Atlantic salmon in Iceland

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Abstract

This report gives a brief overview of the current status of the Atlantic salmon resource in Iceland, highlighting distribution and life history as well as the unique management system, which only allows freshwater and estuarine harvest of salmon. Historical salmon catches and harvest methods will be reviewed and a special section deals with enhancement and the development of commercial sea ranching in recent years. Finally there is a brief discussion on salmon farming in land-based units using geothermal resources and a section dealing with major environmental concerns related to Icelandic salmon populations.

Geography and freshwater resources

Position and climate

Iceland is located on the mid-Atlantic ridge between 63° and 66° N and 13° and 24° W with an overall area of 103,000 km^2 (Thorarinsson 1986). It is almost exclusively built of volcanic rocks, primarily basalts and volcanic activity is common. Geothermal resources are abundant in certain parts and most of Icelandic houses are heated with thermal water.

The Icelandic climate is oceanic with relatively mild winters and cool summers. The climate is very much affected by warm Gulf stream, which bathes its southern and western shores and gets partly deflected to the north coast. The north coast on the other hand is much affected by the cold East Greenland polar current, which greatly affects the climate and marine as well as frehwater resources in that area.

Freshwater species

Five species of freshwater fish are native to Iceland, including Atlantic salmon (Salmo salar), Brown trout (Salmo trutta), Arctic char (Salvelinus alpinus), European eel (Anguilla anguilla) and Stickleback (Gasterosteus aculeatus). Only the salmonid species are of economic importance in net and sport fisheries. Additionally rainbow trout (Oncorhynchus mykiss) were imported to Iceland in the 1950s for fish farming purposes. They also have some importance in put and take fisheries in some areas, but have not been proven to propagate to any extent naturally.

Rivers and lakes

There are about 250 rivers, large and small in Iceland and they have been classified according to origin into glacial, direct run-off and spring fed rivers. The productivity of the rivers varies greatly according to their location, water source, volume of flow, topography and temperature, especially during the summer months. Only 80 rivers produce Atlantic salmon in any quantity but minor runs of salmon are found in many sea trout and char rivers.

There are about 1800 lakes in Iceland with a total surface area of 1200 km^2, which is little more than 1% of Iceland's surface (Gudjonsson 1986). Lake productivity also varies greatly and is influenced by many factors, such as geology, water temperature, depth and altitude. Due to the cool, temperate climate and short summers, the growing season for fish in both rivers and lakes remains short.

The Atlantic salmon

Life history and management

Distribution

The salmon are of the greatest economic value with respect to sports fishing. It ascends about 80 rivers, most of them located in the western half of the country (Figure 1). Other major sports fishing areas are located in lowland areas of the northwestern and northeastern coasts as well as the productive agricultural area of the south coast.

The best salmon rivers originate in lakes, which secures stable water flow and favourable temperature during the summer. A river suitable for salmon usually maintains a water temperature of 10°C for a period of three months during the summer. Salmon are thus primarily found in lake-fed and run-off rivers, but some glacial streams have harboured salmon, where they were traditionally harvested with set nets.

Life history

The Atlantic salmon only spawn in rivers, usually in October-November and the fry emerge from the gravel during the following summer. The parr spend 2-5 years, most frequently 3-4 years, in freshwater before migrating to sea as smolts at a size of 20-25 grams.

The salmon spends 1-3 years in the sea before returning to its home river to spawn. Salmon in southern and western Iceland tend to mature early and return as grilse (1-SW salmon), averaging 2.5 kilograms in weight. Fish on the north and east coasts tend to return more as older salmon (2-SW), from 4-6 kg. in weight although individual males may reach 11 kg. Salmon spending 3 years or more in Iceland are rare.

The geographic difference in age at maturity is probably primarily related to the different oceanographic and climatic conditions in these areas. This is supported by the fact, that repeat spawners (kelts) return after 4 months in the sea in southern Iceland, whereas they spend one year in the sea in northern areas. An increase in age of maturity has also been observed, when ranching stocks from western Iceland have been released in cold northwest coast rivers (Ísaksson and Óskarsson 1986). Stock with genetic tendencies towards late maturity are, however, found in large rivers in both southern and northern Iceland.

Effects of oceanographic and climatic conditions on marine survival of salmon tend to be more pronounced on the north and east coasts of Iceland (Scarnecchia 1984, Scarnecchia et. al 1989, Gudjonsson et al. 1994). This expresses itself in great variation in the size of returning salmon runs and can both be due to poor feeding conditions for smolts and salmon in the sea as well as a reduction or blockage in the migration of smolts in the spring due to adverse climatic conditions. If such conditions prevail for many years, there is a great reduction in the biomass of the local salmon population, demonstrating that those areas are marginal for salmon production and a minor adverse climatological change could possibly favour other types of salmonids, such as arctic char.

Icelandic salmon migrate to distant feeding areas and tagged salmon have been reported from West and East Greenland, the Faroes, Norway and Scotland. Returns from large scale migrotag releases of ranched salmon seem to indicate that salmon from the soutwest, west and northwest coasts migrate primarily towards Greenland, whereas northeast and east coast salmon, although also found in the Greenland area migrate more into the Norwegian sea.

Management

The backbone of the management system in Iceland is the fact that the fishing rights in rivers and lakes are privately owned and go with the land that adjoins the river. They can furthermore not be separated from the ownership of the land. The fishable sections of the rivers are usually in agricultural areas, where the land is most often owned by the farmers themselves.

The river owners are obliged by law to form a fishing association, which takes all major decisions regarding the fisheries as well as enhancement. These associations are responsible for management of the local fishery in accordance with the Freshwater Fisheries Act, dating back to 1932, but they often also attend to local conservation, hire bailiffs, build and run fishing lodges, build fish ladders and undertake various enhancement activities in order to improve fishing.

The current Freshwater Fisheries Act was enacted in 1970, but was partly revised in 1994. One of the important provisions of the Act, dating back to1932, states that salmon fishing in the sea is forbidden, with minor exceptions. Excepted were 9 coastal farms, which had declared salmon fishing as a major income from their estate. Of these only 4 remain on the west coast, which, however, have seen their catches increase considerably as a result of the increased ranching activity. A buyout of these set nets is a high priority task among riverine, ranching and sports fishing interests in Iceland.

Exploitation of salmon in the sea is otherwise entirely forbidden by law, which has prevented any commercial fishery within Iceland´s territorial limits and means that management measures only have to be undertaken in freshwater and estuarine areas.

Icelandic salmon can thus only be harvested with rod and line or in riverine gill nets, which were historically used in glacial streams. These are restricted with respect to annual, weekly and daily fishing time and with respect to the number of set nets and rods used on any river. Set nets are e.g. only allowed during half the week, whereas rod fishing is limited to the daylight hours for 3.5 months during the summer.

Status and utilization of the resource

Harvesting methods

Icelandic salmon were traditionally caught in fixed set nets, but the importance of sport fishing started increasing early in this century. The contribution of sports caught salmon has gradually been increasing and in the 1990s the inriver proportion has been close to 85% from the sports catch. This change both reflects the increased value of the sports fishery as the price of commercially caught salmon has dropped as a result of the great supply of salmon from aquaculture. In some glacial rivers this has led to the buy-out of the nets by the owners of upriver tributaries.

There is great enthusiasm for salmon angling among Icelanders and a number of foreign anglers visit Iceland each summer. The fishing season starts in early June and extends through September, but each stream can only be fished for 3.5 months.

Exploitation rate by angling and netting has been studied in several rivers (Gudjonsson 1988a). The rate in 6 rivers studied fluctuated between years from 10.9% to 81.6%, where the difference was greatest, but the average exploitation rate for angling only was from 26% to 50% and in river systems, where both netting and rod fishing were carried out it was 50% to 55%. Put and take fishery with Atlantic salmon in one Icelandic river has indicated up to 80% exploitation of transplanted ranched salmon, which is surprisingly high.

As the demand for salmon fishing has in the past been greater than the supply of rod days the price of salmon fishing has risen dramatically during the last 20 years. Prizes of US $500-700 per day during the best periods are not uncommon. The total salmon resource has been estimated at a value of 5 million $ US. giving a value of ca. $150 per sports caught salmon, assuming an annual average catch of 35.000 salmon. This excludes secondary benefits to the economy from the sale of sports equipment and accomodation in hotels and lodges.

Salmon catches

Collection of official salmon catch statistics started in 1897. Since then the accuracy of the catch statistics has been increasing and the Icelandic angling statistics are today some of the best in the world, documenting size and sex of each fish as well as bait and approximate location of capture.

Figure 1 shows the statistical salmon fishing areas and the distribution of average wild salmon catches by number for the years 1974-94 between statistical areas. Ranching, which almost exclusively takes place in areas 2 and 3 is excluded. As indicated about 70% of the catch is recorded in areas 1-3, located in the southern and western part of the country, but the remaing 30% in areas on the north and east coasts. Due to the higher sea age of salmon on the north and east coasts the distribution by total weight would be somewhat different.

The total inriver rod and net catch of salmon from 1959 to 1994 is shown in figure 2. In order to reflect changes in wild salmon catches, it excludes some catches in legal coastal nets, which primarily catch salmon from west coast ranching facilities. These catch figures demonstrate well the fluctuations in abundance between years, although some general increase was noted especially in the 1970s. It should be pointed out that fluctuations tend to be much greater on the north and east coasts, which only represent a small part of the total catch. Such low periods in the north coast rivers occurred in the 1965-69 period as well as in the early and late 1980s, which corresponded to cold environmental conditions and low productivity in the arctic water off northern Iceland.

Figure 3 shows the development of total salmon catches during the last 25 years, expressing the large contribution of salmon ranching in recent years, when it has been close to 80% of the total salmon catch.

Enhancement, ranching and farming

Enhancement

The Icelandic rivers being privately owned, the cost of enhancement is entirely financed by the owners of the resource, in this case the owners of the adjoining land. The State mostly acts in advisory capacity but provides some financial assistance through the "Enhancement fund", which is financed through a small fixed percentage of the netto profit of "Fisheries Associations" and the sale of electricity by hydroelectric companies.

Salmon enhancement has been carried out both by indirect methods, such as river improvement and by direct methods such as artificial propagation. The indirect methods have primarily been building of fish passes over waterfalls, improvement and creation of fishing pools and river-flow regulation. During the last 40 years about 50 fish passes have been constructed, opening up about 500 km of river bed to anadromous fish, primarily salmon (Gudjonsson 1988b).

Direct methods involve the planting of fry, parr and smolts, depending on the situation. Fry and parr have primarily been used in areas above impassable waterfalls, which have been deemed suitable for salmon rearing. Success of parr plantings is variable, but return rates of 2 % to the river (1.0-1.5% to the sports fishery) have been documented for microtagged 4-5 gr. parr released in a west coast river (Einarsson 1993). The success of fry releases is also variable and difficult to document, but there is substantial indirect evidence of highly successful releases especially in areas above impassable waterfalls. Success, however, is highly variable between years due to the great dependency on climatological factors.

Smolts have been released in small quantities into rivers since the mid 1960s. Initially two-year smolts were used but one-year smolts have dominated for the last 20 years. Initially smolts were released directly into the rivers, but during the last 15 years it has been emphasized to keep and feed the smolts in a release pond at the river bank for a month prior to release. The success of smolt releases for enhancement in salmon rivers has been highly variable, reflecting various problems related to smolt quality as well as release techniques.

By law the river owners are obliged to use the local stock for enhancement and in some cases the river owners have built and operate smolt stations. Such wild stocks are often poorly suited for artificial rearing and it has frequently been problematic to follow the prescribed rearing cycle worked out for stocks adapted to rearing.

The releases of smolts into salmon rivers is entirely intended for augmentation of the salmon runs and in recent years there has been a considerable increase in the numbers released into some rivers, releases of 5-10 thousand smolts per river being fairly common.

Enhancement with smolts is of course based on the same principles as salmon ranching from sea ranching stations. This principle has been applied in one large river, which does not produce salmon naturally, for the sole purpose of providing salmon for angling. This principle has been called "ranching for the rod", meaning that all the returning salmon will be harvested through a sports fishery.

Since 1989 the releases into this river have ranged from 50-100 thousand smolts and returns have in some instances been highly successful. In 1990 e.g. this river had a total catch of 1600 salmon, which was the highest sports catch in Iceland in that year. In 1994 the same river was one of the top 3 rivers.

This example demonstrates the possibilities of building up a sports fishery for salmon through smolts release, which in the long run will be profitable, although the return rates of tagged salmon in the fishery may only be 2-3%. Two factors probably contribute most to the success of this operation. Firstly there is no environmental reason to use a local stock and a well adapted ranching stock can be used. Secondly, the project has demonstrated that returning salmon congregate on beats in the vicinity of the release ponds, which allows higher exploitation rates than would be possible, if the salmon were distributed all over the river. The fishery can thus partly be managed through selection of proper release sites.

Sea ranching

In the early 1960s the Institute of Freshwater Fisheries established Kollafjörður Experimental Fish Farm, which was instrumental in promoting fish cultural activity and started experimenting with salmon ranching in 1965 (Gudjonsson 1973). This activity and the fact that harvest of Atlantic salmon in the sea has been prohibited by law since the 1930s has laid the foundation for private ranching in Iceland.

Although experimental releases have been performed since the mid 1960s, commercial ranching only started in the mid 1980s and peaked at 6 million smolts released in 1991. The proportion of ranched salmon in the Icelandic salmon catches have subsequently increased from less than 20% in 1980 to more than 80% in the early 1990s (figure 3). Most of the ranching activity takes place on Iceland's west coast but is of minor importance in other areas.

Research has in the past focused on improvements in smolt quality and release techniques but recent investigations indicate, that the performance of salmon in sea-ranching operations can be improved through selective breeding (Jónasson 1994).

At the present time private ranching of Atlantic salmon is not a profitable venture and the large scale ranching stations operating in Iceland must be considered long term developmental ventures. This is a logical consequence of the scaling up of releases in a single ranching station from a few hundred thousand smolts to releases in excess of 3 million smolts.

Salmon farming

Although Iceland has ample ground water resources and thus relatively favourable conditions to produce smolts, it does not have suitable environment for net-pen rearing of salmon in the sea. Sheltered areas are limited, winter storms frequent and undercooling of seawater common in some areas. Many net-pens started operation on the southwest coast of Iceland in mid 1980s, but all have either gone bankrupt or stopped operation.

Many land-based farms were built in the 1980s, primarily in the southwest, where many stations harness thermal energy to enhance growth (Ísaksson 1991). A number of these farms have gone bankrupt, but the remaining operations have had a considerable increase in turnover as a result of great progress in controlling diseases through vaccinations and improved rearing conditions. Most of these farms are using Norwegian rearing stocks, which have proven to be more favourable for rearing than the local rearing stocks, which tend to mature too early. In spite of many obstacles, there is some hope, that salmon farming, especially in land-based units, will play a significant part in the Icelandic economy in the future.

Environmental concerns

In general one can say that the Icelandic salmon stocks are in good state. They mostly escape mixed stock fisheries due to the ban on fishing for salmon in the sea, which has, as previously mentioned, been in force since 1932. Other environmental threats are of minor importance, with the possible exception of indirect effects from ranching and rearing activity.

Pollution

Pollution has not affected major salmon rivers, except for some municipal sewage flushed into some large rivers on the south coast. The extent of this pollution does not seem to be detrimental to salmon and trout populations, which mostly spawn in upstream tributaries. Acid rain has not affected Icelandic rivers, probably due to the great distance to major continents with great industrial pollution.

Threats from farming and ranching

The greatest concern regarding wild freshwater species in Iceland has been the increase in salmon farming and ranching in recent years. Every effort, however, has been made to safeguard the wild salmon stocks.

Many biologists fear that continuous straying of reared and ranched fish into rivers may be detrimental to the wild stocks, which have adapted to a specific environment for thousands of years. Ranched and reared salmon in contrast have adapted to the rearing environment at least through a part of the life cycle and might thus be unsuited for life in the wild.

Icelandic enhancement and ranching operations have yielded a great deal of practical information on the straying of ranched salmon into rivers and between ranching stations as well as the straying of wild fish into ranching stations and between rivers. Some of the findings are summarized in the following sections.

Straying of salmon

Escape and straying of salmon into nearby rivers from sea-water pens was fairly common in southwestern Iceland in 1987-1991 due to a fairly substantial production of salmon in sea-cages (Gudjonsson 1991). The strays were most pronounced in rivers in the vicinity of Reykjavík, the capital city. This problem is currently of minor concern, as all of the cage farms have closed or gone bankrupt.

There is considerable information available in Iceland on the straying of ranched salmon, both to other ranching stations and into rivers (Ísaksson 1994). Straying is variable between years and seems to be higher in years of low return. Strays from one ranching station to other stations can be in the order of 10-15% of total numbers of microtagged salmon returning in high stray years, but only 5% in years of low straying rates.

Observed strays of ranched salmon into salmon rivers have been in the range of 2-4% of the total number of microtagged salmon returning, being higher in rivers close to the ranching stations. Incidence of straying seems to be much higher in rivers flowing directly into the sea, than in tributaries in complex river systems.

Harvest strategy

There is reason to suspect, that occurrence of wild salmon at ranching stations is related to the harvest strategy. Estuarine traps might thus be catching more strayers from salmon rivers than would occur in a freshwater trap. Ranching experience, however, has shown that ranched salmon are reluctant to enter freshwater except during freshets, which can be an infrequent occurrence. The results are discoloured salmon unfit for the market and greater strays from the ranching site to neighbouring rivers.

The estuarine traps are thus of vital importance for the salmon rancher, as they procure a steady supply of bright salmon throughout the season and have the added benefits of reducing straying to salmon rivers, preventing genetic effects. The negative effects are some catches of strayers from wild salmon populations, which causes a great deal of controversy between the ranchers and the river owners. A successful solution to this problem is the greatest challenge facing the Icelandic freshwater management system today.

Regulatory measure

In 1988 a regulatory measure was set to minimize the effects of ranching and rearing on wild stocks. It specified the distance between major salmon rivers and the rearing and ranching operations as well as the distance between ranching operations. It further prohibited the rearing of imported stocks in sea-cages and specified that ranching stations should microtag at least 10% of their releases up to a 10.000 smolt minimum. Most stations have microtagged many times that number annually.

International fisheries

Fair sharing of salmon will be of growing concern in the Atlantic in the years to come. Icelandic wild and ranched salmon move across international boundaries and have been caught in oceanic fisheries, both in the Faroes and West Greenland. The quotas for those fisheries, as negotiated by NASCO (North Atlantic Salmon Conservation Organization), have in recent years been bought by the North Atlantic Salmon Fund, an Iceland based fund, financed by international sport fishing interests and some public funds. This will benefit ranched as well as wild salmon stocks in the countries of origin.

These transactions, however, do not prevent salmon fisheries in the vast oceanic areas outside national jurisdictions by vessels with flags of convenience. It is to be hoped, however, that such unfavourable developments can be stopped through diplomatic negotiations.

Administration

Freshwater fisheries in Iceland, including the salmon fishery, are under the auspices of the Ministry of Agriculture. The Director of Freshwater Fisheries administers the fisheries in accordance with the Freshwater Fisheries Act, coordinates research in rivers and lakes and collects statistics on freshwater fisheries catches and fish farming production. He is also responsible for coordinating enhancement and fish cultural activities, including salmon ranching.

The Director and his supporting organization, the Institute of Freshwater Fisheries, conduct research in rivers and lakes as well as in the field of salmonid aquaculture, including salmon ranching. In addition to the head office in Reykjavík there are 3 local branches on the south, west and north coasts primarily involved in the development and advice on enhancement and aquacultural strategies.

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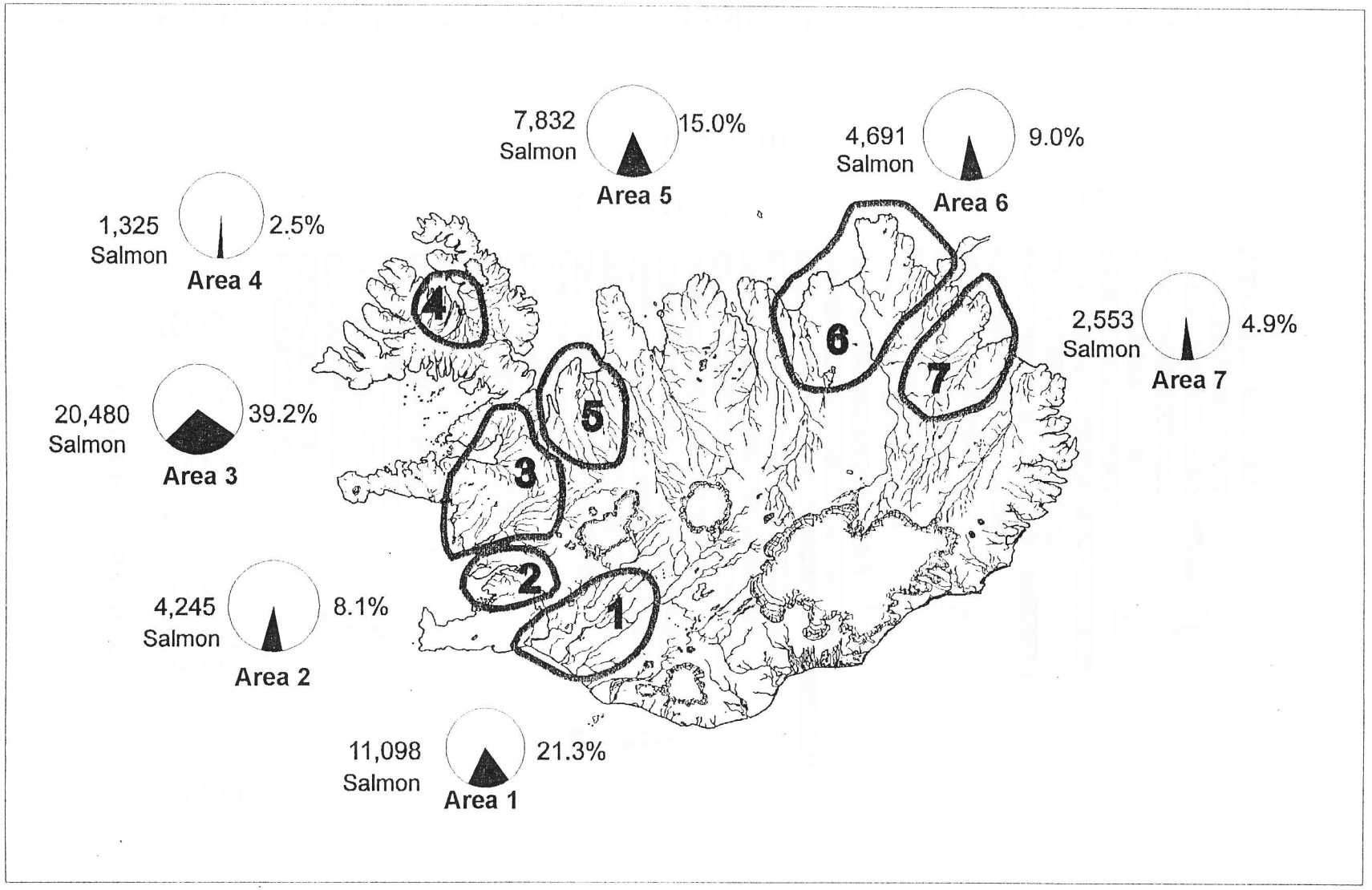

Figure 1. The average yearly catch of wild Atlantic salmon 1974-1993 and the proportion caught in each of the seven districts in Iceland

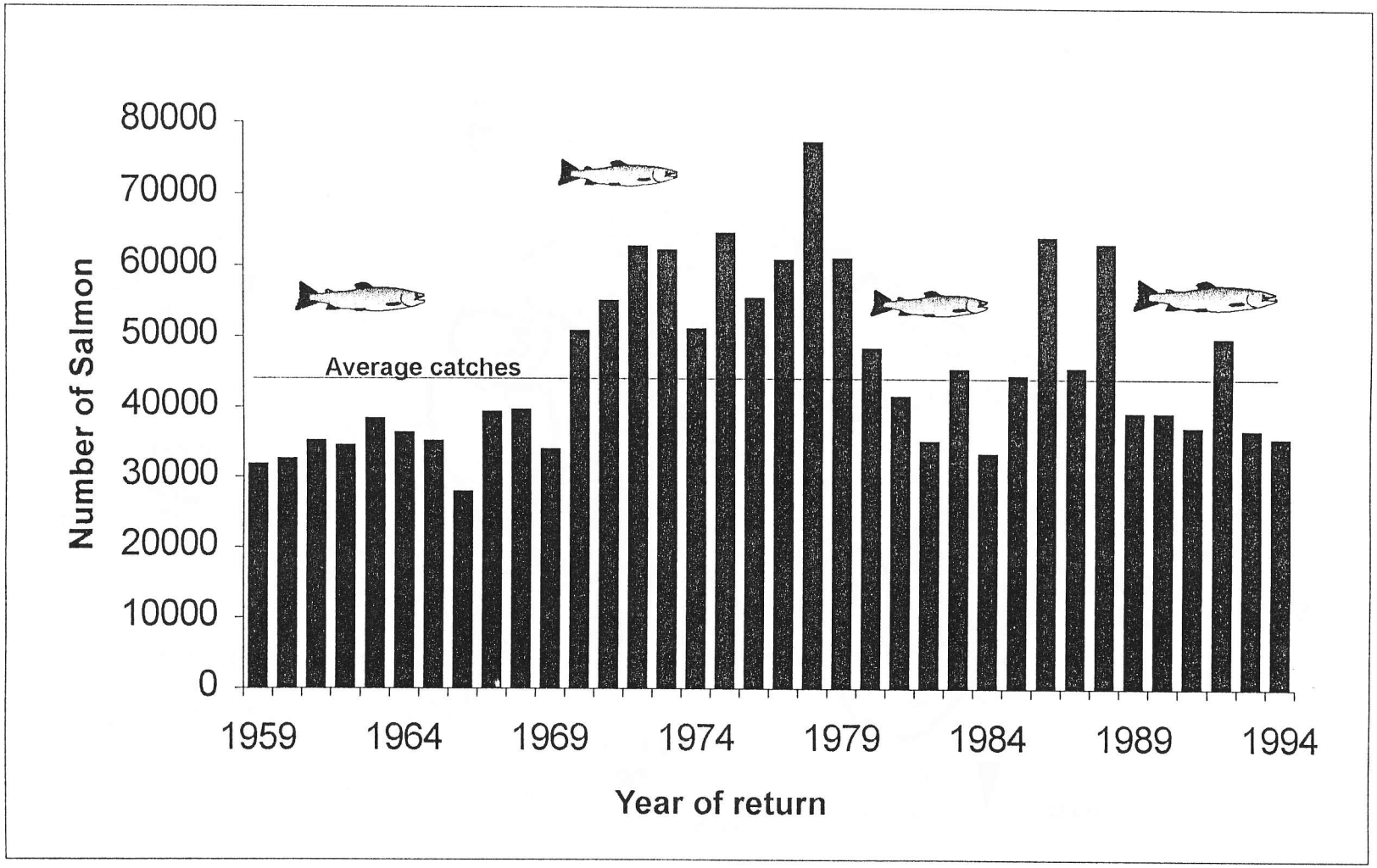

Figure 2. Net and Sports fishery in Icelandic Salmon rivers 1959 - 1994

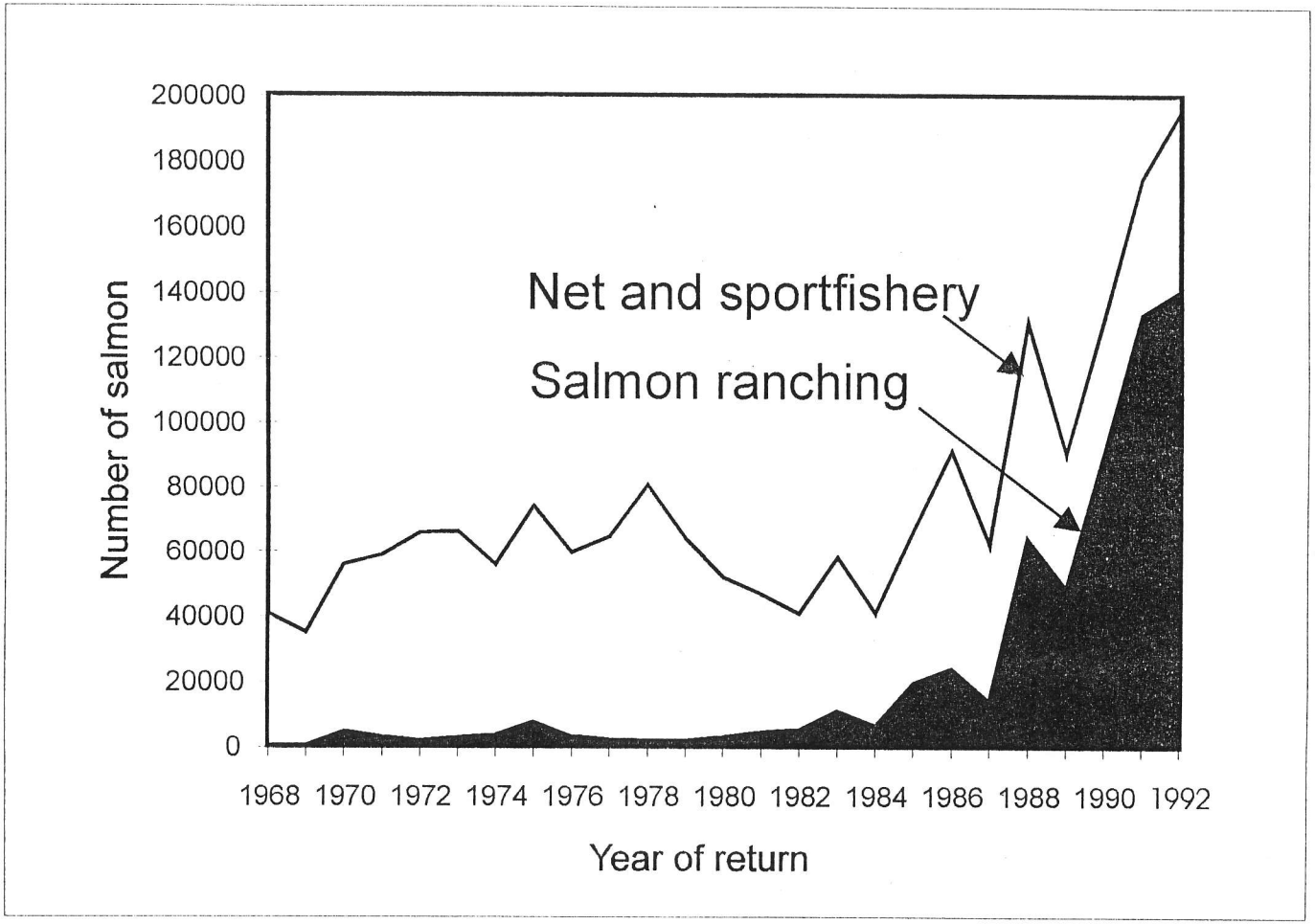

Figure 3. Total Icelandic Salmon Catch 1968 - 1993 showing the increasing contribution of ranching in recent years