1938 in the report of the Provincial Fisheries Department. The feeling on the matter is becoming more intense and comments on the situation are becoming more frequent, but so far, I do not think that anything constructive is being done. In the salmon fisheries, the industry takes as much fish as the fishery department thinks they should be allowed to take. We have what I call a gear paradox. Every time the fishing effort is increased, as a result of improvement in gear or increase in the number of fishermen, the department is forced to put into effect regulations which decrease the efficiency of the gear in a compensating way. I think the situation will become impossible in time, but I think the solution is for economists rather than biologists. It is a problem of national policy and a very difficult one. I think the biologist would be wise not to get mixed up with it.

DR. WALFORD: It always seems most comfortable for us biologists to take refuge in the argument that as fishery biologists we need not be concerned with the economic and sociological problems of man. But man is the principal predator on the fishery stocks; and what are economics and sociology, but phases of the biology of this predator? It is a very difficult position for fishery biologists to be in for they generally don't know enough about economics and sociology to be authoritative in those fields.

MR. H. S. LAPIN (California): Dr. Hart spoke of the fact that the unit of effort would be more efficient where there are fewer fishermen. Would he qualify that with the statement that the catch might be related to the distribution of the fishing harbors more than to the number of fishermen involved?

DR. HART: in the case of our major fisheries, the statement I made is correct, that the same number of fish of all species could be caught in British Columbia if there were fewer fishermen.

MR. LAPIN: I wonder whether the total output could be increased if harbors were increased in number or better distributed?

DR. HART: Dr. VanCleve tells me you are thinking of a situation that concerns the California coast. I do not believe that our output would be greatly increased by having more harbors. Our fishery for salmon is limited by the ability of the market to absorb the production.

SOME FACTORS INFLUENCING THE TRENDS OF SALMON POPULATIONS IN OREGON

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INTRODUCTION

The Pacific salmon fisheries of the Northwest have been heavily exploited since the early settling of the territory. Explorers coming into the region for the first time reported intensive fishing by the large Indian population at natural barriers. Fairly reliable records of chinook salmon (*Oncorhynchus tshawytscha*) production on the Columbia River (Figure 1) indicate that it produced its maximum yield before the end of the nineteenth century. While no good records of the catch on the smaller coastal rivers are available, comments of early settlers indicate that a similar situation prevailed on the several small rivers draining directly into the Pacific Ocean. Attention is drawn to Figure 2 which shows the geographical position of the Columbia and the major coastal rivers.

[1]Read by Mr. Hodges.

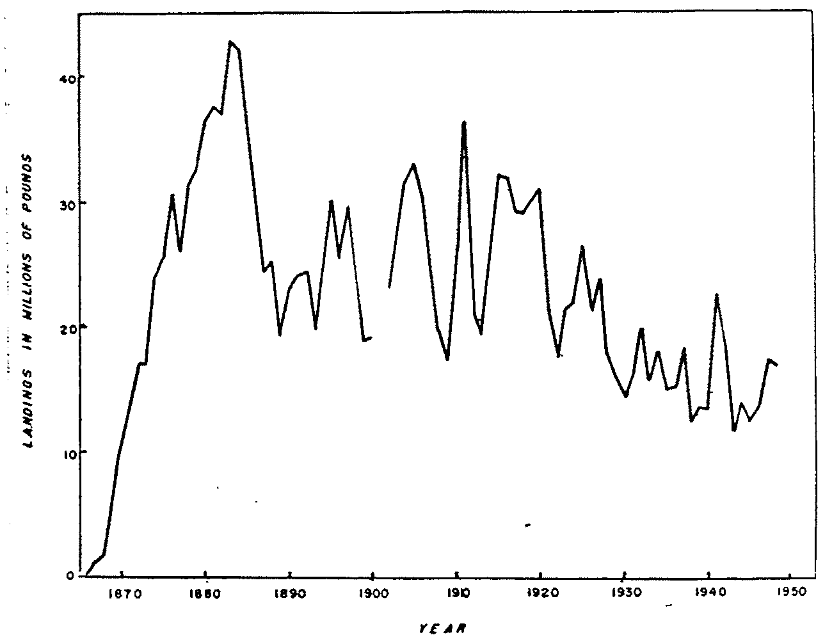

Figure 1. Annual chinook salmon landings on the Columbia River, 1866 through 1948.

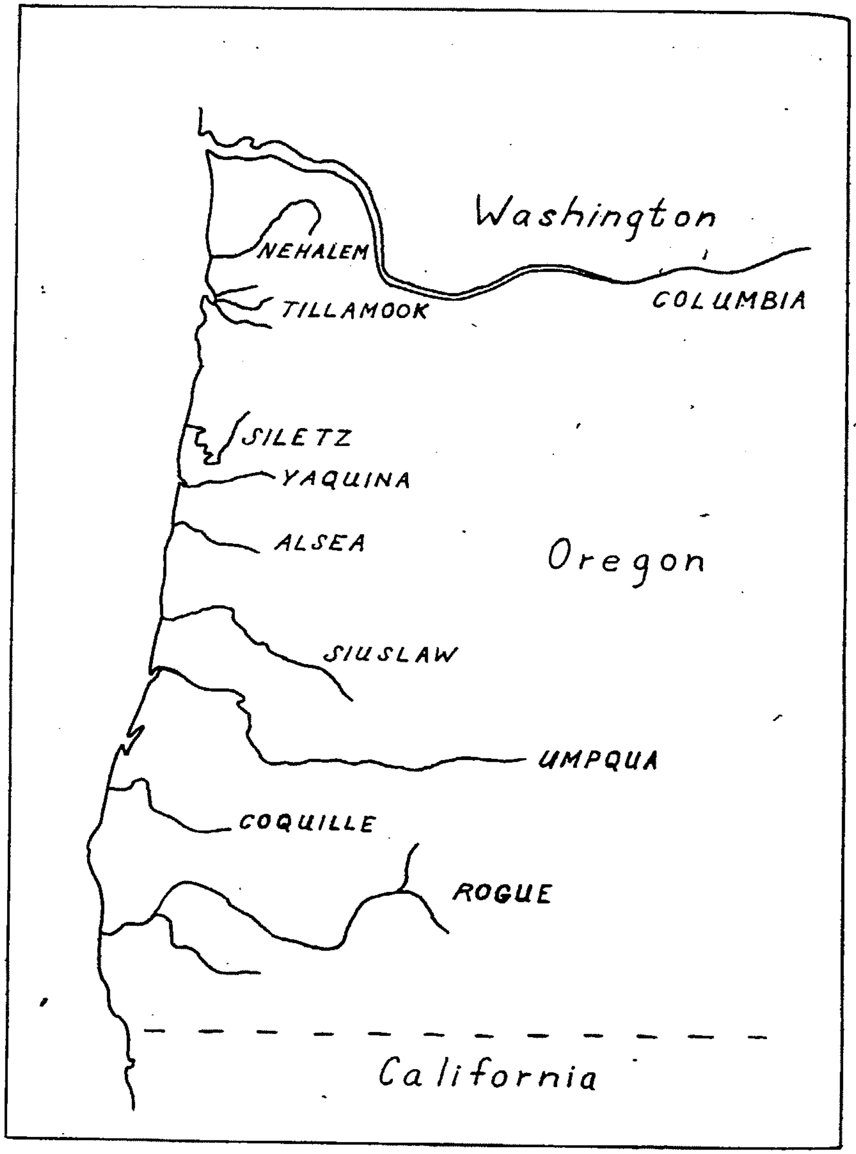

Figure 2. Map of Oregon Coast showing the various important salmon producing rivers.

Even before the turn of the century the most desirable runs appear to have declined in productivity. As indicated by the trend of Columbia River chinook landings a rapid drop in the yield was followed by a leveling off period of about 20 years (Figure 1), and thereafter a more gradual general decline took place. It is apparent that great fluctuations in yield have occurred over the past years, but of greater importance is the gradual downward trend since about 1886. Improved fishing methods have intensified the fishing effort and the demand has been ever-increasing, as will be later seen; yet the resource has yielded less and less as the years pass. This phenomenon has been observed many times in other fisheries and has been in most cases attributed to "overfishing."

E. S. Russell (1942), discussing the haddock fishery and other demersal fisheries of the North Sea, showed the decrease of the haddock fisheries of the North Sea from 1919 through 1937 and attributed this decline to the increased fishing intensity. Quoting the statistical data of other important fisheries of the North Sea (i.e., cod and plaice) in various manners, he concludes that the decline in the stocks, as evidenced by a reduced catch and size, was primarily due to the increase in fishing intensity. Where Russell decided that the effects of the reduced fishing in the North Sea during the First World War had increased the stocks and the productivity of the North Sea, Huntsman (1948) concluded that the reduction in fishing during the war years had little or no benefit, except possibly on haddock and halibut. It was his conclusion as opposed to Russell's that the high take immediately after the war was only a "temporary accompaniment" of an increase of fishing intensity with no permanent effect. Huntsman considered all commercially caught species and concluded that there was doubt whether the reduction in fishing effort during the war made it possible to increase the annual productivity of the North Sea fisheries. As a matter of fact, he concluded that from the statistics there was no indication of "overfishing."

Thompson, Dunlop, and Bell (1931), studying the Pacific halibut fisheries, concluded that the catch of the Pacific halibut had been maintained in the face of an intensive fishery only by increasing the fishing areas and thus exploiting new stocks of fish. The older fishing grounds had been overfished, and the intensity of the fishery was such that it had not been allowed to reach a permanent sustained yield level (i.e., it had continuously declined). Burkenroad (1948) explained the decline in the halibut stocks as a natural fluctuation which might have corrected itself in due time without regulatory restrictions being placed upon the fisheries. Burkenroad's argument was principally that the decline in the stocks of halibut from 1915 to 1918 was several times greater than might be expected from the take of the fishery. Again, the increase in abundance since 1930 appeared to be greater than that which could be expected from the diminution of fishing effort. Thus, without attempting to further analyze Burkenroad's arguments, a critical examination of the data from the North Pacific halibut fishery has revealed to at least one investigator that some factor other than fishing may have been the dominant cause in influencing the trends of the fishery during recent years.

The question of whether in many cases an intensive fishery has any real deleterious, depleting effect on the stocks is being projected into fishery investigations everywhere. The underlying basis of the regulation of the catch as a means of fishery management is seriously being questioned. If factors other than the fishery exert a greater influence upon the trends of the runs, then of what benefit are restrictions upon the take?

Unfortunately there has been too little effort expended toward answering this important question. The problem appears to be equally pertinent whether dealing with a relatively sedentary fish population such as halibut, a highly migratory one such as the sardine, or with highly migratory anadromous species such as salmon. The problem is somewhat complicated in salmon because of the two distinctly different aquatic environments providing the habitat during different periods of life. Since adult salmon have spent from one to three years of their lives in fresh water and another one to four years in the sea, important limiting factors operate on these species in fresh as well as salt water.

We have chosen for our study the silver salmon, *O. kisutch,* one of the major commercially exploited species on the Pacfic Coast. This species, along with chinook salmon, is caught in large numbers at sea by the ocean troll fishery off California, Oregon, Washington, British Columbia, and Alaska. In addition, along with all five species found on the Pacific Coast, silver salmon are heavily fished in inside waters and in the mouths of the rivers in which they have entered on their spawning migration. Silver salmon were chosen because of the obvious decline in the catch through the years for which good commercial statistics have been available (Figure 3); because this species seems to mature predominantly at the end of its third year and thus the individual cycles remain more or less distinct; and because the life history is well known.

The adult silver salmon is heavily fished at sea during its third year of life, entering the rivers from September to December to seek suitable spawning areas in the tributary streams. It is subject also, in many areas of the Northwest, to fisheries in bays and estuaries and is

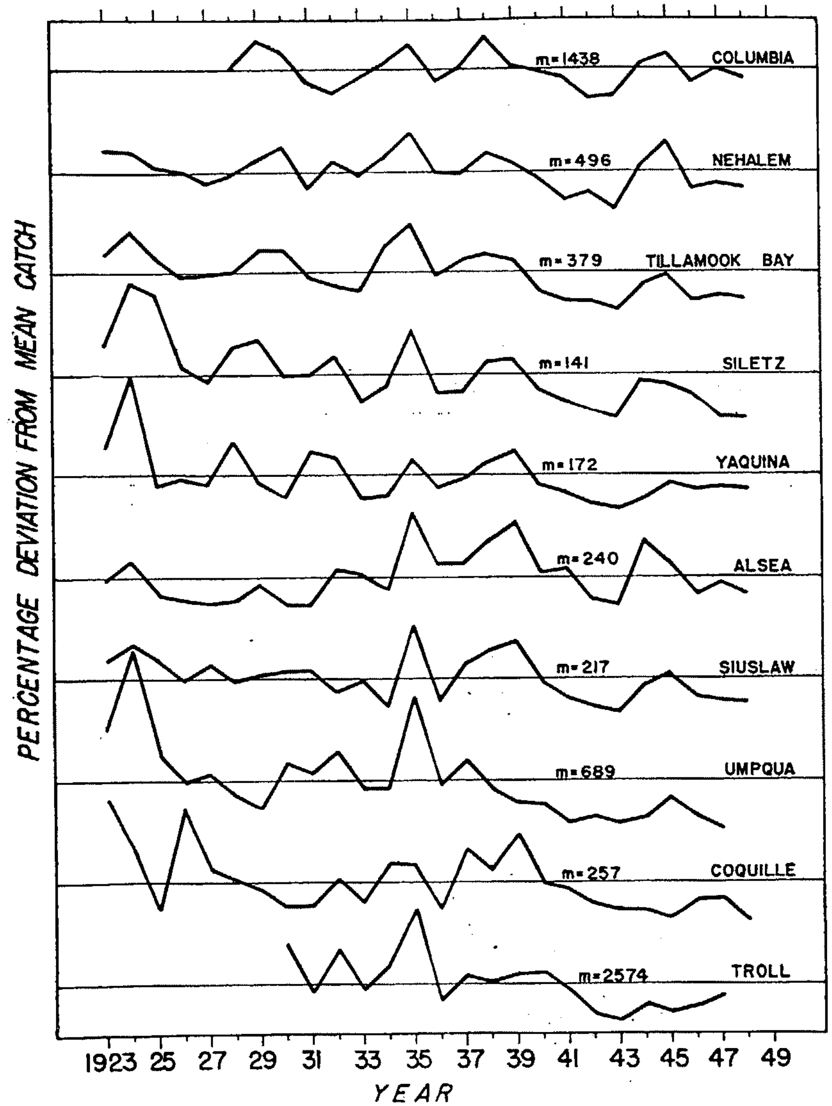

Figure 3. Trends of catches of silver salmon on nine Oregon rivers and the Oregon troll fishery depicted as the annual per cent deviation from the 26-year average, 1923 to 1948.

to some extent taken by sports fishermen on up the streams almost to the spawning beds. Varying water conditions as well as changing physical conditions on the rivers have an additional effect upon the successful migration and spawning of the adults. Fluctuating winter flow conditions then possibly influence the survival of the eggs and fry. Since silver salmon in Oregon streams appear to spend over one year of life in fresh water prior to their migration to the sea, they are subject to all the variable factors present in the fresh-water environment during the entire year: freshet conditions in late winter and spring; natural food production; high summer temperatures; low summer flows; and freezing conditions in the streams during the winter. In addition, of course, natural predators and trout fishermen also reduce the numbers surviving to migrate to the sea. Pollution, logging, and irrigation have each in one place or another been regarded as a factor in the survival of salmon.

In their marine habitat silver salmon are affected by such conditions as variable oceanographic conditions and fluctuating food supplies.

Here we are concerned with attempting to weigh the effects of some of these conditions on the salmon populations. In many cases inadequate data are available and in others only small amounts of data have been gathered. The marine environment is difficult to study, and conditions vitally affecting the salmon in the sea, which have not been measured in this study, may be operating.

TREND OF POPULATION

For the present study nine separate and distinct silver salmon fisheries were chosen; the various rivers used may be seen on Figure 2 to extend from northern Oregon (the Columbia River to the southern area of the Oregon coast, the Coquille River). No attempt was made to select rivers; those chosen contain the only important river fisheries at the present time within the state. The river fisheries are, except for the Columbia, gillnet fisheries, but in addition the trend of the troll fishery for silver salmon is included.

The data are presented as the annual per cent deviation from the mean annual landings of each river from 1923 to 1948, except for the Umpqua River which was closed to commercial salmon fishing after the 1947 season (Figure 3). The average catch of silver salmon is indicated also, which shows that the catch of this species is considerable in all rivers under study.

The trends and relative catches for the Columbia River and the smaller rivers along the Oregon coast are very similar for all years with few exceptions.

Two types of variations are present. Deviations between individual years, including short period increases and decreases, are present on all rivers. The surprising thing is that in general the deviations between years follow the same pattern on all the rivers and in the troll catch as well. Note the above-average catches on most rivers

from 1923 to 1925 followed by several years of rather average landings. During 1935 the landings of silvers reached a peak on almost all rivers, the Coquille being the exception. From about 1938 or 1939 a drastic decline in yield occurred on all Oregon silver salmon fisheries, broken only by an obviously temporary increase in 1944 and 1945 following the war. Figure 4 shows the changes in intensity during the past several years as measured by the number of gillnet licenses sold on various rivers. During the war years the effort was reduced somewhat, but increased again immediately thereafter.

In addition to the short-term fluctuations in catch, which appear remarkably uniform in practically all rivers and fisheries, a general reduction in the catch is also apparent. Even considering the high 1935 catches, the trend of the fisheries has been definitely downward. Since 1935 the reduction in yield has been even more marked.

The Alsea River fishery does not exhibit the gradual decline, but instead shows two distinct slopes to the commercial landings. The landings increased from about 1931 to 1935, remained relatively stable until 1939, and then exhibited the rapid decline evident on all other rivers. The upper river stocks of salmon had been almost entirely artificially propagated for many years on the Alsea River prior to 1929. They had been blocked completely just above tidewater by a low dam and the eggs taken for the local hatchery. The increase in these stocks of silver salmon after 1929 may have been due to the destruction of this dam and the subsequent increase of the stocks when allowed, for the most part, to spawn naturally. In the later years the trend of the commercial catch reacted much like that of the other river systems.

The Coquille River fishery has also reacted somewhat uniquely in that the annual fluctuations (i.e., peaks and depressions of catch) have not followed those of the other rivers or the troll catches. However, the downward trend of the landings on this river is as plainly evident as on any other stream.

Thus, the commercial statistics of the Oregon silver salmon fisheries indicate annual fluctuations which are remarkably uniform and similar in almost every one of the 10 unique fisheries on the Oregon coast. Also, a very definite downward trend in the landings is evident during the past 26 years.

It appears evident from the above that factors influencing the catch of salmon in one river are almost surely to be the same as those affecting the runs in practically all rivers. It would also seem likely that the causative agents of the general decline on any one river are of the same general type causing the decline on all other rivers.

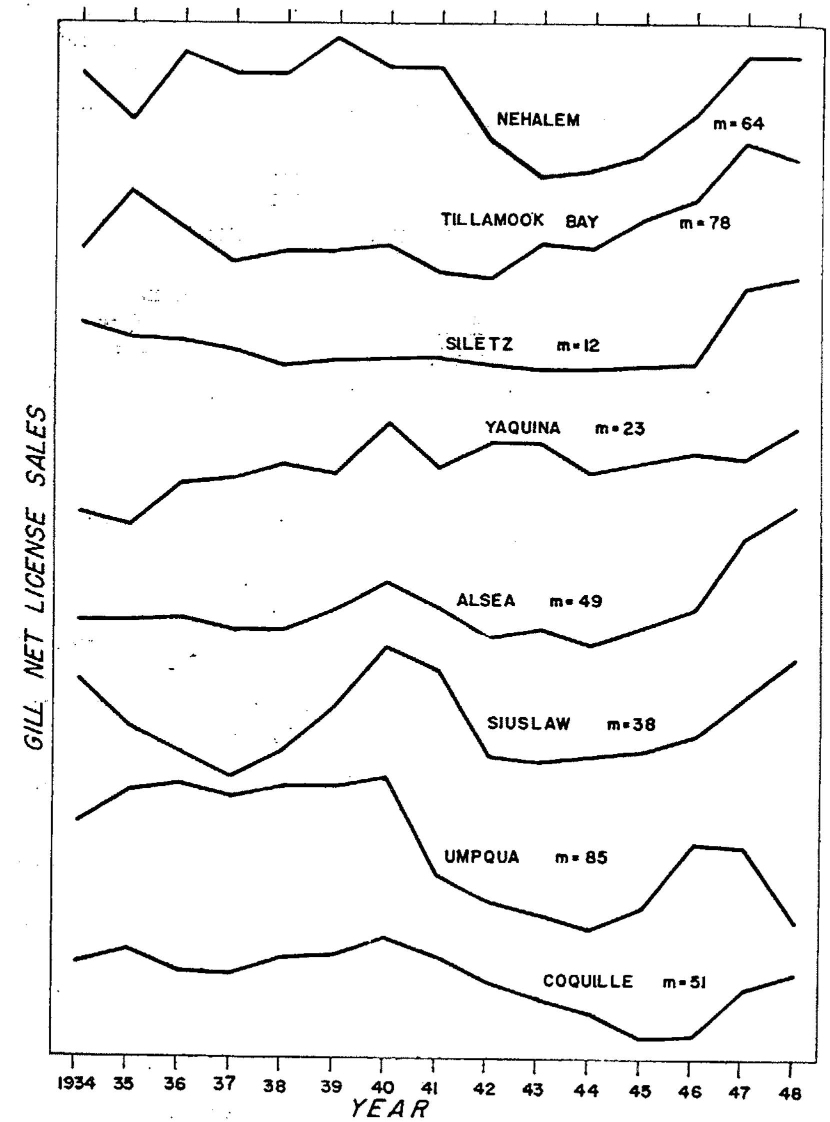

Figure 4. Trends of gillnet license sales on eight Oregon coastal streams producing significant proportions of silver salmon, 1934 to 1948.

POSSIBLE CAUSES OF THE OBSERVED FLUCTUATIONS AND DECLINE

Pollution.—Pollution has been found to be an important inimical factor in the decline of important salmon fisheries in the Northwest. On the Willamette River, a major Columbia River tributary, the serious pollution from municipal sewage and industrial plants, including five waste sulfite liquor pulp and paper mills, reduces the dissolved oxygen content of the water below one part per million during the late summer. This has eradicated the fall chinook run into this river, and from all evidence reduced both the silver and spring chinook salmon stocks.

Fortunately on the Oregon coast very little serious pollution exists. On most of the rivers small towns are situated along the salt-water estuaries near the mouths, and no serious pollution problems limit the fish populations. This possible cause can be dismissed, then, as being a factor affecting the decline in yield of the coast fisheries.

Changes in regulations.—Restrictions in the fishing season have been in effect on all these fisheries except the troll fishery for many years. However, the restrictions, until 1947, had little effect upon the landings of silver salmon. The open season on all rivers was from early in the fall before the silver salmon appeared in the bays, until early winter when very few silvers remained in the lower reaches of the river. The troll fishery was, for all practical purposes, unrestricted until 1948. Thus, the trend in catches cannot be attributed to changes in fishing regulations.

Hatcheries.—Small fish hatcheries have operated intermittently on all the rivers under study and over a considerable period of time on some. Because of the previous small operations on some of the larger streams such as the Nehalem, Yaquina, Siuslaw, and Coquille Rivers, where very small parts of the runs have been handled, it is obvious that with the exception of the Alsea (previously discussed) little effect on the fluctuations or trends of the fisheries can be attributed to hatchery operations.

Logging.—Logging operations in Oregon have long been suspected of playing an important role in the destruction of spawning and rearing areas of the salmon. Not only have areas been made inaccessible to the fish, but the resultant erratic flow patterns, silting, increased water temperatures, and general disturbance of the ecological balance are suspected of having seriously affected the populations of salmon.

In order to determine the effects of logging, the production of lumber in board feet in Coos County in a given year has been correlated with the deviation from the catch trend 6 years later for the Coquille River (most of the Coquille River lies within this county) (Figure 5). A significant correlation of —0.48 ($P<5\%$) was found, showing that

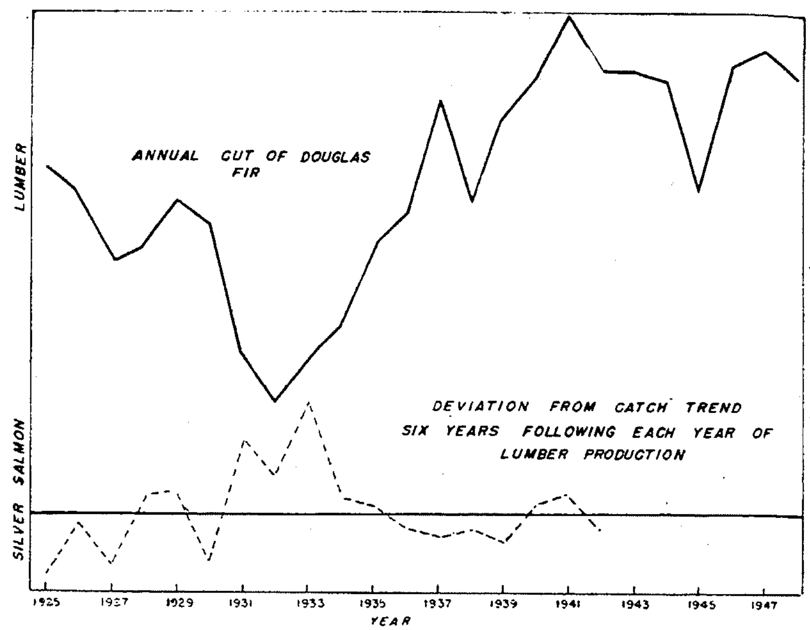

Figure 5. Trends of Coos County Douglas fir lumber production as related to deviations from the catch trend of silver salmon 6 years later, Coquille River, 1925 to 1948.

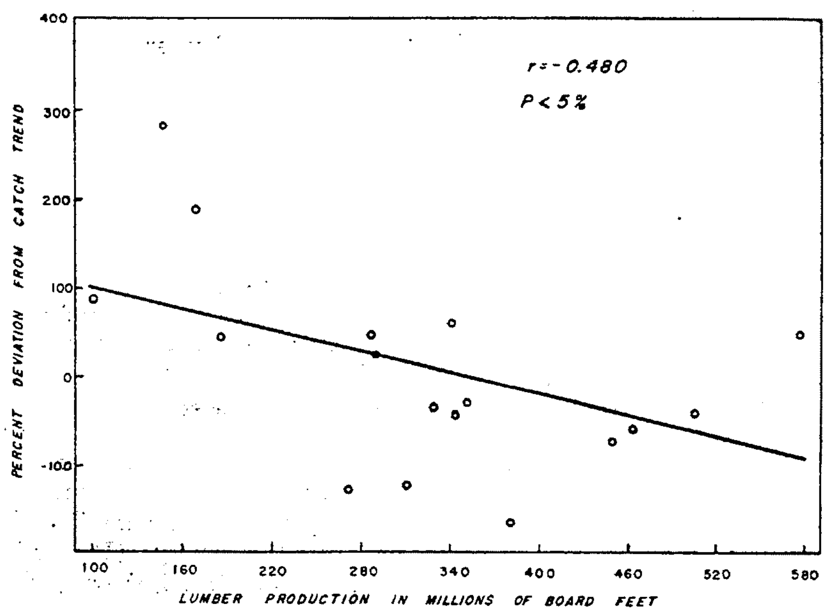

Figure 6. Relationship between Douglas fir lumber production and catch of silver salmon 6 years later, Coquille River, 1925 to 1942.

the periods of high lumber production tended to be followed by a decrease in the catch of salmon 6 years later (Figure 6). In contrast to the other factors discussed, the effect does not show up in the catch of the first cyclic return but rather in that of the second, indicating a possible cumulative effect of logging.

A study of the relationship of logging in Lincoln County to the production of salmon in the Siletz River did not show this correlation. Logging, however, has not been as extensive in this county as in Coos County.

Waterflow.—Floods have long been suspected of adversely affecting the salmon runs. Washing of gravel in which eggs are incubating and subsequent silting of spawning areas would appear to have catastrophic consequences at times. Also, it appears probable that young fish would be similarly affected. With such a possibility in mind, the maximum floods each year were related to the deviations from the trend of the catches 3 years following when the adults affected by such a flood returned. Reference is made to Figures 7 and 8 which show the actual catch and the over-all trend of the catch on the Siletz and Coquille Rivers, respectively; the difference between the trend line and the catch in any one year is the aforementioned deviation.

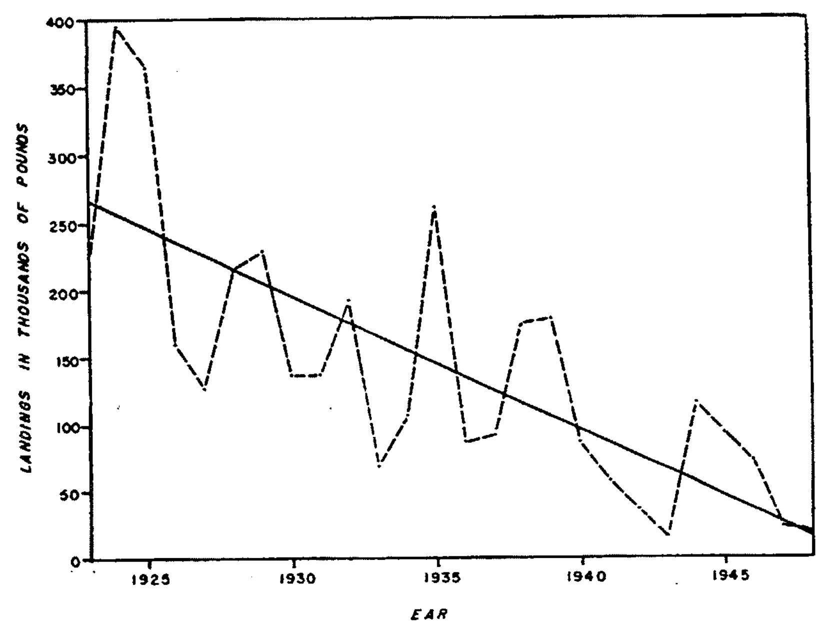

Figure 7. Annual silver salmon landings on the Siletz River, showing catch trend, 1923 to 1948.

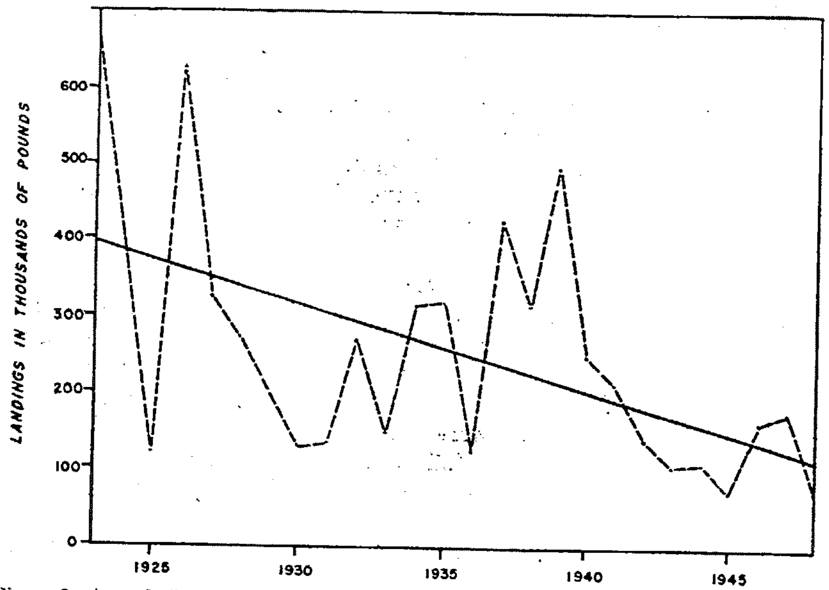

Figure 8. Annual silver salmon landings on the Coquille River, showing catch trend, 1923 to 1948.

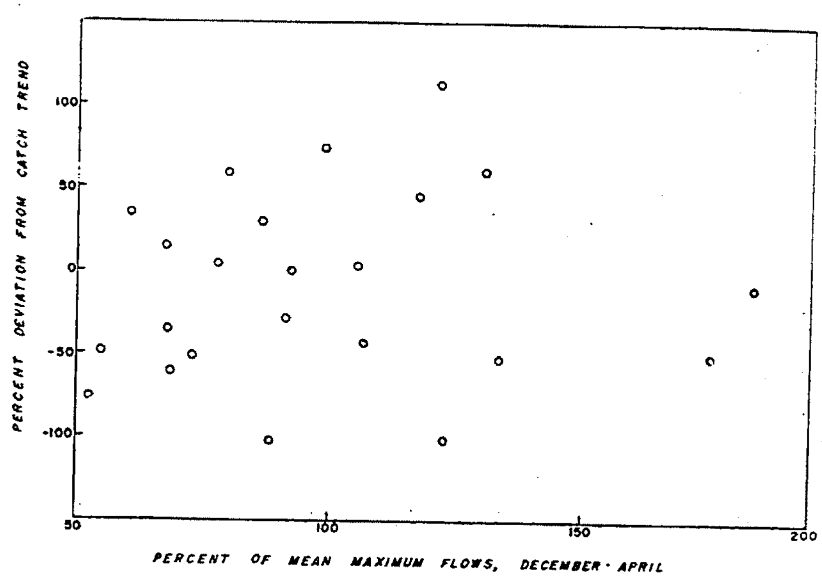

Figure 9. Relationship between the maximum winter flows and the deviations from the trend of the silver salmon landings on the Siletz River, 1923 to 1945.

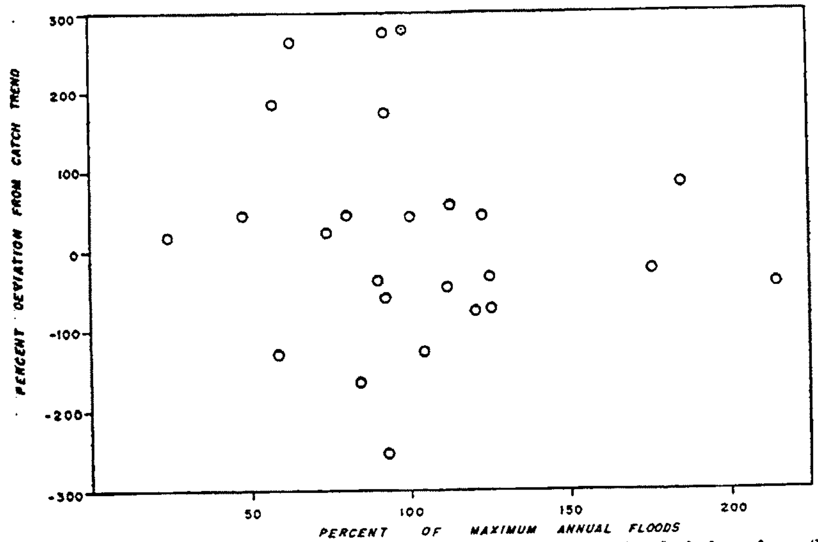

Figure 10. Relationship between the maximum winter flows and the deviations from the trend of the silver salmon landings on the Coquille River, 1923 to 1948.

These two rivers were used in this study because of the ready accessibility of water flow data. Figures 9 and 10 relate the floods of various magnitude to the runs on the Siletz and Coquille Rivers. It appears from the data that there is little relation between the magnitude of high winter and spring flows and production from the fish so affected. Nevertheless, attention should be drawn to the fact that flows more than 50 per cent greater than the average flood, which occurred a total of five times (three times on the Coquille and two times on the Siletz) were followed by a below-trend-line runs in four instances. Perhaps, then, extreme floods can be regarded as detrimental to silver salmon populations. When consideration is given to the fact that many other factors are involved in the catch, the conclusion that extreme floods are detrimental is all the more plausible.

As has been previously mentioned, young silver salmon remain in fresh-water streams during their first year of life and are therefore affected by their fresh-water environment. The streams inhabited by these fish often are extremely low in the summer, and so an effort has been made to relate the flows in July, August, and September with the catch from the fish so affected. Specifically, the deviations from the mean of the minimum July, August, and September flows have been related to deviations from the catch trend line of the returning run. Figure 11 shows this relationship for the Siletz and Figure 12 involves the Coquille River. Little relationship between low summer flows and

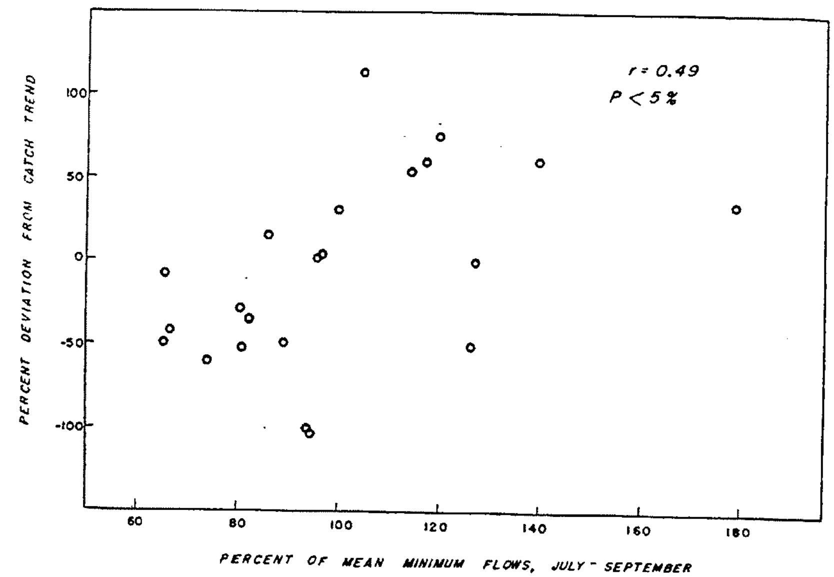

Figure 11. Relationship between the July through September minimum flows and the deviations from the trend of the silver salmon landings on the Siletz River, 1924 to 1945.

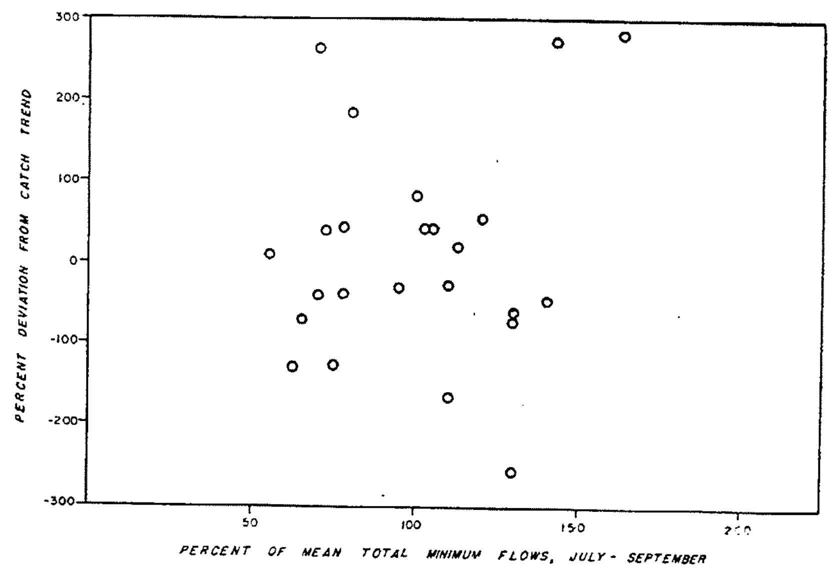

Figure 12. Relationship between the July through September minimum flows and deviations from the trend of the silver salmon landings on the Coquille River, 1923 to 1948.

following runs could be detected in the Coquille chart, a very poor correlation being indicated. The Siletz graph, on the other hand, indicates significant correlation ($r = 0.49$ $P<5\%$), and thus low summer flows may be expected to be followed by low runs and vice versa.

A further study was made of low flows in October and November under the hypothesis that low water at that time would render the fish unusually susceptible to capture in gillnets. With no heavy flows to attract fish out of the tidewater fishing grounds up to the spawning areas, they are presumably available to the fishery for protracted periods and vice versa. Consequently the low flows (actually percentage deviations from mean low flow) of various years were related to the catch (again, deviations from trend) 3 years later when the next cycle returned. Little or no relation between these factors could be detected, and it must be concluded that the waterflow conditions in October and November have not been shown to affect the fish production of the ensuing cycle and therefore spawning escapement.

Salinity.—In order to determine the effect of changes in salinity on the catch trends, the yearly mean salinity at Cape St. James (Queen Charlotte Islands, B. C.) has been correlated with the deviation from the catch trend for the Siletz River. Cape St. James has been selected as most representative of oceanic conditions of the localities for which there are consistent data for salinities for a period of years. Salinities have been measured there by the Pacific Oceanographic Group with headquarters at Nanaimo, B. C. It is known that some Oregon fish range as far north as this location, and it is probable that changes in salinities at Cape St. James reflect changes in salinities off Oregon for which no data are available. In any event at least part of the Oregon salmon populations are directly affected by oceanic conditions to the north.

The mean salinities for various periods of time which would have an effect on the ocean life of the silver salmon were considered. In Figure 13 the mean salinity for the period of June through May (12 months of the 15 months spent at sea) has been used. This period appeared to correlate more closely with the catch trend than any other. The correlation coefficient of —0.211 as obtained is insignificant. Thus, it seems unlikely that the crude measure of oceanographical conditions available, salinities, had an effect upon the trends of salmon catches. It is recognized that a more thorough study is indicated, including currents and food conditions as well as other changes in the ocean habitat before any conclusions can be justifiably made concerning the role variations of the ocean environment play on the survival and maintenance of salmon populations.

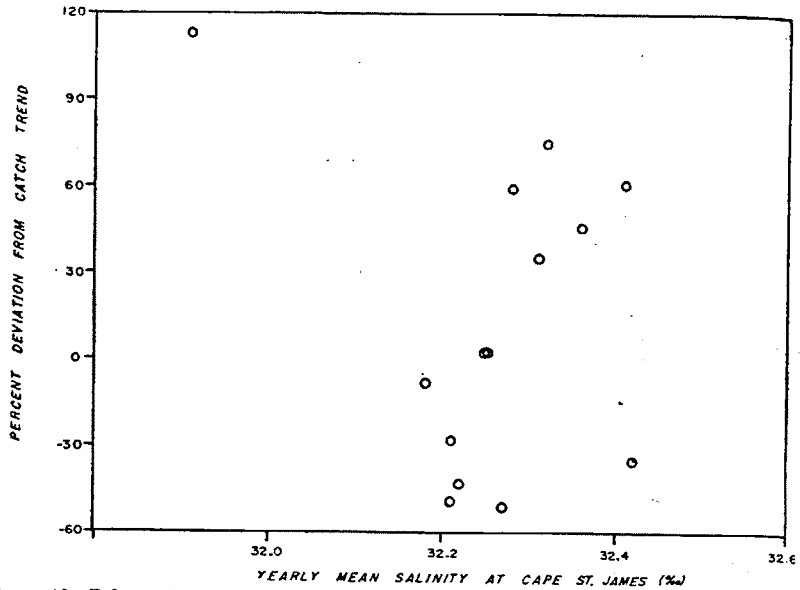

Figure 13. Relationship between the yearly mean salinity at Cape St. James and the deviations from the trend of the silver salmon landings on the Siletz River, 1935 to 1948.

RELATIONSHIP BETWEEN FISHING AND POPULATION TRENDS

One of the most obvious factors which might be affecting the salmon runs is the fishery. As has been mentioned before intensive commercial fisheries exist in the ocean and within the rivers on all the stocks of silver salmon here considered.

Marking experiments.—In order to study the relative intensity of the fishery, 49,450 yearling silver salmon fingerling of the 1944 brood year were marked by excising the adipose and left ventral fins at the Alsea River hatchery of the Oregon Fish Commission in the spring of 1946. Intensive sampling of the troll and river fisheries as well as almost complete recovery in the tributary stream in which the fingerling were liberated in 1947 revealed from 1,720 recoveries the following:

	Percentage of recovery
Ocean troll fishery	45.8
River gillnet fishery	31.3
Sports fishery	4.3
Escapement	18.6
	100.0

Thus, from 1,720 survivals of these hatchery-marked fish almost one half were taken at sea and another one third were captured in the river. About one fish in five reaching their third year escaped the fisheries to spawn.

In the Columbia River the same year a duplicate experiment was undertaken. About 50,000 yearling fingerling silver salmon were marked by excising the anal and left ventral fins at the Booneville hatchery. All marked fish were liberated from the hatchery ponds and the hatchery is arranged in such a fashion that the returning adults mount a fish ladder and enter holding ponds. Following are the tentative results from a recovery of about 2,200 adult salmon:

	Percentage of recovery
Ocean troll fishery	35.9
Columbia River fishery	50.9
Escapement to hatchery	13.2
	100.0

In this instance only slightly more than one third were taken in the ocean, but over one half were taken by the intensive Columbia River fishery. Only slightly over one fish in eight surviving to the third year escaped the fisheries to spawn. In these two experiments the ratio of catch to escapement was from 6.6: to 4.4:1, indicating a very high proportion of catch.

Economic trends.—In evaluating the effect of economic conditions on the fishing intensity, the cost of living index for Portland, Oregon, has been correlated with the relative fishing intensity on the Umpqua River. The cost of living index as obtained from the Portland Chamber of Commerce appears to be a suitable measure of general economic conditions in Oregon. The trends in fishing intensity have been somewhat similar for all the fisheries; consequently the Umpqua River statistics have been used since data are available for the greatest number of years. As shown in Figure 14 a highly significant correlation exists between the cost of living index and the fishing intensity with a coefficient of correlation of 0.86 ($P<1\%$). It is therefore apparent that in general, the amount of fishing increases in "good" times.

Relation between fishing intensity and catch.—The gillnet licenses sold on the various rivers are a fair measure of the amount of fishing since the licenses are sold for an individual river. On Figure 4 it may be observed that in general the number of licenses has remained fairly constant, dropping slightly during the war on most streams and picking up again immediately thereafter. It may be seen that, taken as a whole, no noticeable reduction in effort occurred during the years studied while probably to some extent more efficient gear and boats were contributing to greater efficiency and consequently, greater fishing intensity.

The effect of the fishery on the stocks of silver salmon has been studied by correlating the fishing intensity of a given year with the deviation from the catch trend 3 years later. Again, the Umpqua

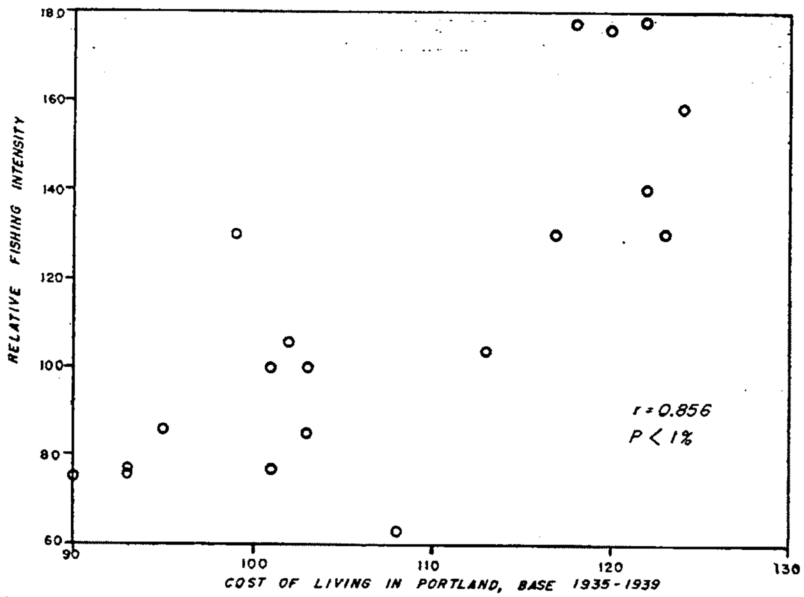

Figure 14. Relationship between the cost of living in Portland and the fishing intensity on the Umpqua River, 1923 to 1941.

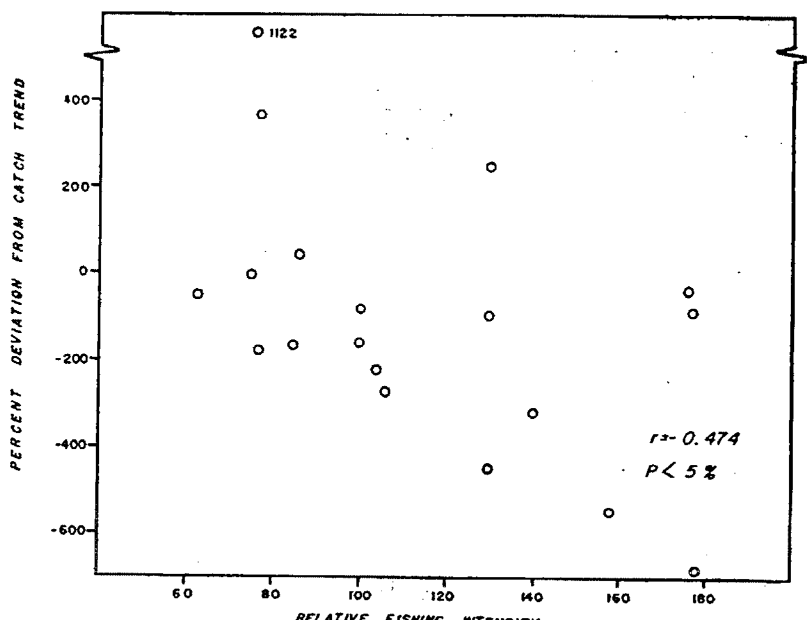

Figure 15. Relationship between the fishing intensity and the deviations from the trend of the Silver salmon landings 3 years later on the Umpqua River, 1923 to 1944.

River data have been used and are shown in Figure 15. A significant correlation exists between these factors as evidenced by a coefficient of correlation of —0.47 ($P<5\%$). The interpretation here is that with a lessened intensity in a given year, the catch 3 years later tends to improve in relation to the trend of the catch over a period of years. Thus it can be seen that the amount of fishing exerts considerable influence on the size of the stocks of silver salmon in succeeding years.

SUMMARY

Large salmon fisheries have existed in the Pacific Northwest for over 75 years, during which time the catches of salmon have fluctuated widely. Since the silver salmon fisheries in Oregon are an important part of the salmon fisheries and commercial statistics are available for at least 26 years, a study was instituted, attempting to evaluate the importance of several rather obvious factors which might be affecting the trends of populations. Catch statistics for nine distinct river fisheries and the ocean troll fishery for silver salmon in Oregon were studied. It was observed that there was considerable yet similar variation in catch between years in addition to a gradual trend of declining annual yields to these fisheries in spite of no evident decrease in fishing intensity over this period. If anything, with the more efficient boats and gear the intensity may have increased. Almost without exception the fisheries have reacted the same on all rivers studied and in the troll fishery as well. This indicates quite clearly that no specific condition exists on any one stream different from all the other rivers. On the contrary, it would seem that the conditions causing the fluctuations in catches are acting somewhat the same on all rivers, indicating that the same causative agent or agents are responsible for these fluctuations. The catch trend over the 26-year period is also downward, and this decline is so similar in all fisheries as to suggest the same factor or factors being responsible in each fishery.

Many conditions exist in the aquatic environment which might conceivably cause these fluctuations in trends and the gradual decline in catch over the past 26 years.

Pollution was obviously not a serious contributing cause since no large towns or industrial plants are polluting most of the rivers under consideration.

Changes in regulations, occurring relatively uniformly in most rivers, while not causing annual fluctuations, could have caused the decline if the application of these restrictions had been gradual. It was found, however, that the regulations, while changing considerably over the past 26 years, had not appreciably affected the silver salmon landings. Practically no restrictions were placed on the ocean troll

fishery and the decline in this fishery was almost identical to that of the river catches. It was concluded that changes in regulations could not have accounted for the downward trend.

Hatchery practices have changed considerably, but, since on several rivers only intermittent hatchery operations have been carried on, and they have artificially propagated only insignificant proportions of the runs, it is not possible that the decline is caused by either increasing or decreasing artificial propagation. In this regard it is well to point out that within the past 10 years significant advances have been made in the artificial propagation of silver salmon. In spite of these improvements the decline has continued.

There has been widespread logging carried out in Oregon on the headwaters of the salmon producing streams. A significant negative correlation was found between the trend of logging in one coastal watershed studied and the abundance of silver salmon (as measured by the catch) in the river two cycles or 6 years later. Thus it would seem that logging is very probably one of the factors contributing to the fluctuations in yields and decline in silver salmon populations.

Water flow, which to some extent is also influenced by logging, was correlated in several ways to the survival and catch of silvers. It was found that there was little relationship between the magnitude of high winter and spring flows and the survival of fish then affected. Even so, flows 50 per cent or more greater than the average flood (which occurred three times on the Coquille River and twice on the Siletz) were followed by returning runs below the trend line in four out of five times. Extreme floods then seem to be detrimental to young silver salmon, but normal fluctuations in winter high water do not seem to alter their survival.

Summer water flows which might limit the production of fingerling were correlated with the resultant run. Correlations were poor on the Coquille River, but on the Siletz, the other river tested, a correlation did exist, indicating that there is a tendency for low summer flows to produce poor returning runs and vice versa.

Also the autumn flows were studied to see whether they might reduce the number of adults reaching the spawning ground. It was found that no relationship seemed to exist between the fall water flows and the runs resulting from that spawning.

Many conditions may exist in the ocean environment affecting the survival of salmon, but only long-range changes could account for the observed decline. No significant relationship was found between salinities taken off Cape St. James on one of the Queen Charlotte Islands and the catches. It is recognized that much more precise measures are necessary before discarding the possibility of oceanic factors affecting the abundance of salmon.

In studying the effect of the commercial fisheries on the trends of the catches, a marking experiment was carried out which revealed that in that one year (1947) approximately from 81 to 87 per cent of the silver salmon surviving to the third year were taken by the fishery. Thus, regardless of any other considerations, the fisheries are taking a very high proportion of the adult salmon.

A further indication of the effects of the fisheries on the stocks of salmon may be found in the relationship between the index of the cost of living and the fishing intensity on one hand, and the relationship between the fishing intensity and catch on the other. A very significant relationship was found between the economic trend in Oregon and intensity of fishing for silver salmon. Furthermore, a significant negative correlation exists between the fishing intensity and the resultant runs. In general, then, when economic conditions in the region have been good, the fishing effort has been great and when the fishing effort is large the succeeding runs of salmon are small.

CONCLUSIONS

Three factors were found to be significantly correlated with the fluctuations and trends in silver salmon production in Oregon.

Logging was found to adversely affect the runs of salmon in later years.

Exceptional winter floods seem to produce poor resulting runs. Low summer water flows also appear to produce lower than average runs on some rivers, while higher summer flows appear to be followed by an increase in the resultant runs.

The intensity of fishing was also found to affect the subsequent productivity of the fisheries. Increases in fishing effort on the rivers studied were followed in succeeding cycles by a lower catch, and when the fishing effort declined the ensuing production of silver salmon generally increased.

Other factors studied did not bear a significant relationship to the fluctuations or trends of productivity of silver salmon.

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DISCUSSION

MR. E. R. DESROSIERS (California): Did I understand you to say that when the fishing was low the resulting 3-year cycle tended to be high?

MR. JOHN HODGES (Oregon): What I meant to say was that when the fishing intensity was low one year, the resultant run 3 years later tended to be high. If the fishing intensity was low and the number of fishermen was low one year, then the affected run would be that appearing years later. The silver salmon resulting run tended to be low compared with the trend line of the catches.

DR. WALFORD: Did you compute a coefficient of correlation?

MR. HODGES: The intensity of fishing and the run 3 years later? Yes, we computed the coefficient of correlation. It was minus .74, and the probability less than 5 per cent, which is what we speak of as being significant, but not highly significant. In other words, we would expect as high a correlation by chance only once in 20 times.

MR. A. C. TAFT (California): It was not clear to me in what ways you thought the logging affected the runs.

MR. HODGES: Actually, the logging has several effects upon silver salmon. In the first place, the big thing of course is the log jams resulting from logging. These block the salmon from the spawning ground. Other adverse factors are rapid runoff, flood conditions, abnormally high water that produce silting, and the building of roads that block small tributary streams.

MR. NORMAN A. RIDDELL (Washington): Do you believe all of your coastal streams are exposed to the same intensity of fishing on silver salmon?

MR. HODGES: No, they are not.

MR. RIDDELL: Wouldn't that chart you showed indicate that the runs were fluctuating on all of the coastal rivers in a similar manner, indicating that fishing would not be the major factor in the size of your run, that some other factors or factor would be more important?

MR. HODGES: I think that is likely true; that would be the interpretation.

MR. FRED A. GLOVER (California): I would like to ask if you believe that legislation to keep the lumber companies from logging in the neighborhood of the spawning areas and streams would solve the situation.

MR. HODGES: It certainly would be a big factor in helping out, and as soon as steps were taken in that direction, I think you would see some changes in the size of our salmon populations. Actually, in some cases, I think some progress is being made, particularly where you have national forests where arrangements are being made with the logging operators requiring them to guarantee cleaning up after the logging operations in the national forests.

MR. H. D. FRY, JR. (California): What do you believe are the mechanics by which the floods affect the losses in the streams?

MR. HODGES: There are a good many possible ways in which it could happen.

MR. FRY: How do you think it does happen?

MR. HODGES: There are several things that possibly happen. We haven't attempted to evaluate them. I mentioned the several floods which result after logging operations. One possibility is the actual washing of the stream bed and washing the eggs along the gravel and out of the stream. Another thing is the possible effect of silting; and of course in the summer there are low flows which actually limit the productive capacity of the stream; and thereby the production of fingerling silvers which are reared throughout the summer and do not migrate to the sea until the following year. Those are some of the possibilities. Another is the increased water temperature in the summer as a result of removal of the cover from the stream.

CHAIRMAN VAN CLEVE: I believe the impression might have been given that there was some suggestion of prohibiting logging in the streams. I do not think you meant that.

MR. HODGES: I know that no attempt has been made to prohibit logging in the streams, but at least if we could get cooperation in cleaning up the streams after logging operations, we would make a long stride in solving the problems, created by logging. Certainly, if we could ask for the prohibition of logging on the streams for certain distances away from the stream it would have a very beneficial effect.

SHALL WE HAVE SALMON, OR DAMS, OR BOTH?

ALVIN ANDERSON
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In the original economy of the western coastal area of the United States the salmon fishery for a number of years has been one of the West's large businesses. To start with, it was purely a commercial activity, involving the utilization of salmon for food purposes only. With the increase in population and the demands of that population for leisure time activity, the salmon resource is now also used to a large extent for recreational purposes, and in the recreational activity much commercial activity has developed.

The salmon, because of its anadromous nature, requires certain specific demands of the coast rivers for migration, for spawning and rearing. Civilization impairs stream utilization to the salmon in several different manners, through migration barriers, pollution, severe flow fluctuations, siltation, and reduced rearing area.

One of the major destructive factors to high productivity of the salmon resource is dam construction. The demand for dam construction results from development for power, navigation, irrigation, and flood control. Streams and rivers and fresh-water supplies have absolute requirements to man, and the greater the population, the greater the requirements in fresh water. As man intensifies his de-