Sacred Ecology

Second Edition

Fikret Berkes

Routledge
Taylor & Francis Group
NEW YORK AND LONDON

First published 1999 by Taylor & Francis

This edition published 2008
by Routledge
270 Madison Ave, New York, NY 10016

Simultaneously published in the UK
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

Routledge is an imprint of the Taylor & Francis Group, an informa business

Typeset in Times New Roman by
Florence Production Ltd, Stoodleigh, Devon
Printed and bound in the United States of America on acid-free paper by
Sheridan Books, Inc., MI

Library of Congress Cataloging in Publication Data
Berkes, Fikret.
Sacred ecology/Fikret Berkes. – 2nd ed.
p. cm.
Includes bibliographical references and index.
1. Environmental sciences – Philosophy. 2. Traditional ecological knowledge. 3. Indigenous peoples. 4. Human ecology. 5. James Bay (Nunavut) – Environmental conditions – Case studies. I. Title.
GE40.B45 2008
179′.1 – dc22 2007029842

ISBN10: 0–415–95827–X (hbk)
ISBN10: 0–415–95829–6 (pbk)
ISBN10: 0–203–92895–4 (ebk)

ISBN13: 978–0–415–95827–1 (hbk)
ISBN13: 978–0–415–95829–5 (pbk)
ISBN13: 978–0–203–92895–0 (ebk)

CHAPTER 7

Cree Fishing Practices as Adaptive Management

The Cree Indian fishery in James Bay is an example of a traditional system that can provide ecological and resource management insights. This chapter describes the unique characteristics of the fishery: its adaptability, flexibility, use of environmental signals or feedbacks, and its ability to conserve ecological resilience. These characteristics suggest that traditional systems may in some ways be analogous to Adaptive Management with its nonlinear, multi-equilibrium concept of ecosystem processes and its emphasis on uncertainty, resilience, and feedback learning. The chapter ends with the exploration of some of the implications of the case for the broader issue of fisheries management, not only for other areas of North America (Langdon 2006) but also internationally.

When I started working with the Chisasibi fishery in 1974, my original intent was to study the impacts of the giant James Bay hydroelectric project on the Cree fishery. (Impacts included the destruction of the fishery but for different reasons than experts initially thought, but that is another story; see Berkes 1981a, 1988a.) As time went by, I became more and more interested in traditional knowledge and Cree fishing practices. I found that extensive local knowledge existed on distributions, behavior, and life cycles of fish simply because such information was essential for productive fishing, as any fisher knows, and was at one time essential to survival. Chisasibi fishers knew, for example, that in spring the best catches of whitefish were obtained following the melting ice edge in bays; fishers knew where the pre-spawning aggregations were in August, and they knew that in September whitefish was best harvested over a sand-gravel bottom at certain depths of water. Whereas most ethnobiologists busied themselves with the identification of species and the recording of aboriginal classification systems, this was only a minor concern for me. The boreal/subarctic was, in any case, a species-poor environment. Thus, my initial traditional knowledge emphasis was on the natural history of fish and fishing. But as I started to gain an understanding of the local system, my interests quickly turned to resource management.

As with many northern aboriginal groups, fish are a staple resource for the Cree of James Bay. They say one can rely on fish even when other resources fail or become unavailable. Unlike many of the other animal resources, the Cree take their fish almost for granted, and no rituals and ceremonies involving fish are found in contemporary Chisasibi (formerly known as Fort George). Nevertheless, there is respect for the fish. The principle that animals are in control of the hunt (see Chapter 5) holds also for fish. A fisher does not boast about his or her fishing. It is believed that boasting brings retaliation from the fish—they stop making themselves available. As well, one does not waste fish; one does not abuse fish by swearing at them or by "playing" with them; and one eats what one catches. The Cree are horrified at the thought of catch-and-release fishing practices commonly used in sport fisheries elsewhere in North America.

Most of the Chisasibi Cree fishery takes place in medium- and large-sized lakes, in the estuaries of rivers, and on the James Bay coast. The major fishing technique used in the estuary and on the coast involves setting short (50 m) gill nets of various mesh sizes from 7 m, outboard equipped canoes. Smaller paddle canoes, sometimes outboard equipped, are used in lakes and rivers. Other fishing techniques include hand-drawn seines at the base of rapids on the La Grande River, rod and reel, and traditional baited set lines for the larger predatory fish. Fishing seasons are part of the seasonal cycle of harvesting activities, and they are signaled by biophysical events in the landscape such as the spring ice breakup in the river and change of color of the vegetation in September. Fishers know how to recognize and respond to a variety of environmental feedbacks that signal what can be fished where and when. Master fishers or stewards provide leadership.

The Chisasibi fishery in 1974 was a subsistence fishery in which people fished for their own needs. There was no competition from commercial fisheries (Chisasibi was too far from markets and there never had been a commercial fishery), and there was minimal competition from sport fisheries. In isolated areas of Canada, subsistence fisheries are not regulated by government, unlike commercial fisheries, which do come under government regulation. The conventional scientific management systems for subarctic commercial fisheries in Canada have employed some combinations of the following tools: the type of fishing gear used, restrictions on gill-net mesh size, minimum fish size, season closures, and the prohibition of fishing at times and places when fish are spawning. Catch quotas are common, and maximum sustainable yield calculations based on population dynamics of the stock have also been used in the larger fisheries. The Chisasibi fishery being a subsistence fishery, I knew at the time I started my work that none of the above measures would be in effect. What I did not know was that the Cree had a system of their own.

The Chisasibi Cree System of Fishing

At first, the ways of the Chisasibi fishery seemed fairly simple. There were two basic strategies: small-mesh gill nets were used within commuting distance of the village (about a 15 k radius) and a mix of larger-mesh gill nets were used further away. The most distant locations were visited rarely, perhaps once every ten years or more, and were fished mainly with large mesh sizes (Berkes 1981b; Berkes and Gonenc 1982). Hunters follow the traditional rule-of-thumb of rotating family hunting areas ideally over a cycle of four years (Feit 1973). Within these areas, fishing lakes would also be rotated, fished one year and then rested for a number of years before being fished again. However, the overall system is actually more complicated than that, as some fishing areas may be used several times per season, with rests in between, and distant lakes less than once every ten years. Thus, we have characterized the fishery as multiple-scale, in both space and time (Berkes 1998; Berkes *et al.* 2000).

Most of my fishery research took place near the village, where small-mesh (2½ in. or 63.5 m) gill nets caught mostly the smaller-sized cisco (*Coregonus artedii*) and the larger-mesh ones (3½ in. or 88.9 m and larger) mostly the larger-sized whitefish (*C. clupeaformis*). All of this was relatively easy to document after I had accumulated about two years of catch data based on the Cree fishery, traveling with the fishers to their customary locations and recording their catches. Selectivity of the smaller gill net was striking: it caught almost ten times more cisco than whitefish, while the larger gill nets caught five times more whitefish than cisco (see Table 7.1). I was unable to establish, however, if the fishers caught more cisco near the village because they used small nets or because there were more cisco than whitefish in the area. My question was soon answered.

As I got ready to use my own experimental nets, the accompanying Cree fisher who knew my concern but whom I had not asked for help, provided on his own initiative the perfect design for a field experiment. He fished two replicates of two paired nets, one 2½ in. and the other 3 in., side by side for nine consecutive days just across the river from the village (see Table 7.2). The experiment settled the question: there were very few whitefish at that location at that season. Even though the 3-in. net caught relatively more whitefish than did the 2½-in. net, the smaller net provided a higher catch per unit of effort, by a factor of two. There was no sense in using 3-in. or larger nets at that *particular* location and season, although the 3-in. net caught equal numbers of cisco and whitefish when all areas and seasons were averaged out (see Table 7.3). To make sure that my generalization held, I had to check and account for seasonal and for year-to-year variations in the catch per unit of effort (Berkes 1981b).

I still was not sure, however, if the 2½-in. net actually *maximized* the catch per unit of effort in the area near the village. Could one use an even smaller net and get an even higher catch, even though the individual fish would be rather small? Just where were the limits of the system? Since the accompanying Cree fisher seemed to have no interest in carrying out *that* field experiment, I ended up using my own nets. The experiment did not last very long. With a 2-in. net, I found myself catching immature cisco, good numbers perhaps but definitely immature fish of the 20–25-cm size group. By contrast, the 2½-in. net had been catching 25–30-cm fish, four to five years old and mostly mature. My catches with the 2-in. net did not escape the attention of other fishers. Over the course of a day, several canoes drifted over to my nets, fishers looked at the size of the fish, measured the mesh with two fingers thrust in, muttered and shook their heads in

Table 7.1 Selectivity of different mesh sizes of gill nets for whitefish and cisco

		Whitefish			**Cisco**	
Net, in.	**No. of net sets**	**No.**	**Avg. wt., g**	**No.**	**Avg. wt., g**	**Ratio of whitefish to cisco**
2½	219	273	250	2,536	250	1:9.3
3	86	130	563	192	378	1:1.5
3½ and 4	30	102	694	22	552	4.6:1

Source: Berkes (1977).

Table 7.2 Catch per unit of effort with paired 2½ *versus* 3 inch gill nets

	Catch per net set, g	
	2½ in.	**3 in.**
Whitefish	110	227
Cisco	1,211	649
Total fish	3,164	1,439
No. of net sets	18	18

Source: Berkes (1977).

Table 7.3 Catch per net set (kg) for the four mesh sizes of gill nets in the near-village fishery *versus* away

		Near village	Away from village
2½ nets:	Whitefish	0.3	1.6
	Cisco	2.9	1.4
	Total catch	4.8	6.6
3 nets:	Whitefish	0.7	2.2
	Cisco	0.9	0.7
	Total catch	2.6	5.5
3½ and 4 nets:	Whitefish	1.0	2.9
	Cisco	0.1	0.6
	Total catch	2.1	7.8

Source: Berkes (1977).

disapproval. I had been in the village less than a year and already I was finding out what social sanctions were like. At first I defended my experiment as "science," but by the end of the second day, I had pulled out all the nets. (I discovered some months later that Cree had some stock phrases to ridicule fishers who used smaller nets than those dictated by custom: for example, one would say, "his nets are so small, he cannot put his penis through it.")

However, the system of socially enforced minimum mesh size for cisco did not conserve whitefish, a larger species. A mesh size of 2½ in. was taking immature whitefish; this was perhaps an explanation for the scarcity of whitefish in the waters near the village. Paradoxically, however, the apparent depletion of whitefish in that area but not elsewhere suggested an indigenous solution to the classical dilemma of a multi-species fishery. In Western resource management theory and practice, the curves of yield against fishing effort and against mesh size are different for each species. That is, it is always difficult to choose a mesh size because different species of fish grow and mature at different sizes. It is therefore impossible to harvest more than one species at the optimum level for each (Gulland 1974). In commercial fisheries, the choice of mesh size and other harvesting strategies often represents a compromise, and the overall results are rarely ideal.

What I was observing in the Chisasibi Cree traditional fishery was a management solution with a clear choice: away from the village, the effort was primarily directed at one larger-sized, highly desirable species, whitefish. Near the village, however, the effort was primarily directed against another, cisco, which was also a desirable species but matured at a smaller size and was probably able to withstand a higher fishing pressure. I still had to check whether this strategy *worked* and that the harvest was sustainable over a period of time.

I found that the productivity (measured as the catch per unit of effort) of the Chisasibi fishery as a whole compared favorably with other whitefish fisheries in the Canadian North (Berkes 1977). I also documented the number of reproductive year-classes in the near-village fishery based on essentially one population (or unit stock) of each of the two major species that inhabited the lower La Grande River and its estuary. The cisco had four reproductive year-classes, 4, 5, 6, 7, and a few of 8-year-old fish; the whitefish had three year-classes, 6, 7, 8, and a few of 9 year-olds (Berkes 1979). This many year-classes signaled a healthy cisco population but a somewhat overfished whitefish population, consistent with the earlier analysis. But what really made a convincing argument for sustainability was the comparison of my Chisasibi data with the results of a long-forgotten survey from the 1920s (Dymond 1933). Sampled 50 years apart in the same waters, Dymond's whitefish and cisco had exactly the same number of age-classes as mine, and the age-specific sizes were similar (Berkes 1979). Just to make sure, I checked my age and growth data against that of government researchers working on the James Bay hydroelectric project environmental impact study and satisfied myself that my biological data were reliable (Berkes 1981b).

By now, I was beginning to get a sense of the Chisasibi fishery as a managed system. The fishers used recognizable management strategies; the harvest was productive and sustainable. By knowing when and where to set the nets, the fishers exercised considerable selectivity over their harvest. In the near-village fishery, the fishers selected for cisco and against suckers (fish that people did not like to eat but used as dog food and trapping bait), and the selectivity could be documented by comparing the subsistence catch against biological samples, year after year (see Figure 7.1) (Berkes 1987a).

As well, I was beginning to understand the fundamental ways in which a subsistence fishery differed from a commercial fishery. People fished for their needs and there was no incentive to create a surplus. During the seasons when the fish were abundant, as in spring and fall in the La Grande estuary, two small nets were sufficient to catch enough for the needs of an average extended family. But in midsummer, the mean catch per net set decreased to about half of that in the spring months. Fishers compensated for this by setting about twice as many nets so that the daily harvest remained constant (see Table 7.4). The marginal effort required to manage an extra net was relatively low. One extra net took only about half an hour to set and minutes to check. In fact, people could set many more nets if they wanted to, but they did not. Their objective was to catch what they needed, about 10 kilograms per day in the case of the extended family (three nuclear families), documented in Table 7.4. The narrow range in the table indicates that "getting what you need" is indeed a fine art. Ten kilograms of fish was enough food for the family, and they could still provide smoked fish to their exchange

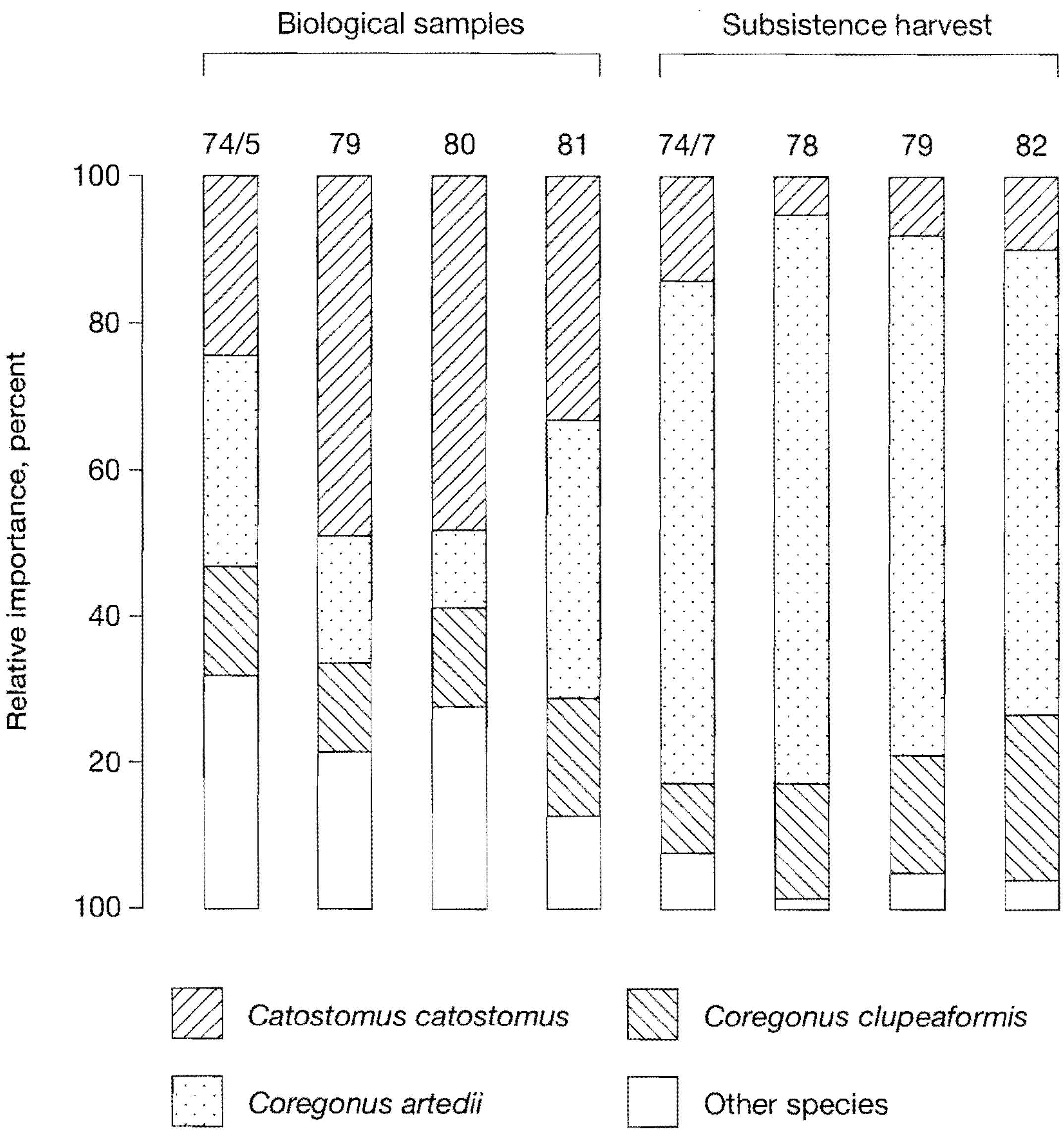


Figure 7.1 Fish species selectivity of the Chisasibi Cree fishery. Compare the biological samples against the subsistence fishery composition, showing selectivity for cisco (*C. artedii*) and whitefish (*C. clupeaformis*) and against suckers (*C. catostomus*).

Source: Modified from Berkes (1987a).

network of relatives and friends. To harvest more would have meant to give away more. But since there was no lack of fish in the community, fish would likely be wasted—a transgression.

Being a product of Western scientific training, I was reluctant for a long time to refer to the Cree fishery as a "management system." The conventional wisdom is that if a group of traditional people *seemed* to be managing their resources sustainably, this can probably be explained on the basis of too few people and too "primitive" a technology to do damage to the resource. Well, the apparent productivity and sustainability of the Chisasibi fishery *could not* be explained

Table 7.4 Relationship between fishing effort and catch per net set for one fishing group setting nets near village

	June	August	October	November
Total fish catch, kg	140	84	60	44
Number of net sets	32	39	14	8
Catch per net set, kg	4.9	2.2	4.3	5.5
Number of days	12	9	7	4
Net sets per day	2.67	4.33	2.00	2.00
Catch per day, kg	11.7	9.4	8.6	11.0

Source: Berkes (1977).

simply on the basis of small population and inefficient technology. If fisheries management is defined as controlling how much fish is harvested, where, when, of what species, and of what sizes (Gulland 1974: 1), then the Chisasibi fishers were managing their fishery. Gulland commented that fisheries rarely achieved all of the above management objectives. It seemed therefore that Chisasibi fishers did better than most fishery managers by the very criteria of Western fishery management science.

Subarctic Ecosystems: Scientific Understanding and Cree Practice

Part of the reason many scientists have difficulty with the notion of traditional management concerns the question of information needs for resource management. The conventional wisdom in fish and wildlife management is that detailed population data are needed for management. According to this view, natural history type of information, including species identifications, life cycles, distributions, habits, and behavior—the kinds of information at which traditional peoples are experts—are necessary but insufficient for the needs of management. Indeed, Chisasibi Cree fishers lacked quantitative information, that is, they did not have data on the population dynamics of the harvested species. Not only that, the fishers openly disapproved of the kind of research biologists did to gather population information: sampling immature fish, and tagging fish to determine the range of the stock and to obtain population estimates by marking and recapturing.

To the Cree, these practices were disrespectful of the animals; they violated rules regarding wastage and about playing with fish. As for the biologists' objectives of "controlling" fish populations and "predicting" sustainable yields, the Cree thought that these were immodest aims of apparently immature people playing god, given that the success of fishing depended on whether the fish were willing to be caught, and the maintenance of an attitude of respect and humility by the fisher.

All of this highlighted a paradox in the research of traditional management systems: how do some of these societies do such a good job of managing resources, given that the very notion of management is inconsistent with their worldviews? In the case of the Chisasibi fishery, part of the answer lies with the traditional Cree understanding of the subarctic aquatic ecosystem. But Cree understanding of ecosystems is not articulated in the abstract; it is only reachable through their practices in the concrete (Lévi-Strauss 1962; Preston 1975). We will therefore switch to a Western ecological discourse on subarctic ecosystems before going back to describing the practice of the Cree fishery.

It is well known that subarctic ecosystems are characterized by low species diversity, high year-to-year variability in the biophysical environment, large population fluctuations or cycles, and generally low biological productivity. However, it is also known that fish population assemblages in unfished or lightly fished subarctic lakes are characterized by a large biomass of old (as much as 50- to 60-year-old) and large-sized fish, analogous, as Johnson (1976) pointed out, to the large biomass of trees in tropical forest ecosystems. The biological reason for the high biomass of such species as whitefish and lake trout (*Salvelinus namaycush*) is a matter of some scientific controversy, but the simplest explanation seems to be that proposed by Power (1978). Growth rates of individual fish in the subarctic are relatively rapid until maturity, but after maturity growth rates gradually slow down. Mortality rates decline rapidly through early life and stabilize at a low level once the fish has reached a large size. The combination of this growth and mortality pattern produces a population with many small, few intermediate-sized, and many large fish, hence the unusual bimodal (two-peaked) population length–frequency distributions often observed.

The presence of many large fish in an unfished or lightly fished northern lake gives the misleading impression of high ecosystem productivity. Since primary productivity (plant productivity) is low in the subarctic, fish productivity is low as well. Actual fish production in the estuaries in James Bay (the most productive part of the aquatic ecosystem) was calculated to be 0.3 to 1.3 kg/ha/yr; in the lakes it was even lower (Berkes 1981b). By contrast, in temperate coastal areas, lagoons, and lakes, common values are in the order of 50–100 kg/ha/yr. Those large, old subarctic lake fish only *seem* to be abundant; in fact, they take a very long time to renew themselves. A trophy-sized lake trout, likely to be over 50 years of age, is almost a nonrenewable resource! According to some studies in lakes of Canada's Northwest Territories, the production-to-biomass ratio of species such as whitefish is about 1:10. That is, as a rule-of-thumb, only about one-tenth (or less) of the fish biomass can be harvested each year on a sustainable basis for a given body of water.

However, even a fishing intensity that low could result in the removal of many of the old and large fish. This is not necessarily a bad thing, since the removal of such fish (and lowered competition for food) would result in higher survivorship, increased growth rates, and earlier maturation of the younger individuals of the same species. Analogous to harvesting a forest, such thinning of fish populations triggers increased productivity. This phenomenon is known to scientists and managers as "population compensatory responses" (Healey 1975) and occurs with all living resources. This is the Western scientific counterpart of the Cree notion that continued proper use of resources is essential for sustainability (see Chapter 5).

As the rate of exploitation of such a fish population increases, at a certain point the population is not going to be able to compensate for the loss of large individual fish and will eventually decline. Species will differ with respect to when this point is reached. For example, lake trout has a limited biological ability to respond to exploitation. Whitefish seem to have relatively greater ability, but species such as cisco, which mature at a smaller size, are better adapted to withstand high exploitation rates. These differences among species have been used to explain, for example, how the fish species composition of the Great Lakes has historically changed from one dominated by large, old, slow-growing, and late-maturing species such as sturgeon (*Acipenser fulvescens*) to one dominated by small, fast-growing, and early maturing fish such as yellow perch (*Perca flavescens*) (Regier and Baskerville 1986).

The two basic fishing strategies of the Chisasibi Cree could be interpreted in this light. Small-mesh gill nets used near the village are consistent with the relative abundance of cisco, a smaller species that matures earlier than does whitefish. The use of larger-mesh nets further away in water bodies exploited intermittently is consistent with the maintenance of populations of older and larger fish. Since the Cree do not use ecological formulations to articulate management choices, their system can only be inferred through their practices.

Three Cree Practices: Reading Environmental Signals for Management

Three readily observed sets of management practices provide insights into the "secrets" of the Cree system. The first is about concentrating fishing effort on aggregations of fish. The second concerns rotational or pulse-fishing. The third involves the use of a mix of gill-net mesh sizes. All three practices are unusual by the standards of commercial, nontraditional fisheries. However, a number of fisheries ecologists have pointed out the merits of pulse-fishing in northern commercial fisheries (Johnson 1976). I discuss each in turn.

The concentration of effort is probably typical of many subsistence systems. Subsistence fishers cannot afford to waste time and effort if they are not catching many. If the return from fishing is poor as compared to that from other subsistence activities, the Chisasibi Cree fisher will very quickly leave his nets and pick up his gun. Because they need to feed their families and because they have limited amounts of equipment, fishers select settings in which fish are easy to catch. Thus, groups of fishers will concentrate, year after year, on the same spawning or pre-spawning aggregations, and on feeding, migrating, and overwintering concentrations of fish, at specific times and places.

An example of such a site is the First Rapids of La Grande River where (until dams were built), large numbers of cisco in pre-spawning aggregations could be obtained in August at the foot of the rapids (Berkes 1987a). There is a high premium on fishers' knowledge about the timing and locations of fish concentrations where the catch per unit of effort is known from experience to be high. Fishers of the more traditional families who spend part of the year on the land know the most suitable fishing areas in every bay or lake within the family territory. Given long travel distances, extensive knowledge of the terrain is also essential. This is particularly true on the shallow and indented James Bay coast where the navigator of the canoe needs to know the configuration of the shoreline at different phases of the tide.

The second management practice, pulse fishing, involves fishing a productive area intensively for a short length of time, and then relocating somewhere else. For example, I recorded the activities of one family fishing group that concentrated its effort in a small inlet, perhaps 100 m by 400 m at low tide, on the James Bay coast not far from the village. They removed a total of 34 kgs of fish between June 7 and 12. The initial catch per net set was 6.4 kgs, and the final, 2.2 kgs, suggesting that a large part of the fishable stock had been removed over that brief period. The group then located their nets elsewhere but indicated that the inlet was a traditional site for the family and that they would be back the following year. Fishing areas may be recognized as traditional but this does not imply that other community members cannot fish there. Stewards do regulate access and effort through their leadership but do not normally limit the access of others into fishing areas. Fishing effort is deployed flexibly and opportunistically, and the initial success of one group seems to encourage others to converge upon an area. For example, on May 24, right after ice breakup in another inlet on the James Bay coast, a fishing group set five nets and obtained 40.8 kgs of fish. By May 27, there were about 20 nets in the inlet, but as the catch per net declined to about 2.8 kgs, the nets were relocated somewhere else (Berkes 1977).

Pulse fishing and fishing area rotation seemed to be taking place over multiple time scales. In the intensively fished area near the village, a good spot would be fished at least once a year, but further away, less frequently (Table 7.3). Further away from the village, in areas that are hunted and fished extensively (as opposed to intensively), a hunter/fisher may use a particular lake once or so every few years. Why do people use pulse fishing and rotation? Clearly, the practice optimizes the catch per unit of effort. In the case of extensively used lakes, the practice also helps maintain a population of large-sized fish in the system. The samples available from the more remote fishing locations show good catches of whitefish of 50–55 cm. Since my samples were not many, however, I wanted to make sure that my findings were not due to chance. Checking unpublished length-frequency data of fish harvested by two other Cree groups, the Mistassini and Waswanipi, I could ascertain that whitefish were indeed at about 50–55 cm and the lake trout 50–60 cm in the more distant, extensively fished lakes, with 40–50-cm whitefish in lakes closer to the communities (Berkes 1981b). Each of the data sets showed a scatter of sizes; it seemed that the Cree fisheries took a range of sizes (and ages) and that there were clearly many big ones, especially in the more remote areas.

The third Cree management practice, the use of a mix of gill-net mesh sizes, was responsible for the harvest of a range of whitefish sizes in the Chisasibi fishery and, one can assume, in Mistassini and Waswanipi as well. The range of sizes was initially puzzling: if large fish were available, why not take the largest only? After all, that is what commercial fisheries did in the North. Large fish were what the market wanted and there was pressure on the fisher to produce a standard product. Working and living with Cree subsistence fishers revealed a different set of values and priorities. First of all, fishers would say they "used whatever nets they had," denying any conceptual design in management but affirming practice. Second, large fish and small fish (even of the same species) tasted different and were used for different purposes. For example, a cisco or a small whitefish could be cooked on a stick over open fire. Large whitefish could be boiled, smoked (traditional), or pan-fried (nontraditional). A large white sucker (*Catostomus commersoni*) would be smoked; a small one would merely be trap bait. There was a need for a variety of things and certainly no pressure to produce a standardized commodity to meet the specifications of a commercial product.

The primary mechanism that drove all three management practices (effort concentration, pulse-fishing, and the use of a mix of gill-net mesh sizes) was the fishers' reading of the catch per unit of effort. It was the key environmental signal monitored by the Cree; it shaped the decisions regarding what nets to use, how long to keep fishing, and when to relocate. But the Chisasibi fishers monitored other environmental signals as well. They noted and took into account the species composition of the fish coming out of their nets, the size, the condition or fatness (considered very important as a signal of health), and the sex and reproductive condition of the fish. As well, they observed the fish and noted any unusual patterns in behavior and distributions. The conduct of the fishery was guided by the need for different food products, social obligations to contribute to community exchange networks, and the conservation imperatives of "getting what you need" and minimizing waste.

A Computer Experiment on Cree Practice and Fish Population Resilience

Fishery biologists and managers have for years observed a troubling trend in Northern Canadian commercial lake fisheries for whitefish and lake trout. A lightly fished lake seemingly full of large-sized fish would be selected for commercial fishery development. Exploitation would start with large-mesh gill nets but productivity would soon decline. Healey (1975) has argued, for example, that the use of large gill-net mesh sizes (5½ in., or 139.7 mm) in the Great Slave Lake has led to the selective removal of older year-classes of whitefish, thus reducing population resilience but without triggering population compensatory responses such as increased growth rates and earlier maturity. His argument, therefore, suggested the use of smaller mesh sizes. However, in several cases in which smaller mesh nets have been used, populations have inexplicably collapsed (Healey 1975).

After several experiences of this kind, biologists came up with the explanation that in many cases the collapse was related to a combination of two things. First, because of the removal of the largest fish, population would come to depend on a small number of reproductive year-classes. Second, if there was poor spawning success for two or more years in a row, for example, due to unusual weather or water conditions, then the population could collapse. That is, the simplification of the age-class structure left populations predisposed or vulnerable to collapse if reproduction was poor. Alternatively, one might say that the presence of many reproductive year-classes in the population was an insurance against the variability of the physical environment that in some years results in complete reproductive failure. It conferred resilience.

I have been using the example of whitefish in subarctic lakes, but the underlying ecological principle has wider applicability. Ecologists interested in evolution start with the assumption that life cycle characteristics of a species must reflect adaptations for improving the chances of survival of that species in its particular environment. The presence of many year-classes of large and slow-growing fish presumably represents a life-cycle adaptation to fluctuations in the ecosystem. In fact, multiple spawning in fish populations elsewhere has been shown to be of adaptive value in dampening the effects of environmental variability, especially those effects leading to poor reproductive success for two or more years in a row (Murphy 1968). Some authors have questioned the supposed fragility of northern ecosystems, pointing out that these ecosystems have a high degree of ecological resilience (Dunbar 1973), defined here as the ability of an ecosystem to absorb perturbations and yet retain its structure and function (Holling *et al.* 1995; Gunderson and Holling 2002). Multiple reproductive year-classes is likely to be a major mechanism for ecological resilience, especially for long-lived fish species.

Intuitively it seemed to me that the Cree practice of using a mix of mesh sizes was a potential solution to the management dilemma of conserving resilience. Hence I proposed a testable hypothesis based on Chisasibi Cree traditional ecological knowledge and management: *Harvest more year-classes at a lower rate by the use of a mix of different mesh sizes* (as opposed to the selective harvest of the oldest year-classes at a higher rate by the use of a single large mesh size); *this would stimulate population compensatory responses without reducing the reproductive resilience of the population* (Berkes 1979). The problem with the hypothesis was that it was all but impossible to test with a field experiment, given the 50-year life span of the northern whitefish. Many descriptive mathematical models in ecology develop and test hypotheses by quantifying processes intuitively known to practitioners. Thus a logical alternative to a 50-year field experiment was a computer experiment (Berkes and Gonenc 1982).

First, we modeled mortality and growth rates in a hypothetical whitefish population. We showed that under certain assumptions, a characteristic bimodal length-frequency distribution is obtained. How such a peculiar distribution comes about can be shown mathematically through the summation of overlapping size-classes of older fish, using any long-lived species that has low growth rates and low mortality rates after first maturity (see Figures 7.2 and 7.3). The population modeled in Figure 7.3 postulates relatively few intermediate-sized (20–40 cms) fish, and an abundance of big fish with a mode at about 50–55 cms representing an accumulation of many old and slow-growing year-classes. The figure also helps illustrate that the fish in these northern lakes are available as easily harvestable large units, not because the populations are highly productive but because they consist of many years of accumulated production. It is a useful way to visualize the appropriateness of a fishing strategy in which one can bank one's food supply by not fishing any one lake year after year but pulse-fishing as needed. "Fish as staple" is not a matter of faith; those fishers *know* that the large fish are in the bank for tomorrow's needs. When they go to rarely fished areas, they set their largest mesh nets (5 and 5½ in.) *because* they are expecting large fish.

ɪewhere has been
ɔf environmental
e success for two
e questioned the
ecosystems have
ere as the ability
ure and function
productive year-
ɪe, especially for

ix of mesh sizes
ving resilience.
Cree traditional
sses at a lower
elective harvest
rge mesh size);
t reducing the
problem with
ld experiment,
criptive math-
ying processes
50-year field
).
ical whitefish
istic bimodal
bution comes
lapping size-
vth rates and
e population
(20–40 cms)
representing
re also helps
harvestable
ecause they
to visualize
food supply
ɪd. "Fish as
ı are in the
ɪy set their
ɪ.

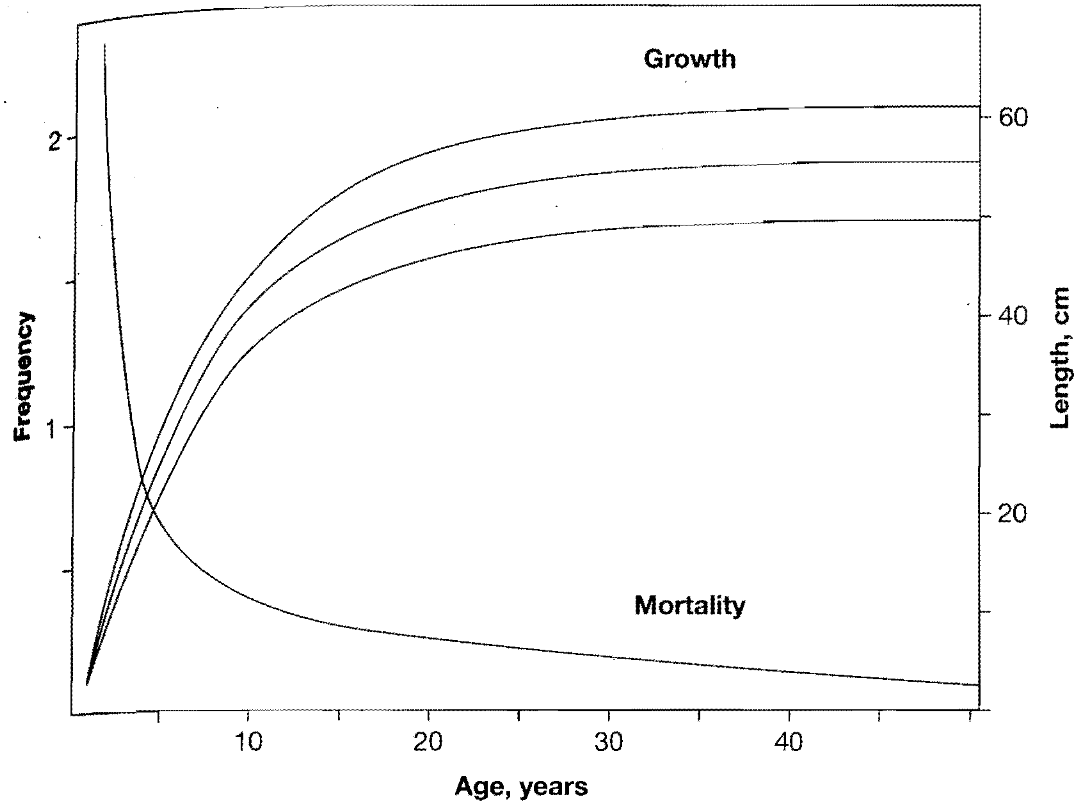


Figure 7.2 Growth and mortality curves of a model lake whitefish population. Intervals on the growth curve indicate ± 1 SD. Equations for curves in Berkes and Gonec (1982).

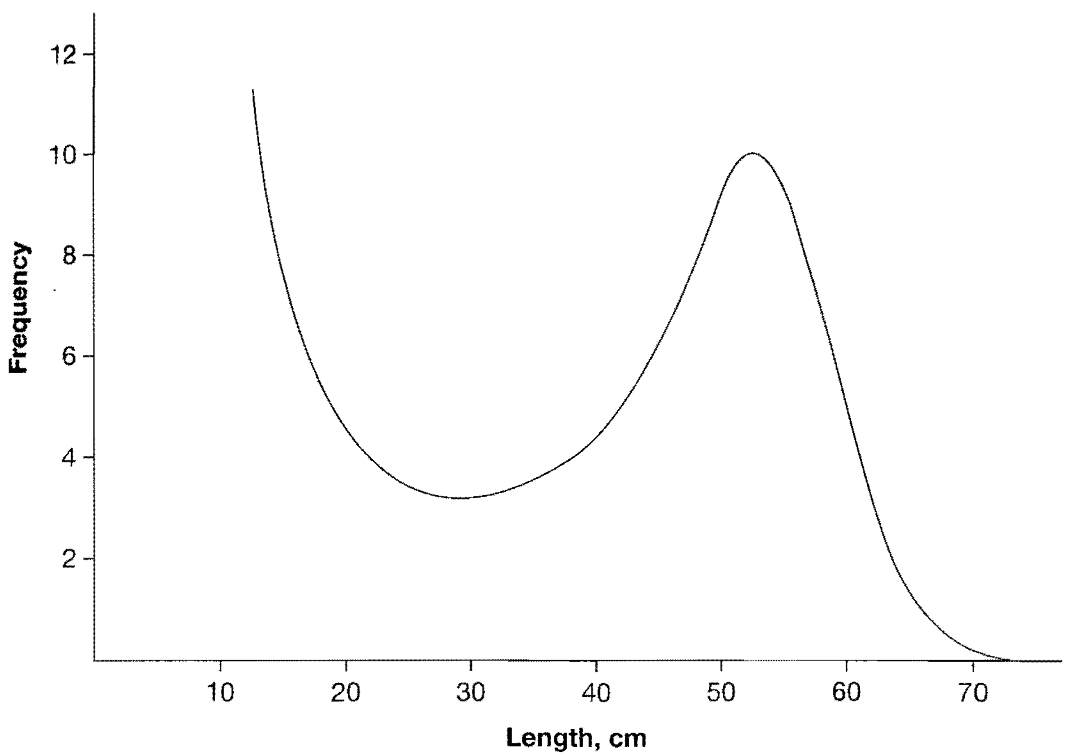


Figure 7.3 Length-frequency structure of a model whitefish population, as calculated from the growth and mortality curves in Figure 7.2.

Source: Berkes and Gonenc (1982).

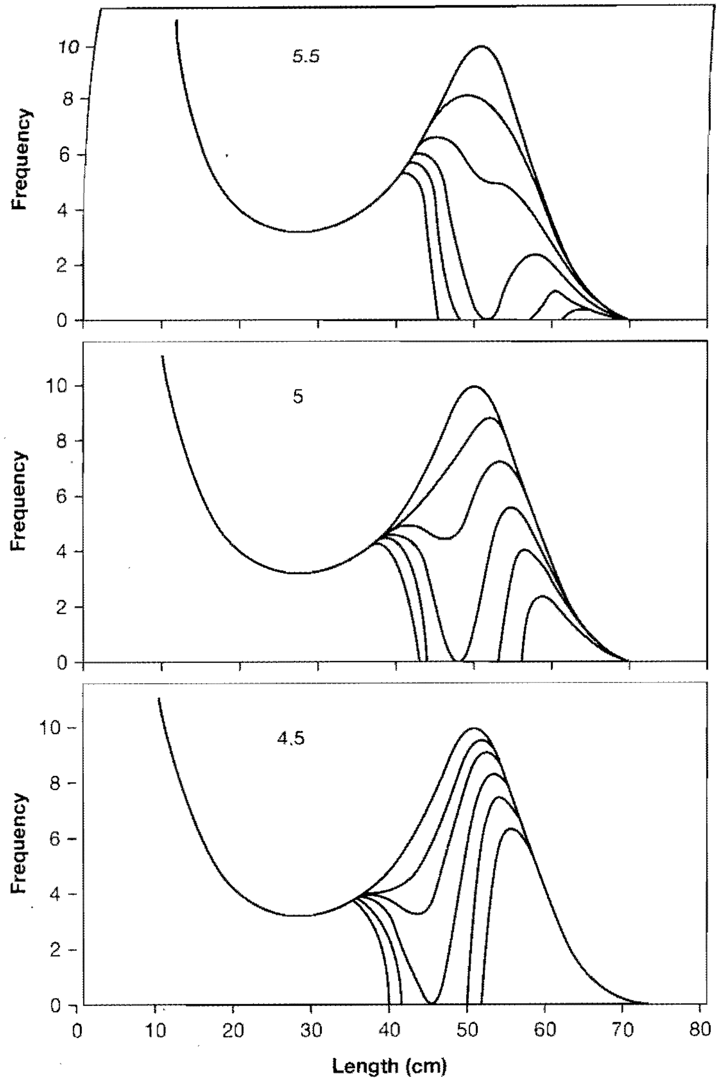
Second, we modeled the effect of a single large mesh size on this hypothetical unfished population (see Figure 7.4). Using the known coefficients of selectivity of gill nets for whitefish, it can be shown that the use of a single large mesh size is indeed efficient in maximizing short-term yields because a large biomass is initially available to 5½- and 5-in. nets, which are the mesh sizes actually used in newly developing northern commercial fisheries. However, a 5½-in. net can result in the depletion of fish over 50–55 cms, depending on the intensity of fishing. Figure 7.4 can also be used to visualize the results of liberalizing mesh size regulations in a hypothetical commercial fishery from 5½ in. (moderate intensity resulting in the depletion of fish over 55 cm), to 5 in. (depletion of fish over 50 cm), and to 4½ in. (depletion of fish over 45 cms).

Third, we modeled the effect of a mixed mesh size strategy to illustrate what population thinning as practiced by Chisasibi fishers may actually look like (Figure 7.5). If the fishery used 3, 3½, 4, 4½, 5, and 5½ in. nets simultaneously, and if the heights of selectivity curves were similar, the length-frequency distribution of the residual population was very similar in shape to that of the original unfished population (see Figure 7.5). This conclusion holds for low and intermediate levels of fishing intensity. We also tried out a number of other combinations of mesh sizes and different assumptions of selectivity and found the outcomes to be basically similar (Berkes and Gonenc 1982).

To summarize, the computer experiment illustrates that the thinning of populations by the use of a mix of mesh sizes conserves population resilience, as compared to the wholesale removal of the older age groups by a single large mesh size. Hence the use of a mix of mesh sizes is more compatible with the natural population structure than the use of a single large mesh size alone. Using a traditional Cree-style fishing strategy, many reproductive year-classes remain in the population even after fishing. At the same time, the reduction of the overall population density increases productivity by stimulating growth rates and earlier maturation in the remaining fish and helps the population renew itself.

Traditional Knowledge Systems as Adaptive Management

The Chisasibi Cree fishing system is as different as can be from the biological management system applicable to boreal/subarctic commercial fisheries. As regulated by government, commercial fisheries tend to be managed on the basis of gear and mesh size restrictions, season and area closures (as during spawning), and catch quotas. By contrast, Cree subsistence fishers use the most effective gear available, the mix of mesh sizes that gives the highest possible catch per unit of effort by area and by season, and they deliberately concentrate on aggregations of the most efficiently exploitable fish. In short, the subsistence



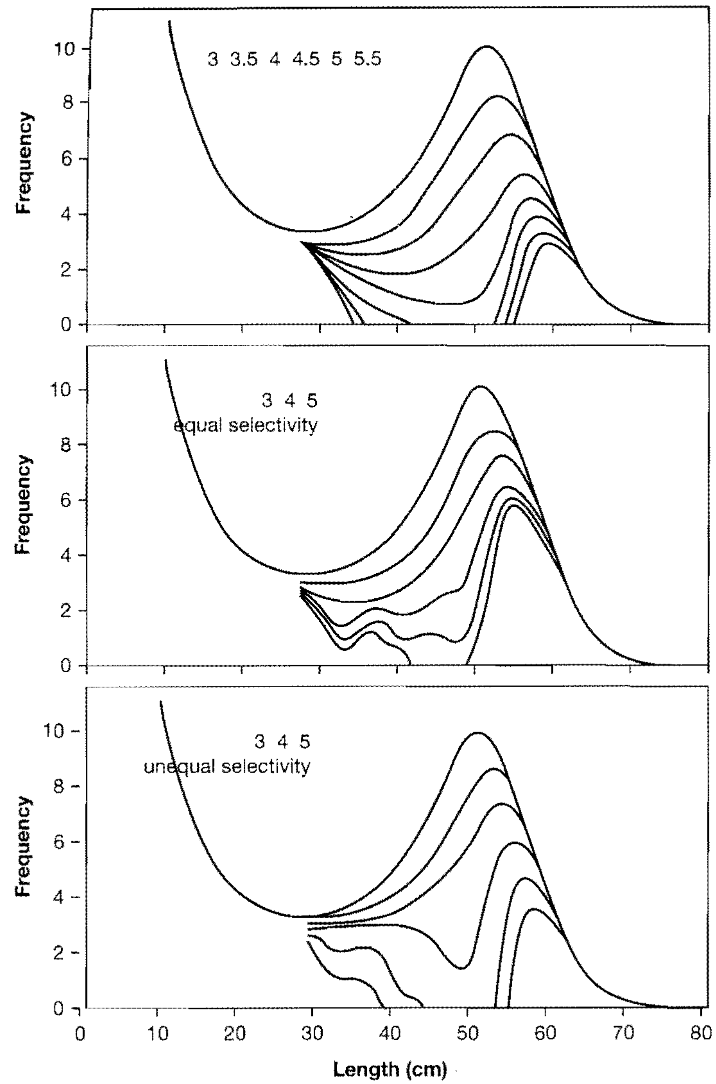


Figure 7.4
(*left*) The change in length-frequency structure of a model whitefish population when fished with single mesh sizes. Contour lines represent different fishing intensities.

Source: Berkes and Gonenc (1982).

Figure 7.5
(*right*) The change in length-frequency structure of a model whitefish population when fished with a mix of mesh sizes. Contour lines represent different fishing intensities.

Source: Berkes and Gonenc (1982).

fishery is a conventional resource manager's nightmare; it violates just about every conservation tool dear to the heart of government managers and biologists.

At the same time, those practices that seem to contribute to the sustainability of Chisasibi fisheries do not seem to be much appreciated by the conventional Western management system: switching fishing areas according to the declining catch per effort; rotating fishing areas; using a mix of mesh sizes to thin out populations; keying harvest levels to needs; having a system of master fishers/stewards who regulate access and effort; and having a land-use system in which resources are used under principles and ethics agreed upon by all. Does it work? The computer experiment helps understand how and why the Cree fishery is adaptive (Berkes and Gonenc 1982), but perhaps a stronger argument is the apparent sustainability of the age-class structure of the two major species over a 50-year period (Berkes 1979). The Cree fishery is difficult to assess using the standards of conventional fisheries management, but there is one kind of Western resource management science that provides a good fit with a traditional system such as that of the Cree.

Adaptive Management has been discussed widely since Holling's 1978 book, and a number of researchers have pointed out the similarities of Adaptive Management with traditional systems. One of the first was Winterhalder (1983) who noted the relevance of one of the central ideas of Adaptive Management to subarctic hunters: how to manage when much is unknown, some things are uncertain, and the unexpected must be acknowledged. He pointed out that Cree-Ojibwa hunters of northern Ontario were experts in using resources in an environment characterized by uncertainty and novelty, and that their foraging strategies used adaptive flexibility, consistent with Holling's models. A second researcher to make the connection was McDonald (1988: 70) who compared conventional and adaptive management systems, with special attention to the Arctic, and concluded that "the adaptive management process potentially provides a methodological framework in which resource scientists and indigenous peoples can work together."

Such a framework seems indeed feasible because, in many ways, there is a remarkable convergence between Adaptive Management and traditional ecological knowledge and management systems. We see in the Cree fishery system that there is learning by doing, a mix of trial-and-error and feedback learning, and social learning with elders and stewards in charge. Like Adaptive Management, there is no dichotomy between research and management in the Cree system. The Cree assume that they cannot control nature or predict yields; they are managing the unknown, as in Adaptive Management. Although the Cree would not use these terms, their thinking is nonlinear and multi-equilibrium. They are used to an unpredictable, ever-changing environment, and they are experts in using resources at different scales of space and time. As in Adaptive Management, the Cree hunter-fisher has respect for complexity and uses practices that conserve ecosystem resilience.

Obviously, there are differences between the two systems as well. Adaptive Management can and does incorporate deliberate experimentation, use of advanced technology (e.g. computer simulations), and reductionistic thinking. Gunderson *et al.* (1995) have in mind large management agencies, not local indigenous institutions, when they talk about social and institutional learning. Management policies can be systematically treated as experiments from which resource managers can learn. The differences are real. But the Cree fisher is also quite capable of conceiving and carrying out field experiments, as in the case of species selectivity of gill nets (see Table 7.2). The Cree do not have formal management policies but they certainly have customary practices that, like the policies of management agencies, can change dramatically, as seen in the case of the caribou. The Cree do not have formal management agencies, but they do have informal institutions in which elders and stewards provide leadership, carry and transmit knowledge, and sometimes reinterpret new information to redesign management systems, again as in the case of the caribou. Traditional management can be reinterpreted as Adaptive Management. Alternatively, Adaptive Management can perhaps be considered a rediscovery of traditional management.

Lessons from Fisher Knowledge

The long-term study of the fishery in Chisasibi is unusual in the literature because subsistence fisheries rarely receive attention, even though they are important in many parts of the world. Also unusual, the Cree fishery shows that it is possible to manage a fishery, in the full sense of scientific fishery management (controlling how much fish are harvested, where, when, and of what species and sizes), completely in the absence of quantitative data and population models.

Cree fishers do have detailed traditional ecological knowledge, including the kind of knowledge that any fisher in any environment needs: when and where to find the fish. But Cree fishers' knowledge extends well beyond that. Fraser *et al.* (2006) showed how the knowledge of the Cree fishers of Mistassini inspired the testing of a hypothesis in evolutionary biology. According to the Cree, there are two kinds of brook trout (*Salvelinus fontinalis*) in Lake Mistassini that they consider to be the same species but clearly different in terms of body shape, color, and behavior. The Cree have observed that the two kinds of trout undertake reverse migrations, that is, one kind migrates into Lake Mistassini to spawn, while the other swims upriver from the Lake to spawning areas. Starting from this observation, Fraser *et al.* (2006) were able to establish that the two kinds of trout were genetically distinct and hypothesized that they represented the post-glacial colonization of Lake Mistassini from two different sources.

Just as Johannes (1981) showed that Pacific Island fishers' knowledge of lunar spawning was richer than that of biologists at that time, fisher knowledge of distinct fish populations is often richer than textbook fish biology. Gallagher (2002) apprenticed himself to Anishnaabe-Metis commercial fishers of Lake Nipigon, north of Lake Superior, to study the unusual forms of lake trout (*Salvelinus namaycush*) reported by them. He found that the three kinds of lake trout that the fishers recognized had distinct coloration, geographic distribution, and depth preferences. Further, he obtained some DNA evidence that they were genetically different as well, possibly corresponding to different stocks of lake trout colonizing Lake Nipigon after glaciation from different source areas.

This kind of detailed knowledge can help local decision-making, but it can also contribute to regional-level planning. The Mekong Basin in southeast Asia supports one of the world's most biodiverse and productive inland fisheries. It is also one of the most difficult fisheries to manage because of regional conflicts. Valbo-Jorgensen and Poulsen (2001) used fisher knowledge as a research tool to produce integrated maps of the migration routes of some of the major fish species of the Basin across six countries. As well, they collected life history and catch information, allowing the identification of several life history strategies used by clusters of species. In an area of high biodiversity, such a finding provides a way for dealing with complexity.

The logic of such approaches is simple: where biological data do not exist and are not likely to become available soon, fisher knowledge provides a feasible alternative for information needs. This is also the logic of Johannes's (1998) "data-less" management: it is feasible to manage fisheries in the vast expanse of Oceania using a combination of fisher knowledge and a network of marine protected areas, in the absence of biological data of the conventional kind.

However, fisher-generated management information is more than low-cost, second-best data. There is an even more important reason for involving fishers in management and using fisher knowledge. When fishers are involved in the conservation and management of a fishery, they are more likely to take ownership of it. There are many examples of this. The local association of fishers and a Brazilian regional NGO, Mamiraua, developed a monitoring technique for the threatened giant Amazon fish, *pirarucu* (*Arapaima gigas*). The method relies on the ability of fishers to count the fish and even to recognize individual *pirarucu* from the way they rise to the surface to gulp air (many Amazon fish breathe air). The method correlates well with the usual biological mark-and-recapture population estimates, and costs much less. More importantly, it empowers fisher organizations to make management decisions and creates a stewardship ethic.

The method has spread across the Amazon Basin and resulted in increased *pirarucu* populations in many areas (Castello 2003).

Local experts using a resource seem to find appropriate rules-of-thumb and local practices and principles to manage the resource. We are still discovering deceptively simple but wonderfully elegant indigenous management practices, such as tidal pulse fishing in Alaska (Langdon 2006). This chapter provided one detailed example (the Chisasibi Cree subsistence fishery) in which the fishers rely on many kinds of observations—but few practices seem to explain much of the documented outcome. Similarly, caribou hunters in Chapter 6 seem to use many kinds of observations but rely heavily on one index, the fatness of the animal, which integrates a number of environmental factors. This conclusion suggests that traditional ecological knowledge and management systems may hold some lessons on how to reduce complexity, and how to deal with complex systems. This theme is going to be picked up again in Chapter 9. But first, we need to explore in some more detail, indigenous ways of knowing: how local experts get to know what they know. This is difficult to do with well-established hunting and fishing systems. But climate change, the subject of the next chapter, is a new experience, and provides a good opportunity to examine indigenous ways of making observations and making sense of these observations, as part of the process of knowing.