STUDIES ON THE ATLANTIC SALMON (*SALMO SALAR* LINN.)

OF

SUB-ARCTIC CANADA

by

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A thesis submitted to the Faculty of Graduate Studies and Research

in partial fulfillment of the requirements for the degree

of Doctor of Philosophy in Zoology

McGILL UNIVERSITY, MONTREAL

December, 1958

ACKNOWLEDGMENTS

The author wishes to express his indebtedness to the following:-

McGill University for a Carnegie Arctic Research Scholarship during the period 1954 - 1957.

The Arctic Institute of North America for Banting Fund grants in 1956 and 1957 and for loan of field equipment.

The Department of Fisheries, Quebec, for field grants in 1955 and 1957.

Mr. W. Pollock of the Department of Zoology, McGill University for the construction of the respirometer used to determine the oxygen consumption of young salmon and brook trout and for photographing and reproducing the Figures in the thesis.

Dr. R. G. Stanton of the Department of Mathematics, Waterloo College and Associate Faculties for assistance with the statistical treatment of the data.

The many people who rendered assistance in the field, in particular, D. R. Oliver, B. H. Bonnlander, R. B. Anderson, Bob May, and Elijah Ananak;

and, finally, his supervisor Dr. M. J. Dunbar for his stimulating interest and encouragement during the course of this work.

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INTRODUCTION

Atlantic salmon (Salmo salar Linn.) have been known to inhabit the rivers flowing north into Ungava Bay for many years. In spite of their importance no biological investigation of the populations has previously been carried out. These populations are of particular interest as it is here that the salmon reaches the most northerly extent of its range in eastern Canada. A few salmon may be taken in the Leaf River but the majority of the Ungava salmon spawn within the tree line in the Koksoak, Whale and George Rivers. It is of interest to inquire into the factors which limit salmon to these rivers and ask why they do not breed farther north in the Leaf and Payne Rivers.

The salmon is important in the economy of the Eskimo inhabitants of the region who rely on it to provide most of their winter dog food. Records of the fisheries are scant but over the years they have shown decreasing returns. It could be inferred from this that the salmon are unable to maintain themselves against the combination of the natural disadvantages of their environment, and also the demands of a fishery. Is this inference supported by biological evidence?

In an effort to answer these questions a study of the salmon populations of the Koksoak and George Rivers was initiated in 1955 and continued in 1956 and 1957. The areas visited during the investigation are shown on the accompanying map (Figure 1). The location of the 1955 field work, Lac Aigneau, proved unfortunate; it was found that migratory fish were unable to ascend the Koksoak River and its tributaries as far as the lake. In 1956 further field work was undertaken at Helen Falls on the George River, and in 1957 at stations along the Koksoak River and its two major tributaries, the Larch and Kaniapiskau Rivers. Most of the work embodied in this thesis was accomplished during these latter two seasons.

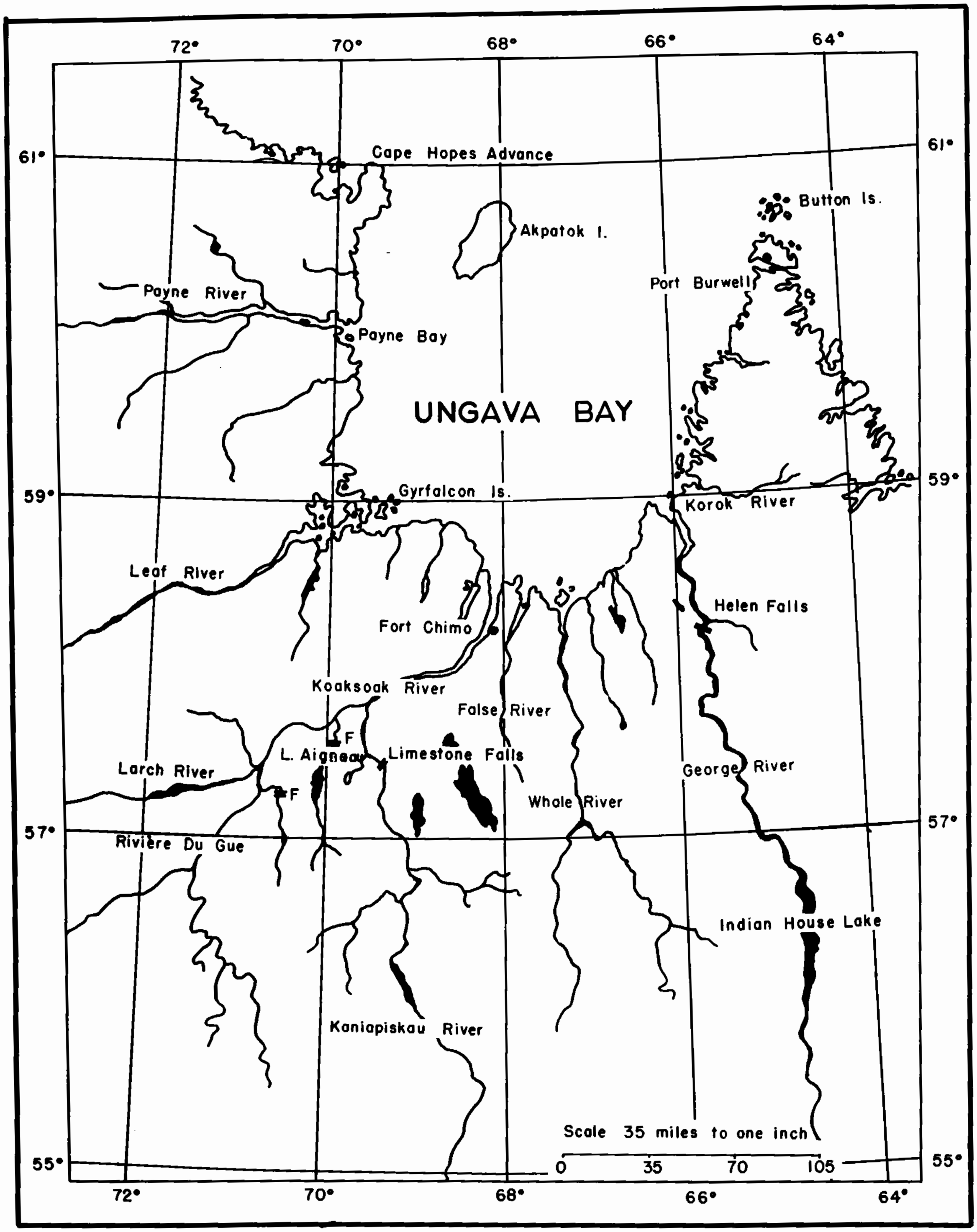

FIGURE 1. The major rivers draining into Ungava Bay.

EARLIER INFORMATION ON THE SALMON AND DETAILS OF THE FISHERY

An early record of salmon in the region of Ungava Bay is given by McLean (1849) who spent the years between 1830 and 1835 in this district as an employee of the Hudson's Bay Company. He states that in the lakes of the vicinity only whitefish, trout and carp are taken; that a few salmon are caught now and then in the river; but that there is no doubt this fish abounds on the coast. A certain amount of confusion exists in the literature as to the identity of certain species of fish. The term carp probably refers to the longnose sucker (Catostomus catostomus) which is plentiful in the lakes of this locality. The earlier references to salmon are especially prone to inaccuracy as the vernacular name for the Arctic char (Salvelinus alpinus) is "salmon" or "Hearne's salmon" in the north. Bell (1884) obviously confuses these two species when he reports Hearne's observations on the salmon of Hudson's Bay and the Churchill River. He himself reports the Indians as capturing in gill nets a species of salmon (on the east coast of Hudson's Bay) which bore a strong resemblance to the common salmon (Salmo salar) in outline, fins, head and mouth and had the same flesh colour and flavour. He also reported the salmon fishery being carried out in Ungava Bay by the Hudson's Bay Company, who transported the catch to England to be sold. This fishery began in 1881 in the Koksoak River and four years later was extended to the Whale and George Rivers.

Lucien Turner (1885), who was stationed at Fort Chimo from 1882 to 1884, gives the following details about the fishery. Fishing was carried out by gill nets of from six to six and one half inches in mesh which were run out from the shore at various fishing stations in the tidal parts of the estuary. The nets were handled by white men and natives, the latter having been introduced to this method of fishing by the whites. Originally the fish were purchased from the netsmen, washed down, packed in crates and frozen aboard the "Diana", the "Diana" being a steamer fitted with a dry air freezing plant, which was sent annually from London for the purpose. At the end of the season the ship returned to England where the catch was auctioned on the London market and brought from 1s. 6d. to 2s. 6d. per pound. Later it was found more convenient and profitable to split and salt the fish for transportation.

Turner reports the catches during the first four years of the fishery as follows:-

1881	40 tons:	average weight of fish	19.0	lbs.
1882	24 "	" " " "	16.0	lbs.
1883	38 "	" " " "	14.5	lbs.
1884	less than 40 tons	" " " "	14.7	lbs.

The returns from the fishery varied not only because of the varying abundance of fish but also because, depending as it did on the somewhat uncertain enthusiasm of the natives towards the work, the same fishing effort was not maintained from year to year. The enterprise was not altogether successful and returns from the fishery gradually diminished.

Low reported in 1895 that the catch for the Koksoak River averaged about 100 tierces (1 tierce equalling probably about 300 lbs.) and that the catches from the Whale and George Rivers averaged about 50 and 120 tierces respectively. The following year (1896) he wrote that the catch had fallen to half this amount and in 1897 it was an almost total failure (Low, 1898). The catches, which had diminished considerably since commercial fishing first began, apparently continued to decline until, in the early 1930's, the fishery was finally abandoned.

After commercial fishing was abandoned, a certain amount of netting was still carried out by the natives, salmon being particularly valuable to them as a source of dog food for the winter.

Dunbar and Hildebrand (1952) give some figures for the annual catches from the Koksoak and George Rivers in recent times. The present catch in the Koksoak varies from 6 to less than 2 tons. In 1947 it was estimated at about 35 barrels (one barrel equalling approximately 300 lbs.), in 1948 it was less than 14 barrels. The George River catch in 1947 was about the same as on the Koksoak, but in 1948 it had fallen to less than 5 barrels.

In recent years the Ungava Eskimos have taken to congregating at Fort Chimo during the summer months where many of the men can obtain work. Since the period during which work is available coincides with the salmon run, fishing has been virtually abandoned on most of the rivers and catches reflect the fishing effort rather than the actual abundance of fish.

DESCRIPTION OF THE MAJOR SALMON RIVERS

THE KOKSOAK RIVER

The Koksoak River is the largest river flowing into Ungava Bay, having a watershed approximately 60,000 square miles in area. The river is formed by the junction of two major tributaries, the Larch and Kaniapiskau Rivers, and flows in a northeasterly direction for about 90 miles before entering the sea. During the entire distance it receives only one tributary stream of any size, namely the High Fall Creek, and this is obstructed by falls a few hundred yards from where it enters the main river. The river varies in width from one half to one and one half miles, flowing through a wide, shallow valley flanked by low hills. The floor of the valley is wooded for the first 30 miles and trees grow for some distance up the sides of the surrounding hills. Near the sea the trees are smaller and less frequent until below Fort Chimo, 30 miles from the coast, they are virtually absent. Along the river's upper reaches the low banks are composed either of sand or boulders and the channel is obstructed by a number of large flat-topped islands with steep shores of sand and gravel. The tidal influence extends for 60 miles from the sea to a mile-long series of rapids which occur where the channel of the river is constricted by some low, rocky islands.

Below these rapids the banks become increasingly composed of boulders and rock and nearer to the sea they become quite steep and irregular, often rising straight out of the water at high tide. The current is rapid, varying between 3 and 5 miles per hour, and because of the exceptionally large tides which occur in the south of Ungava Bay swift currents sweep in and out of the estuary with the tide.

KANIAPISKAU RIVER: The Kaniapiskau is the larger of the two rivers which form the Koksoak. From its source in Summit Lake, just south of latitude 53°north, it flows a distance of about 400 miles to the Koksoak. Although it carries about twice the volume of water of the Larch River, it is of little importance to migratory fish as only the lower 20 miles, below the 60 foot high Limestone Falls, are accessible to the fish. Only two tributaries enter the river in this stretch and neither can be successfully ascended for more than half a mile.

LARCH RIVER: This river originates in Shem Lake 890 feet above sea level near the high land dividing the drainage westward into Hudson's Bay from that eastward into Ungava Bay. The Larch runs in a northeasterly direction for most of its 200 mile course to the Koksoak. The upper reaches, between Shem Lake and Natuakami Lake, a distance of 54 miles with a fall of 370 feet, consist of numerous shallow boulder-filled rapids, without any direct falls. The surrounding country does not slope with the river which consequently flows in a deep valley. Black spruce (Picea mariana) and tamarak (Larix laricina) grow on the floor of the valley and for some distance up its rocky walls. Natuakami Lake is an expanded portion of the river with little current, is 15 miles long and varies from one quarter to 3 miles in width. Low (1896) states that Indians he met here reported taking a few salmon in the lake but that the majority ascended the Kenogamistuk, now named Rivière du Gue, to spawn. The Rivière du Gue is larger than the Larch and flows into it on its south bank some 40 miles below Natuakami Lake. Just 5 miles above its junction with the Larch the du Gue receives a large tributary, the Clearwater River, on its east bank. The lower reaches of both the du Gue and the Clearwater are shallow and swift with boulder-strewn beds and numerous rapids. After receiving the du Gue the valley of the Larch widens out and the river varies from 400 to 1,000 yards in width. The shores are generally sandy with steep banks and numerous boulder-strewn points. The river is moderately swift having a current of approximately 4 miles per hour. For the last 8 miles of its course the valley narrows and the river falls some 60 feet in a number of swift rapids to where it joins the Kaniapiskau River to form the Koksoak.

THE GEORGE RIVER

The George River originates in Lake Hubbard, on the Labrador plateau Lat. 54°46' north, at an altitude of approximately 1,700 feet, and flows northwards parallel to the Quebec-Labrador boundary for a distance of over 350 miles before it enters the sea in the south-eastern corner of Ungava Bay. The head waters consist of a chain of small lakes connected by a series of shallow rivers filled with rapids. The first falls on the river, "Les Trois Cascades", Lat. 55°26' north, occur some 71 miles from its source and are followed approximately 13 miles lower down stream by a second falls. Although the river is exceedingly fast flowing and contains numerous rapids, many of which exceed a mile in length, the only major falls along its course are at Helen Falls, Lat. 58°9', 16 miles above the tidal water. The head waters, situated on the flat table land of the plateau, are in a region lacking noticeable undulations, but farther down the valley first hills and then mountains close in on either side of the river. In the region of Indian House Lake the hills reach 800 to 900 feet above the level of the river and for the remainder of its course the river flows in a deep valley between ranges of hills and mountains. The more prominent of these ranges were named by Mrs. Hubbard who travelled down the river in 1905. In her account

FIGURE 2. Looking down the Kaniapiskau River from the height of the Manitou Gorge portage trail.

FIGURE 3. The George River at Helen Falls.

of the journey, "A Woman's Way Through Unknown Labrador", she not only gives a very good description of the country, but also provides a reliable map of the river.

The shelter afforded by these hills accounts for the increasingly rich vegetation which is found in the lower reaches of the valley. At Helen Falls it is probably at its most luxuriant. Here the forest association, consisting of the co-dominants black spruce and tamarack or larch, forms an almost continuous, if not very dense, cover on the valley floor and the adjacent slopes to a height of some 800 feet above the river. In the thicker stands the trees grow from 6 to 10 feet apart with an average height of 35 feet and a diameter at breast height (d. b. h.) of 8 to 10 inches. Growth is slow, growth rings being generally less than 1 mm. per year. Willow and alder form a dense scrub near the mouths of tributary streams and along the course of the main channel, where the sandy banks are replaced by cobbles, boulders or bedrock. A detailed account of the vegetation of the river is given by Rousseau (1949).

THE WHALE RIVER

This is the smallest of the three major salmon rivers emptyinto Ungava Bay. Lying between the Koksoak and George, it flows through similar terrain. The Whale River is probably some 300 miles long, but since portions are at present incompletely mapped and no account is available of anyone having travelled along the river, it is impossible to estimate how much of its length is accessible to migratory fish. The river was formerly fished commercially by the Hudson's Bay Company and Eskimos who inhabit its estuary say the river contains a large run of salmon. If this is so, it must be assumed that the river contains a reasonable area of accessible spawning ground. On the 8 miles to one inch National Topographical map, which is the best available, a number of rapids but no falls are marked along the lower 120 miles of the river, so presumably this stretch at least is available for spawning salmon.

CLIMATE

A complete analysis of the climate of this region can be found in "Climate of Eastern Canadian Arctic and Sub-Arctic" (Hare - 1950) from which work the following figures have been obtained. The annual precipitation over the watersheds of the Koksoak, George and Whale Rivers amounts to between 20 and 25 inches per annum, of which approximately 8 inches falls in the form of snow. The wettest season of the year is the summer when the mean rainfall is approximately 3.0 inches per month. The mean annual temperature of the region lies between 20° and 25°F.; however, during the summer there are on average 150 days during which the mean temperature is above 32°F. The extremes of temperature range from below -40°F. in mid-winter to above 80°F. at the height of the summer. The range of diurnal fluctuations in air temperature during the summer months, when these fluctuations will be reflected in the river temperature, is approximately 20°F. Lying as they do in subarctic regions, most of the watersheds of these rivers are within the zone of permafrost and only some of the head waters extend south beyond this.

PHYSICAL LIMNOLOGY

The river beds vary in composition from bare, clean rock and boulders to gravel, sand or even silt in some of the quietest stretches not exposed to the current. There is a noticeable lack of any kind of aquatic vegetation growing over the bottom. The banks are of similar materials and in many places fall very steeply from the river terrace. Where they are of sandy material and too steep, they are unstable and, being continually eroded, are devoid of vegetation.

The water is usually exceptionally clear and even during the spring run-off the bottom is visible to a depth of 3 feet, while later in the summer it can be sighted at depths of over 8 feet. The Larch River is an exception to this; at one point about 8 miles above its junction with the Kaniapiskau it has steep blue clay banks and during the spring run-off the eroded particles of clay from these banks colour the whole river so that it is only possible to see a few inches into the water. The turbidity of the water is such that its effects are visible 80 miles down stream. The water clears later in the summer when the level falls below the clay bank to the gravel beach beneath.

The volume of these rivers depends entirely on the season. During the spring run-off the water level may be anything from 10 to 15 feet above the normal summer level. The George River at Helen Falls on July 4, 1956 had fallen only a few inches below the level of its spring maximum. From then until the middle of August it continued to fall, slowly at first and then more rapidly, until finally it settled at a level 10 to 12 feet below the spring high. A similar pattern was followed by the Koksoak River in 1957. During the run-off there is a great deal of bank erosion, especially by ice, which gouges and scrapes the banks so that in many places they maintain an angle of 45^{o} with the horizontal. There is a small rise in water level in the fall prior to freeze-up, and following this, during the winter, the level probably drops to its lowest ebb, since drainage will be at a minimum during this time.

Spring break-up commences first in the headwaters of these rivers and progresses down stream. The rivers are normally ice free by the first week in June but the actual date varies according to the season. In 1956, owing to an unusually late spring, the George River did not open up until the end of that month. Once open, the temperature of the water rises rapidly. In Figure 4 the temperature cycle for the river Aigneau in 1955 and the George River in 1956 is shown. The graph is plotted using daily maxima. The daily means would be at least 1^{o}C. less. An indication of the extent of the diurnal fluctuations in temperature is given for the days when records are available. These are, however, minimal estimates as on no day was the complete 24-hour cycle recorded. The

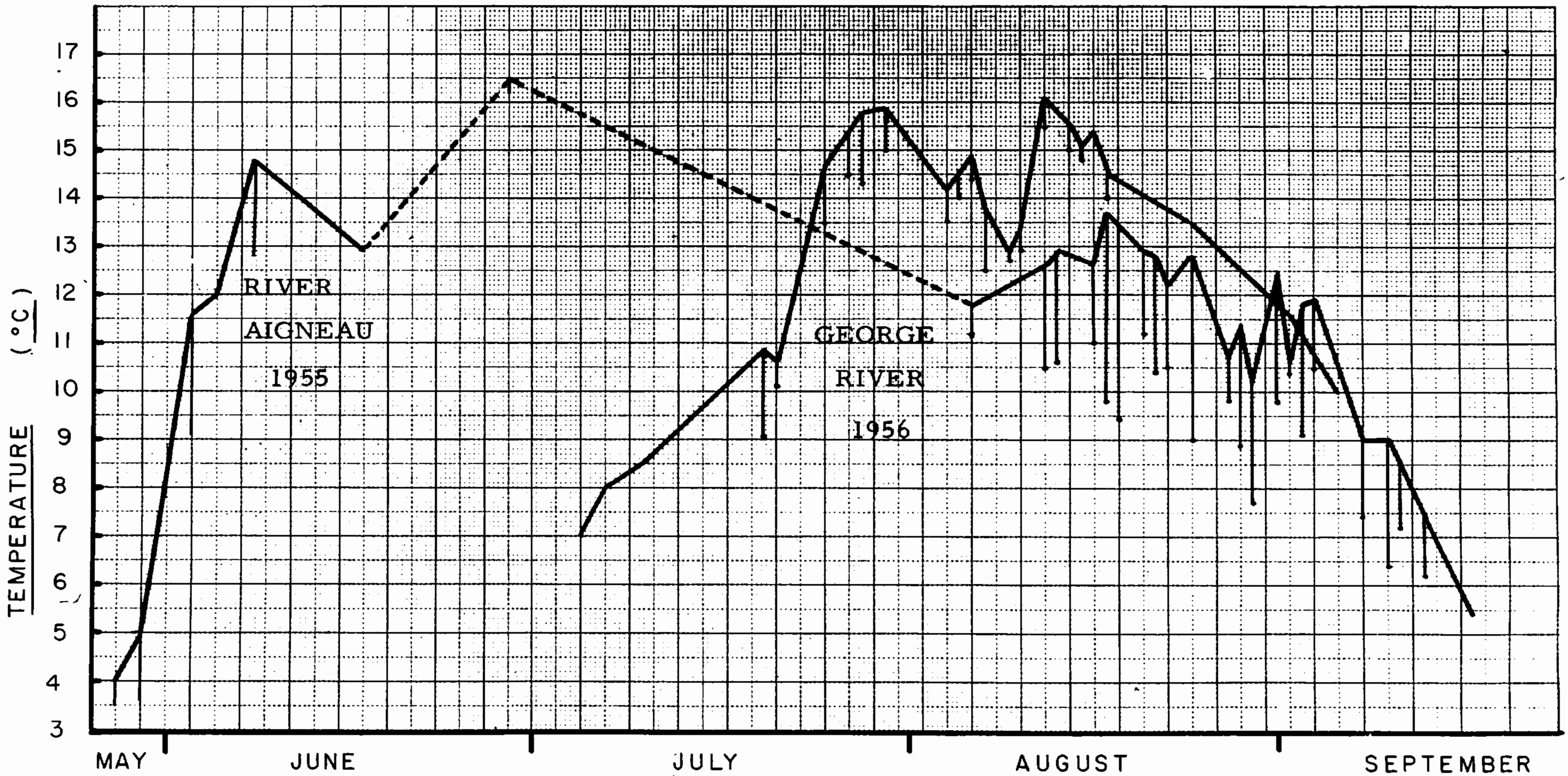

FIGURE 4. The temperature cycle in the River Aigneau 1955 and the George River 1956.

cooling of the river water in late August and September coincides with the deterioration in the weather and the first snow falls, which usually occur in early September. The rivers begin to freeze over in November and by the end of December they are usually well covered with ice. Even in the severest winters, however, parts of the rivers remain open; for example Helen Falls on the George River is never frozen. These patches of open, turbulent water may cause a considerable cooling of the river during the winter months.

Although no systematic measurements of the pH of the water were made, the few spot measurements taken indicate that the water is usually slightly acidic, having a pH value of between 6 and 6.5. Many measurements of the oxygen content of the water were made in connection with the physiological experiments described in the section on metabolism, and these show that the water is at all times well supplied with oxygen, the percentage saturation with that gas being between 90 and 100%. The Kaniapiskau River is exceptional here in that at Manitou Gorge, where the measurements were taken, the water was consistently supersaturated with oxygen, percentage saturation values fluctuating between 110 and 120.

METHODS OF FISH COLLECTION AND EXAMINATION

Nylon gill nets of various mesh sizes were extensively used to capture specimens. The nets ranged in size from fine 1-1/2-inch mesh nets which took smaller fish, particularly juvenile salmon, to heavy 6 and 6-1/2-inch mesh nets for the capture of large adult salmon. In places where the current was too heavy and there were no suitable eddies in which to set nets, fishing rods were resorted to, with great success, chiefly for catching salmon parr. A one-inch mesh, four-foot hoop, Fyke net served to a lesser extent principally to obtain the specimens required for the measurement of metabolic rate. Hand nets were employed to collect fish fry and other small fish. Fishing was least successful early in the spring when the river was cold and swollen with spring melt water. It improved as the river subsided and was at its best during the month of August and early in September.

The salmon were examined in the following manner. The length of each specimen was measured to the nearest 1/2 cm. from the tip of the snout to the end of the central ray of the caudal fin. The young stages, parr and smolts, were weighed to the nearest gram, using a beam balance sensitive to 1/10 of a gram, while the adults were weighed to the nearest 1/2-lb. on a spring balance calibrated in 1/4-lb. divisions. A sample of scales was removed from each fish from an area slightly anterior to the dorsal fin and above the lateral line. The fish were dissected and the sex and condition of the gonads recorded. The stomachs were opened and samples of the undigested food removed, finally the fish were inspected for parasites.

SPECIES OF FISH COLLECTED

Lac Aigneau:

Ten species of fish were taken either in the lake or the river which flows into it. Of these ten all but two had been recorded previously as occurring in the Ungava watershed by Dunbar and Hildebrand (1952). The Longnose Dace (*Rhinichthys cataractae* Valenciennes) and the Mottled Sculpin (*Cottus bairdii* Girard) are the two species of which there are no previous records from the region. In both cases their occurrence in Lac Aigneau represents a considerable northward extension of their range into the Ungava watershed.

SPECIES RECORDED AT LAC AIGNEAU - 57° 15'N, 70° 8'W

Brook or speckled trout - (*Salvelinus fontinalis* Mitchill)

Three spined stickleback - (*Gasterosteus aculeatus* Linnaeus)

Northern Pike - (*Esox lucius* Linnaeus)

Arctic char - (*Salvelinus alpinus* Linnaeus)

Ouananiche - (*Salmo salar ouananiche* Jordan and Everman)

Burbot - (*Lota lota maculosa* LeSueur)

Mottled sculpin* - (*Cottus bairdii* Girard)

Longnose dace* - (*Rhinichthys cataractae* Valenciennes)

Northern lake chub - (*Couesius plumbeus* Agassiz)

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* I am indebted to Dr. W. B. Scott of the Royal Ontario Museum for the correct identification of these species, specimens of which are now in the Museum collection.

The first four species on this list, which is arranged in the approximate order of abundance, can be regarded as common while the last four are apparently infrequent.

GEORGE RIVER:

A total of 12 species of fish were collected, ten of which had previously been recorded from the George River (Legendre & Rousseau 1949, Dunbar & Hildebrand 1952). A thirteenth, the three spined stickle-back, was observed visually and the species was recorded by Dunbar and Hildebrand (1952). The two species not previously listed as occurring in the river are the round whitefish (Prosopium cylindraceum Pallas) and the mottled sculpin. This is the second record of the latter species occurring in the Ungava watershed. Surprisingly Prosopium was found to be one of the commonest species inhabiting the river and over 300 specimens were taken. Dunbar and Hildebrand consider the species to be rare in the Ungava Bay drainage and obtained only a single specimen from a native fisherman at McKay's Island on the Koksoak River. The only other record for the region is a specimen, now in the U. S. National Museum, taken by Turner in 1885, also from the Koksoak River. The apparent scarcity of this fish is possibly due to its small size. The majority of the specimens taken ranged between 18 and 26 cms., the largest being 39 cms. Fish of this size would not often be taken in the usual size of mesh gill net used by the natives in their fishing activities.

SPECIES RECORDED AT HELEN FALLS, GEORGE RIVER

65° 50' N. 58°8' W.

Atlantic salmon - (Salmo salar)

Round whitefish* - (Prosopium cylindraceum)

Longnose sucker* - (Catostomus catostomus)

Lake whitefish* - (Coregonus clupeaformis Mitchill)

Brook trout - (Salvelinus fontinalis)

Lake trout - (Cristivomer namaycush Walbaum)

Arctic char - (Salvelinus alpinus)

Slimy sculpin* - (Cottus cognatus gracilis Hackel)

Mottled sculpin* - (Cottus bairdii)

Northern lake chub* - (Couesius plumbeus)

Common white sucker* - (Catostomus commersoni LeSueur)

Northern pike - (Esox lucius)

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* I am indebted to Dr. W. B. Scott of the Royal Ontario Museum for confirming the identification of these species, specimens of which are now in the Museum collection.

The first six species on this list, which is arranged in the approximate order of abundance, can be regarded as common while the last two appear to be rare.

KOKSOAK RIVER AND LOWER REACHES OF THE LARCH AND KANIAPISKAU RIVERS:

The list for this locality is the same as that for the George River with the last three species omitted and replaced by the longnose dace (Rhinichthys cataractae), the burbot (Lota lota maculosa) and the three spined stickleback (Gastrosteus aculeatus). The six commonest species in order of abundance are: Atlantic salmon, brook trout, round whitefish, longnose sucker, lake whitefish and lake trout. These, and probably the Arctic char, can be considered common. Neither the longnose dace nor the burbot appear to be very plentiful. Specimens of round whitefish and lake whitefish taken in these rivers are now in the collection of the Royal Ontario Museum.

THE LIFE CYCLE OF THE SALMON

Salmon spawn late in the year in redds, or nests, excavated by the females in suitable locations in streams and rivers. The development of the eggs takes place during the winter and the young fry, or alevins, hatch the following spring. At first the fry are nourished by food material stored within the yolk sac and live a retiring existence hidden in the gravel in which the redd was situated. When the yolk sac has been absorbed the fry, now known as parr, begin making excursions from the bed of the river to the surface in search of food. Parr are distinguished by the presence along the flanks of 7 to 12 dark vertical finger markings with a single red spot between each. They remain in fresh water for a period of from 1 to 7 years before they transform into smolts and migrate to the sea. Smolt metamorphosis is characterized by changes in appearance as well as behaviour. The parr markings disappear and the fish becomes silvery in colour. The fins change from yellow to black, and the body becomes slimmer. Metamorphosis and migration usually occur in spring and the fish benefits from spending the following summer in the sea. Little is known of the marine phase of the salmon's life except that it occupies a period of from 1 to 4 years during which growth is extremely rapid. Following this the salmon, now nearing maturity, return to the rivers of their origin to spawn and so complete the cycle.

AGE DETERMINATION

Scales are used in the age determination of Atlantic salmon and the method has been so well established since it was first suggested by Johnston (1905, 1907, 1908 and 1910) that it is unnecessary to attempt to substantiate it further. Pyefinch (1955), in "A Review of the literature on the Biology of the Atlantic Salmon", gives a long list of references dealing with this subject.

Scales appearing during the first summer as microscopic platelets embedded in the epidermis of young salmon grow rapidly until the body is completely covered. Since the number of scales is approximately constant throughout life and the body once covered remains thus, the size of the scales, once formed, is proportional to the size of the fish. As scales grow, concentric annuli are laid down around the original platelet. The distance between these annuli varies, so that during the summer when growth is rapid they are more widely spaced than during the colder months when growth is proceeding slowly or not at all. Knowing this, and with some practice, it is comparatively easy to determine the age of a salmon from one of its scales, provided that the scale is not a regenerated one. A scale which has been accidently damaged or scraped off at any time can be recognized by the scar tissue in its centre. Scar tissue quickly replaces a lost scale and only when the proper size has been attained are annuli laid down around its edge. When adult salmon spawn the edges of their scales become eroded. The reasons for this are not properly understood but it is undoubtedly connected with the strain of reproduction. Should a salmon survive a spawning its eroded scales are repaired but a characteristic scar or spawning mark remains. (Figure 5). In this way it is possible to determine whether a salmon has spawned and, if so, on how many occasions.

FIGURE 5. A salmon scale bearing a spawning mark. The fish from which this scale was removed had a parr life of 4 years duration, spawned in the autumn of its 7^{th} year and was 8 ? years old at the time of capture.

THE AGE AND GROWTH OF THE PARR AND SMOLTS GEORGE RIVER:

An examination of the scales of the migrating smolt population revealed that five age groups were present among them. They varied from 3 to 7 years old, with the 4 and 5 year old groups predominant. In spite of the wide range of ages the mean length at migration is approximately the same in all age groups, namely 21.5 cms. This reveals the rather unexpected fact that the young salmon are able to maintain widely different growth rates although all inhabit the same river. It also means that in an analysis of the growth of the juvenile population these differences cannot be overlooked. If a growth curve for the parr is computed in the normal manner from the mean lengths of each age of fish it indicates that the growth rate declines rapidly with increasing age (Figure 6). The reasons for this are two-fold. Firstly the fastest growing 2 year old parr migrate as 3 year old smolts and hence are no longer present in the population. The same happens with the fastest growing 3, 4 and 5 year old parr so that the older age groups among the parr are composed increasingly of slow growing fish. Secondly an error in sampling affects the curve because in the younger age groups the faster growing, and therefore the larger fish, are more likely to be caught by the methods employed.

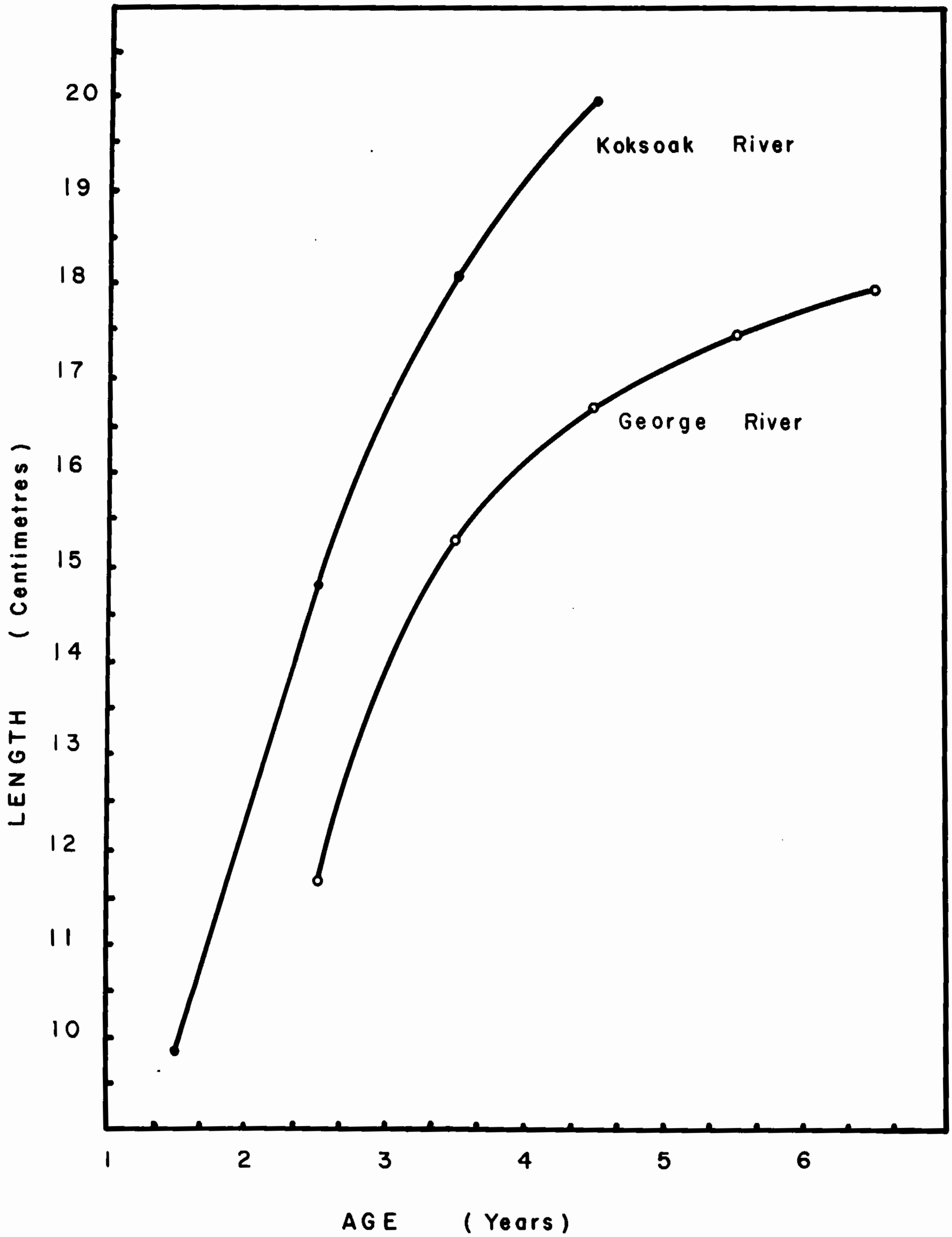


FIGURE 6. The apparent decline in growth rate of salmon parr, from the Koksoak and George Rivers, with increasing age.

In an attempt to overcome these errors and present a truer picture of growth during the juvenile stages, growth curves have been calculated by taking 'back measurements' from scale samples of the migrating smolt and adult populations.

The theory underlying these 'back measurements' is as follows. If the size of the scales maintains a constant ratio to the size of the fish, then it is possible to calculate the length of a fish when its scales were a fraction of their present length. In practice no calculation is necessary. The image of the fish scale under investigation is projected onto a flat surface and a narrow strip of stiff white paper is placed over the image parallel to its central axis. The positions of the tip of the scale, each winter band and the central platelet are marked off along the edge of the strip. By placing this strip on the correct position on a previously prepared scale, the length of the fish when each winter band was laid down can be read off directly (Figure 7). As a precaution this was carried out on two scales from each fish and excellent agreement was found between both estimates.

In Table 1 the results of these 'back measurements' carried out on scales from the migrating smolt population are given. The males and females have been treated separately, but, as can be seen, no apparent difference in growth exists between the two sexes. This result is in agreement with the findings of Jones

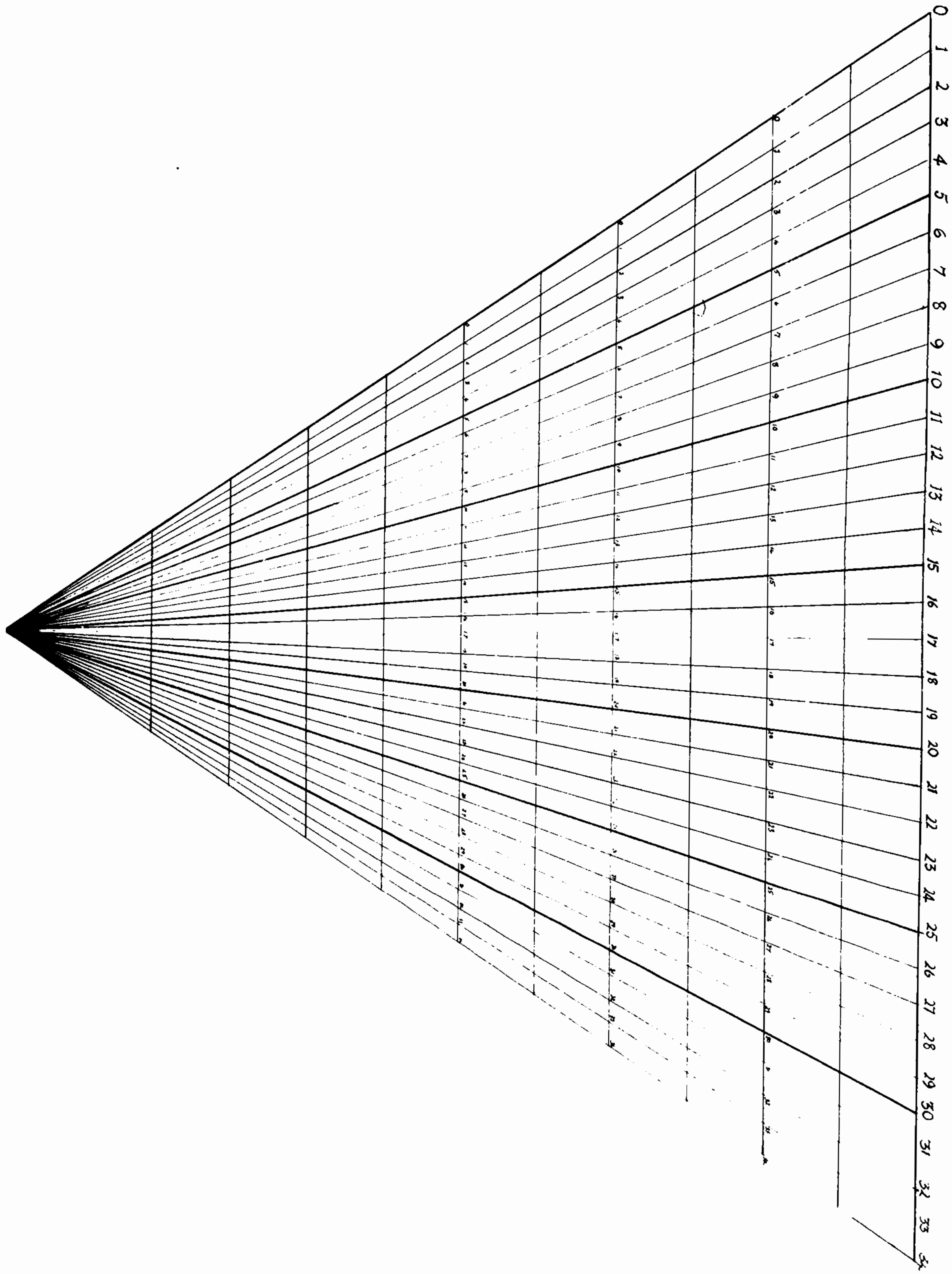


FIGURE 7. Scale used for making 'back measurements' of the scales from salmon parr and smolts.

Table No. 1

PARR GROWTH IN THE GEORGE RIVER AS BACK-CALCULATED FROM SCALES OF MIGRATING SMOLTS

			Calculated mean length (cm.) at completion of each winter band. Figures in ( ) are for a partially complete year's growth.							
AGE	SEX	NO. OF SPEC.	1	2	3	4	5	6	7	
3+	♂	4	7.25	12.40	17.60	(20.5)				
	♀	12	6.54	11.20	16.75	(22.12)				
4+	♂	22	5.75	9.98	14.18	18.66	(21.11)			
	♀	25	5.80	9.96	14.14	18.38	(21.04)			
5+	♂	32	5.00	7.92	11.58	15.31	19.10	(21.28)		
	♀	51	5.10	8.26	11.89	15.52	19.26	(21.18)		
6+	♂	6	5.00	8.00	10.58	13.91	17.0	20.16	(22.91)	
	♀	17	4.80	7.73	10.76	13.67	16.82	19.94	(21.71)	
7+	♂	3	4.83	7.16	9.66	12.33	14.83	17.33	20.16	(22.83)
	♀	3	4.66	7.16	9.66	12.33	15.00	17.83	20.66	(22.83)

(1949) for smolts from the River Dee in England.

Caution must be exercised in estimating the accuracy of results obtained by these methods. To be reliable, the spread of the growth curves for the different aged smolts should correspond with the observed spread in the sizes of different aged parr. Unfortunately this sort of comparison can only be done tentatively as the parr, when collected, are actively growing. Taking the 3 year old parr as an example, specimens taken early in the summer have completed only a small portion of their fourth summer's growth, while those taken at the end of the season may have terminated it. The close agreement between the back calculated growth curves of the smolts and the length-frequency distribution of the parr is shown in Figure 8, in which, in order to compensate for the partial year's growth completed by the parr, their ages have been increased by half a year. It is interesting to note that the 4 year old parr in this figure show a bi-modal length-frequency distribution and that the two modes correspond closely with the back calculated sizes of 5 and 6 year old smolts half way through the fourth year.

Another estimate of the reliability of the results is obtained by comparing the back calculated growth curves of the juvenile population, derived from the smolt sample, with that derived from the adult sample. In Figure 9 these are compared graphically.

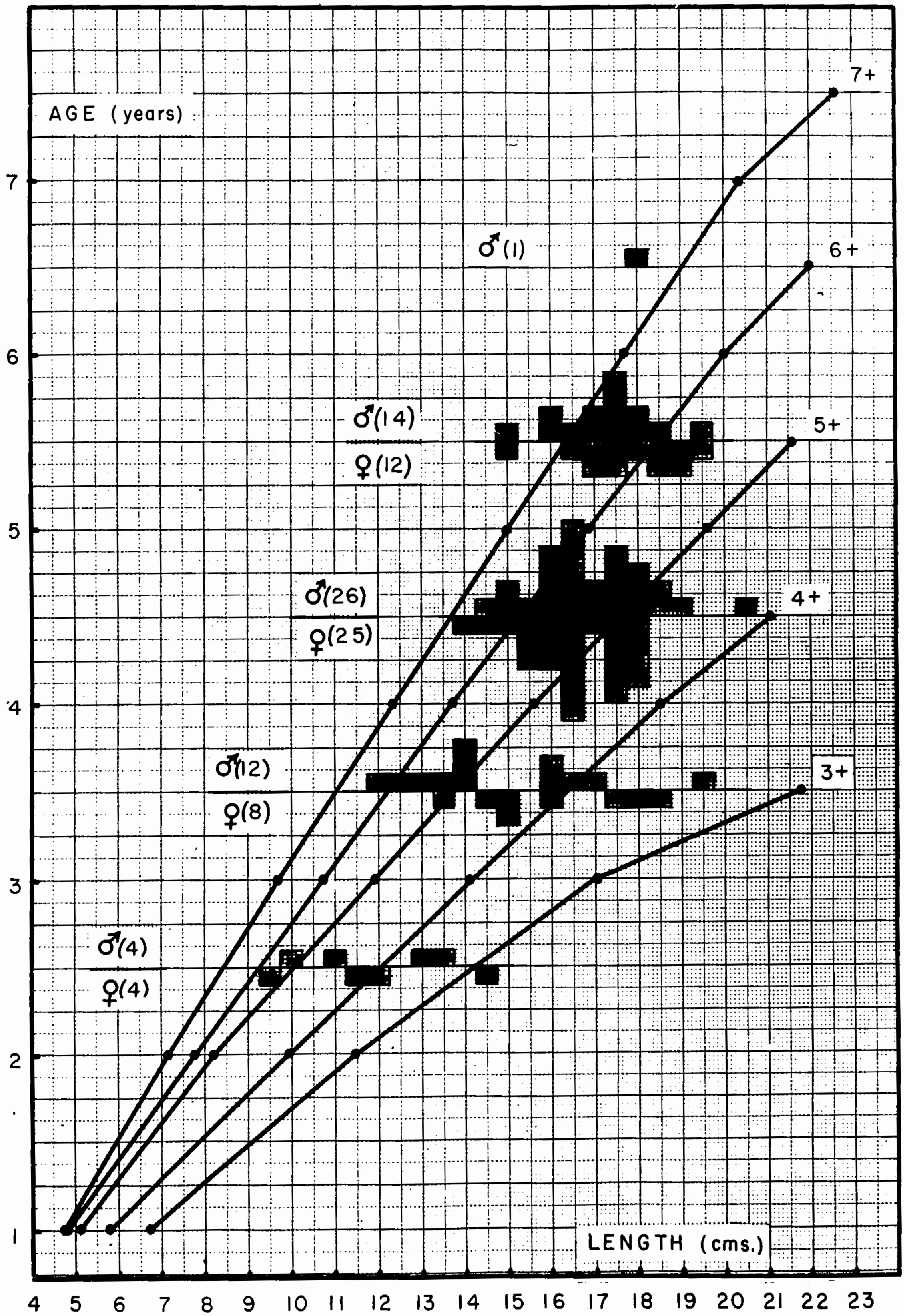


FIGURE 8. The back calculated growth curves of smolts and the length-frequency distribution of parr from the George River.

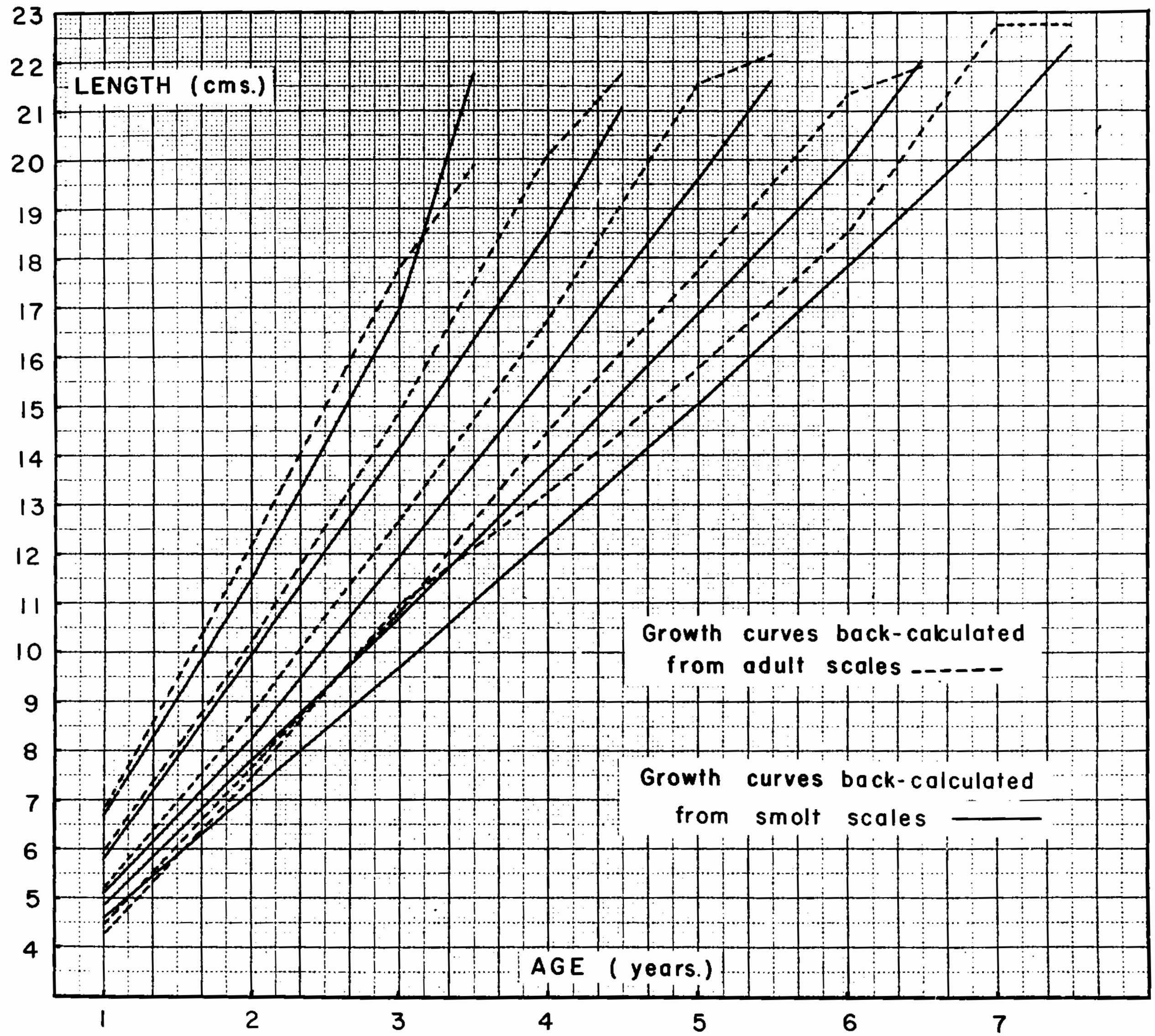


FIGURE 9. A comparison between the growth curves of young salmon in the George River, as 'back calculated' from the scales of smolts and adults.

As can be seen from the figure there is good agreement between the results obtained from the two sources. The results from the adults indicate that there is little river growth in the year of migration, but this may be an artefact due to difficulty in determining the exact point on the scales where river growth ended and sea growth began. Similarly the slightly higher estimates of length at a given age obtained from the adult scales would result if some erosion of the scales had taken place. The number of sampling and biological errors possible in these results unfortunately make the application of statistical tests to the data insufficiently reliable. However, the close agreement between the growth curves derived from the smolt and adult scales and the way the size ranges of the parr overlie these curves indicate that in all probability the results are of value and represent a close approximation to the true facts.

KOKSOAK RIVER AND LOWER REACHES OF THE LARCH AND KANIAPISKAU RIVERS:

The methods used for the analysis of growth during the juvenile stages in the George River have been applied here. Unfortunately the sample of the migrating smolt population is too small to be of much value. Only 17 smolts were taken during July from the lower reaches of the Koksoak and these probably represent the wake of the main migration. These smolts ranged in age from 3 to 5 years. Examination of the scales of adult salmon revealed that the age at migration of smolts from the Koksoak and its tributaries is between 3 and 6 years and, as was found in the George River, the 3 year old migrants maintain a growth rate that is considerably greater than that of the 6 year olds. As was pointed out previously, in an analysis of parr growth these variations must be considered. For the Koksoak material, because of the small size of the smolt sample, this can only be done by back calculation from adult scales, and the reliability of the growth curves thus obtained can be estimated by comparing them with the length-frequency distribution of parr of different ages, as has been done in Figure 10. The close agreement between the two indicates that the calculated curves offer a reliable indication of growth during the parr stages.

POSSIBLE REASONS FOR THE DIFFERENT GROWTH RATES SHOWN BY THE PARR

Having established that the parr in the George and Koksoak Rivers can grow at different rates, the question is raised as to how these rates are established and maintained and whether differences are still apparent after migration? It is possible that growth may be more favourable in one stretch of the river than in another; however, if this occurs, the parr collected in any one locality should all maintain similar growth rates. This is not so. Parr collected at Helen Falls, George River show a range of sizes sufficient to

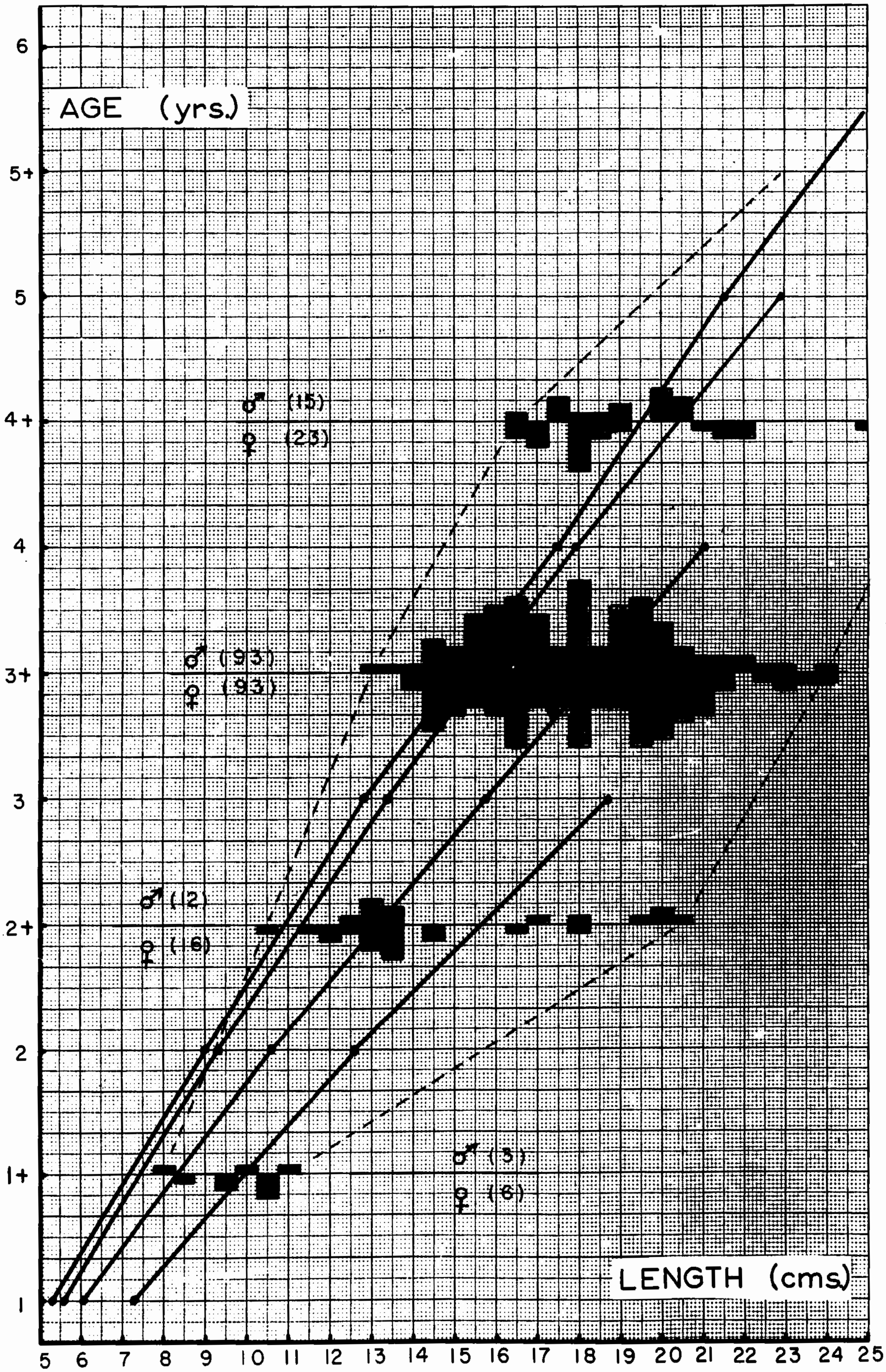


FIGURE 10. Growth of young salmon in the Koksoak River as 'back calculated' from the scales of adults compared with the length-frequency distribution of Koksoak River parr.

enable them to be growing at all rates from the slowest to the fastest.

Dahl (1918) describes work which has been carried out in Norway on factors affecting the growth rate of the brown trout, (*Salmo trutta*), indicating that faster growth is maintained in fry hatched from larger eggs. Since then other work has been published on the subject but the results appear to be conflicting. Higgs (1942) described experiments on the growth of Kamloops trout, (*Salmo gairdnerii*), which tended to confirm Dahl's findings. Alm (1939), working on the brown trout, found that only under uncrowded conditions did the larger fry grow better than the smaller. The eggs of salmon differ in size and Dahl (1915) records the following range of sizes in fertilized salmon ova from a Norwegian hatchery:-

Diameter of ova	% Frequency
5.0 mm.	1
5.5 mm.	10
6.0 mm.	22
6.5 mm.	47
7.5 mm.	20

If different growth rates are initiated in different sizes of ova, and are maintained, this may explain the discrepancies in the growth rates of the parr.

RATE OF GROWTH DURING THE GROWING SEASON

Attempts to demonstrate growth by comparing the means of samples taken at different times during the summer proved impossible owing partly to a lack of specimens taken early in the season, before growth had begun, and because of the complex nature of the growth patterns. The growth of the scales can, however, be followed throughout the complete cycle and, if growth of the scales is indicative of growth of the fish, then the growing season can be determined.

In this region summer growth rings first appear on the scales in July. In 1956, which was an unusually late season, on approximately 50% of the scales from fish caught on the 21st, 22nd and 25th of July summer growth rings were visible. In 1957, a more normal season, all the scales from fish taken at the end of July showed summer growth at their margins and in a few this zone was quite wide. Once growth has commenced, the addition of summer growth rings to the scales takes place very rapidly until by the end of August the scales have, in many instances, completed the summer growth. From then on the annuli are added more closely together so that scales taken in September may resemble July scales on which no summer growth is visible. It is very probable that the fish themselves have a comparable growth pattern.

Allen (1940, 1941 b and 1944) has shown a similar, though rather extended, growth pattern in salmon from the Eden and Thurso

River systems in Great Britain. He considered temperature to have a critical influence on the activity of young salmon. His observations suggested that 7°C. was the critical temperature, above which the salmon leads an active existence and below which they remain quiet. The rise from below to above this temperature in spring marked the commencement of feeding and rapid growth, and falling of the temperature to below this value in autumn marked the end of the period of growth for the year. With the information available it is not possible to state with certainty whether these considerations apply to Ungave salmon. If the growing season corresponds to the cycle of growth shown by the scales, then it is probable they do; however, in many instances animals living under cold conditions show some degree of adaptation which enables them to maintain their activity at lowered temperatures. Taking 7°C. as the critical temperature, the growth season of the Ungava salmon is restricted to between 10 and 14 weeks. Even with adaptation, the growing season is not likely to be extended greatly because of the high rate at which the temperature rises in spring and falls in autumn. (See Figure 4)

Considering 14 weeks to be the growing season and the growth of 4 and 5 year old smolts as typical of the region, the rate of growth throughout this period is estimated to be 1.1 cms. per month or .039 cms. per day in the George River and 1.4 cms.

per month or .050 cms. per day in the Koksoak. Allen (1941 b.) gives figures for the rate of growth between June and August in the Eden and Thurso River systems which vary between .032 and .040 cms. per day. (One figure for the first year's growth in Sinclair Burn, Thurso River is less, being .016 cms. per day). One must conclude from these figures that although the annual growth increments shown by the Ungava salmon may not be large, their growth rate during the growing season is at least as high, and in some instances higher than that of their southern counterparts. This ability to grow rapidly during a brief summer is one aspect of adaptation to environment which tends to compensate for the brevity of the growing season.

SMOLT METAMORPHOSIS AND MIGRATION

METAMORPHOSIS AND MIGRATION:

The typical pattern of smolt metamorphosis and migration in Atlantic salmon has already been described. Metamorphosis occurs early in the spring and the smolts migrate to sea during the same season. In the north the spring is apparently too brief for all this to be accomplished and so the pattern is modified.

In the George and Koksoak Rivers metamorphosis takes place throughout the summer and smolts can be taken at all times of the year. The main seaward migration, however, occurs in July, which is spring in these latitudes. Evidence that 'smoltification' may take place throughout the summer is obtained from the fact that throughout the summer a number of fish can be taken intermediate in appearance between parr and smolts. Unfortunately it is not possible to measure precisely the degree of change and, in the case of doubtful specimens, individual opinions would differ as to what was and what was not a smolt. The metamorphosis involves behavioural as well as morphological changes. There is a gradual development of a silvery colouration due to a subcutaneous deposit of guanin which obscures the characteristic finger markings of the parr. When some of the scales are scraped off, as often happens when the fish are taken in gill nets, the parr markings become visible once more. Allen (1944), in assessing the degree of smolt development, made use of changes in the colour of the pectoral fins from the characteristic yellow of the parr to the black of the smolt, these changes being more easily measured than the degree of development of the silvery coat.

At Manitou Gorge in the Kaniapiskau River large shoals of partly metamorphosed parr and smolts were encountered in late August and September. These shoals consisted mainly of 3 year old fish with a few 2 and 4 year olds present. It is interesting that the mean length of the 3 year old fish in these shoals is significantly larger than the mean length of 3 year old fish in other parts of the Koksoak system; 19.5 $\pm$ .17 as against 16.2 $\pm$ .20 in the tidal rapids and 17.1 $\pm$ .44 in the Larch River. This is not unexpected since only the largest and fastest growing 3 year old fish will migrate as 4 year old smolts.

There was a noticeable lack of younger parr in the Manitou Gorge and, since these shoals were absent earlier in the year, it appears that parr, which metamorphose during the summer, begin to form shoals in the upper reaches of the river during the autumn prior to the year of migration. Although a number of smolts were taken in September in the Larch River no large shoals were encountered similar to those just described from Manitou Gorge. It is possible that the smolts which form shoals in September migrate in the autumn as has been described for a river in Scotland by Calderwood (1906); however, there is no evidence for this. The percentage of smolts in the catches of juvenile salmon at Helen Falls, George River, during the spring migration was approximately 90%. During the first week in August it fell to 40% and remained at that level until September 8th when fishing ceased. Fishing that was carried out on the 15th of September at the upper limit of tidal influence on the Koksoak failed to reveal any smolts. Finally the Eskimos, who are well aware of the spring smolt migration, have no knowledge of any similar migration in the fall.

FACTORS AFFECTING THE MIGRATION:

Considerable attention has been directed towards elucidation of the factors responsible for initiating smolt migration. Temperature, Hoar (1953), White (1940); the presence of freshets after local rainfall, Bull (1931 a, b), Berry (1932), (1933), Allen (1944); light and storm conditions have all been considered sources of migratory stimuli. Temperatures in the Koksoak and George are sufficiently high (above 12°C.) in July for migration; but factors such as freshets are probably of minor importance and are overshadowed by the effects of the spring run-off. Of a different nature, recent work by Hoar (1953) and Fontaine (1954) has stressed the importance of the neuro-endocrine changes which accompany metamorphosis and alter the internal environment of the fish in response to, or in anticipation of, migratory stimuli.

A number of fish were caught in the George and Larch Rivers which appear to have failed to migrate upon attaining a suitable size; for example specimens 29.5, 32 and 36 cms. in length taken in early August in the George River and similar in appearance to normal smolts. Back calculations on the scales of these fish indicate that they attained a suitable size for migration during the fourth summer (ie; 3+ years) in the case of the 36 cm. fish, and during the fifth summer (ie; 4+ years) in the case of the other two. All were in their sixth summer at the time of capture. Similarly a fish taken in the Larch River 29 cms. in length, and possibly two others 27 cms., appear to have remained in freshwater longer than necessary. Power (1958) has suggested that, in salmon populations exposed to severely cold climatic conditions, the development of a susceptibility to migratory stimuli may be retarded more than is the development of sexual maturity and populations which contain a relatively high percentage of fish maturing prior to migration may result. If these forms become isolated in any way from the migrating forms, populations of freshwater (landlocked) salmon can arise.

When the migrating smolts enter Ungava Bay in July and early August they encounter very low temperatures. The temperatures recorded by the "Calanus" (Dunbar 1951 and personal communication) at Station 41, 50 miles north of the George River in August 1947 were 3.4°C. surface, 2.6°C. at 20 metres and 0.5°C. at 50 metres. In July the temperatures are even lower, being between 1° and 2°C. at 20 metres and rising to a maximum at the surface of perhaps 1.5°C. above this. What effect exposure to such low temperatures has on the migrating smolts or how it effects their chances of survival is not known.

SIZE AND AGE AT MIGRATION:

This has already been mentioned briefly in the section dealing with the age and growth of the parr and smolts. Information is available from two sources, actual samples of the migrating smolt population and samples of the adult population. Since the age composition of salmon populations is relatively stable, information from the two sources in respect to the ages of smolts at migration should be supplementary. In Table 2 the ages and sizes at migration of the George River smolts, as estimated from samples of the migrating smolt and adult population, are compared with similar data for the Koksoak River smolts.

It is a well established fact that the age at migration of salmon smolts varies with the latitude.* In the south, parr life is short, 1 year often being sufficient for the young salmon to attain the smolt stage. The length of parr life increases towards the north

* In this discussion the word latitude is used loosely and by it is implied lines connecting places of the same mean summer temperature.

Table No. 2

The length at migration of smolts from the George and Koksoak Rivers as estimated from samples of the migrating smolt population and calculated from scales of Adult salmon. Numbers in ( ) indicate the size of each sample.

AGE AT MIGRATION	LENGTH AT MIGRATION (cms.)			
	GEORGE RIVER		KOKSOAK RIVER	
	Smolt Sample	Calc. from Adult Scales	Smolt Sample	Calc. from Adult Scales
3	21.8 (16)	19.9 (8)	21.3 (11)	18.6 (16)
4	21.1 (47)	21.8 (35)	21.3 (5)	21.1 (61)
5	21.6 (86)	22.1 (52)	20.5 (1)	22.9 (21)
6	22.0 (23)	22.0 (12)		26.0 (3)
7	22.3 (6)	24.2 (2)		

so that very often 3 or 4 years are spent in the rivers prior to metamorphosis and migration. This increase is seen in its extreme development on the George River where the average age at migration of the smolts is between 4 and 5 years and parr 7 years old are not rare. Conditions in the Koksoak are apparently not so unfavourable and the age at migration, as estimated from the adult scales, is significantly less than in the George.

Mean age at migration in the Koksoak River = 4.11

Mean age at migration in the George River = 4.68

$$t = \frac{\bar{x} - \bar{x}'}{\sqrt{\frac{S(x - \bar{x})^2 + S(x' - \bar{x}')^2}{n_1 + n_2}}} \qquad \sqrt{\frac{(n_1 + 1)(n_2 + 1)}{n_1 + n_2 + 2}}$$

(Fisher 1954)

$= 5.4$ $\qquad n = n_1 + n_2 = 210$

$\therefore$ P is less than .001

This conclusion upholds the opinion expressed earlier that the growth rate of the parr is higher in the Koksoak than in the George River.

Although the age at migration varies with the latitude no similar correlation with size at migration has been described. Previous workers have paid a great deal of attention to the problem and their results indicate that size at migration is independent of latitude, at least over short distances. Pentelow et al. (1953)

regard the attainment of a certain physiological condition, which is connected with size, necessary before parr transform into smolts. Jones (1949) is of the opinion that growth rate is the most important factor in determining the age at which smolts migrate. Fish with a high growth rate migrate younger and at a lower minimum size than those that grow more slowly. Allen (1944), in discussing the migration of smolts in the Thurso River, agrees that size is important, but only indirectly inasmuch as it reflects the physiological condition of the fish. Elson (1957), in attempting to reconcile all opinions, suggests that the critical size factor is not the size of the smolts during migration but the size they had attained at the end of the previous summer. He suggests that in general parr which reach 10 cms. or more in length at the end of the summer will migrate the following spring. Variations in the lengths of smolts from river to river are accounted for by differences in the amount of growth shown in the year of migration and by the extent to which the parr had surpassed the 10 cms. length by the end of the previous year. Although Elson's suggestion is applicable to the date at present available, it cannot be applied to either the George or Koksoak Rivers as the majority of the parr in these rivers do not migrate until 2 or 3 years after they attain 10 cms. in length.

Probably the safest approach to the problem of smolt size at migration is to state that it is a function of the size at birth, the age at migration and the annual growth rate. The age at migration and the growth rate are influenced by many factors, some of which can be broadly correlated with latitude. In the form of an equation:-

$$L = L_b + R_1 + R_2 ------ R_A$$

Where L = the length at migration

L_b = the length at birth

A = the age at migration

R_1, R_2 etc. are the growth increments during the 1st., 2nd. and subsequent years.

A is known to be roughly correlated with latitude although the actual physiological mechanisms which regulate it are unknown and therefore cannot be evaluated at present.

R, is determined by 2 factors:-

(1) The length of the growing season which can be correlated with latitude.

(2) The rate of growth during this period which is affected by many variables, eg: the abundance of food, the intensity of competition, the temperature regime, many of which on any given meridian are latitude dependent.

With such a complex set of variables it is unlikely that a simple relationship exists between them. Both A and R are influenced by the latitude, but in opposite directions. Since L is a function of both A and R over short distances, an increase in one will tend to be offset by a decrease in the other, and variations in L between one river and another are attributable to factors which determine the seasonal growth rate.

In the George and Koksoak Rivers the shortness of the growing season is partly compensated for by a high seasonal growth rate and, where this occurs, L increases in a manner comparable with the increase in age at migration (A). If this condition is typical of rivers of the northern fringe of the range of the salmon, then it should be possible to demonstrate a correlation between length, (as well as age) at migration and latitude, provided sufficient of the range is included.

THE AGE AND GROWTH OF THE ADULT SALMON

The adult salmon can be divided into three groups; the grilse, which have spent the summer of the year of migration, one winter and most of the following summer at sea before returning to spawn; the small summer fish which have spent an additional winter and part of the following summer at sea before returning; and finally, fish which have previously spawned. Of these groups the second is by far the largest, comprising 87.9% of the total of 124 fish from the George River and 88.5% of the total of 113 fish from the Koksoak. The grilse are probably not well represented in the totals as many of them would not be caught in large mesh gill nets. This is particularly true of the size of net used by the Eskimos. In a sample of 102 salmon taken by native fishermen at Fort Chimo in 1957 no grilse were present.

The sizes and weights of the various classes of adult salmon are given in Table No. 3. No significance should be attached to the slightly larger size of the Koksoak salmon. This is the result of a sampling bias, most of the Koksoak salmon being caught by native fishermen who employ larger mesh nets than were used at George River.

The most interesting observation that can be derived from the figures is that the marine growth of Ungava salmon is as rapid as that of salmon from more temperate regions. In Table No. 4

Table No. 3

SIZES AND WEIGHTS OF ADULT SALMON FROM THE GEORGE AND KOKSOAK RIVERS

	GEORGE R.		No.	Lgth. cm.	Lgth. Range	Wt. lb.	Wt. Range
MALES	Grilse	(1+)	8	58.8	54.0-65.0	4.1	3.50-4.75
	S. Summer	(2+)	26	78.8	70.0-89.5	10.84	8.00-14.0
	P. Spawned						
	once		2	87.8	81.5-94.0	14.4	11.25-17.5
	twice		1	98.0		14.5	
FEMALES	Grilse	(1+)	1	55.5		4.5	
	S. Summer	(2+)	83	78.7	72.0-85.0	11.4	8.75-14.5
	P. Spawned						
	once		3	88.5	85.5-92.0	16.3	15.50-17.5
	KOKSOAK R.						
MALES	Grilse	(1+)	5	62.0	53.0-69.0	5.4	3.50-6.25
	S. Summer	(2+)	17	82.4	68.0-88.5	13.0	6.00-16.5
	P. Spawned						
	once		5	80.4	71.0-86.0	14.0	8.0 -17.75
FEMALES	Grilse	(1+)	-				
	S. Summer	(2+)	84	81.8	71.0-89.0	13.4	8.0 -16.0
	P. Spawned						
	once		2	91.8	89.0-94.5	18.6	18.0 -19.25

Table No. 4

LENGTHS OF 2-YEAR SEA-LIFE SALMON FROM

VARIOUS LOCATIONS IN CANADA AND EUROPE

Locale & Authority	No. of Spec.	Years at sea	Mean Lgth. (cm.)	Stand. Deviat.	Age at Migration
George R. (1956)	109	2 +	78.7	3.767	4.68
Koksoak R. (1957)	101	2 +	81.9	3.982	4.17
(Blair 1943) Hamilton Inlet	112	2 +	75.8		4.44
South tip Labrador	306	2 +	73.9		4.70
South tip Nfld.	114	2 +	71.8		3.21
(Belding & Prefontaine 1938, 1939) Miramichi R.	639	2, 2 +	77.31	3.288	3.03
Bay of Chaleur	1951	2, 2 +	79.68	4.968	3.75
Port aux Basques	530	2, 2 +	78.52	3.223	3.27
(Jones 1953) Derwent England	179	2 +	84.0		2.01
Dee England	779	2 +	80.0		1.98

Table No. 5

MEAN LENGTHS OF SMALL SUMMER FISH COMPARED WITH THEIR AGE AT MIGRATION

George River	Age at Migration				
	3	4	5	6	7
No. examined	8	35	52	12	1
Mean length cm.	79.3	79.7	78.3	77.5	74.5
Koksoak River					
No. examined	16	61	21	3	-
Mean length cm.	82.0	82.4	80.6	80.5	-

the mean lengths of 2 year sea-life salmon from various localities are compared with those of the George and Koksoak Rivers. The data given by Belding and Prefontaine (1938, 1939) are not strictly comparable as their means include small spring (2), as well as small summer (2+) fish. Despite this it can be seen from the table that the mean lengths of two year sea-life salmon from all regions are reasonably consistent. However abundant the food supply is in Ungava Bay, the extremely low temperatures make it unlikely that salmon could maintain a high growth rate within the bay and in all probability they migrate elsewhere. Menzies (1949) suggests that salmon from both sides of the Atlantic frequent a common feeding ground somewhere in the north Atlantic. Slight differences in the mean lengths of salmon from various localities are due to the distance of the locality from the feeding ground and the date of migration. These observations on the growth of Ungava salmon indirectly support Menzies' theory.

A question that was raised earlier was whether the differences in growth rates apparent among the parr are maintained after migration. In Table No. 5 the small summer fish have been divided into groups on the basis of their age at migration and the mean length of each group calculated. The differences in the means are insignificant in all except one instance. The difference in the mean length attained by small summer fish in the Koksoak which migrated after 4 years and that attained by those which migrated after 5 years gives a probability value of less than .1 according to Fisher's test, (Fisher 1954). The discrepancies between the means, however, are much less than would be expected had the variations in growth rates of the parr been maintained during the sea life.

UPSTREAM MIGRATION OF ADULTS, SPAWNING AREAS AND REPRODUCTIVE POTENTIAL

The information available, Turner (1885) and Dunbar and Hildebrand (1952), on the spawning migration of the Ungava salmon indicates that the runs are variable. Salmon usually enter the rivers during the first few weeks in August, seldom are they seen before the 24th of July and occasionally the run does not begin until the 20th of August. Local factors, such as the state of the tides, seem to influence the actual date, salmon normally entering the rivers at the spring tides.

GEORGE RIVER:

The salmon run in 1956 was exceptionally late. Although a few fish entered the George River around the 1st of August, it was not until after the 20th of August that the main run entered the river. According to local reports, the late arrival was due to the steady northerly winds which had been blowing most of July and August and had kept Ungava Bay choked with ice. The bad ice conditions in the bay in 1956 are amply verified by the fact that the Hudson's Bay Company supply ship arrived at Fort Chimo over six weeks late, having been delayed by ice. The salmon apparently will not travel under ice and, in a year like this, the arrival of the run is delayed until the ice moves out of the bay. Since salmon normally appear to travel near the surface, it seems reasonable that they may be delayed in this manner; it should be added, however, that 1956 was also a late season in many other respects. The entrance of the main run into the river coincided with the spring tides between the 22nd and the 25th of August. Once in the river the salmon moved upstream quite rapidly. Most of the fish taken at Helen Falls still had sea lice clinging to them and had tape worms in their gut, which indicates they had been feeding not very long before. Helen Falls represents a considerable obstruction to the upstream migration of salmon in the George River. Fish can ascend the falls on the east bank of the river, however on the opposite side the fall is insurpassable at one point. During the height of the run, around the 26th of August, large shoals of salmon were visible in the pools and eddies along the edges of the falls and, although the numbers decreased, in September many were still present.

The maximum distance salmon can ascend the George River is probably limited by the falls at Lat. 55^{o}37' N. some distance beyond Indian House Lake. The only major tributary of the George below this is the Ford River, a very cold, clear river falling from the high ground to the east in Labrador, of which only the lower 12 miles or thereabouts are accessible to salmon. Ignoring all the small tributary streams, which salmon probably do not ascend, about 275 miles of river are available for salmon reproduction, an area comparable to that available in the St. John River, New Brunswick.

KOKSOAK RIVER:

In 1957 the main salmon run entered the Koksoak about August 10th and the majority of the fish were above Fort Chimo by August 30th. Twenty days is an average duration for the salmon run at Fort Chimo. It is possible a few fish enter the river earlier in the year than has previously been realized: for example a fresh-run 6-1/2 lb. grilse was taken on July 9th at Manitou Gorge. It is also probable that during September small numbers of fish migrate up the rivers, indeed such a run was recorded in 1948 by Dunbar and Hildebrand (1952).

The rate at which salmon travel up the Koksoak is not known. There are no falls or other serious obstructions to impede progress and as fish were taken in the Larch River still bearing sea lice the first 100 miles can probably be covered in less than a week. The area of the Koksoak system that is accessible to salmon is not precisely known. Salmon can only run up the lower 20 miles of the Kaniapiskau River whereas they can travel probably 150 miles and possibly farther up the Larch. As for tributaries of the Larch, the River Aigneau is of negligible importance, containing few salmon which are restricted to the lower reaches. How much of the Rivère du Gue is available is not known, but, as was mentioned previously (page 10), this may contain some of the most important spawning areas of the Koksoak salmon. Its tributary, the Clearwater River, contains 12 miles of excellent spawning grounds before it is blocked by a 40 foot high fall. A conservative estimate of the total number of miles of river accessible to salmon in the Koksoak system is 300 miles, a length slightly greater than is available in the George River.

PERIOD OF SPAWNING:

The date when spawning commences is not known, but it is unlikely to be before the end of September. Females examined during early September had ovaries which varied from being one half to three quarters enlarged. In no instance were they so near spawning that the eggs were beginning to loosen from the mesentries. The males, on the other hand, lagged considerably behind the females in maturity. In a number of specimens the testes had hardly begun to enlarge and even in the most advanced males the gonads were barely one half enlarged. By contrast, the male parr which were mature were considerably advanced and had, in many cases, fully enlarged sexual organs, although none were taken which had milt running.

REPRODUCTIVE POTENTIAL:

In order to ascertain the reproductive potential of the females, 25 complete sets of ovaries from fish taken in the George River were collected and preserved in 5% formalin. These were later examined in detail as follows: The ovaries from each fish were weighed, individually and together, after removal from the preservative and drying on a soft cloth. At least one tenth of each ovary was then removed and these samples were weighed and counted. Fifty eggs were selected at random from the sample and, after having been placed in rows of ten, each row was measured and an estimate of the diameter of the eggs in the ovaries was obtained. As the counts were made on females which were nearing maturity and had fairly large sized eggs in their ovaries, it is hoped they represent fairly accurately the number of eggs which would have been shed by these fish and errors, owing to the inclusion of atretic eggs in the counts (Vladykov 1956), are not too great. The results of the counts are given in Table 6. As was found by Jones and King (1946 and 1949), the number of eggs produced per pound of fish appears to bear little relationship to the size of the fish. The range in number of eggs per pound in the 12 fish dealt with by Jones and King (1946) was 419 to 770. Calderwood (1930) estimated that a grilse (fish under 6 pounds) and a 12 pound salmon produces 500 and 800 eggs per pound respectively. Allowing for the fact that the George River fish were not quite ripe, the range of 475 to 1,400 eggs per pound seems to be of a similar magnitude. By eliminating the fish with eggs less than 3.00 mm. in diameter, these being presumably the least ripe, the range is reduced somewhat.

It had been hoped that it would be possible to test whether there was any significant variation between the reproductive potential of the Ungava salmon and those of more temperate regions. The variability of the counts and the fact that the fish were not completely ripe makes such comparisons unwise.

DOWNSTREAM MIGRATION OF KELTS:

Information on the return movement of the spent salmon, or kelts, is scarce. The natives appear to have little or no information to offer except that they usually take a few 'slinks' in their nets every spring after break-up. One kelt was taken in the George River below Helen Falls on August 1st and native fisherman downstream reported catching one or two 'slinks' in late July. The lack of information on the movement of the kelts is obviously related to the difficulties involved in winter and spring fishing in the region.

Table No. 6

REPRODUCTIVE POTENTIAL OF GEORGE RIVER SALMON

Weight (lbs.)	Length (cms.)	Ovary Wt. (grams)	Egg Dia. (mm.)	No. of Eggs per lb.	Total Egg Count
4.5	55.5	84	2.56	1,400	6,304
9.0	72.0	92	2.36	967	8,699
9.25	75.5	220	3.38	962	8,898
10.0	76.0	243	3.78	599	5,995
10.0	76.0	394	4.26	911	9,112
10.0	77.0	244	3.36	943	9,427
10.0	75.0	306	3.30	1,088	10,887
10.5	78.5	191	3.60	521	5,474
10.5	77.0	329	3.98	695	7,294
10.5	76.5	208	3.24	825	8,659
10.5	77.5	171	2.66	1,096	11,510
11.0	79.5	327	3.80	720	7,921
11.0	80.0	337	3.68	771	8,471
11.0	79.0	286	3.38	953	10,486
12.0	80.0	230	3.72	475	5,698
12.5	80.0	364	3.88	724	9,046
13.0	83.5	319	3.96	498	6,470
13.0	81.5	291	3.50	765	9,968
13.0	83.0	406	3.90	826	10,739
13.0	81.5	363	3.66	832	10,815
13.5	82.0	351	3.94	540	7,290
14.0	80.0	344	3.66	667	9,332
14.0	82.0	399	3.80	693	9,702
14.0	85.0	738	4.34	895	12,530
14.5	84.5	480	3.92	723	10,476

WEIGHT - LENGTH RELATIONSHIP

The condition factor is a factor which expresses the relationship between the weight and the length of a fish numerically and is useful in comparing fish from different localities. The factor for salmon approximates to unity when the units of weight and length are grams and centimeters. It is greater for a fish which is heavy in comparison to its length and conversely smaller for a slim fish. The formula used to calculate it is:-

$$\text{Condition Factor (K)} = \frac{100 \times W}{L^3}$$

(coefficient of condition)
(coefficient of fineness)

Where W = the weight in grams
L = the length in centimeters

In temperate regions the factor is likely to change with the season, fish normally being thinnest early in spring and fattest in late summer and fall. Unfortunately such seasonal changes could not be demonstrated in the material available. This is because the majority of the specimens were obtained during the interval of a few weeks in August, instead of catches being dispersed evenly over the entire seasonal cycle. Other sources of variation in the factor are age and sex, when these affect body proportions.

In Table No. 7 condition factors calculated for various sizes of juvenile salmon and also for some of the adults are given. It can

Table No. 7 THE CONDITION FACTORS OF VARIOUS SIZES OF JUVENILE AND ADULT SALMON FROM THE GEORGE AND KOKSOAK RIVERS

Length in cms.	GEORGE RIVER				KOKSOAK RIVER			
	Males		Females		Males		Females	
	No.	Condition	No.	Condition	No.	Condition	No.	Condition
Immature Juveniles (Parr and Smolts)								
9							1	1.17
10	1	1.00			1	1.00		
11	1	1.20						
12	1	1.10	1	1.04			2	1.07
13	2	1.14			3	0.92	4	1.04
14	3	1.06	1	1.02	1	0.95	2	1.09
15	3	0.99	4	1.02	3	1.07	5	0.97
16	7	1.03	4	0.98	8	1.01	5	0.98
17	4	1.03	2	1.03	8	0.99	7	1.00
18	5	1.00	6	1.04	13	1.01	16	1.03
19	4	0.86	4	0.97	11	1.07	5	1.06
20	3	0.91	15	0.94	12	1.02	9	1.05
21	10	0.92	13	0.91	2	1.06	6	1.03
22	8	0.91	13	0.92	4	1.00	3	0.97
23	2	0.91	3	0.89	1	1.06	3	0.87
24	5	0.89	3	0.89	1	0.82	2	0.87
25	2	0.84	1	0.87			1	0.85
26							1	0.82
27							2	0.86
29					1	0.75		
32	1	0.89						
36			1	0.90				
Adults (Small summer fish only)								
78.8	26	1.00						
78.7			83	1.06				
82.4					17	1.05		
81.8							84	1.11

be seen from the table that in the juvenile stages no apparent difference exists between the sexes, whereas in mature fish the females have a higher condition factor than the males. Menzies and MacFarlane (1924 a, b) report that mature male salmon are invariably thinner than female fish of the same length. Changes in the body proportions of mature fish are due to the development of secondary sexual characteristics, (ie: the elongate hooked jaw of the male and the enlargement of the sexual organs). Hoar (1939) in studying the weight-length relationship of Atlantic salmon found that male parr and smolts had higher condition factors than females, even when care was taken not to include male parr maturing to spawn. Comparing the coefficients of condition of male and female parr in the George River the average value of K for 44 females was 1.030 and for 45 immature males 1.029. The value of K for 13 male parr, which were maturing to spawn, was 1.16. It is concluded from this that in the George River the condition factors of immature male and female salmon are equal and this appears to be true in the Koksoak River also, (Table No. 7). The coefficient increases in male parr which mature to spawn and this increase is probably mainly due to enlargement of the testes.

Hoar (1939) demonstrated an abrupt fall in the condition factors of salmon from the Margaree River, Nova Scotia, on transformation from parr to the smolt stage. A similar change occurs in the condition factors of George River salmon above about 18 cms. in length, this coinciding with the approximate length at which parr transform into smolts. This change is not evident in the Koksoak River collections because, although the majority of specimens above 18 cms. in length had partly or completely transformed into smolts, they had done so only recently and many of them had not yet deteriorated in condition. (It will be recalled here that the smolts sampled from the George River were on migration whereas those taken in the Koksoak were taken in autumn, probably during or soon after metamorphosis, and would probably not have migrated until the following spring).

Following the smolt stage the condition factor rises again in the adult salmon to a value similar to what it was in the parr.

The findings of Belding (1936) and Hoar (1939) on the effects of environment on the condition factor are particularly interesting. Food supply and temperature appear to be factors of major importance. Low coefficients are associated with an increase in the number of vertebrae resulting in a more slender contour (Belding 1936). Low developmental temperatures are conducive to an increase in the vertebral number of salmonoids, (Mottley 1937). Apart then from any other causes, one would anticipate the condition factor to fall towards the north of a salmonoid's range. In addition food supply has an effect; fish growing in regions where there is abundant food are deeper bodied and have higher condition factors than fish from localities where the food supply is sparse. The condition factors of salmon parr from several localities are arranged for comparison in Table No. 8. As would be anticipated the George and Koksoak River fish are slimmer than the others. The difference probably derives from a number of sources, the lower temperatures in these rivers possibly affecting both the food supply and the number of vertebrae the fish possess.

It may be significant that low condition factors are found only in the juvenile stages. Adult salmon from Ungava are no slimmer than fish from other regions. Hoar (loc. cit.) gives the the coefficients of condition for fish from Saint John harbour, Lorneville and Dipper harbour as 1.06, 1.00 and 1.09 respectively. The coefficients from the George and Koksoak Rivers are 1.04 and 1.10 respectively. Since the condition factors of adults do not differ materially from those of fish from more temperate regions, food supply rather than vertebral number, which would affect adults as well as juveniles, is probably the most important factor in determining the low value of K in the young stages of Ungava salmon.

Table No. 8

Source of Material	No. of Spec.	Mean Length (cm)	Coefficient of Condition
Allen (1941 b) parr 1			
Thurso R. 1937	27	11.9	1.44
24-31 Aug. Sleach Water			
Halkirk Burn	39	9.9	1.35
Sinclair Burn	23	8.8	1.23
Allen (1940) parr 1			
Eden R. July 29, 1937	42	12.9	1.25
Hoar (1939) parr 2 yr. old			
Margaree R. 1936	17	12.6	1.16
Margaree R. 1937	33	11.0	1.09
Belding (1938) parr 3 yr. old	11	11.76	1.13
Margaree R. 1934	16	12.17	1.12
Belding (1938) Moise R. '31, '34			
Parr 2	15	9.51	1.145
Parr 3	13	11.23	1.103
George R. 1956			
(Average for all ages of parr)	89	15.7	1.03
Koksoak R. 1957			
(Average for all ages of parr)	79	16.2	1.01

<u>CONDITION FACTORS OF SALMON PARR FROM A NUMBER OF LOCALITIES</u>

SEX RATIOS

Females outnumber males in the adult salmon populations of the George and Koksoak Rivers by a ratio of approximately 2-1/2:1 A predominance of females is not unusual in mature salmon populations, differences as great as this being not uncommon. Hutton (1939) published the following table showing the percentage of females in the various classes of Wye salmon examined by him:-

Average	Grilse	S. Spr.	S. Sum.	L. Spr.	L. Sum.	V. L. Spr.	Pr. Spd.
1908-37	58-1/4	77-1/4	71	71	58-3/4	19-3/4	19-1/2
1937	67-3/4	83-1/2	77-1/2	82-1/2	25	25	100

Dahl (1910), in a series of figures from the Aaen-Sire River, Norway recorded a predominance of females in most years. Out of a total of 3,182 fish examined by him, between 1886 and 1897, 56% were females. If the grilse are removed from these totals (ie: fish of 64 cms. or less in length) the figures become 2,184 fish examined of which 74% are females. Among the fish less than 64 cms. only 18% are females. This same sort of relationship holds true in Ungava salmon. Of a total of 14 grilse examined in 1956 and 1957, only 1 was female. As was mentioned previously, the grilse population is probably poorly represented in the catches and had more been taken the adult sex ratio would be closer to normal.

Other factors possibly operate to cause an unbalanced sex ratio amongst the adults. Examination of the sex ratio of the migrating smolts indicates that again females are in the majority. (62% of a total of 175 in the George River and 76% of a total of 17 in the Koksoak River). The parr and the recently metamorphosed smolts taken in the autumn, on the other hand, show a 1:1 sex ratio. (Table No. 9) The change from a balanced to a divergent ratio occurs between the parr and the migrating smolt stage. Few studies appear to have been carried out in which the sex ratio has been followed throughout the life cycle. Belding (1936), in his study of salmon from the west coast of Newfoundland, has this to say about the sex ratio, "The 196 parr are about equally divided as to sexes but when grouped by age classes a different picture is presented. The sex distribution in the 2+ class, which represents the normal population before any appreciable number have left the river, indicates the normal ratio of males to females is 1:1.25 and that there is an excess of females during the first years of river life and probably at the time of hatching". He goes on to add that in the 3+ class males predominate by a ratio of 1:0.69, favouring the view that males remain longer in the river than females. Jones (1949) studying the age and sexual condition of parr and smolts in Great Britain also came to the conclusion males remain longer in the river than females. A break-down of the ratios from the George and Koksoak Rivers (Table No. 9) does not support these conclusions.

The reason for the change must be sought for in events which occur between the parr and the smolt stages. The only event which occurs in males and not in females is that many male parr mature and spawn. If these male parr incure as heavy a mortality during spawning as do the adults, then the reason for a shortage of males in the adult population is obvious and the sharp break between the parr and the smolt ratio would be explained, provided male parr only mature during the autumn prior to migration.

Ten maturing male parr and three maturing male smolts were taken in the George River between the 18^{th} of August and the 6^{th} of September. An examination of the ages and sizes of these fish showed that they would probably have migrated the following spring. The 3 maturing parr collected in the Koksoak River were in a similar condition. If this is generally true and if many of the juvenile males are unable to survive the strain of spawning together with the rigors of winter, then a change in sex ratio would result and be first evident in the smolt population.

To summarize, two factors probably account for the predominance of females in the adult salmon of Ungava. Firstly, the grilse, which are largely male fish are poorly represented in the

Table No. 9

THE SEX RATIOS OF SALMON FROM THE GEORGE AND KOKSOAK RIVERS

Age (at Migration in the Adults)	GEORGE RIVER						KOKSOAK RIVER					
	Parr		Migrating Smolts		Adults		Parr		Migrating Smolts		Adults	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1							3	6				
2	4	4					12	16				
3	12	8	4	12	2	6	93	93	3	8	3	14
4	26	25	22	25	10	30	15	23	1	4	15	52
5	14	12	32	51	18	41	1	1		1	8	17
6	1		6	17	5	9		1			1	3
7			3	3	2	1						
Totals	57	49	67	108	37	87	124	140	4	13	27	86
Percentage	54	46	38	62	30	70	47	53	24	76	24	76

catches and, secondly, many of the male parr which mature to spawn die, with the result that females are in the majority in the migrating smolt population. It is not improbable that similar factors are responsible for the unbalanced sex ratio in other salmon rivers.

FEEDING HABITS

The adult salmon can be dismissed briefly. In agreement with the usual findings, once they enter freshwater they cease to feed. Among 150 stomachs opened for examination only one contained food material. This was a stone-fly nymph found in the stomach of a grilse. The remainder were empty and contained no evidence of recent feeding.

The stomachs of young salmon present a more interesting picture. Throughout the summer they are actively feeding, as can be seen by the presence of undigested food in the stomach and faecal matter in the gut. There is no evidence to suggest that the intensity of feeding varies during the season as the percentage of fish with undigested food in the stomach remains constant at approximately 50%.

In order to analyse the diet of the juvenile salmon, samples of partly digested food were removed from the stomach and preserved in 5% formaldehyde. Food samples were obtained from 103 fish from the George River and 95 fish from the Koksoak River. No distinction was made between parr and smolts in this sampling as preliminary inspection revealed no apparent difference in feeding habits. In most cases individual stomachs contained only a small quantity of food so that samples from several fish, taken at the same time, were combined in one specimen vial. An estimate of how full each stomach was revealed that in most instances when food was present the stomach was only considered to be 1/8 full. Only about 5% of the stomachs containing food were recorded as being 1/2 or more full. The value of these figures is difficult to estimate owing to the fact that a fish, on being meshed in a gill net, is liable to disgorge the contents of its stomach, especially if it happens to be full. However, fish caught with rod and line which had little time to disgorge any food showed essentially the same picture.

The method of examination of the stomach samples was as follows:- The contents of the sample vial were poured into a petri dish containing a small amount of water and floated out over the bottom of the dish. The sample was then examined carefully under a binocular microscope and a list of the recognizable organisms tabulated in the approximate order of abundance. Owing to the small size and partly digested state of many of the organisms, no attempt was made to count individuals or estimate the volume of each species volumetrically. Instead, a visual appraisal was made of the percentage by bulk of the recognizable groups of organisms in the sample. Rechecking the estimates by myself and a second observer produced comparable figures and indicate that errors are unlikely to exceed 10% in any sample.

As has been shown in the other studies of the feeding habits of juvenile salmon, Allen (1941 a), White (1936 a), insect material forms the bulk of the diet. In Ungava insects account for approximately 95% of the total food intake. The predominant groups are Ephemeroptera, Hymenoptera, Plecoptera, Diptera and Trichoptera. In the George River these groups account for 12, 10, 21, 26 and 17 percent of the diet respectively, while in the Koksoak the percentages are 9, 22, 25, 20 and 18. With the exception of the Hymenoptera, these groups are principally aquatic. The presence of such a high percentage of Hymenopterous insects is rather unexpected and, indeed, the group possibly forms only an insignificant fraction of the diet in some years. Their presence in 1956 and 1957 (and in the stomach contents of brook trout taken in 1955) is due to an outbreak of the Larch saw-fly (Pristiphora erichsonii) in the region. Specimens of the saw-fly, taken from the stomachs of young salmon, were identified by Dr. R. Lambert of the Department of Agriculture, who stated that the adult flies which emerge in early summer are not strong fliers and live only a few days. Many of them could be blown by the wind and drop into the water before dying.

During the summer there is a change in the composition of the diet from one containing a preponderance of saw-flies, stone-fly nymphs, may-fly nymphs and caddis-fly larvae to one containing a greater variety and a higher proportion of adult insects. These changes in the percentage composition of the more important constituents of the diet are shown graphically in Figure 11. In preparing this figure the summer has been divided arbitrarily into intervals of 10 days. Starting on the 18th of July, five such intervals are available for the George River and six for the Koksoak River. In Table No. 10 a list of all the recognizable food organisms is given together with an indication of what percentage of the diet is formed by each.

A comparison of the composition of the diet with the results of similar studies made in other regions shows few outstanding dissimilarities. Chironmids are less important as a constituent of the diet and are replaced by Simulids, Plecoptera and Hymenoptera, particularly the latter two groups. This is made evident in Table No. 11 in which the composition of the diets of juvenile salmon from three other localities are compared with the diets of those from the George and Koksoak Rivers. Such variations can undoubtedly be attributed to the availability of particular groups of food organisms from one river to another.

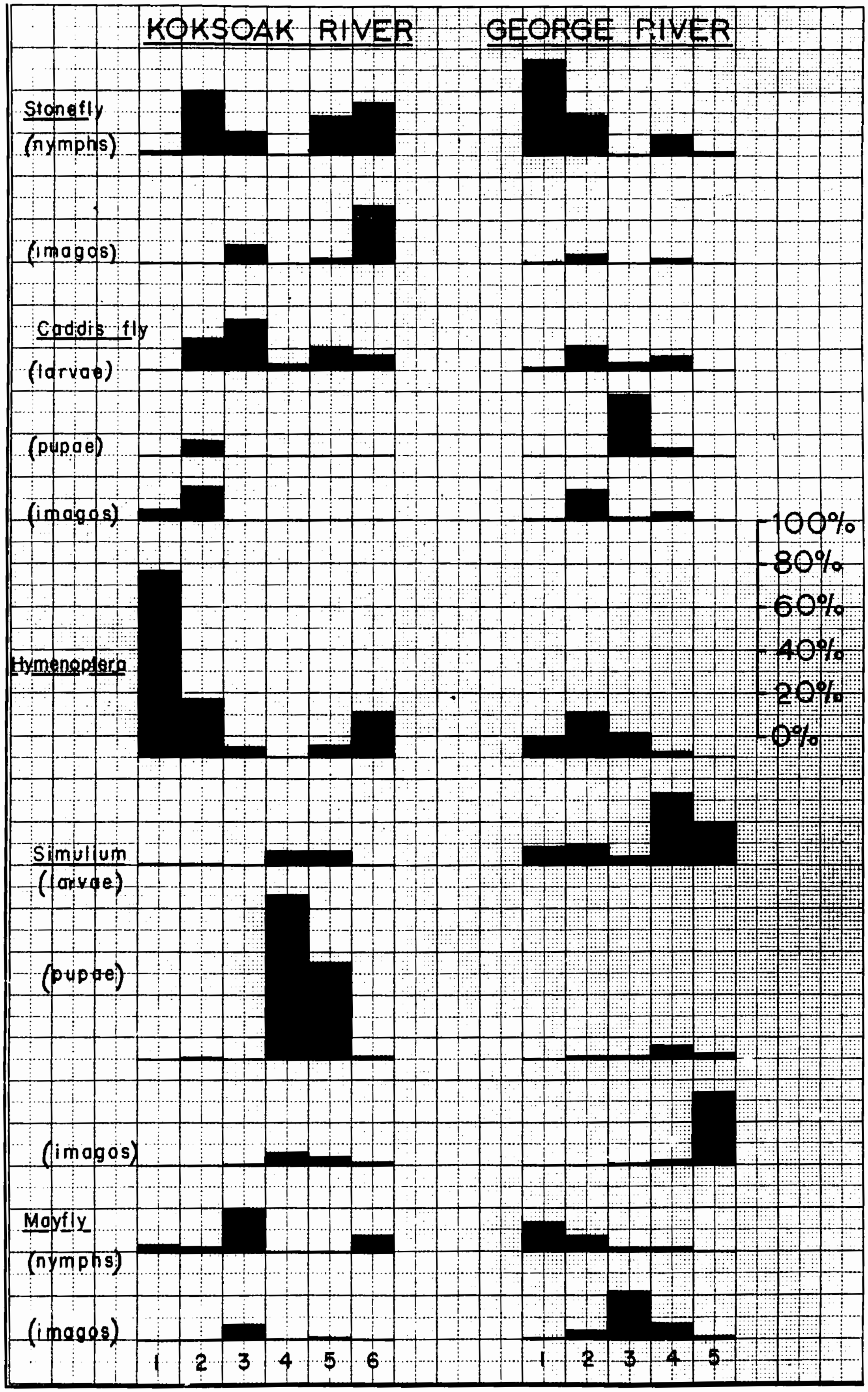


FIGURE 11. Changes in the composition of the diet of young salmon in the Koksoak and George Rivers during the summer.

Table No. 10

LIST OF THE RECOGNIZABLE FOOD ORGANISMS TAKEN FROM THE STOMACHS OF JUVENILE SALMON FROM THE GEORGE AND KOKSOAK RIVERS

	George River	Koksoak River
Chironomid pupae	3.93%	1.06%
Coleoptera imago	1.00%	1.33%
Ephemerid nymph	5.41%	6.72%
Ephemerid sub-imago and imago	6.51%	2.06%
Fish	5.17%	-
Hymenoptera imago	9.61%	21.67%
Plecoptera nymph	18.61%	17.06%
Plecoptera imago	2.48%	8.22%
Simulium larvae	19.13%	1.61%
Simulium pupae	2.75%	13.83%
Simulium imago	4.34%	1.44%
Trichoptera larvae	6.83%	11.89%
Trichoptera pupae	4.58%	1.67%
Trichoptera imago	5.81%	4.17%
Chironomid larvae		
Chironomid imago		
Colonial algae		4.17%
Diptera (terrestrial)		
Hydracarina	3.57%	
Lepidoptera imago		-
Mollusca		-
Nematodes		
Psyllidae imago		
Annelida	-	2.28%
Araneae	-	
Unaccounted	.27%	.82%

Table No. 11

RELATIVE PERCENTAGES OF THE MAJOR GROUPS OF FOOD ORGANISMS

Food Organism	George R. (all ages)	Koksoak R. (all ages)	Eden R. (Allen) (2nd yr)	Thurso R. (Allen) (2nd yr)	West Apple R. (White) (1st summer)
Ephemeroptera	11.9	8.8	22.3	36.2	34.9
Plecoptera	21.0	25.3	0.2	8.5	----
Trichoptera	17.2	17.7	6.3	11.8	16.6
Diptera — Simuliidae	26.2	16.8	21.3	7.9	1.5
Diptera — Chironomidae	3.9	2.0	46.7	14.1	38.9

COMPETITION

Amongst the species of fish inhabiting Ungava salmon rivers there is undoubtedly competition for living space and food. Brook trout, young lake trout, salmon and, to a lesser extent, the two species of whitefish all rely upon a diet composed principally of insect material. Salmon may be separated from the others by a preference for faster flowing water, but in many places all 5 species live side by side in the same stretch of water and must obtain their food from similar sources. By contrast, the different feeding habits of the suckers mean that they will not seriously encroach upon the food supply of young salmon. In a survey such as was carried out in Ungava it is unfortunately not possible to estimate the intensity of competition between species and, beyond repeating that it exists, nothing can be added.

PREDATION

A factor of utmost importance in controlling the abundance of an animal population is the degree of predation to which it is subjected. In discussing a fish population man's predation, in the form of a fishery, must also be included.

Excluding man, in Ungava probably the most destructive predators of young salmon are to be found amongst other species of fish. Of these the lake trout is probably the worst offender, large specimens of this species feeding almost exclusively on young salmon and whitefish. Next in order of importance are the older brook trout and possibly pike should be included, although these are apparently not very abundant. Suckers are exceedingly plentiful in the rivers and are reputed to consume quantities of salmon ova during and following spawning.

White (1939) found that certain species of fish-eating birds took a heavy toll of the young salmon in the Margaree River, Nova Scotia. Kingfishers (Megaceryle alcyon) and Mergansers (Mergus spp.) were the principal avian predators in that river. Mergansers breed in small numbers along the George and Koksoak Rivers but they are probably not numerous enough to be a serious menace to the survival of young salmon. Only a solitary specimen was seen at Helen Falls on the George River in 1956 and less than a dozen were observed along the Koksoak River and its tributaries in 1957.

Kingfishers are even less plentiful. The only evidence of their occurrence was a nest found in 1957 in the bank of a small tributary of the Koksoak, which incidently contained no salmon.

Among the mammalian predators of salmon, seal are possibly of some importance. A small population, numbering perhaps twenty, inhabits the lower reaches of the George River between Helen Falls and the sea. These probably belong to the species Phoca vitulina, the harbour seal. They are reputed to be quite destructive to young salmon, especially during migration of the smolts. Other species of seal are not plentiful in Ungava Bay and their numbers are kept under control in the estuaries of the rivers by the hunting of the natives.

Man's effect on the salmon population is difficult to evaluate, but at present the amount of fishing carried on clearly makes no excessive demands on salmon resources. For the past, the only information available, except for a few estimates of the total catch which, as has been pointed out already, mean very little since they cannot be expressed in terms of fishing effort, are the figures for the average individual weight of the catch during the first four years of the fishery. The average weight of the catch fell from 19 lbs. to 14.5 lbs. during the first three years, from 1881 to 1883. Little can be inferred from these figures. Since the minimum length of the life cycle of Ungava salmon at the present time is four years, commercial fishing should produce no marked effects on the population during the first 3 years of operations. The high average weight of the catches suggests that, especially during the first 2 years, either the fishery was relying to a large extent upon previously spawned fish or the age composition of the population has changed since Turner's time. The only fish examined in 1957 which had weights approximating 19 lbs., the average weight of the catch in 1881, were two previously spawned fish, one weighing 19-1/4 lbs., the other 18 lbs. If, on the other hand, the adult population of the 1880's included a number of large summer fish, fish which have spent 3 years feeding at sea prior to returning to spawn, then the average weight of the catch would be considerably higher than the present value of about 13 lbs. Either one or a combination of both these alternatives is a plausible explanation for the decline in the average weight of the catch since 1881. Declines in the total catches during the years for which records are available are a reflection on the fishing effort rather than on the abundance of fish.

THE METABOLIC RATE OF YOUNG ATLANTIC SALMON

INTRODUCTION:

The term basal metabolism, as applied to humans, refers to the expenditure of energy in a subject at rest, warm and comfortable and completely relaxed, both mentally and physically, 12 to 15 hours after the last meal was consumed. The energy is expended in the functioning of such essential systems as the respiratory and circulatory and in maintaining body temperature. Under basal conditions in humans the major part of the energy required is for maintenance of body temperature and, since heat is lost through the body surface, basal metabolism is largely dependent on surface area. So great is this dependence that in practice it is expressed in terms of a basal metabolic rate (B.M.R.) which is the basal energy required per unit of surface area per unit time. (Calories per square metre per hour in man.)

Poikilotherms as well as Homiotherms have basal energy requirements, but since such organisms do not need to expend energy in regulating body temperature their basal energy requirements are much smaller in magnitude. In these animals basal metabolism is defined as the minimum amount of energy required to maintain the vital processes of the organism, when the activity of its neuromuscular system is reduced to a minimum.

Since poikilotherms are not concerned with regulating the

the bodytemperature there is no obvious dependence of their basal metabolism on a surface area. The most direct dependence is on weight; at a given temperature large animals have a greater basal energy consumption than small ones of the same species. The relationship, however, between body weight and basal metabolism is not simple. Large animals of a particular species generally have a lower metabolic rate when expressed in terms of energy utilized per unit weight than do small animals.

In the one species of fish, Salvelinus fontinalis, on which an exhaustive study of metabolism in relation to size has been carried out, a straight line relationship is found to exist between the logarithm of the oxygen consumption and the logarithm of the body weight, (Job 1955). The slope of this logarithmic line at various temperatures falls between 0.8 and 0.9. Had the oxygen consumption been dependent on the surface area the slope would have been 0.67 and had it depended on the weight, it would have been 1.0. Other observations on fish, (Fry 1957), are in general agreement with this value, which indicates that the basal metabolism of fish is intermediate between surface area and weight dependence. For this reason care must be exercised in choosing the method of expressing the basal metabolism of a poikilotherm. The safest way, but not always the most convenient, is to express it in terms of the organism as a whole. The more usual way is to express it in calories per unit weight per unit time, in which case the weight of the experimental animals should be included in addition.

Theoretically, basal metabolism ought to be expressed in terms of the energy requirements which, measured by means of direct calorimetry, involve measurement of the heat output of an organism, its oxygen uptake and carbon dioxide output. In practice more convenient methods are used and in aquatic poikilotherms, such as fish, measurement of the oxygen uptake is generally taken as a reliable estimate of the rate of metabolism. Knowing the oxygen uptake, the energy requirements can be calculated with reasonable accuracy. Fish metabolizing principally fats and proteins would have a low respiratory quotient approaching 0.8 and an oxygen equivalent of between 4.80 and 4.85 Cals. per litre.

Almost all studies on the oxygen consumption of fish have been laboratory studies, for the obvious reason that many of the variables of the natural environment can be eliminated or controlled. The temperature of the experiments, the previous thermal history of the experimental animals, the length of daylight to which they have been exposed, their state of nutrition and their size can all be readily controlled. From the results of such studies attempts can be made to predict the behaviour of fish under natural conditions. This can only be done with caution since laboratory conditions are often quite different from nature. In their normal environment fish are subjected to daily and seasonal fluctuations in temperature, in oxygen concentration, in light, and probably in many other factors which are not so apparent. These fluctuations are possibly of much greater influence in the lotic environment than in the lentic. Limnological literature contains very little information on the extent of diurnal fluctuations in the lotic environment. The impression obtained from reading many limnological texts is that conditions in large rivers are relatively stable. This, however, may be far from the truth. The few publications dealing with this subject indicate that diurnal temperature fluctuations in the range of 3^{o}C. are not uncommon and these are accompanied by similar fluctuations in the percentage saturation of the water with oxygen, (Butcher, Pentelow and Woodley, 1927). Fluctuations in temperature of a similar magnitude were observed in the River Aigneau, the George and Koksoak Rivers. In 1957 continuous recordings of the river temperature and surrounding air temperature were made at stations along the Koksoak River and some of its tributaries. These recordings confirm the existence of such wide fluctuations in temperature and indicate they tend to be of greatest magnitude and more dependent on immediately local conditions in the smallest tributaries.

The great advantage in carrying out physiological experiments in the field is that natural conditions can be simulated as closely as possible. The physiological condition of an organism being influenced by the normal vicissitudes of its environment will be affected by any change from the normal. In maintaining conditions close to natural field experiments can be performed with a minimum of disturbance to an organism. However difficult the results are to interpret, they are of value as a representation of the behaviour of fish (or any other organism) in its natural environment. Field experiments are subject to criticism. Fish confined to a respiration chamber are not free to move and select their environment, and so perhaps avoid the extreme fluctuations inherent in their habitat. The previous history of the experimental animal is usually unknown except in broad outline. For practical reasons it is generally not possible to modify or control any of the environmental variables and, if this is done the experimental animals are exposed to unnatural conditions. In spite of these criticisms enough is known about the metabolic behaviour of fish under laboratory conditions to make attempts at field experiments valuable.

For studies of climatic adaptation, field experiments are indispensible. Work in this sphere was stimulated originally by the experiments of Fox (1936, 1938, 1939), Fox and Wingfield

(1937), Wingfield (1939) in England and Thorson (1936) and Spärck (1936) in Denmark. From a knowledge of the inhibiting effects of low temperatures on the activity of poikilotherms in temperate regions it would be anticipated that the activity of poikilotherms in colder regions would be restricted by the temperature. This, however, is not generally true, poikilotherms in cold regions display, at the temperatures to which they are normally exposed, activity similar to that shown by their counterparts in temperate regions whose normal environmental temperatures are considerably higher. This indicates there must be some compensating or adaptive factors in the physiological make-up of poikilotherms from cold regions enabling them to offset the effects of low temperature. This compensation can presumably take different forms; either the whole metabolism can be speeded up to allow greater energy consumption, both active and basal, at a lower temperature, or, while basal metabolism remains the same, the organism's ability to consume energy during activity is altered to enable it to remain active at low temperatures. This latter type of compensation would have selective advantages in that basal energy requirements are low and the organism can survive on a minimum amount of food. Perhaps lack of recognition of these two methods of compensation is the cause of the somewhat confusing results obtained in this field of work. Certain authors, namely Spärck (1936), Thorson (1936) and Scholander, Flagg, Walters and Irving (1953) appear to have shown temperature compensation while others, Fox (1936), Fox and Wingfield (1937), feel that their results fail to show any such adaptation. It may be significant that both Spärck and Thorson used lamellibranch molluscs which would tend to remain normally active under the experimental conditions to which they were exposed, while Fox and Wingfield experimented on various pairs of species of echinoderms, annelids and crustaceans whose normal activity may have been restricted by the experimental procedures employed. Bullock (1955) gives a recent review of the literature on temperature compensation in poikilotherms.

METHODS OF MEASURING OXYGEN CONSUMPTION OF POIKILOTHERMS:

There are three methods which have been widely used in determining the oxygen consumption of poikilotherms.

(1) The use of a sealed chamber in which the oxygen is gradually utilized and its depletion followed by sampling at intervals.

(2) The use of a continuous flow apparatus where water of known oxygen concentration is passed through a chamber containing the experimental organism and the overflow collected to determine the amount of oxygen extracted and the rate of flow through the apparatus.

(3) Manimetric methods which entail using a small volume of water and treating the organism as though it were terrestrial. Carbon dioxide produced by respiration is removed and absorbed and, as oxygen is utilized, more dissolves in the water causing the volume of gas in the apparatus to diminish. As a field method this type of experiment defeats its own purpose in that conditions are far from natural. In addition the apparatus involved is complex and delicate and thus unsuitable for field work.

Of the other two methods the first undoubtedly requires the least elaborate apparatus and for this reason is most widely used in field experiments. The major objections to its use are:-

(1) There is some possibility of stratification of the water which may result in local depletions of oxygen and rather variable results.

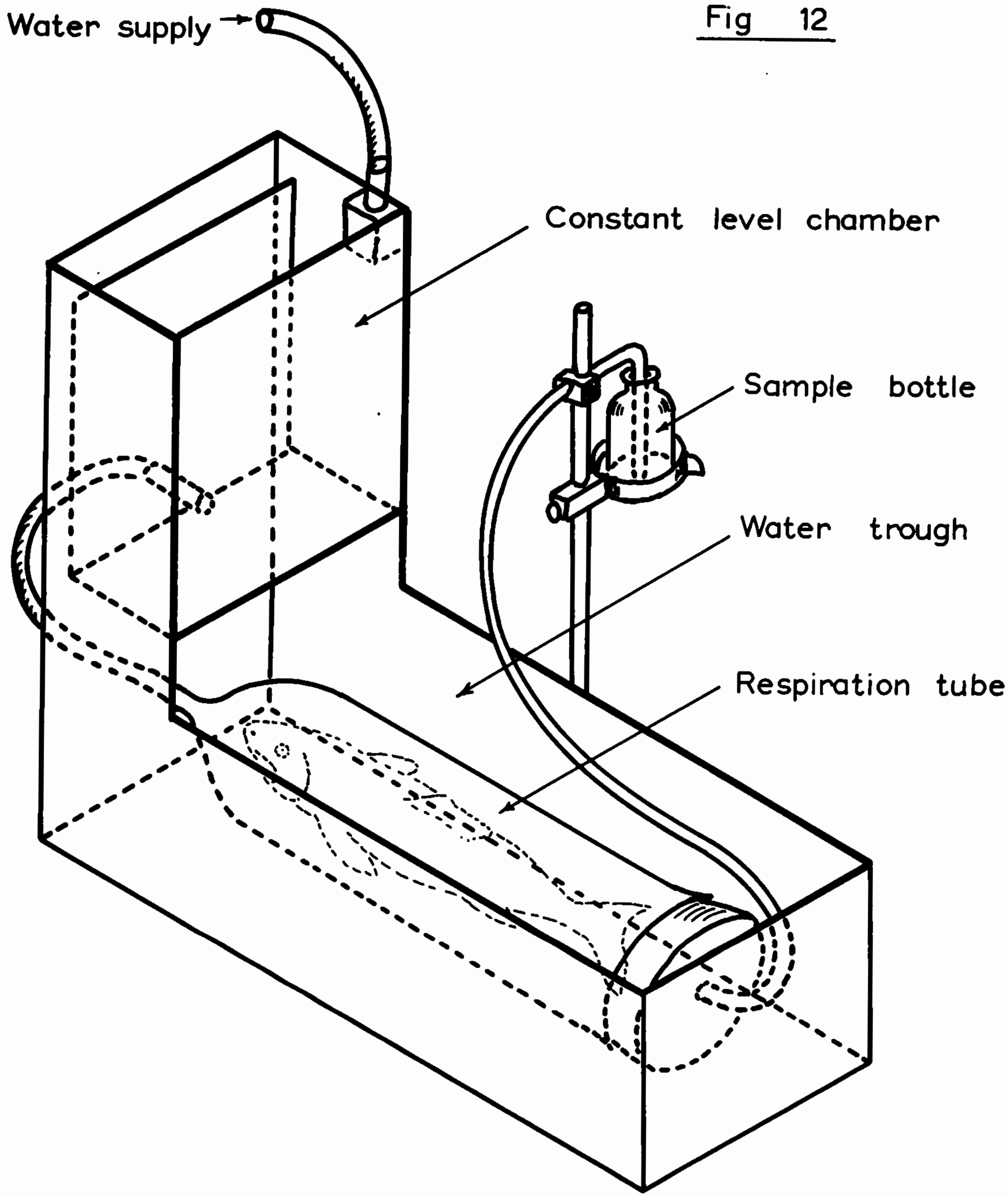
(2) If the fish is to remain in the chamber over a long period of time a large volume of water is required, hence sampling can only be done infrequently if a measurable diminution of the oxygen concentration is to be observed.

(3) Conditions do not mirror the natural but change throughout the experiment as the oxygen content of the water falls and waste products accumulate in the container.

The continuous flow method has obvious advantages as a field method in that changes in the environment are immediately duplicated within the apparatus. Another advantage is that experiments can be continued over an indefinite period, throughout the whole of which samples can be obtained for analysis. In experiments with fish the flow of fresh water over the animal possibly helps to keep it tranquil by simulating its ecological norm, especially if it is a species of fish which usually inhabits running water.

DETAILS OF CONTINUOUS FLOW APPARATUS USED FOR MEASURING OXYGEN CONSUMPTION OF YOUNG SALMON

The apparatus is in essential a simplification of that used by Keys (1930). In the field water is supplied via a long hose from a position some distance upstream from the location of the apparatus, which is so chosen to enable a good flow of water to be supplied to the constant level chamber, (Figure 12). Water which overflows from this chamber falls into the water trough, flows past the respiration tube and spills over the lower end of the trough. A small rubber tube carries water from the lower end of the constant level chamber and delivers it to the respiration chamber in which the experimental fish is enclosed. Water flows through this chamber, past the fish and out via the outflow tube into the sample bottle. The rate of flow through the respiration chamber can be regulated by altering the height of the sample bottle in relation to the level of the constant level chamber. The overflow from the sample bottle is collected in a shallow tray and directed into a short



Details of a continuous flow apparatus used for measuring the oxygen consumption of young salmon and brook trout in the field.

spout. The rate of flow through the respiration chamber can be measured by collecting this overflow for a known period of time. In practice this was for one minute during which time between 50 and 90 ml. would be delivered into a 100 ml. measuring cylinder.

Oxygen determinations using the unmodified Winkler method were carried out on water collected in the sample bottle, which was removed hourly and replaced by another during an experiment, and simultaneously on a sample of water taken from the tube supplying the constant level chamber. The unmodified Winkler method of oxygen determination is the method generally adopted for work of this nature and gives entirely satisfactory results in the purer waters of lakes and streams which do not contain high concentrations of iron, nitrites or organic matter.

EXPERIMENTAL PROCEDURE AND PRECAUTIONS

The apparatus was installed in a suitable location as described above. Care was taken to see that the hose supplying water to the respirometer was immersed in water for the whole of its length to prevent any tendency for warming of the water supplied to the apparatus on a hot day. Similarly the apparatus itself was partly submerged in the water and located in the shade to prevent any direct exposure to the sun. The apparatus was constructed of transparent plexiglass and, in order to prevent any excitement of the fish during an experiment, was covered by a dark cloth which restricted the fish's vision. The bottom of the water trough was covered with clean river gravel so that conditions within the respiration tube resembled as closely as possible those that would be experienced by a fish lying quietly under a rock on the river bed.

The experimental fish were usually taken in a Fyke net, a large version of a minnow trap, in which fish can be caught in an undamaged condition. Whenever possible fish were retained in the net for 24 hours prior to an experiment. In a few instances fish taken by hand net or by rod and line were used. In the latter case particular care was taken to see that the fish were not more than superficially injured at capture and they were retained in keep pools for a few days before being used in an experiment.

In a typical experiment the test fish was placed in the apparatus in the evening and allowed the whole of the following night to settle down and become accustomed to confinement in the respiration chamber. The size of the chamber was chosen to allow the fish sufficient room for restricted movement. If the chamber is too small the fish is unable to move sufficiently to maintain normal equilibrium and often falls over on one side and remains in an excited condition. Sampling was begun the next morning, usually commencing some two hours after sunrise and continued at hourly intervals until about noon. Six samples were considered desirable in each experiment. A period of at least six hours is considered necessary before any attempt at measurement of the basal oxygen consumption can be made. The handling of the fish in placing it in the respiration chamber is sufficient stimulus to cause it to respire maximally for some time, after which the rate of respiration gradually falls to a minimum. (Keys 1930, Wells 1932).

In a number of experiments where the oxygen consumption was determined at intervals immediately after the fish was introduced into the apparatus these findings were confirmed. Figure 13 shows the results of one such experiment carried out on a salmon parr and is typical of the pattern followed; a high initial rate which falls rapidly during the first 2 hours until a basal level is reached, usually after 3 to 4 hours. In a few instances fish never settled down, or else became disturbed during the course of an experiment. The most common causes of excitement were either loss of equilibrium or the passing of faeces. Faeces caused a certain amount of trouble in that they occasionally obstructed the flow of water through the apparatus. Experiments in which these sorts of disturbances occurred were abandoned and not included in the results. One further cause of trouble, which occurred only at Manitou Gorge, was supersaturation of the water. When this happened, bubbles of gas came out of solution inside the apparatus and often

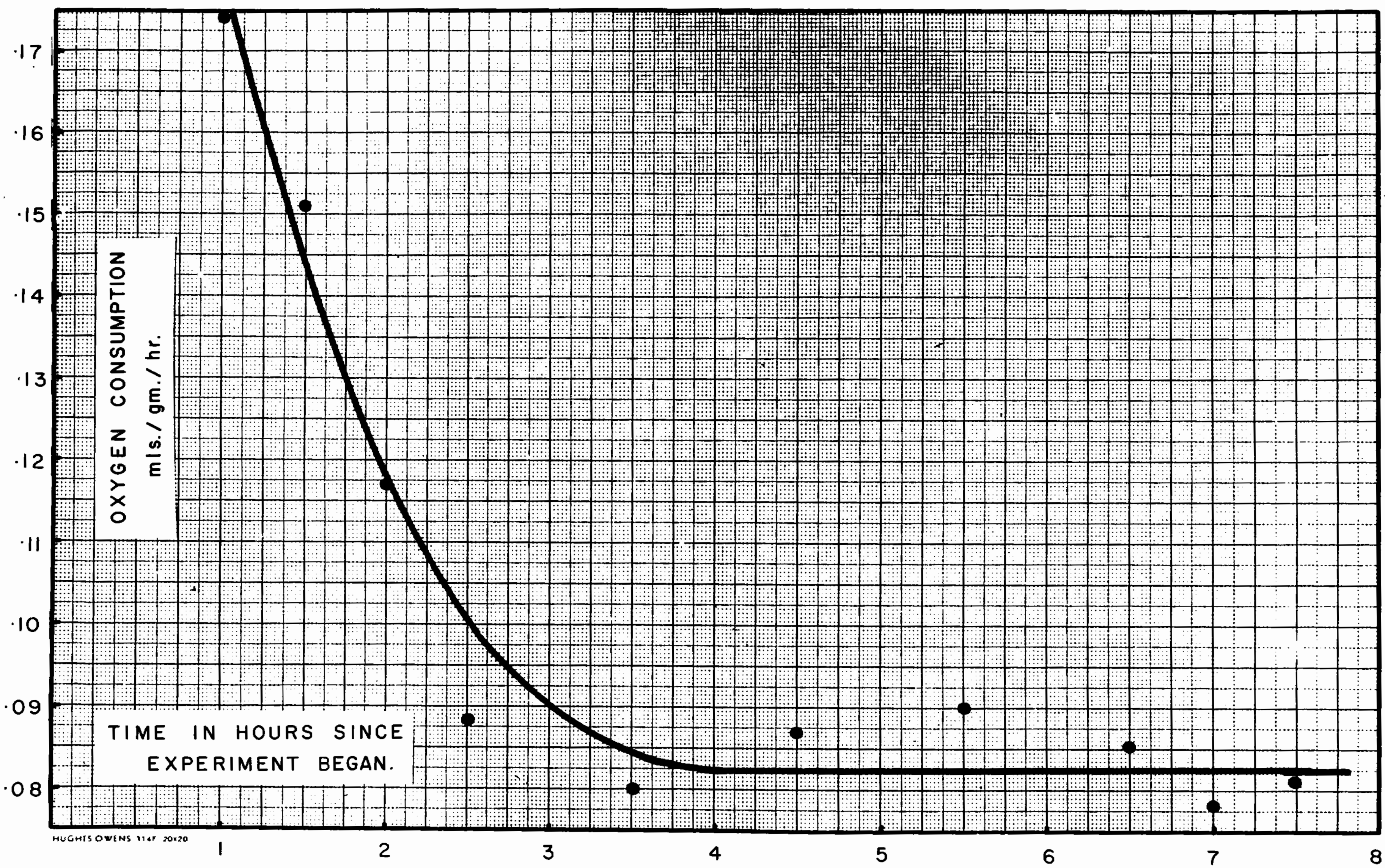


FIGURE 13. The rate at which the oxygen consumption of salmon parr falls to the basal level after handling the fish.

caused blockage of the smaller tubes making satisfactory experiments impossible.

RESULTS

BASAL METABOLISM OF SALMON PARR AND SMOLTS:

The juvenile salmon were divided into two groups, parr being treated separately from smolts. An attempt was made to keep the groups quite distinct and to avoid experiments on fish intermediate in form between the groups. Successful experiments were carried out on a total of 11 parr and 20 smolts, these fish coming from both the George and Koksoak Rivers. Complete details of each experiment are given in the appendix. The mean weight of the parr was 42.5 gms., its standard deviation 11.2, while that of the smolts was 80.0 gms., standard deviation 9.9. Experiments were conducted at temperatures from 4°C. to 16°C. allowing a range of slightly under 12°C. in each series.

Since these are field experiments, no attempt has been made to analyse in detail the exact nature of the curve relating oxygen consumption to temperature. Instead it has been assumed that a straight line relationship exists between the logarithm of the oxygen consumption and the temperature. Judging from the results of other experiments on fish metabolism, (Fry 1957) carried out under laboratory conditions with a range of 12°C., it is justifiable to assume such a relationship.

The regression equation describing this type of relationship has the form:-

$$\text{Log } y = ax + b$$

where y = the oxygen consumption

x = the temperature

and a and b are constants, a designating the slope of the line and b the point of intersection on the y axis.

Values for the constants a and b can be computed from the raw data so as to give the line of best fit, assuming y only to be in error. When this is done the equation relating oxygen consumption to temperature in salmon parr becomes:-

$$\log y = .04360x + \bar{2}.3497$$

and in salmon smolts is:-

$$\log y = .06123x + \bar{2}.1087$$

In order to compare these lines with others it is necessary to calculate limits beyond which it is improbable the lines should fall. For this purpose fiducial limits were calculated according to the formula:-

$$y_o = \tilde{y}_o \pm t \sqrt{\frac{1}{n-2} \sum (y-\tilde{y})^2 \left[\frac{1}{n} + \frac{(x_o - \bar{x})^2}{\sum (x - \bar{x})^2} \right]}$$

where $\tilde{y}_o$ = The calculated value of y at a given temperature x_o

(Bennett and Franklin, 1954)

Using this formula, limits can be placed at any desirable level of probability by substituting the appropriate value of t. When the 95% level of probability is chosen, the limits of the equation for salmon parr are:-

$$y_o = \tilde{y}_o \pm 2.0 \sqrt{.01215 \left[\frac{1}{68} + \frac{(x_o - 10.82)^2}{1022.12} \right]}$$

(t = 2.0 when n = 68 at the 95% level of probability)

The equivalent equation for the smolts is:-

$$y_o = \tilde{y}_o \pm 1.98 \sqrt{.007841 \left[\frac{1}{137} + \frac{(x_o - 9.5044)^2}{1308.39} \right]}$$

(t = 1.98 when n = 137 at the 95% level of probability)

In Figure 14 curves of the oxygen consumption against temperature of salmon parr and smolts have been plotted and fiducial limits at the 95% level of probability are included. The points on the graph are means derived from the measurements on a single fish, each point represents a minimum of 5 values. As can be seen from the figure, the oxygen consumption of salmon parr when expressed per unit weight is significantly higher than that of salmon smolts over most of the temperature range examined and the curve is less steep. The significance of the difference between the regression coefficients of parr and smolts can be tested by the following method:-

$$\sigma d_b = \sqrt{\frac{S(d^2 y_1)(1 - r_1^2) + S(d^2 y_2)(1 - r_2^2)}{N_1 + N_2 - 4} \left(\frac{1}{S(d^2 x_1)} + \frac{1}{S(d^2 x_2)} \right)}$$

$$d_b = a_1 - a_2$$

$$t = \frac{d_b}{\sigma\, d_b} \qquad n = N_1 + N_2 - 2$$

$$= 203$$

(Simpson and Roe 1939)

Substituting the appropriate values in this formula

t is equal to 4.41

∴ P is less than .001 and

the difference between the regression coefficients can be regarded as significant.

The fact that the curve for the smolts is steeper than that for the parr suggests smolts are more sensitive to temperature than parr and, as can be seen in the figure, this increased sensitivity is particularly evident above 10° C. Temperature is considered to be one of the environmental factors important in initiating smolt migration and it may be significant that the curve relating oxygen consumption to temperature is particularly steep at the temperatures at which migration occurs.

WINTER SURVIVAL OF SALMON PARR:

By extrapolation of the curves to winter temperatures it is possible to estimate the basal oxygen consumption during the winter months and from this can be calculated the approximate percentage loss of weight during this period. At the best, such calculations can only provide an indication of what might happen. The exact winter temperatures can only be surmised, any activity the fish indulge in will cause large changes in the oxygen consumption and

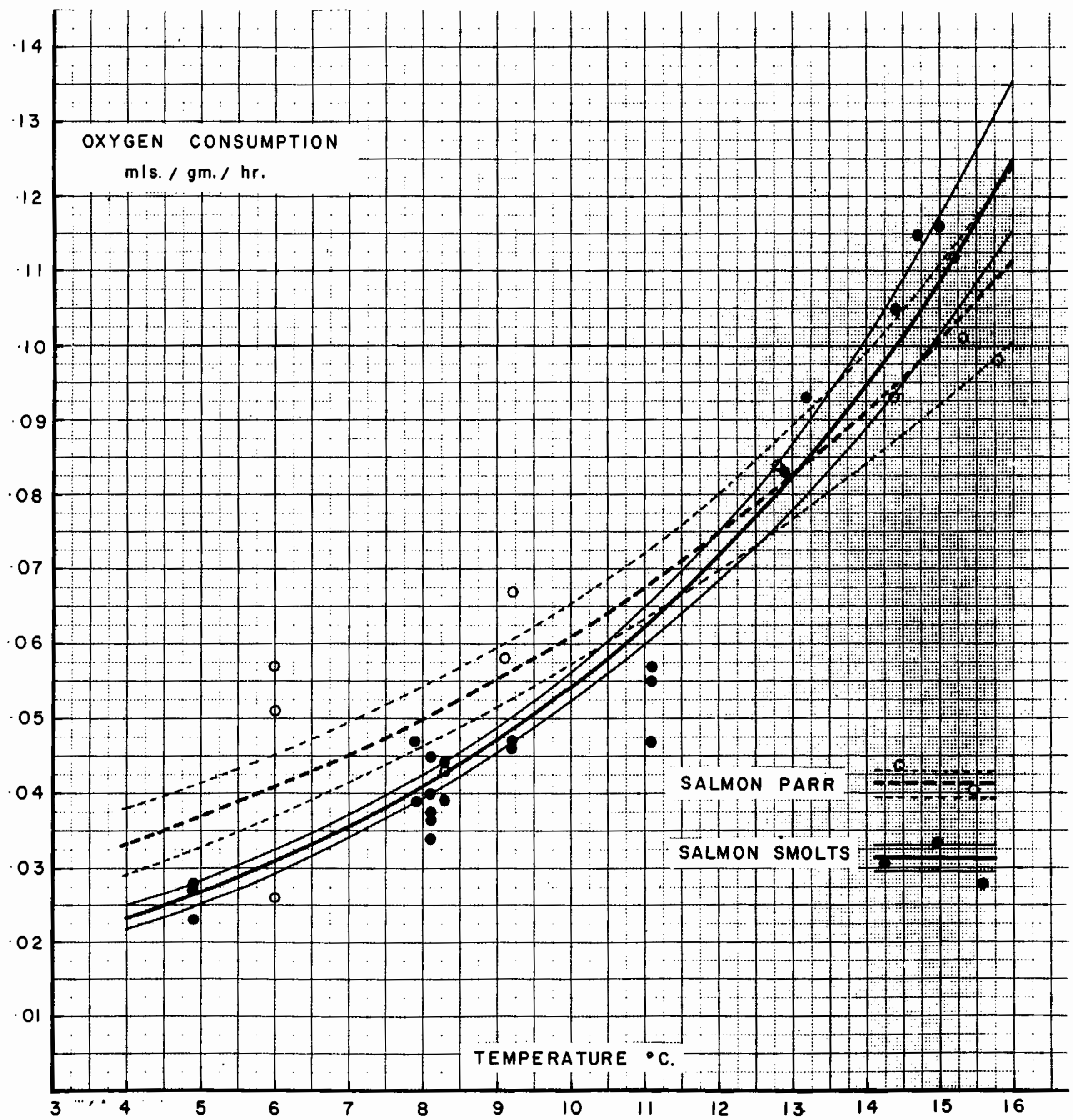


FIGURE 14. The oxygen consumption of salmon parr and smolts at temperatures between 4°C. and 16°C. Each point on the graph represents the mean of at least 5 measurements from a single fish.

finally the length of the period of winter starvation is not precisely known. If the mean winter temperature is taken to be 2°C., (this is possibly a high estimate but may compensate for any errors due to activity of the fish), and the length of winter as 250 days, salmon parr will consume between 140 and 190 mls. of oxygen per gram of body weight during this time. Assuming fat only is being metabolised during winter, the respiratory quotient will be about .72 which establishes the oxygen equivalent at 4.74 Cals. per litre. Using these values, 140 mls. of oxygen represents the burning of .074 gms. of fat and 190 mls. the burning of .10 gms. (1 gram of fat yields approximately 9 Cals. when oxidized in the body). Expressed as a percentage loss of body weight, between 7.5% and 10% is lost during the winter months. This loss is not unduly large and should present no serious problem to survival. Allen (1940) was able to demonstrate seasonal changes in the condition factors of salmon parr from the River Eden. During the winter months, between November and April, the condition factors fell from around .130 to about .110, representing approximately a 15% loss of body weight. Mean winter temperatures in the River Eden are almost 3°C. higher than the estimated winter temperatures in Ungava salmon rivers and winter is shorter by about 100 days. Substituting these values for temperature and duration of season, Ungava salmon parr would lose between 6% and 8% of their body weight during the winter. The difference between the Ungava values and the Eden value can probably be attributed to insufficient allowance for winter activity in the Ungava estimates. If the oxygen consumption of Eden salmon is similar to that of Ungava salmon, (and it is unlikely to be greatly different), during the winter months they are respiring at about twice the basal rate. Assuming Ungava salmon behave similarly, the estimates of weight loss during the winter should be doubled. Doubling the values, a loss of between 14% and 20% of the body weight is not excessive and should be no obstacle to the survival of Ungava salmon parr during the winter.

DIURNAL RHYTHM:

Diurnal rhythms in the oxygen consumption of fish have been described by a number of workers, for example Clausen (1936), Graham (1949) and Job (1954). Possibly related to these rhythms are variations in motor activity during a 24 hour period demonstrated by Spoor (1946) and variations in feeding activity shown by Hoar (1942). In measuring the basal metabolism of fish attention should be paid to the presence of any endogenous metabolic cycle and, ideally, basal oxygen consumption is measured when the cycle is at its minimum. In his work on the speckled trout (brook trout) Job (1954) found the position of this minimum point varied but in 60% of his experiments it fell during the night. In calculating the basal oxygen consumption he considered the lowest value obtained during a 24 hour experiment to be the basal value. For practical reasons it was not possible to adopt a comparable procedure in the field as experiments during the night were virtually impossible. In an attempt to find whether an endogenous cycle of oxygen consumption exists in salmon, experiments with three smolts were continued over a 26-1/2-hour period. Details of these experiments are given in the appendix. In Figure 15 the results are presented in graphical form. The curves of oxygen consumption are smoothed by plotting in groups of three. The curves denoting temperature and oxygen content of the water are plotted directly. The most striking feature of the results is the great similarity between the curves for the three fish. All show maximum oxygen consumption at midnight and midday and minimums during the early morning and late afternoon. Hoar (1942) found a somewhat similar cycle in the feeding activity of young salmon. They fed actively in the evening, usually not ceasing to feed until dark, feeding recommenced at daybreak and increased in intensity throughout the morning, but often slackened off during midday.

The double nature of the cycle of oxygen consumption is brought out most clearly when the temperature effect is eliminated. In Figure 16 this has been done. The results for the three fish have

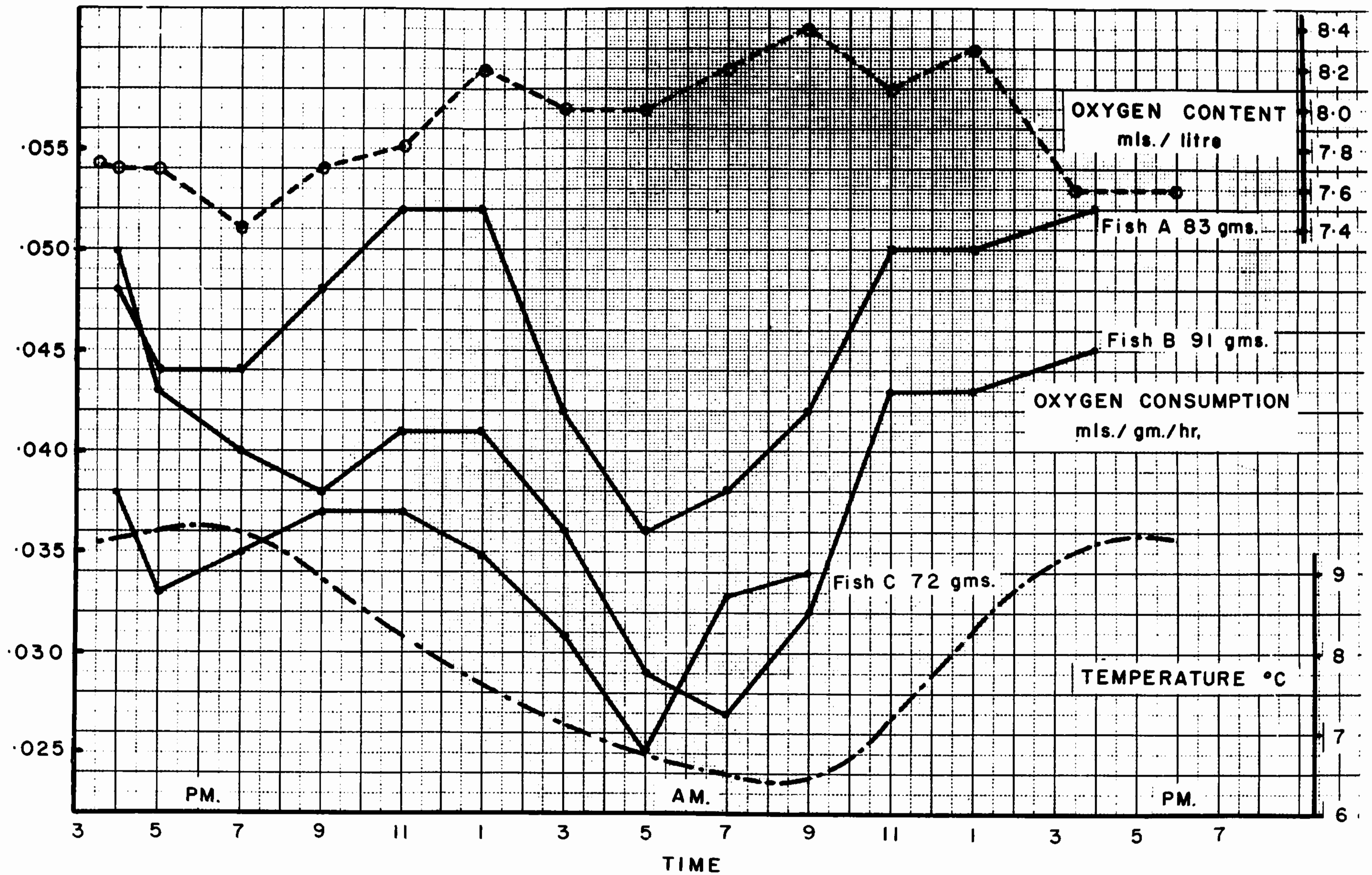


FIGURE 15. The diurnal rhythm of oxygen consumption of three salmon smolts under natural environmental conditions.

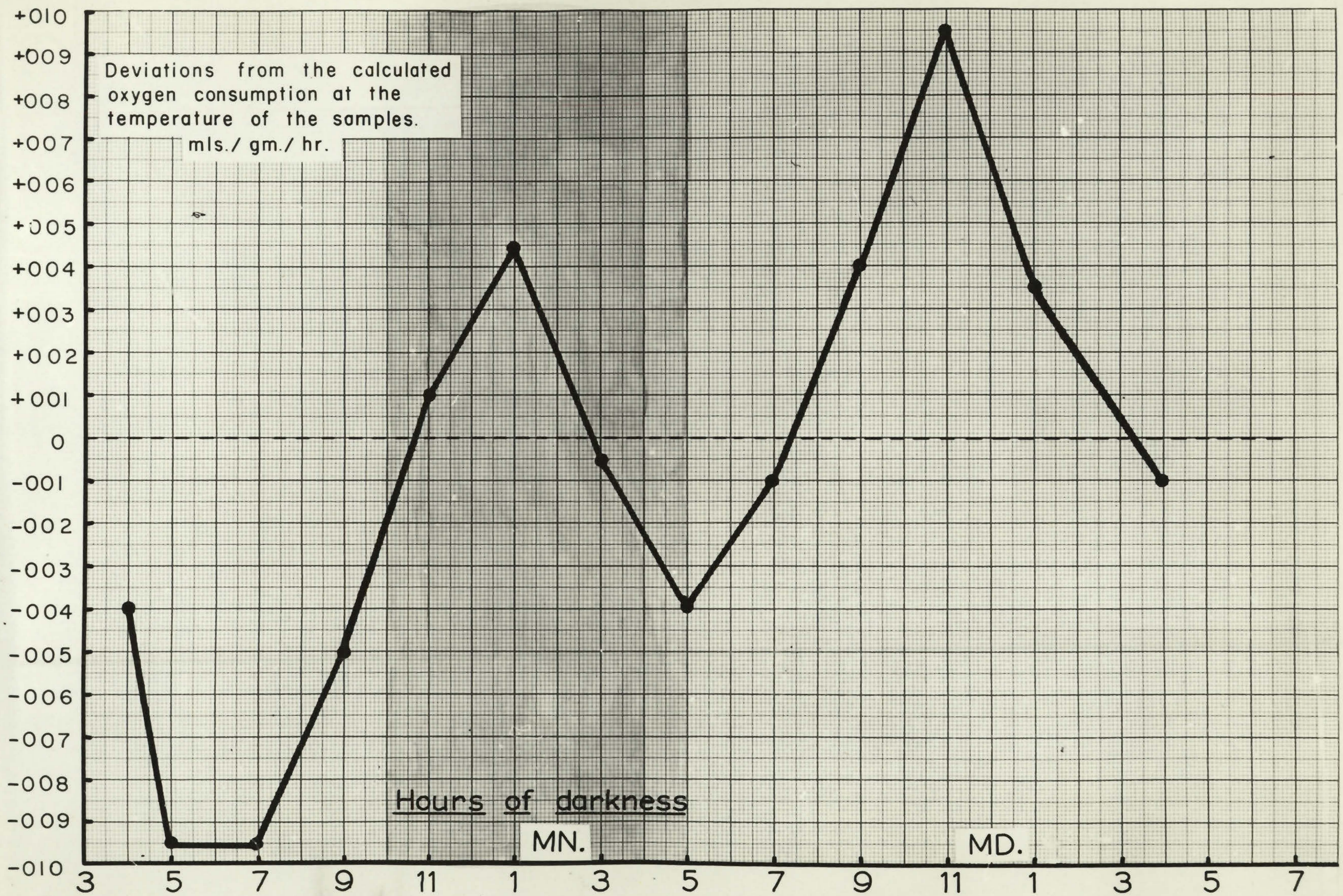


FIGURE 16. A possible endogenous cycle of oxygen consumption in salmon smolts.

been combined and the temperature differences between samples eliminated by subtracting the mean oxygen consumption of the three fish from the calculated oxygen consumption at the temperature at which the sample was taken. The cycle which is thus obtained is possibly endogenous and would persist in fish maintained under constant conditions of temperature. Examination of the results of the other experiments on young salmon reveal that the cycle, if it is real, is probably quite variable. The midday peak may occur anywhere between 6 A. M. and 4 P. M., falling more usually during the morning than afternoon.

Many other factors have been described which effect the basal metabolism of fish but which cannot be demonstrated in these results. No suitable figures are available to demonstrate the existence, or otherwise, of temperature compensation in the basal metabolism of young salmon. Lindroth (1942) gives figures for the oxygen consumption of young salmon but his figures are so much greater than those obtained in Ungava it is doubtful that they represent basal values. (40 gm. parr utilizing approximately .80 mls./gm./hr. at 10°C as against .61 mls./gm./hr. for an Ungava parr of equivalent weight). Seasonal changes independent of temperature were described by Wells (1935) in Fundulus parvipinnis which had its highest metabolic rate in the spring. In nature such changes may be intensified by modifications due to the previous thermal history of the fish which have been described by a number of workers, (Fry 1957). Weight is another factor the importance of which was stressed previously in the introduction. The range of weights of the fish used in the experiments was deliberately kept as small as possible to avoid errors from this source and therefore no correlation between weight and oxygen consumption can be demonstrated in the results.

METABOLISM OF THE BROOK TROUT:

A number of experiments were carried out with the brook trout (*Salvelinus fontinalis*) in addition to those already described with salmon. The brook trout occupies a somewhat similar ecological niche to the salmon but its range extends farther north to Hudson Strait. It is a species which has been studied extensively in the laboratory and figures are available for comparison with the field results.

As with the salmon, a straight line relationship was assumed to exist between the temperature and the logarithm of the oxygen consumption for the range of temperatures involved. (4.0°C - 14.7° C). The equation for this line was found to be:-

$$\text{Log } y = .05671x + \bar{2}.1539$$

(y = the oxygen consumption in mls/gm/hr)

The fiducial limits at the 95% level of probability are given by:-

$$Y_o = \tilde{Y}_o \pm 2.0 \sqrt{.003270 \left[\frac{1}{98} + \frac{(x_o - 9.03)^2}{672.95}\right]}$$

(t = 2.0 when n = 98 at the 95% level of probability)

Fourteen successful brook trout experiments were conducted, the mean weight of the experimental fish was 113.6 gms., the standard deviation 45.

In Figure 17 the curve is plotted and the limits included. Also shown on the graph is a line showing the oxygen consumption of a 100 gm. brook trout calculated from the results of Job (1955). The two curves are very much alike, the slight difference in shapes being due largely to differences in the method of calculation. There is no evidence of temperature compensation in the basal metabolism of Ungava brook trout as compared with those from Ontario.

Although no specific attempt was made to measure maximum consumptions, a few figures were obtained which indicate what the maximum values might be. These were principally from experiments in which readings were taken immediately after the introduction of the fish, also a few came from experiments in which the fish did not settle down, or became excited for some reason. When these maximal values are compared with the curve obtained by Job for the active metabolism of brook trout, it appears possible that Ungava fish are able to consume more oxygen at a given temperature

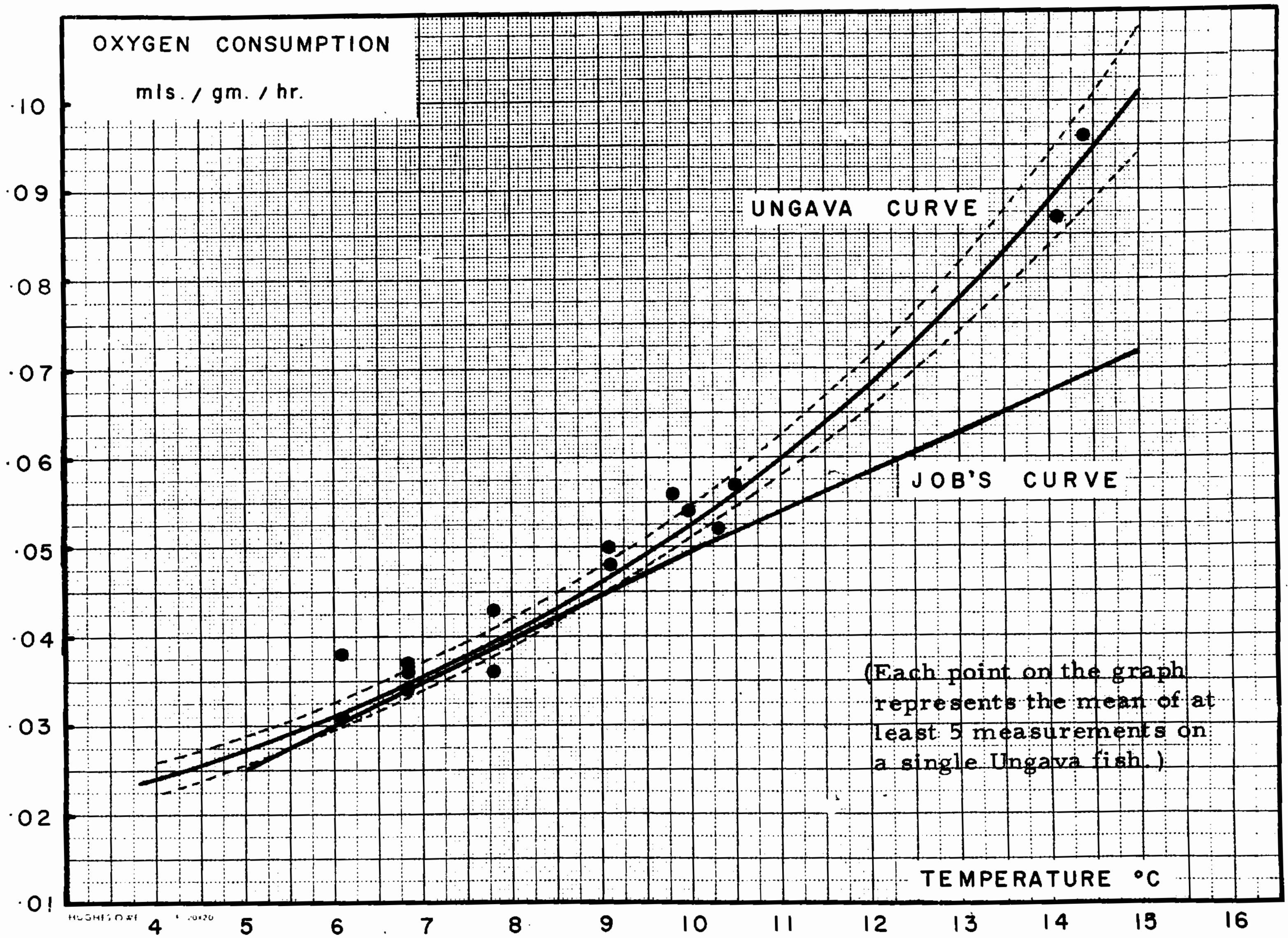


FIGURE 17. The oxygen consumption of Ungava brook trout compared with those from

Ontario (Job's curve).

than Ontario fish. In Figure 18 the curve for the active metabolism of a 100 gm. brook trout calculated from Job's results is compared with the maximal values obtained in Ungava fish. Unfortunately the results are insufficient to justify any conclusions other than that a detailed study of the active metabolism of the Ungava trout may provide some interesting data on the problem of temperature compensation in fish.

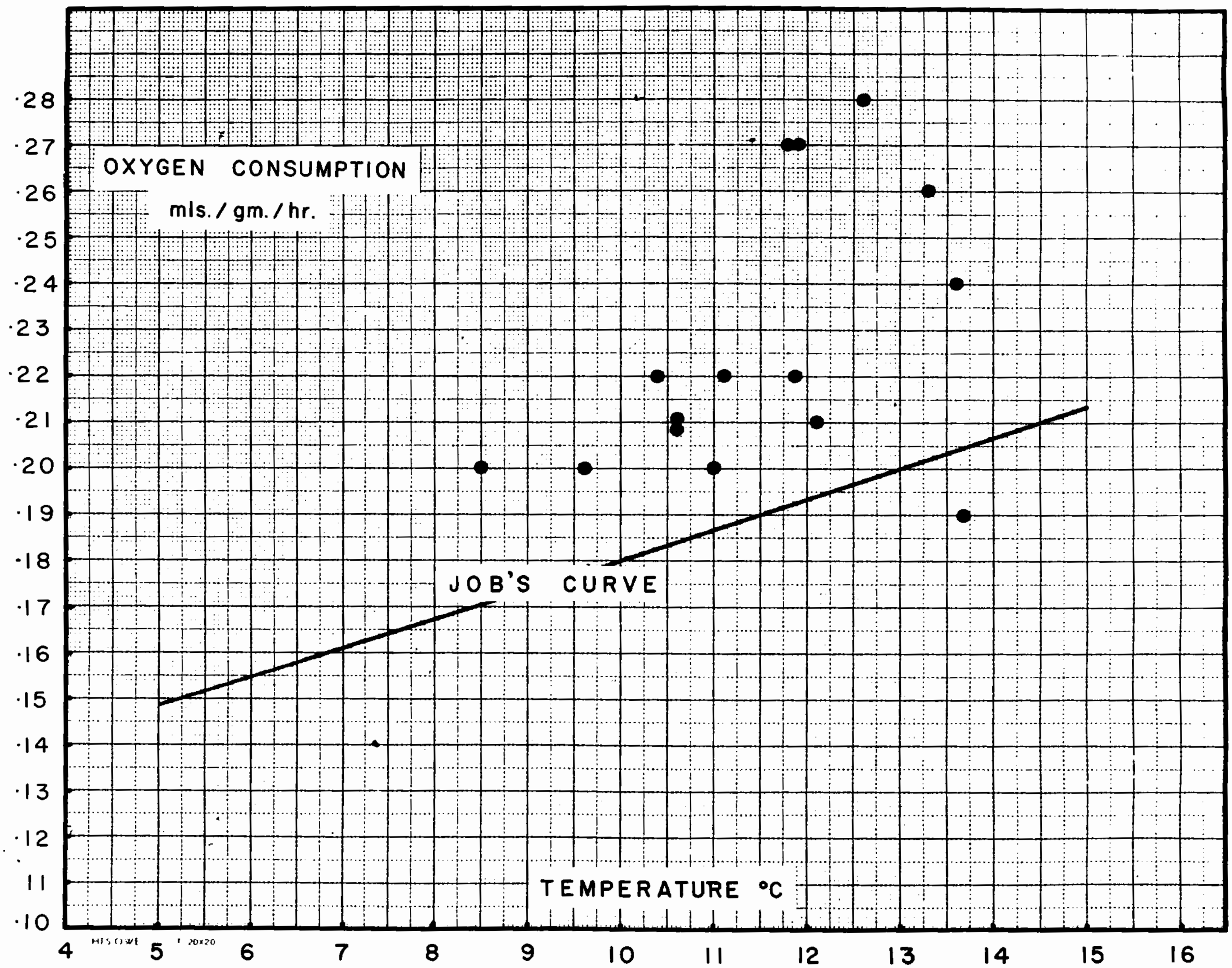


FIGURE 18. Maximal values recorded for the oxygen consumption of Ungava brook trout compared with the curve for the active metabolism of Ontario fish (Job's curve).

DISCUSSION

Two general questions prompted this study of the Ungava salmon populations.

(1) What factors are responsible for limiting Ungava salmon to rivers flowing into the south shore of the bay?

(2) Can the salmon populations which breed in these rivers cope with the natural disadvantages of their environment and with the demands of a fishery?

Although it is not possible to give a definitive answer to either question, the information which has been obtained during these investigations does, to some extent, illuminate the problems.

FACTORS LIMITING THE RANGE:

The reasons why salmon are virtually confined to three rivers in Ungava must be sought in the freshwater phases of the life cycle. Once they enter the sea, growth of Ungava salmon is as vigorous as that of salmon from other regions, a fact which leads one to suppose that when once they leave the rivers, the young salmon do not linger in the ice-cold waters of Ungava Bay. A limit may be imposed in other regions, for example Hudson's Bay, owing to the distance salmon must travel through Arctic waters to reach the rivers. This clearly cannot explain the distribution of salmon in Ungava Bay. Assuming salmon entering the bay do so from the east, migrating around the northern tip of Labrador, the distances to all the major rivers are approximately equal if they swim directly across the bay. Alternatively, if migration is around the coast the Payne River is an additional 100 miles and the Leaf River, 40 miles beyond the Koksoak. Neither of these distances should be unnegotiable.

The rivers in which salmon occur are all large and flow northwards from the interior of the Labrador plateau to the coast. The climate over the watersheds of these rivers is considerably milder during the summer and the summer is longer in duration than it is over the rivers farther west and north. In Table No. 12 are recorded the durations of the seasons with temperatures at a mean of 32°F., 43°F. and 50°F. or over, for the watersheds of the major rivers entering Ungava Bay. Also included are similar figures from localities where Atlantic salmon reaches the northern extent of its range in southwest Greenland, southwest Iceland and northwest Russia. The limit for successful survival of salmon appears to be reached, at least in northern Canada, when the length of the growing season falls to below 100 days. An estimate of the length of the growing season in any locality is given by the number of days with a mean temperature of 43°F. or higher.

While northern races of salmon grow as rapidly during the

Table No. 12

Locality	No. of Days with a mean of 32° or over	No. of Days with a mean of 43° or over	No. of Days with a mean of 50° or over
George River	150	100	50
Koksoak River	150	100	50
Whale River	150	100	50
Leaf River	150	80	20
Payne River	130	50	0
S. W. Iceland (Haell)	225	120	55
N. W. Russia (Pechora River)	175	115	72
*S. W. Greenland (Kapisigdlit)	---	approx. 95	--

* Kapisigdlit is the only place where the Atlantic salmon is known to breed in Greenland, (J. Nielson personal communication). Temperature records from this locality are limited to four years. 1939 - 1942.

THE LENGTH OF SUMMER, OVER THE WATERSHEDS OF THE MAJOR RIVERS ENTERING UNGAVA BAY AND IN OTHER LOCALITIES WHERE THE SALMON REACHES THE NORTHERN EXTENT OF ITS BREEDING RANGE growing season as salmon from other localities, yearly growth increments are undoubtedly less, the result of a short period of summer growth. Salmon in the north are older at migration and in the far north are also considerably larger than those from southerly regions. It is well recognized that age at migration increases with the latitude but that the size may also change in the same direction appears to have been previously unsuspected. Within individual rivers it has been observed that the oldest smolts on migration tend to be slightly larger than the youngest. Unfortunately few figures are available giving the sizes at migration of young salmon which have been derived from actual measurements of the migrants rather than calculated from the scales of adult salmon. Jones (1949) gives a series of figures from British rivers which show this trend. Hoar (1939) found that the average size of 3 year old migrants from the Margaree River was slightly greater than that of 2 year olds. A similar, though very flexible, relationship probably exists over the whole range of the salmon and as the average age at migration becomes greater towards the north so does the mean length. As mean lengths increase it becomes more difficult for young salmon to attain the size for migration and a stage may be reached when the process breaks down. Mean lengths of smolts in the George and Koksoak Rivers are already very high and further enlargement may result in a curtailment of the life cycle by the onset of sexual maturity. This in essence is what was suggested by Power (1958) to occur in Atlantic salmon populations exposed to severely cold climatic conditions and is responsible for the development of non-migratory races.

Winter in the north presents a series of problems. During this period of the year the young salmon are believed not to feed but to remain in a relatively dormant condition in the deeper pools of the river. Throughout this time the fish maintain themselves on the food reserves stored within the body during the previous summer. Compared with other species of fish, the salmon is ill-equipped to face long periods of starvation having as it does a comparatively high rate of metabolism. Its food requirements are therefore quite high and during a long winter most of its energy reserves will be utilized. In Ungava this amounts to a loss of perhaps 20% of the body weight which compared with other regions is not excessive. Nevertheless a limit must be reached when the winter either becomes too long for survival or the summer too short for recovery.

Menzies (1949) in discussing the possible causes for annual fluctuations in the stock of salmon feels that one of the critical stages in the life cycle is the period when the alevins commence feeding. Alevins rely upon the spring bloom of microscopic organisms to supply them with food and if the time they are ready to feed does not coincide with this they can be faced with wholesale starvation. In Great Britain this condition may arise when a mild winter, during which the period of incubation is reduced, is followed by a cold spring. The incubation period for salmon ova at a temperature of 1°C. is about 160 days. Towards the north not only does the duration of winter increase but the time of spawning is usually advanced. Even if spawning in Ungava is delayed until November (this is comparable with the date in Scotland) the alevins will hatch in April. Hatching in April is precarious as spring break-up does not normally occur until May and the microscopic life upon which the alevins depend is probably not available before the end of that month. In years in which there is a late spring, as in 1956 when break-up occurred near the end of June, the alevins' chances of survival may be negligible. The majority of Ungava salmon have either a 6 or 7 year life cycle, so that heavy mortality amongst the alevins in 1956 would be expected to show up in 1962 when the 4.2+ class of adult salmon should be poorly represented in the catches and in 1963 when the 5.2+ class will be scarce. Moving west and north from the Koksoak to the Leaf and Payne Rivers the chances of this happening are greatly increased by the more severe climate.

The wide range of ages at migration of the smolts means that fluctuations in the stock of salmon brought about by factors influencing the freshwater stages will tend to be smoothed out. To take an extreme example: if spawning proved to be a total failure in 1956 then the smolt run in 1962 would only be reduced to about 50% of the normal size by the complete absence of the 4+ class of migrants. This implies a relative immunity to sudden fluctuations in the freshwater stock. On the northern fringe of the range where the struggle for existence is directed largely against the physical environment the ability to withstand environmental fluctuations, which exceed even the threshold for successful reproduction is a definite asset if not a necessity. In more temperate regions where the age at migration of the smolts is much more uniform a spawning failure one year would have a much more severe effect on the stock and one which would persist for a number of generations.

A final aspect of survival of salmon in the north which, because of lack of knowledge, must be largely speculative, is the effect of permafrost on winter drainage and river levels. During winter the active layer above the permafrost table freezes over and when this occurs drainage is at a minimum. Rivers may be reduced to a mere fraction of the normal size or transformed into a series of almost stagnant lakes and pools. Salmon spawn in gravel over or through which a current of water must flow to supply the developing ova with oxygen and remove waste products. Such places are probably amongst the most susceptible to drying and freezing during a prolonged winter. It may be significant that the Leaf and Payne Rivers lie completely within the zone of permafrost while the headwaters of the Koksoak, Whale and George Rivers extend south beyond this area.

To summarize, climatic factors are undoubtedly responsible for the existence of salmon in the large rivers flowing into the south of Ungava Bay and for the absence of them from the Leaf and Payne Rivers. At what phase in the freshwater life of the salmon these operate is not known, but a number of possibilities have been suggested. The cold climate may result in a modification of the normal migratory behaviour of the salmon. It may make the chances of successful reproduction slight. In all probability not one but a combination of factors are responsible for imposing a northern limit on the range of the Atlantic salmon.

THE PROBLEM OF A FISHERY:

A salmon fishery could undoubtedly be maintained in Ungava Bay; however, the returns could never be great in relation to the sizes of the rivers concerned. The reason for this is that at any time the rivers contain at least four year classes of young salmon all competing with each other for the available food and space. The smolts are very large on migration and hence considerably more food is required to produce one smolt from the George River than, for example, one from the Margaree or St. John Rivers; moreover, the latter are in regions where the food supply is probably more abundant. Stated differently, this implies that more space is required to produce a smolt in Ungava than is required in more temperate regions, conversely the population density of each year class must be less. With our present knowledge, it is impossible to attach numerical values to these statements.

The marine phase of the salmon's life is one of heavy mortality. The results of tagging experiments indicate that only about 1% of the smolts survive to return as adults. Our knowledge of the sea life is meagre and it is not known at what stage mortality is highest. Smolts migrating to sea have to make considerable osmotic adjustments as they pass from fresh into brackish water. It is possible that high mortality is incurred by the migrants during this transfer. In the lamprey (Lampetra fluviatilis) at temperatures near freezing permeability to water and probably to salts is lowered, (Wikgren 1953). If this is also true of salmon the cold temperatures of Ungava Bay may materially aid survival of the smolts. The large size of Ungava smolts may also influence their survival. If both these factors combine and counteract those just discussed, tending to produce a decreased smolt production, returns from a fishery will be greater than conditions otherwise imply. Unfortunately for practical reasons it would be extremely costly and difficult to estimate mortality rates amongst Ungava salmon.

The length of the life cycle of Ungava salmon means that there are slow returns on the capital invested each year in the form of fertilized salmon ova. The returns may improve as a result of fishery activity reducing the number of fish spawning each year thus causing a reduction in the population density of the parr and providing the remainder with more favourable circumstances. These may then be able to grow more quickly and migrate to sea at an earlier age.

These are theoretical considerations. From a practical point of view other factors must be assessed. A major obstacle is to find suitable markets for the catches. With the proposed mining and aviation developments in Ungava, local markets for salmon will probably develop in the next few years. Export to outside areas is also a possibility but the profits from such an enterprise are necessarily restricted by the cost of transportation. If exporting salmon is considered, it may be more profitable to enter the luxury food field and process the catches at Chimo, or some other suitable location, exporting them in the form of smoked salmon. The wholesale price of smoked salmon is around $1.25 a pound compared with between 50¢ and 70¢ a pound for fresh salmon.

Probably the most important consideration is the value of the salmon catches in the native economy. Very little salmon flesh is eaten by the natives who select only the roe and liver. The remainder of the fish is stored in barrels where it is allowed to decompose and finally become frozen. This frozen, tainted fish is a valuable winter food for the Eskimo dogs. To replace it with an equivalent would probably cost far more than any profits which could be derived from marketing the salmon catches. As it is at the present moment the natives are desperately short of dog food. During August when the salmon enter the rivers, the natives prefer to work unloading boats instead of fishing with the result that during the latter half of the winter they must buy imported food for their dogs. This they can ill afford to do. It is obvious to anyone seeing the condition of the Ungava Eskimo and their dogs that they need to catch far more fish for their own consumption before they consider selling any.

One possible way of exploiting the Ungava salmon resources is by means of a carefully controlled sport fishery. Salmon can be taken readily on spinning and fly fishing tackle at certain localities along the rivers. Properly managed this could provide a source of employment for the natives, who could act as guides or gillies, and a source of winter food for their dogs as the sportsmen would be unable to consume all the fish they caught. Some of the wages earned by the natives could be used to buy fishing nets so that they could, if necessary, supplement the supply of salmon provided by the anglers. An experimental fishery of this nature has already been started at Helen Falls, George River and has met with some success, (Carpenter 1957). Others could be started on the Whale and Koksoak Rivers, but should be controlled so that the natives can benefit to the fullest extent from all profits that are made. The shortness of the fishing season, the uncertainty of the weather and the inaccessibility of the region are the principal difficulties which have to be faced in initiating such a project. The latter difficulty is being quickly eliminated as Ungava is opened up by mining operations.

The present shortage of dog food, particularly at Chimo, could easily be alleviated if the natives put a little more effort into their fishing. Most of the nets at present are set in the immediate proximity of Chimo, none of them are set farther up river in non-tidal water where the salmon are more vulnerable to capture. The salmon run at Chimo lasts only about three weeks during which time the natives must take all their catch. In 1957 strong winds in mid-August, which are not uncommon during this month, prevented them visiting the nets for five days, which means a quarter of the run was lost. If the fishermen followed the run as it moved up river the fishing season could be extended many weeks well into September. The native nets are usually between 7 inches and 8 inches in mesh. It may pay them to reduce this mesh size to nearer 6 inches as with the present size of net many valuable fish of 10 pounds or so in weight can squeeze through. There is strong resistance to any suggestions such as this on the part of the natives who tell me they have experimented with many sizes of net and find the present size best. Also they feel since they have been fishing for as long as they can remember no outsider can tell them anything they don't already know. They forget that they were first introduced to gill net fishing by white men, employees of the Hudson's Bay Company. The general impression one has is that here is a valuable natural resource which the natives can ill afford to ignore, which is at present being used casually rather than exploited to the full.

Perhaps since the present plight of the Ungava Eskimo is largely the result of contact with civilized man, it is our responsibility to insure that in future years they make fuller use of this and other of their natural resources.

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S U M M A R Y

The Atlantic salmon which inhabit the rivers flowing north into Ungava Bay are of particular biological significance as here the salmon reaches the northern limit of its range in Canada. In spite of their importance, this is the first biological investigation of these salmon to be made.

In Ungava summer lasts only about 3-1/2 months. Smolt metamorphosis and migration, which in more temperate regions can take place in one season, are extended over two. Metamorphosis takes place during late summer and fall and migration is delayed until the following spring.

The migration takes place during July, by which time river levels have fallen considerably from the spring maxima and water temperatures are above 12^{o}C. The smolts are fairly uniform in size, the majority being between 20 and 24 cms. in length, but vary in age from 3 to 7 years. In analyzing the growth of juvenile salmon different growth rates in the five age groups of smolts can be clearly demonstrated by making 'back measurements' on scales taken from members of each group. That these 'back measurements' are a reliable estimate of growth is demonstrated by: - (1) A close agreement between estimates of growth obtained from the scales of smolts and adult salmon. (2) The fact that the spread of the growth curves calculated by 'back measurements' corres-

ponds to the observed range of sizes of parr.

Depending on how it is expressed, the growth of Ungava salmon parr is either inferior or superior to that of parr from more temperate regions. Annual growth increments are not great due to the short summer but daily increments during the growing season are at least as large and in some cases larger than those of other salmon. During the summer the estimated average daily growth increments for the George and Koksoak River parr are .039 cms. and .050 cms. respectively.

The average age of the smolts migrating from the Koksoak River is 4.2 years and from the George River it is 4.7 years. The large size of the smolts suggests that a correlation may exist between position in the range and size at migration such that smolts tend to become larger towards the north. This is comparable to the increase in age at migration from south to north of the range.

The spawning runs of adult salmon enter Ungava rivers between the 24th of July and the 20th of August. The runs consist mainly of small summer (2+) fish, fish which have spent two complete years and part of a third year feeding at sea. The marine growth of Ungava salmon is as vigorous as that of salmon from other regions, the majority of the small summer fish weighing between 10 and 14 lbs. It is unlikely that such growth could be accomplished in the ice-cold waters of Ungava Bay and the salmon probably migrate elsewhere to feed.

Once they enter freshwater the salmon move rapidly upstream. The condition of the gonads in early September makes spawning before the end of that month most unlikely. The number of eggs carried by the females is rather variable but on the average 800 eggs are produced per pound of fish. Females outnumber males in catches of adult salmon by a ratio of 2-1/2:1. The reasons for this are: - (1) Grilse, which are predominantly male fish, are poorly represented in catches. (2) Females are in the majority in the migrating smolt population possibly because males which mature and spawn as parr die, being unable to stand the strain of spawning together with the rigors of winter. Only about 5% of the spawning population survives to spawn on a subsequent occasion.

The juvenile stages of Ungava salmon are slim compared with fish from other localities while the adults do not differ materially from others in their weight-length relationship. Conditions in freshwater, particularly food supply, must determine the low value of the condition factor (K) in the young stages of Ungava salmon. Insects of the family Simulidae and the orders Ephemeroptera, Hymenoptera, Plecoptera and Trichoptera form the bulk of the diet of young Ungava salmon.

Measurements of the basal metabolic rate of juvenile salmon, made in the field using a continuous flow respirometer, indicate that the curve relating oxygen consumption to temperature is steeper for smolts than for parr. Since temperature is considered to be one of the environmental factors important in initiating smolt migration it may be significant that sensitivity to temperature is particularly evident in smolts at the temperatures at which migration normally occurs.

By extrapolation of the oxygen consumption/temperature curve of salmon parr it is possible to estimate the amount of oxygen consumed during the winter and the resulting loss of weight. In Ungava salmon parr this amounts to between 14 and 20 per cent of the body weight.

The diurnal cycles of oxygen consumption of three salmon smolts revealed two periods of increased metabolic activity. These occurred at midnight and midday while activity was at a minimum during the early morning and late afternoon. A similar cycle has been demonstrated in the feeding activity of young salmon.

Measurements of the basal metabolism of the brook trout showed no evidence of temperature compensation in the basal metabolism of Ungava fish as compared with fish from Ontario.

Climatic factors operating on the freshwater stages of the life cycle impose a northern limit on the distribution of Atlantic salmon in Canada. The limit appears to be reached when the length of the growing season is less than 100 days.

<u>APPENDIX</u>

<u>Species</u>: <u>Salmon</u> (Parr)

	Time	Temp. C	O_2 Consum. cc/gm/hr
Date: July 27	9 AM	15.0	.091
Loc: George River	10	15.0	.093
Lgth: --	11	15.2	.105
Wt: 45 gm.	12 Noon	15.2	.133
Sex: --	1 PM	15.1	.108
Age: --	2	15.4	.103
	3	15.9	.105
Date: August 5	5 PM	14.7	.104
Loc: George River	6	14.5	.090
Lgth: 16 cm.	7	14.4	.090
Wt: 39 gm.	8	14.2	.090
Sex: ♀	9	13.9	.090
Age: 3 +			
<u>Rate of Drop to Basal Level</u>	11 AM	12.7	.175
	11:30	12.7	.175
(Fish installed at 10:30 AM)	12 Noon	12.7	.171
	12:30 PM	12.7	.106
Date: August 8	1	12.8	.075
Loc: George River	2	12.8	.083
Lgth: 18.5 cm.	3	12.8	.083
Wt: 59 gm.	4	12.8	.094
Sex: ♂	5	12.8	.094
Age: 3 +	5:30	12.8	.067
	6	12.7	.073
	7:30	12.7	.102

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	August 11	9:30 AM	15.5	.089
Loc:	George River	10:30	15.7	.088
Lgth:	16 cm.	11:30	15.8	.108
Wt:	42 gm.	12:30 PM	16.1	.108
Sex:	♂	1:30	16.0	.106
Age:	4 +	2:30	15.9	.089
Date:	August 13	11 AM	15.4	.110
Loc:	George River	12 Noon	15.1	.110
Lgth:	11 cm.	1 PM	15.0	.110
Wt:	16 gm.	2	15.1	.109
Sex:	♂	3	15.5	.124
Age:	2 +	4	15.3	.109
Date:	July 20	9:30 AM	4.3	.058
Loc:	Koksoak tributary	10:30	5.1	.047
Lgth:	17 cm.	11:30	5.8	.044
Wt:	44 gm.	12:30 PM	6.4	.048
Sex:	♂	1:30	7.0	.043
Age:	3 +	2:30	7.5	.063
Date:	July 20	9:30 AM	4.3	.051
Loc:	Koksoak tributary	10:30	5.1	.046
Lgth:	16 cm.	11:30	5.8	.043
Wt:	40 gm.	12:30 PM	6.4	.067
Sex:	♂	1:30	7.0	.072
Age:	3 +	2:30	7.5	.065

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	July 20	9:30 AM	4.3	.019
Loc:	Koksoak tributary	10:30	5.1	.026
Lgth:	15.5 cm.	11:30	5.8	.030
Wt:	36 gm.	12:30 PM	6.4	.023
Sex:	♂	1:30	7.0	.029
Age:	3 +	2:30	7.5	.028
Date:	August 25	10 AM	7.5	.047
Loc:	Koksoak tributary	11	7.6	.042
Lgth:	18 cm.	12 Noon	8.2	.047
Wt:	60 gm.	1:30 PM	9.2	.056
Sex:	♀	2:30	10.6	.081
Age:	4 +	3:30	11.6	.072
Date:	September 1	8 AM	8.5	.078
Loc:	Koksoak tributary	9	8.9	.060
Lgth:	16.5 cm.	10	9.2	.063
Wt:	47 gm.	11	9.6	.068
Sex:	♂	12 Noon	9.6	.064
Age:	3 +	1 PM	9.9	.066
Date:	September 2	6 AM	7.9	.018
Loc:	Koksoak tributary	7	8.0	.037
Lgth:	16.5 cm.	8	8.1	.053
Wt:	40 gm.	9	8.4	.051
Sex:	♀	10	8.4	.049
Age:	3 +	11	9.0	.052

Species: Salmon (Smolt)

	Time	Temp C.	O_2 Consum. cc/gm/hr
Date: August 4	8 PM	14.5	.119
Loc: George River	9	14.5	.106
Lgth: 21.5 cm.	10	14.5	.118
Wt: 93 gm.	5 AM	14.4	.109
Sex: ♀	6	14.4	.100
Age: 5 +	7	14.4	.098
	8	14.4	.097
	9	14.4	.103
	10	14.4	.095
Date: August 5	11 AM	14.5	.115
Loc: George River	12 Noon	14.5	.115
Lgth: 20 cm.	1 PM	14.6	.122
Wt: 78 gm.	2	14.7	.129
Sex: ♀	3	14.9	.109
Age: 4 +	4	14.9	.112
Date: August 6	7:30 AM	12.5	.081
Loc: George River	8:30	12.8	.071
Lgth: 21 cm.	9:30	12.9	.085
Wt: 76 gm.	10:30	12.6	.094
Sex: ♀	11:30	13.4	.095
Age: 4 +	12:30 PM	13.2	.069
Date: August 9	8 AM	12.9	.092
Loc: George River	9	13.0	.073
Lgth: 21.5	10	13.2	.104
Wt: 84 gm.	11	13.2	.098
Sex: ♂	12 Noon	13.3	.089
Age: 4 +	1 PM	13.3	.099

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	August 14	6 AM	14.8	.100
Loc:	George River	7	14.8	.108
Lgth:	21 cm.	8	15.0	.108
Wt:	89 gm.	9	15.1	.131
Sex:	♀	10	15.1	.131
Age:	5 +			
Date:	September 1	8 AM	8.5	.046
Loc:	Koksoak tributary	9	8.9	.043
Lgth:	19.5 cm.	10	9.2	.040
Wt:	79 gm.	11	9.6	.050
Sex:	♀	12 Noon	9.6	.045
Age:	3 +	1 PM	9.9	.053
Date:	September 1	8 AM	8.5	.057
Loc:	Koksoak tributary	9	8.9	.052
Lgth:	20 cm.	10	9.2	.045
Wt:	83 gm.	11	9.6	.051
Sex:	♀	12 Noon	9.6	.038
Age:	3 +	1 PM	9.9	.041
Date:	September 2	6 AM	7.9	.033
Loc:	Koksoak tributary	7	8.0	.042
Lgth:	18 cm.	8	8.1	.048
Wt:	62 gm.	9	8.4	.048
Sex:	♂	10	8.4	.044
Age:	3 +	11	9.0	.048

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	September 2	6 AM	7.9	.035
Loc:	Koksoak tributary	7	8.0	.041
Lgth:	21.5 cm.	8	8.1	.040
Wt:	103 gm.	9	8.4	.039
Sex:	♀	10	8.4	.041
Age:	6 +	11	9.0	.036
Date:	September 3	8 AM	6.9	.030
Loc:	Koksoak tributary	9	7.4	.030
Lgth:	19.5 cm.	10	7.9	.044
Wt:	81 gm.	11	8.2	.040
Sex:	♂	12 Noon	8.7	.041
Age:	3 +	1 PM	9.4	.047
Date:	September 3	8 AM	6.9	.034
Loc:	Koksoak tributary	9	7.4	.040
Lgth:	19.5 cm.	10	7.9	.056
Wt:	77 gm.	11	8.2	.034
Sex:	♂	12 Noon	8.7	.039
Age:	3 +	1 PM	9.4	.039
<u>Diurnal Rhythm</u>		3:30 PM	9.4	.053
Date:	September 3-4	4	9.4	.030
Loc:	Koksoak tributary	5	9.5	.030
Lgth:	19.5 cm.	7	9.5	.040
Wt:	72 gm.	9	8.9	.036
Sex:	♂	11	8.2	.034
Age:	3 +	1 AM	7.6	.042
		3	7.2	.028
		5	6.9	.023
		7	6.5	.023
		9	6.4	.053
		11	7.2	.026

	Time	Temp. C	O_2 Consum. cc/gm/hr
<u>Diurnal Rhythm</u>	3:30 PM	9.4	.052
Date: September 3-4	4	9.4	.044
Loc: Koksoak tributary	5	9.5	.047
Lgth: 21 cm.	7	9.5	.040
Wt: 91 gm.	9	8.9	.044
Sex: ♀	11	8.2	.061
Age: 3 +	1 AM	7.6	.051
	3	7.2	.045
	5	6.9	.030
	7	6.5	.041
	9	6.4	.042
	11	7.2	.042
	1 PM	8.3	.066
	4	9.4	.042
	6	9.4	.049

	Time	Temp. C	O_2 Consum. cc/gm/hr
<u>Diurnal Rhythm</u>	3:30 PM	9.4	.058
Date: September 3-4	4	9.4	.048
Loc: Koksoak tributary	5	9.5	.043
Lgth: 21 cm.	7	9.5	.040
Wt: 83 gm.	9	8.9	.037
Sex: ♀	11	8.2	.038
Age: 3 +	1 AM	7.6	.049
	3	7.2	.035
	5	6.9	.024
	7	6.5	.027
	9	6.4	.035
	11	7.2	.034
	1 PM	8.3	.059
	4	9.4	.035
	6	9.4	.041

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	September 6	10 AM	10.4	.047
Loc:	Koksoak tributary	11	10.5	.055
Lgth:	20.5 cm.	12 Noon	10.6	.056
Wt:	83 gm.	3 PM	11.5	.062
Sex:	♂	4	11.5	.063
Age:	4 +	5	11.8	.056
Date:	September 6	10 AM	10.4	.037
Loc:	Koksoak tributary	11	10.5	.033
Lgth:	19.5 cm.	12 Noon	10.6	.047
Wt:	74 gm.	3 PM	11.5	.065
Sex:	♂	4	11.5	.048
Age:	3 +	5	11.8	.054
Date:	September 6	10 AM	10.4	.038
Loc:	Koksoak tributary	11	10.5	.044
Lgth:	20.5 cm.	12 Noon	10.6	.055
Wt:	83 gm.	3 PM	11.5	.058
Sex:	♂	4	11.5	.069
Age:	4 +	5	11.8	.065
Date:	September 7	7 AM	4.3	.022
Loc:	Koksoak tributary	8	4.4	.024
Lgth:	18 cm.	9	4.7	.024
Wt:	58 gm.	10	4.9	.025
Sex:	♀	11	5.1	.032
Age:	3 +	12 Noon	5.5	.035

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	September 7	7 AM	4.3	.036
Loc:	Koksoak tributary	8	4.4	.019
Lgth:	20 cm.	9	4.7	.025
Wt:	77 gm.	10	4.9	.028
Sex:	♀	11	5.1	.036
Age:	3 +	12 Noon	5.5	.036
Date:	September 7	7 AM	4.3	.052
Loc:	Koksoak tributary	8	4.4	.020
Lgth:	19 cm.	9	4.7	.021
Wt:	73 gm.	10	4.9	.026
Sex:	♀	11	5.1	.023
Age:	4 +	12 Noon	5.5	.028

<u>Species</u>: <u>Brook Trout</u>

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	September 1	11 AM	10.4	.045
Loc:	Lac Aigneau	12 Noon	10.5	.052
Lgth:	24.5 cm.	1 PM	10.5	.050
Wt:	133 gm.	5	10.4	.057
Sex:	♀	5:30 AM	10.4	.053
		6	10.4	.053
		6:30	10.3	.052
		8:30	10.2	.051

		Time	Temp. C	O_2 Consum. cc/gm/hr
Date:	September 9	7:30 AM	6.4	.029
Loc:	Lac Aigneau	10	6.8	.038
Lgth:	24.5 cm.	10:30	7.1	.033
Wt:	154 gm.	11	7.3	.034
Sex:	♂	11:30	7.5	.037
		12 Noon	7.8	.038
		2:30 PM	8.7	.034
		3	9.0	.038
		3:30	9.0	.038
		4	9.0	.040
Date:	September 10	9 AM	7.2	.034
Loc:	Lac Aigneau	9:30	7.4	.040
Lgth:	19 cm.	10	7.5	.037
Wt:	74 gm.	10:30	7.75	.040
Sex:	♀	11	7.85	.047
		1 PM	8.6	.051
		2:30	8.3	.049
Date:	September 12	10 AM	6.2	.034
Loc:	Lac Aigneau	10:30	6.1	.028
Lgth:	20.5 cm.	11	6.1	.028
Wt:	84 gm.	3 PM	7.4	.049
Sex:	♀	3:30	7.6	.043
		4	7.4	.040

	Time	Temp. C	O_2 Consum. cc/gm/hr
Date: June 18	9 AM	9.0	.053
Loc: George River	10	9.0	.048
Lgth: --	11	9.3	.054
Wt: 84 gm.	11:30	9.5	.054
Sex: ♂	12 Noon	9.6	.057
	1:30 PM	9.9	.048
	2	10.2	.054
	2:30	10.4	.060
	3	10.6	.061
	3:30	10.9	.070
Date: July 20	12 Noon	10.3	.058
Loc: George River	12:30 PM	10.1	.053
Lgth: --	1	10.3	.063
Wt: 63 gm.	2	11.2	.060
Sex: ♂	3	10.4	.058
	4	10.5	.058
	5	10.5	.059
	5:30	10.6	.058
	7	10.3	.048
Date : July 24	10 AM	13.5	.082
Loc: George River	--	13.7	.079
Lgth: --	--	14.0	.085
Wt: 84 gm.	--	14.1	.089
Sex: ♂	--	14.4	.096
	3 PM	14.7	.089

	Time	Temp. C	O_2 Consum. cc/gm/hr
Date: August 16	10 AM	14.5	.089
Loc: George River	11	14.6	.094
Lgth: --	12 Noon	14.4	.091
Wt: 141 gm.	1 PM	14.4	.094
Sex: ♂	2	14.5	.089
	3	14.0	.091
Date: July 17	9:30 AM	4.0	.027
Loc: Manitou	10:30	4.8	.026
Lgth: --	11:30	5.6	.026
Wt: 120 gm.	12:30 PM	6.5	.036
Sex: ♀	1:30	7.5	.055
	2:30	8.0	.058
Date: July 17	9:30 AM	4.0	.018
Loc: Manitou	10:30	4.8	.026
Lgth: --	11:30	5.6	.026
Wt: 123 gm.	12:30 PM	6.5	.036
Sex: ♂	1:30	7.5	.039
	2:30	8.0	.040
Date: July 17	10:30 AM	4.8	.021
Loc: Manitou	11:30	5.6	.035
Lgth: --	12:30 PM	6.5	.036
Wt: 233 gm.	1:30	7.5	.031
Sex: ♂	2:30	8.0	.034
	3:30	8.6	.044

	Time	Temp. C	O_2 Consum. cc/gm/hr
Date: July 18	9:30 AM	5.4	.024
Loc: Manitou	10:30	5.8	.027
Lgth: --	11:30	6.1	.041
Wt: 116 gm.	12:30 PM	7.2	.038
Sex: ♀	1:30	8.1	.041
	2:30	8.4	.044
Date: August 25	10 AM	7.5	.050
Loc: Manitou	11	7.6	.044
Lgth: --	12 Noon	8.2	.039
Wt: 51 gm.	1:30 PM	9.2	.036
Sex: ♂	2:30	10.6	.063
	3:30	11.6	.067
Date: August 25	10 AM	7.5	.034
Loc: Manitou	11	7.6	.033
Lgth: --	12 Noon	8.2	.034
Wt: 131 gm.	1:30 PM	9.2	.040
Sex: ♂	2:30	10.6	.074
	3:30	11.6	.070