The History and Development of Atlantic Salmon Management in Iceland

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ABSTRACT

The history and development of the management system for Atlantic salmon (*Salmo salar*) in Iceland are outlined in the context of geographical, biological, ecological, social, and political factors. Important geographical factors influencing management include the physical isolation of the country, small human population, no human habitation in the interior, low energy demands, and lack of many alternative uses of land around rivers. Biological and ecological factors include small size of the salmon stocks, high variations in annual abundance, long residency of adult salmon in rivers before spawning, and maintenance of good flesh quality of prespawners. Social and political factors include the prohibition of mixed-stock oceanic fisheries, emphasis on recreational fishing, relative cultural and linguistic homogeneity, and administration of salmon by the Ministry of Agriculture as a freshwater fish. The management consists of key national restrictions on harvest designed to provide an ecologically sound framework for stock-specific management, even in the absence of detailed data about stocks. Managers are generalists, and management tends to be parsimonious; i.e., it occurs at the lowest organizational level necessary to achieve goals. The major challenge facing managers is how to protect wild stocks of salmon amid rapidly expanding private cage-rearing and ranching operations.

In attempting to understand the nature of salmon (*Oncorhynchus* sp.) and steelhead (*O. mykiss*) management in North America, it may be instructive to know how other societies manage their salmon, as well as how and why different salmon management systems have evolved. The management system considered here is that for Atlantic salmon (*Salmo salar*) in Iceland. In contrast to North America, the management system in Iceland is smaller, less complex, less contradictory, and less stressed. By outlining and discussing the history and development of Icelandic management, perhaps North American salmon managers will find some ideas relevant to their own management.

The Icelandic salmon resources and management system are outlined first, followed by a discussion of the various geographical, ecological, social, and political factors influencing the development of Icelandic salmon management. Finally, perspectives are presented on the present and future management of Icelandic salmon.

Salmon Resources and Management

About 80 of Iceland's 250 rivers support populations of Atlantic salmon (Gudjónsson 1978) (Fig. 1). Most of the rivers are small compared with major salmon rivers worldwide. Total annual catch from all rivers is about 225 metric tons (Gudjónsson and Mills 1982), or just 2% of the total world catch of Atlantic salmon (McKernan 1980) and <1% of the world salmon catch of all species combined (*Oncorhynchus* sp. plus *Salmo salar*). Except for three rivers that support commercial fisheries, the rivers are managed exclusively for high-quality sport angling by Icelanders and foreigners (Gudjónsson 1978). Average annual angling catch from 1971 to 1980 was 41,700 fish; the commercial gillnet catch from rivers over the same period averaged 21,500 fish. Total catch in Iceland in 1987, excluding salmon ranching, was about 45,000; about 34,000 were caught by rods and the rest were caught by nets (Ísaksson 1988; Gudbergsson 1988). The most productive salmon rivers with the most stable catches are in the southwest and west (Figs. 2, 3); several rivers provide annual yields of 1500–3000 fish. The northern rivers generally have fewer salmon and more variable catches, but produce larger (i.e., more multi-sea-winter) salmon. A few large northern rivers provide annual catches in the range of 1000–2500 fish. Gudjónsson (1978) and Gudjónsson and Mills (1982) provide details on catches by region and by river.

The freshwater fisheries were largely unregulated until comprehensive laws were passed in 1932 (Gudjónsson 1978) and the minister of agriculture was given overall responsibility for the freshwater fisheries. An advisory committee was also formed called the Freshwater Fisheries Council. In its present version, this Council has five members; one member is directly appointed by the minister, but the other four are nominated for appointment, one each, by the Agricultural Society of Iceland, the Marine Research Institute, the Association of Icelandic Angling Clubs, and the Federation of Fishing Associations of Iceland. The Council advises the minister in dealing with fisheries issues and must give approval to many aspects of fishing, fish farming, and other matters.

The Institute of Freshwater Fisheries, with its central office in Reykjavík, is the primary source of scientific research and technical expertise on salmon in Iceland. The Institute and its directorate were both established in 1946. The director of freshwater fisheries, Árni Ísaksson, assists and advises the minister in the administration of the fisheries and supervises the activities of

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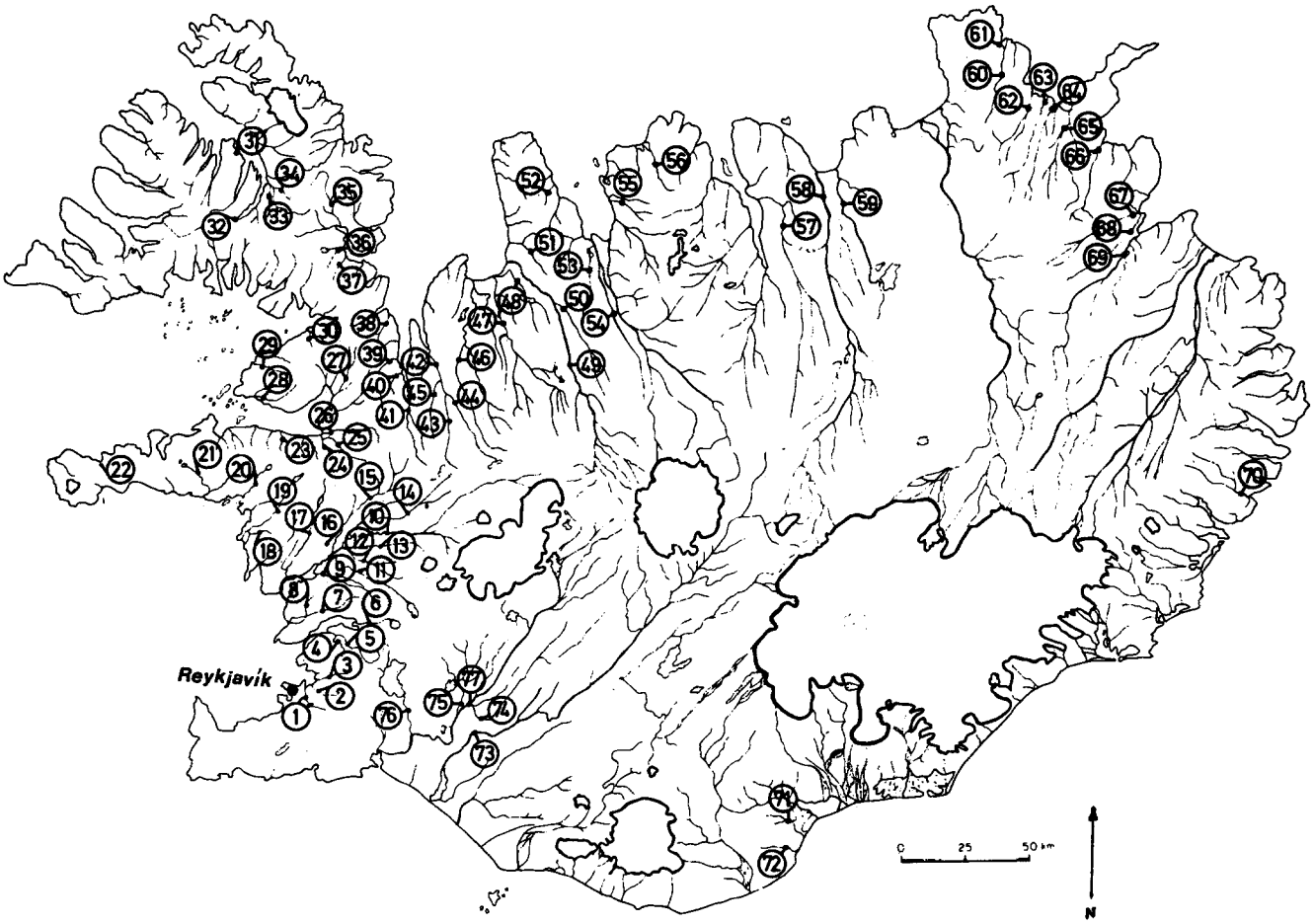

Figure 1. The locations of nearly all of Iceland's significant salmon rivers (From Scarnecchia 1983). Rivers mentioned in text and figures: 1, Ellidaár; 4, Laxá í Kjós; 15, Nordurá; 43, Núpsá; 49, Blanda; 50, Svartá; 73, Thjórsá.

the Institute staff. Staff activities include the collection of catch data and compilation of statistics, distribution of fisheries information, extension, consultation, applied fishery research, and fish culture research (Gudjónsson 1978).

Since the ninth century when the island was settled by Vikings, the rivers have been privately owned (Mathisen and Gudjónsson 1978). The rivers historically supported subsistence fishing and, sometimes during past centuries, also supported export commercial fisheries to Europe (Hartwig 1871). However, the laws of 1932 prohibited salmon fishing in the sea by Icelanders and designated the salmon as a freshwater fish for regulatory purposes. Most coastal fisheries for salmon that had existed were abolished by the laws of 1932. Exceptions were made for seven traditional fisheries where historical fishing rights had been recognized. One goal of the legislation of 1932 was to move more of the income from fishing to locations upriver, i.e., to farmers inhabiting the valleys. Since Iceland was at that time largely an agrarian society, farmers wielded sufficient political power to push this legislation through parliament. According to Thór Gudjónsson, director of the Institute of Freshwater Fisheries from 1946 to 1986, "The laws of 1932 were comprehensive compared to the older laws. But it remained to put them into practice. The experience from practicing these laws showed that alterations and additions were needed. These were made in 1934, 1957, and 1970." (Letter to author, 16 August 1988). The challenge of implementing these laws was undertaken mainly by Gudjónsson and his assistant, Einar Hannesson, with the support of many fishery owners, anglers, and net fishermen. Salmon fishing in the sea is still illegal within territorial waters, and Iceland is opposed to high-seas fishing for salmon (Gudjónsson 1970).

Landowners along each salmon river are required by law to form a fishing association; these associations supervise fishing activities along their rivers (Gudjónsson 1978). There are about 150 such associations. Associations either lease fishing rights to angling clubs or directly sell angling privileges along the rivers. The association is also obliged to practice "fish cultivation" (Icel. fiskraekt), viz, "the protection of fish, improvement to (sic) its conditions for life, the importation of fish into fishing waters, the easing of fish passages, fishing supervision, and anything else which may be conducive to the increase or maintenance of the stock of fish." (The Salmon, Trout and Char Fishing Act 1970). The association thus supervises management on a local basis, and the expertise of Institute biologists is commonly sought in making management decisions.

The duration of the angling season is limited by law to the period from 20 May to 20 September, and nowhere may fishing occur for more than three

Figure 2. Laxá í Kjós, a major salmon river in the southwest. Average rod catch from 1981 to 1985 was 1182 fish; from 1976 to 1980, 1551 fish (Gudjónsson and Mills 1982).

Figure 3. Nordurá, an important salmon river in the west. Average rod catch from 1981 to 1985 was 1250 fish; from 1976 to 1980, 1762 fish (Gudjónsson and Mills 1982).

months during this period (The Salmon, Trout, and Char Fishing Act 1970). Salmon caught at other times and in the sea must be returned to the water. The director of freshwater fisheries, with the consent of the Freshwater Fisheries Council, determines the number of rods that may be fished at any one time in the rivers. In setting these rod limits, the director also seeks the views of the fishing association(s) for that river.

Because ocean fishing is prohibited, salmon are managed exclusively at the level of the individual river or tributary and, usually, the individual stock (Scarnecchia 1983). A comprehensive data collection system was established for angling catches on each river: an angling log (*veidibók* or "angling book") is kept yearly in which data on sex, weight, place and date of capture, and name of angler are recorded for each salmon caught (Fig. 4). These books are sent to the Institute each year. Place of capture along the river is critical in affecting the allocation of fishing income among the members of the association. Landowners adjacent to more productive sections of the river for salmon receive proportionately more income from the fishing.

Artificial propagation of salmon began in 1884 with the construction of the first salmon hatchery (Gudjónsson 1967). In 1932, a hatchery was built on the banks of the river Elliðaár, near Reykjavík, by the Municipal Hydroelectric Power Company (Gudjónsson 1978). Unfed fry from this river were stocked in various rivers throughout the country. In 1961, with the construction of the Kollafjördur Experimental Salmon Hatchery near Reykjavík, salmon hatchery technology began to improve in Iceland with the aid of controlled experimentation. The purpose of the Kollafjördur facility was to "[rear] young salmon to the smolt stage inside the fish farm, the smolts being able to migrate from there into the sea, as well as for liberation into rivers in various parts of the country . . . not as compensation measures for damages . . . but in addition to natural production of salmon. . . ." (Gudjónsson 1967, p. 1–2). Kollafjördur thus produced fish for mitigation and enhancement, while experimenting with ocean ranching. The facility uses geothermal water and heat exchangers to provide warmer water and thus shorten the hatching time and rearing period for young salmon.

In addition to Kollafjördur, other hatcheries have been built around the country to rear smolts and parr for release, e.g., into rivers above waterfalls or in unused tributaries. A few of these hatcheries are partly owned by landowners or fishing associations. In the past, stocks were frequently mixed, but in recent years, stocks of salmon have been generally reared separately and released back into their native rivers.

Since the mid-1970s artificial propagation of salmon in private ranching and farming has greatly increased. In 1984, more than 50 companies were licensed to engage in salmon ranching or farming; 22 of them produced juvenile Atlantic salmon (Severson and McNeil 1985; Fig. 5). Salmon ranching yielded 15,000 adult fish in 1987.

Cage-rearing of salmon, in which mainly Norwegian technologies are used, has also developed in many fjords. In addition, cold and rough water in many Icelandic fjords has stimulated an interest in rearing salmon in sea water in land-based tanks. The rapidly expanding land- and cage-rearing operations produced 490 metric tons of salmon in 1987, a 200% increase from 1986 (Ísaksson 1988). Smolt production for ranching and cage rearing has also expanded rapidly. Over 4.9 million smolts were reared at 29 farms in 1987, an increase of 140% from the previous year (Jóhannsson 1988). Adequate geothermal water supplies are critical to the expanding cage rearing and ranching operations.

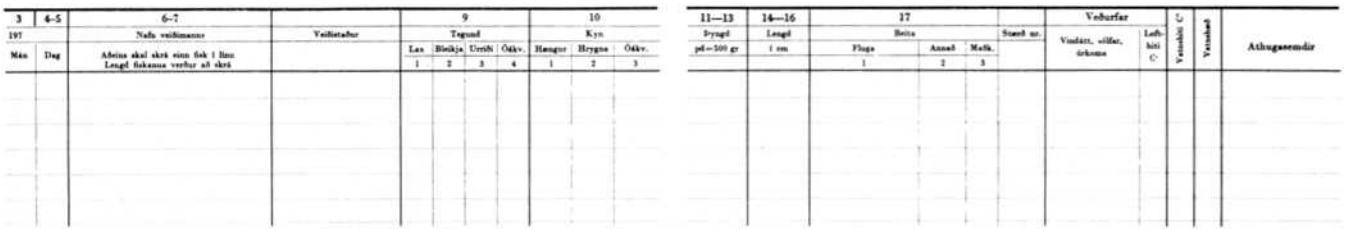

Figure 4. Page of Veidibók showing data collected from salmon caught. Data requested are date, name of angler, fishing station on the river, species of fish, sex, weight, length, bait used, weather conditions, air temperature, water temperature and level, and other comments.

No other species of salmon have been successfully introduced into the wild in Iceland, although stray pink salmon (*Oncorhynchus gorbuscha*), evidently from Soviet experiments, were caught in several rivers in the 1960s (Gudjónsson 1961) and 1970s. Pink salmon eggs were also introduced from Alaska to a site in southwestern Iceland in 1965, and fry were released in 1966, but they did not sustain themselves (Thór Gudjónsson, personal communication; Jóhannesson 1968). Rainbow trout (*O. mykiss*) have been introduced in confinement for production of pan-sized fish. Production in 1987 was 139 metric tons. The importation of live salmonids or other freshwater fish into Iceland is prohibited, although the Minister can permit the importation of eggs if they are certified to be free of diseases (The Salmon, Trout and Char Fishing Act 1970).

Factors Affecting Salmon Management

Geography

Because Iceland has no close neighbors and established a 200-mile exclusive fishing zone by unilateral declaration in 1975, it has effective control over most of its fish stocks, including salmon (Elísson 1981). Although Icelanders have never harvested many salmon from the North Atlantic (Ísaksson 1980; Gudjónsson 1970) other nations fish extensively for salmon off the west coast of Greenland (Christensen and Lear 1980) and north of the Faroe Islands (Shearer and Clarke 1983), outside Iceland's 200-mile limit. Inasmuch as few tagged Icelandic salmon have been recovered in these fisheries (Ísaksson 1980), and few stocks were tagged, the effects of these fisheries on Icelandic stocks are not yet known (Gudjónsson 1970). Even if these fisheries are harvesting Icelandic salmon, the persistence of distinctive small individual stocks and the relative stability of their age structures (Scarnecchia 1983) indicate that interception of Icelandic stocks is not a major problem. The geographical isolation of Iceland gives its inhabitants greater direct control over the fate of their salmon than most other salmon-producing nations.

Iceland's human population is still so small (2.2 per km^2; Ministry of Foreign Affairs 1981) that, despite a high standard of living, there are few direct (habitat loss) and indirect (energy demand) impacts of human population on its salmon stocks. Because 53% of the quarter-million inhabitants live in the southwest, in or near Reykjavík (Ministry of Foreign Affairs 1981), and all the people live near coastal areas, most land—including that adjacent to headwaters—is sparsely inhabited or uninhabited. Lower sections of rivers near the sea are sometimes altered by human activities, but these areas are, according to most investigations, not major spawning or rearing areas for salmon. Many upriver areas above waterfalls provide productive habitat for introduced parr. Anthropogenic pollution of rivers is slight (Gudjónsson and Mills 1982), except for the effects of sheep grazing. This widespread grazing in lowlands and highlands has eliminated low birch forests and reduced grass cover—and sometimes resulted in severely accelerated erosion, reduced substrate quality for rearing salmon, and significant filling in of holding pools for adult fish (Gudjónsson and Mills 1982). With this exception, the rivers have been spared many degradations common to those in other countries.

Domestic demands for salmon angling by the small population of both rural and city dwellers (many of whom either own fishing rights to rivers or have relatives who do) were historically adequately met by the supply of wild salmon. Thus, the human population of Iceland has maintained a reasonable balance with the salmon resource. However, foreign demand for angling (mostly fly fishing) has increased in recent years such that foreigners, who are often able to pay more than Icelanders, now fish on many rivers during the best part of the season (e.g., usually 15 July–7 August), when both grilse (one year at sea) and multi-sea-winter salmon are in the rivers.

Although hydroelectric power is the primary domestic source of energy in Iceland (Ministry of Foreign Affairs 1981), the demands have been modest. Iceland imports its oil, and geothermal

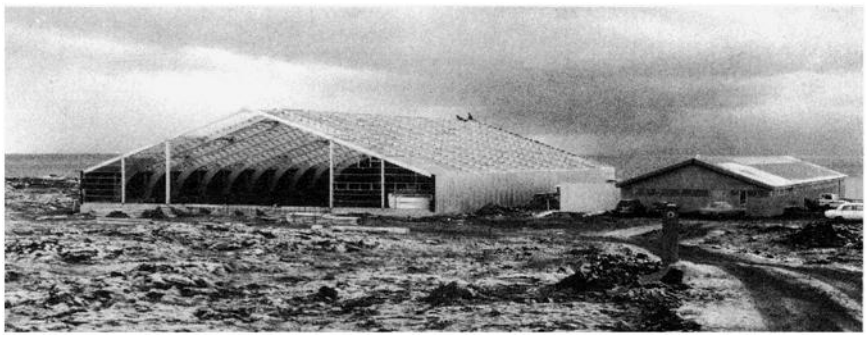

Figure 5. A salmon ranching facility on the Reykjanes peninsula, southwestern Iceland.

energy provides hot water for heating homes and offices, and industrial uses (e.g., aluminum and cement production). As a result, most of Iceland's rivers have been spared hydroelectric dams, man-made blockages of salmon runs, and associated alterations of riverine ecosystems. Other rivers that have been developed (Thjórsá) or are being developed (e.g., Blanda) are large glacial rivers of limited value to salmon anglers. However, many of these glacial rivers have freshwater tributaries that provide excellent salmon habitat. Commercial fisheries (e.g., Thjórsá) and even a "snag" fishery (i.e., Blanda) exist in areas with glacial silt, and rod fisheries often exist in freshwater tributaries (e.g., Svartá).

Iceland's climate is, with rare exception, too cold to support agriculture for grain crops (Hartwig 1871; Lindroth 1937; Magnússon 1977). Water withdrawals for irrigation are nonexistent.

According to Hartwig (1871, p. 79), "In former times Iceland could boast of forests, so that houses . . . used to be built of the indigenous timber." Although the settlers in the ninth and tenth centuries found many low birch forests in the coastal areas, less than 1000 km^2 of perhaps 20,000 km^2 of the original forests remain (Thorarinsson 1968). Because of the aforementioned grazing and wood-cutting for fuel, twentieth century Iceland is largely a treeless landscape. Salmon runs are not blocked by trees, but are often blocked by waterfalls (Einar Hannesson, Institute of Freshwater Fisheries, unpublished).

Iceland has few commercially important mineral deposits, so its salmon rivers have been spared the disruption of sediments by placer and other mining activities. The rivers are also too small, too shallow, or too turbulent to support navigation.

As a result of the management framework and the minimal alternative land uses, high-quality salmon habitat remains in essentially all rivers historically known to support salmon. Salmon have also been introduced into other rivers that for various reasons did not naturally contain salmon.

Ecology

The small size of Icelandic salmon stocks is a result of several factors, including the small size and shortness of most rivers, a cold climate with short growing season for juvenile salmon, and low inherent productivity per unit of area in many rivers. In addition, interannual climatic variability and natural stock oscillations produce extreme interannual variations in stock sizes, particularly in the northern rivers (Scarnecchia 1984). Angling success often varies greatly between years and most of these small stocks are unable to support stable, high value commercial fisheries.

In response to the constraining sea and river temperatures (Power 1981) and other undetermined factors, salmon enter Icelandic rivers and spawn over a relatively brief time. Fish enter rivers from May to October (Gudjónsson 1970), and fisheries are mostly active from early June to mid-September (starting times are later in the north). The fish remain in the river long enough before spawning to support worthwhile fisheries, and fish caught during legal fishing seasons have flesh of high quality. These characteristics counterbalance any incentive to fish in the sea, where salmon are scattered, or where the water may be rough, costs higher, conflicts greater, and gains in flesh quality slight.

Politics and Social Factors

Iceland has strong and explicit laws regulating the harvest of salmon. The key provision was the prohibition of commercial and recreational fishing for salmon in the ocean, which resulted in conservation benefits to the individual stocks of salmon by minimizing fishing on mixed stocks. And as a result of private ownership and the requirement to form associations, there has been little common-property "tragedy of the commons" (Hardin 1969) behavior by Icelanders toward their salmon resources.

Angling regulations, including rod limits, were originally intended to provide anglers about one salmon per day on the average while maintaining the reproductive potential of the stocks. The result of the regulations, however, turned out to be an exclusive fishery (Tumi Tómasson, personal communication). Anglers pay as much as $1,800 (U.S.) per fishing rod per day on the best rivers. Weekly rates on the best rivers can exceed $5,000 U.S. The best rivers provide lodging and guide service. All of the rivers provide a private, exceptionally high-quality fishing experience for wild salmon. Although economic studies have not been done, the potential economic value of an in-river commercial harvest is small compared with the high rents extracted for angling (Gudjónsson 1970). Many associations resist allowing more rods on the river, even if the stocks will tolerate more harvest, because of possible reductions of the exclusivity and total income of the fisheries (Tumi Tómasson, personal communication). According to Mathisen and Gudjónsson (1978, p. 156), "the prime task of management is not to maximize the yield, as in other fisheries, but to achieve the greatest satisfaction of the angling public." There is thus a strong economic incentive for maintaining the recreational fishery, in preference to a commercial harvest, and a strong incentive to have a few high-paying anglers seeking an abundance of salmon in the rivers. This incentive, along with overall rod limits, keep fishing pressure below that causing depletion of stocks.

Throughout the centuries, Icelanders have used salmon primarily for subsistence and as supplementary provisions to their agriculture. Neither the "land ethic" ideas expressed in North America by Leopold (1970) and others, nor the preservationist ideas of John Muir have any well-developed counterpart in Icelandic culture. Tomasson (1980) called the Icelanders empirical in their approach to experience, as opposed to philosophical, theoretical, or ideological. The Icelanders have used the empirical approach in their struggle against nature; such a continual struggle may not be conducive to the development of a preservationist philosophy.

From settlement in the ninth century up to the mid-twentieth century, Iceland was primarily agricultural. Rural agricultural interests used their disproportionately strong representation in parliament to successfully promote the ban on oceanic fishing for salmon. Even today, administration of salmon management reflects the political influence of the farmers. Although the economically vital Icelandic oceanic fish stocks and fisheries are under the jurisdiction of the Ministry of Fisheries, the salmon are administered under the Ministry of Agriculture. This administrative arrangement has allowed the salmon to

benefit from the Icelanders' concepts of territory. Management and harvest of individual stocks in rivers according to the stock concept is thus efficiently matched not only to the life history of the salmon, but also to the ownership patterns of the people. Harvest has not been divorced from stewardship.

The Icelandic owners' associations serve a purpose for salmon resources similar to the old Germanic local *Things*, in providing a forum for coordination and discussion of salmon management issues among the landowners. Since the Age of Settlement, the Icelanders have used local parliaments for coordinating activities and resolving disputes (Tomasson 1980); it is natural that control over the salmon resources (i.e., owners' associations) might be based on this concept.

The Veidibók system of data collection is also well suited to the geography, land ownership patterns, and cultural heritage of Iceland. Since the Age of Settlement, the Icelanders have been inveterate record keepers. Their book of Settlements, or Landnámabók, is a purported record of the names, genealogies, and short biographies of all the principal settlers (Magnússon 1977). Even today, upon visiting an Icelandic homestead, travelers and guests are often asked to record their names, places of residence, and miscellaneous pleasantries in a *gestabók*—a logbook of visitors to the homestead. Many of the older Icelandic residents also have kept logbooks of weather and other natural events. The Veidibók system is consistent with traditional Icelandic record-keeping methods, and has resulted in data useful for allocation of fishing income and for management. Geography and population distribution patterns also contribute to the efficacy of the Veidibók system. Harvest data can be collected at little cost at centralized fishing lodges, often located on the lower reaches of a river. In addition, the Institute has expended much effort in educating associations and anglers on the importance of these statistics.

Salmon rivers in Iceland typically cross few jurisdictional boundaries. Iceland's rather homogeneous ancestral settlement has led to few factional constituencies and has permitted an internally consistent and ecologically adequate salmon management plan to be developed.

Management Perspectives

An Effective Framework for Management

The salmon are still the major industry on the rivers, and non-fisheries interests have not taken economic control of the rivers. Regulations on salmon fishing consist of key national restrictions on harvest areas, time of harvest, and effort that provide an ecologically sound framework for stock-specific salmon management. The prohibition of ocean fishing for salmon allows the Icelandic salmon stocks, as well as their habitat, to benefit from the Icelanders' ties with their land. In addition, limits on the length of the fishing seasons and number of fishing rods per day have resulted in moderate but sustained harvest and stability of sea-age structures of most stocks. Thus, future management options are preserved when the stocks fluctuate widely in abundance, and even when relatively little is known about the ecology of a particular stock. Fisheries do not take the last potentially harvestable fish out of each river but, instead, provide a harvest while allowing biologists to manage on the basis of what they know with respect for what they do not know. The approach has provided an income for landowners, has accommodated and complemented the effective method of data collection, has facilitated analytical research, and has (where finances allow) permitted investigations on the natural ecology of relatively undisturbed salmon stocks free from unrealistic man-made deadlines.

Generalists and Specialists in Management

Historically, there has been little pollution and scant overharvest in Iceland, and few dams have been built. In short, Iceland has had a general lack of the kinds of specialized problems that salmon managers and researchers in other regions spend most of their time addressing. Few biologists are needed to manage, and the need for specialists has historically been nil. The Icelandic management that Levinge (1980, p. 14) called "an exemplary model of salmon conservation" has been established and implemented for more than 80 salmon rivers with a management staff of fewer than 10 biologists. These biologists are generalists—ecologically oriented biologists with diverse job descriptions. Applied research, preparation of management plans and recommendations, extension service (Fig. 6), public relations, and other duties facilitate the development of the broad perspectives needed by ecologically and culturally attuned managers. Managers so trained are likely to allow the ecosystem to dictate the form of management and to draw from a broad ecological and cultural background when they consider how and where technologies should be applied.

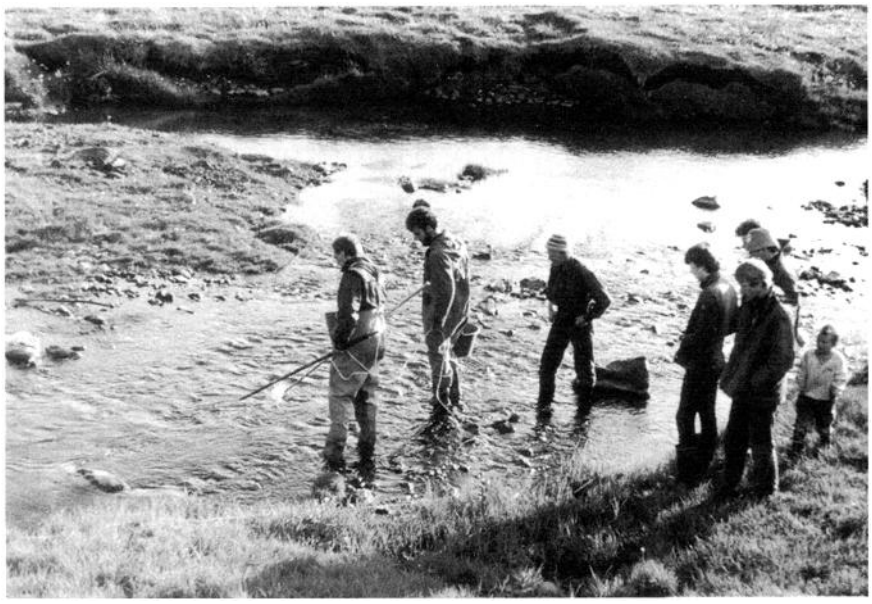

Figure 6. Sigurdur Már Einarsson and Richard Thompson sampling salmon parr with electrofishing gear while local residents look on.

Centralized Versus Decentralized Management

Icelandic salmon management is a highly decentralized, local stock-specific management system within a centralized national framework of ecologically sound harvest regulations and data collection. The management is ecologically, economically, and socially parsimonious—i.e., it occurs at the lowest organizational level necessary to achieve goals. Laws that eliminate oceanic recreational and commercial fishing and regulate salmon ranching are appropriately implemented at the national level, the lowest level at which stock-specific management and incentives for local stewardship can be preserved. However, within a particular river, rod limits are based on the productivity (as indicated by catch) of salmon in that river. Construction of fish ladders, use of egg boxes, fry stocking in sections uninhabited by salmon, and other such activities are planned and implemented on a river-by-river basis. With this mixture of centralized and decentralized management, many different value systems can be accommodated, and local fishing associations and residents are active in management. A similar, equally frugal approach is used for data collection. Day-to-day data collection for Icelandic rivers is handled on a river-by-river basis, but overall collection is coordinated centrally by the Institute of Freshwater Fisheries. The emphasis of national fisheries regulations and policies is not to unselectively usurp management authority, but to establish, with a minimum of laws, the framework for effective local stock-specific management.

The Changing Scene

The system of management developed in Iceland has for 40 years been well suited to the geographical, biological, and cultural environment there. But like all modern, industrialized countries, Iceland is in the midst of a cultural and technological revolution. According to Magnússon (1977, p. 215), "Since agriculture with its over production and [oceanic] fishing with its ever-diminishing catches cannot absorb the annual increase in the labor force, . . . further industrialization of the country is a necessity, whether one likes the idea or not." The population in 1975–79 was growing at an average annual rate of 12.8 per 1000 persons (Ministry of Foreign Affairs 1981), and an increasing percentage of the population is living in urban areas. As more and more Icelanders live in high-technology cities isolated from the land and the rivers, societal values toward land and salmon are changing, and political powers of farmers are waning. There are concerns about the increasing prevalence of absentee-ownership of farmsteads. At the same time, the economic demands for employment as well as demands on the salmon resources are increasing.

As in other regions, Icelandic salmon management is responding to the population pressures and technological changes with more technology. Many of these management technologies, such as coded wire tagging equipment, hydroacoustic gear, and computerized data storage programs were introduced in the mid-1970s with the aid of U.S. fisheries specialists from the University of Washington under a grant from the United Nations Development Program (Mathisen 1978). Interest in hatcheries and salmon ranching has increased greatly since that time, primarily by those not owning portions of salmon-producing rivers. The 490 metric tons of salmon produced by cage and tank rearing in 1987 is over twice the total annual catch (recreational plus commercial) in all of the rivers combined. The 4.5 million smolts produced from 29 rearing facilities in 1987 (Jóhannsson 1988), and the estimated 12 million smolts produced in 1988, contrast with a mere 600,000 wild smolts estimated to emigrate from all of the salmon rivers each year (Sigurdur Gudjónsson, personal communication).

The major rationale for salmon ranching and cage and tank rearing in Iceland is that they can potentially increase the production of salmon and provide income for a growing human population. Without an ocean fishery, hatchery-ranched salmon presumably will return to release sites rather than be caught at sea; the economic investments of salmon ranchers will thus be protected. Because most other nations with well-developed salmon production technologies have intercepting ocean fisheries to contend with, it is not surprising that salmon ranching would develop in Iceland. With the ready availability of Norwegian technology to build on, geothermal water supplies, and numerous fjords, it is also clear why cage and tank culture would develop.

So in Iceland, as in other salmon-producing nations, there has been a rapid change in the role of most salmon hatcheries from being a tool of management (with an ecological purpose), to being a food producer (with a production agricultural purpose), or even to being an end in themselves (with a scientific-technological purpose). Many Icelanders, particularly farmers and anglers, favor controls on the locations and activities of aquaculture operations to protect the genetic integrity of wild stocks. As of 1989, the fishing laws are being revised to deal with the complexities of this issue. It has been suggested that ranching and cage-rearing sites should be located away from rivers inhabited by important wild stocks, and that land-based tank culture may be safer for wild stocks than the cages, and should thus be emphasized.

Severson and McNeil (1985) did not discuss potential problems with straying of ranched hatchery stocks which could negatively affect indigenous wild stocks, despite severe straying problems associated with their corporation's release site for coho salmon in the Yaquina River, Oregon (Nicholas et al. 1982). Hatchery-reared or pen-reared salmon could also stray and spread diseases, such as *Gyrodactylus* sp., which has nearly destroyed some wild Norwegian stocks (Johnsen and Jensen 1986). But according to Severson and McNeil (1985, p. 9), "ranched salmon [in Iceland] can be expected to enhance sport fisheries through planned stocking of streams and through straying of hatchery adults." They also argue that straying would be reduced by locating hatchery release and recovery sites on the Reykjanes Peninsula (west of Reykjavík) where underground water flow predominates and streams are rare. In their view (p. 10), "Salmon ranching is clearly in Iceland's interest."

If the growth of private salmon aquaculture is any indication, many Icelanders also believe that salmon ranching and cage-rearing of salmon are in Iceland's interest. Through long-term research and development at the government-owned Kollafjördur hatchery

and from research at private sites, Icelanders have progressed in their technologies for rearing and ranching salmon. Perhaps Iceland's future, like that of other salmon-producing nations, will consist of even more widespread ranching and farming of salmon. But Icelanders have a continuous history of 1100 years on their land, and a record of stock-specific wild salmon management. Thus, it must be the Icelanders themselves who decide the role of salmon ranching and farming in their management. Future generations of Icelanders will evaluate how well this generation of managers balanced the economic demands of the present against the long-term welfare of the salmon resources.

Acknowledgments

This paper is dedicated to Thór Gudjónsson and Einar Hannesson, both recently retired from the Institute of Freshwater Fisheries, who have, in my opinion, been most responsible for the well-being of Iceland's salmon resources. Both men have helped me greatly in providing background information for this paper. In addition, Mr. Gudjónsson kindly reviewed the paper for accuracy. Special thanks are also due to Árni Ísaksson, the director of the Institute, and Dr. Tumi Tómasson for correcting some of my misconceptions of Icelandic salmon management. Despite their efforts, responsibility for any remaining errors rests with me. The paper also benefitted from reviews by Dr. W. J. McNeil and an anonymous reviewer. Sigurdur Már Einarsson, Sigurdur Gudjónsson, Sumarlidi Óskarsson, Gudni Gudbergsson, Jón Kristjánsson, and others have contributed valuable discussions and shared field experiences that have hopefully resulted in a better paper. This is journal paper no. J-13059 of the Iowa Agriculture and Home Economics Experiment Station, Ames, IA, Project No. 2816.

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