Rebuilding Salmon Fisheries In New England

By Timothy Joyner and Conrad Mahnken

The shallow ocean waters over the broad northeastern shelf and slope of North America support an abundance of marine life which has been an important source of food for nations facing the North Atlantic Ocean. The richness of the salmon resources were appreciated by the first Europeans likely to have set foot on North America.

The American historian, Samuel Eliot Morison, drawing from information in the "Groenlendia thattr" (Tale of the Greenlanders) in the Flateyarbok (Flat Island Book) compiled by Jon Thordharson in 1387, gives an account of the Norseman Leif Ericsson's short-lived settlement in Newfoundland in 999 or 1,000 A.D. The saga tells how the Norsemen were impressed by the abundance and size of the salmon in the river and lake at the site. They were, in Morison's words, ". . . bigger salmon than they had ever seen."

In the summer of 1534, Jacques Cartier, a master mariner from Brittany sailing for France, conducted extensive explorations of the northeastern coast of North America. Having a Frenchman's high regard for gastronomic delights, he carefully noted in his log that the waters of Chaleur Bay teemed with salmon.

Throughout colonial times in New England, salmon remained abundant. During the 19th century, however, industrial development of the region brought about the damming and pollution of many of the rivers and streams that served as spawning grounds. This, coupled with overfishing, probably led to the depleted state of salmon stocks in New England today.

Now there are only small remnants of the stocks of Atlantic salmon which once spawned in streams around the entire rim of the North Atlantic Ocean — from the Arctic southward to the Connecticut shore and to the Iberian Peninsula on the other side.

Of these remnants, most are found in the sparsely populated, northern parts of the region. As these remaining stocks are highly prized, the development of commercial fisheries for Atlantic salmon on the high seas off southwest Greenland and in the Norwegian Sea has become a matter of great concern in international fisheries management.

There are two possible approaches to the problem on increasing the salmon stocks of the North Atlantic: (1) the development of systems for improving fresh water habitats and for increasing the survival and geographic range of native stocks of Atlantic salmon and (2) transplanting stocks of Pacific salmon to the Atlantic region.

In 1954, W.E. Ricker, a Canadian fisheries scientist, discussed the relative merits of the two approaches. He argued with respect to the first that such measures as controlling predation by birds, opening up new nursery grounds with fishways, continuous artificial propagation, better spawning escapements, etc., were worthwhile 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."

On the other hand, he suggested that transplants of pink and chum salmon from the West Coast, species that go to sea shortly after hatching and consequently are less dependent on extensive resources of high-quality fresh water, would be the best way to generate an inshore fishery sustained by natural spawning.

Addressing himself to Canadians, he said that it would be in the national interest to develop an inshore anadromous fishery in which Canada would have a proprietary interest to insure it against the day when its ". . . eastern offshore banks will be so continuously scoured by the trawls of competing nations that good quality bottomfish can no longer be taken in paying quantities."

FIG. 1. WHAT MIGHT BE is seen in this photo of a coho salmon caug[ht] in the North River of Massachusetts in 1973 on sportfishing gear. In t[he] article below, the authors point the way for restoring both sport a[nd] commercial salmon fishing in New England.

—Photo courtesy of Mass. D[...]

Formidable Task

In New England, the task of restoring the rivers and streams so that they will again be suitable for the spawning of large numbers of native Atlantic salmon promises to be formidable. For the short-term improvement of the salmon fisheries, therefore, the substitution of hatcheries for the lost spawning grounds would seem to hold the most promise, and indeed a number have already been built by federal, state and provincial agencies in New England and the Canadian Maritimes.

Production, however, has not come up to expectations, the fly in the ointment being that the Atlantic salmon are proving to be more difficult to rear in hatcheries than the trout and Pacific salmon with which hatcherymen have had the most experience.

Why then, shouldn't stocks of Pacific salmon — with proven adaptability for hatchery culture — be reared in New England?

Recently the state fishery agencies there have addressed themselves to this question and have experimented with stocks of Pacific salmon. The results have been spectacularly different. We will attempt to explain these differences by showing how geographical factors have affected these experiments and then we will propose measures for reinforcing their successes and avoiding further failures.

Prior to the publication of Ricker's paper in 1954, there had been several attempts to introduce Pacific salmon to t[he] Atlantic coast of North Americ[a]. Pink and coho salmon had be[en] planted in Maine and chino[ok] salmon in Lake Ontario strea[ms] and in New Brunswick. Perm[a]nent runs from these plants [did] not become established, althou[gh] in Maine, small returns did occ[ur] for several cycles.

At that time, the only s[...] pink and [...] cessful, self-perpetuation runs [...] made from fi[...] Pacific salmon which since 1[...] Sakhalin had become established in [...] western Paci[...] Waitaki and other rivers of [...] in the Murr[...] South Island in New Zeala[nd] [...] arctic coast [...] Subsequently, in the 1960s, W[...] In 1960, 300[...] Coast stocks of coho we[re] [...] returned to [...] established in the Great Lak[es] [...] rea. Smaller [...] followed by the development o[f] [...] along the co[...] vigorous sport fishery. [...] south as Ber[...]

From 1956 to 1961, ma[...] coasts of Icela[...] transplants (4-46 million) of [...]

FIG. 6. NATURAL GROWING AREA for young salmon is Plum Island Sound in northern Massachusetts. Much of the huge marsh area is already a wildlife preserve.

FIG. 7. NEW STATE FISH HATCHERY at Quinebaug in Connecticut draws its water from underg[round] sources, the ideal setup for raising salmon, say the authors. Other southern New England states have e[...] good supplies of ground water.

Table 1.—Tolerable and preferred sea-surface temperatures for Pacific salmon.

Species	Tolerable range °C	Preferred range °C	Reference months for preferred range
Sockeye	1-15	2, 3-9	May, Sept.
Chum	1-15	2, 3-11	May, Sept.
Pink	3-15	4-11	May, June
Coho	5-15	7-12	May, June, July
Chinook	2-13	7-10	July, August, Sept.
Cherry	5-15	7-12	March, April, May

Table 2.—Predicted growth for coho salmon in fresh water at Quinebaug Hatchery and in saltwater pens in Plum Island Sound (see text).

Date	Average water temperatures °C	°F	Event	Body weight Grams	Ounces
Nov. 1	11.1	52	Eggs taken	—	—
Jan. 30	11.1	52	Eggs hatched	—	—
Mar. 11	11.1	52	Sacs absorbed	—	—
Mar. 31	11.1	52		0.9	.032
Apr. 30	11.1	52		2.0	.071
May 31	11.1	52		4.2	.148
June 30	11.1	52		8.6	.304
July 31	11.1	52		18.2	.642
Aug. 4	11.1	52	Fish to salt-water pens	20.0	.706
Aug. 15	14.5	58		26.3	.928
Aug. 31	14.5	58		39.0	1.38
Sept. 15	17.0	63		60.3	2.13
Sept. 30	17.0	63		93.0	3.28
Oct. 1	13.5	56	Fish released	131.4	4.64
Oct. 31	13.5	56	Fish released	189.7	6.70

roe of pink and chum salmon were made from fish culture stations on Sakhalin Island in the northwestern Pacific Ocean to stations in the Murmansk area on the Arctic coast of European Russia. In 1960, 300,000 adult pink salmon returned to the rivers of the 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. Russian fishery scientists think that the roe from returning adults died during incubation, river temperatures in the winter and spring being colder in the European Arctic than on Sakhalin Island, home of the parent stock.

During the past six 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 trout 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 which flow into Great Bay, and is seeing the beginning of a small salt water sport fishery in that bay.

In New Hampshire in the fall of 1972, over 1,000 adult coho from the Columbia River stock planted in 1970 returned and 200,000 eggs were taken. These were incubated in state hatcheries along with 350,000 coho eggs from the Green River Hatchery in Washington. As development of self-sustaining, naturally spawning runs of coho salmon into Great Bay is not considered feasible, the New Hampshire fishery managers are focusing on hatchery production. A new state hatchery, primarily for the production of coho salmon is being constructed at Milford, N.H., with funding assistance from the National Marine Fisheries Service.

New Hampshire coho salmon have been appearing in the estuary of the Merrimack River in Massachusetts, where a number have been caught by sport fishermen. 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.

Of 60,000 Green River (Washington) coho planted in the spring of 1971, personnel of the Division of Marine Fisheries of the Mass. Dept. of Natural Resources recovered 178 spawners returning to the North River in the fall of 1972. The weight ranged from 3 to 12 (average 7) lbs. Of the 130,000 eggs taken from these returning spawners, 90% hatched successfully and the fry are being reared for future planting.

During the summer before the spawning run, there were incidental catches of coho in the ocean off the North River by both sport and commercial fishermen (Fig. 1).

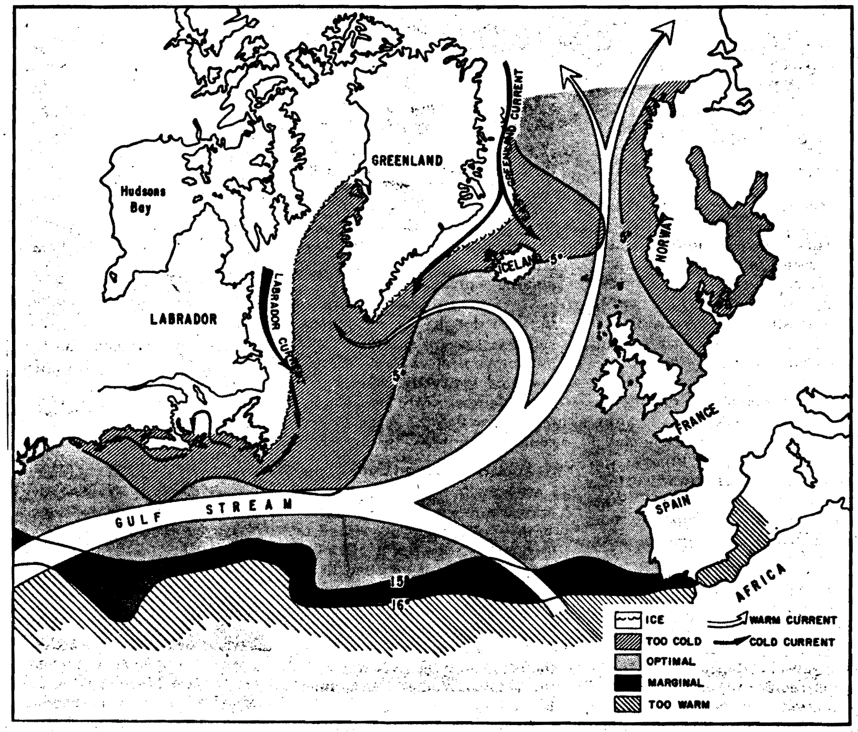

FIG. 2. Summer sea-surface temperatures, North Atlantic Ocean.

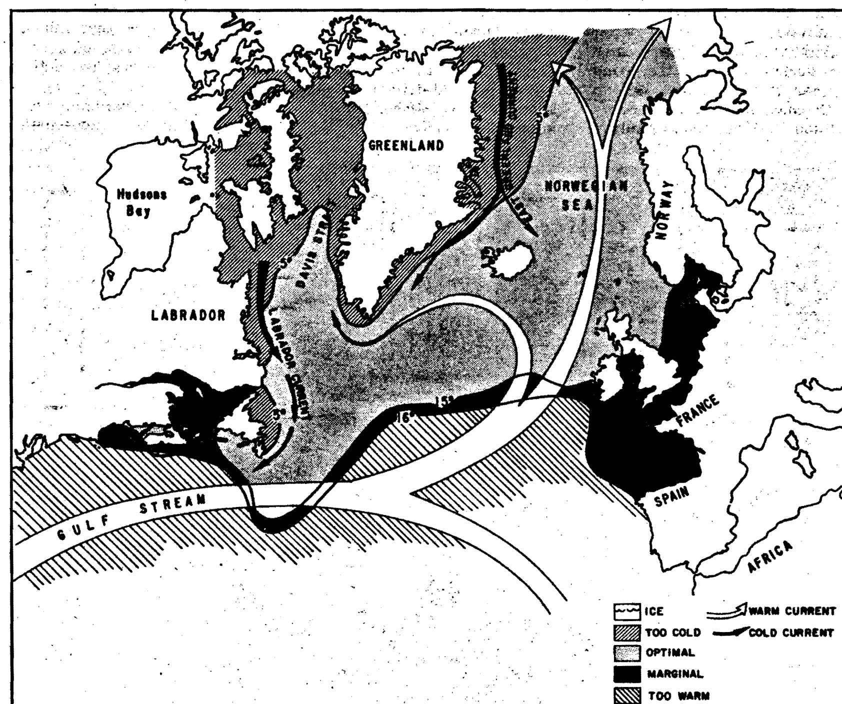

Fig. 3. Winter sea-surface temperatures, North Atlantic Ocean.

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 against the stark failures experienced in Connecticut and Rhode Island. We will now try to show that these results reflect how seasonal changes in the ocean environment off New England matched the timing of the homing migration of these fish.

To most human travellers on the high seas, ocean water appears pretty much the same from place to place. It is salty, which distinguishes it from drinking water. In the tropics, it is usually warm and appears deep indigo in color. As one approaches the poles, it is usually cold and appears gray-green if it has not solidified to ice. Outside of these features there is little to distinguish one part from another.

To an oceanographer, these features are the tools of his trade. He measures salinity, temperature and the way sea water absorbs and reflects light. He may go further and measure the gases and solids dissolved or suspended in it and identify the living creatures that can be screened out of it.

His outlook is objective, as his thick skin, warm blood and the ship's galley allow him to be independent of the ocean he is sailing on which in no way is immediately significant to his vital processes.

A salmon, thin-skinned, cold-blooded and hungry, experiences the ocean subjectively, its vital processes being directly affected by changes in the properties of the water it is swimming in.

Salmon, like most other cold-blooded marine animals, are restricted to narrow ranges of

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temperature and dissolved oxygen. In the upper layers of the ocean, dissolved oxygen seldom reaches levels low enough to be avoided by salmon. Temperature, however, can vary markedly over short distances and therefore can be significant in determining where salmon go at sea.

Table 1 gives the tolerable and preferred ranges of ocean temperature for various species. Within the range for each species, there is a spectrum of narrower temperature bands to which different races 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. Figures 2-3 show the distribution of surface temperatures in the North Atlantic favorable for temperate-zone races of salmon.

Salinity

As far as the vital processes of a salmon are concerned, the salt content of its environment is crucially important only during the juvenile stages of its life. Its eggs require fresh water for incubation, and the young salmon can tolerate salt water only after the kidney has developed enough to hold a proper balance of salts between the blood and body fluids inside and the salt water outside of the fish.

With pink and chum salmon this occurs early and the young fry can go directly into the sea. With coho, Atlantic and cherry salmon, the kidney is not ready to assume this function until the fry have grown to be large fingerlings. This usually takes more than a year.

In any case, by the time a salmon has gone to sea, salinity does not seriously affect its vital processes. Although changes in salinity between ocean water masses do not jeopardize a salmon's life, they do affect where salmon go — serving as signposts for their migration from the ocean back to their home streams.

As a primary factor determining the density of sea water, salinity also affects the structure and movement of ocean waters and thus, indirectly, the distribution of temperatures and the location, direction and speed of currents.

Food and Ocean Currents

Within the boundaries defined by the temperature and oxygen saturation of sea water fitted to their vital processes, availability of food and the location and direction of ocean currents determine where salmon are likely to be found at sea. From the point of view of a salmon, once he has found a suitable environment in the ocean, his next concern must be food.

The location of forage for salmon (plankton and small fish) is largely related to ocean circulation. Its abundance is determined by the sunlight and chemical nutrients available for the growth of single-celled plants at the bottom of the food chain.

Where wind-driven surface currents move offshore, upwelling replaces surface waters with nutrient-laden water from the depths. Forage growing in this enriched medium moves with the surface currents and tends to concentrate along the edges of the marginal vortices that split off from the currents, causing a "patchiness" to its distributions in the ocean.

Fish such as salmon, which feed on plankton and smaller fish, will seek areas where forage is concentrated, much as hunters on the land will seek water holes and grazing meadows where their prey are likely to gather. Thus, as game trials are used by hunters on the land, salmon follow ocean currents to find their food. It is likely that they also use them to find their way back to the rivers and streams where they spawn.

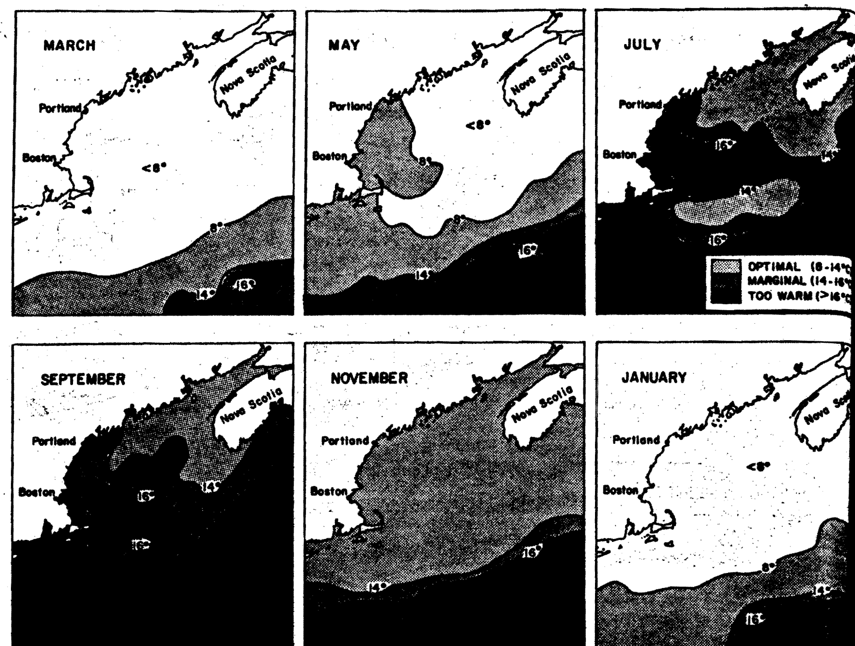

Fig. 4. Sea-surface temperatures, Gulf of Maine.

From Pacific

For mass transplanting Pacific salmon stocks, Ricker suggested that:

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 ne[w] situation . . ."
2. "Donor stocks should b[e] carefully selected in order t[o] match up the fresh water a[nd] marine conditions of existenc[e] of the old and new sites a[s] closely as possible."

He was concerned primari[ly] with the establishment of se[lf-] sustaining runs of naturall[y] spawning Pacific salmon, a[nd] were the 1956-61 USSR exper[i]ments in the European Arctic. T[o] do this, the matching of enviro[n]mental requirements of don[or] stocks with appropriate con[di]tions in the receiving waters [is] critical.

However, the urgency for pr[e]cise matching can be somewh[at] relaxed if the fresh water e[n]vironment can be controll[ed] artifically. This can be done m[ost]

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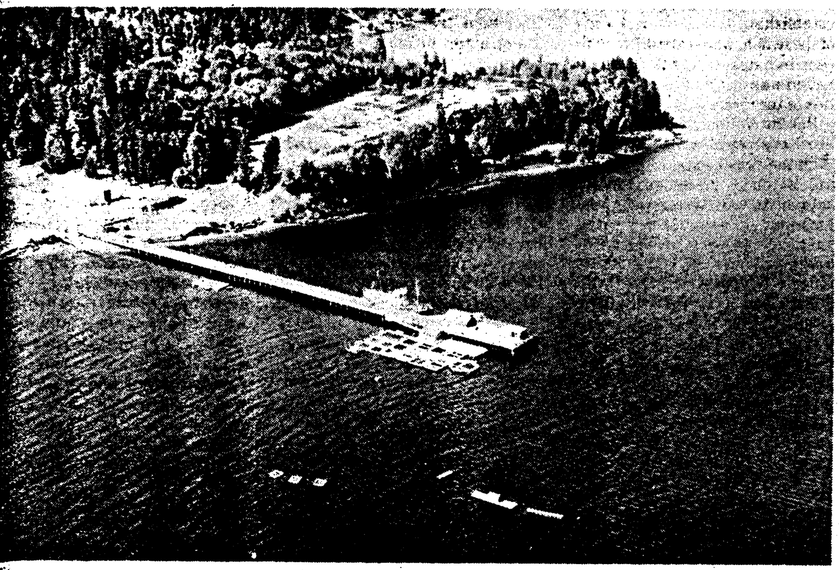

Fig. 5. National Marine Fisheries Service Experiment Station, Manchester, Wash.

idily in hatcheries.

The success in New Hampshire establishing coho salmon runs o Great Bay partly stems from willingness of that state's fish- y managers to undertake tchery rearing to compensate lack of suitable spawning unds and to accommodate to fresh water requirements of imported Washington stocks. e conditions for ocean sur- al, however, still had to be et.

n this, New Hampshire was ore fortunate than Rhode and and Connecticut. These ter states failed in attempts to tablish runs of coho salmon m Oregon and Washington into ck Island and Long Island nds although they used much same hatchery techniques for ubation and rearing as were d in New Hampshire. The asonal sea-surface tem- atures of the Gulf of Maine g. 4) suggest an explanation these contrasting results.

n the summer and early fall, a nperature front extends tward from Cape Cod to the lf Stream. Temperatures in ess of 16°C (61°F) occur south the front creating a thermal rier which would block the re- n of fall-spawning coho mon to rivers and streams th and west of the Cape.

North of Cape

orth of Cape Cod, however, e would be little to prevent n from moving, in late sum- and early fall, into estuaries prelude to this spawning mi- tion into the rivers. The mal barrier moves to the h and offshore in the late fall winter and does not start to d up again off Cape Cod until y summer.

the late winter an isothermal d favorable for temperate- races of salmon (8-14°C or F) moves from the open sea h of Long Island and pro- sses gradually northward advancing seasons until it mes compressed along the e coast and into the Bay of dy by late summer. By fall, it ns to spread and move again hward, eventually returning wintertime position south of Island.

is suggests that Pacific on, 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 fish- ermen. We believe they would move with the southward spread of 8-14°C water and, if chosen from stocks selected for the tim- ing of their migrations back to fresh water, would appear home streams when the 8-14°C band was in a favorable position off- shore.

It seems likely to us that while fall-running coho were a poor choice for establishing runs of Pacific salmon in Rhode Island and Connecticut, spring-running cherry salmon, chinook salmon or steelhead trout would be able to migrate from the ocean into streams flowing into Block Island and Long Island sounds.

Accelerated Rearing

We have been emphasizing the importance of providing fresh water rearing conditions suited to the requirements of donor stocks and have pointed to the dif- ficulties experienced by the US- SR with transplanting pink salmon adapted to the relatively mild winters of Sakhalin to the European Arctic where the win- ters are much colder.

Similar problems could be ex- pected in attempting to generate self-reproducing runs of Pacific salmon in New England. Rearing the transplanted stocks in hatcheries where water tem- peratures could be controlled would seem to be a better alternative.

In hatcheries in cold climates, where the water supply is from the surface, the growth of salmon is slow, and it often takes a year or more for the young fish to be ready to go to sea. In hatcheries where the temperature of the water can be kept close to the op- timum for incubation of eggs and growth of the fry, development can be accelerated so that the fish can go to sea before the end of their first year.

Control over temperature would give hatcherymen flexibili- ty for adjusting the rate of growth so that transplanted stocks would be ready to move into salt water at the earliest appearance of the seasonal "window" when ocean temperatures were appropriate to receive them.

Delaying the release of hatchery-reared salmon is being tested in the State of Washington as a means of improving returns. These experiments have pro- duced unexpected results.

In the past, the young salmon have been released at times that coincide with their normal seaward migration from their home streams. Recent studies by the Wash. Dept. of Fisheries have shown that delaying their release from the hatchery alters the normal migratory behavior. Con- tinuous and extraordinarily high catches in the Puget Sound sport and commercial fisheries of "de- layed-release" salmon show that these fish tend to remain near the site of release instead of migrat- ing out to sea.

The same sort of behavior re- sults when salmon are held in salt water pens beyond the time of their normal out-migration before being released. Not only

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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.

At the National Marine Fisheries Service's Experiment Station at Manchester (Fig. 5), salmon have returned to Clam Bay on central Puget Sound where they had been held in salt water enclosures before they were released. The mature fish ran into Beaven Creek, a stream that flows into Clam Bay, rather than to their hatchery stream at Minter Creek on southern Puget Sound.

Plan For New England

The streams of New England once teemed with Atlantic salmon. In the rush to develop the wilderness, little heed was paid to fish so commonplace that they were often used as fertilizer. Fishing was unregulated, streams were dammed and rivers were polluted by the wastes of industrial cities. As its fresh water environment deteriorated, the Atlantic salmon disappeared from most of its natural range.

Today, there is a growing movement to restore the quality of the rivers and streams of New England, but it will take time. Over the past several decades, the efforts to re-establish natural runs of Atlantic salmon have not yielded much success. Re-establishing large, natural runs of these fish, which are difficult to rear in hatcheries, will probably have to await the full rehabilitation of the rivers.

Pacific salmon, however, are much easier to rear in hatcheries. With the new techniques for rearing hatchery-produced Pacific salmon in salt water pens, the amount of fresh water rearing space for growing juveniles can be significantly reduced. A modest hatchery program combined with salt water rearing should be able to produce enough Pacific salmon to generate a vigorous fishery along the New England coast.

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.

With the hot summers and cold winters of New England, fresh water rearing can be done best in hatcheries in which the temperature of the water can be kept near optimum. The ground water in much of southern New England remains close to 11°C (52°F) the year round. In such water, coho salmon could be reared from eggs in the fall to smolts ready to migrate by early summer when ocean temperatures off New England would be appropriate for them.

The smolts could then be trucked to salt water homing stations north of Cape Cod where they could be held in salt water pens for imprinting and additional growth before releasing them. In this way, the salt water stations would provide capacity for extended rearing without taking up additional hatchery space, improve the chances for increased survival at sea and condition the fish to return to streams near the release sites when mature.

There are many bays and sounds between Cape Cod and the Bay of Fundy that would be suitable for salt water rearing. One of these is Plum Island Sound in Massachusetts. (Fig. 6).

The projected growth for a system in which coho would be reared in fresh water at a temperature of 11°C and then transferred in early summer to a rearing station in Plum Island Sound is shown in Table 2. Release of the fish from the salt water station in October would take advantage of summer temperatures in the sound which would favor the production of large, vigorous fish well prepared for survival at sea. When mature, they would return to the Ipswich and Parker rivers, small streams feeding into Plum Island Sound, where they could be readily trapped and the spawn taken to an appropriate hatchery. This kind of system could generate fisheries for Pacific salmon along the New England coast without the need for many large hatcheries or extensive natural river spawning.

Ground water resources capable of producing large volumes of fresh water at temperatures suitable for accelerated rearing of salmon are available in New England. The new state hatchery at Quinebaug in Connecticut (Fig. 7) is an outstanding example of a fish-rearing facility built around a superb source of ground water. The site of the new hatchery being built at Milford, N.H., was also chosen on the basis of good ground water. Western Rhode Island has ground water resources that have scarcely been tapped that would be well-suited for the development of salmon hatcheries.

The geography of New England suggests that a regional system might best serve the development of salmon fisheries. Such a system would include fresh water facilities centralized in a few well-designed, large-volume hatcheries, primarily in southern New England where ground water temperatures are optimum for rapid fresh water growth. Smolts of fall-running coho, reared at these hatcheries, could then be transferred to homing stations along the coast from Cape Cod to Maine to be released after a period of holding in salt water pens to condition them to return to nearby streams.

Spring-running cherry salmon from Japan, which are tolerant of high temperatures in the rivers to which they return and which are easy to rear in hatcheries, would probably be the best choice for providing a salmon fishery for southern New England in the spring, when the water temperatures in Vineyard, Block Island and Long Island sounds are favorable for their homing migration.

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By Bruce

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