SALMON OF THE NORTH PACIFIC OCEAN—PART III
A REVIEW OF THE LIFE HISTORY OF NORTH PACIFIC SALMON
5. PINK SALMON IN BRITISH COLUMBIA

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SPAWNING AND INCUBATION

The spawning of pink salmon, *Oncorhynchus gorbuscha* (Walbaum), in British Columbia takes place mainly in September and October. The period tends to be progressively later from north to south. In spite of this regional variation in timing, and additional distinctions that can be made between " earlier " and " later " fish in different parts of the larger river systems (Fraser, Skeena*), the spawning migration of pink salmon is relatively compact and continuous and no well-marked division into " summer " and " autumn " runs can be recognized.

In some instances spawning takes place in stream-mouth areas where water levels change with the tides and where varying degrees of salinity are experienced. At Hooknose Creek, in the central region of the British Columbia coastline (King Island), about 15% of the escapement spawns in areas of tidal influence (Hunter, 1959). In small coastal streams the upstream limit of the spawning areas is usually defined by a waterfall situated within a few miles, or less, of the sea. In larger rivers without major obstructions, the end-point may be less definite. In some years at least, pink salmon travel 50 to 70 miles up the Bella Coola River, while in the Fraser and Skeena watersheds some fish regularly reach areas which entail travelling 200 to 300 miles in fresh water (Thompson River; Seton-Anderson system; Babine River). Although pink salmon occupy and are more readily observed in small streams, the major part of the Fraser River escapement and a not inconsiderable part of the Skeena River stocks spawn in the main stems of these large watersheds.

The grounds that are intensively occupied by pink salmon tend to have a relatively low gradient which is combined with beds of not very coarse gravel.

Under conditions that permitted some latitude in the selection of redd sites, Hourston and MacKinnon (1957) found that pink salmon showed a preference for sites where the water was about one foot deep with a velocity of about two feet per second.

Competition has been observed between males for attendance on females while the latter are digging redds, with several males eventually participating in the spawning act (Wickett, 1959a). Spawning of a male with more than one female is frequent (Hunter, 1959).

No close correlation has been found between water temperature and egg deposition. In small, non-glacial streams spawning may begin at a temperature of 16°C or even higher. By the time the later fish have deposited their eggs the temperature may have fallen to 11° or 10°C. Peak spawning in the Fraser River system has been reported at about 10°C (Andrew and Geen, 1960).

Egg counts made on fish entering the spawning areas or taken from the commercial catch have given averages ranging from about 1,500 to 1,900 in various years and various areas. Published data are insufficient to show whether there are consistent differences in the fecundity of stocks breeding in different areas. In individual streams, however, the average egg-content of females may differ by as much as 25% between years of highest and lowest fecundity (Pritchard, 1948; Hunter, 1959; Neave, 1962). A relation between size of fish and number of eggs was shown by Foerster and Pritchard (1941). For McClinton Creek (Queen Charlotte Islands) they reported an average increase of 57 eggs for each increase of one centimeter in length and 472 eggs for each increase of one kilogram in weight.

The period of incubation is greatly affected by water temperature. Under natural conditions in British Columbia the hatching of the fry from the egg has been reported as occurring from late December to late February. The alevins remain in the gravel for a further period of at least several weeks during which time the yolk sac undergoes absorption and incorporation into the body. Swimming fry

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* *Ed. note:* For convenience, a map showing the major rivers and lakes referred to in this report has been printed at the back of this bulletin (p. 86).

have been observed in British Columbia streams as early as late February but the peak of the emergence in all localities reported on occurs during April or May.

DOWNSTREAM MIGRATION OF FRY

The downstream migration of fry begins immediately on emergence from the gravel. In small, clear streams the passage of fish in the vicinity of the spawning areas ordinarily takes place at night, the exodus beginning at or soon after the onset of darkness and concluding at or before daybreak. In cases where the distance to the sea is not more than about 10 miles the course is covered by most individual fry in a single night or less. When the distance is too great for this accomplishment fry often hide in the stream bed during daylight hours and presumably recommence their journey the next night. During a lengthy journey, however, some breakdown of the strictly nocturnal habit takes place and a variable proportion of the run travels by day. Some migration during daylight hours has also been observed near the spawning areas under conditions of high turbidity or flood (McDonald, 1960; Neave, 1955).

Migration is apparently initiated by a decrease in light intensity. According to Hoar (1956), loss of visual contact with the stream bed results in the fish being carried downstream by the current. Migratory activity is decreased by bright moonlight or by the advent of strong artificial light. At the same time there are many observations to show that pink salmon fry frequently swim actively downstream, at least for short distances, at speeds much higher than that of the current (Pritchard, 1944; Neave, 1955; MacKinnon and Brett, 1955; Wickett, 1959b).

While the young fish behave as individuals during the early stages of the seaward migration, after exposure to light under experimental conditions they form schools (Hoar, 1956). On the Skeena River, schooling of pink salmon fry was not observed until the tidal zone was reached—a distance of up to 260 km from the major spawning areas (McDonald, 1960). Individual fry reaching the slack water of an estuary at night swim slowly in a random manner (Neave, 1955). Thereafter, however, they are found in schools of up to many thousands of individuals, swimming near the surface in bright daylight.

OCEAN DISTRIBUTION

Initial dispersion from the stream mouth, up to distances of 30 or 40 miles in various directions, appears to be often accomplished within a few days. Large numbers of young pink salmon, often intermingled with chum salmon of similar age, continue to frequent the water's edge, along mainland and island shores, until mid-July, by which time an average fork length of about 75 mm has been attained. The offshore movement appears to be gradual or irregular and pink salmon of the year have been captured in Dixon Entrance, British Columbia, at a distance of only 6–12 miles from the nearest land in early September. These fish had reached an average length of 150 mm.

The distribution and movements during autumn and winter of pink salmon originating in Canada are not known. High seas taggings in 1962 showed that in April and early May fish which subsequently migrated to the central coastal area of British Columbia were well to the south of their spawning streams, some of them being near the latitude of the Columbia River (45°31′N, 126°36′W). A northward movement took place during subsequent weeks. In some instances this movement carried fish well beyond the latitude of the spawning areas, the final approach to which was therefore from the northwest. Tag recoveries failed to show the presence of Canadian pink salmon farther west than 145°W except in the northern part of the Gulf of Alaska, where single recoveries showed them at 58°33′N, 148°05′W in June and at 57°17′N, 145°55′W in July (INPFC Ann. Rept. 1962).

The vertical distribution of pink salmon in the ocean is not well known. The gillnet and longline catches on which knowledge of the horizontal distribution is based are ordinarily made within six or seven meters of the surface. In the central Gulf of Alaska a few fish have been caught at depths down to 24–36 meters. (Manzer and LeBrasseur, 1959; Neave, 1960.)

INSHORE MIGRATION

In the closing stages of their ocean life, from June onward, pink salmon appear in numbers along the coasts of the outer islands of British Columbia and adjacent areas of southeast Alaska. Three approaches —Dixon Entrance, Queen Charlotte Sound and Juan de Fuca Strait—give access to the inner waters into which the main Canadian spawning streams debouch. The first two are utilized annually by large numbers of pink salmon, whereas heavy migrations through Juan de Fuca Strait are limited to alternate (" odd ") years.

A series of tagging experiments has shown that the fish arriving at a given river do not necessarily follow a single line of approach, but reach their destination both from the north and from the south. Thus, pink salmon reach the Fraser and streams on the east and west sides of Georgia Strait both via Juan de Fuca Strait and Queen Charlotte Sound and, similarly, the Skeena and streams in the central coastal area are supplied via both Queen Charlotte Sound and Dixon Entrance. The proportions of the runs utilizing a given approach, however, may vary considerably in different years.

Schools of pink salmon often frequent bays and estuaries for days or even weeks before entering the streams. Fish tagged at this stage still show movements away from, as well as towards, the nearest spawning grounds. It appears, therefore, that spawning populations are not necessarily well-segregated until actual entrance into the spawning streams.

The speed of travel upstream is affected by the difficulties encountered and perhaps also by the state of maturity of the fish. In 1957 the average rate of travel in the lowest part of the Fraser (46 miles) was estimated to be 23 miles per day. Above this point, migrations of 160 and 138 miles to upriver spawning grounds were made at an estimated speed of 10–12 miles per day (Ward, 1959). A rate similar to these latter figures has been reported for pink salmon ascending the Skeena system to a counting fence on the Babine River—a distance of almost 300 miles (Godfrey *et al.*, 1954).

AGE AND SIZE

A pink salmon whose scales showed clear evidence that the fish was in its third year was collected from the Skeena River in 1956 (Anas, 1959). In captivity, pink salmon have been held alive (unspawned) at the Biological Station, Nanaimo, for several months beyond the normal spawning age. With these exceptions the evidence that British Columbia pink salmon invariably mature in their second year, and do not live beyond the spawning season, is inviolate. It is based on the examination of several thousand scale samples of maturing fish, on the return as adults of fish marked as fry, and on the regular occurrence of pinks at two-year intervals in some streams, the intervening years being " blank ".

Individual pink salmon caught on the British Columbia coast have been reported as occasionally reaching a weight of 14 pounds (6.3 kg). The long-term average of individual fish caught in the various coastal and river fisheries of British Columbia is a little more than four pounds (about 1.9 kg). However, significant differences in weight are recognizable (a) between fish caught in different areas, (b) between " even-year " and " odd-year " fish in the same areas, (c) between fish of the same genetic line in different years.

Variation in weight is discussed by Hoar (1951) and by Godfrey (1959). Fraser River fish are consistently larger on the average than pink salmon from the other main producing areas. Throughout the coast there is a tendency for fish maturing in odd years to be larger than the even-year fish. Variation in categories (a) and (b) is presumably associated with genetic differences or possibly with the utilization of different feeding areas. On the other hand, the considerable variation which occurs between generations of a single stock must be ascribed to changes in the environment. Godfrey (1959) has found evidence that such changes can be cyclical.

Combinations of the above-mentioned kinds of variation can produce striking differences in the average weight of individual fish in a given area. For example, on the west coast of Vancouver Island in 1946 (an even year in which pink salmon throughout the British Columbia coast showed exceptionally poor growth and in which Fraser River fish were lacking) the average weight was only 2.77 pounds (1.26 kg). In 1955 (an odd year, when fish were above the long-term average in size and when many Fraser River fish were present) the same area showed an average weight of 6.08 pounds (2.76 kg).

Fluctuations in average weight are commonly in the same direction throughout the length of the British Columbia coast.

FOOD

During their brief period in fresh water many of the free-swimming fry do not feed at all. In relatively long tributaries of the Skeena the ingestion of food items (mainly nymphal and larval insects) has been noted (McDonald, 1960). Regular feeding is evident from the time of entrance into the sea. The stomachs of juvenile pink salmon taken close to shore have contained copepods, euphausiids, amphipods, ostracods and the larvae of decapods, cirripedes and tunicates. Diptera have been noted as food items with surprising frequency, in several localities (unpublished data of J. I. Manzer, Nanaimo Biological Station, Fisheries Research Board of Canada ; Annan, 1958). The diet of pink salmon in their final summer in the high seas has been found to consist of a considerable variety of organisms, the most important categories being euphausiids, amphipods, fish, squid, copepods and pteropods.

EVEN-YEAR AND ODD-YEAR POPULATIONS AND RACE-FORMING TENDENCIES

As a result of the rigid two-year cycle there is a virtually complete genetic separation between the pink salmon which spawn in even years and those which spawn in odd years. Certain peculiarities in the abundance of the alternating populations are apparent.

In most British Columbia fishing and spawning areas pink salmon are numerous in both even and odd years and while a marked numerical superiority of one of the two lines may persist for a varying number of generations, reversals of the relative positions of the stocks are not infrequent. In contrast with the semi-balanced or fluctuating condition of the stocks in these areas is the picture presented by the pink salmon of the Fraser River system and the adjacent areas of Howe Sound and Puget Sound. Fish in, or en route to, these waters provide catches of up to 11 million fish to Canadian and United States fishermen in odd years. In even years the numbers are so small as to be quite insignificant. A parallel case is presented by the pink salmon stocks breeding in the streams of Masset Inlet and Naden Harbour in the northern part of the Queen Charlotte Islands. Here, heavy runs occur in the even years while fish are virtually absent in the odd years. In other streams of the Queen Charlotte Islands there is also a strong preponderance of even-year fish but in some instances small runs also occur in odd years. In both the Fraser and Masset regions the alternation of " on " and " off " years has persisted throughout the history of commercial fishing in these areas. Possible causes of disparity between even- and odd-year stocks are discussed by Neave (1952, 1953) and Ricker (1962).

While by far the most striking evolutionary development in the species is the sharply defined separation into even- and odd-year lines, the homing tendency (discussed below) of course imposes a degree of reproductive isolation on the stocks spawning within a given year in different regions, in different river systems or even in different tributaries of a single system. In general, variations between such populations in morphology, physiology or habits are not great and those which exist cannot always be ascribed with certainty to genetic differences because of the absence of precise information on the external conditions encountered by different populations.

Counts of gill rakers and pyloric caeca made by Pritchard (1945) showed slight but in some cases significant differences between samples taken from different British Columbia areas or streams. In no instance was the difference sufficiently well-marked to provide a useful means of identifying the place of origin (or the destination) of fish caught elsewhere. However, recent studies by United States investigators, using a combination of meristic characters, have shown that marked dissimilarities exist between British Columbia pink salmon (especially Fraser River fish) and pink salmon from western Alaska and Asia (INPFC Ann. Rept. 1958).

As previously mentioned, certain differences exist between some of the populations of large watersheds in the timing of the spawning migration and of the period of peak spawning. In the Fraser system the fish which spawn in the lower part of the main river and those which proceed to tributaries at and above the Fraser Canyon are relatively early, with peak spawning occurring between late September and mid-October. The tributaries below the Canyon show peak spawning from mid-October to the beginning of November (International Pacific Salmon Fisheries Commission Ann. Repts. 1957, 1959). In the Skeena system most of the pink salmon travelling farthest upstream (to the Babine and Kispiox Rivers) pass through the lower part of the Skeena in late July and the first half of August, while those proceeding to the Lakelse River (much closer to the sea) are mainly present after August 10 (McDonald, unpub.). In both the Fraser and the Skeena, however, there is considerable overlapping in the timing of " early " and " late " runs.

HOMING

The very strong tendency of individuals of all species of Pacific salmon to return to the spawning grounds where they originated is accepted as a basic premise by present-day investigators and administrators. Attempts to increase stocks, the forecasting of runs and the terms of international agreements regulating ocean fisheries are to a large extent based on this conception. In British Columbia, support for this doctrine, as applied to pink salmon, has been provided by the following considerations.

(a) Marking (by fin-clipping) of seaward-migrating fry has resulted in the recovery from the same streams, after an appropriate period of ocean life, of many adult fish bearing the same marks. Such experiments have been conducted on native populations at Hooknose Creek (King Island), Morrison Creek (Vancouver Island) and McClinton Creek (Queen Charlotte Islands). In each case large numbers of the marked adults were recovered from the natal stream and few or none were recovered from other streams.

(b) The complete or nearly complete absence of fish in alternate years in some areas indicates that these streams receive no large-scale immigration of fish originating in areas which possess large runs in these years.

(c) Pink salmon eggs from the Skeena River system were planted in Wahleach (Jones) Creek, a tributary of the lower Fraser River, in 1954 (this being a " barren year " in the Fraser system). About 1.1 million fry migrated downstream from this planting. In 1956 about 3,000 adult pink salmon entered Wahleach Creek. All other spawning tributaries of the Fraser showed the complete or virtually complete absence of pink salmon which is characteristic of even years. Furthermore, 12 of the returning adults were caught and tagged in the Fraser River at a point some miles above the mouth of Wahleach Creek. Nine of these fish were subsequently recovered from Wahleach Creek, having travelled downstream to reach it.

While evidence of the kinds indicated above leaves no doubt as to the very strong tendency of pink salmon to return to their home stream, the frequency and geographical extent of their deviations from this habit have not yet been satisfactorily determined. In the marking experiments quoted above it was of course impossible to scrutinize all spawning populations (or even those which were relatively close at hand) with the same care that was given to the natal stream. In the McClinton Creek experiments two marked fish were found in other streams of the same inlet and a few others were recovered from the fishery at times and places (up to 400 miles away) which appeared to preclude the possibility of their return to McClinton Creek (Pritchard, 1939 ; 1941). In years of high abundance pink salmon frequently appear in streams in which they are absent, or so scarce as to pass unnoticed, in other years. Although pink salmon from transplanted eggs showed a high degree of homing at Wahleach Creek, earlier " off-year " plantings made in McClinton Creek yielded no significant number of returning adults either to this stream or to the stream from which the eggs were taken (Pritchard, 1939 ; 1941).

The " wandering " of transplanted fish to streams quite distant from those in which they were released (as indicated by the McClinton Creek results and by experiments in other regions, including the recent transfers of the species to northern European streams) cannot be regarded as reliable evidence of the prevalence of non-homing in indigenous populations. Tagging experiments, however, show that schools of migrating adult pink salmon, even when very close to shore, contain fish moving to very different destinations. Under these conditions it would not be too surprising if minor groups sometimes failed to desert a large body of fish and were " carried " to areas far removed from the natal stream.

MORTALITY AND SURVIVAL

Quantitative observations on the mortality occurring at various stages of the life history in natural populations of pink salmon have been made in Canada at McClinton Creek, Morrison Creek, Hooknose Creek and in the Skeena River system. The outgoing fry and returning adults from transplanted populations have also been counted or estimated at McClinton Creek, Wahleach Creek and Robertson Creek (Vancouver Island).

In natural populations, losses of adults in fresh water prior to spawning are mainly associated with impediments to upstream migration. Many of the smaller streams frequented by pink salmon are at a very low level in late summer and may remain in this condition for a time after the arrival of the migrating fish, making waterfalls difficult or impossible to surmount, or, in shallow reaches, providing an insufficient depth of water for the fish to swim in. In addition to the losses caused directly by prevention or delay of migration such obstacles can have the effect of increasing the vulnerability of the fish to predation by bears or to prolonged human fishing. In the main stems of the larger rivers obstructions caused by low water levels are much less frequent and their effect has often been mitigated by the construction of fishways. Drastic effects on major stocks have been produced twice within the last fifty years by landslides. The first of these, which was caused by railway construction operations, occurred in the Fraser Canyon in 1913 and completely destroyed the large stocks of pink salmon which had utilized spawning grounds above this point. Only since the completion of fishways in 1945–46 has replenishment of these areas begun. A natural landslide which occurred on the Babine River (Skeena watershed) in 1951 prevented the passage of most of the pink salmon reaching this point in that and the following year, before the obstruction was removed.

No major pink salmon runs in Canada are as yet obstructed by man-made dams or by large-scale diversions of water for agricultural or hydroelectric purposes. Many small watersheds have been adversely affected, at least temporarily, by changes in stream flow associated with removal of forest cover.

The losses incurred at the time of spawning, through non-fertilization of eggs and through failure of females to deposit all their eggs, are very small in the instances which have been investigated. Cameron (1940) found an average fertilization of 98.2% in samples taken at McClinton Creek in 1938. Average retention of eggs by spent and deceased females was estimated to be from 0.1% to 2.7% in nine years of observation at Hooknose Creek (Hunter, 1959 and unpub.).

During the period in which the eggs and alevins are buried in the gravel, mortality is quite variable and can be very high. Losses, at various times and places, can be ascribed to (a) removal of gravel and the contained eggs or alevins by flood or by the digging operations of fish, resulting in death by mechanical injury, predation or translocation to unsuitable situations, (b) asphyxiation, due to insufficient water supply or to reduction of the oxygen content of the water, (c) unfavourable temperature for development, (3) drying of spawning beds, resulting in desiccation, freezing or prevention of emergence, (e) mortality caused by fungus or disease, (f) predation, (g) exposure of eggs to salt water.

Redd samples taken in January or February (after most of the surviving eggs have hatched) indicate that the average mortality of eggs and alevins in Hooknose Creek up to this time can vary from 35% to more than 90% in different years (Hunter, 1959 and unpub.). Intermediate values have been recorded for Masset Inlet streams (Cameron, 1941 ; Neave *et al.*, 1953). In the Hooknose Creek observations the highest percent mortalities were in years of heavy egg deposition and were probably caused in large measure by oxygen deficiency. Such deficiency can be produced by the extraction of oxygen from the water by large masses of eggs (living or dead) or by other organic materials. Similar effects can result from reduction of stream flow due to deposition of silt in the gravel. In the streams examined most of the mortality in the spawning beds occurred during the pre-eyed stage of development.

Predation has not been recorded as a major cause of mortality during the incubation period but can assume great importance at the time of emergence and during the ensuing downstream migration. In the Canadian streams that have been investigated the chief predators are sculpins (*Cottus*), young coho (*Oncorhynchus kisutch*) and " trout " (*Salmo* and *Salvelinus*). Cameron (1941) estimated that 60% of the pink salmon fry migrating over an average distance of less than two miles in McClinton Creek in 1941 was eliminated. Hunter (1959) estimated that in Hooknose Creek pink and chum fry (combined), migrating over a slightly shorter distance, were subjected to losses by predation of from 23% to 85% in different years. Within a given year predation takes a higher percentage near the end of the season of migration than in the initial stages.

The total percent output of migrating fry resulting from the estimated number of eggs carried into a spawning stream has been estimated for various natural populations in British Columbia, as shown in Table I.

In comparing these figures it should be noted that the points at which the fry were intercepted did not necessarily represent identical stages in the accomplishment of the migratory journey. At least in the case of the Skeena and Fraser streams the figures cannot be regarded as representing the total freshwater mortality since they do not take account of losses incurred by both adults and fry in traversing the distances between these tributaries and the sea (about 75 to 175 miles).

Pink salmon eggs raised under artificial conditions to the eyed stage and then planted in prepared channels have yielded relatively high outputs of migrating fry at Wahleach Creek (40%) and Robertson Creek (90%). These survival figures include losses that occurred in the hatchery as well as in the gravel. The high survival during the stream period is attributed to favourable characteristics of the gravel, controlled stream flow and minimal predation prior to the fry passing the counting point.

The mortalities incurred in descending the main stems of long rivers and in the successive stages of marine life have not been estimated.

Estimation of total ocean mortality naturally requires information on the number of fry reaching the sea and the number of surviving adults which return to fresh water. In practice it requires the assumption that all survivors return to the natal stream or that those which do not are replaced by an equal number of fish which originated in other streams. Data are not yet adquate to provide estimates of the total marine mortality of the stocks of large watersheds. McClinton Creek in six seasons of observation showed a return from the sea representing from 0.3% to 6.8% of the outgoing fry (Pritchard, 1948). Hooknose Creek in 10 seasons showed a range of from 0.7% to 5.2% (Hunter, 1959). The counting fences were situated in the tidal portions of both of these streams.

TABLE I. Percent output of pink salmon fry in various B.C. streams.

Locality	No. of years recorded	Percent output of fry	Reference
McClinton Creek (Queen Charlottes)	6	6.9–23.8	Pritchard (1948)
Morrison Creek (Vancouver I.)	2	4.7–6.7	Neave (1953)
Hooknose Creek (King I.)	13	0.9–37.2	Hunter (1959 and unpub.)
Lakelse River (Skeena system)	1	18	McDonald, unpub.
Kispiox River " "	1	23	McDonald, unpub.
Kitwanga River " "	1	15	McDonald, unpub.
Wahleach Creek (lower Fraser)	1	37	Hourston and MacKinnon (1957)

The figures quoted are of course for the survivors of fish which had been subjected to both natural and fishing mortality in the sea. The fishing mortality of the stocks of these individual streams is not known. Some data are available, however, for larger areas, through tagging experiments and through comparisons of commercial catches and estimates of escapements. Neave (1953) considered that fishing mortality in a large central region of the British Columbia coast amounted on the average to about 60% of the incoming adults. Hunter (1959) indicated a range of 29% to 63% exploitation for a small portion of the same region in the years 1949 to 1955. Fishing mortality of Skeena River populations has varied from 50% to 75% in 1955 to 1960 (Withler, unpub.). Pink salmon returning to the Fraser and Puget Sound in 1959 incurred about 80% exploitation. Under present management policies fishing mortality cannot be expected to approximate a constant percentage from year to year or from area to area, since it is regulated with a view to providing escapements in accordance with long-term conservation requirements.

CHANGES IN ABUNDANCE

The findings that have been referred to above indicate that in a small stream such as Hooknose Creek the percent survival from eggs to migrating fry may vary as much as 40 times (0.9% to 37%). By applying the estimated general fishing mortality of the area to the adult escapements of this stream, Hunter (1959) suggested that the marine survival (excluding fishing mortality) might vary as much as 10 times (1%–10%). Combination of these freshwater and marine survival rates would suggest the possibility of a 400-fold difference in the survival to maturity of the eggs available for deposition. In spite of wide variation in percent survival the fluctuations in size of observed populations are ordinarily much less extreme. This is because much of the mortality (at least during certain stages of the life history) is compensatory, i.e., it tends to take a higher percentage of large populations than of small ones. This appears to be especially true of the period from spawning to fry emergence. Presumably the parent fish belonging to small populations can select the most favourable sites and are subjected to less mutual interference. There will also be less competition between eggs or alevins for available supplies of oxygen. However, an important feature of the mortality which occurs during fry migration (as indicated at McClinton Creek and Hooknose Creek) is that this effect is reversed, the percent loss being greater when the fry populations are smaller (depensatory mortality), due to the tendency of the predators to take a fixed number of fry during the short period of their migration (Neave, 1953). The final output of fry from a given seeding of eggs depends on the balance between these two kinds of mortality, plus, of course, other mortality (extrapensatory or independent) which is not related to density. Since depensatory mortality tends to prevent small populations from increasing in size it would be very desirable to learn whether it continues to operate during the passage of the fry down the main stems of large rivers and in the earlier stages of marine life.

The maximum observed changes in population size in a single generation of pink salmon in the small streams mentioned above has amounted to a 5- to 10-fold difference, as measured by comparing the adult escapements. The effect of fishing mortality is not known in these instances. As might be expected, the available evidence indicates that when a number of spawning populations are combined, as in the case of a large watershed or a fishing area to which numerous streams contribute fish, the fluctuations are less extreme. Estimates of the total adult populations (catch plus escapement) of the Skeena area from 1955 to 1960 show that in any two consecutive generations the larger population has not been more than three times the size of the smaller. (This ratio, however, was probably considerably exceeded in the historic " crash " which occurred between the 1930 and 1932 adult populations.) While catches alone cannot be regarded as precise indices of abundance, it may be noted that in the last twenty-five years the total British Columbia catch has only once shown as much as a twofold difference between consecutive generations.

PREDICTION OF RUNS

Since the operations of the fishing industry and the application of conservation measures can be carried out much more economically and effectively when the general magnitude of a run is diagnosed beforehand, much effort and consideration is being devoted to this field. Attempts to predict the size of adult runs are based on (a) estimates of the population surviving at certain stages of the life cycle, (b) assessment of the favourability or otherwise of the environment. For many years the Canadian Department of Fisheries has provided information on the relative abundance of spawning populations of salmon and has noted external conditions (flood, drought, etc.) which might affect spawning efficiency or survival of eggs and alevins. Observations of both (a) and (b) type have been intensified and extended in recent years. Much effort is being expended on numerical assessment of escapements, particularly in the Skeena and Fraser streams. Estimates of survival to the fry-migrant stage, at first confined to a few individual small streams, have been applied to larger areas such as parts of the Queen Charlotte Islands and the Skeena and Fraser watersheds. Several attempts have been made to use environmental data in the prediction of pink salmon runs. The apparent effects of freshwater levels and density of spawning stocks on subsequent abundance are discussed by Wickett (1958). Vernon (1958) found a close correlation (inverse) between summer seawater temperature in Georgia Strait and the subsequent abundance of adult Fraser River pink salmon. This correlation appears to provide information on survival up to a later stage in the life history than freshwater data can do.

The prospect of attaining greater reliability in the prediction of pink salmon runs in British Columbia seems to depend not only on the accumulation of additional freshwater data (especially the fry output to the sea of large populations) but also on acquiring a much better understanding of survival throughout the period of ocean life.

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