THE POTENTIAL OF PACIFIC SALMON INTRODUCTIONS FOR RECREATION

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by

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INTRODUCTION

There are two possible approaches to the problem of increasing the salmon stocks of the North Atlantic: (a) the development of systems for improvement of freshwater habitats and for increasing the survival and geographic range of native stocks of Atlantic salmon, and (b) the transplanting of stocks of Pacific salmon, *Oncorhynchus* spp. to the Atlantic region. In a 1954 paper, Ricker discussed their relative merits. He argued with respect to the first that such measures as bird control, opening up of new nursery grounds by fishways, continuous artificial propagation, better spawning escapements, etc., were worthy and should be intensified but that even the most optimistic could not expect that they could "...do more than double or triple the supply of salmon on the Atlantic coast as a whole in any foreseeable future." He reserved his most favorable arguments for the second approach. He pointed out the far greater abundance of salmon in the North Pacific Ocean than in the North Atlantic Ocean as reflected in the comparative Canadian catch statistics for 1948 (roughly 150 million pounds from the Pacific vs. 5 million from the Atlantic). He ascribed the difference to the fact that "...the two most numerous Pacific salmons live in rivers only during spawning and incubation periods and do not require the freshwater food or living space which appears to limit the supply of Atlantic salmon." He went on to suggest that transplants of pink, *O. gorbuscha*, and chum salmon, *O. keta*, from the west coast would be the best approach to generating such an inshore fishery This paper is an attempt to outline the pros and cons inherent in the introduction of exotic salmon species in New England waters.

The first salmon hatchery on the Pacific Coast of North America was opened in 1872 on the McCloud River in northern California by the U.S. Fish Commission. From this simple beginning, salmon hatcheries in the Pacific Northwest have become the most highly developed of modern aquatic culture systems. Information on disease, nutrition, growth energetics, physiology, behavior, and life history--resulting from research at salmon laboratories--is plentiful and has been used as a starting point for research on other species of fish as well. In the State of Washington, hatcheries are operated by both the State and Federal governments. The first hatchery in the State was opened in 1895 near Kalama on one of the tributaries of the Columbia River.

At first, hatchery rearing extended only through the early fry stage when the tiny salmon were released into the streams. In 1895, the first year of operation of the Kalama hatchery, more than 4 million fry were planted. By the 1930's, as many as 189 million eggs were being taken for fry propagation.

At salmon hatcheries, the period of rearing has been gradually extended before the young salmon are released to migrate downstream to salt water. Larger migrants are better able to cope with environmental hazards enroute to the sea and tend to return at a higher rate than earlier-released fry.

In 1970, the Washington Department of Fisheries planted more than 34 million large fingerling smolts. In addition, 80 million smaller fingerlings and nearly 12 million fry were planted. In 1975, more than 150 million fingerlings and fry were planted. The high percentage of adult coho salmon, O. kisutch, of hatchery origin in Puget Sound sport and commercial catches attest to the success of such programs. In 1972, an unusual year, 90% of the sport and commercially-caught coho returning to home streams in Puget Sound were estimated to have been reared at hatcheries. Today, the annual sport catch in Washington waters alone is about 1 million fish annually.

The hatchery systems of the Pacific Northwest continue to grow in importance as demand for recreational and commercial fish increases. Today in Alaska, British Columbia, Washington, Idaho, Oregon and California there are a total of 113 hatcheries and 42 rearing ponds for the rearing and releases of anadromous salmonids.

In modern Northwest hatcheries, extended rearing is being applied to the rearing of coho salmon which, in 1970, made up more than 30% of the salmon released in the State of Washington.

Delaying the release of hatchery-reared salmon is being tested in the State of Washington as a means of improving returns. These experiments have produced unexpected results. In the past, the young salmon have been released at a time to coincide with their normal seaward migration from their home streams. Recent studies by the Washington Department of Fisheries have shown that delaying their release alters the normal migratory behavior. Continuous and extraordinarily high catches in the Puget Sound sport fisheries of "delayed-release" salmon show that these fish tend to remain near the site of release instead of migrating out to sea. The same sort of behavior results when salmon are delayed in saltwater pens beyond the time of their normal outmigration before being released. Not only do the salmon remain relatively close to the release site, but the mature fish run up streams in the vicinity of the site rather than returning to the hatchery stream to spawn. (2 slides--net pen locations and aerial of Domsea Farms.)

Delaying the release of young salmon, then, has the following advantages over normal hatchery procedures:

1. They tend to remain in the immediate locality and stay available to local fishermen.

2. When they are held in salt water before being released they do not return to the hatchery stream to spawn but move instead to a suitable stream near their point of release.

3. Survival to maturity is increased, with improved escapement and returns to sport and commercial fisheries.

The application of delayed-rearing techniques should make it possible to manipulate migration patterns by inducing salmon to return to selected homing stations.

With the new techniques for rearing hatchery-produced Pacific salmon in saltwater pens, the amount of freshwater rearing space for growing juveniles can be significantly reduced. In New England, a modest hatchery program combined with saltwater rearing should be able to produce enough Pacific salmon to generate a vigorous sport fishery along the New England coast. In this way the saltwater stations would provide capacity for extended rearing without taking up additional hatchery space, improving the chances for increased survival at sea and conditioning the mature fish to home on streams near the release sites.

BIOLOGICAL CONSIDERATIONS PERTINENT TO THE INTRODUCTION OF PACIFIC SALMON

To some recreational fishermen and fishery managers, the introduction of Pacific salmon species is a spectre, threatening the very existence of Atlantic salmon stocks and enhancement programs. To others it is perhaps the answer to rehabilitating coastal regions, now devoid of Atlantics, with a desirable recreational fish. To me it is not a question of either or but how can we best accomodate both.

Let us consider some biological factors affecting both Pacific and Atlantics if large scale introduction of Pacifics was to occur. By way of introduction it is important to note that the NMFS proposal originating from the NWFC did not suggest introducing Pacific salmon into streams presently supporting Atlantic salmon. Rather, the proposal suggests introduction into streams and rivers that are presently barren of Atlantic salmon runs. It is proposed only to use such streams as homing sites for stocks that will be propagated in hatcheries. It is intended that the introduction of Pacific salmon will provide a complementary interim fishery in New England coastal waters.

WHAT ARE SOME OF THE PROBLEMS ASSOCIATED WITH THE INTRODUCTION OF NON-INDIGENOUS SPECIES OF SALMON?

I. Competition in streams, Salmo vs. Oncorhynchus

Question:

> The coho life-style is quite similar to the Atlantic salmon. They use the same spawning areas at the same time of year. Coho, perhaps more than other anadromous salmonids will successfully move long distances upstream to spawn, penetrating into the smallest tributaries, even though water flows may be extremely low. Are they likely to compete with other salmonids when they get into the same rivers?

To our knowledge there is no evidence available on competition between Atlantic salmon and coho in streams. It is, however, a legitimate concern when introduction of coho into Atlantic salmon streams is contemplated. No real information is available on simultaneous habitation of streams by coho and Atlantics and so the following discussion is speculation on my part. In the northern portion of the range, coho might compete with other species for spawning area in small streams that have intensive small-gravel spawning beds, but if Atlantic salmon behave at all like a similar congeneric western species, the steelhead, that cohabits streams with coho, they will simply move to unoccupied areas to complete spawning. In large rivers we suspect that Atlantic salmon would probably spawn along the edges of the main river channel much the same as the majority of steelhead do on the West Coast. In the west, young of the two species (steelhead and coho) emerging from the gravel occupy niches that are quite different in many respects. Young steelhead reside in the fast-moving, highly-oxygenated parts of our streams, remaining primarily in the main stem to feed rather than in the small tributaries. Observations on the behavior of young Atlantic salmon, raised here on the Pacific coast, is that they would also be a main stem, bottom-feeder, darting out to pick up small bits of food brought past by a strong current. Coho, on the other hand, feed in mid-water niches and can be reared easily in still waters. Fry definitely prefer small tributaries, side channels and backwaters of larger streams, particularly those with slow meandering pools. We feel that there would be very little direct competition for food between coho and Atlantic salmon during the first year of their life. Coho migrate to sea in their second spring and during the downstream migration there might be some competition for food, but it would probably be insignificant as coho tend to go off-feed during their outmigration. Atlantic salmon, with a shorter incubation period and slightly earlier spawning time than coho, would have the advantage both in selection of stream gravels and emergence time of fry. Being better adapted to cold water conditions and the shorter incubation period and earlier emergence would give the young *S. salar* a growth advantage over coho helping reduce predation by young-of-the-year coho. In western streams there *is* greater predation on coho by anadromous species of *Salmo* than the reverse.

II. Straying

Question

> The usual homing percentage of coho's is approximately 85% to the native streams. The 15% of wanderers is reported higher with introduced stocks.
>
> Is it not illusory to think that coho once introduced can be effectively prevented from entering potential Atlantic salmon streams?

True, some straying does occur in most salmonid species and could occur in the Northeast. But significant straying is usually limited to streams adjacent to the natal stream. The likelihood of individual strays as far north as Canada finding mates or the offspring surviving in sufficient numbers to perpetuate the run is very low. Poor New England stream water will be an effective barrier to the survival of offspring from strays.

The above argument is reinforced by the very fact that no significant straying has occurred in New Hampshire where coho have been introduced.

III. Fitness of the Ocean Environment

Question

> Are the waters of the Gulf of Maine suitable as receiving waters for Pacific salmon? Can Pacific salmon stocks be transplanted from ocean to ocean?

Prior to the publication of Ricker's (1954) paper, there had been several attempts to introduce Pacific salmon to the Atlantic coast. Pink and coho salmon, *O. kisutch*, had been planted in Maine, and chinook salmon, *O. tschawytscha*, in Lake Ontario streams and in New Brunswick. Permanent runs from these plants did not become established, although in Maine, small returns did occur for several cycles. At that time, the only successful, self-perpetuating runs of Pacific salmon transplanted from their natural habitat were the chinook salmon which since 1905 have become established in the Waitaki and other rivers of the South Island in New Zealand (Davidson and Hutchinson, 1938).

From 1956 to 1961, mass transplants (4 to 46 million) of the roe of pink and chum salmon were made from USSR fish culture stations on Sakhalin Island in the northwestern Pacific Ocean to stations in the Murmansk area on the Arctic coast of Europe. In 1960, 300,000 adult pink salmon returned to the rivers of that area. Smaller numbers appeared along the coast of Norway as far south as Bergen and along the coasts of Iceland and Great Britain. These runs subsequently dwindled. Rass (1965) suggests that roe from the spawning of transplanted adults had died from low temperatures in the rivers during the incubation period, the weather being colder at that time on the Murman Coast than on Sakhalin Island to which the fish were adapted.

During the past 6 years, fishery management agencies in several of the New England states have made modest plants of coho salmon in an attempt to generate runs of these fish into their rivers. The eggs were from Washington and Oregon and reared at hatcheries in New England. The efforts of Connecticut and Rhode Island agencies have proved futile; no returns to the home rivers from any of the plants by these two states have ever been achieved. New Hampshire, on the other hand, has had returns to the Exeter and Lamprey Rivers.

Massachusetts has also recently begun a modest effort of its own to establish coho salmon in the North River just to the south of Boston. The remarkable success of Great Lakes introductions is well known and will undoubtedly be discussed at the banquet by Howard Tanner.

In these recent attempts to transplant Pacific salmon to New England, the success of the New Hampshire experiment and encouraging early returns from Massachusetts contrast with the stark failures experienced in Connecticut and Rhode Island. Why?

Temperature and food are the two most important factors in determining the ocean distributions of Pacific salmon. Assuming food is not limiting, let us consider temperature. The tolerable and preferred ranges of ocean temperature for various species of Pacific salmon are given in the slide. Within the range for each species, there is a spectrum of narrower temperature bands to which specific races of the species are adapted. It is important, therefore, in selecting stocks for transplanting, to choose races whose habitats match as closely as possible the seasonal temperature regimes of the intended receiving waters. The next slide shows the distribution of surface temperatures in the North Pacific Ocean, favorable for temperate-zone races of salmon.

The seasonal sea surface temperature structure of the Gulf of Maine suggests that Pacific salmon species could be accomodated very nicely. In the summer and early fall, a temperature front extends eastward from Cape Cod to the Gulf Stream. Temperatures in excess of 16°C (61°F) occur south of the front which would block the return of fall-spawning coho salmon to rivers and streams south and west of the Cape. North of the Cape, however, there would be little to prevent their moving into estuaries from the cool offshore waters in the late summer and early fall as a prelude to their fall spawning migration. The seasonal, surface-temperature structure of the Gulf of Maine, and of Nantucket, Vineyard, Block Island, and Long Islands Sounds is such that the thermal barrier moves to the south and offshore in the late fall and winter and does not start to build up again off Cape Cod until early summer. An isothermal band favorable for temperate-zone races of salmon (8-14°C, or 46-57°F) moves from the open sea south of Long Island in the late winter, progressing gradually northward with the advancing seasons, until it becomes compressed along the Maine coast and into the Bay of Fundy by late summer. By the fall, it begins to spread to the south, eventually returning to its wintertime position offshore, south of Long Island. This suggests that Pacific salmon, planted in New England, would be found in ocean waters off the coast of Maine and in the Bay of Fundy in the summer, where they should be accessible to both sport and commercial fishermen. They would tend to move with the southward spread of 8-14°C water and, if chosen from stocks appropriately selected for the timing of their migrations back to fresh water, would appear off their home streams when the 8-14°C band was in a favorable position offshore.

From the foregoing, it seems likely that the early fall-running coho salmon was a poor choice for establishing runs of Pacific salmon in Rhode Island and Connecticut. A late fall-running stock might have had better success.

The matching of the environmental requirements of donor stocks with appropriate conditions in the receiving waters can be critical. By paying attention to the greater latitudinal shift of ocean temperatures with the seasons in the North Atlantic, introductions of Pacific salmon can be timed so that ocean conditions match those of the North Pacific.

IV. Capacity of the Northwest Atlantic to Support New Salmon Populations

<u>Question</u>

Can the Northwest Atlantic support additional salmon populations? Is feed the limiting factor and will competition for food adversely affect the Atlantic salmon?

For the sake of comparison let's examine the capacity of a salmon hatchery system in a geographically and oceanographically similar location but in the Pacific Ocean--the chum salmon hatchery program on the Japanese island of Hokkaido. Hokkaido has approximately twice the shoreline area of the Gulf of Maine from Cape Ann to St. John. The river systems are similar in number and flow and in some respects water quality. Hokkaido is situated in the same relative ocean position on the northwest boundary of a clockwise circulating ocean gyre. Both Hokkaido and the Gulf of Maine are located at 43° N latitude (Slide).

The ever improving success of the Hokkaido hatchery system is largely due to rearing techniques:

A. Massive production of chum salmon fry with total releases now exceeding one billion fry annually.

B. Supplemental feeding and extended rearing.

C. Careful matching of releases with seasonal conditions of ocean temperature and plankton abundance.

It is also interesting to note that this year, combined returns to the hatcheries and coastal fishery exceeded 16 million adult fish. It would appear that the capacity of the ocean environment to support chum salmon has not yet been reached for runs emanating from Hokkaido. If Hokkaido is a valid analog to the New England coast, then ocean capacity is not presently a pressing matter.

Other important biological factors affecting the success of transplanted and resident stocks are too numerous to consider here but would include ocean predation, danger of introducing new diseases, selection of donor stocks, etc. Biological factors aside, Pacific species are easier to rear at the hatchery. They show better survival, require less raceway space and a shorter period to smoltification, and have a higher percent return to the hatchery. The rearing costs are therefore lower.

CONCLUSIONS

The basic issue is not Atlantic vs. Pacific salmon. The basic issue is how to optimize production of the ocean range; to fill available ecological niches with stocks best fitted to convert available feed to useful protein; and to provide a broadly based recreational fishery for the greatest number of New England sportsmen.

Based on the evidence that we have briefly touched on in this paper, we believe that development of a regional system for rearing Pacific salmon in New England is possible and could lead to the establishment within a very few years, of a vigorous inshore salmon fishery.

If New England States elect to introduce Pacifics and subsequently find the introductions detrimental to Atlantics or if straying successfully occurs it should be a relatively simple matter to eliminate them in river mouth weirs, ladders or barriers. If we have been able to wipe out most of the world's salmon runs unwittingly, imagine how effectively we can do it wittingly if we deem it necessary.

And finally if the New England states embark on a serious plan to introduce Pacifics the following points should be noted:

1. Relatively large plantings should be made to one or a few sites, at first, so that there will be an adequate expendable surplus while the selection process is weeding out genes whose effects are in poor adjustment to the new situation.

2. Donor stocks should be carefully selected in order to match the freshwater and marine requirements of the species.

3. A regional agency for planning and controlling introduction of non-indigenous salmonids should be formed. Such an agency could play a key role in developing an international ocean range management plan for all salmon species in the North Atlantic. The duties of such an agency might be to encourage cooperation between the Canadians and European nations for coordination of smolt production; monitoring of condition of ocean stocks; and abstention from high seas fishing backed by surveillance. The need for an ocean range management system to encourage ocean ranching will be the keynote of the European Fish Farming Conference in London in October and might provide an ideal forum for presenting such a plan.