## Chapter Seven

# 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.

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. While 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 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 meter) gill nets of various mesh sizes from 7-meter, 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-kilometer radius) and a mix of larger-mesh gill nets were used further away. The most distant locations were visited rarely, perhaps once every five to ten years, and were fished mainly with larger mesh sizes (Berkes 1981b; Berkes and Gonenc 1982). Hunters following the traditional rule of thumb of rotating beaver trapping areas over a cycle of four years would also rotate their fishing areas, fishing a lake for some weeks in one year and then resting it for three years before they went back to it.

**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 |
| 2 1/2 | 219 | 273 | 250 | 2,536 | 250 | 1:9.3 |
| 3 | 86 | 130 | 563 | 192 | 378 | 1:1.5 |
| 3 1/2 and 4 | 30 | 102 | 694 | 22 | 552 | 4.6:1 |

*Source:* Berkes (1977)

**Table 7.2 Chisasibi, August, catch per life with paired 2 1/2 and 3 inch gill nets.**

| | Catch per net set, g | |
|---|---|---|
| | 2 1/2 inch | 3 inch |
| Whitefish | 110 | 227 |
| Cisco | 1,211 | 649 |
| Total fish | 3,164 | 1,439 |
| No. of net sets | 18 | 18 |

*Source:* Berkes (1977)

Most of my fishery research took place near the village, where small-mesh (2 1/2 inch or 63.5 millimeter) gill nets caught mostly the smaller-sized cisco (*Coregonus artedii*) and the larger-mesh ones (3 1/2 inch or 88.9 millimeter 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.

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 2 1/2 inch and the other 3 inch, 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-inch net caught relatively more whitefish than did

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

| | | Near village | Away from village |
|---|---|---|---|
| 2 1/2 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 |
| 3 1/2 and 4 nets: | Whitefish | 1.0 | 2.9 |
| | Cisco | 0.1 | 0.6 |
| | Total catch | 2.1 | 7.8 |

*Source:* Berkes (1977)

the 2 1/2-inch net, the smaller net provided a higher catch per unit of effort, by a factor of two. There was no sense in using 3-inch or larger nets at that *particular* location and season, although the 3-inch 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 2 1/2-inch 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-inch net, I found myself catching immature cisco, good numbers perhaps but definitely immature fish of the 20–25 centimeter size group. By contrast, the 2 1/2-inch net had been catching 25–30 centimeter fish, four to five years old and mostly mature. My catches with the 2-inch 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 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 2 1/2 inches 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 multispecies 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 (e.g., 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 lived in 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 and 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 fifty 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 with the data of government researchers working on the 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

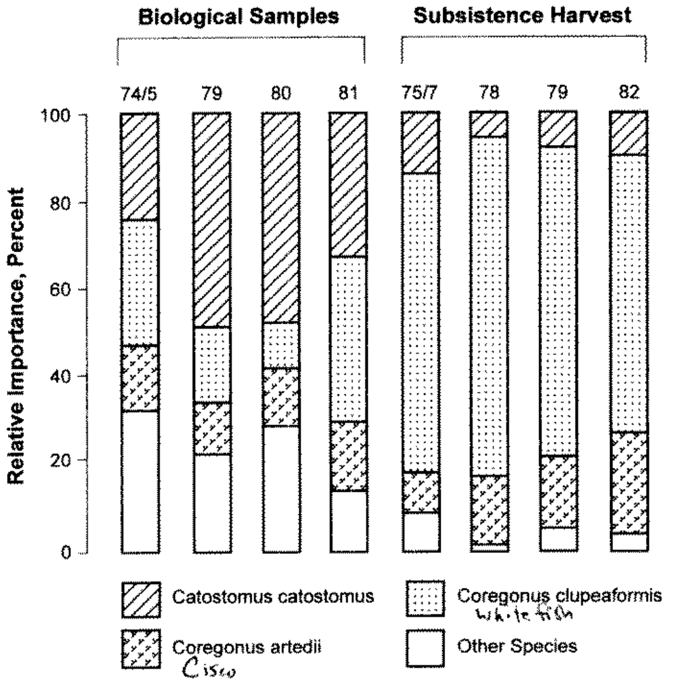

**Figure 7.1** Fish species selectivity of the Chisasibi Cree fisher. Compare the biological samples against the subsistence fishery composition, showing selectivity for cisco (*C. artedii*) and whitefish (*C. clupeaformis*) and against suckers (*C. catostomus*). *Source:* modified from Berkes (1987).

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 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.

**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)

Being a product of Western scientific training, I was for a long time reluctant 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 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.

Krech.

## 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 important 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.

disrespect.

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 the fish and the respectful attitude of the fisher. All of this highlights 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 (Levi-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 fifty- to sixty-year-old) and large-sized fish, analogous, as Johnson (1976) pointed out, to the large biomass of trees in moist tropical 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 distribution 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 fifty 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" (e.g., 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 individuals 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 like sturgeon (*Acipenser fulvescens*) to one dominated by small, fast-growing, and early maturing fish like 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, although a number of fisheries ecologists have pointed out the merits and potential benefits of pulse-fishing in northern commercial fisheries (Johnson 1976).

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 meters by 400 meters at low tide, on the James Bay coast not far from the village. They removed a total of 34 kilograms of fish between June 7 and 12. The initial catch per net set was 6.4 kilograms, and the final, 2.2. kilograms, 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 24 May, right after ice breakup in another inlet on the James Bay coast, a fishing group set five nets and obtained 40.8 kilograms of fish. By 27 May, there were about twenty nets in the inlet, but as the catch per net declined to about 2.8 kilograms, they were relocated somewhere else (Berkes 1977).

Pulse fishing and fishing area rotation seemed to be taking place over two different time scales. In the intensively fished area near the village, a good spot would be fished at least once a year. 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. Since fishing is often coupled with hunting and trapping activities, the ideal practice is a four-year rotation, both among the Chisasibi Cree (see chapter 5) and among other James Bay Cree communities such as Waswanipi (Feit 1973, 1986). 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 showed good catches of whitefish of 50–55 centimeters. 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 centimeters and the lake trout 50–60 centimeters in the more distant, extensively fished lakes, with 40–50-centimeter 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 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 standard commodity.

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.

This should relate in some fashion to size of resource.

## 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 (5 1/2 inch, or 139.7 millimeter) 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: (a) because of the removal of the largest fish, population coming to depend on a small number of reproductive year-classes, and (b) poor spawning for two or more years in a row. 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, which in some years results in complete reproductive failure.

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). 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 fifty-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 fifty-year field experiment was a computer experiment (Berkes and Gonenc 1982).

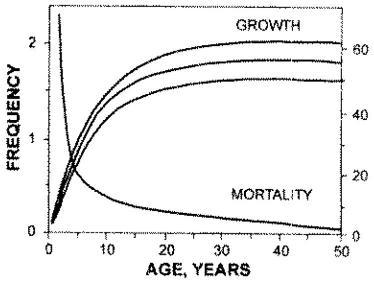

**Figure 7.2** Growth and mortality curves of a model lake whitefish population. Intervals on the growth curve indicate ±1 SD. Equations for curves in Berkes and Gonenc (1982).

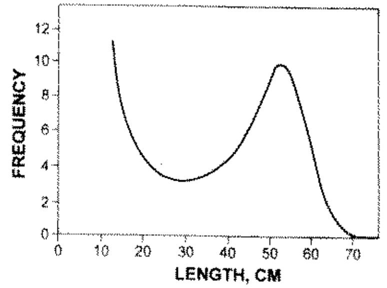

**Figure 7.3** Length-frequency structure of the model whitefish population, as calculated from the growth and mortality curves in figure 7.2. *Source:* Berkes and Gonenc (1982).

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 centimeters) fish, and an abundance of big fish with a mode at about 50–55 centimeters 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.

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

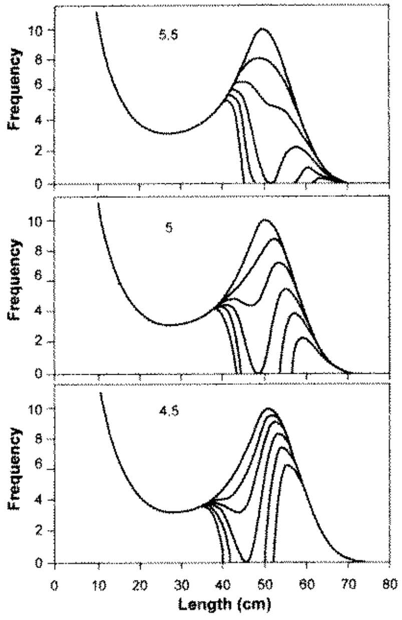

**Figure 7.4** The change in length-frequency structure of a model whitefish population when fished with single mesh sizes. Contour lines represent different fishing intensities. *Source:* Berkes and Gonenc (1982).

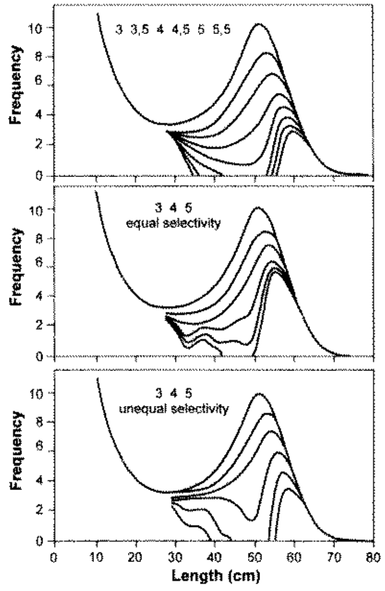

**Figure 7.5** The change in length-frequency structure of a model whitefish population when fished with a mix of mesh sizes. Contour lines represent different fishing intensities. *Source:* Berkes and Gonenc (1982).

large biomass is initially available to 5 1/2- and 5-inch nets, which are the mesh sizes actually used in newly developing northern commercial fisheries. However, a 5 1/2-inch net can result in the depletion of fish over 50–55 centimeters, 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 5 1/2 inches (moderate intensity resulting in the depletion of fish over 55 centimeters), to 5 inches (depletion of fish over 50 centimeters), and to 4 1/2 inches (depletion of fish over 45 centimeters).

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, 3 1/2, 4, 4 1/2, 5, and 5 1/2 inch 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 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 fishery is a conventional resource manager's nightmare; it violates just about every conservation tool dear to the heart of government managers and biologists.

In turn, 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 fifty-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