make their observations in a relational context; causality itself remains uncertain. Changes in goose behaviour and availability are perceived by the Cree within a view of their social–ecological system that could be described as a complex and dynamic web of interactions. Given the large number of factors involved, treating these variables quantitatively is, in any case, not feasible because an inverse relationship exists between the complexity of a system and the degree of precision that can be used meaningfully to describe it (Zadeh 1973).

Science approaches problems such as climate change by quantifying a relatively small number of variables, such as mean temperature. By contrast, many indigenous ways of knowing, including that of the Cree, seem to approach these problems with a different strategy—by qualitatively scanning a large number of variables. Such an approach to environmental monitoring is not unique to the Cree and has been observed in other indigenous knowledge systems, as in Maori ways of 'eyeballing' animal abundance (Moller *et al.* 2004) and Inuit ways of monitoring the health and edibility of their food species (Berkes *et al.* 2007). The ability of indigenous knowledge systems to deal with a large number of variables qualitatively may be analogous to the use of fuzzy logic in western science (Berkes and Kislalioglu Berkes 2009). This approach to ecological understanding appears consistent with a focus on adaptive learning rather than 'control' (Holling and Meffe 1996; Davidson-Hunt 2006; Pahl-Wostl 2007). An approach favoring sensitivity to environmental variability and detection of change in complex systems is highly relevant to addressing the challenges of contemporary environmental problems.

Different knowledge traditions, perspectives and cultural referents emphasize various dimensions of reality (Demeritt 1998). Conventional positivist science is one of the approaches to get at reality. There are others. Complexity is one of the metaphors used by some Western scientists to explain phenomena that have challenged reductionist explanations in science. In the intercultural context where this research took place, complexity thinking is seen as one approach emerging from western thought that allows consideration of and discussion on phenomena that transcend analytical/reductionist models of conventional science (Pahl-Wostl 2007).

We assume that other knowledge traditions have also allowed the development of ways of comprehending and dealing with environmental patterns that cannot be easily predicted or controlled (Sardar 1994), and this research contributes to ongoing efforts to foster dialogue between these various knowledge strands. What we propose here is one way of exploring the parallels between the science of fuzzy logic and indigenous knowledge, and developing a pluralistic tradition of knowledge systems. The process of monitoring for variability and change, while working with the continuum of nature, and appreciating indigenous ways of knowing, may provide key insights for living with complexity.

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References

Bateson, G., and Bateson, M. C. (1987). Angels Fear: Towards an Epistemology of the Sacred. Bantham, New York.

Berkes, F. (1977). Fishery Resource Use in a Subarctic Indian Community. Human Ecology 5: 289–307.

Berkes, F. (1998). Indigenous knowledge and resource management systems in the Canadian subarctic. In Berkes, F., and Folke, C. (eds.), Linking Social and Ecological Systems. Cambridge University Press, Cambridge, pp. 98–128.

Berkes, F. (2008). Sacred Ecology: Traditional Ecological Knowledge and Management Systems, 2nd edn., Routledge, London.

Berkes, F., and Folke, C. (eds.) (1998). Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, Cambridge University Press, Cambridge.

Berkes, F., and Kislalioglu Berkes, M. (2009). Ecological Complexity, Fuzzy Logic and Holism in Indigenous Knowledge. Futures 41: 6–12.

Berkes, F., Colding, J., and Folke, C. (2000). Rediscovery of Traditional Ecological Knowledge as Adaptive Management. Ecological Applications 10: 1251–1262.

Berkes, F., Kislalioglu Berkes, M., and Fast, H. (2007). Collaborative Integrated Management in Canada's North: The Role of Local and Traditional Knowledge and Community-based Monitoring. Coastal Management 35: 143–162.

Bird-David, N. (1990). The Giving Environment: Another Perspective on the Economic System of Gatherer-hunters. Current Anthropology 31: 189–196.

Carlson, H. M. (2008). Home is the Hunter: The James Bay Cree and their Land. University of British Columbia Press, Vancouver.

CRA (Cree Regional Authority) (2005). Workshop on Migratory Birds Data Collection in Eeyou Istchee: Sharing Knowledge, Proceedings of workshop held in Wemindji, February 8–9 2005. http://www.envcree.ca/communities/documents/WorkshopReport.pdf.

Davidson-Hunt, I. J. (2006). Adaptive Learning Networks: Developing Resource Management Knowledge through Social Learning Forums. Human Ecology 34: 593–614.

Davidson-Hunt, I., and Berkes, F. (2003). Learning as you Journey: Anishinaabe Perception of Social–ecological Environments and Adaptive Learning. Ecology and Society 8(1): 5. http://www.ecologyandsociety.org/vol8/iss1/art5.

Demeritt, D. (1998). Constructivism and nature. In Braun, B., and Castree, N. (eds.), Remaking Reality: Nature at the Millennium. London, Routledge, pp. 173–193.

Dove, M. R. (1985). Swidden Agriculture in Indonesia: The Subsistence Strategies of the Kalimantan Kantu'. Mouton, Berlin.

Feit, H. A. (1987). Waswanipi Cree management of land and wildlife: Cree cultural ecology revisited. In Cox, B. (ed.), Native People, Native Lands: Canadian Indians, Inuit and Métis. Carleton University Press, Ottawa, pp. 75–91.

Flannery, K. V., Marcus, J., and Reynolds, R. G. (1989). The Flocks of the Wamani. A Study of Llama Herders on the Punas of Ayacucho, Peru. Academic, San Diego.

Folke, C., Colding, J., and Berkes, F. (2003). Building resilience and adaptive capacity in social–ecological systems. In Berkes, F., Colding, J., and Folke, C. (eds.), Navigating Social–Ecological Systems. Cambridge University Press, Cambridge, pp. 325–387.

Gadgil, M., Berkes, F., and Folke, C. (1993). Indigenous knowledge for biodiversity conservation. *Ambio* 22 : 151–156.

Grant, S., and Berkes, F. (2007). Fisher Knowledge as Expert System: A Case from the Longline Fishery of Grenada, the Eastern Carribean. Fisheries Research 84: 162–170.

Gudeman, S. (1986). Economics as Culture: Models and Metaphors of Livelihood. Routledge, London.

Gunderson, L. H., and Holling, C. S. (2002). Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington.

Hallowell, A. I. (1960). Ojibwa ontology, behavior, and world view. In Diamond, S. (ed.), Culture in History: Essays in Honour of Paul Radin. Columbia University Press, New York, pp. 19–52.

Harvey, W. F., and Rodrigue, J. (2006). A Breeding Pair Survey of Canada Geese in Northern Québec – 2006. Maryland Department of Natural Resources, Baltimore.

Holling, C. S., and Meffe, G. K. (1996). Command and Control and the Pathology of Natural Resource Management. Conservation Biology 10: 328–337.

Hornig, J. F. (1999). Social and Environmental Impacts of the James Bay Hydroelectric Project. McGill–Queen's University Press, Montreal.

Hunn, E. S., Johnson, D., Russell, P., and Thornton, T. F. (2003). Huna Tlingit Traditional Environmental Knowledge, Conservation, and the Management of a "Wilderness" Park. Current Anthropology 44: S79–S104.

Ingold, T. (2000). The Perception of the Environment: Essays in Livelihood, Dwelling and Skill. Routledge, London.

Lansing, J. S. (2006). Perfect Order: Recognizing Complexity in Bali. Princeton University Press, Princeton.

Levin, S. A. (1999). Fragile Dominion: Complexity and the Commons. Perseus, Reading, MA.

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., Pell, A. N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C. L., Schneider, S. H., and Taylor, W. W. (2007). Complexity of Coupled Human and Natural Systems. Science 317: 1513–1516.

Mackinson, S. (2001). Integrating Local and Scientific Knowledge: An Example in Fisheries science. Environmental Management 27: 533–545.

McDonald, M., Arragutainaq, L., and Novalinga, Z. J. (1997). Voices from the Bay: Traditional Ecological Knowledge of Inuit and Cree in the Hudson Bay Bioregion. Canadian Arctic Resources Committee, Ottawa.

Moller, H., Berkes, F., Lyver, P. O., and Kislalioglu, M. (2004). Combining Science and Traditional Ecological Knowledge: Monitoring Populations for Co-management. Ecology and Society 9 (3): 2. http://www.ecologyandsociety.org/vol9/iss3/art2/.

Olsson, P., and Folke, C. (2001). Local Ecological Knowledge and Institutional Dynamics for Ecosystem Management: A Study of Lake Racken Watershed, Sweden. Ecosystems 4: 85–104.

Pahl-Wostl, C. (2007). The Implications of Complexity for Integrated Resources Management. Environmental Modelling & Software 22: 561–569.

Parlee, B., Berkes, F., and Teetl'it Gwich'in Renewable Resource Council (2006). Indigenous Knowledge of Ecological Variability and Commons Management: A Case Study on Berry Harvesting from Northern Canada. Human Ecology 34: 515–528.

Peloquin, C. (2007). Variability, Change and Continuity in Social–Ecological Systems: Insights from James Bay Cree Cultural Ecology. Thesis, University of Manitoba, Winnipeg. http://mspace.lib.umanitoba.ca/dspace/handle/1993/3019.

Peloquin, C., and Berkes, F. (in press). Beyond conservation: Customary land stewardship in a complex and changing world. In Mulrennan, M., Scot C., and Scott, K. (eds.), *The Science and Politics of Protected Area Creation: Striking the Balance* Vancouver, University of British Columbia Press.

Prato, T. (2005). A Fuzzy Logic Approach for Evaluating Ecosystem Sustainability. Ecological Modelling 187: 361–368.

Preston, R. J. (1978). La relation sacrée entre les Cris et les oies. Recherches Amérindiennes au Québec 8: 147–152.

Preston, R. J. (2002). Cree Narrative: Expressing the Personal Meanings of Events, 2nd edn., McGill–Queen's University Press, Montreal.

Quinn, N., and Holland, D. (1987). Cultural Models in Language and Thought. Cambridge University Press, Cambridge.

Rappaport, R. A. (1984). Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People, 2nd edn., Yale University Press, New Haven.

Reed, A., Benoit, R., Lalumière, R., and Julien, M. (1996). Goose Use of the Coastal Habitats of Northeastern James Bay. Canadian Wildlife Service, Environment Canada, Ottawa.

Ridington, R. (1982). Technology, World View, and Adaptive Strategy in a Northern Hunting Society. Canadian Review of Sociology and Anthropology 19: 469–481.

Rosenberg, D. M., Berkes, F., Bodaly, R. A., Hecky, R. E., Kelly, C. A., and Rudd, J. W. M. (1997). Large-scale Impacts of Hydroelectric Development. Environmental Reviews 5: 27–54.

Sardar, Z. (1994). Conquests, Chaos and Complexity: The Other in Modern and Postmodern Science. Futures 26: 665–682.

Scott, C. (1986). Hunting Territories, Hunting Bosses and Communal Production among Coastal James Bay Cree. Anthropologica 28: 163–173.

Scott, C. (1996). Science for the west, myth for the rest? The case of James Bay Cree knowledge construction. In Nader, L. (ed.), Naked Science: Anthropological Inquiry into Boundaries, Power and Knowledge. Routledge, London, pp. 69–86.

Scott, J. C. (1998). Seeing Like a State: How Certain Schemes to Improve the Human Condition have Failed. Yale University Press, New Haven.

Short, F.T. (2007). The Status of Eelgrass in James Bay. Report to The Cree Nation of Chisasibi, Durham, NH, University of New Hampshire.

Silvert, W. (1997). Ecological Impact Classification with Fuzzy Sets. Ecological Modelling 96: 1–10.

Toledo, V. M., Ortiz-Espejel, B., Cortés, L., Moguel, P., and Ordoñez, M. D. J. (2003). The Multiple Use of Tropical Forests by Indigenous Peoples in Mexico: A Case of Adaptive Management. Conservation Ecology 7(3): 9. http://www.consecol.org/vol7/iss3/art9/.

Vayda, A. P., and McCay, B. J. (1975). New Directions in Ecology and Ecological Anthropology. Annual Review of Anthropology 4: 293–306.

Zadeh, L. A. (1973). Outline of a New Approach to the Analysis of Complex Systems and Decision Process. *Transactions on Systems, Man and Cybernetics* SMC-3: 28–44.