# DEVELOPMENT OF FRESHWATER FISHERIES

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## Summary

Evidence for the importance of freshwater fisheries to human populations dates back to prehistoric times. Few fish exemplify the history of freshwater fisheries better than the

salmonids. Once plentiful throughout their native range these fish gradually became victims of overexploitation, polluted waterways, and widespread water extraction. Attempts to protect the fisheries have resulted in major enhancement programs designed to increase stocks. However, these efforts have brought about mixed genetic populations in many rivers where once discrete stocks were found. Scientists anxiously await the outcome of such enhancement programs, the impact of which on the fisheries is uncertain.

Other attempts to improve freshwater fisheries include stocking with various non-endemic fish species. Such efforts may initially increase production but may not be sustainable. The introduction of non-endemic species, especially carnivorous fish, has resulted in declines of native species and loss of artisan fisheries. Reservoir fisheries are considered important in Asia and other tropical/subtropical countries. The artificial impoundments provide new bodies of water for stocking permitting both artisanal and commercial fishing. Aquaculture is considered vital as a means of reducing pressure on freshwater fisheries in much of the world. The culture of freshwater fish may be extensive or intensive. The Chinese lead the world in polyculture but, like the North American catfish farmers, they are dependent on a few large river deltas for their industry's well-being.

The decline in many commercial freshwater fisheries has seen an upsurge in recreational fisheries in some parts of the world in an attempt to alleviate unemployment and sometimes to increase protein availability. Recreational fisheries have considerable commercial potential if they are well managed, and at the same time may act as a catalyst for conservation. Freshwater fisheries are and continue to undergo evolutionary change. Their future rests on a clear recognition of the desired evolutionary stage and management plans to prevent the slide toward the final stage, which, put simply, is extinction.



## 1. History of Freshwater Fisheries

### 1.1 Early Fisheries

Freshwater fish have been hunted by man since at least Paleolithic times (see *History of Agriculture*). Between circa 35 000 BC to 10 000 BC, Advanced Paleolithic people invented a wide range of hunting tools including fishing tackle: lasting evidence of a hunter-fisher economy comes from the ornate carvings of such prey species as deer while fish appear on spears and harpoons made of antler. The Magdalenian people were adept at such carvings and at cave art. Paintings of salmon-like fish are to be found among the mammoth, bison, reindeer, and horse in the great cave paintings of France and Spain. Maglemosian Assemblages dating back to 6000 BC include nets made of plant fiber with floats constructed from bark. Hooks carved out of bone are found in these Assemblages, but bone hooks date back to at least 8000 BC (Natufian Assemblages).

Fish are depicted in the ancient totems and art of many aboriginal peoples, and fish species must have had considerable significance to these tribes (see *Development of Marine Fisheries*). In Australia, ancient drawings of eels are seen on rocks, and it is

known that these fish and barramundi-like species have been harvested by indigenous Australians for thousands of years.

Hunter-fisher societies are found currently only at extremes of climate for the most part (e.g., the Mongoloid Yukaghir people of northern Siberia and Patagonian people of South America). Other interesting societies of nomadic hunter-fishers are the Australian Aborigines and Africans of the equatorial rainforest. All these peoples trap and spear freshwater fish demonstrating both an in-depth knowledge of life-cycles and seasons.

However, great changes occurred to human societies at the onset of the Neothermal. As the ice sheet of the Late Pleistocene melted, sea levels rose and large freshwater lakes were formed as the glaciers retreated; the glaciers turning to rivers. Human settlements became concentrated on river courses and around the numerous lakes. Archaeological evidence points to freshwater fisheries being among the important food-gathering activities of these Paleolithic and later Neolithic societies.

As the ice receded the colonization of almost the whole habitable world was achieved by people who subsisted entirely on forms of hunting, fishing, and plant gathering. It is possible to trace associations between certain species of freshwater fish and people of the Old Stone Age through to modern times. This extraordinary history is a chronicle of mankind's early communion with the underlying realities of the earth's physical environment and eventual destruction of this harmonious relationship. No fish illustrates such a historical overview of a fishery better than the salmon.

### 1.2 The History of Atlantic Salmon Fisheries

The development of the salmonid freshwater fisheries commenced as a subsistence or artisan fishery remaining as such until the late eighteenth century. Increasing human populations, urbanization, and new technology gave rise to a hitherto unheard of exploitation of salmon. Greed and neglect accompanied by the Industrial Revolution started the decline in populations of salmon in general and their extinction in some geographical regions. The twentieth century witnessed attempts to protect the fishery, and development turned to hatchery production and stocking.

Atlantic salmon, *Salmo salar*, originally inhabited hundreds of rivers from as far south as Portugal in the Old World and New England in the New World, north to Arctic areas. Cave dwellers of the late Paleolithic Era have left vertebrae of salmon in their caves, while their art depicts these fish. The Spanish salmon fishery nurtured not only Stone Age people but the prehistoric Iberians, later the Celts, Greeks, Phoenicians, and Romans. In the Middle Ages the Moslem conquerors of the Spanish Peninsula were to wonder at the rich salmon fishery in such rivers as the Sella.

The association of man with salmon in Scandinavia dates at least from the Neolithic Age. Archaeological evidence of sites occupied by Neolithic people in the geographical region show they fished on a considerable scale. Even in the Middle Ages salmon were one of the most important foods, and legislation dating from about 900 AD states "the salmon shall go from beach to mountains, if it wishes to go." In the Scandinavian

countries arable land was relatively scarce due to the harsh climate and thus the freshwater salmon fishery provided food for the long winter.

In the United Kingdom, salmon rivers became valuable property by the Middle Ages. Owners were lords of the manor, municipalities, and monastic institutions. The fish were usually caught for local consumption but by the thirteenth century export had begun. In the reign of Charles II some US$ 370 000 worth of Scottish salmon was exported annually suggesting huge quantities of fish were taken. As in other countries at this time, the prodigality of some salmon rivers was noted, in particular those of Scotland, Sweden, and the American colonies.

In North America and Canada, the salmon had been an important part of the diet of Indians for thousands of years. The Indians made weirs at strategic points, and the vestiges of these traps may be seen today. Other fish caught in these weirs were eel, sturgeon, lamprey, and bass.

The use of the salmon resource changed from one of meeting the needs of local consumption to one of harvest for more distant markets. Daniel Defoe in 1724 wrote about the abundance of salmon in northern Scotland stating “there were salmon in such plenty as is scarce credible and so cheap that, to those who have any substance to buy with, it is not worth their while to catch it themselves. This they eat fresh in the season and for other times they cure it by drying it in the sun, by which they preserve it all the year” and “They carry it to Edinburgh and to all the towns where they have no salmon and they barrel up a great quantity for exportation.” In 1786 salmon was shipped to London from Scotland in ice and by 1817 more than 300 000 kg reached London annually from just two northern Scottish rivers alone.

Similar events were happening elsewhere. In Ireland for example, while the Irish people fished, their English landlords sold the harvest to ports as far afield as Spain and Italy. Canadian salmon became a major export even by 1756. In 1857 one such Canadian fishery was described thus “not content with netting and spearing in the bay, fishers ascend the rivers and fish by day and by night, not only during the fishing seasons but also spearing fish on their spawning beds.” Even more ominously it was said of the rivers in the Gasper Peninsula and Bonaventure regions that they were “richer than the diamond mines of the East.” The Restigouche yielded daily hauls of 2000 to 3000 fish but by the mid nineteenth century this dropped to between 200 and 300 fish while the 2000 barrels of salmon exported to Britain and the United States became a mere 300 barrels. The loss was attributed to Indians spearing the fish on the spawning beds in response to money paid to them by merchants.

Laws have been passed to protect salmon fisheries since the eleventh century. In Scotland the earliest laws date from 1030 AD declaring a closed season between August and November. Edward I, in 1285, likewise proclaimed a closed season for salmon in some English rivers, while Edward II extended the closed season to other rivers and banned the use of devices for taking the salmon fry for pig feed.

Later British laws protected the fish in a more direct manner through more accurate recognition of the spawning season while attempting to ensure weirs and other

obstructions did not prevent the fish reaching their spawning grounds in the upper reaches of rivers. Richard (the Lion Hearted) in the twelfth century decreed that every dam or dyke that affected migrating fish must have a gap large enough to allow "a well fed pig to stand sideways in the stream, not touching either bank." Such legislation was written into the Magna Carta of 1215. In 1466 an anti-pollution law was passed in Dublin stipulating that no tanner, glover, or any person might use the river Liffey for washing leather work or limed ware.

In Europe laws prohibiting dams for mills were largely ignored during the nineteenth century, while in North America mill dams and logjams caused by the timber industry prevented fish from reaching their spawning streams.

Attempts to protect and conserve the salmon clearly were greatly abused. Leonard Mascall's *Booke of Fishing* published in 1590 highlighted abuses such as the use of guns, crossbows, oils, ointments, powders, and pellets to stun and poison the fish. He laments that "none cares for the preserving of the common wealth" and hopes that "careful men were put in office and such as favors the common wealth and all other put out that seek for their own profit only. Then should we have within few years much plenty of river fish."

By the eighteenth century recognition of declining stocks resulted in new statutes and attention turned to size limits, prevention of taking spawn and fry and setting of nets. However, no conservation laws could or would protect the fisheries from the Industrial Revolution.

During the nineteenth century both industrialization and urbanization advanced exponentially. Factories sprung up along the banks of rivers creating pollution. Furthermore, canal systems and later hydroelectric power along with a multitude of other industries demanded water from rivers and lakes, returning the resource as a poisonous waste. The captains of industry seemed indifferent to the rapid changes affecting the rivers. It took many years for governments in industrialized countries to pass laws to control pollution for reasons of public health and even longer to pass laws protecting fish and other aquatic organisms. Rivers such as the Thames, Clyde, and Rhine in addition to nearly all those of France, Spain, and Portugal became denuded of salmon.

Overfishing per se also has contributed to the decline of the salmon. This is well illustrated in North America where much of the overfishing has taken place at sea rather than in freshwater. Salmon are anadromous fish, and unless fish successfully return to their natal streams the species will become extinct. Thus, other anadromous salmon species are threatened by sea fishing including the Pacific salmonids of the North American Pacific coast.

While the latter species have faced environmental crises of similar magnitude to those of their Atlantic cousins, they have also been ruthlessly exploited by the canning industry. Unlike the Indian tribes who fished the Pacific salmonids until they caught their winter supply (subsistence fishing), the cannery owners fished as long as the runs of fish persisted.

### 1.3 Pacific Salmon

The history of the Pacific salmon fisheries is similar throughout the range of five species: chinook, chum, coho, pinks, and sockeye. These fish were an important subsistence food item for Indians, Eskimos, and Aleuts. Later the fish were caught for food by fur trappers but only for their needs. In 1870 a cannery was built at the mouth of the Franc River, British Columbia. By 1913 some eighty canneries were established. Output soared from 62 000 cases in 1880 to an average 700 000 between 1900 and 1909, 1.2 million in 1910, and 1.5 million in the 1920s. In Alaska the story was similar, some 4.9 million cases of canned fish being produced by the 1940s.

However, such exploitation was unsustainable with the declines in all habitats other than Alaska being attributable to environmental degradation by industry and forestry and ineffectual laws to prevent overfishing at sea. In Alaska, the decline can be laid simply at the feet of corporate enterprise which ensured that attempts at conservation of the stocks were ineffectual. The canners refused to allow any restraint on their operations despite the pronounced fluctuations in seasons by the 1940s. By the late 1970s only 2 million cases of tinned salmon were produced in Alaska and about 1 million in British Columbia.

Pacific salmon fisheries are also found in Asia. *Oncorhynchus* species in Asia are found in rivers flowing into the Pacific and Arctic Oceans from lat 35°N to lat 70°N. From Korea to the Chuckchi Peninsula chum and pink salmon are the common species. Masu or Cherry salmon are present in Japan and Russia. Great rivers such as the Kolyma, Indigirka, Yana, Lena, and Amur are particularly important. The Amur forms a border between Russia and China, thus giving the Chinese an opportunity to harvest salmon.

The aborigines of eastern Siberia depended heavily on salmon. The Kamchadales who dwell along the Kamchatka Peninsula once lived almost exclusively on fish. As late as the 1920s these people are said to have caught about 20 million salmon annually and fed 15 million of these to their dogs.

Following the communist revolution of 1917 these societies were organized into collective farms and the commercial fishery developed. By 1960, this once thriving salmon fishery was in decline. Habitat destruction, dams, poaching, and pollution proved to be key factors. However, there is evidence that the Japanese high seas fleet had a major impact in the 1950s and 1960s.

An examination of the fate of both the freshwater salmon fisheries of Korea and Japan is a history of neglect. Hydroelectric dams prevented the upstream movement of spawning fish, and pollution increased as a result of heavy industry. So bad has been the neglect in Korea that salmon were considered extinct in the rivers of this country by the 1930s. In Japan, few of the 350 former salmon rivers support natural stocks of fish.

The salmon fisheries of Japan and indeed elsewhere were to become increasingly dependent on hatchery propagation by the 1970s. A new form of freshwater fishery was born—salmon culture rivers—or enhancement programs.

## 1.4 Development of Salmonid Culture Fisheries/Enhancement Programs

By the later part of the nineteenth century salmonid hatcheries were established in both Europe and North America. Hatchery development was in part due to a recognition that stocks were declining and in part resulted from a desire to introduce salmonids to other parts of the world. It was generally believed that the more eggs and fry released, the greater the returns of saleable fish. Indeed, authorities in the United States, alarmed at the plundering by canneries, insisted these businesses operate hatcheries. Little, if any, benefit to the fishery resulted from these first major efforts at stock enhancement. The releases of fish were never based on any scientific assessment of the habitat, while greater advances in hatchery techniques and biological knowledge of the species were required.

During the 1980s, some 4.5 billion juvenile salmonids were released annually in attempts to support the major anadromous salmon fisheries of the North Atlantic and North Pacific. This figure had increased to more than 5.5 billion in the 1990s. The success of these enhancement programs is mixed. In some fisheries, degradation of original habitat has continued driving remaining wild stocks close to extinction. In such cases, it is argued that hatchery stocking justifies habitat destruction.

It has been calculated that some 541.7 million juvenile salmon were released into rivers of British Columbia in 1987. These fish were Pink (16 million), Chum (199 million), Coho (22 million), Chinook (55 million), Sockeye (247 million), and seagoing rainbow trout or steelheads (2.7 million). These releases have been accompanied by important advances in improvement of the quality of juvenile salmonids. Furthermore, transportation of the juveniles past major obstacles has resulted in greater numbers of smolts reaching the sea. On the Columbia River, the US Army Corps of Engineers catch 20 million migrating smolts in the upper reaches of the river and barge or truck the fish around the dams releasing them in the lower reaches. This program is an example of the new approach to salmon fishery development.

In Norway, Sweden, Japan, and parts of the US destruction of natural stocks has been so great that there is heavy dependence on hatchery-reared fish releases to sustain the fisheries. Such fisheries now have mixed stocks of wild and reared fish, and their future is in the balance.

Hatchery stocks are being introduced even to the more remote freshwater habitats of salmonids where natural stocks exist in reasonable numbers. Here the challenge is to manage both “types” of salmonid without threatening the wild stocks. The fisheries in British Columbia and Alaska face this problem. Exactly how new genetic introductions will affect the fishery remain to be determined.

Undoubtedly future culture/enhancement of salmonid fisheries will evolve according to demand in the face of production from aquaculture, but there remains a need for increased scientific understanding of hatchery and wild fish interactions. Reports from the UK and the US set out some of the challenges and suggest a series of considerations prior to enhancement by hatchery stocks (see Figure 1)

**Background**

Environmental assessment
Stock assessment
Details of other problems in water catchment

**Stocking**

Source of fish
Rearing establishment
Number of generations of captive rearing
Age of fish to be released
Numbers of fish to be released per year
Areas of release
Methods of release
Numbers of years stocking to continue

**Evaluation**

Methods of evaluation
Establishment of benchmarks or controls
Duration of the evaluation program

Box 1. Challenges and considerations prior to enhancement of hatchery stocks

Salmon biologists have considered salmon to be the most harassed fish on earth. The attempts to augment stocks remain a central challenge, while possibilities of climate changes may yet again put enormous pressures on the sustainability of salmonid fisheries.

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**Biographical Sketch**

**G. Nigel Forteath**, Ph.D, was born in Shillong, India. He was educated in Scotland, and started his career by working on trout farms and eel fisheries. He arrived in Australia in 1969 and obtained his B.A. (Zoology) degree from the University of New England, N.S.W., in 1974 and a Ph.D. from the University of Aberdeen, Scotland, in 1977.

He was appointed Professor of Aquaculture at the University of Tasmania in 1993 and was Director of the National Key Centre for Teaching and Research in Aquaculture University of Tasmania between 1987 and 1997. Dr. Forteath has been a member of the Tasmanian Fishing Industry Research Advisory Board, the Fisheries Research and Development Council, and the Australian National Fisheries Training Board. He is now an aquaculture consultant. He has written several books and published many research papers on aspects of aquaculture.