ATLANTIC SALMON

PRESENT STATUS AND PERSPECTIVES OF SEA RANGHING

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INTRODUCTION

Sea ranching of salmon has a long history in the countries bordering the Pacific ocean, as will be covered by other speakers at this meeting. With the exception of some Oregon and Alaska operations, this activity can mostly be classified as public ranching, as the returning salmon are mostly harvested with conventional fishing gear in a mixed stock fishery with the resulting danger of overharvesting wild stocks(Isaksson 1988a).

The most important commercial operations in those areas are based on species, which are released at a very small size, such as pink and chum salmon. Atlantic salmon are, on the other hand, very large at release and ranching can thus only be economical if return rates and prices are high.

In the Atlantic many countries have conducted sea ranching in the form of enhancement on a relatively small scale compared with the large contributions of ranching to the Pacific salmon fisheries(figure 1). The total commercial catches of Atlantic salmon are also minute compared to the total landings of the Pacific species which amount to over 500 thousand tons. Out of the 10 thousand tons of Atlantic salmon landed annually we can estimate that approximately 20% are contributed by ranching, mostly in the successful Baltic salmon fisheries maintained by Sweden and Finland.

Iceland is the only country, which has embarked on private sea ranching, where all the salmon are harvested in a terminal fishery. The salmon are processed according to the stiffest requirements of the fish farming industry and compete directly in the marketplace as an aquaculture product. The primus motor in the development of this industry was the fact that salmon fisheries are not permitted within Icelands 200 mile territorial limits and salmon and trout rivers are privately owned.

In this talk I will primarily concentrate on the **Icelandic experience with private sea ranching.** It has almost a 30 year history on a pilot scale, but has only recently started on commercial basis.

I will discuss the **early ranching trials at Kollafjörîur Fish Farm** and the **development of ranching from release sites,** which was an important step towards large scale releases in suitable locations.

I will then describe the **develoment in smolt production and ranching releases** in Iceland and possible **environmental consequences of ranching.**

Finally I will discuss the apparent **strong influence of various environmental factors on ranching success** and their importance for the ranching potential in various parts of Iceland.

THE EARLY RANCHING TRIALS

Although ranching has only recently started to increase dramatically, it has been carried out on a small scale since the early 1960's. Kollafjordur Experimental Fish Farm, shown in this slide, can be considered the pioneer of private ranching with Atlantic salmon. It was established in 1961 and started releasing smolts in 1963 at a location, which had no previous salmon runs. The idea for such a facility actually came from the release operations at the School of Fisheries in Seattle Washington.

Salmon runs were quickly built up and Kollafjordur Fish Farm has paved the way for the commercial operators, since smolt production and release methods have been developed there and the Fish Farm already has over 25 years of ranching experience(Gudjonsson 1973).

Figure 2 shows the return rates to Kollafjordur Fish Farm from 1963 to 1987, grouped into years with similar rearing and release technique. The return rates are shown in percent as well as kilograms per thousand smolts released. Also shown are the total numbers of smolts released(Isaksson 1987).

It is obvious that these figures are not totally representative of sea survival for different years, since there are a lot of experimental groups which depress the average in various years. There was, for example, a conversion from two-year to one-year smolts about 1969, which lowered the return rates in subsequent years, a problem only fully solved in 1973. There have also been transition periods in fish feeds, release techniques and tagging methods. The average for the whole period is close to 6 percent.

The introduction of the microtagging technique in Iceland in 1974 was a **major breakthrough** in salmon ranching research. Previous tagging methods, mostly involving external tags were totally unacceptable for the relatively small Icelandic smolts. The microtagging technique, on the other hand, allows **economical tagging of large quantities** of smolts with relatively high survival rates in ranching experiments.

From Icelandic microtagging experiments one can draw the following conclusions:

1. **Return rates of microtagged smolts** are almost comparable to those of untagged smolts.
2. Realistic return information can thus be gotten **for small smolts (smaller than 20 grams).**
3. Tag loss can be considered **negligable.**
4. Microtagged smolts are **easy to transport** to distant ranching sites.

These tagging methods have thus set the stage for more extensive experimentation in salmon enhancement and ranching.

RESEARCH AND DEVELOPMENT

Icelandic salmon ranching research has been concentrating on various **methods to improve ranching performance.** Initially the emphasis was on developing **correct rearing processes** for viable smolts as well as various **methods of release.** In recent years there has been more emphasis on methods to **improve the economics of ranching,** such as the production of **Zero-age smolts** instead of conventional 1-year smolts and the possibilities of **selective breeding** in ranching programs. The aspects of most interest in a breeding program are increases in return rate and the size at return, although many other items listed in figure 3 could be of interest.

In 1987 an experimental program was started at Kollafjordur Experimental Fish Farm to look into the feasibility of selective breeding in ranching. The program, which is supported by the Nordic Council, is a cooperative research effort between Iceland and the Scandinavian countries, primarily Norway, which has a long experience in selective breeding of salmon. The program uses a rearing house at Kollafjördur Fish Farm with 150 small tanks, each containing the progeny of one family, which will be marked as a group and released to test family characteristics. The program has already shown interesting hereditary traits regarding growth and survival, although final results will not be in until 1992.

It was soon clear that there would be few suitable ranching sites on the Icelandic coast which also would be suitable for smolt rearing. It was thus of prime importance to establish **if ranching could be conducted profitably from release sites far from the place of smolt rearing.** It was furthermore important to establish the ranching potential in various parts of Iceland.

To determine this, microtagged salmon smolts of Kollafjordur stock reared at Kollafjordur Fish Farm **were released at 4 different locations** in the late 70's and early 80'(Isaksson and Oskarsson 1986).

The results from those experiments are shown in figure 4. Returns are shown in percent, but different shades of grey indicate, whether the fish returned as grilse(i.e. 1 year fish) or salmon(2 year fish). The major conclusions from these experiments are the following:

1. Return-rates to the various release sites are **comparable and sometimes** better than those to Kollafjordur, the place of rearing.
2. Return rates were **lowest to the northernmost station**, which lies in an area characterized by a colder climate, delayed summer and relatively cold oceanic temperatures. The salmon in this are, however, stay relatively longer in the sea, demonstrating the **environmental influence on maturation** (colder sea).
3. This information suggests that the same ranching stock could be used all over western Iceland, and selective breeding could thus be **conducted in a central breeding station.**

Figure 5 shows the splitting of the Icelandic ranching stations into two major groups, that is ranching from rearing stations and from release sites. Ranching from release sites is getting more common, as return rates have been encouraging and many sites do not have favourable rearing conditions. There are 5 large stations operating on this principle, mostly on the west coast.

Ranching from rearing stations can also be split into two subgroups, those having **stream water for ranching** and those having to **rely on pumped well water** in addition to the hatchery effluent. The ones with a natural stream on the watershed have a clear advantage, especially with respect to the recovery of salmon, which tend to enter during freshets. The well water stations have to rely more on estuarine traps for the capture of salmon.

SMOLT PRODUCTION AND CURRENT RELEASES

We will now look at the smolt production in Iceland and current releases in ocean ranching.

Figure 6 shows the development in smolt production during the last 10 years. This development,probably more than anything else, reflects the favorable conditions for smolt production in Iceland and recent optimism regarding salmon farming and export of smolts to other countries such as Norway and Ireland. As salmon farming operations only need small quantities of smolts **the only possible way to dispose of the surplus smolts is to release them for ranching in new or existing ranching stations or release them into salmon rivers** . This method has not been considered viable in dealing with smolt surpluses in other countries such as Norway due to the heavy oceanic fisheries and environmental concerns.

Figure 7 shows the total releases in commercial salmon ranching operations during the last 10 years.

We can see that the releases really started increasing in 1987 with a threefold increase over previous years. Releases in subsequent years increased dramatically with approximately 6 million smolts released in 1990.

It should be pointed out that the increased releases in the last 4 years not only reflect greater interest in ranching but rather a phenomenal increase in smolt production. With an existing or pending financial crisis in some of the ranching stations there may be some stagnation in releases this coming year.

ENVIRONMENTAL CONCERNS

Due to the relatively small salmon catches in Iceland, which have been less than 300 tons, it does not take very large releases in ranching operations to exceed the catch of wild salmon. It has been estimated that the total outmigration of wild smolts from Iceland could be about 1 million smolts. Releases of hatchery smolts are **already 5 times that number.**

Figure 8 shows the current and predicted trends in relative numbers of wild and ranched salmon. It seems quite clear that ranched salmon will be dominating the catch in the future and are already contributing close to 80 percent. This development raises a lot of questions regarding the effects of ranched salmon on the wild stocks and the necessity to set new laws and regulations to **protect the wild populations**, taking also into account increased cage rearing in certain areas.

In 1988 new regulations came into effect which should prevent as much as possible the mixing of reared and ranched stocks with wild populations on the spawning grounds(Isaksson 1988b). The main points are the following:

1. Sea cages and ranching stations must not be within 15 kilometers of large salmon streams.
2. They must be at least 5 kilometers away from minor salmon streams.
3. Distance between sea cages and ranching stations must be at least 2 kilometers. Same is true within each group.
4. Foreign stocks must not be used for enhancement or ranching.
5. Ranching stations must microtag 10 percent of their releases, up to a 10 thousand smolt minimum.
6. Finally there were provisions stating that each salmon stream should be enhanced with its own stock, if at all possible.

These regulations are to be revised every two years.

CLIMATIC AND OCEANOGRAPHIC EFFECTS

During the last decade it has become increasingly clear, how great a role the oceanic environment plays in the success of salmon ranching. In general one can say that in fairly normal years the return rates in Icelandic stations tend to stay between 5 and 10%. In the 1980s several years of extremely unfavourable climatic and oceanic conditions have occurred which drives the return rates far below the norms with additional unfavourable effects on average weight and several other parameters.
These years tend to be associated with abnormally strong polar currents towards Iceland from East Greenland and corresponding decrease in the flow of warm Gulf stream water around the northwest coast of Iceland.

These effects are not only of concern in Icelandic ranching but might also be partly responsible for a serious shortage in salmon abundance on the feeding grounds at West Greenland. Notorious years are the summer of 1984 and more recently 1989.

Icelandic oceanographers noted a dramatic change in oceanic conditions off the north coast of Iceland between 1987 and 1988(Icelandic Marine Institute reports 1989, 1990). Figure 9 shows the thermal gradient between 4 and 5 degree sea water in north Icelandic waters the spring of 1987, which was a productive year. Influx of warm water was considerable, whereas polar currents were moderate.

The oceanographic conditions in 1988 are shown in figure 10. The change from the previous year was dramatic. The unproductive polar currents were quite strong and influx of warmer water was quite small. The change has seriously affected the productivity of the oceanic areas off northern Iceland. Unfortunately similar conditions were observed in 1989.

There is no reason to believe, that low temperatures alone are responsible for the observed changes in salmon production, but rather that they serve as a useful visual tool to demonstrate the changes in various temperature related changes such as primary production.

In addition to the poor oceanic conditions there is evidence that very low freshwater temperatures and resulting delay in smoltification in freshwater during the spring of 1983 and 1988 has played a major role in very low survivals and growth rates observed in ranched and wild salmon alike in 1984 and 1989 return years. In that context one should bear in mind that the Icelandic climate is very much shaped by the surrounding ocean.

The unfavourable conditions in 1983 and 1988 had very marked effects on return rates, average weight, maturation and sex ratios of salmon returning to Kollafjördur Fish Farm in the 1984-85 and 1989-90 return years. The changes clearly show up in the following figures.

Figure 11 shows the return rates of microtagged grilse and two-sea winter salmon to Kollafjördur Fish Farm in the 1980s. Also shown are total numbers of returning salmon. No smolts were released at the fish farm in 1986 due to a BKD eradication program.

Notice that most years are over 5 percent and some over 10 percent. The years 1984/85 and 1989/90 stick out as abnormally low years. An increase in the proportion of two sea winter salmon is also fairly apparent in those years.

In figure 12 we see the average weight of microtagged male and female grilse returning to the Fish Farm during the same period. Normal weights usually lie between 2.5 and 3.0 kilos with males considerable heavier than females. In the 1984, 1989 and 90 return years the average weights dropped almost to 2.0 kilos with very little weight difference between the sexes. These lowerings in average weights were also observed in many salmon streams in Iceland in those years, indicating a broad overall influence of environmental factors.

Figure 13 shows the grilse/salmon ratio in the returns of the same groups to Kollafjördur Fish Farm. The ratio is normally 80-90 percent grilse but in the 1984/85 and 1989/90 return years the ratio dropped to 50-60 percent, indicating possible delay in maturation of grilse, when sea conditions are unfavourable. Similar changes have been observed when west coast grilse stocks have been released on the north coast of Iceland, indicating that the ratio is highly dependent on environmental factors.

Usually grilse in southwestern Iceland have a fairly even sex ratio, sometimes with a slight male dominance. This trend can be observed in figure 14 from the Kollafjörîur experiments, with the exception of return years 1984, 1989 and 1990, when the male ratio shot up over 75 percent. This is a common phenomenon in northern Iceland, where two-sea-winter salmon tend to dominate the scene. This is a further evidence of delayed maturation of female grilse in years of unfavourable feeding conditions and harmonizes well with lowered survival and reduced average weight of grilse.

Figure 15 shows a model intended to describe the effects of oceanographic conditions on various population parameters in Icelandic ranching populations. It also ties the oceanic conditions to various parts of Iceland, conditions normally being more favourable in southwestern part of the country under the influence of the **Gulf stream**. Conditions on the north coast are, on the other hand, less favourable in many years as a result of the **cold less saline water** and ice being brought by the **East Greenland current**.

The left side of the figure shows the conditions, which tend to dominate in southern and western Iceland with **high grilsification, relatively large grilse, high return rates** and **even sex ratio in the grilse**. The right side of the figure shows the reverse situation, with **low return rates, smaller grilse, more male grilse** and **higher proportion of two-sea-winter salmon**.

The return years to Kollafjördur Fish Farm are listed on the diagonal line as they fit into the model. The separation of 1984, 89 and 90 return years from other years is very clear.

From the information presented we can summarize the ranching potential in Iceland as shown in figure 16. Shown are the **expected average return rates** in different parts of the country as well as the **ratio of 1-sea-winter salmon to older salmon.** The major ranching stations are also shown as dark spots. Just a few points should be emphasized:

1. As shown before there are **thermal gradients** on the borderline of warm and cold oceanic currents off the northwest and southeast coasts of Iceland, which affect the ranching potential in respective areas.
2. The largest ranching stations are **on the west coast**, where the return rates are highest and seem to be most stable, although we do see negative effects on growth and survival in very unfavourable years.
3. Return rates on the north coast are **considerably lower**, but the proportion of 2-sea-winter salmon is much higher. This coast is affected by **cold polar currents** in some years, which reduces sea survival, as often observed in wild populations in that area.
4. Return rates on the south and west coast seem to lie **between 5 and 15 percent** with bulk of the salmon returning as 2.5 kilogram grilse.
5. Ranching potential on the east coast is little known, but is probably **comparable or inferior** to the conditions on the north coast, since this area is dominated by cold polar currents.

From this data we can see that parts of Iceland are on the borderline for stable production of Atlantic salmon. In years when cold polar currents dominate north Icelandic waters the salmon production in north and northeastern Iceland is seriously reduced. In addition to the periods discussed in this talk there was a serious reduction in salmon abundance in northern Iceland from 1965 through 1969, with large quantities of drift ice off the coast far into summer.

This information may have some bearing on the decisions that have to be made in Norway regarding the siting of ranching operations. The Gulf stream does have greater and more stable effects on the coast of Norway than it does in Iceland. Nevertheless it is known that the East Greenland current can have influence far south into the Atlantic as it did in 1980 and thus affect the feeding distribution of salmon e.g. in Faroese waters. Ranching sites at southerly latitudes might thus be more productive than those situated very far north.

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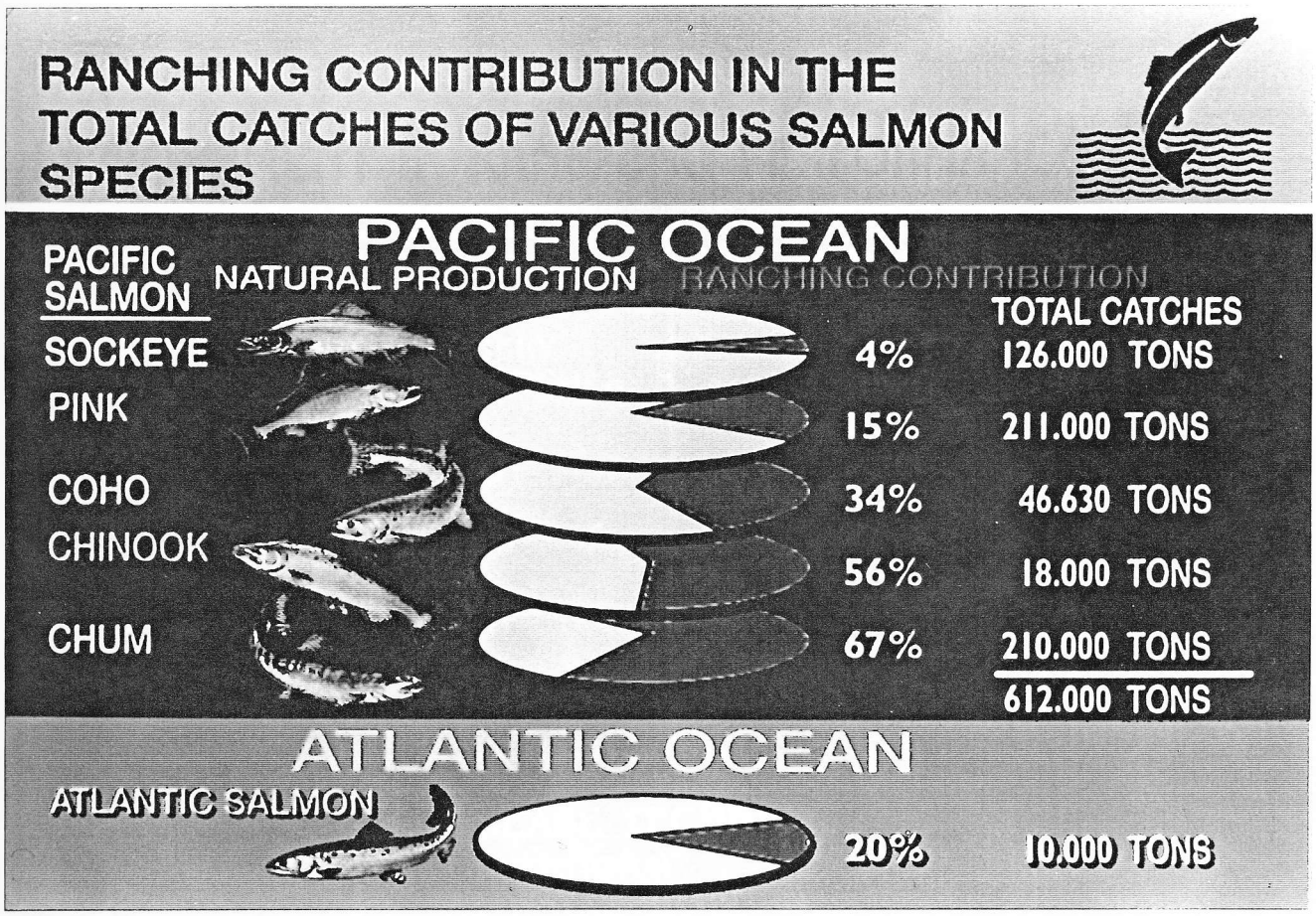


Figure 1.

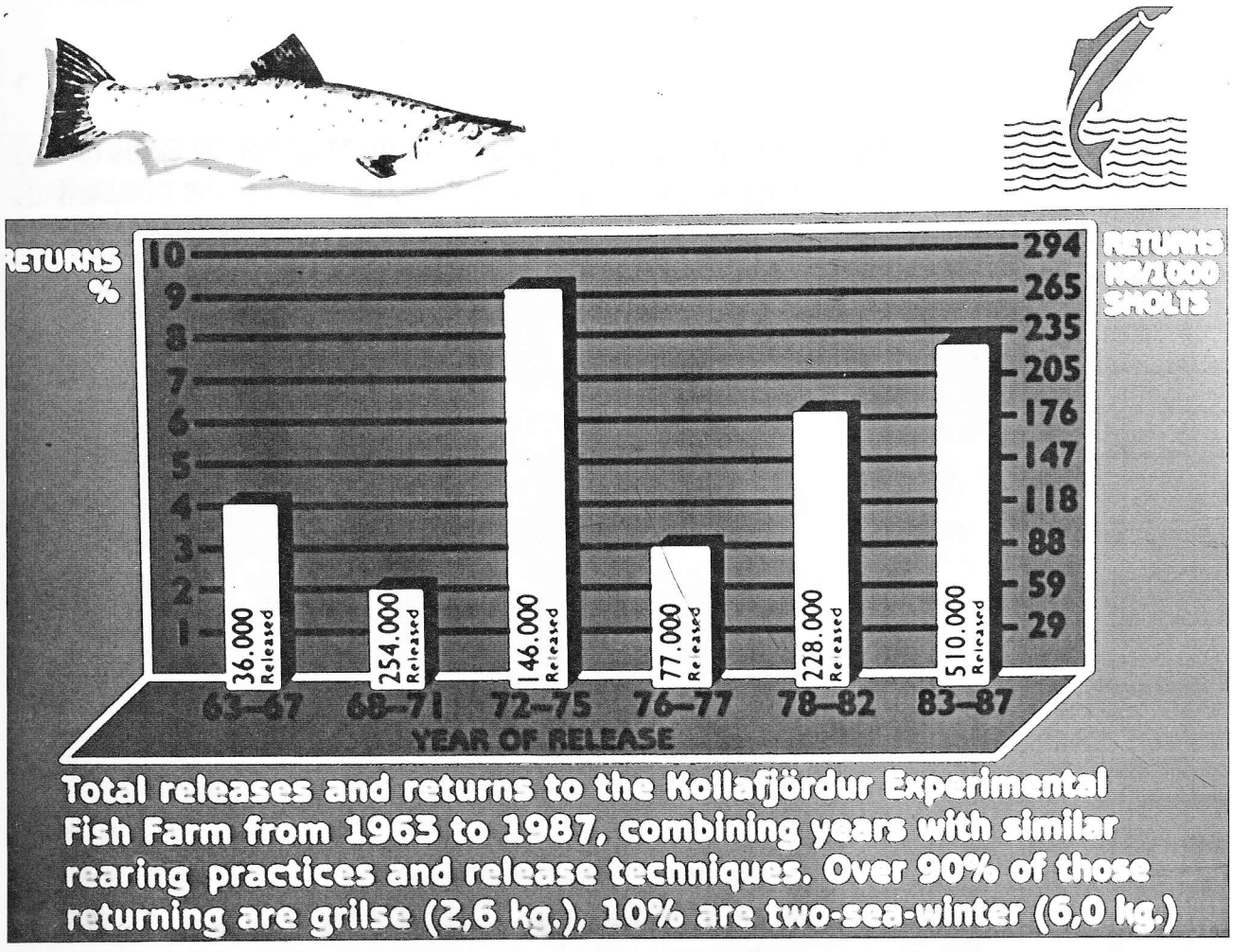


Figure 2.

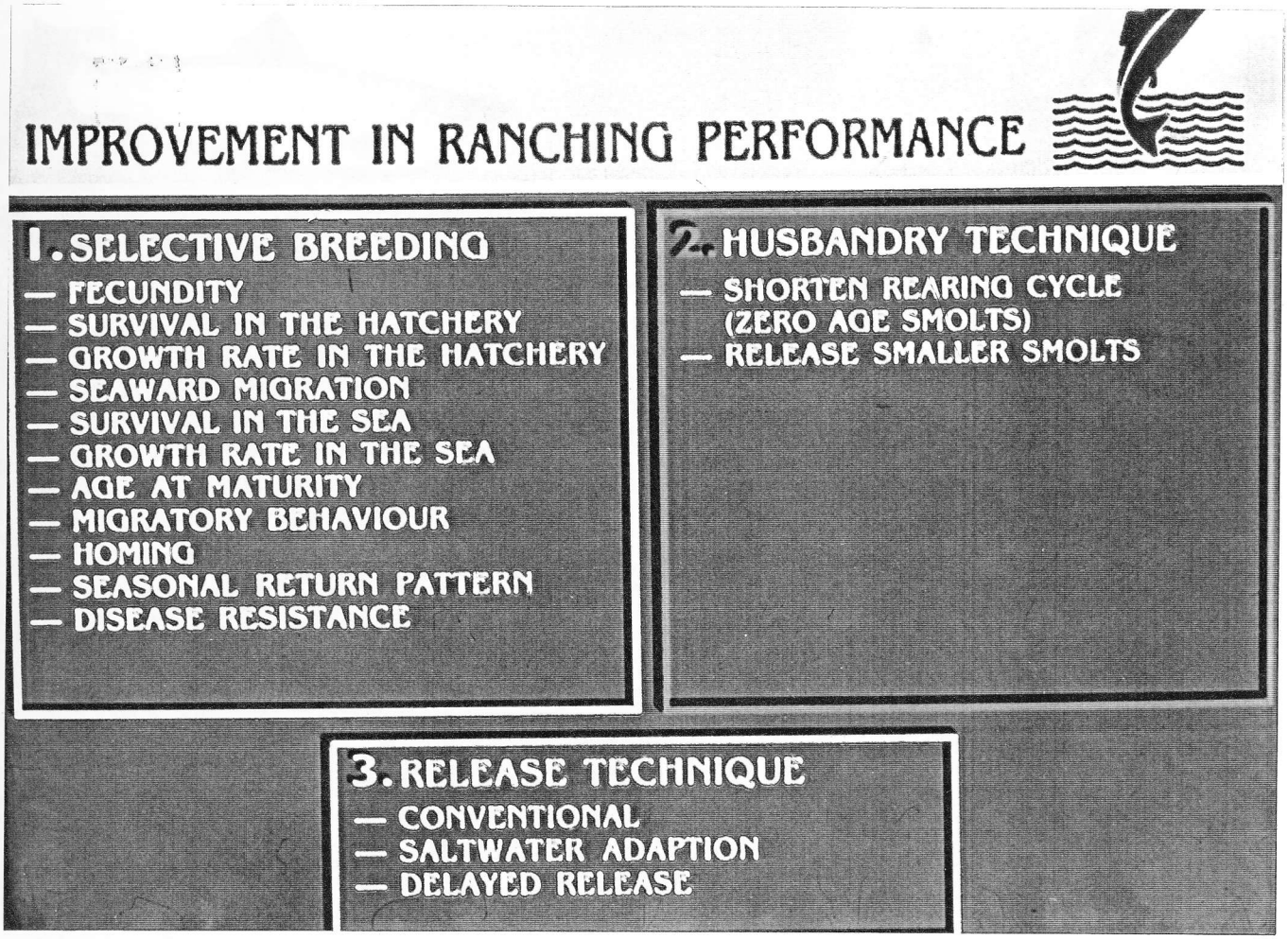


Figure 3.

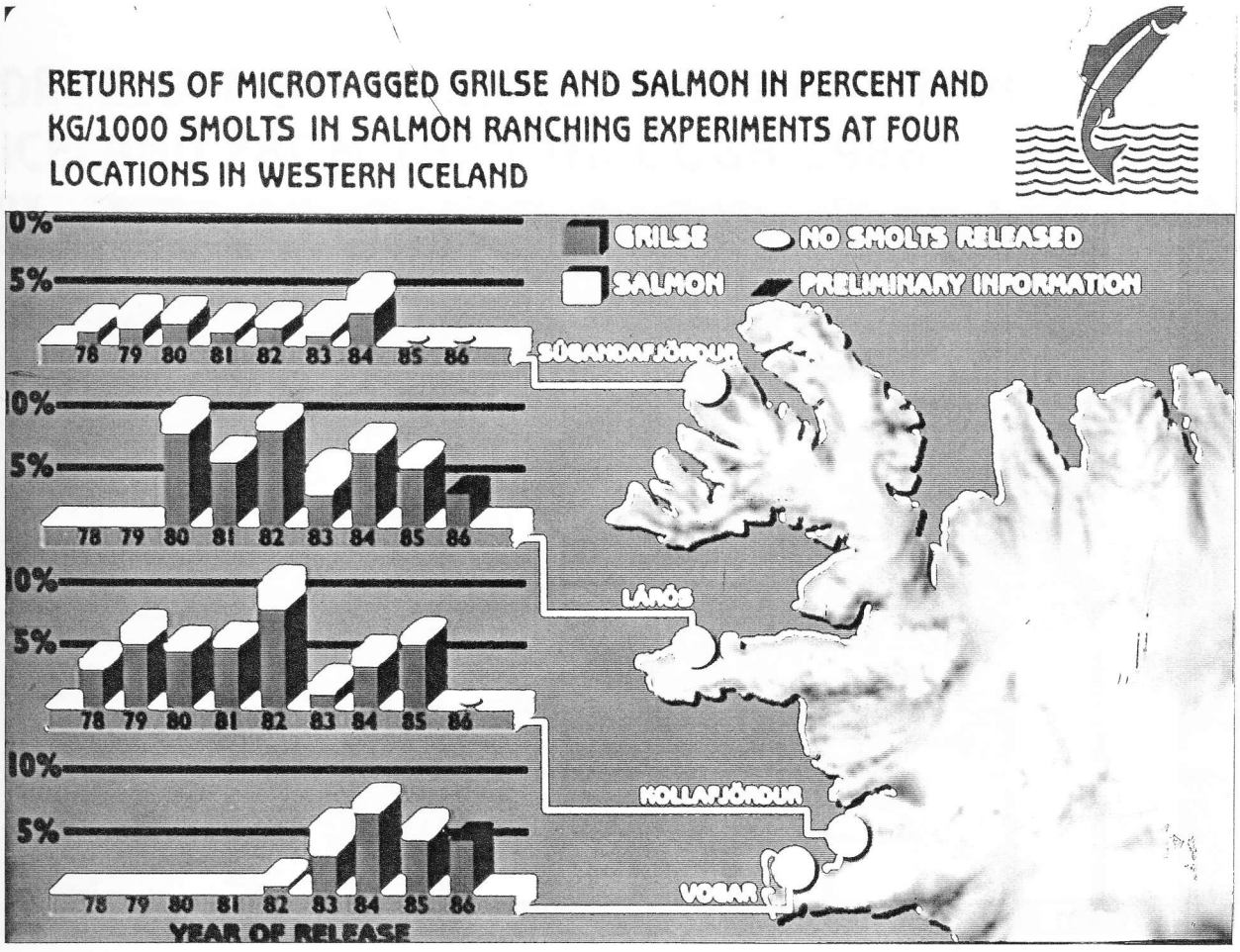


Figure 4.

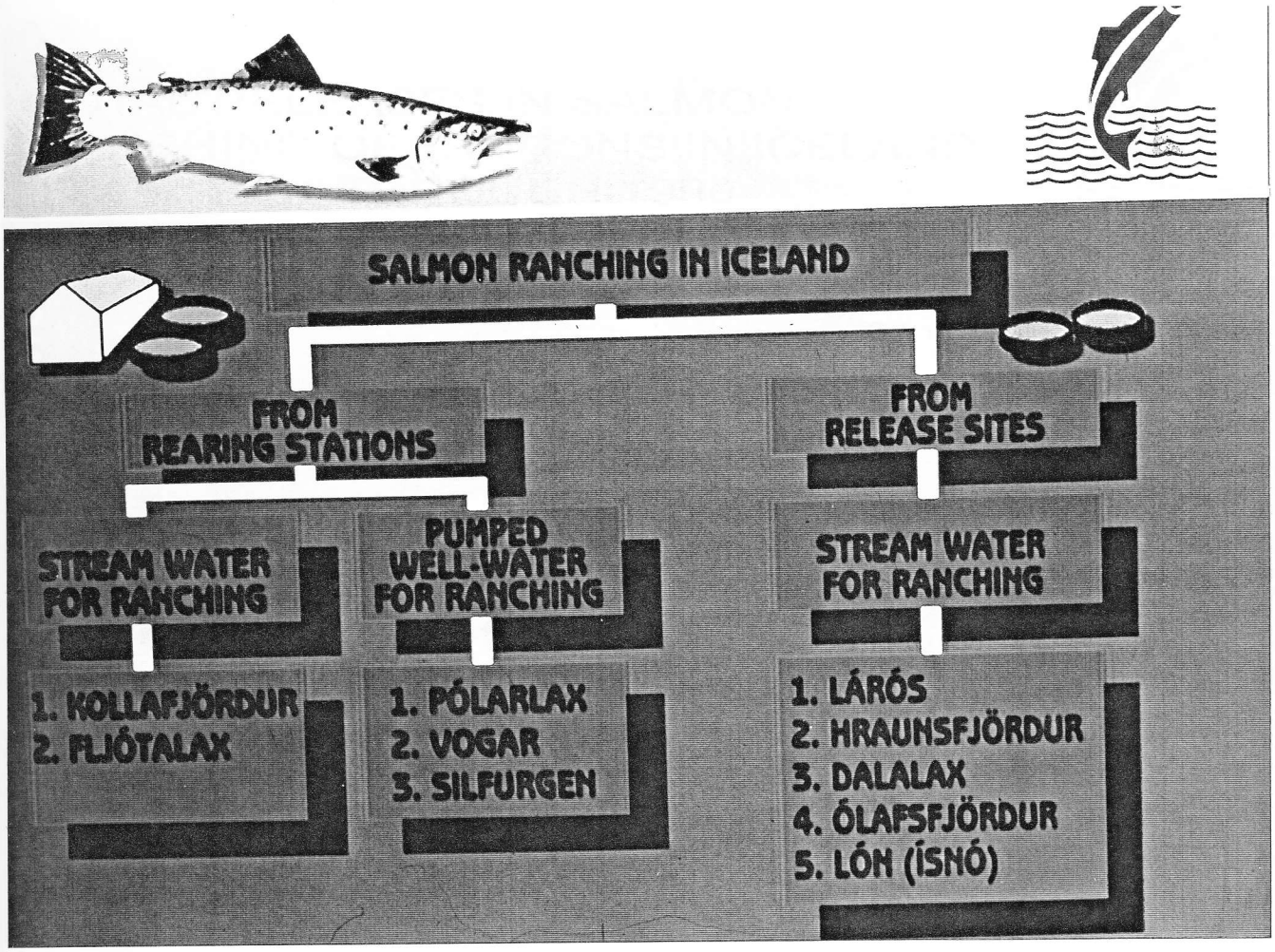


Figure 5.

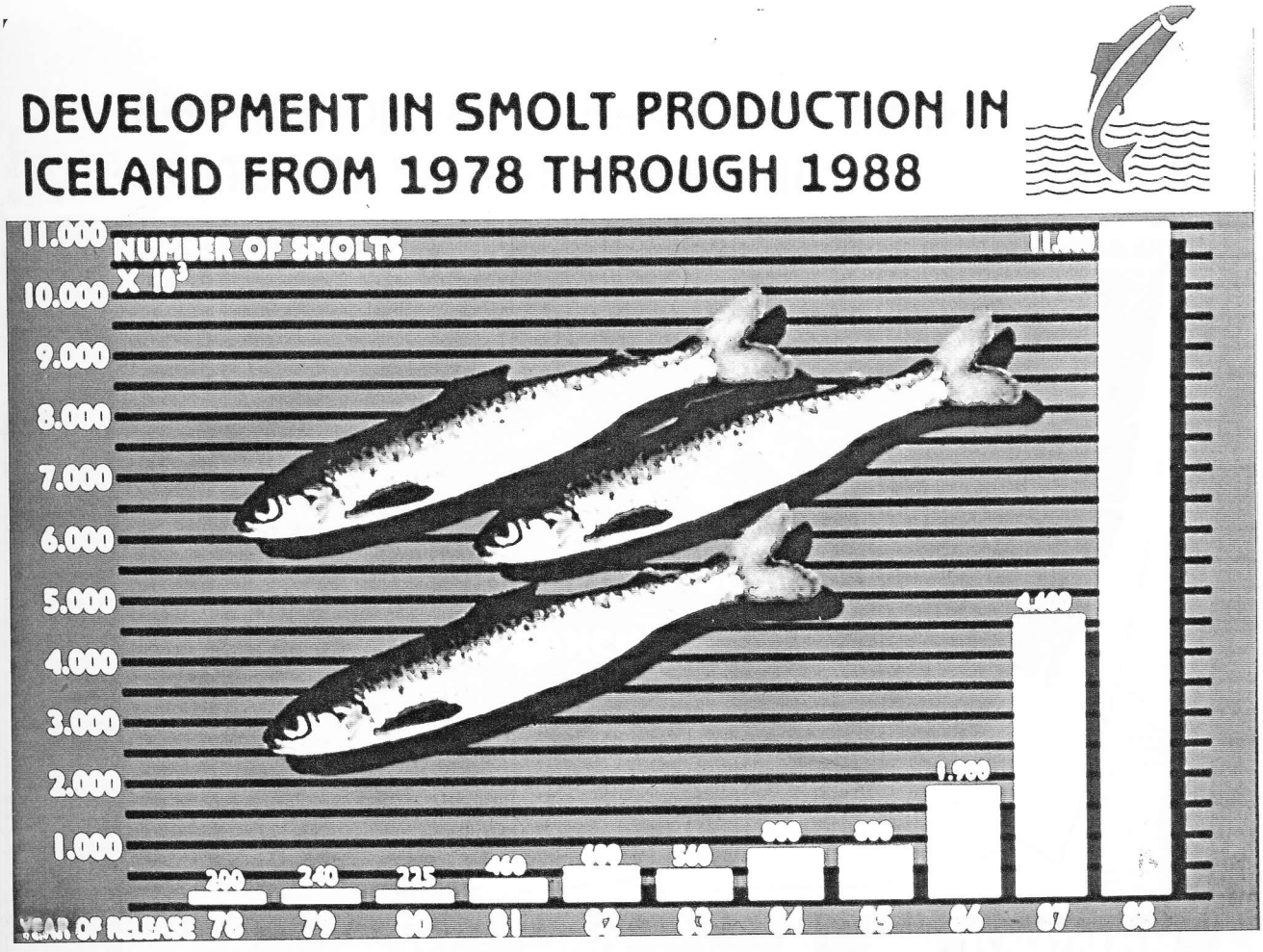


Figure 6.

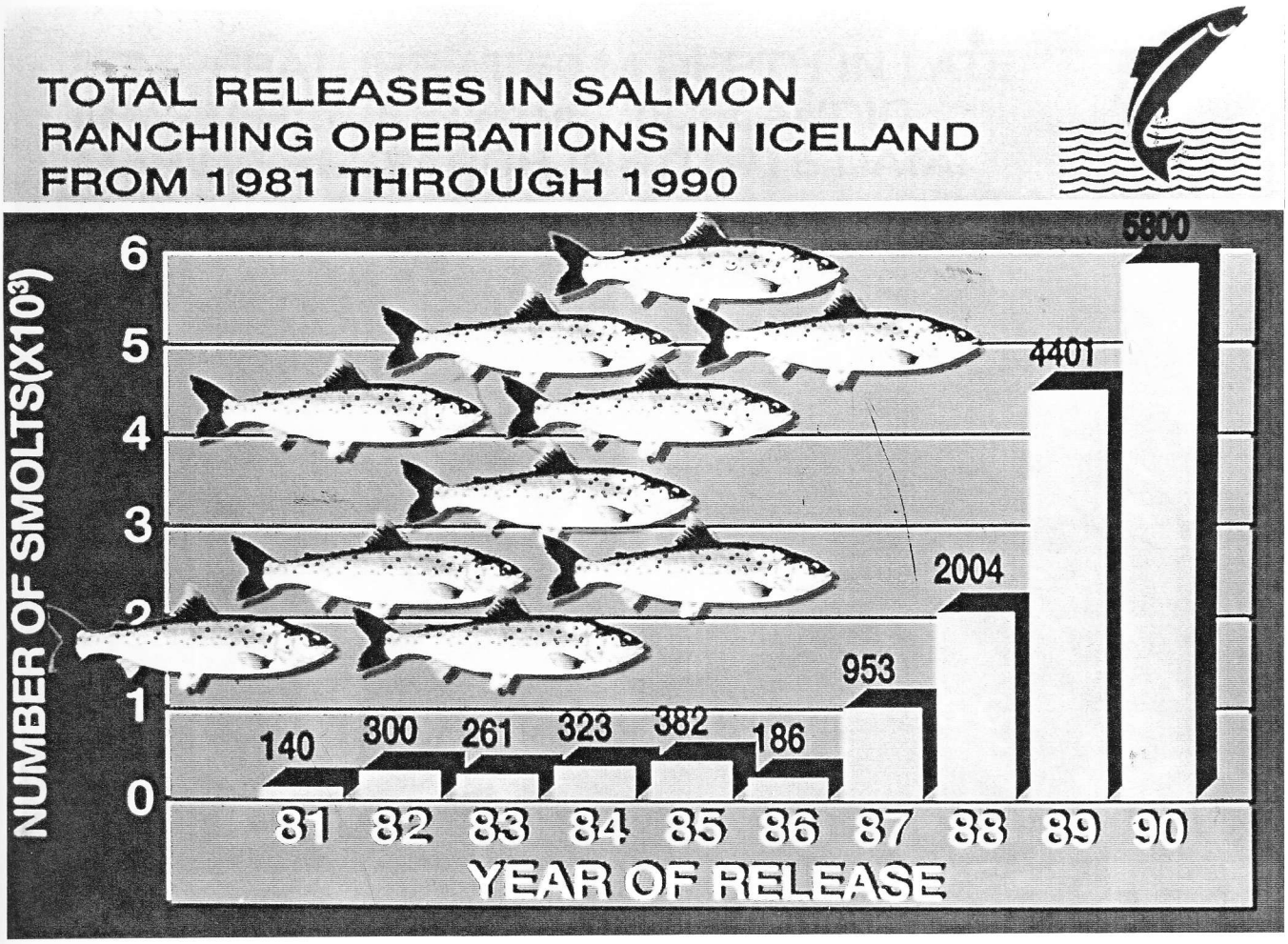


Figure 7.

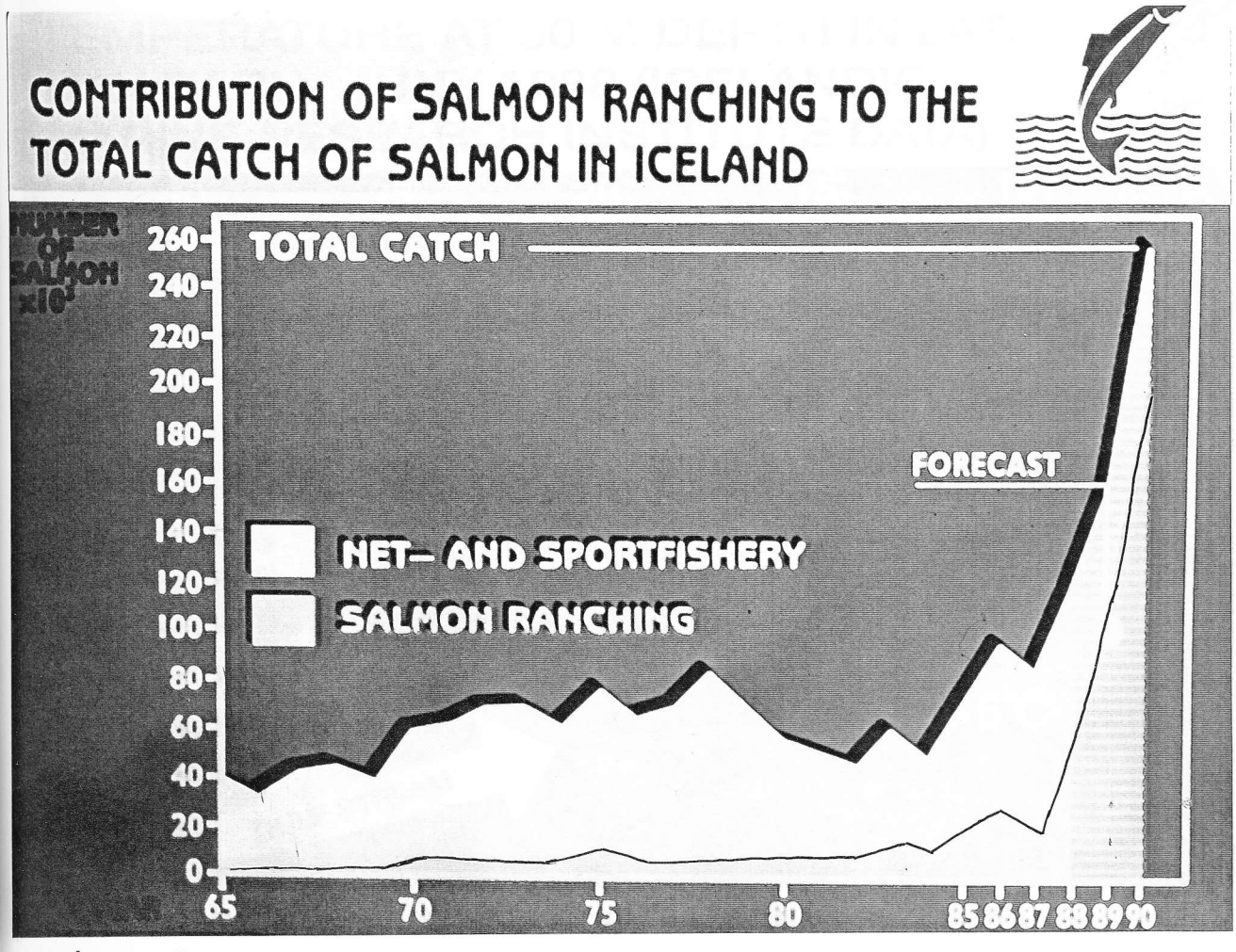


Figure 8.

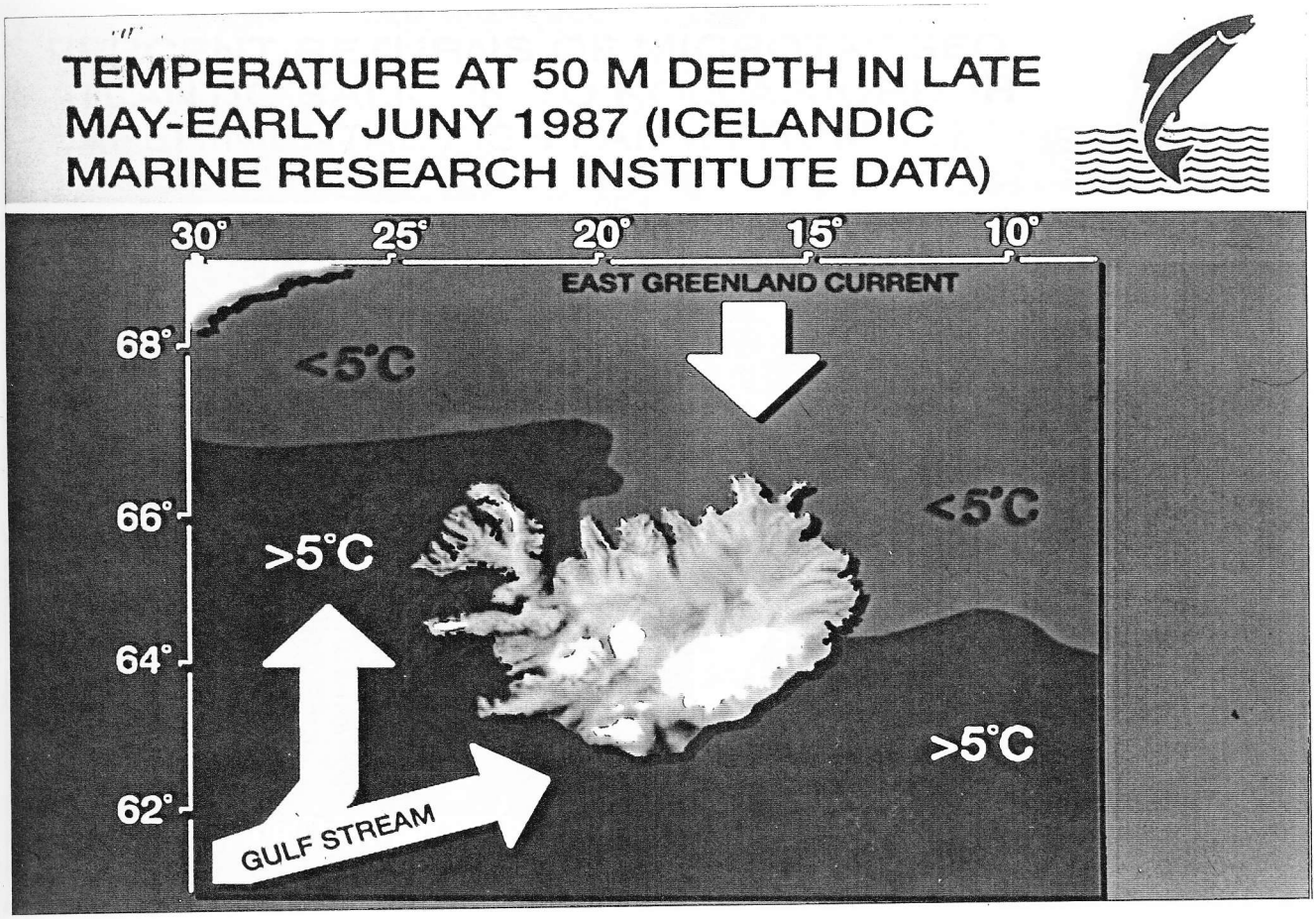


Figure 9.

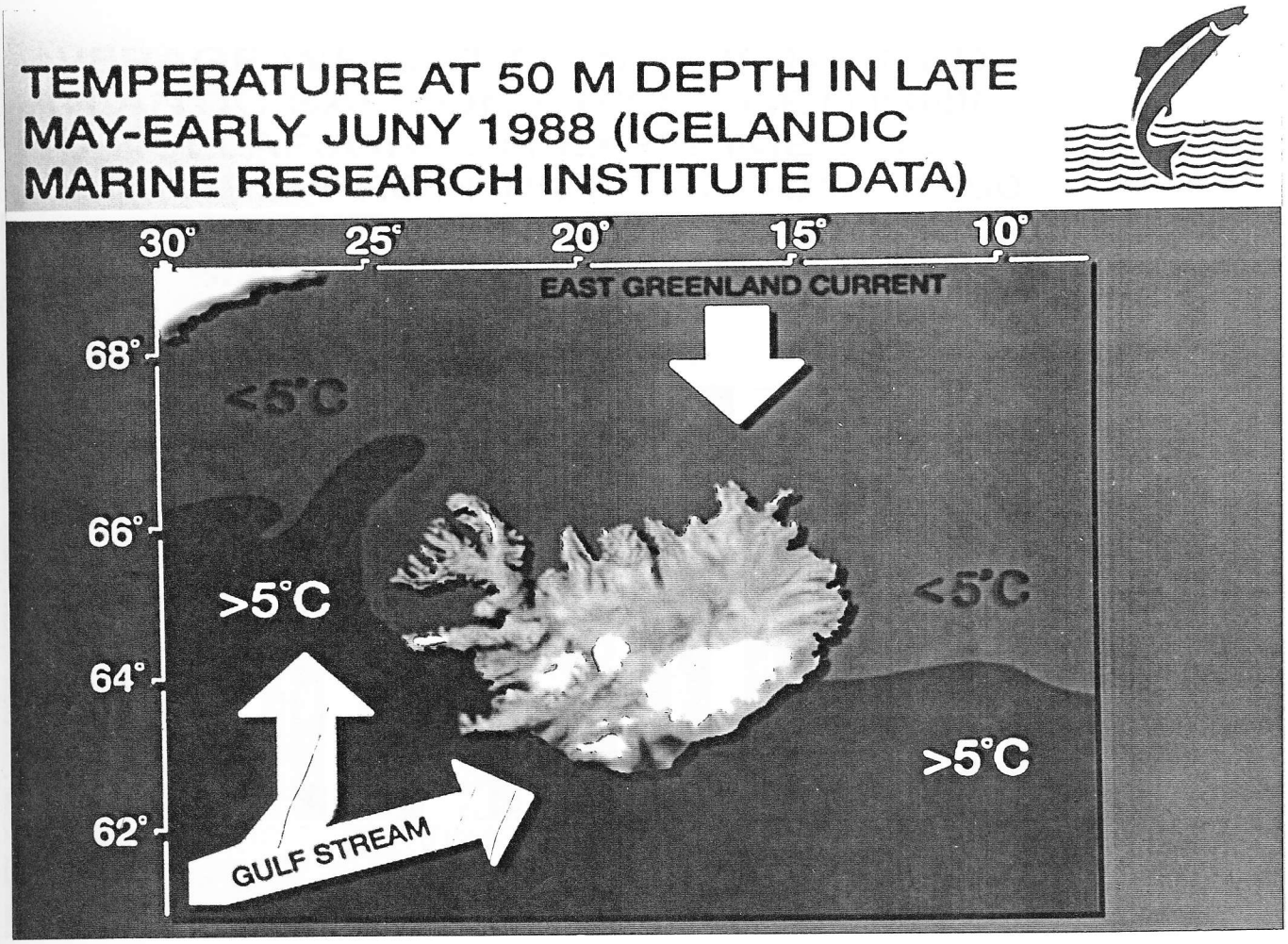


Figure 10.

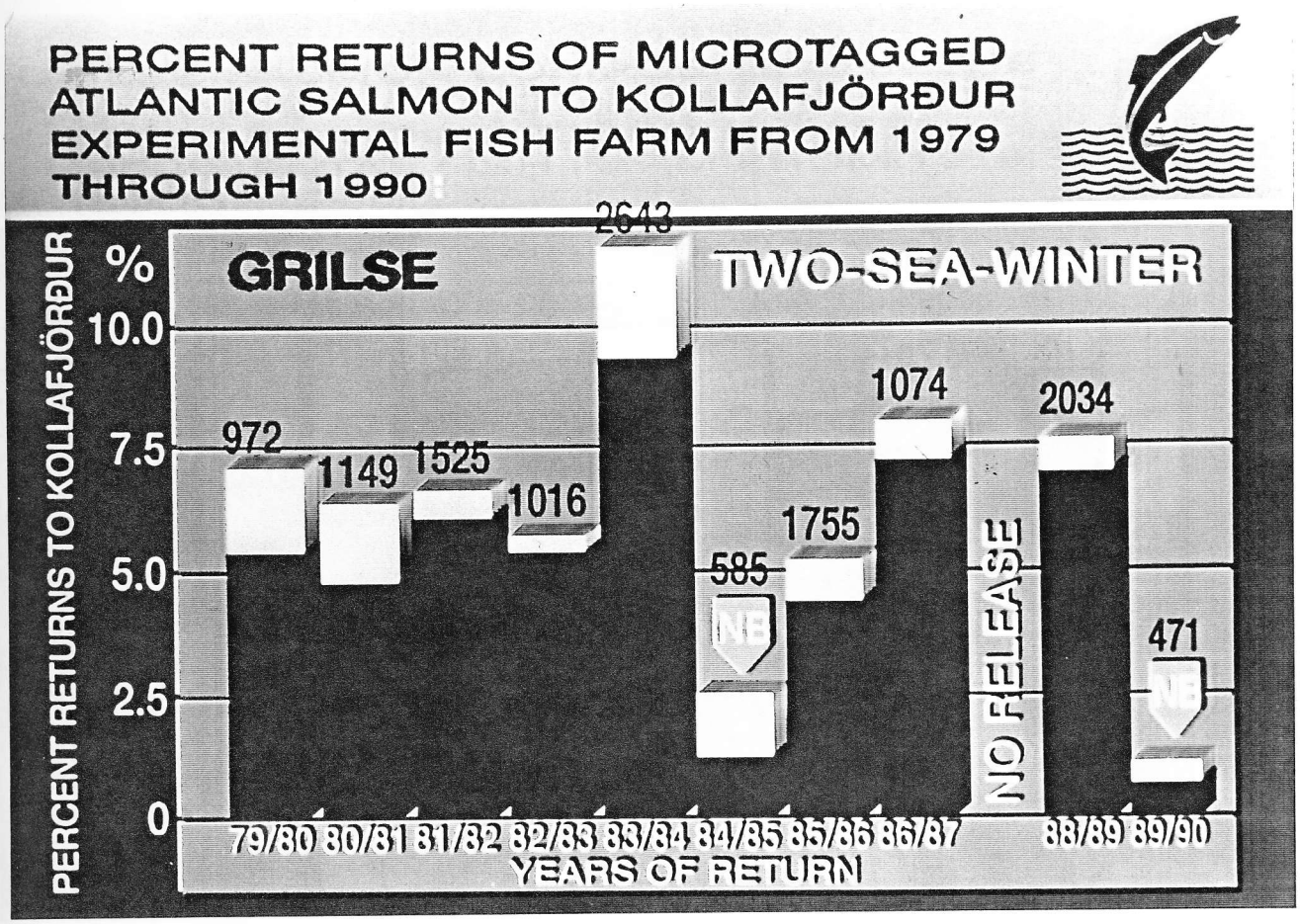


Figure 11.

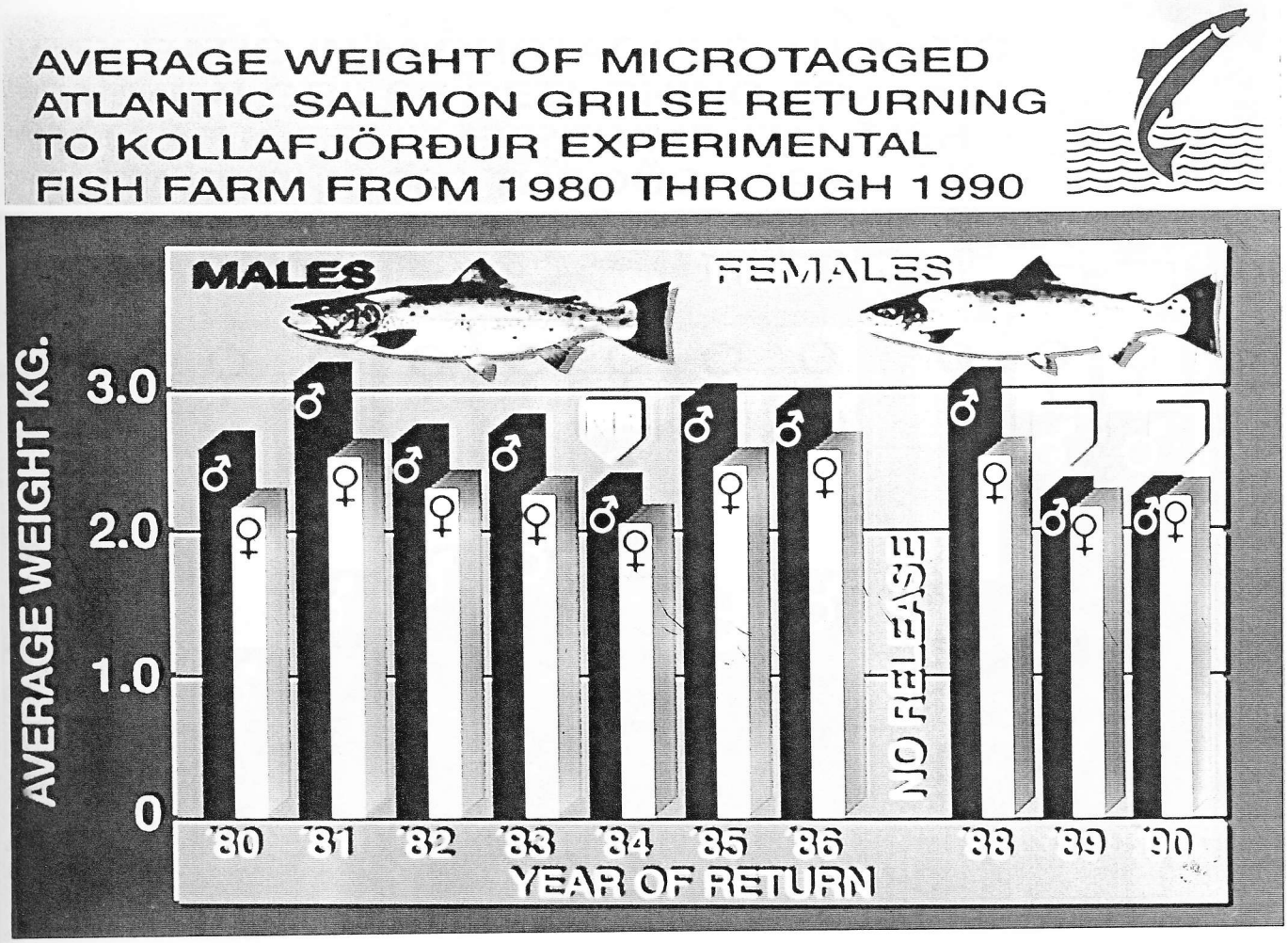


Figure 12.

GRILSE-SALMON COMPOSITION IN THE RETURNS OF MICROTAGGED ATLANTIC SALMON TO KOLLAFJÖRÐUR EXPERIMENTAL FISH FARM FROM 1979 THROUGH 1990

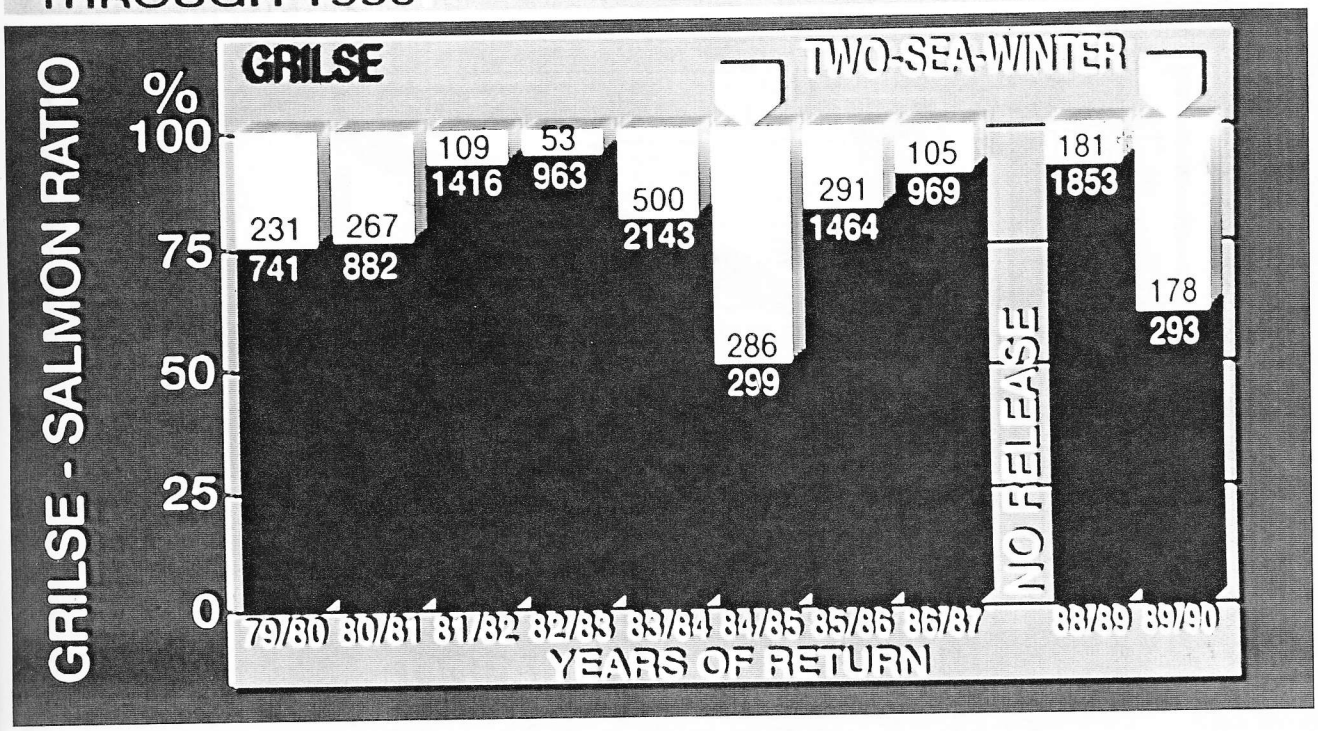


Figure 13.

SEX RATIO IN MICROTAGGED ATLANTIC SALMON GRILSE RETURNING TO KOLLAFJÖRÐUR EXPERIMENTAL FISH FARM FROM 1980 THROUGH 1990

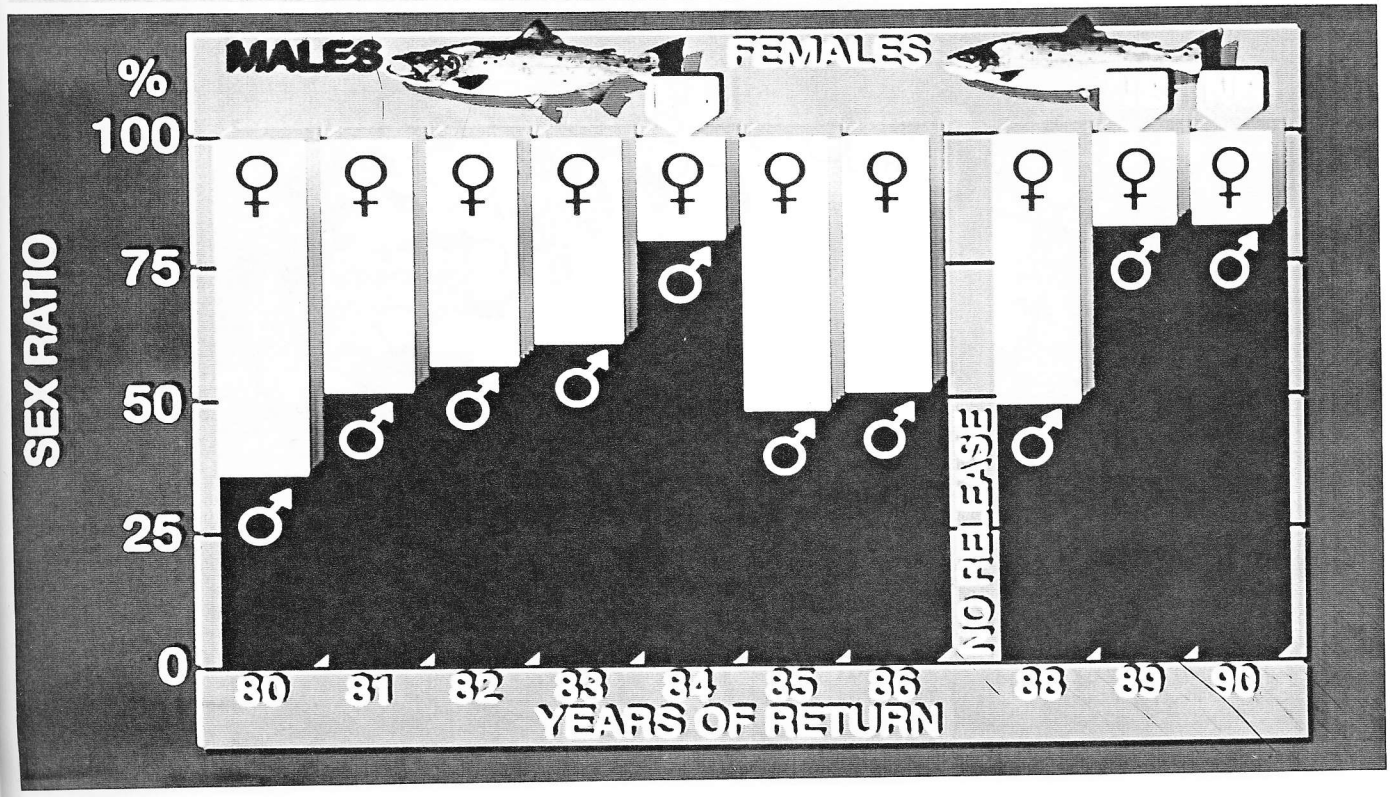
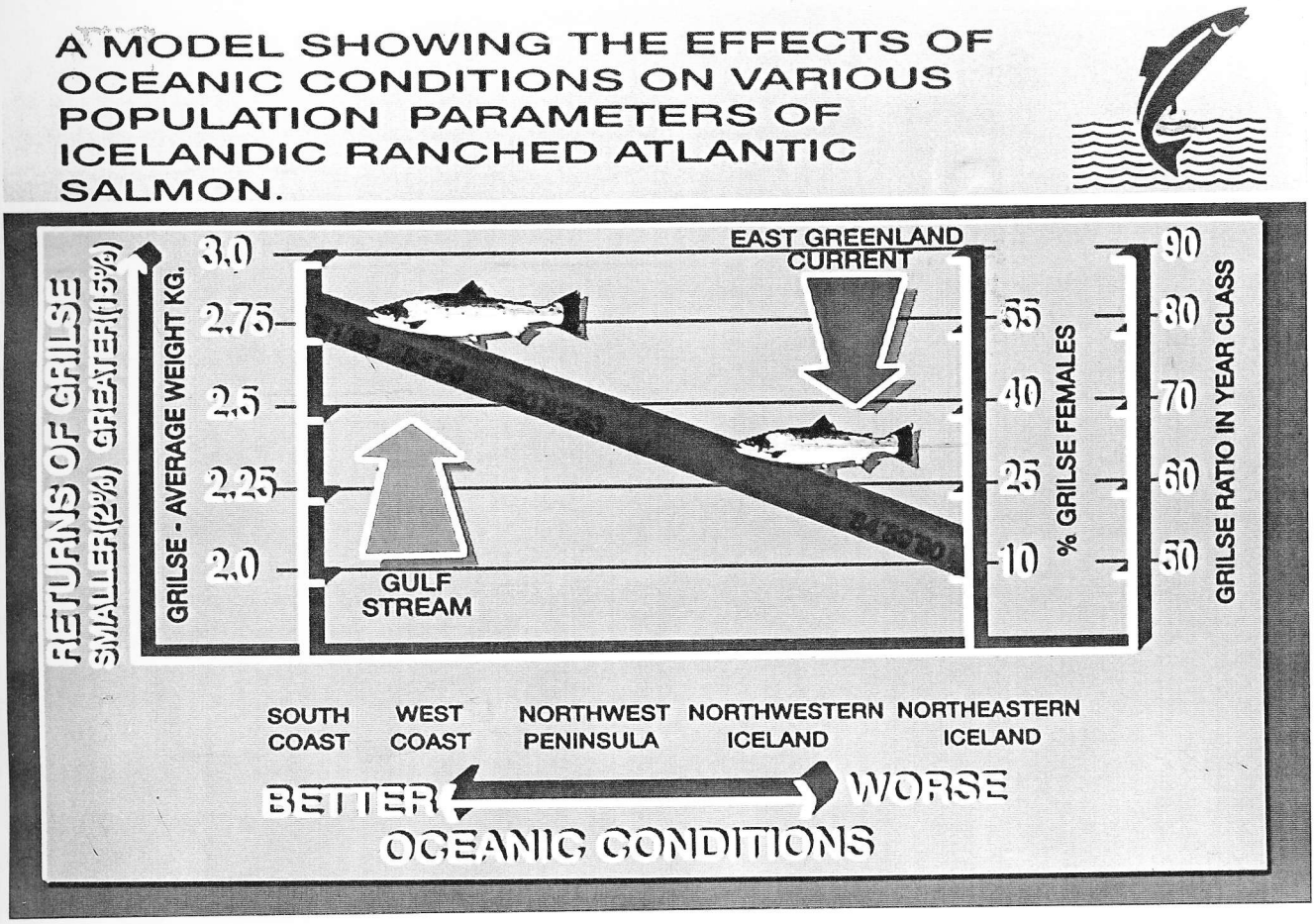


Figure 14.



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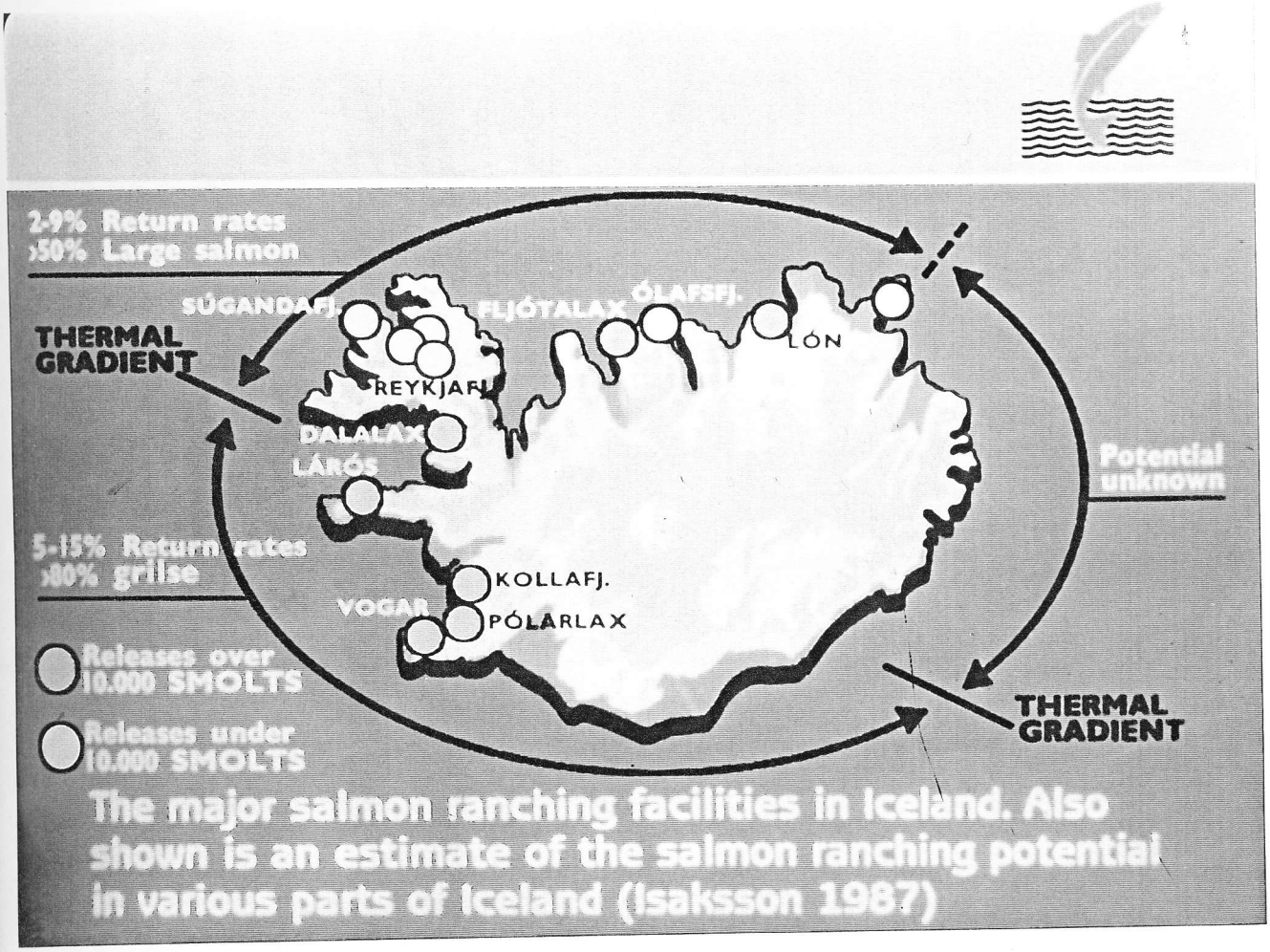

Figure 16.