mutations is needed if the theoretical considerations offered here are to be confirmed, and this will require extension of present chromosome studies to the subchromosomal and perhaps to the molecular level. If such a measure were developed, it might be of considerable value in predicting for humans the carcinogenic potential of the low doses of radiation, small fractions, and varying dose rates to which many are exposed. Even then, however, the postmutational events discussed here in connection with experimental studies could well determine whether a tumor developed in a particular individual, and the possible effects of various environmental factors on these events would have to be evaluated.

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Fishing Treaties and Salmon of the North Pacific

Present treaties, economic in intent, cannot be made effective for conservation without more knowledge.

W. F. Thompson

The great expansion of world fisheries in recent years, particularly by Japan and Russia, has brought the ships of these nations to the fishing banks off our coast. They are exploiting whatever they can catch, of course, but we are particularly interested just now in their effect on our salmon. It seems a foregone conclusion that, unless restrained, they will affect all five species throughout their range as far south as California.

These salmon, then, must be conserved by treaty. There are already three treaties to restrain North Pacific high-seas fisheries. The oldest and most successful is the treaty between the United States and Canada for regulation of the halibut fishery. There is, at present, a treaty between Russia and Japan limiting their catch of salmon in the western Bering Sea, and one among the United States, Canada, and Japan regarding salmon fishery in the eastern Bering Sea and our coasts to the southward (see Fig. 1).

This last-mentioned treaty is not working to the satisfaction of the three signatories. If it is to be rewritten or if new treaties follow, we must know what we are doing. With what will these new treaties deal and how will they conserve the endangered species? Will the treaties be for conservation, or will they merely adjust economic interests? The history of the existing treaties throws light on these questions.

But first it must be understood what conservation means from the scientific standpoint. Perhaps the failure to understand the scientific facts leaves the battle to the short-sighted economics of competition for the catch.

The discussion can start with a point that may catch attention because it ties together space research, now in the limelight, and the basic biology of fish.

One of the first and greatest of the space-fiction writers was H. G. Wells, also a historian and biologist, who

The author, who died 7 November 1965, had been professor emeritus of fisheries at the University of Washington, Seattle, since 1958 and professor since 1930. From 1924 to 1937 he was director of the International Fisheries Commission, and from 1937 to 1943 he was head of the United States-Canada International Pacific Salmon Fisheries Commission. He founded the University of Washington Fisheries Research Institute and was its director from 1947 to 1958. He was also one of the incorporators and the first president of the American Institute of Fishery Research Biologists. This article was originally a talk given before the Seattle Power Squadron, 21 October 1965. Requests for reprints should be addressed to College of Fisheries, University of Washington, Seattle 98105, for the attention of Dean Richard Van Cleve.

wrote *The War of the Worlds*. He described an invasion of the earth by Martians who were irresistible from a military standpoint and caused great havoc. But shortly they fell victims to bacteria which they had never met on Mars. Whereas we had become immune to the bacteria by many eons of heavy selective mortalities, the Martians had not. They could not resist even the bacteria of decay, and so their attack on earth failed. Wells did not go on, as he might have, to point out that many other kinds of organisms adverse to Martians, such as insects and food plants which they were not bred to use, also exist to make their stay here unfeasible. Nor did he point out that man, when he explores space, may meet worlds full of organisms, and physical features to which he has not been fitted by natural selection, operating through death of the many unfit through eons of time. Intruders, even our own "spacemen," can live in a different organic world only if they isolate themselves completely.

But Wells was using in his fiction a basic principle of the evolutionary theory laid down by Darwin in the 1870's, one which time has tested and found correct, but which we continue to ignore in many ways. Darwin said that adaptation of species, by natural selection, to numerous extremely complex environments enables them to become abundant. Wells, in his space fiction, was putting this in spectacular terms, contrasting the failure of the nonadapted with the success of the adapted in this world of ours.

This principle applies to the salmon along our coasts. Each stream or lake has its own extremely complex characteristics, and if salmon live in one of them we find that these salmon are adapted in an equally complex way to that environment. We are far from understanding these two complexes, the fish and the environment, but we do know that in order to return to the place for which it has been fitted the salmon returns from the sea to its home stream, there to meet and breed with its own kind. Thus it develops and perpetuates the genetic characters which fit it for survival in that stream. So we have a multitude of groups of salmon, each self-perpetuating, which we loosely term races, and which the scientist calls gene pools, each fitted to survive in a particular home. If it leaves this home the race either dies off or readapts.

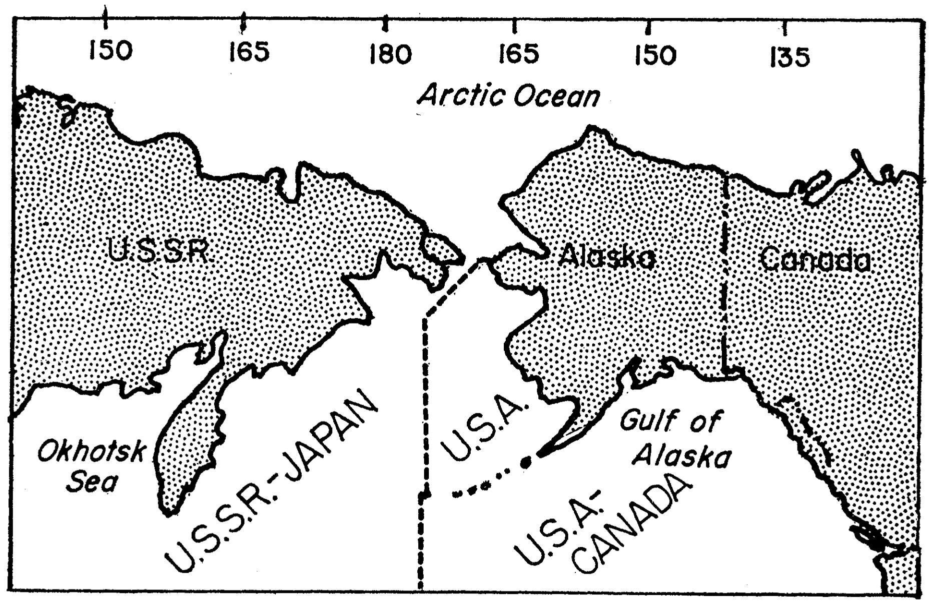

Fig. 1. Division of the Pacific Ocean north of 45°N latitude according to the convention among the United States, Canada, and Japan, for salmon fishing by their respective nations. The area west of 175°W longitude is controlled by Japan and the Soviet Union under a separate treaty.

Darwin may have had in mind species as units. But as our knowledge of the variation within species has grown it has become obvious that his concept applies equally well to subdivisions of species, and to the process of speciation.

But we do not know much about these independent, subspecific groups of salmon, segregated during spawning, and so we do not know just how to conserve the numerous kinds that exist. In our fisheries, we have been accustomed to dealing with mixtures of many of these units, although each of these units has its own particular requirements. Each environment may demand a different type of adaptation and regulation. When we think of the individual race or colony, or gene pool, we find that we do not know just what it requires nor how it varies. We can only moderate our ruthless fishery, blindly and in partial fashion; we cannot avoid its effects completely. We should face this lack of knowledge frankly if we hope to do anything to remedy it.

Crisis Years for Fish

We think of what is required in terms of the average years. Yet it is not the usual years that determine life or death for the multitude of these little independent gene pools, but the years of crises, of high mortalities. For example, we can see such crises when we bring rhododendrons into Seattle gardens. They may do well for a number of years, but sooner or later there comes an unseasonal frost and most of them die. In native species of plants nature has guarded against such unusual mortalities by the development of cold-resisting characters, useful perhaps only in such crisis years. But it has also guarded against severe mortalities of all kinds in many ways, such as the production of a great many seeds by a great many breeding adult plants. Such safeguards against the unusual are as necessary to the continued existence of salmon as they are to that of plants. But in salmon we cut down these numbers, these safeguards, without regard to the need for them. We collect salmon eggs for our hatcheries at such times as suit our convenience because we judge, by comparison with the average year, for which we assume values of which we are not sure, that there is a surplus. We do not have any measure of how many fish we should allow our fishermen to take even in this average year, certainly not in a crisis year. Nor do we know what years are crisis years because we do not know what conditions vary to make them crises.

There are some general principles which may help our consideration of the problem. It is a simple and generally accepted fact that the average of a series of variables varies less than the individual variable. So the individual salmon gene pool can be expected to vary more than the mixtures which are fished. In the process of segregation the variability of the successively less complex mixtures should increase until it reaches a maximum in the individual segregated population. The individual crises should not only become more obvious, but the less extreme crises should come to view. And since each crisis year has its generation of young, it becomes necessary to consider the chances that successive crises will affect the successive generations of young of any one genetic line. In the salmon it is possible that the individual small segregated gene pool is in frequent crisis and that the weaker gene pools tend to disappear at times, a tendency that is presumably counteracted by the known tendency of a small percentage of homing salmon to stray away from the home stream.

So far we cannot give a very satisfactory account of such matters. Our great salmon rivers like the Karluk, the Fraser, and the Columbia show depletion because many of their individual breeding units are overfished or injured by obstructions. We do not seem to be able to accept and use the knowledge that science could place at our command to control this depletion. Our fishermen do not wish to change their ways, nor our governments to change their programs. Nor do the ecologists and geneticists focus their attention on fishery problems of this kind.

Yet our salmon do have resilience and can persist for years at low levels, as we have seen in the case of "sockeye" salmon at Hell's Gate in the Fraser River and the Atlantic salmon in England. But there are some things we have to do if we are to continue to have an abundance of salmon. And, if we are to have competitors, we must have international treaties that will allow us to do these things. We can study age by means of scales, and migrations by tagging, but above all we must answer: what happens to the individual, independent, segregated gene pool or "race" when it is overfished? How can we study it?

We build hatcheries, but we violate Darwin's principle by getting eggs from fish adapted to one river and planting them in another to which they are not adapted. By protecting the eggs in these hatcheries, we avoid the heavy mortalities which nature uses and must have to shape and adapt the races. We thus destroy the ability of the fish to meet changes in conditions, and perhaps we may allow them to drift away from the form they should have. We do not do as the New Zealanders did for Chinook salmon from the Sacramento: they bred from successive returning generations to modify the genetics of the race. Instead, as evidence of success we are content to count only the first generation returns from our hatchery plants, forgetting that they are not yet adapted and must still, as young, survive the strange conditions in the streams. We insure failure to adapt by "planting" a new and strange batch each year, injuring the stock from which it comes, only to confuse and destroy those fish that happen to have survived from the stock of the year before.

We regulate our fisheries. But we concentrate them on the best races and one by one these shrink or vanish and we do not even follow their fate because we have not learned to recognize their independent component groups or to separate them one from the other. We continue our unequal demands, knowing only that our total catches diminish, as one by one small populations disappear unnoticed from the greater mixtures which we fish.

We also regulate our fisheries to allow some arbitrary percentage to escape to spawn, forgetting that a far higher percentage may be needed in the crisis years in the small population units, crisis years that we fail to see. We need a new and more demanding theory of conservation, a flexible one fitting the needs of small populations as they vary from year to year and from each other. So we greatly underestimate what is needed or when it is needed and feel self-righteous about our conservation.

The Need for More Knowledge

We must have many biological facts and statistics of the catch, perhaps of a kind we do not yet have—not only of our own catch, but also of the foreign entrants into the fishery. We must have the cooperation of these foreign fleets if they take part of the catch. Thus, if we are to keep our salmon, we must design laws and treaties for the proper kind of research.

To show what this means for the immediate future I would like to tell something of the history of the halibut treaty, with which I was concerned from its beginning. Conservation came only after agreement on things of immediate concern economically, for the public and the industry do not see these things that I have told you, things going back to the basis of evolutionary science.

My experience with halibut began 50 years ago. Halibut resources were badly depleted on the nearby southern banks off British Columbia, and winter fishing there had practically ceased. The fishery had spread to more distant western banks, and heavy winter yields came from these, flooding the market to the detriment of prices paid to southern fishermen. But winter weather was too severe, as I knew from personal experience in 1916. Shortly, however, boats fishing in winter acquired internal combustion engines, then new, and were able to tap banks in summer around Kodiak Island and even farther west. So the western boats also came to favor winter closure, particularly as the cold storage plants needed a closure to dispose of their stocks. At first too many regulations were included and, finally, all were eliminated except one all wanted, the winter closure, despite the fact that this was recognized as not being effective for conservation.

A provision for scientific research was attached to the treaty of 1924 as a concession to public opinion. But, given a chance, research developed until it took the lead, devising effective regulatory limits. To enforce these limits the treaty was rewritten, and the abundance has increased greatly. The fleet fishes less for more fish, as a result of better methods of managing what fish come to us as young. That is success, but it should not be the final answer. We still do not know exactly how far regulation should go to restore the *number* of young. There is still much research to be done, even after 40 successful treaty years.

It is apparent from this experience that the machinery of a treaty must first make a bargain economically acceptable to all concerned; and then long-term conservation stands a chance. For the great majority of the interested men, Japanese or American, concern for tomorrow yields place to financial concern for today, and it is they who accept or reject the treaty, not the scientist.

The story was similar in the case of the treaty dealing with the Fraser River sockeye salmon. Equal sharing of the catch being satisfactory, the cause of the decline was then found to be an obstruction in the river. This gave a satisfactory cause for joint action in building fish-ways. Once the organization existed, then conservation could follow.

In the North Pacific treaty among the United States, Canada, and Japan this is doubtless also true. There must first be a settlement of economically important factors. It is certain that, as it is now, the Japanese fleet takes a goodly fraction of the run of Bristol Bay red salmon. The present treaty has shown this, for its research has been centered on that point, by tagging, by analysis of physical features differing in salmon from the two continents, and so forth. The fraction of the catch taken by the Japanese is, or can become at any time, sufficiently large to nullify our regulation of what remains. With or without the treaty their catch creates a situation we must face.

We do not yet know whether the Japanese are able to claim a share of Bristol Bay salmon on an economic basis alone. Our fishery is inherently far more efficient than theirs because the fish are concentrated in the Bay where we fish, whereas those available to the Japanese are scattered over the ocean. But our fishery is highly regulated, operating only one or two days a week. If unrestrained, it could take practically all the fish in the schools concentrated in the estuaries. The Japanese can compete at world prices by means of their expensive high-seas fishery only because we make our fishery more expensive, and because we ensure that fish escape to breed to maintain the Japanese catch of Bristol Bay salmon. Thus the Japanese fishery exists by virtue of the restraints on our fishermen, in both an economic and biological sense. No treaty can be acceptable to us which thus places the burden of conservation on us and leaves the Japanese fishery unencumbered. But how can an economic balance be reached which will place the Japanese fishery in proper perspective? If the catch is divided, how much should they have? How can we convince them that conservation as we practice it is economically practical? Is our case for conservation that good?

As far as I can see there is no hope of inducing the Japanese to accept an effective conservation treaty except by freeing our fishermen as far as necessary to test their economic vitality in comparison to that of the Japanese fleet. Why yield anything to the Japanese fleet if it cannot compete with ours? They are coming to the bargaining table with more advantages than they should have. In the end, we must accept their competition, but I hope only after wearing it down to size, not by restricting ourselves. This illustrates the economic problems which must be solved before it can be determined how much of conservation and of research each party to this treaty must bear.

I have already mentioned the scientific problems which must be solved. They are formidable.

The Present Treaty

At present the North Pacific Fisheries Treaty research is devoted to determining the "line" separating American and Japanese fleets. It is not devoted to conservation, nor has it faced the problems on which conservation depends, except in an incidental way. Nor will it do so until economic competition and rivalry for the supply are out of the way.

All these treaties, it appears, are in reality, though perhaps not consciously, attempts to provide a system of ownership of the North Pacific salmon and halibut by Japan and Russia to the west, by the United States in the eastern Bering Sea, and by the United States, and Canada along the coast of North America. Is this a step toward division of the oceans? To ownership of its resources? Will it succeed? I think not, immediately. It is, as yet, built on a poor foundation as far as conservation of the resources is concerned. It is on a debated basis economically. And it is and will continue to be threatened by any other nation that wishes to enter the areas covered by such local agreements.

It is unnecessary to say that the future of these treaties will not be left in the hands of the scientist. Action by the nations must first filter through the industry and the politicians. As in the cases of the halibut and the Fraser River salmon, the scientist may be given a chance later to develop his attack on fundamental problems. But, as of now, he will find that first he must serve without questioning too closely the purposes of the economic and political interests, just as he is obtaining now data to determine the "line" to separate Japanese and Americans, even though he knows that what he does for that purpose will not solve the biological problems of conservation.

Is our science as pervasive, as generally accepted and applied, as we think it is? It is certainly not so in fisheries. We spend our time debating whether to have 3-mile or 12-mile territorial limits while our fisheries diminish, whether within or outside these territorial limits.

What has been written here is, in essence, an appeal for a rational approach to great problems which must be met in using the resources of the seas and which can only be solved by the use of basic biological principles, some of which date back to Darwin. It is to be hoped that those familiar with those principles—ecologists, geneticists, those studying speciation, geographical distribution, and population problems, and those in other related fields—will respond, and each lend his influence to formulation of a scientific basis for these treaties and for conservation of our fisheries in general.