

RELATIONSHIP OF VARIABLE OCEANOGRAPHIC FACTORS TO MIGRATION AND SURVIVAL OF FRASER RIVER SALMON

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INTRODUCTION

Management of the various Fraser River salmon fisheries requires an intimate knowledge of the abundance and movements of salmon runs, which is drawn largely from a detailed study of commercial catches. Abnormalities in abundance, in routes of migration or times of occurrence, unless forecasted, may negate the beneficial effect of fishing regulations formulated in advance of the fishing season. A flexible method of regulatory adjustment during the course of fishing may help rectify the adverse effects of vagaries in the salmon population but it cannot be accepted as a substitute for advance knowledge and planning.

OCEANOGRAPHIC FACTORS AFFECTING SOCKEYE SALMON MIGRATIONS IN THE NORTHEAST PACIFIC

The formulation of fishing regulations in advance of the fishing season requires knowledge of abundance, timing and migration routes of the Fraser River sockeye runs. It is known that adult sockeye abundance has been affected considerably by marine survival rates which have ranged from 4.22 to 18.54 per cent in recent years. However, since there is some reason to believe that freshwater and estuarial factors as well as the physiological condition of seaward migrants may influence subsequent marine survival, an oceanographic or ecological study of marine conditions, as related to sockeye survival, appears rather impractical until these factors are more fully understood. While variations in survival are important, it is relatively simple to make compensatory adjustments in fishing regulations for unexpected changes in abundance, provided that the timing of the runs is inherently consistent, as it is in most years, and the routes of inshore migration follows a consistent pattern. If, however, the measurement of abundance from commercial catches in initial fisheries is confused by a delay in arrival, or a change in the route of migration, or both, then the problem of properly managing the fishery becomes most complex.

Normally the bulk of the maturing Fraser River sockeye arrive off the west coast of Vancouver Island and approach the Fraser River around the south end of the Island through Juan de Fuca Strait (figure 1). A smaller part of the population, less than ten per cent, passes around the northern tip of Vancouver Island and approaches the Fraser River from the

north through Queen Charlotte and Johnstone Straits. In 1957 it was noted that a larger share of the population approached Vancouver Island from the north, a larger percentage (approximately 16 per cent) diverted through Queen Charlotte Strait and it was also noted that the fish were slightly delayed, and migrated over a longer period of time.

In 1958, the sockeye run of approximately 19,000,000 fish failed to appear off the west coast of Vancouver Island in its usual initial landfall and arrived northerly of Vancouver Island in the Queen Charlotte Sound area. The fish then moved in a southerly direction with an estimated thirty-five to forty per cent of the total population entering Queen Charlotte Strait, thus approaching the Fraser River from the north instead of the usual route through the Juan de Fuca Strait. In addition to the vagary in their route of migration the fish appeared in the fishery ten days later, and over a longer period of time than was anticipated on the basis of previous catch records.

The effects of the radical departure from normal in the route and timing of the 1958 Fraser River sockeye populations were serious. A surplus escapement of 1,500,000 fish occurred. These could have been harvested had the fish followed the usual migration route at the usual time. The delay in the arrival of the escapement on the spawning ground disturbed the normal relationship of the spawning population to its reproductive environment, and may have seriously jeopardized its reproductive potential. The physiological development of the fish was so disturbed in the latest arriving section of the population that an estimated ten per cent of the total escapement failed to reach their spawning grounds, some 350 miles upstream.

In analyzing all possible causes of the vagaries of the route and timing of the 1957 and 1958 runs of sockeye to the Fraser River it is logical to conclude that the physical marine environment, at least during the maturing year, must have been responsible. Oceanographic observations over recent years show that when the fish went to sea the normal currents and water masses were present off the approach to Juan de Fuca Strait, and that anomalous oceanographic conditions first developed off the southern British Columbia coast in 1957 and were intensified in 1958.

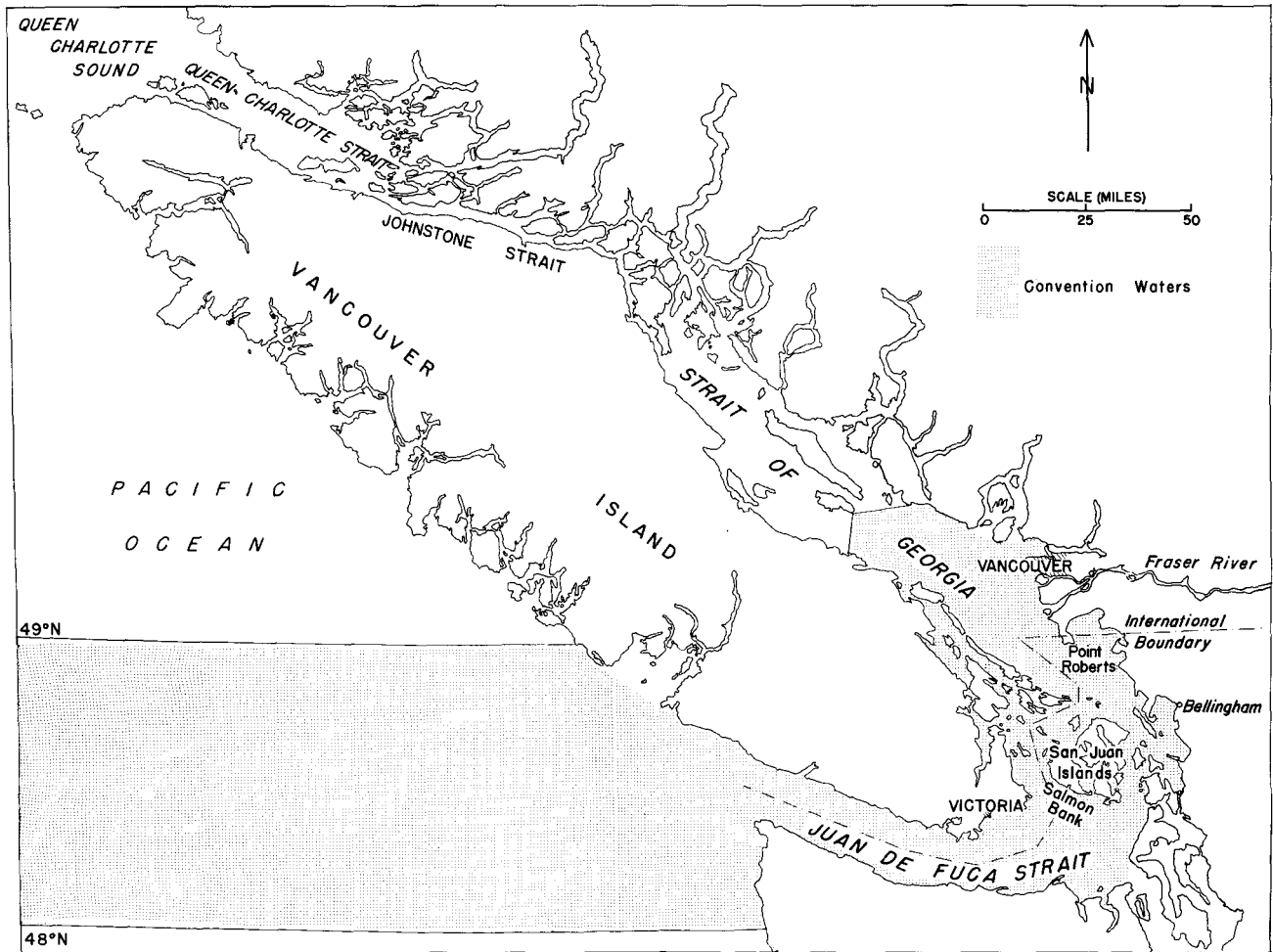


FIGURE 1. Vancouver Island and Fraser River approaches.

The trans-Pacific drift current normally flows eastward into the Canadian approaches. In the spring of 1957 this flow began to veer towards the north. By mid-summer 1958 the flow was due north in the region within 600 miles of the Canadian coast. Associated with this change of current direction, warm water intruded northward. It was evident as far as the northern end of the Queen Charlotte Islands. It reached its maximum extent in August 1958, and has degenerated somewhat since then. In the affected region the seawater temperatures were 2° to 3° centigrade warmer than is considered normal at the surface. The temperature anomaly decreased with depth, and vanished at about 500 meters. The occurrence, duration, and extent of the intrusion was determined by observing the temperature increase at 180 meters depth, well below the influence of seasonal heating and cooling. The increase in surface temperature is significant because the normal seawater temperatures in this area, at the time of the summer shoreward migration of sockeye salmon, are near the upper limit of preference for sockeye.

Sampling by investigators in the northeast Pacific during 1956, 1957 and 1958 under the sponsorship of the International North Pacific Fisheries Commis-

sion showed that the distribution of feeding Fraser River sockeye apparently tended to shift northward coincident with the warm water intrusion, and that no concentrations of these fish were found in the area westward of Vancouver Island as in preceding years. It may be postulated that the more northerly landfall of the 1957 and 1958 sockeye runs was the direct result of temperature preference on the part of the feeding sockeye in the ocean. The lateness in arrival might be ascribed to the consequent displacement of the sockeye to more distant feeding grounds or to a circuitous migration path to avoid the warm water intrusion. This concept is tenable because in 1958 there was a narrow band of cooler, near normal water, close along the west coast of the Queen Charlotte Islands. This would provide a coast-wise migration route into Queen Charlotte Sound. A modification of this concept would be that strengthened ocean currents slowed the migration rate of the fish. It can be further postulated that the more northern distribution of the fish brought the sockeye into higher latitudes where the days were longer during the late spring and summer months. This may have the effect of retarding maturation and thus delaying the correlated migration. A study of the degree of matura-

tion and energy reserves of sockeye arriving at the mouth of the Fraser River commencing in 1956 reveals that maturation and energy reserves were approximately the same in 1958 as were those of sockeye in the preceding years, in spite of the ten day differential in arrival. These findings tend to support the latter of the above hypotheses. The increased temporal dispersion of the run can also be explained on the basis of light response. If the fish were spread over a range of latitudes wider than normal, the resultant greater variation of day-length encountered would account for the increased interval over which fish arrived in the fishery.

Whatever the pattern of forces that created the vagaries in 1957 and 1958 Fraser River sockeye runs, a serious derangement in the management of the 1958 fishery resulted. The economic importance of predicting these vagaries in advance has been established.

THE RELATION OF OCEANOGRAPHIC CONDITIONS IN GEORGIA STRAIT TO PINK SALMON SURVIVAL

Great variability in the abundance of pink salmon populations has been well established in North America and the runs of this species to the Fraser River are no exception. Annual catches of pink salmon in the approaches to the Fraser River have varied from 950,000 to over 11,000,000 fish during the last twelve biennial runs. Predictions of ultimate adult survival based on the success of fry emergence have been notable for their inaccuracy, hence any reliable method of predicting adult survival must be based on something more than the number of pink salmon fry migrating to their marine feeding grounds.

Studies of the relationship of various fresh water and estuarial environmental factors to ultimate adult survival have resulted in what appears to be a fairly reliable method of predicting the approximate abundance of adult pink salmon populations destined for the Fraser River. Surface seawater temperature for the period April to August in Georgia Strait, which lies adjacent to the mouth of the Fraser River, has shown a close inverse correlation with the total pink salmon catch of the following year ($r = -0.8595$). The period April to August includes the time during which young pink salmon may be expected to be residing in Georgia Strait in advance of their emigration to the Pacific Ocean. Whether the water temperature of Georgia Strait has a direct or indirect relationship to survival is not yet known and further knowledge regarding the relationship can be obtained only by a detailed study of the young pink salmon during their estuarial existence.

OCEANOGRAPHIC FACTORS AFFECTING THE MIGRATION OF SALMON THROUGH COASTAL CHANNELS ADJACENT TO THE FRASER RIVER

The Fraser River salmon fishery is composed of several individual units each of which is highly efficient and subject to severe restrictions in order to

allow for equality in the total catch of each of the two national groups involved and for adequate escapement. The pink and sockeye runs entering Juan de Fuca Strait are highly vulnerable to a Canadian fishery operating on the north side of the Strait. A U.S. fishery on the south side of the Strait has never been consistently effective and its lack of success has been attributed in a large part to the vertical distribution of the fish in the southern area. If the U.S. fishermen were to develop a successful fishery in the southern side of the Strait the whole scheme of regulation would have to be revised with a major displacement of the existing over-all fishery.

A study of the currents in Juan de Fuca Strait reveals that in the northern half of the Strait the ebb transport of mixed saline and land drainage water greatly exceeds the flood transport of highly saline ocean water. The reverse situation occurs on the southern side. Since the fish are apparently seeking waters of reduced salinity as they approach the Fraser River they probably prefer the lower salinities of the northern shore and for this reason it is highly doubtful if salmon are available at any depth or in any great numbers on the southern side.

The eastern end of the Juan de Fuca Strait lying principally in Washington State consists of a zone of mixed water made up from the flood transport of seawater and land drainage. In this area the Fraser River salmon separate from other stocks destined for southern Puget Sound streams and apparently proceed northerly to a major extent through Rosario Strait (east of San Juan Islands). The alternate channels represented by Haro Strait (west of San Juan Islands) and San Juan Channel are available to them but based on availability indices these channels are not utilized to any great extent except by fish migrating during the late summer and early fall period. Occasionally, however, the northerly movement of fish will shift suddenly from Rosario Strait to Haro Strait, and very occasionally the principal movement will shift into Canadian waters. These shifts in migration have a drastic effect on the management of the fishery and must be related to changes in the physical environment of the available channels. Studies of salinity and temperature changes as related to variations in the flow of the Fraser River and to wind direction in the approach channels to the Fraser River would probably provide reasons for sudden and periodic shifts of the fish from their normal approach channels, to those which are not normally used by the majority. It is well established that the major flood tide transport is through Rosario Strait and the major ebb transport is through Haro Strait. Local and temporary fluctuations in temperature and salinity or in daily net transport through the various channels from Georgia Strait and the Fraser estuary have not been determined. An understanding of the causes of the shift in migration and an ability to anticipate the change even twenty-four hours in advance, would eliminate a very serious problem in the proper management of the fishery.

SUMMARY

It appears that offshore variations in physical oceanographic features have an effect on the feeding distribution, path and time of inshore migration, temporal dispersal of the inshore migration and the sur-

vival of Fraser River sockeye salmon. Oceanographic influences in inshore waters largely control the ultimate survival rate of the pink salmon and the approach characteristics of both Fraser River sockeye and pink salmon migrations.